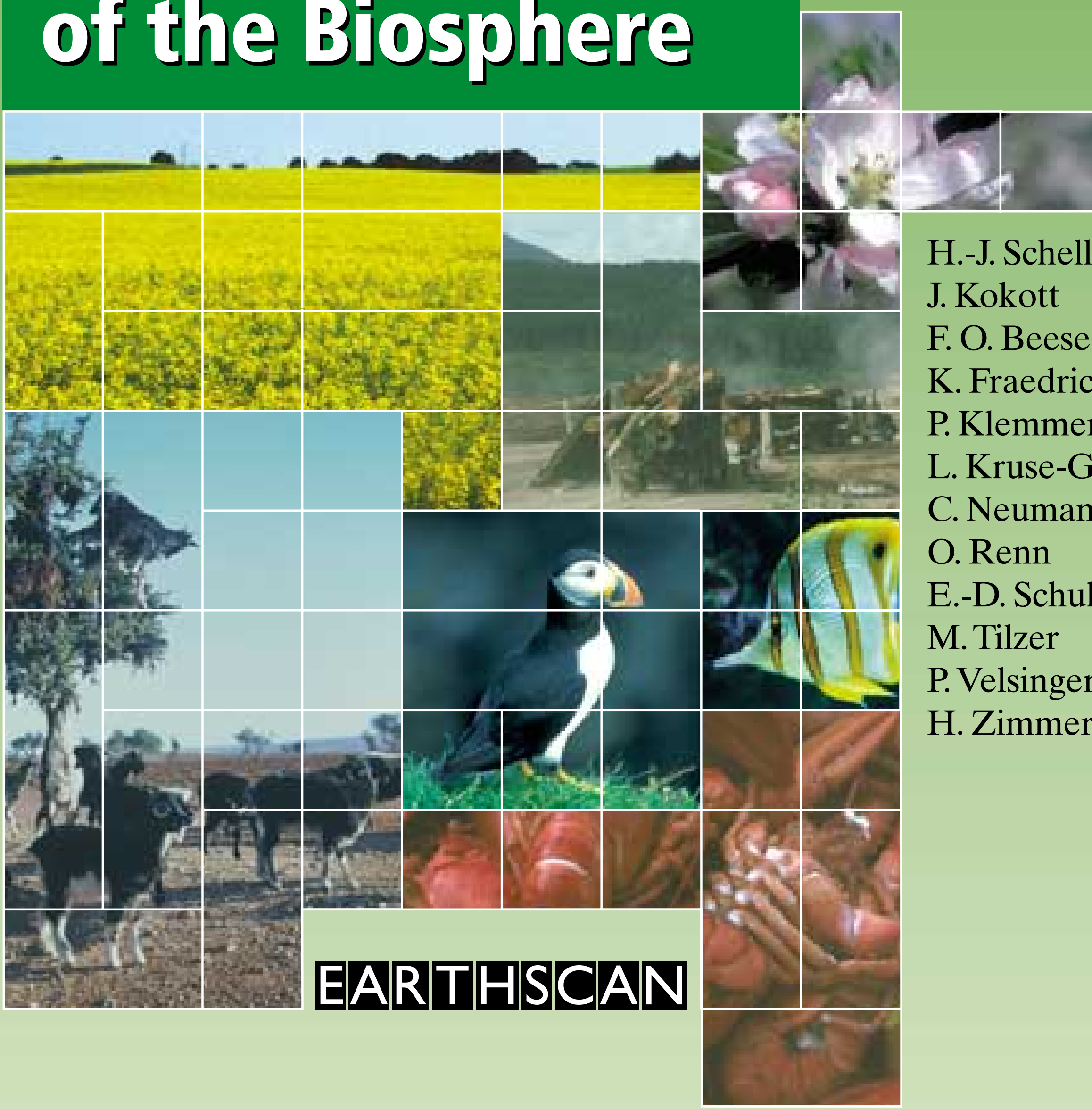
World in Transition

German Advisory Council on Global Change (WBGU)

Conservation and Sustainable Use of the Biosphere



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World in Transition

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German Advisory Council
on Global Change

World in Transition:

Conservation and Sustainable Use of the Biosphere

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Acronyms

ACFM	Advisory Committee for Fisheries Management (ICES)
AGDW	Arbeitsgemeinschaft deutscher Waldbesitzerverbände (Association of German Forest Owners' Federations)
AIA	Advance Informed Agreement
AIDS	Aquired Immune Deficiency Syndrome
ATBI´s	All Taxa Biodiversity Inventories
BfN	Bundesamt für Naturschutz (Federal Agency for Nature Conservation)
BIODEPTH	Biodiversity and Ecosystem Processes in Terrestrial Herbaceous Ecosystems (EU)
BIOLOG	Research Programme 'Biodiversity and Global Change' (BMBF)
BMBF	Bundesministerium für Bildung und Forschung (German Federal Ministry of Education and Research)
BMS	Bristol-Myers Squibb
BMZ	Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (German Federal Ministry for Economic Cooperation and Development)
BRIM	Biosphere Reserve Integrated Monitoring
CAC	Codex Alimentarius Commission (FAO, WHO)
CBD	Convention on Biological Diversity (UNCED)
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CCD	United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa
CDM	Clean Development Mechanism (FCCC)
CELSS	Controlled Ecological Life Support Systems (NASA)
CFP	Common Fisheries Policy (EU)
CGIAR	Consultative Group of International Agricultural Research
CGRFA	Commission on Genetic Resources for Food and Agriculture (FAO)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora (United Nations)
CLIVAR	Climate Variability and Predictability Programme (WCRP)
CMS	Convention on Migratory Species
COP	Conference of the Parties
CPGR	Commission on Genetic Resources for Food and Agriculture
CSD	Commission on Sustainable Development (United Nations)
CST	Commission on Science and Technology (CCD)
DFG	Deutsche Forschungsgemeinschaft (German Research Foundation)
DIVERSITAS	Ecosystem Function of Biodiversity Programme (SCOPE, UNESCO, IUBS)
DMS	Dimethylsulfide
DNA	Desoxyribonucleic Acid
ECHAM	Climate model based on the ECMWF model
ECMWF	European Centre for Medium-range Weather Forecast
ESA	European Space Agency
ESCOP	European Scientific Cooperative for Phytotherapy
EU	European Union
FAO	United Nations Food and Agriculture Organization

FCCC	United Nations Framework Convention on Climate Change
FSC	Forest Stewardship Council, Canada
GATT	General Agreement on Tariffs and Trade
GBA	Global Biodiversity Assessment (GEF, UNEP)
GBIF	Global Biodiversity Information Facility (OECD)
GEF	Global Environment Facility (United Nations)
GISP	Global Invasive Species Program (IUCN, SCOPE, UNEP, UNESCO)
GMO	Genetically modified organisms
GNP	Gross National Product
GOALS	Global Ocean-Atmosphere-Land System (CLIVAR)
GOOS	Global Ocean Observing System (WMO)
GPP	Gross Primary Production
GROMS	Global Register on Migratory Species
GTI	Global Taxonomy Initiative
GTZ	Gesellschaft für Technische Zusammenarbeit (German Society on Development Cooperation)
HEAR	Hawaiian Ecosystems at Risk Project
HIPC	Highly Indebted Poor Countries Initiative (IWF, World Bank)
IBOY	International Biodiversity Observation Year (DIVERSITAS)
ICBG	International Cooperative Biodiversity Group Programme (NIH)
ICCAT	International Commission on the Conservation of Atlantic Tuna
ICDP	Integrated Conservation Development Projects
ICES	International Council for the Exploration of the Sea
ICSU	International Council of Scientific Unions
IFF	Intergovernmental Forum on Forests (United Nations)
IGBP	International Geosphere Biosphere Programme (ICSU)
ILO	International Labour Organization
IMA	Interministerieller Ausschuss der Bundesregierung (Interministerial Commission of the Federal Government)
IMF	International Monetary Fund
IMO	International Maritime Organization
INBio	Instituto Naçional de Biodiversidad, Costa Rica
INTECOL	International Association for Ecology
IPBD	Intergovernmental Panel on Biological Diversity (recommended)
IPCC	Intergovernmental Panel on Climate Change (WMO, UNEP)
IPF	Intergovernmental Panel on Forests (United Nations)
IPPC	International Plant Protection Convention (FAO)
IRRI	International Rice Research Institute, Philippines
ISSG	Invasive Species Group (IUCN)
IUBS	International Union of Biological Sciences (UNESCO, SCOPE)
IUCN	The World Conservation Union
IUFRO	International Union of Forestry Organizations
IUPGR	International Undertaking on Plant Genetic Resources (FAO)
JGOFS	Joint Global Ocean Flux Study (IGBP)
KfW	Kreditanstalt für Wiederaufbau
LMOs	Living Modified Organisms
LPJ	Lund Potsdam Jena Model (global dynamic vegetation model)
MAB	Man and the Biosphere Programme (UNESCO)
MAT	Mutually Agreed Terms
MFCAL	Multifunctional Character of Agriculture and Land Approach (FAO)
MVP	Minimum Viable Population
NASA	National Aeronautics and Space Administration, USA
NBP	Net Biome Productivity
NCI	National Cancer Institute, USA
NEP	Net Ecosystem Productivity
NGO	Non-Governmental Organization

NIH	National Institute of Health, USA
NPP	Net Primary Production
OECD	Organisation for Economic Cooperation and Development
ÖPUL	Österreichisches Programm zur Förderung einer umweltgerechten, extensiven und den natürlichen Lebensraum schützenden Landwirtschaft (Austrian Programme to Promote Environmentally Sound Farming that is Extensive and Conserves Natural Habitats)
PCR	Polymerasis Chain Reaction
PEFC	Pan-Europäische Zertifizierungsinitiative (Pan European Certification Initiative) (German Forestry Council)
PIC	Prior Informed Consent
PVA	Population Viability Analysis
SBI	Subsidiary Body on Implementation
SBSTTA	Subsidiary Body on Scientific Technical and Technological Advice (COP)
SCOPE	Scientific Committee on Problems of the Environment (ICSU)
SHIFT	Studies on Human Impact on Forests and Floodplains in the Tropics (BMBF)
SPS	Agreement on the Application of Sanitary and Phytosanitary Measures (WTO)
STAP	Scientific and Technical Advisory Panel (GEF)
TEK	Traditional Ecological Knowledge
TEV	Total Economic Value
TFAP	Tropical Forest Action Plan
TISC	Tutzinger Initiative für eine Bodenkonvention (Tutzing Initiative for a Soil Convention)
TÖB	Tropenökologisches Begleitprogramm (Tropical Ecology Support Program) (GTZ, BMZ)
TRAFFIC	Trade Records Analysis of Flora and Fauna in Commerce (WWF, IUCN)
TRIPs	Trade-related Aspects of Intellectual Property Rights
TTX	Tetrodotoxin
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
UNDP	United Nations Development Programme
UNEP	United Nations Environment Progamme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen (German Advisory Council on Global Change)
WCMC	World Conservation Monitoring Centre
WCP	World Climate Programme (ICSU)
WCPA	World Commission on Protected Areas (IUCN)
WCRP	World Climate Research Programme (WCP)
WHC	World Heritage Convention
WHO	World Health Organisation (United Nations)
WIPO	World Intellectual Property Organization
WMO	World Meteorological Organization (United Nations)
WTO	World Trade Organization (United Nations)
WTTC	World Travel and Tourism Council
WWF	World Wide Fund for Nature
ZADI	Zentralstelle für Agrardokumentation and -information (Central Office for Agricultural Documentation and Information)

Summary for Policymakers

A

Overcoming the crisis of the biosphere

We are currently experiencing a major crisis of the biosphere: the *Sixth Extinction of genetic and species diversity*. Every day nature's genetic and physiological blueprints are lost without us being able to explore the opportunities that they present to us. The cause of this Sixth Extinction is humankind who has transformed, isolated, fragmented or destroyed the world's landscapes and ecosystems. This process is so far-reaching that the general ability of the living world to rebuild a complex interrelation of species after severe disruptions is at risk for millions of years to come. The vast majority of scientists believe that there are only a few decades left to prevent this fateful development with environmental policy measures.

The German Advisory Council on Global Change (WBGU) believes that the crux of all strategies of this kind is to place at least 10 per cent of the Earth's land area under protection. As a result the planetary biosphere services (such as regulating the world's climate) could be preserved, as could the biodiversity hotspots where the natural capital of genetic information is concentrated.

In Europe a demand of this kind has long been a statutory requirement, but in Germany it has not yet been implemented. Scientific analyses show that an appropriate global protected area system can be financed by well-considered cuts in the worldwide system of agricultural subsidies.

The most important instrument of biosphere policy under international law is the Biodiversity Convention. In the field of biosafety the Council's recommendations became reality in the form of the Cartagena Protocol shortly after this report went to press. Other important steps have not yet been taken: the German Federal Government should advocate that the United Nations Rio+10 Declaration contain firm calls for these steps to be implemented.

Urgent need to act

The German Advisory Council on Global Change focuses its 1999 report, entitled 'World in transition: conservation and sustainable use of the biosphere', on an interdisciplinary analysis of the biosphere crisis. A number of concrete recommendations for political decision-makers are derived on this basis.

The measures recommended can only hope to be successful, however, if they are fitted into the logic of a global framework on 'biosphere governance'. The community of nations will have to decide whether, in what way and in what places it wishes to preserve, maintain or actively design. It will be many years before biosphere governance will step out of the shadow of the profound ignorance that surrounds the biosphere. For instance, although prognostic capacity was very quickly acquired in relation to climate issues, the complexity of life on this planet has only really begun to be sounded by the academic world. In addition to formulating recommendations, therefore, there is a need to outline a research strategy for the biosphere.

Biosphere and biological diversity are therefore issues that in future must be placed much higher on the international and national political agenda – both in terms of policy and research.

Imperatives for conserving and shaping the biosphere

In this report the Council formulates five 'biological imperatives' to serve as orientation points for policy and with which the values of the biosphere are conserved and used sustainably for this and future generations. The order of the imperatives does not imply any ranking: the Council treats all of these maxims for action equally alongside each other.

First biological imperative: preserve the integrity of bioregions

The Council recommends pursuing a *dual strategy* here. First of all, it makes sense to impose usage restrictions within regions or zones that are intended to assume a regional regulatory function or where ecosystem services are most important. Added to that are the protected areas of trans-regional or even global importance. Secondly, however, in those zones that are suited to extensive or intensive use in agricultural or forestry terms, sustainability limits should not be exceeded. The Council has drawn up practical 'guidelines' for these zones to ensure that sustainability is maintained.

Second biological imperative: secure existing biological resources

The *biological resources* that are required to ensure the continuous adjustment and further development of crops and livestock must not be jeopardized. These include the wild species related to the cultivated plants. Particular attention should be paid to zones in which valuable plant genetic resources occur in a considerable concentration ('centres of genetic diversity').

Third biological imperative: maintain biopotential for the future

The biosphere contains many substances and blueprints that are as yet unknown, we must secure these *options* for the possibility of future use. There are particularly great opportunities in areas in which biological diversity is concentrated in natural ecosystems (eg tropical forests, coral reefs) and therefore a relatively large number of interesting 'solutions' of a biochemical or structural nature are to be found. These hotspots of biological diversity are particularly worthy of protection.

Fourth biological imperative: preserve the global natural heritage

There is a global consensus across the international community in favour of preserving the natural heritage. There are a variety of reasons for this: they range from the concrete 'survival arguments' through to more normative rationales. What is required in order to meet this goal is a *network of protected areas* that includes representative examples of every natural ecosystem on the Earth. Of course, it is not just certain ecosystems or landscapes that belong to the natural heritage, but also the species that live in them. *Measures to protect species* are therefore necessary if such species would otherwise have no other means of survival.

Fifth biological imperative: preserve the regulatory functions of the biosphere

The major *biogeochemical cycles* within the Earth's system are currently subject to extensive influence from humankind. This influence can already be felt at the coupling between the biosphere and the climatic system, since climate change has a negative impact on the biosphere and vice versa. Consequently, the global 'guard rail' that the Council has already developed for climate protection may be transferred and applied to the biosphere. For the global regulatory mechanisms there are already geographically explicit c*ritical focal points* that require special protective measures. Minimum demands may thus be formulated with regard to the area of natural ecosystems that needs to be protected.

Eliminating knowledge gaps

Perhaps the most important aspect under the heading 'biosphere' is the dramatic lack of knowledge. Only a small proportion of species has been described so far and we do not even know the total number of species worldwide. Explaining scientifically the ecological functions performed by just one species or ecosystem is complicated and difficult enough: the task of providing such an explanation for all species is colossal. Therefore, it is essential to set clear priorities for biosphere research.

Currently, one important foundation of knowledge is at risk: even in Germany the ability to identify animal and plant species is limited to an ever-diminishing group of experts. Knowledge about regional biological diversity may also be about to be lost. A research strategy that hopes to address biodiversity cannot however limit itself to research in biosciences in the narrower sense – such as taxonomy or ecosystem research. It must integrate the sustainable use of biological diversity (research in agriculture, forestry and fisheries). This calls for an interdisciplinary approach that also incorporates, for example, economics, ethics, psychology and sociology.

The crisis of our biosphere demands that researchers adopt a problem-oriented, strategic approach. The starting point should be the following core questions: Which of the goods and services that the biosphere provides to humankind and to society are in jeopardy? What area of natural ecosystems and how much biological diversity is required at the local, regional and global levels, to ensure the supply of these goods and services for the long term?

In its 1999 report, the Council outlines a strategic framework for biosphere research that can serve as a basis for an interconnected European, and indeed, international research programme. The parameters are set by three demands: (1) Priority must be given to research into the knowledge base necessary for implementing the biological imperatives and the 'guard rails'; (2) furthermore, there must be research into specific methods and instruments; (3) in light of the knowledge and theory gaps, extensive basic research is necessary that must contain both bio-ecological and socio-economic elements.

The core policy recommendations from the German Advisory Council on Global Change

A 'guard rail' for the biosphere: protect 10–20 per cent of land area

Current knowledge does not allow for the exact or scientifically founded 'guard rail' for biosphere protection in the sense of an actual proportion of the overall surface area that should be protected. Calculations based on estimates with regard to the preservation of different components and aspects of the biosphere that apply various assessments of its function and value, though inadequate in many methodological respects, do provide important reference points. The various approaches arrive at similar numbers: a representative selection of 10–20 per cent of the Earth's land area should have 'conservation use' as its priority land use form. The Council therefore considers it imperative to consolidate and develop further the existing worldwide system of protected areas. New protected areas should be designated in line with ecological criteria; the existing protected areas should be brought into that context and developed into a system of protected areas. The status of implementation of the Habitat Directive and its foreseen EU-wide network, NATURA 2000, has to be considered very unsatisfactory in Germany. The Advisory Council once again calls for implementation to be advanced quickly and for the overdue amendment of the Federal Nature Conservation Act to be completed.

An effective worldwide system of protected areas is affordable

A worldwide system of protected areas in the order of magnitude called for by the Council would trigger additional costs of approx US$21.5 thousand million per year, according to initial rough estimates. It should not be impossible for the international community to close that funding gap. Funds could be released by reducing environmentally damaging subsidies, for example agricultural subsidies. Nevertheless, funding from the public purse alone will not suffice to provide adequate global protection for biological diversity. Therefore, political support should be given to efforts to establish 'biosphere funds', run in the private sector with certain tax relief facilities. The Council furthermore recommends making the foundation system in Germany more attractive in tax terms, for example by means of favourable treatment for environmental foundations.

More resolute implementation of the Biodiversity Convention

The Biodiversity Convention is the central set of international rules on biodiversity to enjoy broad-based acceptance. Its Parties committed themselves to *conservation* of biological diversity, *sustainable use* of its component parts and *fair and equitable sharing* of the benefits arising out of the use of genetic resources. There should be much more energetic pursuit of the implementation of these goals in Germany. For instance, they should be reflected to a greater extent in classic approaches to nature and species conservation and expand these by adding concepts for sustainable use of the biosphere. This would mean primarily incorporating agriculture, forestry and fisheries, but also the fields of biotechnology, research promotion, economic and fiscal policies, and development cooperation. The Council therefore considers it appropriate for Germany to develop a national biodiversity strategy. Close cooperation among the Federal Ministries is an important precondition for achieving such a strategy; the Council therefore recommends that an 'Interministerial Working Group on Biodiversity Policy' be convened.

Establish an 'Intergovernmental Panel on Biological Diversity'

International biosphere policy currently lacks sufficient scientific advice. The UN's 1995 Global Biodiversity Assessment did provide an initial scientific overview, but this work was not consistently continued. The Council recommends as a first step investigating the extent to which these tasks could be achieved by closer networking among existing bodies. One can assume, however, that on that basis a scientific body of experts on biodiversity will be necessary in the form, for example, of an Intergovernmental Panel on Biodiversity (IPBD). Such a body would bring together all of the leading scientists as was the case around the climate issue. The contributions of an IPBD would lend the biodiversity debate greater objectivity. The world of science, too, would benefit in terms of improved coordination and connectivity. The Council recommends building on the experiences of the Global Biodiversity Assessment and the IPCC in establishing the IPBD in order to avoid potential structural weaknesses from the outset.

Strengthen UNESCO's MAB programme

The UNESCO programme 'Man and the Biosphere' (MAB) offers good opportunities for regional implementation of the Biodiversity Convention. In particular, the Council welcomes the trend towards larger, better connected and trans-national biosphere reserves. However, the MAB programme could be used more effectively as an instrument of international cooperation on biosphere protection. Since there is no financing mechanism for this specific task, countries should be encouraged to make greater use of the possibilities the GEF presents.

Achieve a legally-binding agreement on the protection of the forests

There is apparently no halt to the destruction of forests. This is making success in climate policy more and more difficult to achieve and is destroying valuable biological diversity. In order to improve forest protection worldwide the Council has in the past proposed the addition of a Forest Protocol to the Biodiversity Convention and still holds this solution to be the most promising. More important, however, than the external form of such an agreement would be its swift adoption and legally-binding character. Private-sector activities are also an important condition for the success of global forest protection. The efforts to promote sustainable forestry through certification should be supported as positive examples.

Maintain the diversity of cultivated plants

Conservation of biological diversity is of crucial importance to global food security. The Council therefore recommends the promotion of agricultural production in the most diverse and multi-functional form possible. Endangered cultivated plants should be placed in a Red List because many traditional varieties are in danger of disappearing forever. Worldwide a considerable portion of the *ex-situ collections* of rare plant species ('genebanks') is considered endangered. They must therefore be safeguarded, supplemented and made part of a global network.

Seize the opportunities of bioprospecting

The development of international standards for access to genetic resources, their sustainable use and the fair and equitable sharing of benefits should be pushed forward swiftly in the context of the Biodiversity Convention. This provides opportunities not only for the conservation of biological diversity, but also for the industry using natural products. One important precondition for cooperation with the countries of origin is, however, their appropriate participation in the research results and support for national capacity building. The rights of indigenous communities must be guaranteed. For companies using natural products, a focal point at the German Society on Development Cooperation (GTZ) would make sense, both for contacts and development of participatory strategies. The Council would also like to propose examining together with the trade associations the possibility of an internationally applicable labelling system for sustainably produced pharmaceuticals.

Apply 'bioregional management'

In light of the links to climate and soil protection, any successful international 'biosphere policy' would reach beyond the more traditional biodiversity policy. Since the state alone cannot fulfill all that has to be done, as many players and institutions as possible should be included. The primary aim must be to see the protection of genetic, species and ecosystem diversity as inseparable from its sustainable use. The Council recommends increased application of the strategy of 'bioregional management' for land use according to the categories 'Protection against use', 'Protection through use' and 'Protection despite use' and incorporating all of the major players. This concept is particularly well suited to development cooperation; but additionally the extent to which this approach could be reconciled more effectively with Germany's planning system should be appraised.

Step up bilateral and multilateral cooperation

One cannot emphasize enough the importance of development cooperation in the context of biosphere protection since it offers opportunities for the necessary crisis management in the field. Germany has been a committed advocate for international biosphere protection and is the third largest contributor to the Global Environment Facility (GEF). In terms of debt-for-nature swaps, Germany is one of the leaders in the field. The Council expressly welcomes the German Government's initiative to waive the debts of the highly indebted poor countries (Cologne Debt Initiative) as it gives the countries involved greater scope in terms of conservation measures. However, a larger financial commitment from the industrial countries is essential. The Council notes with great concern that Germany is farther away than ever from reaching the 0.7 per cent goal.

B Introduction: Humanity reconstructs the biosphere or The three pillars of folly

In early 1962, the American biologist Rachel Carson published her book entitled 'Silent Spring' – a black mark on the seemingly immaculate façade of the agro-industrial revolution of the post-war period, a book that gave strength and direction to the emerging environmental movement and thus, possibly, changed the course of modern history. In a compelling combination of analysis and poetry Carson's work for the first time highlighted the threats posed to the natural biosphere by the thoughtless use of chemical plant protection agents.

Almost forty years later many of the terrifying visions of 'Silent Spring' have not become reality (in line with the logic of the 'self-avoiding prophecy'?). Nonetheless, some aspects of the ecological reality of the late 20th century eclipse Carson's worst presentiments in the most banal and malicious way. A brief report in the Frankfurter Allgemeine Zeitung of 14 April 1999 casually states: 'The European Commission has prohibited the import of fish and fisheries products from Lake Victoria, East Africa. Allegedly some fishermen deliberately discharge pesticides into the Lake in order to improve their catches. In the last few weeks a number of people have died in the littoral states of Uganda, Tanzania and Kenya due to poisoning from residues of plant protection agents in fish.'

Is it not a grotesque irony of the biosphere's fate that those chemicals whose unintentional side effects in conjunction with a definitely beneficial increase in food production were denounced in the 1960s, are now being deliberately misused in the 1990s in order to directly destroy higher animal life with their main toxic effect? This observation makes it alarmingly clear that the onslaught of humankind on creation is no longer being waged in the wealthy centres of 'Western civilization', but mainly in the least developed countries of the world, where sheer poverty makes all scruples and considerations of self-protection appear pure luxury when plundering natural resources. As a result, destructive and thoughtless exploitation of fauna and flora is currently being perpetrated in most tropical and subtropical regions. While the hunt for the last hyacinth macaws (worth US$40,000 each on the black market) is on in the Amazon rainforests and the ecological integrity of the West African jungle is being sacrificed to the extraction of individual high-value trees, the destruction of the coral reefs of the Indonesian archipelago by cyanide and and dynamite fishing continues at a breathtaking pace.

This means that the total triumph of a single species over millions of species in co-evolution is nearing completion; the crowing glory of this victory will ultimately be a completely reconstructed biosphere. This most spectacular of all monuments to civilization will sit on three main pillars, namely:

1. the reduction of genetic and species diversity,
2. the functionalization and homogenization of ecosystems and landscapes,
3. the modification of the regulatory services of the biosphere at the planetary level.

Species, landscapes, cycles – these are in fact the three basic quantities whose hyper-complex interactions determined the identity of the pre-modern biosphere (Box B-1). Humankind not only shapes the associated elements according to its short-sighted wishes, it also tears their interaction out of the evolutionary time-space context and forces an artificial, highly unstable metabolism on the biosphere. Today, for example, essential nutrients for plant growth are transported and distributed by the machinery of international trade to a greater extent than by natural processes.

The extent to which the reconstruction of the biosphere by its modern 'flagship species' has already progressed can be shown by dry figures, but perhaps even more impressively by some current, randomly selected examples that throw a harsh light on the limited wisdom of the 'architects':

Since the beginning of 1999 there has been bitter debate in the United Kingdom about the ecological risks of genetically modified crops. In particular, the effects of the release of GMHT (genetically-modified herbicide tolerant) cereal varieties on the natural interrelationship of species in a mature cultivated landscape are the subject of extremely controversial assessments. Given the limited theoretical knowledge and the almost complete empirical ignorance of some experts, a debate of this kind is not only understandable, but is also necessary (WBGU, 1998a). However, it will become dubious and even counterproductive if it diverts public attention from the fact that – beyond all speculation – a verdict can already be given on normal, 'standard' agriculture as regards the extinction of species: as the New Scientist magazine reported on 27 February 1999, from 1971 to 1995 the populations of the previously dominant British bird species fell by up to 90 per cent. 'The problem has been caused by the everyday use of highly toxic chemical sprays, by ripping out hedgerows, and by the relentless spread of farming practices which we have never quite had the collective energy or will to resist.'

An almost touching counterpoint to the destructive everyday practice is being attempted by a zoological project in the Hai-Bar Nature Reserve, near the Israeli port of Eilat: there, in the middle of the Negev Desert, all of the animal species that are mentioned in the Holy Scriptures are to be brought together again in a limited area. In spite of successes

Box B-1

Biosphere and biological diversity

The Council uses the following definition for the two key terms in this report: 'biosphere' and 'biological diversity':

Biosphere
The biosphere is the area of the Earth occupied by life, from the inhabited layer of the Earth's crust (including the seas and oceans) right up to the lower layer of the atmosphere. The biosphere forms a global ecosystem almost exclusively driven by solar energy, made up of organisms and that part of non-living material which interacts with the organisms. It is characterized by complex, worldwide biogeochemical cycles. As living creatures, people (and their economic activities) are also components of the biosphere. The biosphere is closely functionally interlinked with the other spheres of the Earth: the atmosphere, the pedosphere and hydrosphere.

Biological diversity
Biological diversity (or biodiversity) means the diversity of life forms in all their varieties and interrelations. It includes the entire range of variations within and variability between systems and organisms at the various levels as well as the structural and functional relationships between these levels, including human interventions:
– *Ecological diversity* (diversity of biomes, landscapes and ecosystems through to ecological niches),
– *Organismic diversity* (diversity among taxonomic groups such as phyla, families, genera through to species),
– *Genetic diversity* (diversity of populations ranging from individuals to genes and nucleotide sequences).

with the reintroduction of oryx antelopes, wild asses and ostriches, the project will not be able to fulfil its objective because at least twelve species of large animal from the pre-Christian era have now become extinct worldwide. Noah has come too late this time...

After the fatal avalanches in Austria, Switzerland and France in the winter of 1999, the discussion about how to manage in a 'nature-friendly' manner one of the most fascinating bioregions on this planet flared up again briefly. But the process of converting the ecosystem of the Alps into a leisure park is already almost fully completed; the destruction through tourism development of the most beautiful physiographic region in Europe has set dubious standards for other mountain landscapes worldwide.

Every year 120 million tourists flock to the Alps and spend 370 million nights there. Ninety million, ie three quarters of the people seeking 'recreation', come by car. 'According to a survey conducted by the International Alpine Protection Committee (CIPRA), they travel over 4,000km of motorway, 16,000km of trunk roads, 80,000km of minor roads and 300,000km of farm roads and access roads. There are 12,000 cable car and lift installations, 3,400km^2 of skiing areas; the number of snow machines doubled between 1990 and 1995. If we remember that only 20 per cent of the Alpine area can be used at all, the extent to which infrastructure has now been packed in becomes clear, as does the almost automatic polarization between protecting remaining areas and designating areas for development.' (T. Geus in the Frankfurter Allgemeine Zeitung of 18 March 1999).

This is the status quo that is, however, to be 'overtaken' as quickly as possible by means of an ultimate expansion phase. 'There are plans for 45 mountain railways, skiing areas or expansions of skiing areas – 30 of which are in Switzerland and 11 in Tyrol – including the avalanche protection that will be needed for this in order to be able to operate in hitherto unprotected areas. In addition to this, 22 hydroelectricity plants and dams, 49 trunk road projects, 5 high-voltage power lines and 18 theme parks, countless hotel complexes, further snow machines and golf courses' (T. Geus, see above) are planned. Thus, the brief phase of reflection during which the environmental associations found a broader audience and the federal state of Salzburg even decided on a moratorium on expansion seems to have come to an end without major involvement by the public – the brief upsurge of media interest with regard to the avalanche winter of 1999 will hardly change anything. The smothering of previously semi-natural areas with impermeable surfaces, the fragmentation of biotopes and the displacement or decimation of endemic species will thus continue at an accelerated pace. In a few decades, when the natural capital has largely been consumed and consequently provides no more dividends for the tourism industry, the architects of this brave new Alpine world will recognize that the ecological services of this bioregion (eg the vegetation-determined regulation of many hydrological processes) have also been lost along with the intactness of this unique physiographic region.

And now we turn to a main function of the biosphere that extends far beyond the landscape scale: the ability of terrestrial and marine life to maintain the major cycles in the Earth System (water, climate relevant substances, nutrients, trace elements) and buffer them against extrinsic and intrinsic disruptions. All on its own life keeps the planet in a quasi-stationary state away from thermodynamic equilibrium and thus creates the basis of its own further development into forms of ever higher complexity. This overall process is so complex and varied that scientists are only today able to take the first, tentative steps towards rudimentary understanding. The considerable significance of the biosphere for the stability of the world's climate has, however, long been recognized, even if difficult riddles remain to be solved.

For example, how did life on Earth manage to regulate the oxygen content of the atmosphere at exactly 21 per cent over hundreds of millions of years?

The dynamic equilibrium of the ecosphere that was in balance for aeons is now at stake for the first time – as a result of large-scale human intervention in the composition and structure of the planetary biosphere. One example of this is the 'lungs' of the biosphere, ie the tropical rainforests in their entirety. Since the onset of European colonization their total area has been reduced by over 50 per cent, and the inherent ability of most of the rest to function has been weakened. As reported recently in the journal *Nature* (Nepstad et al, 1999), the destruction is currently progressing at double the pace assumed from satellite images. In concrete terms this means that in Amazonia alone, every year around 10,000–15,000 km^2 of rainforest are disappearing – in El Niño years this rate may double as a result of deliberate and accidental fires. As a consequence of this, the sophisticated computers of the leading climate modelling centres are spewing out a new worst case scenario: if climate change resulting from anthropogenic greenhouse gas emissions continues unabated, large areas of the remaining tropical rainforests could collapse towards the middle of the 21st century and thus signal a new round in the galloping destabilization of the Earth's atmosphere (Cramer et al, 1999a).

Luckily, this is just hypothetical, albeit frightening, conjecture, but a look at the current trends in the way civilization is reconstructing the biosphere is hardly less frightening: the background extinction rate is an estimated 1–3 species per year (May et al, 1995). As a result of human interventions this extinction process has probably increased one *thousandfold*. The estimates cited in the literature of the rates of human-induced species extinctions range from 1 to 130 species *per day* or from 1 to 9 per cent of the total biota per decade. This needs to be seen against the background of the fact that so far 1.75 million species have been counted, but actually far more (20 million?) exist/have existed in the biosphere. Since AD 1600 only approx 1,000 species extinctions have been documented explicitly. But this figure is without a doubt a great underestimation of the true extinction dynamism that only proves how little we know about our fellow creatures.

It is therefore completely legitimate to term the pressure of civilization on species diversity as the '6th Extinction' in the history of life on Earth. The five other major biospheric crises of the past (those of 440 million, 365 million, 225 million, 210 million and 65 million years ago) have played a key role in the course of planetary evolution. The experts still argue about the causes of the 'Big Five' – the reason for the 6th Extinction, which may even exceed its predecessors in terms of impact and speed, is, however, solely due to the dominance of a single species.

It is not only human-induced reductions in the number of species that contribute to the rapid loss of genetic diversity, but also the systematic loss of natural hereditary genetic variation. This applies in particular to the reduction of plant genetic resources in agriculture. For example, in the last 15 years around 1,500 locally adapted rice varieties have become extinct in Indonesia; in Sri Lanka around 75 per cent of all rice varieties with relevance to agriculture are descended from one parent plant (WRI et al, 1992). These genetic and species losses are all the more serious because they are irreversible processes: what is lost remains lost, missed opportunities never return.

As far as the Earth's landscapes are concerned, a far-reaching conversion or degradation is taking place across all habitat types. An illustration of this is the fact that in California 90 per cent of all pre-Columbian wetlands have now been lost and the situation is not much different elsewhere in the world. Whereas the area of the planet's forests shrunk by almost 20 per cent between 1700 and 1980, the area of arable land grew by almost 500 per cent!

The intervention in the global metabolism of the biosphere is no less dramatic: around 40 per cent of the photosynthesis output of green plants is manipulated by humans today; the CO_2 concentration of the atmosphere, a prime parameter for the biosphere, has already been increased by over 30 per cent by anthropogenic processes; in nitrogen fixation and freshwater consumption, the activities of the anthroposphere now dominate the natural cycles. This is a *reconstruction* of the pre-existing conditions into which humankind stepped, not a mere adjustment.

In this report the Council will describe and explain the reconstruction of the biosphere as a 'project of modernity'. The analysis will concentrate on the three main pillars – species, landscapes, cycles. Furthermore, it will identify the functional links among these pillars, which also form the links among the different time-space scales. To achieve this last objective the Council will use its tried and tested systematic interdisciplinary approaches.

WBGU reports always attempt to gain a holistic view of the issue in question. It is not so much a case of pure status and threat analysis, which is already well documented in the scientific literature – and would fill several volumes in the case of the biosphere. Rather, the Council is primarily concerned with answers to the question as to which national and international measures represent adequate responses to the objective diagnosis. In the case of the modern transformation of the biosphere, such measures are long overdue – however, they can only be successful if they fit into the logic of a *global*

Box B-2

Sustainability – what is it?

In the global environmental debate, the terms 'sustainability' or 'sustainable' made their first appearance in the combination 'sustainable development' (World Commission on Environment and Development, 1987). This means, if interpreted literally, nothing other than a future of the international community that is characterized by constant progress with respect to living conditions and the quality of life. There are now also attempts to use the adjective 'sustainable' on its own: sustainable production, sustainable consumption, sustainable conservation, etc.

In this context it is important that 'sustainable production' is seen as an extended interpretation of 'production patterns that are environmentally sound and socially equitable in the long term'. To this end, the complementary nature of ecological, economic and socio-political aspects are plainly to be emphasized. However, this interpretation of the term is redundant because environmental and social acceptability are the basic requirement for successful long-term management of Planet Earth – this understanding is the very creed of the Rio process.

With respect to operationalizing 'sustainability', the relevant literature falls apart in a jumble of opinions, some of which are characterized by disjunctive paradigms (Schellnhuber and Wenzel, 1998; Knaus and Renn, 1998). The most banal model is the notion that it might be possible to plan long-term planetary development such that this would meet all of the criteria of sustainability. This 'global' (in the systems sense) control presupposes considerable knowledge about all futures and must therefore remain an illusion.

On the other hand, there are realistic paradigms in terms of local control, such as observing aggregated indicator systems for assessing and controlling the human-environment system in a more stable and sustainable state, or preserving certain options for action for the next generation.

The least ambitious model – and therefore the one that the Council considers most capable of being implemented – is the principle of avoiding trajectories in the option space that are definitely unsustainable,. in other words the 'guard rail' principle (WBGU, 1998a, 2000a). This is based on identifying short or medium-term trajectories that result in irreversible and/or intolerable changes to the status quo (eg to global atmosphere-ocean circulation). These trajectories must be avoided. In this way, sustainability is preserved as an opportunity but the optimization of the remaining scope is placed in the responsibility of the generation concerned.

framework of 'biosphere governance'. What this does and does not mean is explained in detail in Section I of the present report. In advance, we should like to refer to two fundamental aspects: on the one hand, it can no longer be a matter of *whether* 'biosphere governance' should happen (after all, this has long been a reality, in an erratic, uncoordinated way), but entirely of *what* form it should take. In the process, the international community will have to decide whether, how and where it wants to *preserve, manage* or *actively shape*. Obviously, combinations of these strategies are possible in different places and times. On the other hand, biosphere governance will continue to be overshadowed for many years to come by a considerable *lack of knowledge* about the precise mechanisms of biosphere dynamics. For example, whereas sound predictive abilities have long been acquired in the area of climate, scientists have only just started to understand the complexity of the planetary biosphere.

But global change is progressing apace and does not give us pause for thought. Who nevertheless wants to set the course for global sustainable development (Box B-2) will have to take far-reaching decisions about the further fate of the biosphere today – even if not all of these decisions will be 'right'. The only alternative would be the folly with which the three pillars of the biosphere are currently being pulled down.

The biosphere at the centre of the people-environment relationship

C

The biosphere-centred network of interrelations C 1

The biosphere is probably the environmental sphere most affected by global change. The Council understands global change to be the change in the guiding parameters of the Earth System (eg atmospheric temperature or population), the shifting of large-area structures, processes and patterns, the decline of strategic natural assets and the modification of the linkages within the Earth System (WBGU, 1994). The biosphere is directly and indirectly affected by all of these changes; it forms, modifies and stabilizes the human environment to an extent that cannot be adequately portrayed by a simple reductionist description.

Human interventions in the biosphere not only affect the biosphere itself, but also indirectly the pedosphere, hydrosphere and atmosphere. They trigger complex cascades of effects that not only affect humans directly, but also the biosphere and the environment via indirect chains of action, whose dynamics are largely beyond our current understanding.

Modular, analytical system approaches can only ever record partial aspects of the entire problem. This is why the Council has developed a method for phenomenological system analysis that records global change as a holistic phenomenon and provides problem-centred networks of interrelations for further analyses (WBGU, 1997).

Describing the changes in the Earth System as a qualitative pattern, the so-called trends of global change, and their interactions in the form of networks of interrelations is the primary focus.

It is obvious that a biosphere-centred network of interrelations cannot be created in a single stage. At first the most important trends have to be identified. The biosphere itself has already been characterized by a number of internal changes that will influence each other (Section C 1.2). In the next stage this analysis is expanded to all of the trends associated with the biosphere. Here, even with the highly-aggregated observation method chosen, there is the problem of conserving the clarity and comprehensibility of the representation. It makes sense to break this network of interrelations down into three issue groups to satisfy this requirement. These are interactions that are associated with

1. the reduction of genetic and species diversity,
2. the functionalization and homogenization of ecosystems and landscapes,
3. the modification of the planetary regulatory services of the biosphere.

This breakdown may appear arbitrary at first glance. The analysis will show that typical chains of action will become discernible that reflect the dynamics and character of the damage. Chains or loops of action can also be discerned at the regional level. To this end the Council has developed the 'syndrome concept' that allows global change to be broken down into regional syndromes (WBGU, 1995a). The above-mentioned chains of action, which are arranged according to the most important issue areas, can be called core elements of the syndromes. This context will be shown in the last part of the Section.

C 1.1
Trends of global change in the biosphere

If we put ourselves in the role of a global observer looking at the worldwide change in the biosphere with a 'miniaturization glass', global trends can be identified that endanger the biosphere as a consequence of their interaction with the anthroposphere. The following discussion identifies and characterizes those biosphere trends that the Council considers particularly important in terms of global change. These trends are sometimes in interaction with each other or with trends from other spheres (eg hydrosphere, industry). These interlinkages are described in more detail in Sections C 1.2 and C 1.3.

Conversion of natural ecosystems

The most noticeable trend is the *conversion of natural ecosystems*. This means the conversion of natural or semi-natural ecosystems into ecosystems that have been strongly marked by human activity. This process is irreversible in the foreseeable future. Thus, for example, forests are converted into arable fields,

Continent	Area	Undisturbed	Partially disturbed	Dominated by man
	[km^2]		[%]	
Europe	5,759,321	15.6	19.6	64.9
Asia	53,311,557	42.2	29.1	28.7
Africa	33,985,316	48.9	35.8	15.4
North America	26,179,907	56.3	18.8	24.9
South America	20,120,346	62.5	22.5	15.1
Australasia	9,487,262	62.3	25.8	12.0
Antarctica	13,208,983	100.0	0.0	0.0
World as a whole	162,052,691	51.9	24.2	23.9
World as a whole (without rocky and ice regions and infertile land)	134,904,471	27.0	36.7	36.3

Table C 1.1-1
Human influence on ecosystems worldwide. The following criteria were considered: vegetation (primary, secondary, type of agriculture and forestry), population density, human settlement and land degradation (eg desertification).
Source: after Hannah et al, 1994

pastureland or plantations, and natural watercourses into canals. This form of change in land use is a key factor in global change and possibly the most important reason for the loss of biological diversity (UNEP, 1995). For example, the loss of land through conversion is cited at 68 per cent for the Indo-Malay countries and 65 per cent for the tropical countries in Africa (MacKinnon and MacKinnon, 1986). Today, only 27 per cent of the Earth's surface covered by vegetation is classed as undisturbed by humans (Table C 1.1-1).

This trend can be differentiated from the trend of *degradation of natural ecosystems*, in which there is no direct destruction of natural structures but a mostly slow, anthropogenic influence that is marked by a gradual loss of structures or functions (UNEP, 1995). In order to allow an exact differentiation the trend *degradation of natural ecosystems* has been sub-divided into the three trends below.

Fragmentation of natural ecosystems

Fragmentation means the spatial breakdown of formerly coherent natural ecosystems into smaller, isolated partial areas, which, for example, arise through the construction of transport infrastructure or through conversion (Noss and Csuti, 1997). As a result of this, the habitats of individual species are made smaller and the populations are isolated from each other. Fragmentation slows down the genetic exchange between populations or can even bring it to a standstill, with the result that there is a gradual loss of species in the fragments. Fragmentation can frequently be seen after a large-scale conversion, eg the areas excluded from the clearance of primary forest form individual 'islands' in the midst of arable land, pastureland or secondary vegetation that are often too small to ensure the long-term functioning of the partial ecosystems. Both globally and regionally, fragmentation is one of the major threats to biological diversity (WRI et al, 1992).

Damage to ecosystem structure and functions

This addresses the loss of functional units in an ecosystem, which, for example, can be triggered by the extinction of dominant species or keystone species (Section D 2), by immigration of alien species (Section E 3.6) or by substance overload (Section E 3.2). As a result, the functional interactions between the species (eg food webs) are modified in such a way that the ecosystem changes greatly (triggering succession) or the original ecological services can only be performed to a limited extent (UNEP, 1995).

Substance overload of natural ecosystems

There are a large number of substances that exert negative influences on ecosystems. Excessive loading with organic (degradable) substances and nutrient salts (eg nitrate, phosphate) can trigger eutrophication in lakes, rivers and streams and coastal waters and put the groundwater at risk. Inputs of pollutants from the air (eg SO_2, NO_x) and the resultant acid rain damage forests and lakes. Organochlorine pesticides (eg DDT or lindane) from agriculture and forestry that biodegrade slowly (persistent) can cause direct damage, but also have an indirect effect via accumulation in food chains. Not least, a wide variety of toxic substances reach the biosphere from many sources: eg mercury pollutes South American rivers and streams as a result of gold mining, cyanides are used for fisheries in southeast Asian reefs (Section E 2.4), dioxin is released into the environment from industrial processes or radioactive waste is disposed of at sea (radiation). The consequence of this substance deposition is that today no spot on Earth can be considered to be free of anthropogenic pollution.

Genetic and species loss

Genetic and species loss is a major consequence of the above-mentioned ecosystem trends (WBGU, 1996; Stork, 1997). The Earth is currently in the middle of the 'Sixth Extinction' (Leakey and Lewin, 1996), ie a drastic collapse of the number of species (Section D 1.2). It is estimated that the current species extinction rate is 1,000–10,000 times higher than the natural background rate (May and Tregonning, 1998). The extinction of species that can be seen today can certainly be compared to the fifth Extinction at the transition from the Cretaceous Age to the Tertiary Age, both in terms of extent and speed (Wilson, 1995). The genetic impoverishment of wild species and the extinction of traditional crop varieties and their wild relatives (genetic erosion) have become worrying features of global change in recent decades (FAO, 1996b; Meyer et al, 1998; Sections D 3.4 and I 2).

Resistance formation

Resistance formation describes the adaptability of parasites or pathogens of humans, animals and crops to anthropogenic interventions, such as the increasing resistance to antibiotics or biocides. This trend is the reason why humankind is constantly competing against nature when fighting diseases: research has to develop new drugs against resistant strains and cross new genes into crops (WBGU, 2000a; Section D 3.4). This on-going development process is, in turn, dependent on ever-new biological material or information from nature (Section D 3.3). The new spread of diseases that had been thought to be under control is an indication of the significance of this global trend (WHO, 1998; WBGU, 2000a).

Increase in anthropogenic introduction of species

This trend refers to the introduction of species into other regions, accidentally eg in the ballast water of ships or intentionally through targeted settlement (Sandlund et al, 1996). The increasing release of genetically modified species can also be included under this heading. This trend is one of the most noticeable consequences of globalization and increasing international transport and trade for the biosphere. It has a considerable impact on biodiversity and, alongside ecosystem conversion, is considered to be the most important cause of the losses of animal species documented to date (WCMC, 1992). This trend will be dealt with in detail in Section E 3.6.

Overexploitation of biological resources

This trend means the unsustainable anthropogenic use of biological resources, eg by hunting, shooting, fishing, pasturage or forestry. It can have serious consequences for species use and frequently also for the entire ecosystem and may become a major cause of species loss. For example, this trend is responsible for 23 per cent of the losses of animal species documented to date (WCMC, 1992). This means the deliberate or accidental exceeding of sustainability limits in the narrow sense: more is harvested than grows back. A classic example is the present high seas fishery (Section E 3.4). In an extreme case the consequence is the extinction of the 'target species'; damage to the ecosystem structure and function is more frequent. The trend has to be delimited against the conversion of natural ecosystems: if, for example, a forest is burned down or cleared, then the biological resource is not only being used, it is being completely removed. After this, it is this site that is primarily being used, eg for agriculture or settlements. This is to be differentiated from overuse, eg the selective felling of a valuable tree species so that the forest remains but the tree species disappears from the forest.

Biospheric sources and sinks

The effects of the biosphere on the climate and the water cycle are of particular importance (WBGU, 1998b). For example, as a result of the trend of *loss of biosphere sinks,* anthropogenic inputs into the atmosphere may develop a greater impact because the biosphere plays an active role in the substance cycles. On the one hand, it is a direct sink, for example for climate-relevant trace gases as CO_2. On the other hand, it works as a 'catalyst' in the biogeochemical cycles. It accelerates and intensifies the transfer of carbon dioxide from the atmosphere into the soil, stabilizes a concentration equilibrium between the environmental compartments (atmosphere – soil, atmosphere – water, water – soil) and thus also intensifies the sinks via weathering processes.

In addition to the loss of sinks, the reinforcement of biospheric sources is considerable, too. The biosphere can directly emit a number of environmental and radiatively-active substances. In addition to the influence on the local water cycle, more complex control mechanisms are also increasingly being discussed. The emission of dimethyl sulphide (DMS) by some marine algae leads, for example, to increased cloud formation and, thus, to a homeostatic influence on the climate via the albedo of the clouds (Section F 1). Other aspects are the emission of CO_2 by soil-dwelling organisms or the release of nutrients by the biogenic weathering of minerals.

C 1.2 Mechanisms with a direct impact within the biosphere

The biosphere trends described in Section C 1.1 cannot be viewed in isolation from each other; some of them interact directly. In this context the term 'interaction' should not be understood in purely mechanical terms; much rather the following patterns are meant: Trend A and Trend B occur jointly in a region in which environmental degradation can be seen. In many cases this is an outcome of a clear causal relationship between cause and effect, but can also only be a weak indirect link merely indicative of a more deep-seated cause of the coincidence.

Fig. C 1.2-1 illustrates this dynamic network. Especially important interactions primarily affect the two trends *damage to ecosystem structures and functions* and *genetic and species loss*. Both of these trends correlate with each other and can also mutually amplify each other to the extent that in an extreme case the ecosystem collapses and is replaced by another ecosystem (Section D 2.4). Direct impacts on both trends emanate from the 'primary' causes: the conversion, fragmentation and substance overload of natural ecosystems, introduction of species and overuse. Conversion is especially serious because it not only leads to species loss, but also reduces the sink effect of natural ecosystems and strengthens biospheric sources of greenhouse gases as CO_2 or CH_4 (WBGU, 1998b). The above-mentioned close correlation between conversion and fragmentation is illustrated by a correspondingly strong interaction. Fragmentation and isolation generally lead to genetic and species loss in the natural ecosystem as a result of population-biological processes (Loeschke et al, 1994). The species diversity of the cultivated landscape that developed after conversion and fragmentation may even increase as a result of the higher number of ecosystem types, but the biological diversity of the original ecosystem type decreases (for example, this applies to Central Europe in the post-Ice Age; Section E 2.1). The increase in the anthropogenic introduction of species can exert a devastating influence on the structure of the natural ecosystems concerned if the introduced species encounters a high number of resources with only a few biological 'opponents' (eg competitors, predators, parasites). Direct or indirect genetic and species loss can ensue (Section E 3.6).

C 1.3
Impact loops in the biosphere-centred network of interrelations of global change

The relationships within the biosphere outlined above shape a large proportion of its dynamics. However, the biosphere is also linked to the other spheres of global change: trends from the hydrosphere or industry, for example, also affect the biosphere and trigger chains of action there that can amplify the degradation trends in the biosphere. These more deep-seated driving forces are described here.

If we imagine the plethora of worldwide changes within the context of global change, then, surprisingly, there are relatively few, but important, trends that have an effect on the biosphere from 'outside'. We can image the complexity of individual examples of biosphere damage by marking these important trends and clarifying their connections by means of amplifying or attenuating arrows. In this respect, characteristic chains of action can be recognized, ie trends linked by arrows that represent sequences in a

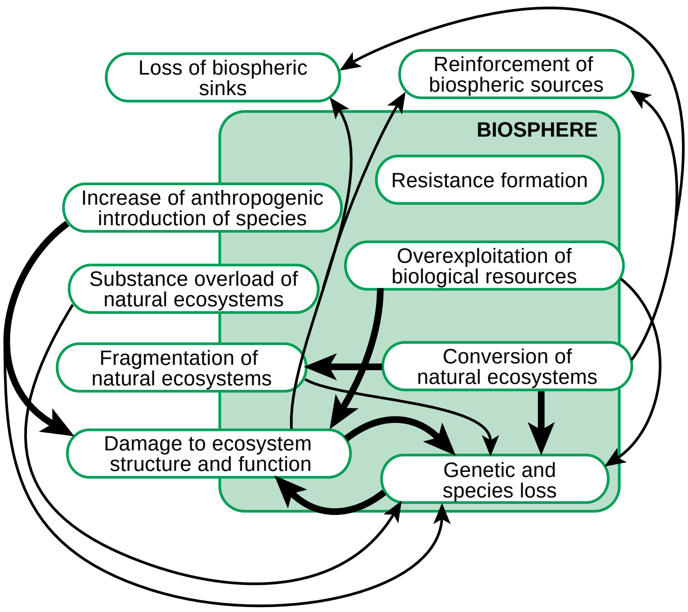


Figure C 1.2-1
Trends and their interactions within the biosphere. Thick arrows show especially important interactions.
Source: WBGU

larger, closed impact loop. Such impact loops identify specific degradation patterns and the key problems in the biosphere. Obviously, an impact loop cannot reveal all causes and effects, that would only be possible with a complete syndrome analysis in which the individual sequences or chains of action of the impact loop are assigned to one or more syndrome(s) (eg Overexploitation Syndrome; Chapter G). Nevertheless, the impact loops clearly show the anchoring of biosphere damage in the dynamics of global change. In the following, seven of these typical impact loops that have a major influence on the worldwide degradation of the biosphere will be presented as an example.

C 1.3.1 Threat to genetic and species diversity

Two globally relevant examples were chosen for the description of impact loops in which the effects of the trend *genetic and species loss* are most important; these examples are typical of the function of biodiversity as 'survival insurance' (Fig. C 1.3-1):

1. Threat to food security through the loss of genetic and species diversity.
2. Threat to the acquisition of natural products and active substances through the loss of genetic and species diversity.

Threat to food security

The extent to which food security and the requisite genetic and species diversity are influenced by global change has already been shown repeatedly by the Council (WBGU, 1998a, b) and is enlarged upon in this report (Section D 3.4). The global significance of this subject became clear in 1997 when it was discussed at the United Nations World Food Summit and the FAO Conference on Plant Genetic Resources (BML and ZADI, 1997).

Two trends lead directly to genetic and species loss: the *intensification of agriculture* and the *decline in traditional agriculture*. Both trends mean that traditional crop varieties and rare livestock breeds are suppressed by high yielding varieties or breeds. The traditional varieties form a valuable genetic reservoir that is being used to adapt important crops to changed environmental conditions or new pathogens by means of breeding or genetic transfer in order to feed the world (Sections D 3.4 and I 1.2). In this way, genetic and species losses can block or slow down progress in biotechnology and genetic engineering and, ultimately, hamper the increase in food production. As a consequence, the compulsion to extend or intensify the agricultural area may increase, which closes the self-reinforcing effect cycle. This impact loop motivates one of the Council's biosphere imperatives: preserve resources for food security (Section I 1.2).

The loss of natural products and active substances

Genetic and species loss hampers the development of new active substances, product substitution, advances in medicine and in biological and genetic engineering by reducing the stock of specimen biological material. Cases have already been brought to light in which a species that demonstrated valuable properties in laboratory tests could no longer be found in renewed field research as a result of ecosystem conversion. This development is amplified by the fact that the loss of traditional social structures and lifestyles is also associated with the loss of the traditional knowledge of the people, with its shamans and medicine men and women, about the various species, their characteristics and possible uses (eg traditional medicinal plants or crops; Sections D 3.3 and E 3.5). Medical and technological progress is losing a living and valuable body of knowledge here. The following is a positive feedback loop: pharmaceuticals groups or other companies dependent on natural products have an interest in protecting genetic and species diversity in the ecosystems that they use so that they can also use these sources in the future. One example of this connection is the contract between INBio, Costa Rica and Merck (WBGU, 1996; Section D 3.3) that can be interpreted as an increase in environmentally sound ways of doing business.

C 1.3.2 Misappropriations in natural and cultivated landscapes

The destruction of natural ecosystems

The insistence of many developing countries upon rapid economic development, which is often associated with neglecting the long-term consequences, is one of the main driving forces for the conversion of natural ecosystems (Fig. C 1.3-2). This mainly – but not only – concerns harvesting primary forests (Section E 2.2) and earning foreign currency from the sale of timber or products manufactured from it in the country, for example. The increasing consumption of energy and raw materials and the 'downstream' trends of industrialization, globalization and the increase of world trade are indirect driving forces here. International indebtedness can also contribute to conversion because it heightens the need for foreign currency. Conversion runs in parallel to the expansion of transport routes because they are the prerequisite for removing the timber and open up the

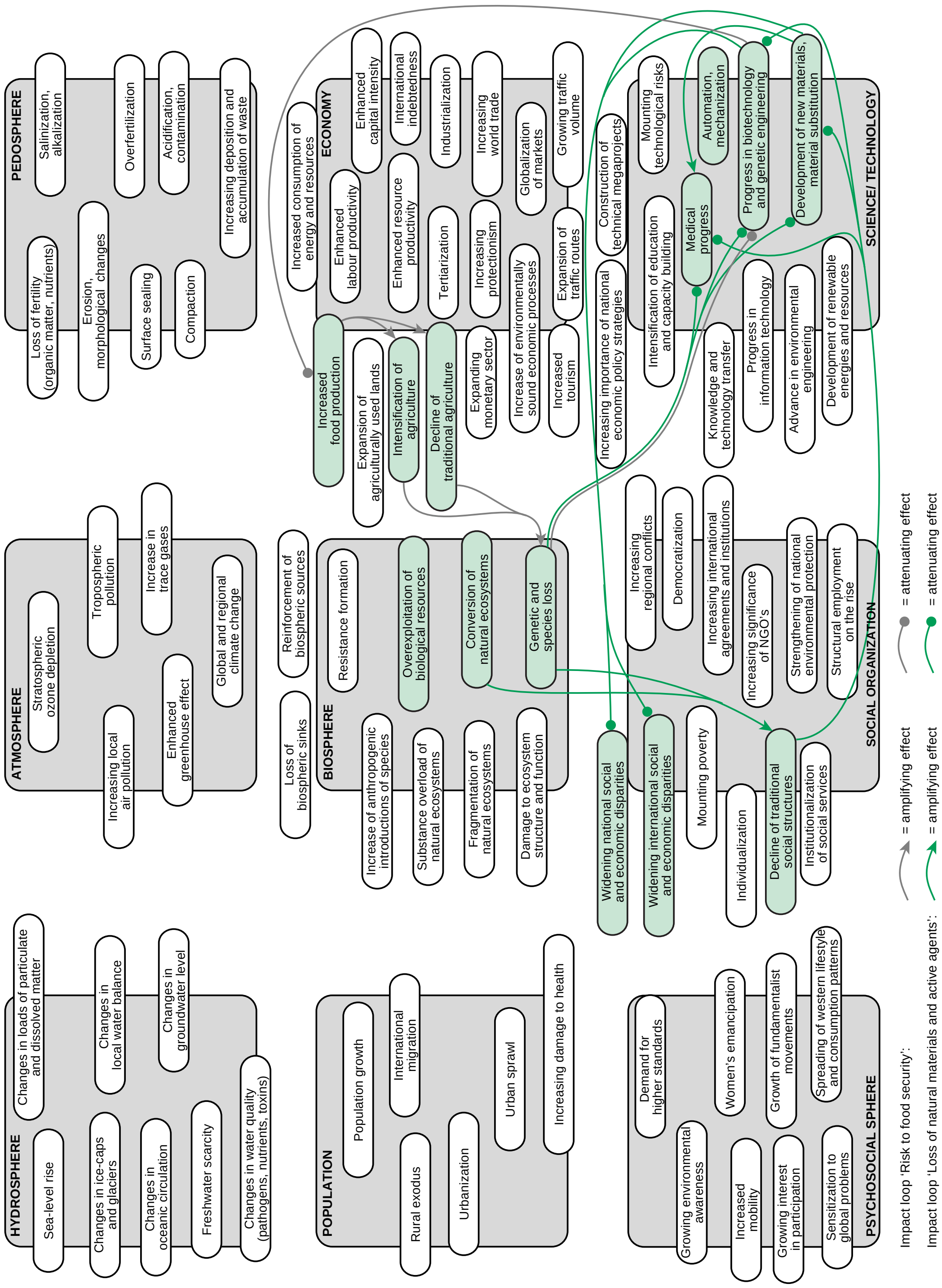


Figure C 1.3-1
Network of interrelations for the consequences of genetic and species loss.
Source: WBGU

way for a migrating population; in fact conversion and the expansion of transport routes mutually amplify each other. The cleared – or, in the case of the conversion of wetlands, drained – land is frequently used directly for agriculture (expansion of agricultural land) in order to offer a livelihood to the growing population. This connection offers a second, important, motivation for conversion that takes places on land where harvesting wood alone is not worthwhile.

The effects of conversion vary according to the region and natural conditions (soil, climate). Nevertheless, some interactions can be defined that can be repeatedly found. For example, the conversion of natural ecosystems is equivalent to leaving the soil free to weathering, which leads to erosion and the washing away of nutrients and humus. In mountainous regions in particular, soil degradation leads to the dereliction and karst development of large areas.

In tropical regions land cleared of primary forest cannot be used for agricultural purposes for very long because of soil exhaustion (loss of fertility): at the climax of succession after just a few years there is infertile grassland that cannot be used and can only be recultivated at great expense. The cycle closes quickly because the falling yields force another expansion of arable land. The new clearance and subsequent cultivation in turn destroys semi-natural land. The conversion has the consequences on the biosphere described in Sections C 1.2 and E 2.2: biological diversity is lost in the interaction of fragmentation and damage to the ecosystem structure and function.

Damage to ecosystem services

When this development takes place on large areas or in especially sensitive regions there is a 'lateral loop' that speeds up the processes and exacerbates them. The large-scale conversion of forest also always changes the local hydrological regime. Forests perform especially important ecosystem services in this case (Sections D 2 and D 2.5-1): precipitation and direct run-off are slowed down, the forest stores considerable amounts of precipitation and only returns it gradually to the environment. As a result, a much larger proportion returns to the atmosphere through the evapotranspiration of plants and thus stimulates local precipitation activity. The water cycle is therefore short-circuited at a local level and the residence time of the water in the region is lengthened. As a result of the clearance of forests, especially mountain forests on slopes, these ecosystem services are endangered. The direct consequences are soil erosion as well as the leaching of nutrients and humus. This soil degradation thus amplifies the impact loop described above. Indirectly this loop is accelerated by changes in the local and regional climate: the reduction in precipitation may be a great additional burden for the remaining semi-natural ecosystems.

In addition, there is another indirect consequence of the increased erosion. The washed out soil increases the sediment and nutrient loads in rivers and streams, which means that freshwater and coastal ecosystems can be overloaded with substances. But on the other hand, the equilibrium in rivers and streams is directly altered meaning that, for example, bank erosion or increased sedimentation in the river deltas may threaten semi-natural ecosystems (Section E 2.4).

Introducing alien species

Since the Middle Ages the greatly increased travel and trade activities have led to organisms increasingly overcoming biogeographical barriers. Although only a tiny fraction of the introduced species can establish themselves in the new habitat, those that do often have severe consequences for the native ecosystems (Section E 3.6).

Throughout the world there are many examples of the damage to ecosystem structures and functions by alien species (Bright, 1998). Since new species can apparently establish themselves more easily in systems that have already been damaged, such trends often indirectly lead to an increase in species not native to the area. As competitors, parasites or predators of native flora and fauna, alien species can lead directly or indirectly to genetic and species loss, which is why this trend is seen as an important direct cause of the loss of biological diversity (Sandlund et al, 1996). Ecosystems of an insular nature that have undergone geographically isolated evolution and therefore often have a large number of endemic species are particularly affected by this. In addition to genetic and species loss, however, there may also be an increase in species diversity on a regional scale if the number of species destroyed is exceeded by the number of newcomers, such as is the case in Central Europe, for example (Section E 2.1). However, at a global level, introduction lead to species loss and to a homogenization of the species inventory that levels out ecosystem, regional and local special characteristics.

The anthropogenic introduction of species also directly affects humans because the introduction of pathogens such as bacteria or viruses can lead to considerable risks to health (eg plague, AIDS or cholera).

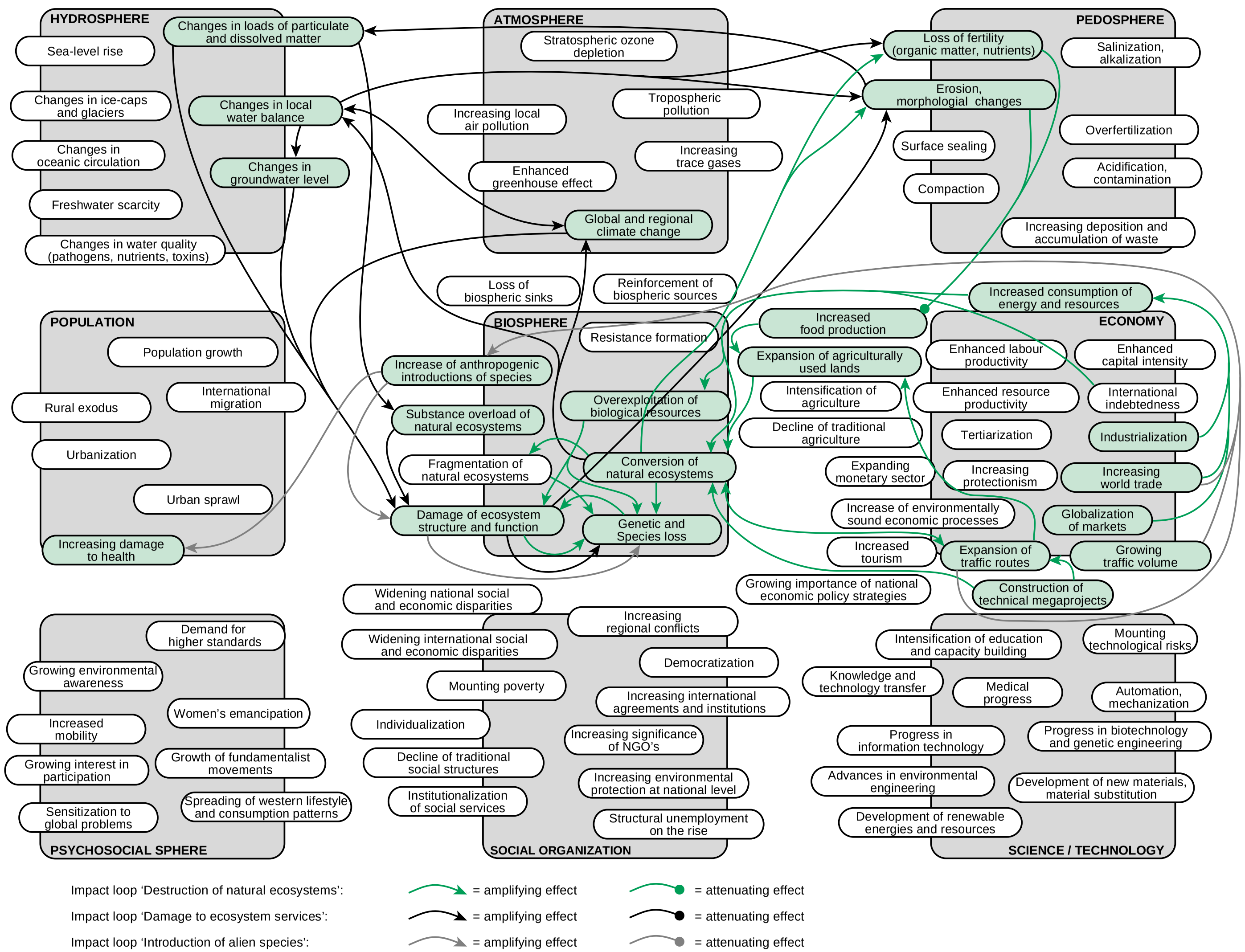


Figure C 1.3-2
Network of interrelations for ecosystems and landscapes.
Source: WBGU

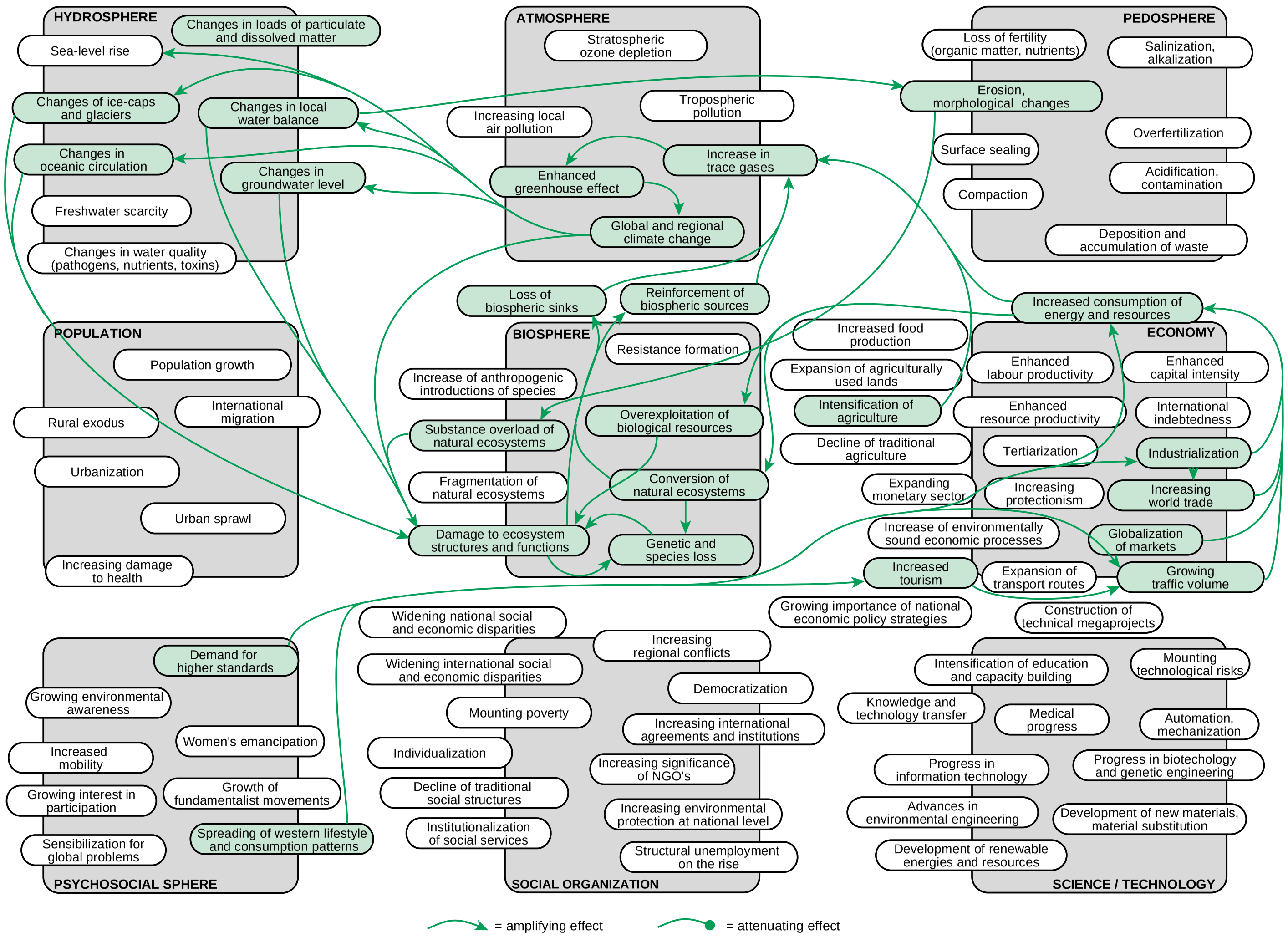


Figure C 1.3-3
Network of interrelations for the regulatory function of the biosphere.
Source: WBGU

C 1.3.3
Impairment of the regulatory functions of the biosphere

The role of the biosphere in the Earth System is not limited to a passive anchoring in the physical framework conditions of Planet Earth. Within certain limits the biosphere is also actively involved in controlling the environmental conditions (Section F 1). Since there is no regulatory mechanism between actual and ideal conditions with defined regulatory parameters in nature, the homeostatic principle comes into play here: a dynamic equilibrium of substances comes into being as a result of a negative feedback between contradictory principles, which, for example, not only has a major influence on the radiatively-active composition of the atmosphere, but also on soil fertility or the water cycle. Ultimately, practically all substance compositions of the environmental media (soil, water, atmosphere) would probably be greatly influenced by the biosphere and, possibly, even 'regulated' via negative feedback (Section F 5). The intensities of the biologically moderated substance sinks and sources that have organized themselves into practically stable dynamic equilibria in the course of evolution are central to this. This biosphere's role is being increasingly disrupted by human intervention (Section F 3). Here the two trends of *loss of biosphere sinks* and *reinforcement of biospheric sources* are the focus of analysis (Fig. C 1.3-3).

Changes in biospheric climate regulation

The radiatively active cascade is an important biospheric regulatory cycle, in which humankind intervenes by means of the conversion of natural ecosystems and an increasing overexploitation of biological resources. As a result, on the one hand biological sinks for anthropogenic carbon dioxide emissions are lost, on the other hand carbon stored in the soil (humus, dead biomass) and radiatively-active methane are released (reinforcement of biospheric sources). The greenhouse effect is further amplified in conjunction with the worldwide trend of an increasing consumption of fossil energy and the associated rise in trace gases in the atmosphere.

This change in the atmosphere's thermal balance, which amplifies the trend of *global and regional climate change*, leads, on the one hand, to a change in the local water balance, on the other hand, direct harmful effects can be seen in the biosphere. A change not only in the air temperature, but also to the water balance and, thus, to the groundwater level, leads to damage to the ecosystem structure and function if the ecosystem concerned has only low adaptability. This obvious environmental damage is given a high profile in the media and often brings about renewed efforts to protect and conserve nature (Section C 1.3.4). Growing environmental awareness, also in conjunction with sensitization to global problems, is, however, in stark contrast to growing demands and the increasing spread of western patterns of consumption and lifestyles. These trends are closely linked to internationally significant developments, such as increasing tourism (Section E 3.7), agricultural expansion, growing traffic volumes and economic globalization (Fig. C 1.3-4), which are usually associated with heavy consumption of resources and energy. In this way, as a result of the worldwide appropriation of land, they amplify the loss of biosphere sinks and thus modify biosphere climate regulation.

Disrupting the role of the biosphere in the water cycle

The hydrological cycle is also largely influenced by the biosphere. As well as an additional effect on the climate via the large-scale movement of energy towards the poles, the reduction of radiation through clouds or the greenhouse gas effect of water vapour in the atmosphere, the water cycle has important additional aspects: it transports nutrients, creates the conditions for the reduction of high solar radiation by forming clouds and plays a major role in the global energy balance. As a result of the conversion and the substance overload of natural ecosystems, this fragile equilibrium is being disrupted. Consequently the water retention capacity or storage capabilities are greatly impaired. On a larger scale, there is a loss of biosphere sinks that encourages erosion processes and morphological changes. In turn, this changes the local water balance and thus, for example, the groundwater level.

If certain levels are exceeded this impact loop can feed back positively. One example of this is the process of self-reinforcing desertification. The overuse of soils that may already be marginal not only has a direct influence on the biosphere, but also, almost imperceptibly at the beginning, on the special functions of the flora for the local water cycle. If the biologically-modified water retention capacity is then reduced, the ecosystem stability falls and minimal changes in the climate or use can lead to a catastrophe.

C 1.3.4
Humankind as the preserver of nature

The negative ecosystem trends that can be observed worldwide, such as the extinction of species, are

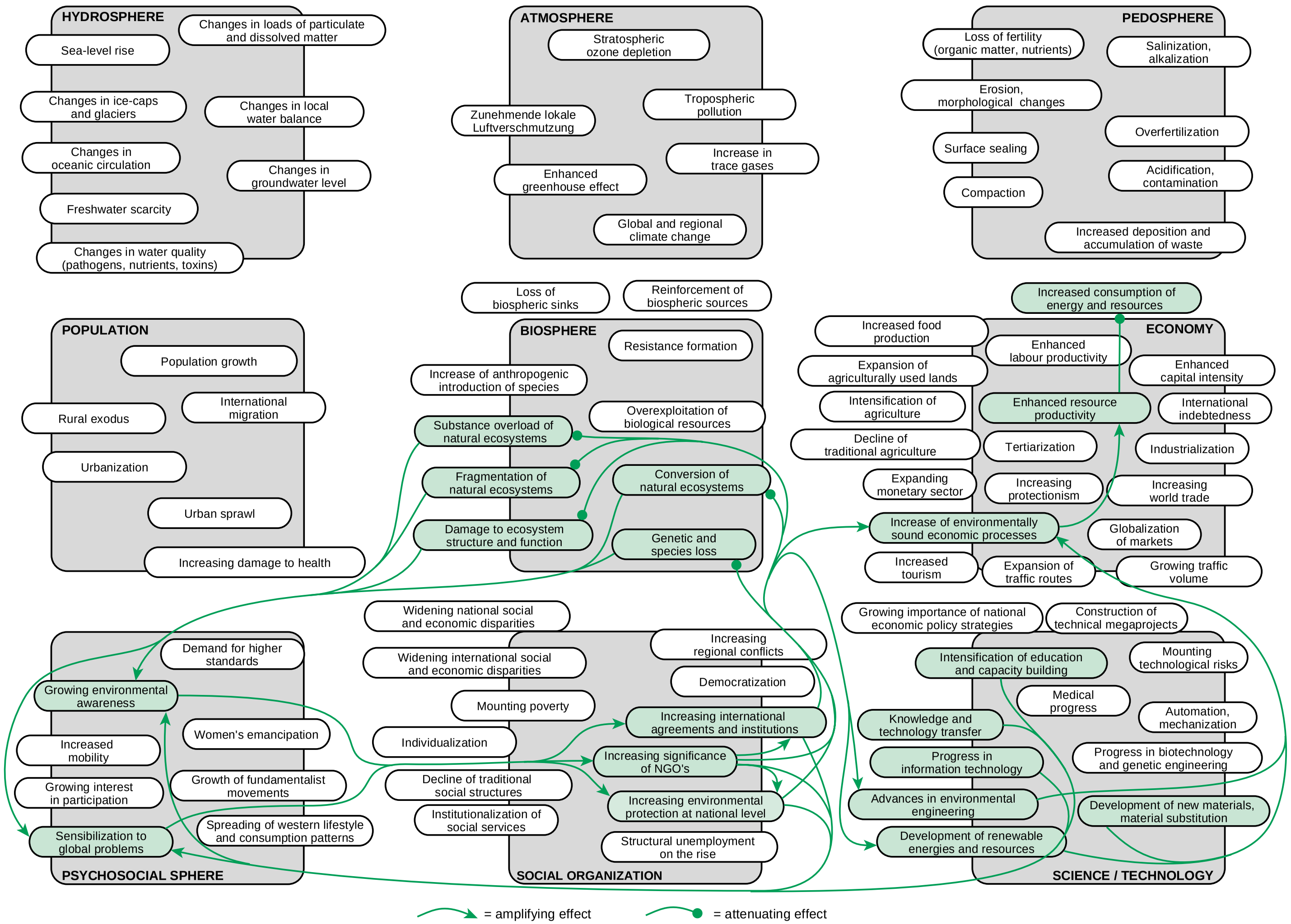


Figure C 1.3-4
Network of interrelations for the positive impact loop in the biosphere.
Source: WBGU

receiving more attention from the public (Sections E 3.1 and I 2.5). As a result, environmental awareness is strengthened, and in recent years sensitivity to global problems has also been increasing: the cross-border character of many environmental changes (eg climate change) is becoming clearer. These concerns manifest themselves in the growing significance of environmental NGOs and the growing pressure on political decision-makers. They react with strengthened national environmental protection policies (eg environment ministries) and, at international level, these fears and insights have now led to a number of institutions and environmental agreements (WBGU, 1996; Section I 3).

The work of the environmental institutions is always directed at awareness-raising in society: it may thus have an effect on environmental awareness. But there are also direct successes measurable in the environment: environmental policy certainly has an attenuating effect on the trends towards the loss of biodiversity. One example is the protection of wetlands, which has at least slowed down the disappearance of ecosystems and species as a result of relevant regulations (national nature conservation legislation, Ramsar Convention). CITES, too, (Section D 3.1) has been successful: thanks to international trade bans, the populations of individual species of some plants and animals have recovered. This closes the circle of a positive, self-reinforcing feedback.

Industry has reacted to this pressure from politicians, NGOs and the media by increasing environmentally sound economic patterns. Examples of this include the efforts to certify wood products from sustainable forestry or voluntary commitments for environmental protection on the part of industry.

This 'conservation loop' clearly shows that man and society are not helplessly at the mercy of the negative developments in the biosphere, but that there is most certainly a potential for reaction and adaptation. Recognizing these processes and consciously encouraging them is therefore an element of national and international environment policy. However, these positive approaches must not conceal the fact that it has so far only been possible to halt the conversion and degradation of ecosystems to an insignificant extent.

Impact loops as core elements of syndromes

C 2

The global impact loops described in the last sections, ie closed chains of action in the biosphere-centred network of interrelations, show why a harmful change within the biosphere cannot be viewed separately from the trends that are associated with it. Furthermore, impact loops illustrate in a special way the dynamics of these frequently self-reinforcing developments.

In a regional consideration it can be seen that the global impact loops as a whole or as essential sequences are elements of syndromes (Box C 2-1). Syndromes link certain regional forms of environmental damage with their specific causes. They reflect typical combinations of harmful people-environment interactions that can be seen all over the world and, in their entirety, form the basic patterns of global change (WBGU, 1994, 1997). Syndromes are characterized by their trans-sectoral character, ie the problems take effect across the borders of individual sectors (eg industry, biosphere, population) or environmental media (eg soil, water) but always have a direct or indirect relationship to natural resources. The syndromes are given global relevance when in their entirety they modify the character of the Earth System and thus have a direct or indirect noticeable influence on the foundations of life for a majority of people or when globally coordinated action is required to overcome the problems.

Each of these syndromes (or 'global diseases') represents a human-induced interlinked effect with very specific environmental stresses. It is thus an independent environmental degradation pattern, ie one that is largely separate from the other syndromes. Syndromes are characterized by a geographical patchwork structure. If each syndrome would be assigned a specific colour with several degrees of intensity, the overlaying of the syndromes then would provide a meaningful picture of the environmental and developmental state of the Earth.

Box C 2-1

Overview of the syndromes of Global Change

Overutilization syndromes

1. Overcultivation of marginal land: *Sahel Syndrome*.
2. Overexploitation of natural ecosystems: *Overexploitation Syndrome*.
3. Environmental degradation through structural changes in traditional cultivation methods: *Rural Exodus Syndrome*.
4. Non-sustainable agro-industrial use of soils and waters: *Dust Bowl Syndrome*.
5. Environmental degradation through extraction of non-renewable resources: *Katanga Syndrome.*
6. Environmental degradation through developing and reshaping natural regions for tourism: *Tourism Syndrome*.
7. Environmental degradation through military use: *Scorched Earth Syndrome*.

Development syndromes

8. Mismanaged or failed large-scale projects with targeted reshaping of the environment: *Aral Sea Syndrome*.
9. Environmental degradation caused by transfer of locally inappropriate agricultural production methods: *Green Revolution Syndrome*.
10. Environmental degradation resulting from high-speed economic growth: *Asian Tigers Syndrome*.
11. Urbanization and environmentally harmful behaviour in human settlements: *Favela Syndrome*.
12. Urban sprawl and spread of infrastructure as a characteristic of environmentally harmful agglomeration: *Suburbia Syndrome*.
13. Local, singular industrial disasters with long-term effects: *Major Accident Syndrome*.

Disposal syndromes

14. Environmental problems with disposal by diluting pollutants in the air and water: *Smokestack Syndrome*.
15. Environmental problems with disposal by compacting and landfilling waste substances: *Waste Dumping Syndrome*.
16. Environmental degradation by local contamination, waste accumulation and contaminated sites: *Contaminated Land Syndrome*.

Identified chains of action	Relation to the Overexploitation Syndrome	
	Significance	Example
Threat to food security	high	overfishing the seas
Loss of natural products and active agents	high	clearing tropical forests
Destruction of natural ecosystems	high	clearing tropical forests
Damage to ecosystem services	high	clearing tropical forests
Introduction of alien species	none	
Humankind as the preserver of nature	increasing	Biodiversity Convention
Changes to biospheric climate regulation	high	Clearing boreal forests
Disruption of the role of the biosphere in the water cycle	high	clearing mountain forests

Table C 2.1-1
Significance of individual impact loops from Section C 1 for the Overexploitation Syndrome (Chapter G).
Source: WBGU

C 2.1
Chains of action as part of a syndrome

Using the example of the Overexploitation Syndrome, which describes the large-scale exploitation of biological resources using high levels of capital and technology as set out in detail in Chapter G, it can be shown how individual chains of action can be elements of a syndrome. Table C 2.1-1 uses several examples to illustrate this assignment. The mechanism of the Overexploitation Syndrome can also be shown in the form of a network of interrelations (Fig. G 2.2-1). On the basis of the assignments shown in Table C 2.1-1, however, a network of interrelations of syndromes could also be compiled by overlaying impact loops. This aspect of research merits further consideration, since the deviation of this overlaying from the network of interrelations acquired by the integration of expert knowledge and case studies directly allows the identification of the driving forces of overexploitation.

C 2.2
Chains of action as part of several syndromes

Individual chains of action are usually common components of several syndromes that have an impact in a region. An individual chain of action can, for example, contain trends that form the link between several syndromes active in a region. This is shown in Table C 2.2-1 using the example of the disruption of the role of the biosphere in the water cycle.

The common link here is the intervention in the subtle interaction between the soil, biosphere and hydrosphere. If several disturbances occur in the form of simultaneous impacts generated by various problematic environmental usages, the impacts can mutually amplify each other and irreparably damage a region in the long term. The following chapters address and investigate in depth a broad array of systematic connections between the characteristic forms of people-environment interactions and damage to the biosphere.

Syndrome	Mechanism
Overexploitation Syndrome	Loss of biological sources
Sahel Syndrome	Reduction of the soil's precipitation storage capacity
Suburbia Syndrome	High water consumption and reduction of the formation of new groundwater as a result of sealing
Dust Bowl Syndrome	High removals of groundwater for irrigation and raised transpiration rates
Aral Sea Syndrome and Katanga Syndrome	Structural changes to the water balance

Table C 2.2-1
Mechanisms by which individual syndromes are involved in disrupting the role of the biosphere in the water cycle.
Source: WBGU

Genetic diversity and species diversity D

The use of genetic and species diversity as illustrated by the higher plants

D 1

D 1.1
Introduction

The problem at the very heart of conserving species diversity can be shown by the example of the conifers (Pinaceae) and orchids. The Pinaceae family comprises worldwide just some 250 species (WCMC, 1992) that are the dominant form of vegetation on 19 million km^2 of the Earth's surface, for example in the boreal coniferous forests. By contrast, there are 25,000–35,000 species of orchid (WCMC, 1992), but in no part of the world is any vegetation determined in its structure or biochemical cycles by orchids. The question therefore arises, does humankind need the 35,000th orchid, and – if there is no direct need – what are the reasons for worldwide endeavours to preserve this species for the future?

This chapter gives an overview of the Earth's biological diversity at the level of genetic and species diversity. We first discuss the use of species diversity for the example of the higher plants, and then go on to present selected issues of concern in more detail.

D 1.2
The bases of genetic and species diversity and their geographic distribution

Any differentiation within a species begins with a DNA mutation that only rarely proves to be of direct advantage in evolutionary terms. More frequently this advantage only emerges after a longer period or when environmental conditions change (pre-adaptation). The establishment of barriers to crossbreeding marks the transition from a population into a new and distinct species (Box D 1.2-1). Genetic diversity is almost impossible to measure. That is why various molecular biological indicators are generally used when making statements in this regard (detailed explanations in Bisby, 1995 and Mallet, 1996).

The origins of life lie approximately 4 thousand million years in the past. Since that time the number of species has constantly increased, even though there have also been mass extinctions in the course of the Earth's history (Fig. D 1.2-1). But the human-induced extinction rate we see today is 1,000–10,000 times higher than any natural background rate (Barbault and Sastrapradja, 1995; May and Tregonning, 1998).

Worldwide, approximately 1.75 million species have been described (Table 1.2-1). This represents

Box D 1.2-1

Mechanisms that lead to species diversity as illustrated by the impact of fire

On the territory of the Republic of South Africa there are approx 23,500 plant species, of which 80 per cent are endemic. This is particularly true of the Cape peninsula, which is famous for being a flora kingdom in its own right, the Capensis. But even there, one cannot find 23,000 species in any one area under investigation (eg 1 hectare). The local diversity (termed α-diversity) is relatively low and constant (5–30 species per m^2). But then on each mountain one finds a completely new flora (there is a high β-diversity, the measure of regional diversity). The reason lies in the differentiation of the landscape by fire as a natural on-site factor. Fires occur in limited areas, whenever sufficient biomass has accumulated (every 30–40 years). After a fire, it is those species that are best adapted to the fire that germinate. The seedlings have relatively little competition, so any mutation has a good chance of survival. If after several years the plants bloom on this burned area then in each population a limited exchange of genes with neighbouring populations and, thus, the opportunity to stabilize mutations through inbreeding occurs. This leads over longer periods to genetic isolation and speciation in limited populations, ie endemisms (Bond, 1983). Similar mechanisms lead in arid regions to the formation of new species since every time it rains isolated populations emerge and these remain isolated for a time from neighbouring populations.

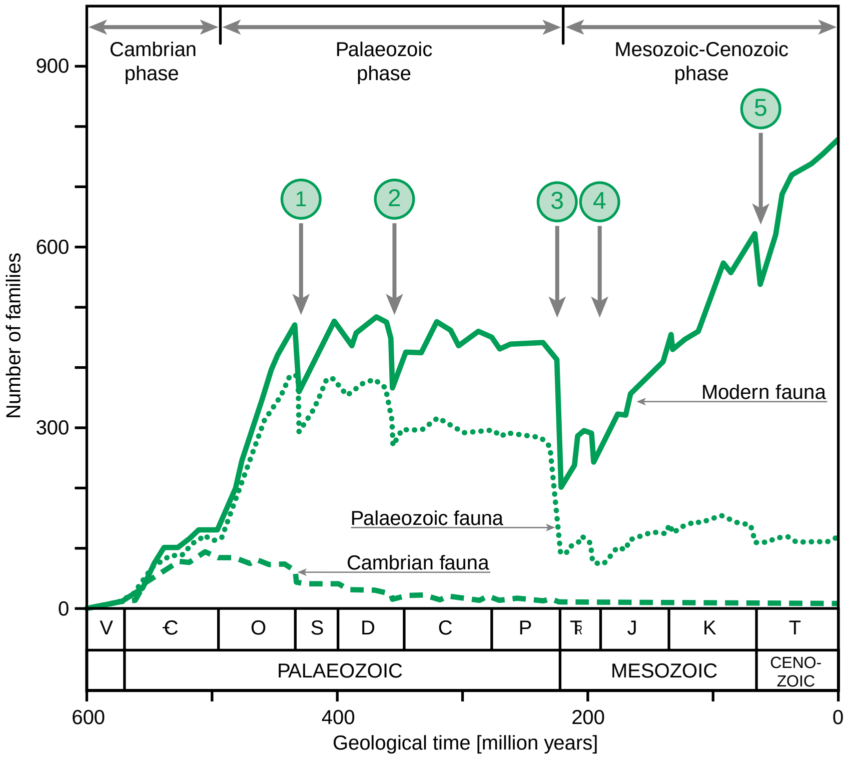


Figure D 1.2-1
Change in global species diversity illustrated by the marine animal families.
Extinctions:
1. end-Ordovician
2. late Devonian
3. end-Permian
4. end-Triassic
5. Cretaceous-Tertiary.
Source: Barbault and Sastrapradja, 1995

probably just 14 per cent of the total number of species on Earth, the total being estimated at 13.6 million. The plants and vertebrates are relatively well described. There are particularly large gaps in our knowledge of microorganisms and the arthropods. It is above all the insects that dominate species diversity on Earth. Among the beetles alone there are twice as many species as there are among plants, and ten times the number of vertebrate species.

Table D 1.2-1
Estimates of the number of species worldwide. The certainty of these estimates has been categorized as follows: good = within a factor of 2; moderate = within a factor of 5; low = within a factor of 10; very low = not in the same order of magnitude.
Source: after Heywood, 1997

Division	Described species [in 1,000]	Estimated number of species [in 1,000]			Proportion [% working estimate]	Certainty of assessment
		Lower level	Working estimate	Upper level		
Viruses	4	50	400	1,000	2.9	very low
Bacteria	4	50	1,000	3,000	7.3	very low
Fungi	72	200	1,500	2,000	11.0	moderate
Monocellular organisms	40	60	200	200	1.5	very low
Algae	40	150	400	1,000	2.9	very low
Vascular plants	270	300	320	500	2.3	good
Nematodes	25	100	400	1,000	2.9	low
Crustacea	40	75	150	200	1.1	moderate
Arachnida	75	300	750	1,000	5.5	moderate
Insects	950	2,000	8,000	100,000	58.7	moderate
Molluscs	70	100	200	200	1.5	moderate
Vertebrates	45	50	50	55	0.4	good
Others	115	200	250	800	1.8	moderate
Total	1,750	3,635	13,620	110,955	100.0	very low

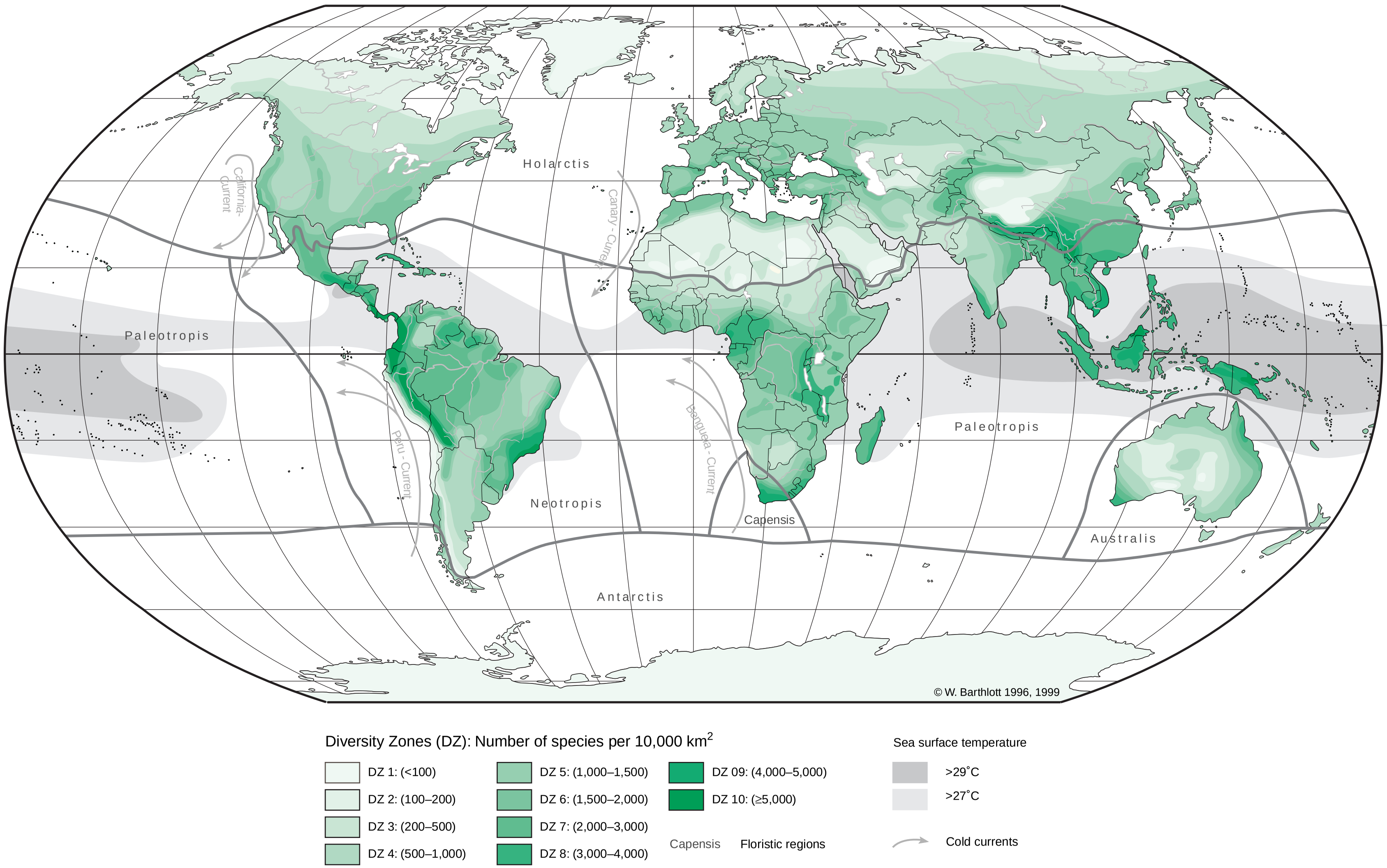


Figure D 1.2-2
Global biodiversity: species figures for vascular plants. Robinson projection.
Source: Barthlott et al, 1999, adapted on the basis of Barthlott et al, 1996; Botanisches Institut and Geographisches Institut [Botanical Institute and Geographical Institute], University of Bonn and Deutsches Fernerkundungsdatenzentrum, Köln [German Remote Sensing Centre, Cologne]. Cartography: M. Gref, Geographisches Institut, Universität Bonn [University of Bonn Geography Institute]

Country	Number of species	Number of endemisms	% endemisms	Endangered species	% endangered
Brazil	56,215	?	?	1,358	2.4
Colombia	51,220	1,500	2.9	712	1.4
China	32,200	18,000	55.9	312	1.0
Indonesia	29,375	15,000	51.1	264	0.9
Mexico	26,071	3,600	13.8	1,593	6.1
South Africa	23,420	?	up to 80%	2,215	9.5
CIS	22,000	?	?	214	1.0
Venezuela	21,073	8,000	38.0	426	2.0
USA	19,473	4,000	20.5	4,669	24.0
Ecuador	19,362	4,000	20.7	824	4.3
Peru	18,245	?	?	906	5.0
Bolivia	17,367	?	?	227	1.3
India	16,000	5,000	31.3	1,236	7.7
Australia	15,638	12,000	76.7	2,245	14.4
Malaysia	15,000	?	?	490	3.2
Germany	2,682	6	0.2	900	33.6

Table D 1.2-2
Higher plants in the 15 most species-diverse countries in the world and in Germany. Note that the data on the endangered species is extremely uncertain.
Sources: IUCN, 1998a; WCMC, 1992

We have taken the plants as an example in this chapter since the records for this group are relatively complete and therefore the problem of assessing unknown species relatively minor.

Plant species are certainly not distributed evenly across the Earth in statistical terms; there are regions with species numbers far higher than the average (Barthlott et al, 1996; Fig. D 1.2-2). In general terms, the number of species decreases as we move from the tropics to the poles. But within the same climatic zones there are also large geographic differences in species richness. The Northern Andes and the Indonesian archipelago are the Earth's richest regions in this respect. In the extra-tropical region the winter rain regions (eg Capensis) and Eastern Asia stand out in terms of species wealth.

The ten countries with the largest numbers of plant species are listed in Table D 1.2-2. These countries have more plant species than, say, Germany by an order of magnitude. In addition to the overall number of species, the number of species with limited distribution (called endemics) is an additional feature of importance for characterizing flora. There is a loose connection between the number of species and the number of endemisms, but there are also some countries with an unusually high number of endemic species (eg Australia or Madagascar). The number of endemic species in the most species-rich countries is greater by a factor of 1,000 than in Germany.

The Red Data List of endangered plant species worldwide includes 34,000 species from over 200 countries that are threatened with extinction (IUCN, 1998a). 91 per cent of these species are endemic in each case to just one country. Our knowledge of the number of endangered species, however, is patchy even for the higher plants. The comparatively large number of endangered species in Australia and the USA is more an indicator of better knowledge than a comparable measure of actual threat.

The large differences in the richness of flora and endemisms stem from many factors. These have to do with floral history (Germany is poor in species as a result of the Ice Age), the wealth of habitats and climates in a country (and thus indirectly the surface

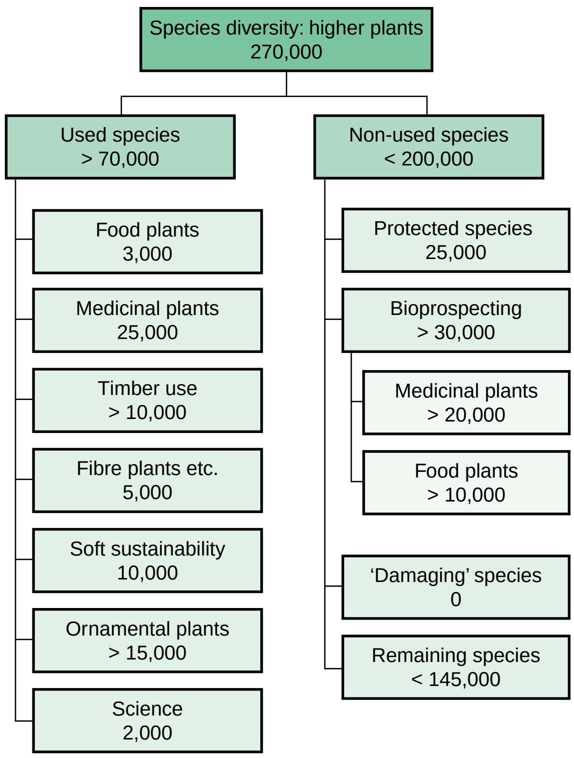


Figure D 1.3-1
Human use of global plant diversity.
Sources: WRI, 1997; WCMC, 1999b or estimated

area covered by a country: USA), the type and frequency of successional disturbances (eg fire) and the biological environment that promotes the establishment of mutations and speciation (eg the specialized pollination mechanisms of orchids). And, of course, our level of knowledge also plays a major role.

D 1.3
Human use of species: the higher plants

If we take the approx 270,000 plant species that have been described worldwide, then each of these has a very different significance for humankind. If the plants are usable then this provides the essential incentive for efforts to maintain these species in a world that is being used to an ever greater extent by people. Therefore, in the following presentation, we shall attempt to categorize plants according to the various forms of use to which they have been put (Fig. D 1.3-1).

D 1.3.1
Plant species used

D 1.3.1.1
Food plants

A large number of the some 3,000 plant species that are used for human nutrition have been cultivated by humanity. Of that number, 150 are significant in terms of global trade, but just 20 species account for approx 90 per cent of our total food consumption. Just three important crops – wheat, rice and maize – meet 60 per cent of calorie and protein needs (Hawksworth and Kalin-Arroyo, 1995). It is assumed, however, that 75,000 species are edible (Myers, 1997).

Each of these species contains a host of different strains or varieties that are related in different ways to wild species. In the case of rice, two species are cultivated (*Oryza sativa* and *O. glaberrima*) but a full 100,000 varieties of the first are known, then there are 20 closely related wild forms from the same genus, and an additional 71 closely related grass species (Vaughan and Chang, 1995). Securing varietal diversity must therefore be the primary concern in order to maintain this genetic pool from which breeders can draw for future use (Sections D 1.3.3.2 and I 1.2). In the long term, these genetic resources may be best protected *in-situ.* collection and conservation of these resources in gene banks only covers an extremely small portion of the entire genetic variability – and so, in the long term, it is much too risky a strategy. This important issue will be dealt with in detail in Section D 3.4. Closely linked to that issue are legal questions that need to be clarified in the context of international agreements (Section I 3).

D 1.3.1.2
Medicinal and poisonous plants and drugs

Around 120 active substances from 90 plant species are used worldwide in medicines (WCMC, 1992). This represents however just the use of plant substances for medical purposes in industrialized countries. In developing countries, where traditional medicines play an important role, the figures are far higher. The pharmaceutical ingredients are rarely identical to the original natural substance; rather they are derivatives that are prepared in in-vitro settings (organic synthesis, fermentation) and in the vast majority of cases without regular recourse to the natural biomass of origin. A total of 25,000 plant species are probably used worldwide for medicinal purposes; 75 per cent of all medications are plant-based (Hawksworth and Kalin-Arroyo, 1995). Use can however promote the extinction of the species: in Central Europe alone the viability up to 150 plant species is threatened as a result of intensive collection (Hansen, 1999).

D 1.3.1.3
Construction, furniture, industry and fuel wood

Here the border between use and non-use is blurred because one can fashion a 'hut' or particle board out of almost any woody, that is ligneous, plant. Uses of woody plants were far more diverse in previous centuries (Box D 1.3-1). It is hard to estimate or quantify such usage, and almost impossible if we include fire wood and the so-called 'non-timber forest products'. In Germany, 112 species of wood are available commercially (Sell, 1997). The nomenclature of the known timber species by Bärner (1942) includes 13,000 species. If wood became in short supply, however, other species could be used. And of course we must not forget the some 600 species that are used for rattan furniture, which draw almost exclusively on natural stocks (WCMC, 1992; WBGU, 1998a).

D 1.3.1.4
Fibrous plants, dye plants, industrial plants

Despite the synthesis of many artificial substances, humankind is still dependent on a number of plants for the manufacture of fibres. The importance of

Box D 1.3-1

Use and substitution of ligneous plants in the last 120 years

The following evaluation regarding the use and substitution of woody plants is based on the analysis of an Italian book from 1877 which describes in detail the use of woody plants in Belluno and Trentino provinces (Soravia, 1877). In the book, 63 woody species and genuses are addressed. These are trees, shrubs and dwarf shrubs but for many of the genuses there is no subdivision into species (eg in the case of maple, linden, rose, blackberry). One can assume that this book explores the entire woody flora of the area. Current use has been compiled from various sources: Sell, 1997; Frohne and Jensen, 1998; Teuscher, 1997 and Reif, 1983. It should be noted that these are not limited to the restricted locality described in the 1877 exploration. Thus, current uses are overvalued.

In 1877 there were 94 forms of use for the 63 wood species, dominated by medicinal extraction (52 species) and followed by dyes (35 species) and fuel wood (32 species). For lathe work, furniture construction, fodder and food between 20 and 30 species were used, for ash production, nectar sources for bees, barrel staves, tanning, house construction, carving, shoe soles, birding, wagon wheels and cogs between 10 and 20 species were used. For the remaining species there were specialized uses, for example, the dowsing rod could only be made of hazel.

Of the 94 forms of use, only 27 are still practised in 1999 (25 per cent), 14 additional local uses have been added and it has not been taken into account that in more remote valleys in Trentino the use of woody plants has remained more diverse. 72 usable species over the course of the last 100 years have be substituted by the use of metals, plastics or other materials. 20 species (19 per cent) switched use and are today used as ornamental plants but in cultivated, not wild forms. Around 30 to 52 of the earlier medicinal plants are still used today in general medicine or natural remedies. Six species in Germany are under protection in the red data book, approx 25 species are used in landscape protection and land reparcelling as natural hedges. The legendary 'Ötzi' carried over 17 wood species with him in the form of tools, fuel and food when he died over 5,000 years ago (Spindler, 1993).

fibres for textiles has decreased distinctly and there are just a few species that are important in this respect (cotton, coconut, sisal agave, hemp, flax, jute). Far more important is the extraction of cellulose from wood as a base substance for paper and cardboard. Essentially, cellulose can be extracted from almost all plant species, but there are only a few dozen of the 30,000 world wood species that play a significant role worldwide in industrial cellulose extraction.

In addition, there are the species that are used to extract dyes, oils, fats, resins and rubber, to produce perfume substances, biogenic pesticides or other products. For example, of the 600 eucalyptus species, just 50 are cultivated for the extraction of essential oils (Groeteke, 1998). In Germany, essential oils from over 150 species are available commercially (Primavera Life, 1999).

Over 5,000 species are probably involved worldwide. This estimate must however remain rather uncertain since most of the products are of only local significance and are not traded internationally.

D 1.3.1.5
Species in support of 'soft' sustainability

It is well known in farming that plant monocultures bring with them risks in terms of sustainability. This is true both of the use of certain resources from the soil and also with regard to parasitic attacks. It is only with considerable inputs in the form of fertilizer and pest control that intensively managed monocultures can be maintained, otherwise within a foreseeable period yields drop and it may become necessary to abandon the site (Section E 3.3.4). Seen in that light, mixed cropping is more sustainable than monocultures, even if a small number of species is ultimately used. This is the sense in which the term 'soft' sustainability is used here.

In intensive agriculture mixed species are not desired ('weeds'), since these generally reduce yield. In grazing systems, species diversity is sometimes desirable since fodder composed of different species is more digestible for ruminants. High protein content in combination with a high fibre content can, however, also be generated by mixing in artificial fodder (fibre content: silage from maize, protein content: soya), where the addition of particular amino acids improves digestibility and fodder utilization. In that case, the advantages of species diversity are substituted by technical means and the cultivation of suitable monocultures. Trade in fodder products is important in this regard. The problems in using animal products as fodder for ruminants were discussed in the 1998 risk report (WBGU, 1998a).

In the case of perennial ligneous plants (forest) the addition of non-crop species is more significant. According to everything we know about the metabolic cycles at work in forest ecosystems, a deciduous mixed forest with several tree species and the associated ground flora has greater sustainability than a monoculture. Correspondingly, shade trees in tropical cocoa and coffee plantations are important. There are examples, however, where stocks with few species grow sustainably for long periods. For example, the boreal coniferous forests of the Canadian Shield are dominated in large expanses by just one tree species

(*Picea mariana*) that is interspersed with a small number of ground flora species (Archibold, 1995). Homogeneous stands are common in the case of pines, too.

It is very difficult in the case of this group to estimate the number of species required worldwide, particularly since in the tropics there is a long tradition of mixed cultures of crops (coconuts and mangos as providers of shade, spice and fruit trees as shrub species, and *Alocasia* for carbohydrates). On the other hand, through targeted efforts in agro-forestry to cultivate a mixture of usable woody and herbaceous species, the number of non-usable wild species that are used to further the goal of 'soft' sustainability is probably low. Over 2,000 tree species are known worldwide that are used in agro-silvicultural systems (Lundgren, 1989). It is therefore assumed that worldwide no more than 10,000 species are used (often unintentionally) for this purpose.

D 1.3.1.6
Ornamental plants

Many plants are prized by people in all countries for their beauty alone. Often these are elements of the local flora or exotic species – quite regardless of whether the species can be kept long-term in field conditions or in the garden. In the United Kingdom alone 25,000 plant species are kept in botanical gardens and 14,000 species are available commercially as ornamental species or for collectors (eg *Lithops*, cacti; Crawley, 1997).

Although the number of species is high, this means protection for a relatively small subgroup since it tends to be the cultivated varieties and not the wild varieties that come onto the market (roses, tulips). For rare or endemic species that are exploited by commercial collectors, this sort of use can even represent a danger.

D 1.3.1.7
Plant species in science and technology

For systematics, a classic branch of research within biology, diversity at genetic and species level is the very object of research. Since the species descriptions of the early natural historians and the introduction of the binomial system by Linnaeus (Systema Naturae, 1735; Species Plantarum, 1753), right through to modern day taxonomy on the basis of molecular-biological techniques, it has become possible to clarify to an ever-greater degree the relationships between organisms. In this respect, species are documents of the history of life. In addition, 'model plants' have been used in the biosciences for a long time, the best-known example being the crucifer *Arabidopsis thaliana* (Box D 1.3-2). For bio-indication, ie to detect the presence of contaminants, a broad array of plant species is in use. In future these could also be used to a greater extent for environmental monitoring (Hampicke, 1991; Box D 1.3-3).

An emergent field over the last few decades in technological research has been bionics, which is concerned with the technical realization of processes and structures present in nature (Box D 3.3-4). The spectrum of natural models ranges from dandelion seeds to the surface structure of lotus leaves for the development of parachutes or dirt-repellent paints.

Despite the abundance of possible applications, only a small number of plant species are used directly in science and technology. This number is probably around 2,000 species, but may increase considerably in future.

D 1.3.1.8
Summary: usable plants

In total, humankind probably uses a total of over 70,000 plant species; that is around one quarter of the species diversity described to date in the plant kingdom. Heywood (1993) names up to 30,000 species for the tropics alone.

That number does not include the indirect use of the plant kingdom by grazing livestock. Goats, sheep, cattle and horses eat almost any type of herbaceous plant. In addition, goats also graze on ligneous plants, and it was not without a reason that in the Middle Ages there was a ban on grazing goats in forests. Since permanent pasture covers approx 25 per cent of the Earth's surface – on all continents and from the savannahs to the Arctic – this concerns a large portion of the plant kingdom.

Furthermore, of course, no figure can be put on the aesthetic or emotional 'use' of plant diversity; with regard to the importance of this form of diversity, the reader is referred to Section E 3.1 and Chapter H.

D 1.3.2
Endangered plant species

A number of these non-usable plants are subject to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). These are primarily the rare, red-listed species. Worldwide, 25,200 species or almost 10 per cent of the world's flora belong to this category (CITES, 1997). However, it should be noted that this Conven-

Box D 1.3-2

Arabidopsis: The story of the wallflower that became a queen

Arabidopsis thaliana – Thale cress – is one of 141 cruciferae in Germany's flora, small, unremarkable flowers that occur on poor, dry sandy soils. *Arabidopsis* is neither particularly pretty nor rare and is just one of many pioneer plants in the open soil.

The career of *Arabidopsis* began when the Frankfurt botanist Laibach (1943) discovered that this species had an unusually diverse growth habit that was apparently genetically determined. There are high and low flower panicles, ones with more or fewer branches, early and late blooming individuals, those with hair and those without. Because of the short time from germination to formation of seed and the high variability of its structure, *Arabidopsis* was highly suitable for genetic investigations at a time when the genetic code had not yet been discovered. Around 20 years later Dr Röbbelen (Göttingen) and Dr Kranz (Frankfurt) began a seed collection (1963) that initially served for crossbreeding experiments, but later provided the basis for physiological and molecular experiments. The move into molecular biology meant diminishing interest in the diversity present in nature. Most of today's experiments are conducted on just a few wild genotypes.

Its molecular career began in the 1980s when Koorneef et al (1983) produced the first genetic map of *Arabidopsis*. When it was also found that the genome of *Arabidopsis* could be transformed by agro-bacteria and that this species contained the smallest genome of all known plant species, *Arabidopis* began its triumphal march at the head of all other model plants. There were not just new physiological experiments, such as experiments on changed sugar levels (Schulze et al, 1991), but also futuristic experiments in which polyhydroxybutanoic acid – a biodegradable plastics feedstock – was synthesized in the chloroplasts of *Arabidopsis* (Nawrath et al, 1994). Currently experiments are being conducted to saturate the genome by mutation on the basis of insertion of agro-bacterium T-DNA. This allows for the swift identification of genes that are involved in certain physiological processes (Walden et al, 1991).

These physiological experiments led in 1996 to the *Arabidopsis* Genome Initiative in which it was decided to sequence the entire genome of *Arabidopsis* by the year 2000 and deposit it in a public database. Thus, *Arabidopsis* would be the first flowering plant for which the entire genome is known. After much molecular preparatory work on the fine structure of the genome, in October 1998 the complete map of the 4th chromosome was published (Meinke et al, 1998). Within 20 years this species therefore rose from a once obscure weed to a member of the 'Modern Genetic Model Organisms'.

But why is that so important? With the knowledge of the genome of one tough survivor species we have available all of the information about the genes that are necessary for the functioning of a plant. Past experience with other organisms suggests that great similarities with other plant species can be expected. By researching *Arabidopsis* we know the genes that cause certain processes such as drought resistance, saline resistance and heavy metal resistance. This would be a breakthrough in breeding research. In addition to the resistances, the hormonal metabolic processes are also attracting attention, particularly the steroids. Many of these plant hormones are similar to those that occur in the human body. And so *Arabidopsis* becomes important medically. There is one bitter note: a large pharmaceutical company has gathered up the knowledge about the genetic structure of *Arabidopsis* as published on the internet and with great speed has sequenced the large majority of the rest of the genome – probably with the aim of patenting it. Thus, the success and the profit from the groundwork of scientists is lost to them.

From an ecological standpoint *Arabidopsis* is probably just a 'queen for a day', because it is already clear that it does not represent all plant functions. It is a relatively specialized organism that, for example, has no mycorrhiza and, because of its short life span, can survive without any mechanisms to defend itself against predators or disease. This species is a master of survival that focuses on swift mutation and high reproductive rates, with the mutations surviving on sandy sites where there is little competition. And so it is clear already that to understand the interaction between pathogens and mycorrhiza, further species need to be sequenced.

tion merely bans trade in these species and so cannot provide comprehensive protection (Section D 3.4). Worldwide, at least 34,000 species are under threat (WCMC, 1992), and national protective provisions only cover some of these. Other international conservation conventions, such as the Ramsar Convention on wetlands, only focus on particular habitats. The Convention on Biological Diversity could build an important bridge here (Section I 3).

D 1.3.3 Species not currently being used: genetic resources for the future

If we do not include the used or crop plants, the true ornamental plants and the protected species from the total, then around 175,000 species remain that are not subject to use by humankind and have not received attention under protective efforts thus far. It is this group of species for which the Convention on Biological Diversity is so important (Section I 3).

D 1.3.3.1 Medicinal plants

Some of the species belonging to this relatively large residual group of species not currently in use will be used with some degree of probability at some point in the future as genetic resources, eg to extract certain pharmaceuticals (Section D 3.3). So far, only around 5,000 plant species have been examined systematically for potential active substances. However, there are indications that with the advent of new biotechnological procedures, dependence on natural

Box D 1.3-3

The importance of orchids as indicators of environmental change

In Section D 1.1 the orchids were highlighted as an extremely species-rich family where one might have the impression that loss of species diversity has little consequence for the functioning of ecosystems. In this section, the orchid flora of Thuringia is used as an example to illustrate how this species-rich plant group is actually a very sensitive indicator of environmental change.

Thuringia has 51 species of orchids, the most diverse orchid flora in Germany; five of the species previously identified are now extinct, however (Arbeitskreis Heimische Orchideen Thüringen e.V., 1997). The distribution of each individual species has been documented since 1577, and in a more intense and extremely detailed fashion since the middle of the 19th century, so that today maps are available which can be used to understand trends in the distribution of orchids over time. Ordnance survey quadrants serve as a basis for the distribution maps.

The distribution and diversity of orchids found at some time or another in Thuringia was overwhelming; there was hardly a quadrant without orchids. The top figure was 43 species and was recorded in the area of Jena. Comparison with the species found since 1990 shows that in almost 16 per cent of the quadrants orchids can no longer be found. And the total number of species has also declined sharply. This decline has occurred in both common and rarer species. Fig. D 1.3-2 shows the distribution of all species before and after 1990 in all quadrants of Thuringia. Species that were found in fewer than 100 quadrants have either become extinct or have been pushed back into just 10 per cent of the sites (lower section of the curve). Species that were present in 100–200 quadrants are now found in only half of the sites. Even species with much more extensive distribution (>200 quadrants) have lost on average 40 per cent of their sites. Fig. D 1.3-3 uses the example of the green-winged orchid (*Orchis morio*) to demonstrate the dramatic decline of this striking species group (Arbeitskreis Heimische Orchideen Thüringen e.V., 1997). This is all the more remarkable since orchids are protected by conservation measures and so enjoy greater protection than other species.

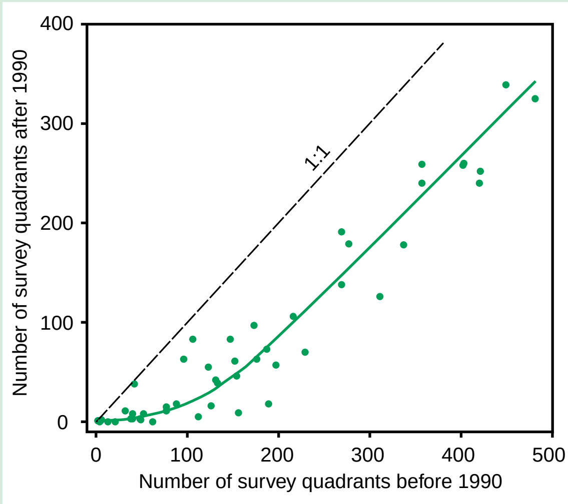


Figure D 1.3-2
Occurrence of all orchid species in each of the quadrants of the 1:25 000 map of Thuringia, presented for the period before 1990 and after 1990.
Source: Arbeitskreis Heimische Orchideen Thüringen e. V. [Working group on domestic orchids in Thuringia], 1997

The causes for the loss of orchid diversity include changed land use, drainage of wetlands, intensification of grass-land management and forestry, advancing construction around large towns and cities and increasing eutrophication as a result of airborne nitrogen loading.

The disappearance of the orchids, therefore, is a measure of humankind's intervention into the natural balance. One can assume that there was not a decline in the total number of species in each area, but that sensitive, non-competitive species gave way to a group of more robust species able to withstand human disruptions. In that way a group of plants that, other than through beauty, have no direct 'function' for humankind has become a highly sensitive environmental indicator.

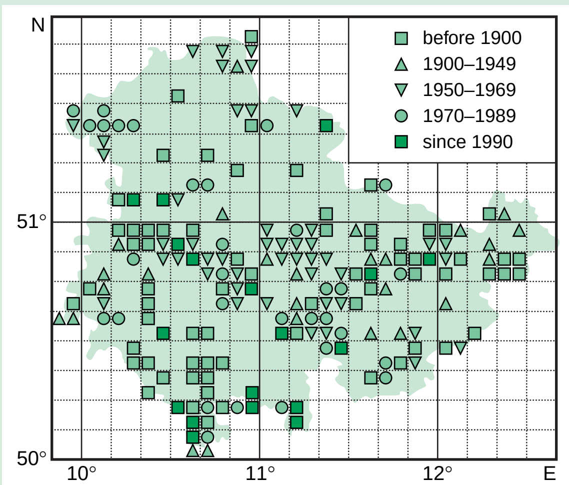


Figure D 1.3-3
Reports of the green-winged orchid (*Orchis morio*) in Thuringia. Note that in earlier floral studies often no location was reported since the species was widespread and also called 'Gemeines Knabenkraut' [ie common green-winged orchid]. Currently there are just a handful of sites with a few individuals and the species is acutely threatened with extinction.
Source: Arbeitskreis Heimische Orchideen Thüringen e. V., 1997

substances for the development of medicines will be reduced (Gettkant et al, 1997).

Every single plant species is potentially an interesting candidate for such an examination since all plants have developed chemical defence substances against herbivores or pathogens that could in turn prove effective in pharmaceutical terms. Mendelsohn and Balick (1995) have calculated on this basis that, of the approx 125,000 flowering plants in the tropics, at least 375 potential medicines could be developed with a saleable value of up to US$4 thousand million. If we look at the relationships among the currently known medicinal plants, we notice that the majority come from a relatively small number of families (Frohne and Jensen, 1998), which however represent around one-third of all species worldwide. If only half of these species can be used to develop an active substance and we subtract the medicinal plants that are already known, another 20,000 species would be interesting in terms of their secondary metabolism. However, once the gene has been extracted and put into production for such substances, and the gene expressed into other organisms (particularly microorganisms) for industrial production, the 'genetic donor' could then fall back into obscurity (Miller et al, 1995). The problems and opportunities related to bioprospecting are discussed in detail in Section D 3.3.

D 1.3.3.2
Food plants

In a similar way to medicinal plants, one could imagine bioprospecting for plants that have particular resistance features that would be important in cultivated crops. This is less a matter of resistance to pest organisms, since that generally involves specific interactions between host and pest and can be combated specifically through molecular changes in the respective host-recognition systems. Complex resistances are primarily a matter of tolerance to the stresses of drought, salt and heavy metals that could become important as a result of the expansion of agriculture to marginal sites and the increasing salinization in irrigated farming (Flowers and Yeo, 1995; WBGU, 1995a). In the context of resistance to heavy metals, good progress has been made by selection within the crop species and not through transmission of genetic information from related species. This can change quickly, however, as more knowledge of the molecular foundations of resistance is gained. In the case of rice, however, most of the closely related species are already being collected systematically in order to cross-breed certain desirable features in the future (Vaughan, 1994).

Food plants admittedly differ very much with respect to their wild species base. However, these wild forms are particularly important when breeding for resistance to biotic and abiotic factors is concerned (Cleveland et al, 1994). These resources are not just acutely endangered because of the intensification of land use, but also because of the concentration in cultivation on a small number of high-yielding varieties. This is aggravated by the fact that the industrial high-performance varieties are not fertile and so no further genetic development is possible. For example, the whole soya production of the United States is based on just six individual plants from a site in Asia (Zedan, 1995). The farmer is no longer in a position to produce his own seed. That means an enormous supply risk under variable weather conditions and in disaster-prone areas. With the trend towards planting genetically modified species that are not sterile and not – eg through polyploidization – genetically distinct from the wild varieties, there is an additional danger of the spread of characteristics into the wild population through outbreeding and the potential loss of genetic information in those populations (WBGU, 2000a). The Biosafety Protocol (Section D 3.2) is intended to respond to this and other dangers.

It is also conceivable that new food plants will be recruited and marketed out of the pool of around 75,000 edible species. The fruits of tropical plants are particularly interesting in that respect, as are the starch- and protein-storing tubers. However, the use of plants in extreme habitats in which no agricultural use is currently feasible (eg salty sites) could also become possible (Myers, 1997). Whether these can be domesticated – whether they can be improved through targeted breeding for food production and differentiate themselves genetically from their wild forms remains an unknown at this stage (Diamond, 1998).

In essence, there are presumably over 10,000 species that could become food plants or have particular stress-resistance characteristics that make them interesting as a potential genetic resource for cultivation. Presumably, however, in this case the search for resistance features is more promising in related species, so that the figure might have to be corrected downwards. Once the genetic characteristics have been harvested, however, the wild species might well fall back into the insignificant group.

D 1.3.4
Harmful species

In contrast to certain animal species and to pathogens, there is no species in the plant kingdom that is sufficiently harmful to justify targeted elimination (nor has this succeeded when attempted in the past). Even poisonous plants have great utility in the production of pharmaceutical ingredients (eg digitalis, belladonna). Agricultural 'weeds' or problematic plants can also be used as a by-product (eg animal fodder) or used in their original habitat.

D 1.3.5
Assessment of non-usable species

According to current calculations, the above discussion leaves approx 145,000 species (>50 per cent) for which at the present time or in the foreseeable future no economic function can be derived and that are not protected by international agreements. If one is looking for a justification for the preservation or the elimination of these species, the following thoughts are relevant:

- The species are redundant to other species already being used or having a potential use. There is no significant 'damage' if these species are eliminated (cf however Section D 2).
- The crux is preservation for use by future generations, and it is not foreseeable what products future generations will be able to use even if they are not usable at the present time (option value, Chapter H).
- There are ethical grounds not to eliminate species (existence value, Chapter H).
- Aesthetic aspects speak in favour of preserving species. Lawton (1991) described this well by comparing species to medieval cathedrals or compositions of Mozart: they are preserved because they are beautiful and enrich our lives (symbolic value, Chapter H).

At the moment we know too little about these species to be able to classify them. One can only put forward analogous arguments on the basis of other processes. Mankind 'uses' just 5–10 per cent of the DNA present in the human body actively. We currently know no function for >90 per cent of our DNA, but one would not (even if one could) remove that 90 per cent of DNA, because we apply the precautionary principle. Analogical conditions are familiar from physiology where the majority of enzymatic processes do not operate at full capacity but in many cases at <50 per cent of capacity. It has been shown that in this case, a high capacity is a protection against overload in the event of variable environmental conditions (Stitt and Schulze, 1994).

Clearly, species diversity is not only an option for future generations but also a safeguard against a changing environment. The principle of pre-adaptation is extremely important for the evolution of species. For example, in the Pleistocene the C_4 grasses went through massive species development. They colonized vast areas of subtropical grasslands at a low CO_2 level in the atmosphere. Evolution of this metabolic path of photosynthesis, however, stretches back to the late Miocene. In other words, the metabolic path was present before the drop in CO_2 came about and became important as a response to the changed environment in the Pleistocene (Ehleringer et al, 1997). Maize is a C_4 grass and is one of our most important crop plants today.

To the extent to which it is the human objective to achieve as high a plant production as is sustainable, this can be achieved with monocultures only in optimum and constant conditions. But to the extent to which this production takes place in different sites and in years with different weather patterns, the number of species (or varieties) required increases significantly. If in addition we are trying to safeguard development in the future, then the number of species needed for the preservation of high productivity rises again. In other words, the apparently redundant species ('the 30th grass species in a meadow') gains importance for the preservation of productivity in the long run (insurance hypothesis, Section D 2). Setting up international genetic centres for the most important usable plants is one way of taking account of this fundamental premise.

The 53 per cent non-used species cannot be evaluated directly, because

- there is a time lag between current protectors (current generation) and future potential users (future generations) who are potentially endangered in their very survival by a loss of options at the current rate,
- there is a geographic gap between the suppliers of genetic resources (tropical countries) and the potential users (industrialized countries),
- there are institutional deficits for the protection of this 'ownerless' wealth (rare species found in nature) that need to be remedied by specific rights regulating trade, liability and ownership.

In analogy to the fundamentals of physiology and genetics, a 53 per cent proportion of non-used species seems low rather than high as a safeguard for the future of humanity. Although that does not mean that all species are necessary for humanhind, it does not tell us which species we can do without.

D 1.4
Use of animals and microorganisms

An investigation of animals and microorganisms in a similar way as has been done for the plants is fundamentally more complex as a result of the fact that we have not even come close to completing a description of all species. Such an assessment would therefore relate to species that are as yet unknown.

If we were to evaluate the animal kingdom, the number of species currently being used would presumably be smaller than in the case of plants and thus the unused proportion much greater. This is also true of the ecologically significant proportion of species for 'soft' sustainability (predator/prey systems, pest control).

As far as the microorganisms are concerned, the proportion of species not currently in use would be significantly larger than in the case of the plants. A substantial part of current bioprospecting efforts is directed to analysing new natural substances from this group of organisms.

Ecological functions of species — D 2

Assessment of the plant world with regard to its usefulness for humankind (Section D 1) comes to the conclusion that a considerable proportion of the species are currently not being used directly. However, this does not allow us to turn the argument on its head and state that we can do without these species without damage to the environment. In this section we shall therefore set out the significance of species and species diversity independent of direct human use. Starting from the role of genetic diversity for the adaptability of organisms, we shall describe the functions of species within ecosystems. Then the ecosystem processes will be outlined which stem from the diverse interactions of organisms with their abiotic environment. Finally – from an anthropocentric viewpoint – we shall enumerate the products and services that humankind draws from the biosphere. The ecological functions of biological diversity for agriculture will be treated separately in Section E 3.3.4.

D 2.1
Genes, populations and species

The recognizable variability between individuals of the same species (phenotype) stems from the interaction between hereditary genetic differences (genotype) and the environment. Genetic diversity and environmental conditions therefore form the connecting bridge between the biological features of the individual and those of the species and are ultimately the very basis for species and ecosystem diversity (Barbault and Sastrapradja, 1995; Fig. D 2.1-1).

The success of an individual depends essentially on the 'match', ie the degree to which its genetic make-up (and the external and physiological features influenced by that make-up) match with the environment in which it exists; this can be measured in terms of the spread of this make-up in subsequent generations (fitness; Darwin, 1859). Selection from the surplus supply of descendants begins with the individual but has considerable impact on the genetic make-up of the population because it changes the frequency distribution of the genes (more precisely: alleles) within the population. The higher the genetic diversity within a population, the better it is equipped to adapt at a later date to changes in its environment, because in a broad genetic spectrum it is easier to find individuals with good adaptation. In the classic development of useful plants and animals through breeding, this rule also applies: access to as broad a genetic diversity as possible is the prerequisite for optimum breeding success.

Population size correlates with genetic diversity. If a population shrinks dramatically then genetic diversity, and with it fitness and adaptability, is also lost, which can ultimately lead to the population's extinction (Meffe and Carroll, 1994). Maintaining genetic diversity in populations and the mechanisms of its change (eg by mutation or genetic drift) are therefore pivotal scientific questions in the context of species conservation (Loeschke et al, 1994).

Since species are generally seen as reproductive communities or gene pools, genetic processes are at the heart of speciation. Changes in the genetic make-up of populations as a reflection of the ecological interaction of individuals with their environment are the driving forces of evolution, which ultimately lead to the generation of species diversity. There is not sufficient scope here to go into more detail with regard to the various forms of speciation (eg through

Ecological diversity		**Organismal diversity**
Biomes		Kingdoms
Bioregions		Phyla
Landscapes		Families
Ecosystems		Genera
Habitats		Species
Niches	**Genetic diversity**	Subspecies
Populations	Populations	Populations
	Individuals	Individuals
	Chromosomes	
	Genes	
	Nucleotides	

Figure D 2.1-1
The three levels of the concept of 'biological diversity'. The population definition links the three levels.
Source: Heywood and Watson, 1995

vertical evolution or isolation of subpopulations) (cf for example, Barbault and Sastrapradja, 1995).

D 2.2 The role of species within ecosystems

Every organism is linked to its environment via a system of interactive relationships. First of all, there are links to the abiotic environment: eg organisms are dependent on light, water, nutrients or structural features of their environment. The activities of the organism influence the environment by changing the site conditions, using resources or being available for other organisms. Furthermore, each species is situated within a web of interactions with the biotic environment, ie with other individuals of the same or other species. The participating organisms can be divided into the following roles depending on the nature of these relations (Begon et al, 1996): competitors (within a species and between species), predators (predator-prey relationship), decomposers (decomposition of dead organic matter), mutualists and symbionts (mutually supportive relationship), parasites and pathogens. Organisms can generally assume various roles either simultaneously or over the course of their life cycle.

These interactions between organisms are a prerequisite for evolution and thus contribute over the long term to the formation of species. This is because they promote processes such as avoiding interspecies competition by niche differentiation or the mutual 'evolutionary escalation' in the case of the coevolution of species. For example, the length of the calyx and the proboscis of pollinating butterflies evolved in parallel. In the short term it is however possible for biotic interactions in one area to lead to a reduction of the number of species, for example when two species are competing for the same resource, one of the two can be displaced.

Furthermore, a number of indirect interactions link the organisms of a given ecosystem together. Thus a complex web emerges in which each organism or species influences the other in very specific ways. Complex systems, or *ecosystems*, are made up of these diverse webs of abiotic and biotic interaction. These are characterized by non-linearity and have self-organizing capabilities.

D 2.3 Ecosystem processes

By 'ecosystem' we mean the complex interactions of a biotic community and its abiotic environment. In the first formulation of the term, by Tansley (1935), it also constituted a discrete, that is clearly delineated, unit with a recognizable character. Thus, the definition has a clear spatial association. The basic components are the producers (generally green plants, but also microorganisms), consumers (animals and microorganisms that feed off living organisms) and decomposers (microorganisms and animals that break down organic matter). They are linked to one another through food chains and webs by which they pass on the energy they have absorbed from the producers. This energy flux is not distributed equally. Depending on environmental conditions, different paths will predominate at different times (Zwölfer, 1994), just like the road system of a city that is used differently depending on the time of day and day of the week. Another essential feature of ecosystems is the conversion of nutrient elements and other substances in biogeochemical cycles.

When environmental conditions change, the network of interactions within the ecosystem reacts: resources are overused or go unused, and in response species regroup and food webs are reordered. Ecosystems are adaptable, but can also be degraded by human influence, ie their structure and the processes in the system can gradually change both in quality and quantity in such a way that the biological diversity and resources are lost or that the system becomes more vulnerable.

The explanation of nutrient cycles gives us our first access point to understanding the role of the various organisms within ecosystem processes. Fig. D 2.3-1 shows the nitrogen (N) cycle in a terrestrial ecosystem. Organisms need nitrogen to build up amino and ribonucleic acids; it is therefore an essential nutrient.

A large number of organisms are involved at each stage of the cycle. Ecologically, it is important that the turnover happens at very different rates. So, in the soil ammonium-N and nitrate-N can run through a cycle within a day that goes via the amino-N of microorganisms and their excretions. The turnover via plants has a constant of around one to ten years. Turnover takes over 1,000 years if denitrification to N_2 gas takes place. It is also important to know that the cycle can take a series of shortcuts. If the mycorrhizal fungi break down proteins directly then no other microorganisms are involved. Similarly, plants can compete with microorganisms for the free ammonium or nitrate – with varying physiological consequences.

This idealized representation of the nitrogen cycle does not in itself clarify the role of biological diversity because, in principle, a cycle of that sort could be maintained with very few participants, such as happens in sewage treatment plants where the nutrient supply is kept permanently high and the abiotic conditions remain relatively constant. In natural ecosystems, however, these conditions are not at all constant and generally not ideal. This leads to the situation in natural ecosystems of a large number of organisms and organism groups being involved in the cycle, which results effectively in a temporal and spatial partitioning of resource availability. For example, under certain conditions the conversion of nitrate into elementary nitrogen (denitrification) does not happen in one step; but rather several interim products arise that are then processed further by bacteria. The association of species in various organizational forms (trophic level) or functional groups is therefore the prerequisite for resources in a given site being used in as large a quantity as possible.

It should be noted that, with regard to biogeochemical cycles, there are differences between open and closed systems. Open systems, such as agroecosystems, are constantly deprived of nutrients that have to be returned to the system via fertilization (Section E 3.2.4).

Interactions between organisms and their environment have a number of systemic effects: resources are used and transformed, energy flows are established and controlled, information is exchanged and processed. These energy, biogeochemical and information flows are ecosystem processes that do not stem simply from the effects of individual organisms or species, but rather emerge as features of the system. In particular, the diverse interactions among individuals mean that an ecosystem is more than just the sum of its parts.

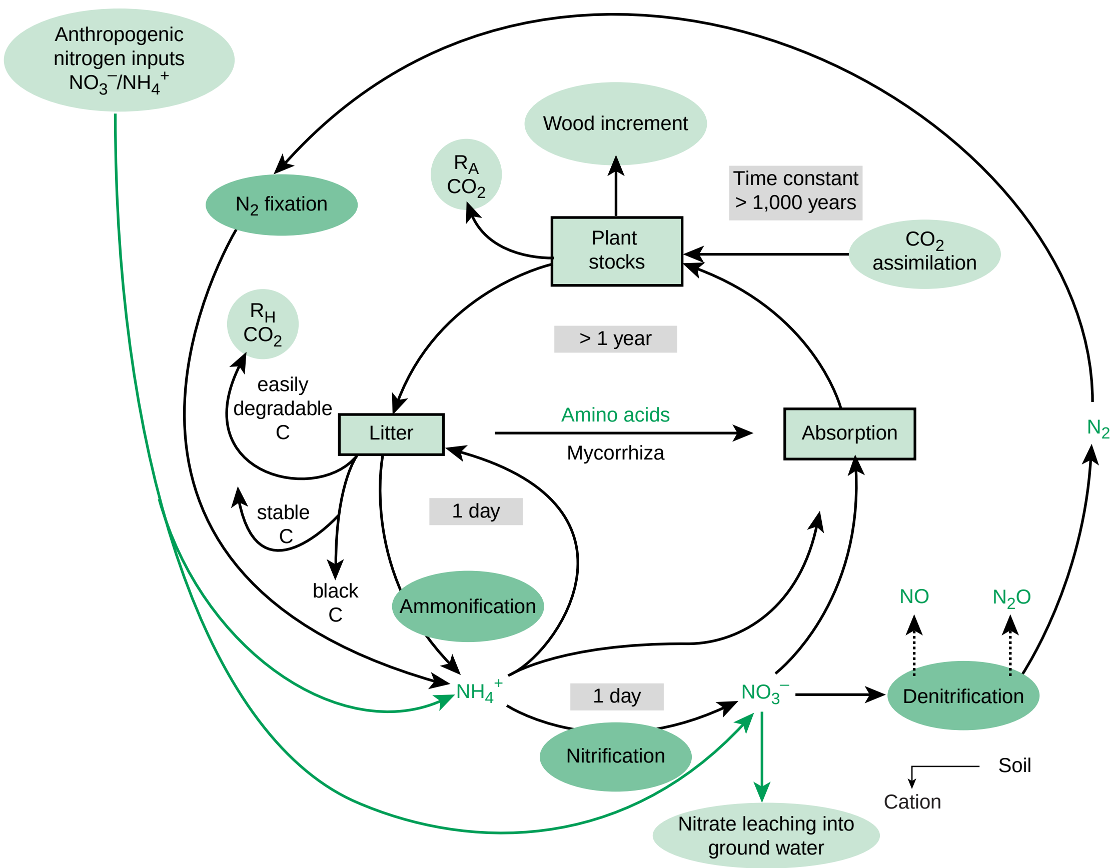


Figure D 2.3-1
Conversion of nitrogen (N) in a terrestrial ecosystem. When plant litter or animal remains are broken down or mineralized, ammonium (NH_4^+) forms in the soil through ammonification. In nitrification, this is further oxidized to form nitrate (NO_3^-). Plant roots absorb these two nitrogen compounds and the plant uses them to form amino and ribonucleic acids. Furthermore, mycorrhizal fungi can absorb amino acids and pass them on to plants. Access to this cycle is via fixation of elementary atmospheric nitrogen by microorganisms and anthropogenic input. Denitrification or nitrate leaching removes nitrogen from the system. C = carbon. Further explanation in the text.
Source: Schulze, 1999

D 2.4 Linkages between biological diversity and ecosystem processes

The species assemblage is responsible for the ecosystem processes described above. However, species richness varies greatly among ecosystems. There are ecosystems with a huge diversity of species and interactions, eg in tropical forests or coral reefs, but on the other hand there are species-poor systems that with just a handful of species still manage to maintain a large proportion of the ecosystem processes described above. That begs the question: What is the link between biological diversity and the stability of ecosystems?

One way of exploring this link is to gradually remove individual species from the system. Since all species interact with other species and the abiotic environment, the loss of even just one species constitutes a structural change in the ecosystem. The remaining assemblage reorients and reorganizes itself sometimes without any noticeable consequences (eg loss of the elms in Central European alluvial forests) and sometimes with grave consequences (eg disappearance of the North Pacific seaweed and kelp stocks; this is a result of the sea otter having been overhunted, with a subsequent population explosion of the algae-eating sea urchins formerly held in check by the otters; Bond, 1993).

The reason for these differing consequences is that not all species within an ecosystem are equally 'important' – individual species can have a crucial influence on the structure or stability of ecosystems. Other, redundant species can disappear from the ecosystem without tangible consequences (cf also Box D 2.4-1).

In an ecosystem, species are therefore not interchangeable. This is particularly true of heterotrophic organisms (dependent on organic food) that can adapt over a long period of evolution to certain chemical characteristics of the host or food substrate. The host evolves ever-new ways of protecting itself so as to remove itself as a foodstuff. Such specializations of resource use that develop in the course of coevolution mean that certain species are closely linked in food chains and therefore a high degree of mutual dependence emerges. The loss of one plant species (in the sense of drastic reduction of population density or local extinction) also results in a population decline of any species specially adapted to that plant. Many herbivorous insects, for example, are highly specialized to their host plants and they cannot compensate a loss of their host by switching to another plant species.

Ecological science has so far hardly ever been able to predict reactions to species loss since the features and requirements of the individual species and their linkage into the ecological system are generally unknown. However, the foundations have been laid for understanding such interactions. There are a few model organisms and ecosystem types from which the competitive patterns can be predicted correctly on the basis of the preferences and features of individual species (Tilman, 1977; Rothhaupt, 1988). By the same token, it is also difficult to recreate species-rich ecosystems artificially, as initial setbacks in restoration ecology demonstrate (Box D 2.4-2).

For these reasons there has so far been no comprehensive theory of ecological systems that could clearly explain the link between biological diversity and ecosystem features and processes. However, there are a number of well-founded ideas regarding the link between diversity and ecological processes (Lawton, 1994; Mooney et al, 1995) upon which plausible hypotheses may in turn be based. Five hypotheses summarize the possible effects of species loss on ecosystem processes (Fig. D 2.4-1):

1. *Redundant species hypothesis*: This hypothesis arranges species into functional groups in which the various species have similar functions in relation to a given process (eg the ability to bind nitrogen). It is now assumed that to maintain the functioning of an ecosystem a minimum diversity has to be present but above that minimum the large

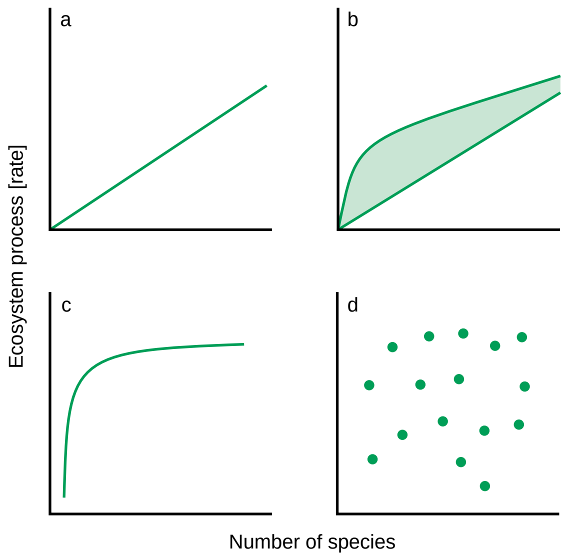


Figure D 2.4-1
Possible relations between ecosystem processes and the number of species in communities according to the (a) diversity-stability hypothesis, (b) rivet hypothesis, (c) redundant species hypothesis and (d) idiosyncratic response hypothesis.
Source: Gaston and Spicer, 1998; after Johnson et al, 1996

Box D 2.4-1

Stability, redundancy and keystone species

STABILITY

The term 'stability' when applied to ecosystems is often defined in different ways (Grimm and Wissel, 1997). There are three basic types of stability: the question of whether a system can be classified as stable of course depends on the time-scale under consideration. Furthermore, the parameter of the selected community by means of which stability is to be assessed is important. However, mostly the identity and frequency distribution of the species within a system are prominent candidates. But other characteristics such as biomass production or the size of the nutrition pool might also be possible aspects relevant to a description of the stability of ecosystems (Pimm, 1991; Tokeshi, 1999). The following terms must be distinguished in that context:

- *Persistence*: the tendency of a system in the absence of external disruptions to persist in a constant state over certain periods of time. This is in the simplest case represented in such time scales in which no change occurs in the system.
- *Resistance*: the ability of a system in the specific case of an exogenic disruption to persist in its original state.
- *Resilience, elasticity*: the ability of a system to recover from changes resulting from an exogenic disruption and to revert to its initial state. Resilience is generally understood to be the time period between occurrence of the disruption and resumption of the original state.

An increase in the number of species as a result of an invasion is for example a sign of destabilising processes present in the system, in other words there are unused resources or niches that make an invasion possible. More recent theoretical studies underpin the fact that complex linked systems with a high proportion of weak interactions show greater resilience to change (McCann et al, 1998). This stands in contrast to earlier models according to which simpler systems were supposed to be more stable (May, 1973). One thing that these early models have in common, however, is that they were based on a number of very unrealistic assumptions (Polis, 1998). Simple model observations do not take into account the fact that the species of different trophic levels are not distributed at random across an ecosystem. Furthermore, functional coupling of species was not sufficiently considered (Kaunzinger and Morin, 1998). Mathematical models on the stability of communities, while serving as useful instruments to identify stabilising conditions, can hardly be verified empirically.

REDUNDANCY

When analysing the function of species in species-rich ecosystems one comes across the term redundancy again and again. Species that do not have any apparent function for a particular ecosystem process are seen as redundant or 'superfluous'. Following on from this idea the Redundant Species Hypothesis was formulated (Walker, 1992; Lawton and Brown, 1993). Tracking down redundant species is problematic, above all in the light of the extremely limited scope of experimental ecology to investigate the influence of species number on several ecosystem processes at once, on different spatial scales or over longer periods of time (Gitay et al, 1996). Hence, a locust species will have no influence on the pollination rate in a pollination experiment because it does not interact with the process being observed (Martinez, 1996). A plantation forest (timber monoculture) will be able to maintain many ecosystem processes over decades or even centuries, but might be less resilient than the original species-rich forest, in which other species can replace species lost, in the case of extreme catastrophic occurrences, insect infestation or storm damage (Mooney et al, 1995). Therefore in order to be able to designate a species as redundant, one would have to investigate all possible functions under all possible environmental conditions over long periods of time – a task that is both practically and theoretically insoluble (Gitay et al, 1996). In light of such thoughts, many authors have proposed using more specific epithets and qualifiers ('At the investigated site species x can be classified as redundant in terms of process y over the period under investigation z') or other terms: functionally compensating or complementary, functionally coequal, similar or repetitive (Martinez, 1996). Such terms do more to reflect our limited knowledge of the complexity of ecological systems.

KEYSTONE SPECIES, DOMINANT SPECIES, ECOSYSTEM ENGINEERS

The Council has already elucidated the fact that a decrease in species number can have very varied impacts on ecosystem processes (WBGU, 2000a). *Dominant species* have a different effect on stability and momentum than rare species, although rare species become important at the point at which dominant species are damaged.

There are *keystone species* for individual processes: if they become absent this has a disproportionately high impact on the entire system. These are not just large, noticeable species that account for a large proportion of material and energy turnover. In a study that has since become a classic case study investigating the communities on the rocky Pacific shores, the removal of a predatory starfish (*Pisaster ochraceus*) led to the complete domination of a single mussel species (*Mytilus californianus*). The elimination of its predator allowed the mussel to completely push out all 15 species of competing macroscopic algae and invertebrates that had previously inhabited the rock surfaces (Paine, 1966, 1974). The dramatic influence of this starfish could not have been predicted in advance on the basis of its relative frequency within the system.

Another category of species with a disproportionately high impact on ecosystem processes are what are termed *ecosystem engineers* (Lawton, 1994). They modify either directly or indirectly the availability of resources for other organisms by changing the physical state of biotic or abiotic substances. They modify or preserve habitats, or even create new ones. This can happen via their own structures, as for example, via dead or living biomass in trees or corals, or indirectly via mechanical or chemical changes to the surroundings, eg the way beavers dam watercourses. The impact on ecosystems of the loss of such species is generally easier to predict than in the case of keystone species in the narrower sense, but in both cases the impact is considerable.

Box D 2.4-2

Restoration ecology: Restoring degraded ecosystems

In addition to the protection and conservation of largely intact natural or semi-natural ecosystems, the increasing amount of destruction in these systems will make restoration of degraded areas more important in future, as is practised for example by recultivation of mining landscapes. Depending on the objectives set functioning ecosystems, complete with their material cycles, can be restored or a state as close as possible to the ecosystem's original state with its complement of species can be created (Meffe and Carroll, 1994; Dobson et al, 1997).

A long-term experiment conducted by the University of Wisconsin attempted to restore the tall grass prairie formerly typical of America's Midwest on degraded land (Jordan III, 1992). After over 40 years of experimentation one can say that the original flora has at least in some areas been successfully restored, although the constant invasion from species alien to the ecosystem shows that not all niches have been occupied successfully. The original set of animal species has not re-emerged and will not re-emerge given of the shortage of space for large animals such as bison.

It is more difficult to restore degraded grazing land in rainforest areas (Uhl, 1992). The natural dissemination mechanisms for plant seeds by birds or bats cannot be used since these animals often avoid the open land. But seeds that do make it to the grazing land by chance are eaten up more readily by rodents and other animals than in closed forest areas. The few seeds that germinate ultimately die because of unfavourable micro-climatic conditions in the unprotected soil. So, humankind has first to create the conditions for the repopulation of such areas – by promoting anti-feedant, stress-tolerant species of trees – before natural processes of succession lead to stable, species-rich ecosystems. It is still unclear whether anything more than just a 'minimum set' of easy species can be thus achieved in the medium term.

The restoration of destroyed or degraded ecosystems is therefore an extremely difficult undertaking. So little is known as yet about the complex interactions among organisms and between organisms and their abiotic environment that setbacks in restoration are inevitable. One might compare it to repairing complicated machinery even if all of the individual pieces of a completely dismantled combustion engine were available, someone who was not an expert would have a very hard time trying to get the engine to function. Furthermore, efforts to restore ecosystems in most cases involve far higher costs than the preventive measures to protect these areas. Restoration is therefore in no way an alternative to protective measures. It can, and indeed must, provide an important supplement when degradation has already set in.

majority of the other species are redundant in their function, ie superfluous (Walker, 1992; Lawton and Brown, 1993). 'Minimum diversity' is reached when representatives of all functional types are present and there is no accumulation of unused or partially used resources.

2. *Insurance hypothesis*: The insurance hypothesis builds on the redundant species hypothesis. It assumes that the web of ecological interactions in a species-rich system is more tightly interwoven, this forming an 'insurance' against unforeseeable disruptions and making the web more error-tolerant (Mooney et al, 1996, Yachi and Loreau, 1998). For example, if the climate changes from warm to cold, then some of the thermophilic species, together with the species linked to them, will be at a disadvantage, whereas the cold-loving species will become more competitive. Species that previously contributed little to the overall functioning of the system can compensate for the loss of previously more important species. This can take the form of a slow and constant change. It can also, however, take the form of externally hardly noticeable, but increasing, strain on the existing ecosystem structure escalating into a sudden system swing or collapse that will be followed by a completely different ecosystem structure.
3. *Rivet hypothesis*: The rivet hypothesis stems from a comparison of the species in an ecosystem with the screws and rivets that hold an aeroplane together. It postulates that with any loss of a species ecosystem processes are impaired, in the way the wing of a plane would be less and less firmly attached to the fuselage of a plane by the removal of rivets. Once a critical threshold has been crossed, the system collapses, the wing breaks and the plane drops from the sky (Ehrlich and Ehrlich, 1981). The link between species richness and ecosystem processes is thus not linear and can take a number of possible courses.
4. *Diversity-stability hypothesis*: This hypothesis states that, as an increasing number of species are lost, the ability of ecosystems to withstand disruptions or to maintain high energy efficiency or productivity levels is reduced (Johnson et al, 1996). This assumes a linear linkage between the number of species and ecosystem processes, which distinguishes it from the rivet hypothesis above.
5. *Idiosyncratic response hypothesis*: Finally, the idiosyncratic response hypothesis assumes that there is a dependence between biodiversity and ecosystem processes but that the roles of the individual species are so diverse and complex that no scale or trend in the systemic interactions may be predicted (Lawton, 1994).

Among these hypothetical linkages between diversity and ecosystem processes there are of course endless permutations and transitions. This is reflected in the genesis of these hypotheses. For instance, the insurance hypothesis is the logical continuation of the redundant species hypothesis, integrating environmental fluctuations over longer periods of time. The experimental testing of these hypotheses has led in the last few years to increased efforts in ecological research (eg Ewel et al, 1991; Naeem et al, 1994; Tilman and Downing, 1994; Tilman et al, 1996; Hooper and Vitousek, 1997). In model ecosystems in the laboratory or in the field, for instance, the number of species was manipulated for experimental purposes. In all experiments a positive relationship between biodiversity and various ecosystem processes was found, albeit to differing degrees (but cf also Huston, 1997). An initial more general formulation of the links was made in the European research project BIODEPTH (Biodiversity and Ecosystem Processes in Terrestrial Herbaceous Ecosystems) in which a significantly positive relationship was demonstrated between the number of plant species and biomass production in eight European meadow sites under completely different soil and climatic conditions (Hector et al, 1999). All experiments also had in common the fact that they underscore the importance of certain features in species, or their role as part of functional groups. Such functional features of dominant species can have considerably more influence on ecosystem processes than species diversity *per se* (Grime, 1997; Tilman et al, 1997; Wardle et al, 1997). In addition to species number and functional diversity, the frequency distribution of species within a community is important for ecosystem processes. What remains problematic is transferring these findings to other systems or scales. It can be stated that there is no experimental indication so far that species loss might not have a negative impact on ecosystem processes.

As in climate research, considerable problems arise in differentiating the signal from the background noise in observations and experiments. Ecosystems are subject to major, complex and varied influences that are not under the control of the observer. Understanding ecosystems as models has so far not been sufficient to forecast correctly the system's response to a loss of biological diversity, to say nothing of the difficulties in linking these swings in a mechanistic way with the features and abilities of individual species. There is still a long way to go before we can analyse the full complexity of even a relatively simple ecosystem, eg a small body of water. However, the consequences of a change in species diversity may at this stage be generalized as follows (Mooney et al, 1995; Baskin, 1997):

- The *number of species* in an ecosystem doubtless influences a number of ecosystem processes; the curve of the linkage between species diversity and process rate and the position of a possible saturation point vary depending on the system and process under investigation. A loss or increase (through invasion) of a given species has the greatest impact when the total number of species is small.
- The *most frequent species* in a community typically contributes the most to the productivity of the population or to nutrient turnover. The loss of such dominant species therefore has a greater impact on these processes than the loss of smaller and/or rare species.
- The impact of the loss or addition of a particular species depends on its *functional similarity* with the other species in the system. If it has clearly distinct features (eg ability to fix nitrogen), ie belongs to another functional group, the impact will be far more manifest than if it were similar to the other species.
- Certain *functional characteristics* of organisms lead to greater effects on ecosystem processes than others. These features relate predominantly to influences on resource availability, on the rate of resource use and the disturbance regime. By way of example, we can identify organisms that are at the top of the food pyramid (predatory cats, top-down control), ones that change the availability of soil nutrients (nitrogen-fixing organisms, bottom-up control) or initiate disturbances (eg beavers). Such species often are keystone species or ecosystem engineers for the system – ie their effect is disproportionately great in relation to their abundance or biomass (Box D 2.4-1). The loss of such species therefore results in large and often unforeseeable system changes. But if the composition of species at the base of the food pyramid or in species that have very similar functions changes, then compensatory effects occur without the resulting clear impact in the quantity of resource consumption in the system.
- Species that in themselves have insignificant effects on certain ecosystem processes may trigger major *indirect effects* if they influence the abundance of other species. For example a pollinating insect has no direct influence on population productivity, but in its capacity as 'information carrier' it can be essential to the survival of a highly productive species that dominates the system.
- After a dramatic loss of species caused by *human-induced conversion* of ecosystems (eg land use change for subsequent agricultural use) it is generally ecosystems with low biological diversity that remain. These are predominantly made up of species that can survive rapid and extreme disruptions or transformations. They are however not necessarily adapted to provide ecosystem services over long periods of time. Such systems are not

comparable with natural species-poor ecosystems that have developed over long periods of time.

In the question of the ecological consequences of species loss, ecological research faces major challenges. The difficulty of generalizing linkages observed in certain systems, the problems in connection with experimental approaches (particularly in the case of long-lived organisms: an oak forest survives over ten generations of foresters) and the complexity and verification problems in the case of models – to name just a few of the problems – are reasons why one should not expect quick, groundbreaking results from this field of research. Having said that, there are hardly any alternatives to persistent, basic ecological research: the enormous knowledge deficit with regard to how ecological systems function cannot be filled in any other way. This is a field of research that should be supported to a greater extent by the German government (Section J 3.1), particularly since the practical consequences of possible findings could be of such significance. The application of ecological research results already has major and increasing influence on our perception and valuation of ecological systems and the services that they provide humankind and society.

D 2.5
Ecosystem products and services

In the above discussion we have examined the structure and functioning of ecosystems from the point of view of basic ecological research without exploring the influences or the demands made on ecosystems by humankind and society. As has already been described in Chapter B, however, there is now hardly an area or ecosystem type that is not subject to human influence or direct or indirect use. There is a close linkage between the structure, functioning and processes of ecosystems and their human use: by attributing value to certain characteristics that were originally value-free, ecological processes are transformed into products and services (Chapter H), in a fashion similar to the patenting of genes. This is not an automatic process, however: a large part of the problems arising at the human-biosphere interface stems from the fact that the prices for ecosystem products and services are not an outcome of market mechanisms, but rather need to be integrated deliberately into cost calculations.

The characteristics and processes that natural or semi-natural ecosystems demonstrate provide an array of products and services on which humankind is dependent and which cannot be replaced by technological means. At this juncture it shall suffice to briefly list these products and services (Box D 2.5-1). The listing illustrates at a glance that humankind's use of biological systems cannot be reduced to marketable products from agriculture, forestry or fisheries.

Despite the numerous gaps in our knowledge and fundamental uncertainties, certain basic guiding principles or rules may be derived from the current state of ecological research that provide a framework for the rational management of ecological systems and the conservation of biological diversity (Mooney et al, 1996):

- The loss of genetic diversity within a species is risky because this diminishes the potential to adapt to disturbances (climatic, pests, biogeochemical, etc; Section D 3.4).
- Low species diversity in a system is also risky because presumably the resilience and resistance of ecosystems to disturbances correlate positively with species diversity (Bolker et al, 1995). The simplification of ecosystems in the direction of monocultures and intensive production definitely detracts from stability. Such impoverished systems can only provide a fraction of the ecosystem services that species-rich systems provide. Creating durably stable ecosystems should be a major economic goal. Experience in agriculture shows, however, that the constant export of resources (harvesting for human demands) without long-term replacement (fertilizer) or maintenance measures is not possible.
- The loss or addition of individual species can have a great impact on ecosystem processes. It is very difficult to predict which species play a key role in a given system, although in principle it is possible. It is at this point that pure research has direct relevance for ascertaining the conditions and limitations upon humankind's intervention in the natural world.
- There are particularly sensitive ecosystems, such as islands, arid or arctic zones, that have difficulty in buffering disturbances. These systems are characterized by a low redundancy of functional types.
- Fragmentation and increased disruption of natural or semi-natural ecosystems result in profound changes in the features of a system. Long-lived large organisms (eg forest trees) are replaced by small short-lived (eg ruderal flora) organisms that reduce the system's capacity to store carbon or nutrients.
- Low ecosystem diversity in the landscape also has disadvantages: the costs of management and the vulnerability of the region to disturbances increase. For example, farmers in areas with many hedges have to use fewer pesticides since many beneficial animals come into the fields from the hedges and reduce the number of pest organisms

Box D 2.5-1

A taxonomy of ecosystem services and products and associated value categories

FUNCTIONAL VALUE
1. Regulatory services: climate and water
   - Maintaining composition of gases in the atmosphere,
   - Protection against ultra-violet rays through oxygen production and subsequent formation of ozone in the stratosphere,
   - Partial stabilisation of the climate,
   - Reduction of temperature extremes and strong winds,
   - Maintenance of biologically necessary humidity conditions,
   - Controlling the hydrological cycle.
2. Global biogeochemical cycles
   - Carbon, nitrogen, phosphorus, sulphur.
3. Formation and protection of structure (soil, slopes, coasts)
   - Formation and maintenance of soils,
   - Erosion of original rock, transformation of nitrogen, phosphorus and sulphur into compounds available to plants,
   - Protection against erosion,
   - Flood protection (alluvial forests, flood meadows, etc),
   - Coastal protection through formation of coral reefs and dune systems,
   - Slope protection: landslides, etc.

TRANSITION FROM FUNCTIONAL TO USE VALUE
1. Sink services
   - Breakdown and transformation of poisons and nutrients, biodegradation.
2. Pest control and pollination
   - Pest and disease control,
   - Pollination of important crops and wild plants.

USE VALUE
1. Biomass production
   - Fisheries, agricultural and forest products, harvesting of natural substances.
2. Technology and research
   - Nature as a model for technology: error-tolerant systems, bionics, ideas for engineers: building materials, fibres and industrial products, nature as a model for medical research.
3. Tourism and leisure/recreation
   - Nature as a destination for those seeking recreation, ecotourism, zoos, botanical gardens, parks.

SYMBOLIC VALUE
1. Ecosystems as cultural vehicles
   - Close connection between ecosystems and particular cultural types (Section E 3.5).
2. Biological diversity as the source of quality of life
   - Experience and stimulation: aesthetics, art,
   - Experience of the wilderness as elemental experience,
   - Leisure pursuits from mountain climbing to diving (partly also use value),
   - Recreation and recuperation, rest and meditation
   - Education, transmission of knowledge.

OPTION VALUE
1. Informational services
   - *In-situ* maintenance of genetic heritage of evolution: maintenance of a universal 'genetic library', from which humankind derives the basis of its existence in the form of crops and livestock, medical substances, etc.

Sources: Myers, 1996a; Costanza et al, 1997; Daily, 1997b

(Schulze and Gerstberger, 1993). Furthermore, the desired services and products from ecosystems cannot be achieved with uniform landscapes. Therefore, it is important to look at the landscape level in order not to lose sight of important ecosystem services (eg slope protection, erosion protection, drinking water, recreation; Box D 2.5-1; Section E 3.9 and Chapter H).

- Efforts in the context of restoration ecology demonstrate that in many instances intervention into the biosphere is irreversible (Box D 2.4-2). This applies not only at the species level (an extinct species is lost irretrievably), but also for populations (that have adapted genetically through evolution to a particular region) and for certain types of ecosystem. Management decisions that cannot be reversed must be taken with particular care. In case of doubt, the precautionary principle should always be applied.

Biodiversity needs to be conserved not only for its own sake, but also to safeguard future economic and cultural development. Therefore it must be in the interests of all countries to maintain a certain portion of their terrestrial, aquatic and marine ecosystems in its natural state (Section I 1). Such core zones incorporated into regional use strategies should remain free of any commercial use (Section E 3.3.2). They can also act as monitoring and control sites with the help of which we can appraise the impacts of human intervention.

D 3 Focal issues

D 3.1
Trade in endangered species

In addition to the threat to ecosystems as a result of increasing conversion and fragmentation, economic use is also a considerable cause of the decline and even the extinction of species. For example, trade is estimated to account for approx 40 per cent of the threat to vertebrates (Hunter et al, 1998). Demand for products from rare animals or plants, such as ivory, rhinoceros horn, tiger bone, leather goods, furs or tropical timber, but also the demand for living species such as rare tropical ornamental plants, cacti, orchids, exotic birds or humphead wrasse (Section E 2.4) is considerable. They are used for the fashion or food industries, for medical and pharmaceutical research purposes, exhibitions and collections in the industrialized countries (Sand, 1997). To protect animal and plant species living in the wild from excessive exploitation through global trade, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) was adopted in 1973 (Box D 3.1-1) and has so far been ratified by 144 states.

D 3.1.1
Gaps and weaknesses in the CITES provisions

By the sectoral focus on trade, only a segment of the international system of species conservation can be covered since other threat factors, such as degradation and fragmentation of natural habitats, are not

Box D 3.1-1

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

The provisions of CITES allow international trade in endangered species to be regulated via a worldwide system of import and export controls and permit requirements. The condition is inclusion of a given species in one of the three appendices to the Convention that, depending on the degree of threat to the species, provide for various restrictions on international trade (through to a complete trade ban). The Appendices currently include approx 34,000 plant and animal species. The decision on including a species in a list or moving it from one list to another is made at the Conferences of the Parties that take place every two to three years and requires a two-thirds majority of the member states. The 11th Conference of the Parties is scheduled for April 2000 in Nairobi.

Appendix I lists the species acutely in danger of extinction that may be damaged by trade. Import or export of an animal or plant of such species is only admissible under the strictest conditions so that essentially inclusion in Appendix I means a ban on trade in that species. Appendix II contains species whose stock is potentially endangered if trade is not regulated. Appendix III includes species for which one member state wishes to prevent or restrict exploitation on its territory, and it requires the cooperation of other contracting parties to control trade.

Implementation of CITES requires a number of measures on the part of the member states at legislative and administrative levels. For example, the minimum requirements for an effective protective system are the establishment of relevant authorities, a national ban on all trade that is in violation of the Convention, provision of suitable punishments for illegal trade or possession of one of the endangered species and the possibility of seizure for illegally acquired animals or plants. The CITES secretariat in Geneva monitors and supports implementation at international level; in addition to organizational tasks it assumes an important role in collecting and disseminating information, working on scientific and technical investigations, standards and means of implementing the agreement. It can draw on the support of qualified NGOs in this role. One example of valuable collaboration with an NGO is TRAFFIC (Trade Records Analysis of Flora and Fauna in Commerce), a joint initiative by WWF and IUCN which plays a key role in research, monitoring, initiatives, training and enforcement at national, regional and international levels. At the 1987 Conference of the Parties furthermore permanent committees were established that take on the regular monitoring and evaluation of the biological and trade-related status of the species in the appendices for their particular areas and are assist in closing data gaps. They work in cooperation with external scientific bodies and have an advisory function (Sand, 1997).

considered. Even in the context of trade, the provisions only come into play if specimens of or products from endangered species appear in *international* trade. Another gap can be illustrated by the sea turtles. They may be listed in Appendix I of CITES and thus subject to strict international trade regulations. But this cannot prevent the survival of sea turtles being jeopardized by economic activities involving another species (shrimp), since they are caught in the nets that are cast for shrimp.

The categories in the CITES Appendices have proven too broad in light of the complexity of the various degrees of threat. As the Advisory Council wrote in its 1994 report, this fact, coupled with the requirement of a two-thirds majority of member states, results in decisions with regard to the inclusion of a species or moving a species from one list to another that do not always reflect the threat status of that species, but are also determined by political or economic considerations (WBGU, 1995a).

In addition, despite the relatively long period of time for which the agreement has been in force, there are still fundamental deficits in national and local implementation. In the course of a study it was found that almost 20 years after conclusion of the agreement the vast majority of member states had not even implemented the minimum standard (Sand, 1997; Resolution 8.4). Fundamental enforcement problems are, in particular, the control of legal international trade in Appendix II species, the repression and pursuit of illegal transactions with endangered species and the difficulty of identifying the species listed in the Appendices by customs officials (WBGU, 1995a; Tierney, 1998). The persistently late, and partly incomplete, submission of annual national reports makes the work of the CITES Secretariat all the more difficult. The reasons for such patchy implementation lie in part in a lack of experience, but also in insufficient personnel, institutional, technical and financial resources. In particular in developing countries – the main holders of biological diversity – there are specific problems that require increased cooperation among member states (de Klemm, 1993; WBGU, 1995a).

D 3.1.2
The 'Protection through sustainable use' concept

In the light of such difficulties there are a growing number of member states at the Conferences of the Parties who question the premise on which CITES is based, namely that the threat to species from commercial exploitation can only be counteracted by strict regulation of trade (right through to trade bans) (Dickson, 1997). In some cases, regulation has simply shifted the legal trade into the illegal sector (Tierney, 1998). Thus, under the banner of sustainable use, it is argued that limited, controlled trade under given circumstances could be an effective conservation instrument. The new version of the classification criteria adopted at the 9th Conference of the Parties in 1994 takes account of this idea with regard to decisions for transferring a species from Appendix I to Appendix II (Resolution 9.24). Drawing on these criteria, it was decided at the 1997 Conference to move the African elephant to Appendix II and thus resume limited trade in untreated ivory as of 18 March 1999. The states of the region in turn undertook, among other things, to resolve the weaknesses in legal enforcement and controls, to reinvest profits into the maintenance of elephant stocks and to adhere to preventive measures (export quotas, labelling of origin, trade with only one importing country (Japan), sale of ivory only by one single government-controlled entity, permission for independent monitoring of the sale, packaging and transport process). Furthermore, the application for renewed higher classification shall be submitted at the request of the CITES Standing Committee if illegal trade takes the upper hand or if there is non-compliance with the conditions agreed upon (Decision 10.1; Dickson, 1997). Further development of the elephant populations in the respective countries and compliance with the commitments thus made will be a touchstone for this concept of sustainable use in the context of CITES.

Over and above this approach there are calls for limited trade to be admissible for Appendix I species to the extent to which trade contributes to financing their conservation and no negative effects are felt on the stocks of the species in question (Gray, 1998).

D 3.1.3
Assessment and recommendations

PROTECTION THROUGH SUSTAINABLE USE

The Council is of the view that the new conditions for the transfer of a species from Appendix I to Appendix II, if implemented appropriately, provide adequate scope both for species conservation and the various social, economic and legal parameters of the regional states. A limited resumption of trade does blur the clear distinction between legally and illegally procured products, thus making controls more difficult and the moral pressure on customers lower. By taking into account the specific demands of the regional states and increasing cooperation, however, the opportunity for high acceptance and better implementation of control and protective measures is increased. The development and enforcement of adequate monitoring mechanisms, certification systems and identification methods (eg genetic tests) remains an important task in relation to Appendix II species.

In the case of Appendix I species, the acute danger of extinction continues to demand strict trade regulation. This reduces drastically the number of specimens or products found (as a result of exceptions) in legal international trade, making the control and monitoring job of the responsible authorities easier and helping to prevent possible forgery of requisite documents. It should however be considered that strict regulation of Appendix I species cuts off important sources of income for the regional states (particularly developing countries). Nonetheless, given the acute danger of extinction, appropriate compensation should not take the form of a relaxation of the trade ban, but rather financial assistance, compensatory payments, debt waivers and development assistance projects (Section I 3.5).

Export quota arrangements and management plans

In the case of the quota arrangements arrived at for the species in Appendix II, it must be criticized that this does not fix the absolute number of specimens but rather the number that is allowed in international trade (Sand, 1997). This is a deficit that arises out of the sectoral approach of CITES and illustrates the need for all instruments and agreements within a global protection system of species and species diversity conservation to interlock (Chapter I). However, in the countries of origin, annually fixed export quotas for Appendix II species may guarantee a certain amount of control over the level of international trade. As the Council recommended back in its 1994 report, for really effective protection they would have to take into account key biological data on the basis of the latest scientific findings (eg population dynamics and reproductive patterns) as well as the scale of the threat from trade, habitat destruction and environmental stress. It would make sense for the role of the relevant committees (Animals Committee, Plants Committee) to be strengthened considerably and their recommendations be given more weight. As in the case of the decisions regarding the African elephant, export quota arrangements should be supplemented by management plans for the use, reinvestment in and maintenance of national populations, something that may indirectly also promote the conservation of habitats.

The German Federal Government should also advocate that when decisions are made with regard to including a species in Appendix II, at the same time a resolution be adopted that addresses the necessary research, protection, conservation and control measures in the regional and buying countries. One example is the resolution on the conservation of the sturgeon (Resolution 10.12).

Mechanism for the classification of species

In order to counteract the primarily politically or economically motivated classification decisions, for some time now the appointment or at least participation of an independent scientific decision-making body has been advocated. With regard to the people making up that body, an independent expert body could be considered (possibly an Intergovernmental Panel on Biodiversity, Section I 3.2.1.1) or the existing committees (Animals and Plants Committees). It must be considered however that the decisions with regard to including species in a list or moving them between lists are quasi legislative acts that cannot be simply transferred to scientists. Both when delegating decisions to experts, but also if giving voting participation to experts, the problem of democratic legitimacy arises.

It would therefore make more sense to expand the competences of the existing committees to include examining and evaluating biological and trade-related data and issuing corresponding recommendations, not just for species already listed in the Appendices but also for species worthy of inclusion. Collaboration with external institutions qualified in these areas is recommended (IUCN, red lists). Furthermore, the scientific recommendations of the committees could gain more weight through publication.

Effective enforcement mechanisms in the case of infringement or non-compliance

In the case of violations of the Convention it is the Secretariat's job to contact the enforcement authorities of the member states in question. However, the measures and investigation of the facts that follow depend upon their being in accordance with national legal provisions and the 'initiative right' of the member state in question (Art. 13 CITES). It would be necessary here, in addition to supporting incentives and recommendations for implementation of the agreement, to establish binding provisions with regard to investigations, assistance measures or sanctions. In such cases in the past the Secretariat has at times involved the Standing Committee that, in a resolution, has recommended applying collectively Art. 14 para 1 CITES and to ban any trade in endangered species with the state in question (Sand, 1997). Examples of such a move were measures against the United Arab Emirates, Thailand and Italy, which improved their legislation and enforcement in response and thus managed to get the sanctions lifted (Birnie, 1996). Such measures should be continued and established in a more binding form. In order to address appropriately the differing degrees of violations a milder measure might be intensified monitoring of products from the country in question. It should be considered that such trade restrictions might be in conflict with the WTO/GATT trade regime. Its Committee on Trade and the Environment (CTE) does, however, indicate that possible disputes between member states of a multilateral environmental agreement that provides explicitly for trade measures (as is the case with CITES) should be solved in that forum and not through the WTO arbitration procedure (WTO, 1996).

PUBLIC IMPACT AND AWARENESS-RAISING

The concept behind CITES has not proved successful in all cases (WBGU, 1995a). Despite its limited approach and the difficulties in implementation, however, it makes an important contribution to the global system to protect species diversity, and the scope it does offer should continue to be used and expanded. In particular, by categorizing various species in Appendix I, the public has become sensitized to the problem of extinction. The trade ban on ivory was discussed in detail in the press and in many cases substitute products have been found, for example synthetic materials instead of leopard skin for coats or substitute materials for ivory (Sand, 1997). This type of public impact could be promoted through targeted publicity work and increased transparency (Section I 3.3). A meaningful supplement for directing economic use beyond the conservation approach of CITES is sustainable tourism (eg sustainable safaris, national parks; Section E 3.7). Species conservation can be linked to economic benefits for local communities in those cases.

D 3.2
Regulations on biosafety

D 3.2.1
Why do we need international regulations on biosafety?

Great expectations are being attached to genetic engineering – particularly in the area of agriculture and food. There is a hope that this new branch of the economy will create additional jobs and secure economic growth. Developing countries should benefit from the new technology as a component of effective poverty reduction strategies, or yield increases through genetically engineered herbicide resistance or saline and drought tolerance (Henningsen, 1998a). Biotechnology, in particular release experiments with genetically modified organisms (living modified organisms, LMOs), are however associated with certain risks (naturalizing of transgenic plants and their uncontrolled spread, negative secondary effects, impact on foods). In its risk report the Council assigned certain transgenic plants in this area of application of genetic engineering to the *Pythia* risk class (WBGU, 2000a). Characteristic of this risk class is the high degree of uncertainty both with regard to the probability of occurrence and the scale of damage. In neither case do we have sufficient certainty of assessment.

Risk awareness developed first of all in the industrialized countries. New biotechnological methods were developed in those countries and that is also where there was the first need for release experiments and, consequently, the first political debates and legislative procedures. The national regulations turned out to vary greatly; but they all have in common the fact that there is a bureaucratic procedure that has to be gone through with a duty to acquire information that must be submitted at high costs as a prerequisite for approval (Dederer, 1998).

There is a certain incentive to implement such experiments and tests in countries where such rules are not in place. In some cases firms have carried out such release experiments without sufficiently informing the countries in question and thus have 'exported' the risks associated with the tests. Generally, the countries that were affected were those that, as a result of a lack of their own biotechnology industry, saw no reason to act to put regulations in place. Risks were therefore exported from industrialized countries to developing and take-off countries without the latter being sufficiently included in the resultant new insights into patent protected products. The danger of insertion of transgenic elements into the environment is high, particularly in those regions where there are species-related wild plants. Several crop species, such as maize, potato and tomato, but also certain species of cotton, originated in the countries of South and Central America. Despite that fact, insect-resistant and herbicide-resistant cotton were tested by the Calgene company in Bolivia and Argentina (1991) and genetically manipulated tomatoes that are able to delay their maturing process (Flavr Savr) were tested in Chile and Mexico (1990 and 1991) (Shiva et al, 1996; GRAIN, 1994).

However, biotechnology and genetic engineering are among the key technologies of the coming decades. Within the industrialized countries there is, therefore, competition for the best sites for biotechnological and genetic research. The legal frameworks represent one of the main competitive factors in that context (Dederer, 1998). Insofar, there is the danger, given the (still) deficient knowledge of potential damage, of underestimating the risks in order not to create competitive disadvantages for one's own industry in the area of biotechnology, or prevent a business drain. Box D 3.2-1 gives an overview of existing international regulations affecting biosafety.

A binding protocol under international law on biosafety is therefore necessary for the following reasons:

- A protocol would have the advantage of harmonizing existing national legislation and thus particularly in terms of the assessment procedures, creating an easily understood minimum standard that would rule out site advantages at the cost of biological diversity or human health.
- Developing countries could be protected against the risk of becoming the testing and experimental ground, without sufficient safety precautions, for genetically manipulated varieties from industrialized countries (Graziano, 1996; Hunter et al, 1998).
- The impact of release often cannot be limited to one national territory; an international agreement with a common protection standard would provide the neighbouring states with greater security.
- The codification by means of a binding document under international law would send a strong political signal with regard to the importance of the topic in hand (cf Montreal Protocol on Protection of the Ozone Layer).

Box D 3.2-1

Biological safety in existing international law

Soft-law regulations

There are currently no comprehensive arrangements under international law addressing the issues surrounding biosafety; there are however various 'guidelines' initiated by international organizations that regulate aspects of biosafety on a voluntary basis.

- *Codex Alimentarius*: the Codex Alimentarius Commission (CAC) was established in 1962 by the FAO and WHO to create a programme to establish food standards. The Commission now comprises 162 states. The aim of the programme is to guarantee consumer protection in the area of food and creation of fair standards in the trade in food (Art. 1 a CAC). To fulfil these tasks, the CAC drafts standard or has these drawn up by suitable organizations (Art. 1 c). These food standards form a collection, the Codex Alimentarius, which is published and adapted to developments (Art. 1 d, e). They have no binding power on member states, but are considered internationally recognized recommendations (Decision of the General Assembly 39/248). Under that aspect, genetically treated foods also fall under the general protective regimen of the Codex, but the latter does not contain specific regulations governing genetic modification. For many governments, the Codex Alimentarius is primarily an interesting instrument for breaking down non-tariff trade barriers; therefore, the reduction of trade barriers has moved more and more to the forefront of the Commission's work over the last few years (Merkle, 1994).
- *UNIDO (United Nations Industrial Development Organisation) Voluntary Code of Conduct*: The UNIDO secretariat developed a Code of Conduct for the release of organisms into the environment. The Code contains recommendations to national legislators to create laws according to which when geneticall modified organisms are released the responsible national authorities should be involved. Simple notification is sufficient, however, no approval is required (Shiva et al, 1996).
- *Code of Conduct for biotechnology*: The Commission for Genetic Resources for Food and Agriculture that was formed in 1983 at the FAO conference and now has 158 members developed a Code of Conduct governing the use of biotechnology. A preliminary draft was divided into four Chapters, Chapter 3 focussing amongst other things on the concerns surrounding biosafety issues. In 1993 the Commission stopped its work on this area of the Code since biosafety issues fall more under the auspices of the CBD. The recommendation was made that the drafts drawn up so far should be seen as suggestions for future regulations (Shiva et al, 1996; FAO CL 103/Rep).
- *UNEP International Technical Guidelines for Safety in Biotechnology*: Under Decision II/5, in which the Second Conference of the Parties to the CBD in 1995 commissioned a working group to draw up a biosafety protocol, the urgency of creating binding rules for the safe use of biotechnology was underlined. These guidelines were to serve as orientation until the protocol was adopted. They contain the parameters of existing protective provisions and, above all, regulations in the area of risk management, information exchange and capacity building.
- *Chapter 16 of* Agenda *21* is dedicated to the environmentally sound use of biotechnology and calls above all for the development of risk assessment and management rules for all areas of biotechnology.

Binding regulations under international law

- *Art. 19 Paragraph 4 CBD*: This provision in the Convention on Biological Diversity, that prescribes that the exporting states have a duty to provide information with regard to the possible adverse impact of the use of living modified organisms, is binding under international law.
- *The International Plant Protection Convention (IPPC)*: This Convention entered into force in 1952, currently has 106 members and was revised in 1979, 1983 and 1997. The aim of the Convention is to prevent and contain epidemic plant diseases. In this connection the member states may, pursuant to Art. 4, impose import restrictions and bans with regard to certain plant varieties. Within its protective scope, the Convention is also applicable to genetically modified plants, ie also to seeds. Since, however, the purpose of the IPPC is to prevent the spread of plant epidemics, the measures mentioned above could only be used if this danger were impending and emanated from a genetically modified plant (Shiva et al, 1996; FAO, 1998a).

D 3.2.2
The biosafety protocol

Since July 1996 international negotiations have been taking place to develop a biosafety protocol that was to have been concluded in February 1999. Since no consensus had been achieved by that date, adoption of the protocol was postponed; no date has been set for further negotiations; the only thing that is certain is that they should be scheduled before May 2000. The aim of the protocol is to establish rules that would guarantee an international minimum standard for biotechnology activities. The protocol would be the first agreement (binding under international law) in this field.

D 3.2.2.1
Overview

The legal basis for the protocol is the Convention on Biological Diversity (Section I 3). Art. 19 para 3 of the Convention commits the contracting parties to examine 'the need for and modalities of a protocol setting out appropriate procedures, [...] that may have adverse effect on the conservation and sustainable use of biological diversity'. Once the expert group had completed its assessment, the second meeting of the Conference of the Parties (COP-2) in 1995 decided by Decision II/5 to deploy a working group to draw up a draft protocol. This was agreed upon in Cartagena in February 1999 (CBD/BSWG/6 /L.2/Rev.2) but was not adopted by the Extraordinary Meeting of the Conference of the Parties (ExCOP). In terms of content, the disputed point at the unfinished conference right up to the end was whether and to what degree the following areas or principles should also form part or indeed the basis of the protocol:

- inclusion of human health as an asset to be protected,
- application of the protective mechanisms of the protocol,
- incorporation of socio-economic impact in a risk analysis; placing the precautionary principle at the basis of risk assessment,
- the substantive form of the advance informed agreement (AIA) procedure.

Also, no consensus was reached on the nature or scale of a liability regime in the context of the protocol. Experience from other internationally binding agreements has shown that resolving liability questions is difficult and involves a great deal of talk and time. For example, in the context of the 1989 Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, the contracting parties have still not managed to establish a liability regime that has the support of all parties. To promote a swift conclusion of the protocol negotiations at the last, 6th meeting of the Biosafety Working Group, a consensus was reached that they will not begin working on the liability rules until the First Meeting of the Parties to the Protocol and that work should be concluded within four years. Highly controversial questions have thus been removed from the protocol negotiations and postponed. The Council would like to point out in this context that a sophisticated system of liability – in particular with regard to the preventive function it should assume – is an essential component of an effective biosafety regime. The removal of certain points so expedient for swift consensus must not be allowed to lead to a neglect of this regulatory area.

At the 6th meeting of the Biosafety Working Group and the 1st Extraordinary Meeting of the Conference of the Parties to the Convention on Biological Diversity that immediately followed it, in many areas no progress was made. By contrast to previous sessions, the composition of the interest groups had changed. Whereas up to that point the industrialized countries and developing countries (G77 and China) had been on opposing sides, now agreement on a protocol proposed by the EU and advanced with many compromise wordings foundered on a number of large agricultural exporters (Argentina, Australia, Chile, Canada, Uruguay and – although with no voting rights – the USA), even though the proposal catered to the particular interests of these countries. LMOs for example that are destined for direct consumption or use as fodder were to be excluded from the AIA procedure (Bai et al, 1999). And the provision that allowed importing states to refuse import, even if there was an absence of scientific certainty, was left out (Art. 8 para 7 of the draft protocol).

It is nonetheless remarkable that a majority of the developing countries and take-off countries (exceptions: Argentina, Chile, Uruguay) advocated a strong biosafety regime during the formulation of the protocol.

D 3.2.2.2
Details of the regulations that are still hotly disputed

Including human health in the protocol as an asset worthy of protection

Taking a lead from Art. 19 para 3 and the explicitly protective purpose of the Convention on Biological Diversity (CBD), it is argued that the protocol should only protect negative impacts on biological diversity, and not on human health. Likewise, the direct legal basis for the development of the protocol, the operative portion of Decision II/5 of CBD COP-2, only refers to biological diversity. However, the considerations expressed in II/5 clearly show that human health is also a concern that was shared by a majority of the Parties and that should be addressed by the protocol. Furthermore, Art. 19 para 3 should be read in combination with Art. 8(g) of the CBD. The latter provision calls for Parties to subject the use or release of LMOs to a national risk control procedure that should also consider risks to human health.

From a European point of view it should be pointed out that Art. 4 of the Directive on the Deliberate Release into the Environment of Genetically Modified Organisms (GMOs) (90/220/EEC) obliges the European Union (EU) member states to ensure 'that all appropriate measures are taken to avoid adverse effects on *human health* or the environment which might arise from the deliberate release or placing on the market of GMOs'. Furthermore, it is also conceivable under certain circumstances and on the basis of current international law to ban by national legislation the importation of genetically modified products with possible dangerous impact on human health, without violating GATT. According to Art. XX(b) of GATT it remains the right of the member states to issue rules to protect the life and health of people, animals and plants within their own territory even if these have the effect of restricting trade. Aware that such broadly defined terms actually invite hidden restriction of international trade, in 1994 the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) was adopted. According to Art. 2 para 2 of the SPS the measures taken may only be applied in the degree necessary for protection *'on the basis of scientific principles and [may] not be upheld without sufficient scientific evidence'*. Pursuant to Art. 5 para 7 a member can *in cases in which the scientific evidence in this regard is insufficient, [...] take provisional sanitary or phytosanitary measures [...].* An example that would fall under this exception to the free trade regulation could – although it is not poised for admission onto the market – be the 'genetically modified (GM) potato'. In a much disputed experiment, a gene was inserted into potatoes that normally protects snowdrops from being eaten by insects and had proved relatively non-toxic in toxicological investigations. Time-intensive experiments that are at present not required in trials leading to commercial approval showed however that the GM potato had significant effects on the development of organs, metabolism and immune system of laboratory animals to which it was fed (Puztai, 1998; Sentker, 1999; Coghlan et al, 1999). One single experiment can certainly not be taken as sufficient scientific proof in the meaning of Art. 2 para 2 of the SPS, but Art. 5 para 7 SPS allows national precautionary measures in the case of a recognized, scientific, but not yet proven, risk potential.

Scope of application of the protocol's protective mechanisms

Opinions differ, first of all, on the extent to which end products (particularly foods) into which LMOs have been processed should be included in the protocol besides 'living' modified organisms. Countries that want to give the protocol very narrow scope base their arguments on the wording of Art. 8(g) and 19 para 3 of the CBD. These provisions relate only to LMOs, that is *living* modified organisms. The opposite side demands an effective approach that takes account of the comprehensive goals of the Rio Summit. This stance is based on a number of scientific studies according to which, in such cases, too, a damaging impact on species diversity and human health cannot be ruled out (Henningsen, 1998b).

Furthermore, it should be mentioned that both EU Directive 90/220 and German legislation treat genetically modified organisms and their products the same (Art. 1 para 1, 2nd indent of the Directive; Art. 2 para 1, No. 4 of the German Genetic Engineering Act).

There is also lack of agreement on the issue of the extent to which agricultural mass-produced goods that are still *living* that serve as food, fodder or for further processing should fall under the scope of application of the protocol. Agricultural exporters issued a vehement call for these goods to be excluded. In the current draft of the protocol agricultural commodities are only excluded from the AIA procedure. And so, not just the processed food products are to be excluded (eg cornflakes, soya oil), but also the living products themselves (maize, soya sprouts). The danger for biodiversity is in part seen as low since the foods would not be released into the environment. The considerable danger of an unintentional release speaks crucially in favour of their being included however.

Another question is whether agricultural commodities constitute a danger to human health. To that extent, the discussion has to be seen in the context of the dispute about whether human health enjoys protection under the protocol. If – as is foreseen in the draft protocol – this is affirmed, then it would be illogical to rule out genetically modified foods as a potential source of danger to human health.

Incorporating socio-economic criteria into the risk analysis and evaluation

There is also a heated discussion about whether socio-economic consequences that may occur as a result of the use of LMOs should be part of the risk assessment. One side demands that the countries importing LMOs take into consideration such consequences as 'genetic erosion and the associated loss of income and displacement of traditional farmers and farm products' (CBD/BSWG/5/Inf.1). The opposing side considers such a regulation to be misplaced in a biosafety protocol and sees such aspects as opening the way up for the justification of arbitrary trade barriers (Miller and Huttner, 1998).

Wherever socio-economic aspects are the only objection to importation it may be asked whether and to what extent a right to sustainable development through genetic engineering could protect endangered traditional agricultural structures. Furthermore, there is the question of whether it should be possible to limit trade on such grounds.

The precautionary principle

There is disagreement on whether, when using or releasing LMOs, the precautionary principle should be applied in assessing safety. The main premise of the precautionary principle is that when a possible danger is recognized *'the lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat*' (Preamble of the CBD; Birnie and Boyle, 1992). The precautionary principle is international common law *in statu nascendi*, although its specific demands are often not made precise. At any rate, the safety demands grow in step with the scale and irreversibility of the potential damage. It may furthermore be assumed that a precautionary principle under international law in general would set lower safety requirements than the current strong precautionary principle enshrined in Germany's laws on state-of-the-art hazard minimization ('Gefahrenabwehr') and installation licensing.

The need to include the precautionary principle in the biosafety protocol was primarily rejected by states that export agricultural commodities, which in general posit the harmlessness of genetically manipulated organisms in these negotiations. Ultimately, this dispute needs to resolve the question of whether the country exporting or importing the LMOs bears the burden of proof (and the research costs associated with that) with regard to their danger. If one uses the precautionary principle as a basis, it would be the duty of the exporting country to prove that no danger to biological diversity or human health can be expected from the LMOs. If the protocol on the other hand assumes the general harmlessness of the LMOs then the importing countries would have to set out why a specific case represented a threat; otherwise, their refusal could be seen as an unjustifiable trade barrier.

The framework in which the biosafety protocol is embedded urges consideration of the precautionary principle. The preamble of the CBD and the 15th principle of the Rio Declaration of 1992 make explicit mention of it. And the practice in several EU states allows one to assume that they have considerable reservations with regard to the harmlessness of LMOs. Although the consent of the responsible authority was given – having applied the precautionary principle – the governments of Austria and Luxembourg banned the use of Novartis Bt maize that was introduced onto the EU market via the French subsidiary of the Swiss company.

Since, according to Art. 16 para 1 of Directive 90/220, any member state may prevent the use and/or sale of a product as long as it has the reasonable assumption that it 'constitutes a risk to human health'. Greece also drew on this provision to prevent the use of genetically modified rape. In France and the United Kingdom it is, at least for the moment, illegal to plant 'GM maize' (in France by order of the administrative court, in the UK through a 3-year moratorium imposed by the government (Whyndham and Evans, 1988)). The Environment Committee of the European Parliament urged the Commission to order a moratorium on any further approval for the cultivation of GMOs. The responsible Scientific Committee of the EU, that issues recommendations for the approval of new varieties, initially expressed serious concerns about the safety of a genetically manipulated potato variety from the Dutch company Avebe and denied approval (Notification C/NL/96/10). Then in February 1998 the Commission in its proposal for an amendment to Directive 90/220 provided for a more intensive risk assessment system and increased control of the production cycle (98/0072 (COD)).

However, the precautionary principle only made it into the preamble, not into the operative portion, of the draft biosafety protocol in the version as last proposed by the EU. The amorphous nature of the precautionary principle may fan unjustified fears. But we should refer in this context also to the SPS Agreement that takes account of this precautionary idea (without expressly mentioning the precautionary principle) with its exemption provision in Art. 5 para 7 that is also applicable to the area of 'green genetic engineering': for example, genetically man-ipulated Bt maize has the ability to produce a poison that comes from bacteria (*Bacillus thuringiensis*), thus protecting itself from attack by pests, particularly the larvae of the European corn borer. Initial independent experiments fuel the suspicion that, as a side effect, a disproportionately high number of beneficial animals may also die, particularly the natural enemies of the pests that eat the toxin-enriched larvae. A natural interaction is thus in danger of being pushed off balance (Concar, 1999). It is particularly worrying that, in the series of experiments mentioned, more of the beneficials died by eating the poisoned European corn borer than in the cases when they were given the same amount of Bt poison directly.

The Council therefore recommends that in future talks, the precautionary principle be maintained as the basis for the biosafety protocol. This is appropriate not just because of the protocol's context, but also since releasing LMOs is essentially an irreversible act, and there can be no guarantee of the possibility of 'fetching back' the organisms once released and preventing their genes from spreading into wild populations. At the same time, the terms of the precautionary principle under international law should be made more specific in order for it not to become either an empty buzz word or an inappropriate trade barrier.

The Council points out that a reliable, purely scientifically oriented indicator in the context of assessing potential risks of genetic engineering is the insurance sector. In its publication 'Gentechnik und Haftpflichtversicherung' [Genetic engineering and third-party liability insurance] the Swiss company Schweizer Rück concedes that the risk profile of genetic engineering, both with regard to the uncertain legal basis and the scale of possible (long-term) damage, is 'extremely multi-faceted and largely escapes anticipation' (Epprecht, 1998). On the basis of this statement, it is clear that implementing the precautionary principle does not necessarily have to be through regulatory instruments, but could also be achieved through a liability regime with preventive elements (WBGU, 2000a). If the risk cannot be insured, whatever the level of the premiums, on the grounds of unpredictability of magnitude and occurrence of damage, then this might have a ban-like effect. If the risky activity is still desired then liability law can develop its control function by introducing liability limits.

Content of the Advance Informed Agreement procedure (AIA)

In the regulations foreseen for the protocol the 'advance informed agreement' instrument takes up a large amount of space. The country into which the LMOs are to be brought must receive information from the exporting country that allows it to come to an approval decision with full knowledge of the facts. The actual scope of applicability of this procedure with regard to freedom of trade is still disputed. And more specifically there is a dispute about whether the AIA procedure should apply without qualification to all LMOs, whether import without prior consent can be ruled out from the outset (no 'fiction of consent') and to what extent it is necessary to inform neighbouring states. It has also not yet been clarified whether prior risk analysis in the country of export has to be carried out at that country's expense (Gündling, 1998) or what period of time should be granted the country of import for a risk analysis. In the current draft of the protocol, agricultural commodities are exempt from the AIA procedure. The Council would like to point out that Art. 8(g) of the CBD calls on member states to control risks associated with LMOs at national level. The obligation on nation states arising from Art. 8(g) does, therefore, recommend application of the AIA procedure to agricultural commodities. Essentially, exempting agricultural commodities from the AIA procedure within the envisaged biosafety protocol would simply be failing to create a minimum standard at international level.

Another issue has become entangled in this discussion. In the view of countries exporting agricultural commodities, labelling of those commodities in the accompanying shipping papers should not be necessary since, as imported goods, they are not subject to AIA and thus labelling them would be misleading. However, it can be countered that labelling is not just sensible in the context of the AIA procedure, but also for risk management outside the AIA procedure.

D 3.2.2.3
Are there still chances of achieving a protocol?

Officially, the negotiations on the adoption of a biosafety protocol have been postponed by the decision of the 1st Extraordinary Meeting of the Conference of the Parties to the CBD. In fact, the negotiations have reached a dead end. The trench of disunity has since the last negotiations in February 1999 run less between the developing countries and industrialized countries and more between a few exporters of agricultural commodities and the other states. The former see the protocol as a trade agreement masked as an environmental agreement.

A resumption of the talks could, however, proceed more positively if the protocol's opponents could be made to understand that the losses they fear as a result of the protocol are much smaller than they are assuming. As indicated above, the current basis established by international law makes it conceivable that the importation of genetically modified products could be banned by national legislation without this infringing GATT. This statement is not to say that a protocol is not needed, but rather to highlight its true place: to create an optimized regulation taking into special account the features of LMOs and to establish the implementation of risk management at international level, as already called for in Art. 8(g) CBD.

D 3.2.2.4
Recommendations

The Council supports the stance adopted by Germany on the biosafety protocol that endorses inclusion of human health and the precautionary principle. The need for a protocol still exists and requires continued strong commitment from the advocating countries. The reasons for its failure lie with the interests of a few states in exporting their agricultural commodities. The Council has pointed out that there are already mechanisms in place for a country to protect itself in accordance with existing international trade agreements against damaging impacts of genetic engineering in agriculture and food, and advises that this be made clear to the opponents of the protocol at the forthcoming negotiations and that the positive effect of an internationally agreed regime be underscored. Furthermore, despite the exclusion of the liability issue from the draft protocol, account should be taken of the control function of a liability regime; and the latter should still be sought.

Insufficient scientific findings with regard to the risk potential in the area of 'green genetic engineering' is one reason for the failure to achieve consensus in comparison to other protective regimes (Basel Convention of 1989, PIC Convention of 1998, negotiations on a POPs Convention (persistent organic pollutants)). In this field there is a need for intensive research. Since 'green genetic engineering' is a technology with major economic expectations there must be a particular guarantee that the research is independent of special interests.

D 3.3
Bioprospecting

D 3.3.1
Introduction

Numerous government institutions and private companies are collecting, recording and analysing genetic resources. Exploration of biological material for the purpose of preparing it for potential industrial use is termed 'prospecting biological diversity' (WBGU, 1996; referred to just as 'bioprospecting' here). Because of the greater degree of success, this method is pursued predominantly in countries with higher biological diversity (Balick et al, 1996).

In this section only a few examples for the use of natural substances can be picked out from this extensive field. The closely related field of bionics with the development of technological innovations on the model of nature will then just be touched on. These examples are intended to illustrate both the opportunities for a forward-looking sustainable use of biological diversity and also the possible risks of impairing that diversity (eg through overuse).

Alongside conventional synthetic chemistry, particularly in Germany, there has always been highly developed natural substance chemistry. With the development of natural substance products based on fermentation in the 1940s and the increasingly improved techniques in synthetic organic chemistry, interest in the discovery of new natural products as prototypes for pharmaceutical and agrochemical products had for a time dropped in the 1960s and 1970s. Through modern chemical, molecular-biological and physical procedures, natural substance chemistry has experienced something of a renaissance in recent times that, ultimately, has led to the current interest in bioprospecting. Successful medical products on the basis of new active substances are one impressive example of this development. In particular, the important potential of the higher plants, but increasingly also the microorganisms, provide prototypes for new pharmaceuticals, agro-chemicals and other consumer goods (Feinsilver, 1996). The factors that have led to this renaissance in the research and product development of natural substances include, in particular, improved molecular biology testing systems to record biological functions (bioassays). Furthermore, progress in chemical separation methods for the production of pure substances and in the structural understanding of molecules, in conjunction with the worldwide increase in competition, have promoted the upsurge of natural substance chemistry. A changed perception and valuation of nature and biological diversity for the well-being of humans is also an important driving force. Consequently, interest is growing in natural medicine practices from all parts of the world.

The hunt for new, natural active substances takes various forms. In the case of plants, it is best to travel to the regions with high biological diversity and carry out ethno-botanical experiments with the help of the knowledge of indigenous communities in order to increase the 'hit rate' for the discovery of new lead substances (Teuscher, 1997). Some of the large pharmaceutical companies such as Pfizer, the International Plant Medicine Corporation (California), Merck & Co., Sharp and Dome, Shaman Pharmaceuticals (USA), etc are pursuing that route and are looking for new agents in 'mega-diversity countries' such as Ecuador, Costa Rica, Mexico, Colombia, Peru and Brazil. An early example of this kind of bioprospecting is the story of Syntex that was set up in Mexico in 1994. It already indicates the political dimension of international bioprospecting (Box D 3.3-1).

D 3.3.2
Ecological basis for bioprospecting

Biological diversity encompasses the diversity of genes, species and ecosystems (Box B-1). It can also be manifest as biochemical diversity (Harborne, 1995). This realization has definitely sharpened the awareness of ecologists for highly effective chemical substances, such as signal substances, which have an important role in the complex interaction between animals and plants. So, for example, there is an enormous number of what are called secondary metabolites that are developed by living organisms in response to a changing environment and in defence against their enemies. They can be classified as follows:

- Chemical substances that provide protection against extremes of cold or heat, flooding or drought.
- Biochemical adjustment to soil characteristics (heavy metals, salt content).
- Adjustment to pollution by noxious substances: eg detoxification of sulphur dioxide, phenols or fungicides and herbicides.
- Defence mechanisms against being eaten through substances that are toxic to predators.
- Signal and messenger substances that communicate information between organisms (eg pheromones, kairomones).

These secondary metabolites, that have through evolution become optimized for their specific biochemical functions, can be of great benefit to humankind. Research into the functional relations of organisms would therefore seem to provide greater opportunities for the discovery of new pharmaceutically successful natural products than would a random screening for agents. We have the application of new molecular investigation techniques to thank for the development of this new field that can identify more and more successfully organic molecules in minute amounts. Particularly in medicine, a number of highly effective toxins that play a significant role are generally the products of biochemical evolution of defence mechanisms. And the evolution of biochemical products by the feeding organisms, or organisms interacting in another way, is also interesting for bioprospectors. The number of plant secondary metabolites that are produced, sometimes in overlap, by fungi, animals and microorganisms is estimated to be approx

Box D 3.3-1

Syntex – a historical example of bioprospecting with global impact

Bioprospecting did not begin just with the advent of the realisation that biological diversity was being lost on a global scale. Older examples allow a retrospective analysis that includes the role of the multinational pharmaceutical industry, national decision strategies and intellectual property rights (Gereffi, 1983).

Up to 1940 steroid hormones for medical requirements in the form of hormone replacement therapies could only be gained from animal sources. When looking for alternatives, the American chemist Russell Marker discovered the yam (*Dioscorea mexicana*) as a source for steroids. As he was not able to interest US industry, he moved to Mexico and there began to produce diosgenin, an intermediary product in the synthesis metabolism of many steroids, from *D. mexicana*. Diosgenin was easily transformed into progesterone, a female sexual hormone. Marker developed business relations with locals and founded the Syntex company in 1944.

Syntex conducted a large amount of the original research in steroid chemistry itself with the result that it was for a decade the leading producer of steroids. With the synthesis of norethindrone, a modified progesterone, Syntex laid the foundation for the first oral contraceptive (Djerassi, 1990). Searle, a Chicago-based company, brought the first contraceptive pill onto the market in 1960, Enovid®. Searle, Upjohn, Merck & Co. and Schering did more pioneering work and in the subsequent years a number of highly effective steroids were developed for a variety of diseases. Today, Merck & Co. holds a large majority of the 30 patents that have been issued. The Syntex example illustrates the following features that characterize modern bioprospecting and successful cooperation.

- The success of Syntex was probably originally based on an ethno-botanical principle. The locals in Mexico used a different species of dioscorea to poison fish. This was achieved as a result of its diosgenin content.
- It was a multinational company that made used of the knowledge of the indigenous population and directed the capital flows that resulted from the development of the natural substance back into the country of origin of the natural resources.
- Syntex could stand firm in the face of the quickly developing competition for a long period on the basis of its access to the first plant source for steroids.
- A fundamental criterion for success was the direct and early participation of the Mexican government, which backed the company's development in the critical phases. The direct contact between the company and the local farming communities lent itself to successful planting practices for the plants producing diosgenin.

500,000, of which perhaps 100,000 are currently known (Teuscher, 1997). An impressive example of the diversity in secondary substances in the animal kingdom is the conotoxins of the cone shell (Olivera et al, 1991). Each of the some 500 species of cone shells has a set specific to its species comprising between 50 and 200 individual toxins that can attack different parts of the nervous system and thus are very promising in the context of developing therapies for neurological disease.

The large number of potential species in comparison with the number of species already identified is particularly important for bioprospectors hunting for new secondary metabolites (Table D 1.2-1).

D 3.3.3
The use of biological diversity – the example of medicine

D 3.3.3.1
Natural substances in the development of medicines

The new interest the pharmaceuticals industry is showing in natural substances has grown out of the realization that less than 1 per cent of known natural substance compounds are currently being used as medicines. And yet the proportion of natural substances in all medicines brought onto the market between 1992 and 1996 was 34 per cent. 44 per cent of new natural substance preparations come from the USA; Japan supplies 27 per cent and 29 per cent come from other regions (Müller, 1998). Between 1989 and 1995 more natural substances began the lengthy road of pre-clinical and clinical trials in cancer therapy than genetically engineered products, and 62 per cent of the approved cancer drugs stem from natural substances (SAG, 1997). Natural substance chemistry and synthetic chemistry complement one another perfectly, since alongside the original natural products, substances can be manufactured in a semi-synthetic way from natural substances, for example by derivatization. In other cases they can be synthesized completely on the model of the natural product. Of the 520 drugs that were developed between 1983 and 1994, 5.3 per cent are derived from mammal materials (eg antibodies), 5.8 per cent are natural products, 24.4 per cent are modified (semi-synthetic) natural products, 8.8 per cent are derived from synthesis on the model of a natural product and 55.6 per cent were purely synthetically developed substances (Cragg et al, 1997).

In synthetic chemistry 10,000–100,000 synthesis products have to be analysed in order to find one single new chemical lead structure. The development of such a medication costs around US$150–400 million. This amount has to be recouped over a patented life of 15 years at most. As a result of the many negative 'screening' results it is therefore not surprising that currently there is hardly more than one fundamentally new lead structure being developed each year by synthetic chemistry. It is interesting that only half of the natural substances have overlapping structural relationships with the synthetic products (Müller, 1998) and therefore natural substances are a large source of potentially new prototypes. On the other hand we should not overlook the fact that identifying a lead structure in a natural product is generally only the start of an even more intensive phase of work to optimize that lead structure. For example, elucidating the structure of the Calicheamycins (*Micromonospora echinospora* ssp. *calichensis*), a cancer therapy currently in clinical trials, opens up a whole new field for synthetic chemistry in structural modification to optimize functions.

New prototypes from natural substances are above all urgently needed in fighting infections and in cancer treatment and diagnosis (WBGU, 1998a). It is therefore no surprise that for example in the German Federal Ministry for Education and Research (BMBF) support focus 'Technology to decode and use biological blueprints' 24 of the 44 industrial companies receiving support are pharmaceutical or biochemical companies. The modern biological and molecular-biological technologies are an important basis for natural substance detection programmes, including testing systems (bioassays) with which the biological activity that is sought can be proven. So, for example, cell culture or cell receptor function tests can search for growth blockers for cancer cells or for blockers for inflammation mediators in the immune system. They serve to ascertain information on the general toxicity of the substances under study, their mechanism, breakdown rates, etc. In the isolation of natural products through this type of bioassay (Fig. D 3.3-1) tests for activity take place after each preparation step of the raw material. Only those fractions in which the desired activity is found are processed further. Through chemo-analytical processes the active pure substance is then isolated and the structure identified through physical and molecular detection procedures.

The use of bioassays to detect natural substances allows even concentrations of substances in a few nanograms to be detected (10^{-9}g l^{-1}). This makes them ideal instruments since natural products are usually found in tiny amounts in the raw material. Substances that are present in 0.001 per cent of the dry weight of a plant can be detected. Around 50mg of the pure substance is sufficient to elucidate its struc-

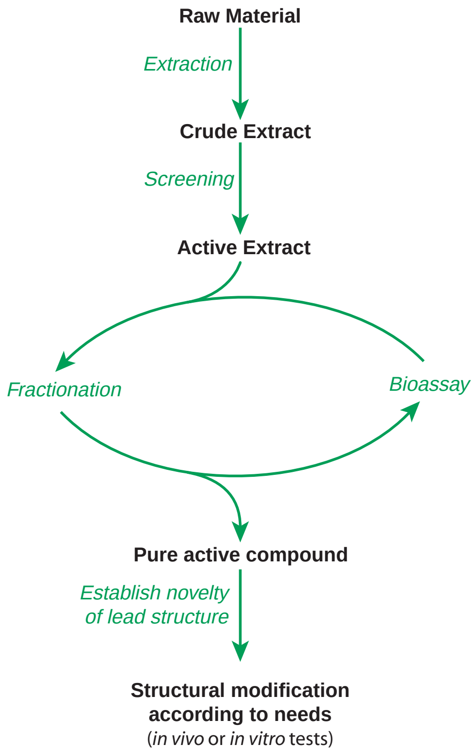


Figure D 3.3-1
Strategy for the bioassay-led isolation of natural products. Source: modified on the basis of Cragg and Boyd, 1996

ture; up to the first test in a mammal organism, approx 500mg is required (McChesney, 1996). This development phase for a medicine takes around 1.5 years and the average time for complete development is ten years. The direct clinical costs (without the cost of screening agents in 10,000–100,000 substances) are around US$24 million (Fig. D 3.3-2; Table D 3.3-1), the costs of the overall development of a medicine are ten times higher (McChesney, 1996).

D 3.3.3.2
Plants

China and Central Europe have the oldest tradition of using plants for medicinal purposes. The first European record of the characteristics and use of medicinal plants dates back to the 1st century BC in Greece (Grünwald, 1998). Today in industrialized countries around 500 of the approx 300,000 plant species estimated to exist worldwide are used as the base material for the production of medicines (Grünwald, 1998). Examples are the alkaloids (eg pain killers, numbing, cytostatic, anti-pyretic) and the large group of steroids (eg cardio-active, hormonally active, reduce serum fats). Around 40 per cent of all medications approved for use in Germany are derived from plant material.

The term phytotherapy refers to medicines that are exclusively plant-based, and either comprise the entire plant or its extract. Europe has the highest proportion of the international phytomedicine market with a sales volume of US$6 thousand million, compared with US$2.1 thousand million in Japan and US$1.5 thousand million in North America. Germany leads the market with annual sales of US$2.5 thousand million, thus accounting for approx 41 per cent of the European Union market. This corresponds to the highest per capita expenditure in Europe (Grünwald, 1998). One of the reasons for the large phytotherapeutic market is certainly the increase in chronic illnesses as a result of higher life expectancy and dissatisfaction with conventional therapies. An emotionally grounded rejection of 'purely chemical' medicines and demand for 'natural biological' alternatives may be added to that.

Phytotherapy accounts for 30 per cent of all non-prescription drugs in Germany and it is only in Germany that insurers are prepared to cover a considerable part of the costs (US$1.1 million per year; Grünwald, 1998). Within the EU the aim is harmonization of laws; this will have considerable consequences for the phytotherapy market. In the same way as for other medications, plant-based preparations will in future only be approved once their safety, effectiveness and quality have been proven (Grünwald, 1998). The European Scientific Cooperative for Phytotherapy (ESCOP) is developing an evaluation basis for the approval of plant products in Europe. Multinational firms are showing interest in this quickly developing market segment (eg Ciba and Bayer are selling products from the Swiss phytomedical company Zeller AG; Boehringer Mannheim is selling Bionorica products).

Until today, around half of the required amount of medicinal plants are said to occur in the wild (Teuscher, 1997). Extracting sufficient amounts of natural plant substance is often a limiting factor, both for the manufacture of phytomedical products and also for the extraction of pure substances. In order to gain 50mg of plant material for structural elucidation, one requires 20–50kg of fresh plant material. For the phase of preliminary toxicity determination and other bioassays, another 400–500mg of the pure substance is required. Another 2kg are required in order to submit the medication for pre-clinical evaluation that is followed up by clinical trials. For a medicine taken once only, in a dose of 2g by around 10,000 people, 20kg of pure substance must be manufactured. This can mean a required biomass of 20,000 tonnes. For medicines that have to be taken on a daily

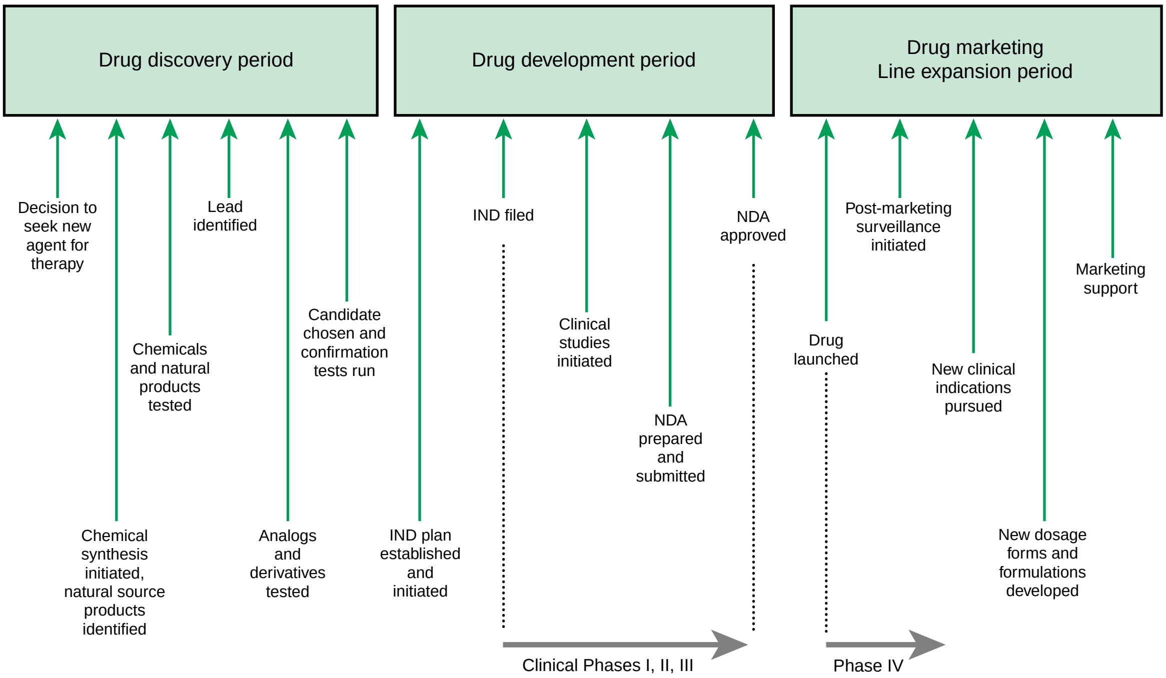


Figure D 3.3-2
Pipeline concept of drug development. Explanation in text and in Table D 3.3-1. IND = Investigational New Drug Application, NDA = New Drug Application
Source: modified on the basis of McChesney, 1996

Table D 3.3-1
Periods of time typically required for the development of new drugs. The figures relate to the development stages outlined in Fig. D 3.3-2.
Source: McChesney, 1996

Stages of development	Time frame [years]	Average period [years]	Direct clinical costs [1,000 US-$]
1. Project design up to IND development	0.5–2.5	1.5	400
2. Clinical Phase I	0.5–1.5	1.0	2,600
3. Clinical Phase II	1.0–5.0	2.5	11,400
4. Clinical Phase III	1.0–5.0	2.5	7,400
FDA testing of the NDA	1.0–5.0	2.5	2,200
Total development	4.0–19.0	10.0	24,000

basis, these amounts are 10–100 times higher. Collecting wild plants is often not justifiable ecologically, quite apart from the fact that there are often considerable fluctuations of substance content within a wild population (McChesney, 1996). One alternative is to produce medications by cultivating wild plants. Worldwide so far around 3,000 wild plant species have become established as cultivated plants and time periods of up to five years for herbaceous plants and over ten years for woody plants have to be calculated for transformation into a cultivated plant. A very effective example of the domestication of a wild plant on a large scale is *Erythroxylum coca*, that in 1990 produced at least 1,000 tonnes of cocaine (McChesney, 1996). Alternatively, in the context of a bioprospecting programme, existing cultivated plants can be found that can synthesize the desired substance or one of its pre-phases in sufficient quantity to cover the need in crop plantations.

So far only 5–15 per cent of the higher plants have been investigated for possible bioactive substances (Balandrin et al, 1993). The broad scale screening of plants is juxtaposed with ethno-botany that makes targeted use of traditional natural medicinal knowledge (eg that of the shamans). Some firms in collaboration with indigenous experts are trying to extract new substances from the medicinal herbs of the Third World. Already around 10 per cent of all pharmaceuticals in Western medicine are based on medicinal plants from the Third World. Whereas 10,000–

100,000 synthetic substances have to be tested to bring a new medicine onto the market, the same number of randomly collected plants is sufficient to develop on average five new medicines. The success rate of ethno-botany is probably even higher, for here the effect of traditional medicinal plants is already proven (SAG, 1997).

In contrast to the long development story of Aspirin® (Box D 3.3-2) the development of Taxol® represents the modern bioprospecting approach (Box D 3.3-3). In the case of Taxol® a horizontal genetic exchange, probably with a fungus in the bark of the yew tree, means that in future Taxol® does not have to be produced from yew plantations but can be produced from cultures of this fungus. By identifying the gene for the substance of interest, eg through modern molecular diagnosis (eg differential display) and highly effective sequencing techniques, even more prospects open up. As will be explained with examples in Section D 3.3.4, the desired gene can be transferred ('transfected') into a cultivated plant, but also in an easily cultivatable microorganism. With this type of measure, economic viability can often be enhanced.

D 3.3.3.3
Terrestrial microorganisms

Terrestrial bacteria and fungi are predestined as producers of secondary metabolites as generally they live in symbiotic or parasitic relationships. As illustrated by the example of Taxol®, increasingly microorganisms are being identified as the real source of substances which originally were wrongly ascribed to a parasitized plant (or animal) or one living in symbiosis. The poisonous ergot of rye alkaloids that are produced by sac fungi living on cereals (Ascomycetes of the *Claviceps* genus) are a classic example. Accordingly, the interest in bioprospecting microorganisms is growing, particularly since so far only a fraction of these have been identified and analysed (Table D 1.2-1).

Consequently, some 50 per cent of individual projects supported under the BMBF's support focus 'Biotechnology 2000' address the use of microorganisms and their products. A large number of highly effective antibiotic, cytostatic (cell-growth inhibitors) or immune-suppressant substances from various microorganisms have been used for years. Over 20 different antibiotics are produced from *Streptomyces* species alone. This family also produces a larger number of cancer blocking cytostatica and

Box D 3.3-2

Aspirin® – a one-hundred year history

Back around 400 BC Hippocrates was prescribing an infusion from the bark of the white willow (*Salix alba*) against inflammation of the joints. The proponents of the signature theory in the Middle Ages used white willow tea to treat stiff joints and rheumatic pain because the willow had supple branches. The natural painkiller was forgotten for a while until in 1763, a Mr Stone from England described the anti-pyretic effects of willow bark. This finding was used in 1806 at the time of the Continental Blockade in Germany as an urgently needed substitute for China bark (*Chinchona*) that could no longer be imported. The following steps led to the manufacture of pure acetylsalicylic acid, the active substance in willow bark:

- in 1828 J A Buchner isolated a yellowish mass from willow bark, that he named Salicin.
- in 1829 the French apothecary Leroux isolated Salicin in crystallized form.
- in 1838 R Piria manufactured salicylic acid from Salicin. At around the same time the Swiss apothecary Pagenstecher distilled salicylaldehyde from the flowers of the herbaceous meadow-sweet (*Filipendula ulmaria*; syn. *Spiraea ulmaria*); oxidation to salicylic acid followed.
- in 1853 the chemist C F Gerhardt managed for the first time to synthesize an impure, but also non durable, acetylsalicylic acid.
- in 1874, after H Kolbe had elucidated the chemical structure of salicylic acid, industrial production began.
- in 1876 Ries and Stricker proved that the synthetic salicylic acid was suited to treating rheumatic fever and it cost ten times less than the natural substance.

The chemical factory of Friedrich von Heyden (Radebeul-Dresden) and the Elberfeld paint factory, previously Friedrich Bayer & Co., tried to develop a variety that would be tolerable to the stomach. In August 1897 the chemist Dr Felix Hoffmann (Friedrich Bayer & Compagnon) reported for the first time a chemically pure and durable acetylsalicylic acid (ASA) extracted by acetylisation. The preparation was registered under the name Aspirin® and patented in 1899. The First World War, with its immense need for pain and fever medication, the renewed and now total import blockade on quinine and finally the great fever pandemic of 1918/19 all promoted the success of Aspirin®. The British pharmacologist John R Vane received the Nobel prize for medicine in 1982 for elucidating the active mechanism of ASA. Currently, new forms of ASA with longer effect and reduced side effects are being developed, such as Celebrex® and Vioxx®; they were approved for the US market in 1999. ASA is constantly being ascribed new indications, eg lowering the risk of heart attack or reducing the risk for certain types of cancer. Bayer AG took a long time to correctly place Aspirin® in the market which for a long time now has not been under patent protection. Today in Bitterfeld 785 tonnes of acetylsalicylic acid is processed annually to produce Aspirin® tablets (1.8 million per hour) – that is a third of total world Aspirin® production with annual sales of US$425 million. Aspirin® is the most frequently sold drug on all continents.

Box D 3.3-3

The Taxol® Story – an example of modern bioprospecting

In 1958 the United States National Cancer Institute (NCI) launched a programme to study 35,000 plants in the search for activity against tumours. As part of the programme the US forestry authority collected material from the Pacific Yew (*Taxus brevifolia*) in 1963. Anti-tumour activities were found in the extract and identified as the active substance paclitaxel (Wani et al, 1971). The way paclitaxel works is to inhibit cell division by disrupting the organization of cell skeleton structures; this was identified by Schiff et al in 1979. In 1983 the NCI began Phase I and in 1985 Phase II testing. In 1989 successes in the treatment of ovarian cancer were reported (McGuire et al, 1989; Thigpen et al, 1989). As a result of budget cuts, NCI started looking for a partner to move into commercial development. Of the 20 companies originally interested, four applied for partnership. In 1990 NCI began Phase III and in 1991 NCI selected Bristol-Myers Squibb (BMS) as its commercial partner for the development of paclitaxel (Taxol®). BMS made Taxol® its main research area and in 1992 it was approved as a treatment for metastatic ovarian carcinoma. BMS stopped harvesting natural stocks of the Pacific Yew, which had raised ecological concerns, and began developing renewable sources for the substance. In 1995 a semi-synthetic Taxol® was produced and in 1997 the semi-synthetic Taxol® was approved for the treatment of AIDS-related Kaposi's sarcoma, non-small celled lung carcinoma and ovarian carcinoma.

Paclitaxel is a natural substance with a complex chemical structure that is found in the inner bark of the Pacific Yew in a proportion of just 0.01–0.03 per cent. Even though it is now possible to synthesize the substance in an elaborate process from a precursor (baccatin) that occurs in the English Yew (*Taxus baccata*) this cancer treatment is still scarce and too expensive for widescale application at treatment costs of around US$13,000 per patient. One possible solution is production by microorganisms. Stierlie et al (1993, 1995) discovered a fungus that lives in the yew bark (*Taxomyces andreanae*) and synthesizes paclitaxel. The amounts that can be produced using the fungus are still small (24–50 ng l^{-1} per culture solution). It may be expected that this mode of exploitation can be improved considerably through culture procedures and genetically engineered modifications in the fungus. But the search for efficient microorganisms seems to have been successful recently in Nepal. *Pestalotiopsis microspora* isolated from *Taxus wallachiana* produces commercially interesting quantities of paclitaxel (Strobel et al, 1996).

individual immune suppressants. The discovery of immune suppressant substances such as Cyclosporin (product of the fungi *Tolypocladum inflatum* and *Cylindrocarpum lucidum*) or Tacrolimus (*Streptomyces tsukubaensis*) have revolutionized organ transplant procedures. More recent antibiotics such as *Streptomyces orientalis* are currently the only remaining weapon against certain multi-resistant strains of *Staphylococcus aureus*, a pyogenic bacterium.

Fungal infections (mycoses) have become more and more significant in medicine in the last two decades. As a result of aggressive therapies that strongly suppress the immune system (eg chemotherapy and organ transplants) or as a result of HIV infection, skin and mucus infections from moulds and dermatophytes often spread to the patient's internal organs. The story of the development of antimycotic medicines is a typical example for the parallel development of natural substances and synthetic products. At the end of the 1950s, the foundation for the development of a chemical synthesis of fungistatica was laid. The new substances being used today on humans came out of chemical research seeking fungicides for vegetables and cereal plants. The first synthesized substance was chlormidazol by the Grünenthal company (1958), but it did not bring any great economic success. The Janssen company recognized the antimycotic effect of etomidat and the herbicide R10100 and modified the herbicide chemically to form imidazols. Over a 30-year development of imidazol derivatives the modern highly effective fungistatica have emerged.

The increasing resistance of yeast fungi (that fortunately develops less fast than in bacteria) makes it necessary to develop new antimycotica. Currently, industry is concentrating in its intensive search for antimycotica on derivatives of naturally occurring anti-microbial substances produced by microorganisms; thus here molecular biological, chemical and pragmatic biological research strategies are balancing one another in fungistatica research (Clark, 1992; Odds, 1995). The production of fungistatica, eg in the form of phytoalexins formed by leguminous plants, is one of the bases for plants' resistance to disease. The ability of a fungus to parasite a particular plant depends first of all on the genetically fixed speed of phytoalexin production in the plant. Secondly, some fungi are able to detoxify the phytoalexins produced by the plant. A detailed knowledge of these varied and complex processes should open up good prospects for the industrial development of natural fungistatica for use in crops (Harborne, 1995).

D 3.3.3.4
Marine microorganisms

In terrestrial natural substance chemistry it is already clear that with the increasing number of investigations the hit rate for truly new chemical lead structures is falling. Pfizer, for example, when sifting through 20,000 bacterial strains up to 1980, found just two potentially marketable substances, of which ultimately only one went into development. The hit rate can be increased through automated 'mass screening' with the help of the bioassays mentioned above. A more targeted approach is to investigate rare organisms, ie life forms from ecological niches or habitats not hitherto well examined.

The sea is just such a habitat. Of 79 classes of animal, 72 are represented in the sea and over half are endemic to the sea. In the opinion of influential scientists, in Germany the chemistry of low-molecular marine active substances has for a long time not been accorded the attention it deserves. The hesitant development of marine research activities at German universities in the past cannot be explained by any lack of importance of marine substances, for in the past 25 years substances have been isolated from marine organisms that are incomparable in their complexity: in the 1970s the halogen compounds from red algae, for example, and then the complicated and medically interesting diterpenes from brown algae. In the 1980s interest turned to pharmacologically active compounds from the invertebrates, in particular sponges and tunicates. For example, Didemnin B derived from tunicates for the treatment of brain tumours and tumours of the lymph glands has already been applied in Phase II studies. Dehydrodidemnin B, another product from tunicates, is considered a potential therapy for tumours in the large intestine and elsewhere (Jacob, 1995). Bryostatin 1 from *Bulgula neritans*, a marine bryozoan, blocks the growth of tumour-feeding blood vessels. Cancer researchers are currently ascribing a great development potential to substances of this type.

Sponges and tunicates still pose a breeding problem, however, and the collection of larger numbers is not justifiable in ecological terms. In this situation the increasing realization that a number of interesting metabolites are not formed by the tunicates or sponges themselves but rather by the microorganisms that live in symbiosis with them is proving favourable. A well known example is Tetrodotoxin (TTX), a depolarizing muscle relaxant. It is formed by the *Alteromonas* species, the symbionts of the puffer fish and the blue-ringed octopus.

It is as a result of the elaborate and cumbersome extraction and preparation procedures that so far only 7,000 marine metabolites are known, compared with the 110,000 terrestrial metabolites. Metabolite harvesting from marine microorganisms is dogged, as with sponges and tunicates, with problems of isolation and cultivation. There is therefore a great need for research in the area of cultivation and breeding methods. We can expect corresponding improvements to lead to a considerable expansion of fields of application in the private sector. Of 10^6 bacteria per ml sea water, under normal cultivation conditions generally only 100 colonies mature. Since modern molecular-biological and analytical methods already make it possible to make characterizations from very small amounts of the substance, the chances of identifying new marine natural substances are currently rising constantly. The first microbial ingredients were isolated from marine open water bacteria. These are boric compounds that have an antibiotic effect and also demonstrate good effects in the organism against malarial agents. Aplasmomycin was for many years the one and only natural substance containing boron. It has since been joined by others (Sato et al, 1978). Iodine compounds are also typical products of marine microorganisms and thus candidates for the discovery of marine active substances.

D 3.3.4
Other areas of use

Natural substances are required in various branches of industry, with plant products and to a lesser degree microbial components taking up the dominant position. We shall mention here just a few, important areas such as industrial use of plant oils for demand for special fatty acids, proteins, carbohydrates such as starches (eg to produce polymers) and sugars as the basic ingredients for industrial fermentation or production of new artificial substances. Some of the most important bio-molecules in economic terms are enzymes that catalyse a number of cellular reactions and are used industrially to trigger chemical reactions, thus saving energy. The cosmetic industry and the food industry, with its need for food additives such as pigments or flavourings, are also significant buyers of natural substances and also function as prospectors for the development of new forms of use. In the German chemical industry currently about 20 million tonnes of carbonaceous raw materials are used, including 51 per cent fats and oils, 43 per cent carbohydrates (starches and sugars) and 6 per cent proteins and protein hydrolyzates (Behler et al, 1997). In all of these areas, there are attempts to manipulate production options using biotechnological methods, eg by using the genes of non-indigenous plants in industrial plants to modify their products. Extraction of high-quality basic materials for oleic chemistry by maximizing individual fatty acids in the producing cultivars is an important example.

In addition to the direct use of natural substances or their prospected genes, there is increasing interest in the development of technical innovations on the model of biotic nature. This field is called bionics and takes a systematic approach to the technical realiza-

Box D 3.3-4

Bionics

Bionics is the strategy of developing technical innovations on the model of biotic nature. It focuses systematically on the technical implementation, further development and application of the strucures, procedures and developmental principles of biological systems (Plän, 1999). Even if it is rare for a biological solution to be adopted directly, the latter can give crucial impetus to the development of new solutions (Nachtigall, 1998)

CONSTRUCTION BIONICS

This sub-field focuses on analysis and comparison of constructional elements and mechanisms from biology and engineering. There are often astonishing commonalities, one instance is pump construction (salivary pumps in insects, vertebrates' hearts). In natural structures individual elements often assume several functions: this principle of integrational construction can be used as a model. In materials bionics unconventional biological structural elements are examined for their suitability for technical application (eg pneumatic structures, surface-spanning membranes, natural morphological processes). Some examples of models in material bionics research are:

- *Spider's thread*: material for bullet proof vests and better parachutes.
- *Byssus threads from mussels*: model for a protein-based three-component underwater adhesive.
- *Ventral scales of the American snake Leimadorphys*: model for the development and patenting of a technical coating for cross-country skies.
- *Shark scales*: model for Riblet films that reduce the frictional resistance of air in aeroplanes by 2–4 per cent.
- *Self-cleaning surfaces*: model of plant leaves (Barthlott and Neinhuis, 1997).

The great progress made in understanding the molecular basis of biological phenomena has opened up whole new areas for materials research. Biomolecular material synthesis comprises the synthesis of biomolecules, the production of new biopolymers – such as proteins with particular physical or chemical characteristics – or the manufacture of functional or structural materials by biomineralisation, fibre formation or coating. Equipment bionics develops technical equipment on the model of nature. Particularly in the area of pumps and conveyance engineering, hydraulics and pneumatics, many ideas are being generated.

PROCESS BIONICS

Processes by which nature controls sequences or cycles are investigated for their potential technical use. A prominent example is photosynthesis with its possible importance for future hydrogen technology. Examples of effective ecological materials turnover and natural methods of recycling are being investigated for their application to the cybernetic influencing of complex industrial and economic processes. From the study of biological light-gauge construction (shells and cases, spiders' webs) structural bionics gains ideas for engineering lightweight buildings. At the biomolecular level biological energy transformation is increasingly forming the focus of development efforts (energy bionics). For example, certain enzymes involved in cellular energy metabolism (various hydrogenates) are already being considered for biological hydrogen extraction. The development of bio-electro-chemical fuel cells very much speeded up the use of artificial electron acceptors for electron exchange between biological systems and an electrode surface. Interactions between moving organs and the surrounding medium, which are interesting in terms of fluid mechanics, are found in small and medium Reynolds Numbers (microorganisms, insects) and in very high Reynolds Numbers (whales) that for instance can be of interest for kinetic resistance in water (movement bionics). Biological solutions too, in functional morphological form, can produce ideas: such as the surface structure of birds' wings that because of the inherent roughness of the plumage in certain areas produce positive boundary layer effects. Nature's sensors (eg for navigation, orientation or measurement) that make use of all conceivable chemical and physical stimuli are increasingly being examined for possible technical applicability (eg biosensors). For microactorics also, biological models are being considered. This trend will increase at an amazing rate with the current transition to micro and nano engineering. One example of this is the 'flagellum motor' made up of just a few proteins in certain bacteria. Biopolymers that are photo-optically active (eg bacteriorhodopsin) are currently being developed further for storage and processing of optical information.

INFORMATIONAL BIONICS

The development of parallel computers and 'neuronal circuits' received crucial stimulus from neurobiology and biocybernetics. In the next few years we can expect increasing cooperation to the benefit of both disciplines. Evolutionary engineering is trying to make use of the processes of natural evolution in technology. In particular, in the case of highly complex systems, experimental development by means of evolutionary bionics (trial and error) is an interesting alternative. The modern biosciences could also offer new options for overcoming foreseeable performance limits in information technology. Biomolecular construction and functional principles in nature are combined with the building blocks and technology of microelectronics, which has led to the development of new components. Examples of this are DNA chips for genome analysis, peptide chips for proteome analysis, neurochips or neuro-silicon components

The great number of examples of natural principles that engineers find interesting clearly shows what value biological diversity also has in the context of our modern technological developments. This value is generally underestimated, however, or not even considered since it is difficult to express in monetary terms. The development of economic methods for capturing this value is therefore an important research task (Section J 3.2-3) in order to be better able to 'attach a value' to biological diversity and promote its preservation.

tion and application of the construction, process and development principles of biological systems (Box D 3.3-4). Bionic principles that can be used directly or in modified form promise solutions to technological problems at the molecular level.

D 3.3.5
Future development of natural substance chemistry and the use of biological diversity

The high number of substances that are screened with the aim of identifying substances for medicinal or industrial use leads very quickly to a situation where a large number of potentially interesting substances are awaiting structural elucidation. In recent times this collection of potential substances has increasingly been joined by substances from syntheses of combinatorial chemistry. These are chemical preparations that are generated around a nuclear structure in a controlled random process. The strengths of this technology lie above all in the optimization of known lead structures and a clear status under patent law. The libraries emerging in synthetic chemistry are being supplemented by natural substance extracts that generally demonstrate a high level of diversity in secondary metabolites and are suited to the search for new lead structures.

Attention is directed more and more to untapped natural substance sources such as the tropical rainforests, hot springs, deep sea and other extreme areas. Addressing symbionts and associated living communities is often seen as a priority and is considered a fascinating, but difficult, field that should wherever possible be dealt with in an interdisciplinary manner by chemists, microbiologists, biotechnologists and medical specialists (Section J 1.3). This cooperation should preferably be realized in university research establishments. The development and implementation of procedures for high performance screening of substances for inclusion in substance libraries on the other hand, given the strategies and costs involved, are increasingly taking place in the domain of industrial development and research. The aim of such screening programmes is – by searching for active substances – to identify chemical lead structures and ultimately find interesting genes. A lead structure and its chemical variations generally serve as the basis for chemical mass synthesis. The identified genes are transferred to organisms (eg cell cultures, bacteria, plants) and can be used to produce the substance or use the newly acquired metabolic services for other applications. The networking among research institutions and industry that is necessary to achieve such goals was one of the stated aims of the individual focal areas under the 'Biotechnology 2000' research programme implemented by the German research ministry (BMBF). This is true both for the project 'Molecular natural substances' and the project that is oriented strongly to industrial application: 'Technology to decode and use biological blueprints'. The Council expects that the current evaluation of the results of the past 5-year support period will be positive and recommends the work to be continued.

D 3.3.6
Legal framework and socio-economic aspects of bioprospecting

The potential for conflict between the developing countries providing the natural substances and companies operating globally that have an interest in these resources is considerable. Various international agreements address directly or indirectly the cooperation between countries of origin of biological diversity and the industrialized countries, or rather the players interested in using that diversity.

The Convention on Biological Diversity (CBD) sets the framework under international law for the sustainable use of genetic resources (WBGU, 1995b). The sovereignty of countries with regard to biological diversity as a natural resource is explicitly affirmed, but at the same time access to biological diversity should in principle be facilitated. In order to achieve both goals, the use of genetic resources is tied to general conditions (PIC – Prior Informed Consent [of the country of origin], MAT – Mutually Agreed Terms). The concrete form of the cooperation agreements is left up to the suppliers and the users of biological diversity. Since the CBD came into force a number of national and regional provisions have been developed in the countries of origin of genetic resources that reflect a generally high expectation in the new bioprospecting market and also link the research and use of biological diversity to complex administrative procedures. Against this background and on the basis of the fact that bioprospecting can contribute to the conservation of biological diversity and its sustainable use, the current negotiation of guidelines for access to genetic resources and compensatory measures under CBD are a welcome development. The aim is to agree on a basis that is accepted equally by the countries of origin and the user countries for the establishment of agreements for prospecting projects that also create incentives for investment in bioprospecting research and for comprehensive conservation programmes. It must be considered at this point that bioprospecting is a very dynamic field and the demands and requirements of the parties supplying and the parties using the natural substances, depending on the project, may vary greatly. In the envisaged general guidelines, sufficient scope should be reserved for the cooperating partners.

Costa Rica's National Institute for Biodiversity (INBio, founded in 1989) fulfils the criteria stated for a sustainable bioprospecting strategy probably best at the current time and is considered a successful project of a biodiversity-rich country active in the development of the market for biological diversity (WBGU, 1995b). INBio is a parastatal non-profit organization that researches the natural assets of the country, preserves them and promotes their sustainable use (Chapela, 1994). INBio operates cooperation projects with pharmaceutical companies from industrialized countries (Merck & Co., Sharp, Dohme; WBGU, 1995b). In so doing, it does not just forward samples of natural substances to interested parties; these are already classified by INBio and have gone through an initial screening for active substances. The information on the genetic resource and other material is codified in order to be able to respond to later demand. For the complex interaction of bioprospecting programmes, particularly between countries at different levels of technological development, the INBio programme may be seen as exemplary in many respects.

The work of INBio runs in close coordination with the authorities responsible for conservation in Costa Rica. INBio commits to investing a portion of its financial returns from research and development collaborations directly into conservation projects. Transparency and the direct coupling of shared benefits with national capacity building and biosphere conservation – in the form of technology transfer and financial participation – are important preconditions for the long-term success of bioprospecting and access arrangements.

Another project that is of relevance, particularly for Latin America, is the International Cooperative Biodiversity Group Programme (ICBG) that is integrated in a development programme backed by the US National Institute of Health (NIH) and addresses the conservation of biological diversity, sustainable development and human health. The ICBG focuses on prospecting medicinal plants, in particular by taking account of the traditional knowledge of indigenous and local communities.

Of the many projects initiated worldwide, some bioprospecting programmes should be mentioned that seek to investigate exclusively the biological resources of Yellowstone Park in North America. They are an example of bioprospecting taking place in developed countries and encountering to a certain extent similar problems to those faced by developing countries, such as the political aspects and in particular the legal regulation of the process. The story of *Thermus aquaticus*, a thermophile bacterium that was discovered in 1966 in one of the hot springs in Yellowstone Park, is prototypical. In 1980 *Th. aquaticus* hit the headlines when the US company Cetus developed a new molecular biological method for detecting genetic material, called polymerase chain reaction (PCR). The thermal stability of this bacterium and its enzyme (Taq-Polymerase) predestine it for use in polymerizing cycles of PCR that take place at higher temperatures. Currently, Hofmann La Roche holds the patent and earns several million dollars a year from PCR. The company expects income of approx US$1 thousand million in the year 2000.

Conclusions and prospects for the future

The debate surrounding the development prospects and ecological impacts of bioprospecting as a use of biological diversity has now become strongly polarized. Accordingly, the arguments of the interested players range from the divergent to the contradictory. Many countries of origin, for example, have generally high and in some respects justified expectations of the prospects of achieving development through bioprospecting. In order to bring some objectivity into the debate and promote a long-term reconciliation of interests that gives account to the development opportunities of both the demand and supply sides of biological diversity, differentiated market and industry studies need to be conducted and representative projects evaluated. This could contribute to clarifying the expectations upon and consequences of the alleged 'bioprospecting boom', and may provide an important basis for developing differentiated conservation strategies.

Bioprospecting does not just hold great potential for pharmaceuticals but actually for all branches of industry, whether it be agriculture, the chemical industry of for engineering applications. Aside from differentiation by field of application, there is also a need for separate consideration of the processes of production. It must be clearly differentiated as to whether the prospecting is directed towards biomass, bio-molecules and their genes or construction principles, since the economic impact of the different types of bioprospecting projects can be very different.

This necessary differentiation and the resulting implications make it clear that there is a substantial research deficit that is of relevance to policy. The literature refers at several points very generally to the new upturn in natural substance research. Whether this general prognosis is correct and in what industrial branches particular benefit is to be expected cannot be ascertained at this stage. At the same time, there is a need for basic research evaluating bioprospecting with regard to its ecological impacts, its future economic importance and its ability to assert itself vis-à-vis other forms of use (eg timber use in tropical regions). This is all the more urgent in light of competing uses and the separation of biotechnological procedures in natural substance research from the actual raw material of the biomass. More discussion of the considerable need for research can be found in Section J 1.3.

For responsible use of bioprospecting, the following points are of particular importance:

- Suitable provisions governing access to, and use of, biological resources and agreement of measures for sharing the benefits of bioprospecting can promote economic interests in both the countries of origin and the user countries. At the same time the profits flowing back into the countries of origin offer an opportunity to maintain biodiversity and its continued sustainable use in the countries of origin. In order to be able to use these opportunities the Council advocates integration into bioregional management strategies(Section E 3.9).
- Given the lengthy development periods, the high investment costs and the associated economic uncertainties of prospecting companies, the expectations of the countries of origin should be directed less towards short-term financial gain, and more to the development of technology transfer and the general strengthening of national capacities. Creating transparent, politically stable structures for investors – particularly young companies – is essential for the development of long-term successful cooperation projects.
- In the bioprospecting countries it could be helpful to promote institutions that draw up inventories of biological diversity for the purpose of bioprospecting and clear the way for cooperation with private users. In Germany, it would be appropriate to support a focus on 'bioprospecting' via the GTZ's sectoral programme.

Bioprospecting currently stands at the centre of a lively and polarized public debate. The important political implications of bioprospecting and the implementation of the CBD in that regard are considered more closely in Section I 3.2. At the forefront of debate are questions relating to the form benefit-sharing should take and a possible agreement on framework guidelines to supplement bilateral cooperation agreements.

D 3.4 Agrobiodiversity: functions and threats under global change

D 3.4.1 Agriculture and biological diversity – a contradiction in terms?

The success story of modern agriculture, witnessed in the enormous increase in yields, is based on four factors: (1) the dominance of a small number of species in the agricultural system; (2) the dominance of a small number of high performing genotypes within those species; (3) the creation of optimum conditions for the selected species and genotypes and (4) the ever broader spread of agricultural systems characterized by points (1) to (3).

The major yield increases in agriculture are based to a considerable extent on the fact that the biomass production of certain components has been increased at the cost of others. For example, in cereal breeding the relationship of grain to straw has shifted considerably in favour of grain. The system of cultivation is directed in such a way that a large part of the photosynthetic activity per square unit also benefits grain formation in wheat (by eliminating the competition for light, water and nutrients). Critics, however, maintain that often the system has not been more productive in terms of the calorific yield per unit area (eg Shiva, 1992).

These processes can also be described differently: by actively reducing the biological diversity on a given site (soil processing, sowing, destruction of weeds and pest control), one single component receives targeted support. Thus it is clear that agriculture on-site essentially conflicts with the concern to preserve biological diversity. On the other hand, 10,000 years of agriculture have also brought forth a diversity that would not otherwise have existed: what is called agrobiodiversity. This term is used to describe the diversity of all organisms in agro-ecosystems and the diversity of the systems themselves.

In the discussion of biological diversity one generally differentiates between three levels: genetic diversity (ie diversity within the species), species diversity and the diversity of ecosystems (Box B-1). In this section the functions of, threats to and conservation strategies for genetic and species diversity in agriculture will be discussed. Agrobiodiversity at the ecosystem and landscape level will be addressed in Section E 3.3.4 using the example of intensively managed agro-ecosystems.

Whereas agriculture almost always reduces the number of species per square unit when compared to an uncultivated reference unit (and thus contributes massively to the loss of species) it has on the other hand brought forth amazing genetic diversity (in some cases >100,000 varieties per species). A dilemma exists in the fact that 'modern' agriculture is in danger of destroying one of the foundations of its own success, the rich diversity of cultivated plants and domestic animals (Miller et al, 1995).

Although there are discussions with regard to the actual extent of this danger, the trend continues: agrobiodiversity is declining. We must, therefore, find answers to the following questions:

- What factors influence agrobiodiversity?
- To what extent is agrobiodiversity threatened?
- What functions does biodiversity perform in agricultural systems ?
- What measures must, if any, be adopted in order to preserve agrobiodiversity?
- Where is there a need for research and/or action?

A few more definitions are necessary at this point. By *agro-genetic resources* we refer to the portion of biological diversity that 'feeds humans and at the same time is cared for by humans' (FAO, 1996b). This definition is not just significant academically; it is also of political significance: agro-genetic resources are treated differently in the relevant international agreements than the other components of biodiversity (Convention on Biological Diversity, Section I 3.1; IUPGR of the FAO, Section I 3.3.2.2). From this understanding of agrogenetic resources, the FAO derives its prioritization of conservation measures. There are three options: in nature (*in situ*), in the field (*on farm*) and in seed or gene banks (*ex situ*).

Gollin and Smale (1999) understand agro-genetic resources to be 'latent biodiversity' and accord them therefore a reserve function, a reserve on which one can always fall back in times of need. It is therefore a complement to those components of diversity that are currently used in agriculture on the basis of their ecological or product characteristics (current agrobiodiversity). The discussion with regard to functions, value and threat to agrobiodiversity must take account of the variety of these approaches. In the following, we therefore distinguish between genetic resources (latent agrobiodiversity) and used (current) agrobiodiversity.

Spatial and temporal development of genetic diversity

Fig. D 3.4-1 illustrates the standard model of development for genetic diversity within a species at the beginning of its domestication (that represents the first 'bottleneck' when genetic diversity is drastically limited), through maximum genetic diversity (many locally adapted farmers' varieties and breeds) to minimization of genetic diversity in industrial agriculture. The current agrarian systems are located at different points along the development scale.

The development represented in the standard model dominates the discussion since Frankel (1970) and others drew attention to the fact that farmers' varieties and indigenous landraces were disappearing at an alarming rate. The basic lines in the debate on this development are:

- Does the process of the emergence and loss of genetic diversity really take place like that? The model was essentially derived from observations in Europe and the USA; in those places it describes the processes very precisely. Brush (1995) found, however, that in three case studies in centres of diversity (for maize, potatoes and wheat) the adoption of modern varieties and the application of mineral manures and pesticides did not go hand in hand with the loss of old native breeds. The traditional varieties will continue to be preserved because they have characteristics that are absent in the new varieties.
- Does the loss of current diversity in the field constitute a problem or not?
- Is the number of morphologically differentiable native varieties even the appropriate measure of diversity that should be used? Many argue that systematic plant breeding within one single variety combines the favourable allele from many different native varieties.
- Is maintaining genetic diversity (as a resource) a goal worthy of funding?

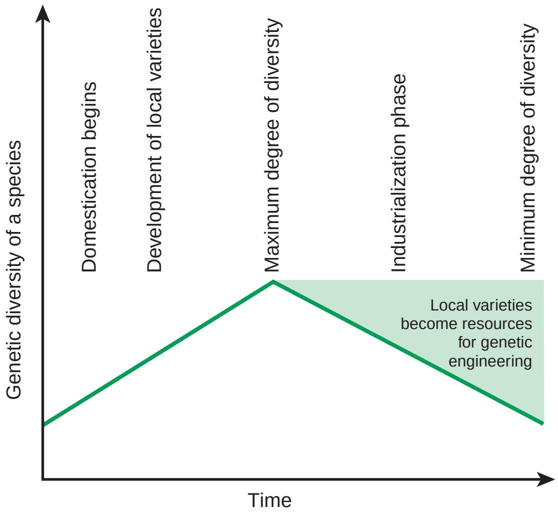


Figure D 3.4-1
Model of the state of genetic diversity of a species in the course of its development. 'Modern' varieties replace farmers' varieties. They are no longer cultivated and become 'latent' biodiversity if they are conserved as genetic resources (shaded area).
Source: WBGU, 2000a

In order to discuss these issues with respect to genetic diversity and species diversity as components of agrobiodiversity and to derive from that measures to preserve agrobiodiversity, the following discussion places the functions and state of agrobiodiversity in relation to the threat to agrobiodiversity, within the context of globally significant issues.

D 3.4.2
Functions and importance of agrobiodiversity

The components of biological diversity in agro-ecosystems do not behave any differently from other ecosystems in any essential way (Section D 2). The difficulty in exploring the 'functions' of agrobiodiversity lies in the fact that the functions of individual components of diversity in the agro-ecosystem have hitherto only been conceded any significance (Section E 3.3.4) if they influence the productivity of the agrarian system. So, for example, the ability of hyperparasites X to limit the number of parasites Z is valued as the positive contribution of diversity component X ('biological control'). On the other hand, the capacity of plant A ('weed') to reduce the cultivated species B is seen as a cause of yield loss, and so A is not seen as a component with a 'function', but rather as a disruption.

As a result, current biodiversity is to some degree consciously being eliminated or substituted. There are accordingly three explanations for non-use of agrobiodiversity:

1. the contribution of the component is negative,
2. the possible positive contribution of the component is not known,
3. use is not made of the positive contribution of the component because this use is too expensive or can be substituted more cheaply (Section D 3.4.4).

To better analyse these 'functions', Vandermeer and Perfecto (1995) suggest subdividing agrobiodiversity into planned biodiversity and associated biodiversity. The term 'planned biodiversity' would refer to the components that are introduced intentionally into an agro-ecosystem and managed there. Associated diversity would include all other species that live in the system (eg diversity of soil organisms). It is impossible to describe all interactions within an agro-ecosystem at the species level; that is why the concept of functional groups was developed. This means:

- Groups of species that have ecologically similar functions (eg nitrifiers or decomposers).
- Interaction between species (eg host-parasite relationships) that are seen as 'community processes'.

Ecological function of agrobiodiversity

Planned biodiversity

In most cropping systems different crop species are combined intentionally, ie to be grown alongside or after one another. This happens first of all to be able to harvest different products, but also to achieve different ecological effects, such as erosion prevention, soil loosening by planting crops with deep roots, suppression of pathogens, or nitrogen accumulation (Vandermeer, 1989). It is highly probable that the ecological stability and sustainability of use could be increased considerably if systems with a greater planned biodiversity were developed (Olson et al, 1995; Piper, 1999).

Associated biodiversity

In agro-ecosystems the goal is to create optimum conditions for intentionally used components of diversity. Intervention in the system to that end almost always has an impact on the associated biodiversity. So, for example, adding soluble phosphorus to wheat leads to a two- or three-fold reduction in mycorrhizal colonization (Rooper and Ophel-Keller, 1997). Very often it is specifically arable intervention that has the greatest impact on associated biodiversity such as the use of the plough on animals in the soil or the use of agrochemicals on microorganisms or associate plants. One could assume that it would be sufficient for there to be one species per 'job', since the concern is primarily to ensure that community processes that contribute to agrarian productivity can continue. However, as a result of the heterogeneous nature of the system, changing climatic conditions and substrate diversity, it is hardly conceivable that such a system would continue to function over the long term (Section D 2). Natural systems with monocultures are more the exception than the rule. And yet no generally applicable statements have yet been made in relation to agro-ecosystems concerning whether a high degree of biodiversity has a stabilizing or destabilizing effect (Kennedy, 1999). There are, however, many examples in which components of associated biodiversity provide stabilizing contributions to the system.

Infraspecific, or genetic diversity (at the variety level)

The use of identical genotypes over years or large areas, as well as keeping a large number of domestic animals on a small space, make ecosystems vulnerable to pests and disease. The outbreak of Southern Corn Leaf Blight in corn hybrids in the USA in 1969/70 (Box D 3.4-1; WBGU, 1998a) triggered the first public discussion outside expert circles and the issue of 'genetic vulnerability' forced its way into public consciousness. One speaks of genetic vulnerability when one genotype is dominant in a region that is vulnerable to a disease, a pathogen or abiotic stress and if this vulnerability lies in its genetic make-up (NRC, 1993).

One important ecological function of diversity at variety level is to minimize this vulnerability. In this connection, frequent reference is made to the advantages of historic farmers' varieties. There is, however, little information about the genetics of farmers' varieties (Zeven, 1998). Using barley as an example, it can be demonstrated that the results are dependent on the selection of material and method. Petersen et al (1994) found molecular markers in wild barley (ssp. *spontaneum*) for a greater genetic diversity than in the investigated range of modern varieties (ssp. *vulgare*), but the diversity in the farmers' variety collection was lower than in the current varieties. Nevo et al (1986), in contrast, found that the cultivated barley varieties of the Middle East possessed a higher degree of diversity of morphological features than wild barley. In actual fact, the genetic diversity within a single variety or between varieties in a region does not have an influence per se on the genetic vulnerability. What are decisive are the characteristics in each case, not the 'degree of relationship': not morphological or molecular markers, degrees of relationship or data on heterogeneity; rather the actual features, eg resistances. Genetic diversity as is present in and between historic farmers' varieties, does not by itself mean improved resistance or tolerance. However, since farmers' varieties were adapted to the specific conditions at a given site by continuous selection over long periods of time, they often have the respective resistances and tolerances.

In countries with highly developed seed systems, genetic diversity in the field replaced 'temporal' diversity (Duvick, 1984). One variety is replaced after a number of years, for example, when its resistances are no longer effective. Geographic biodiversity is thus replaced by temporal diversity.

The value of genetic diversity in the agro-ecosystem has changed over the course of the process. Systematic plant breeding combines the most valuable characteristics from genetically diverse material and thus generally achieves higher levels of resistance (eg via genetic pyramiding). Genetic diversity then fulfils its function within the agrarian system, that is to reduce disease and vulnerability to stress, but no longer in simultaneous, geographically distributed cultivation. Instead, it becomes a reservoir of individual valuable characteristics that can be combined and recombined. It becomes, in short, a genetic resource.

As the example of the Southern Corn Leaf Blight (Box D 3.4-1) demonstrates, low genetic diversity can lead to increased incidence of disease and massive spread of damaging agents. Thus, to ensure yields today the spatial arrangement of several varieties is necessary.

Consequences

There are three different categories of functions that the individual components of agrobiodiversity can fulfil, namely

1. ecological functions on site (current biodiversity),
2. functions as suppliers of various products and services (current biodiversity),
3. functions as genetic resources, ie as repositories of information or 'raw materials' eg for the breeding process (latent biodiversity).

Whereas current agrobiodiversity provides positive contributions directly to the productivity of the system and, therefore, is cultivated by the farmer, this is generally not the case with latent agrobiodiversity (unless the farmer is also a breeder). The more agrobiodiversity is separate from active use, the greater the effort that has to be invested in maintaining it as the genetic resource that it has become. At the same time, the ecosystem services of biodiversity that are now missing must be replaced. At the level of agricultural production this happens via 'external inputs', such as pesticides that ultimately only become necessary when large areas are covered by a few varieties of just one crop species. At the level of manufacturing industry it is similar: the greater the amounts of food that are not consumed fresh, but rather in industrially processed form, the greater is the demand for large uniform amounts of 'raw material'. Loss of taste intensity, for example, is often a consequence of breeding for maximum yield and can be replaced in industrial processes with additives.

The less diversity there is in the industrial structure of the purchaser, the lower the diversity in procedures and production methods, which also in turn reduces the demand for diversity in quality.

Measures to reduce the negative external effects of agriculture therefore often have a direct impact on the use of agrobiodiversity, as do trade initiatives with the aim of supplying high-quality fresh produce.

Box D 3.4-1

Genetic vulnerability

In the fifties and sixties in the USA the large-scale cultivation of varieties of hybrid maize began, with 80 per cent of the hybrids containing what was known as the Texas cytoplasm. It gives the inert plant male sterility and is required for the production of hybrids. In 1969/70 the varieties with Texas cytoplasm were stricken with an epidemic-like spread of Southern Corn Leaf Blight. The maize varieties with normal cytoplasm were not affected. It was found that male sterility and vulnerability to the agent *Bipolaris maydis*, race T, could both be traced back to the product of a mitochondria gene, Turf 13.

In this example the problem was neither the hybrid technology *per se* nor uniformity or close genetic proximity of the hybrids, rather it was the broad spread of Turf 13. The genetic disposition of the maize hybrids lay here in the existence of a 'genetic monoculture' in relation to their vulnerability to Southern Corn Leaf Blight.

Thus, organic farming systems are almost without exception more diverse than conventional systems. The organic trader often offers several varieties of cereal and leguminous species where normal supermarkets perhaps only stock one variety.

Wherever agriculture or horticulture has no essential interest in one variety or species, there is the acute danger it will be lost. The components that have become 'latent biodiversity' must be preserved *in situ, on farm* or *ex situ* if they are not to be lost irretrievably. The discussion of agrobiodiversity currently focuses on two questions:

1. Whether *in-situ*, *on-farm* or *ex-situ* conservation is to be preferred, and
2. How the returns on the use of genetic resources should be distributed (Section I 3.1).

It must be considered that preserving genetic resources, even if organized in an optimum fashion, always has the nature of a precautionary measure. The greatest challenge lies in the following question:

How can we bring about as diverse an agricultural production as possible that makes *active use* of the ecological functions of agrobiodiversity and thus minimizes the adverse environmental impacts of agriculture while providing high-quality and varied products?

D 3.4.3
State of agrobiodiversity

What state is agrobiodiversity in? In most agroecosystems investigated, only a very small proportion of the participating species are known. There is very little information, especially regarding the composition of soil microorganisms. Non-domestic plant and animal species and their diversity are often not recorded. The best information is available on domesticated animal and plant species and their genetic diversity, but even here knowledge is patchy.

Microorganisms

Here we can distinguish between domesticated and non-domesticated microorganisms. Non-domesticated microorganisms are often not recorded at the level of species but rather in their functional group (eg the diazotrophs able to fix elemental nitrogen). The majority of existing species, particularly soil dwellers, have yet to be described. The species composition of agro-ecosystems and the relationships of functional groups to one another are altered by agricultural intervention. For example, in the soil of a harvested field, denitrification figures can be recorded that are up to 44 times higher than in non-worked soil (Rooper and Ophel-Keller, 1997). With the use of agrochemicals, certain functional groups can be seriously impaired in their diversity. The danger that entire functions (eg decomposition) are lost altogether if the species ratio changes (Mooney et al, 1995) does not generally exist. Exceptions to this rule are for example the highly specific symbiosis of *Rhizobium trifolii* with clover (Marschner, 1990). There is little information regarding the genetic diversity of microorganisms in agro-ecosystems (Kennedy, 1995). Exceptions to this rule are, for example, crop pathogens that in some cases are extremely well researched.

Microorganisms are also used directly to harvest food. But only a small proportion of the assumed 1.5 million species of fungi are used by humans (Hawksworth and Kalin-Arroyo, 1995), such as the yeast, mould and edible fungi. Microorganisms are intensively used to process milk and to produce beer and wine; bacteria such as *Lactobacillus* or moulds such as *Penicillium camembertii,* for example. Increasingly important is the biotechnological manufacture of food products, for instance by bacteria or fungi in bioreactors. There is a certain amount of potential for transforming hitherto unusable plant waste into fodder or food with the help of microorganisms.

Animals

Altogether, there are 50,000 vertebrate species, of which approx 40 domesticated species play a role in agricultural systems (WCMC, 1992; Hawksworth, 1995). Those found worldwide are cattle (*Bos indicus* and *Bos taurus*), sheep, pigs, chickens, domesticated buffalo (*Bos bubalus*) and goats. Most of the other species are only of local or regional importance (eg camels). Even if we add to the domesticated animal species the 'used wild species' (eg elephants and falcons) the number of vertebrates used by man remains small, even though there is large breed diversity within the individual species (Hawksworth and Kalin-Arroyo, 1995). Table D 3.4-1 gives an overview of the numbers of breeds of domestic animals worldwide and the numbers endangered.

Plants

It is assumed that worldwide approx 300,000–500,000 species of higher plants exist, of which around 250,000 have been described (FAO, 1996b). Approximately 30,000 of these plant species are edible and 7,000 are considered crops (not including ornamental and forest plants) (Fig. D 3.4-2). In addition, there are the non-cultivated components of agrobiodiversity such as wild herbs, weeds and wild relatives of cultivated species. Of the 7,000 cultivated plant species just 30 are considered 'crops that feed the world' (Table D 3.4-2). Just three species – rice, wheat and maize – provide almost 50 per cent of the

Table D 3.4-1
Global overview of domestic animal breeds and numbers at risk.
Source: Loftus and Scherf, 1993

Species	Number of breeds	Breeds at risk
Cattle	783	112
Sheep	863	101
Goat	313	32
Pig	263	53
Buffalo	62	1
Horse	357	81
Donkey	78	11

world's calorie needs (energy). With an additional six species (sorghum, millet, potato, sweet potato, soya, sugar cane and sugar beet), 75 per cent of the world's calorie needs are covered (Fig. D 3.4-3). In addition to these 'main species' there are numerous cultivated plant species that are only of regional significance. For example, tef (*Eragrostis tef*) is extremely important in Ethiopia but only marginally so internationally (Rehm 1989). Furthermore, there is the complex of what are termed 'minor species', 'neglected crops' or 'under-utilized crops', which are adapted to special, often extreme, sites and are of local or regional significance for human sustenance. 'Neglected crops' are cultivated plants that have been neglected by research and breeders, eg coriander (Diederichsen, 1996) or yam, whereas 'under-utilized species' are those not used very much in agriculture, eg *Lupinus albus* in the Mediterranean.

Gene centres

The theory of the gene centres of cultivars was developed by the Russian scientist Vavilov (1926). The gene centre of a species is the region in which the greatest genetic diversity within that species occurs.

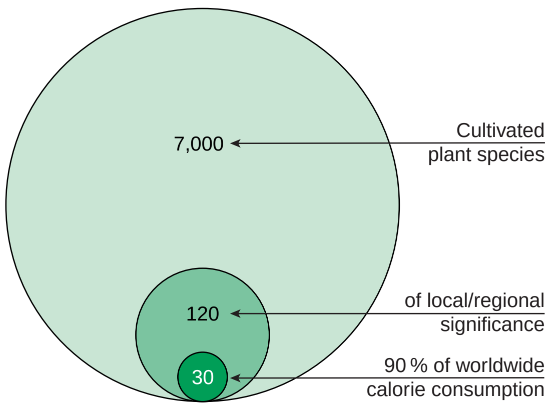


Figure D 3.4-2
Estimated number of cultivated plant species (globally).
Source: FAO, 1996b

Vavilov initially considered the gene centres to be identical to their centres of origin. The theory was developed further by Harlan among others (1971) who defined centres and non-centres in order to differentiate the regions of origin from the regions with 'secondary' or later colonization by the species (Fig. D 3.4-4). A gene centre can therefore, but according to more recent findings need not, be different from the region of origin of a species (Hammer, 1998; Becker, 1993). For example, in Ethiopia there is a broad spectrum of farmers' varieties of barley but not one single wild form (Zohary, 1970), so barley cannot have been domesticated there (in actual fact its region of origin is far away in the Middle East). Gene centres were mainly defined for cultivars. They were and still are important sources in the search for genetic variability for these species and often the destination for collecting trips and studies.

In the gene centre of maize (*Zea mays* L.) in Mexico there are regions in which the original ancestor of maize, teosinte, can still be found alongside maize. Thus, introgression into maize material is possible, followed by further evolution of maize (Miller et al, 1995). This type of introgression from genetic material is only one of the possible ways in which cultivars can continue to evolve. Other ways are for example recombination, epistasis and mutation (Rasmusson and Phillips, 1997).

Regions with high genetic variability of a species are generally in areas in which, as a result of natural geographic diversity, there is a tradition of small-scale agriculture. Often these are isolated, diverse

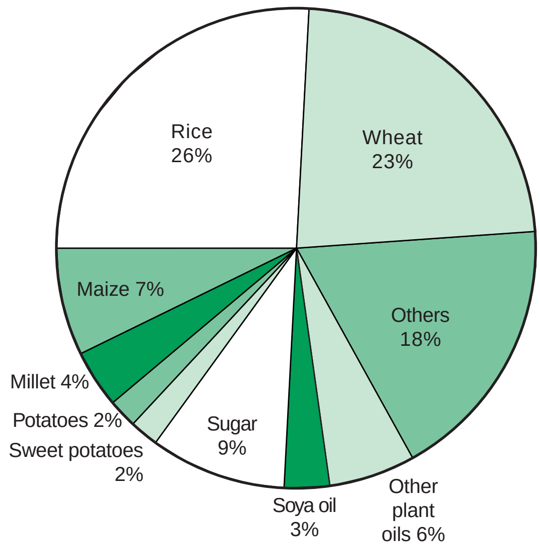


Figure D 3.4-3
The most important cultivated plant species in terms of world food provision.
Source: FAO, 1996b

Crop Species	Number	Crop Species	Number	Crop Species	Number
Wheat	784,500	Tomato	78,000	Sugar beet	24,000
Barley	485,000	Chickpea	67,500	Oil palm	21,000
Rice	420,500	Cotton	49,000	Coffee	21,000
Maize	277,000	Sweet potato	32,000	Sugar cane	19,000
Bean	268,500	Potato	31,000	Yam	11,500
Soya	174,500	Field bean	29,500	Banana/plantain	10,500
Millet/sorghum	168,500	Manioc	28,000	Tobacco	9,705
Cabbage	109,000	Rubber	27,500	Cocoa	9,500
Pea	85,500	Lentil	26,000	Taro	6,000
Peanut	81,000	Garlic/onion	25,500	Coconut	1,000

Table D 3.4-2
The 30 most important cultivated plants in the world ('crops that feed the world') and their *ex-situ* collection stock.
Source: FAO, 1996b

landscapes, hilly with marginal and very heterogeneous soils and climatic conditions, where different varieties were selected for the local conditions (Brush, 1995; Zohary, 1970). Traditional systems of cultivation still persist in these regions today, since modern intensive agriculture is simply not viable given the natural topographical conditions.

Loss of genetic and species diversity

The loss of plant genetic resources at the species or variety level (genetic erosion) can only be followed in certain examples, since there is no complete overview (Box D 3.4-2). So, for example, Hammer (1998) describes the loss of the species *Anacylus officinarum* and *Bromus mango*. There are similar examples of genetic erosion or loss at variety level. From these developments estimates can be made for other regions (FAO, 1996b; Hammer 1998). The actual loss of genetic diversity can be calculated over a defined period of time by comparing the results of studies in earlier years with more recent findings. For Albania, the result of such comparisons was a loss of 72.4 per cent between 1941 and 1993, for Southern Italy 72.8 per cent between 1950 and 1985 (Hammer, 1998).

Consequences

The loss of genetic diversity is very serious in many regions. One of the reasons for this is the transition from traditional agriculture to intensive or industrial agriculture. Farmers' varieties (and crop species) are no longer used in the agricultural system. Their complete loss can only be prevented by their being preserved as 'genetic resources'.

A precise evaluation of the state of agrobiodiversity is not possible in the absence of systematic com-

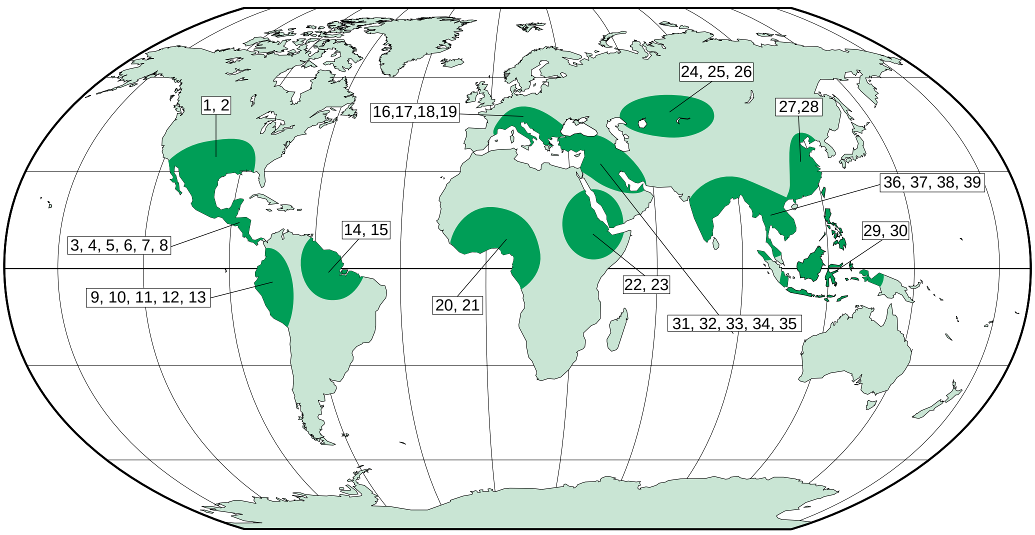


Figure D 3.4-4
Regions of origin for the most important crop species.
1 Sunflower, 2 Tepary bean, 3 Avocado, 4 Cocoa, 5 Sweet potato, 6 Maize, 7 Climbing bean, 8 Tomato, 9 Cotton, 10 Lima bean, 11 Peanut, 12 Pepper, 13 Potato, 14 Pineapple, 15 Yam, 16 Grape, 17 Barley, 18 Olive, 19 Rye, 20 Yam, 21 Watermelon, 22 African millet, 23 Sorghum, 24 Lucerne/alfalfa, 25 Millet, 26 Hemp, 27 Foxtail millet, 28 Soya bean 29 Coconut, 30 Breadfruit/jackfruit, 31 Barley, 32 Dates, 33 Onion, 34 Pea, 35 Wheat, 36 Banana, 37 Yam, 38 Rice, 39 Tea.
Source: adapted on the basis of McNeely et al, 1995

parative studies. Extensive studies have been carried out solely on the state of *ex-situ* stocks of animal and plant genetic resources, and even here only for the main species (FAO, 1996b). To improve the characterization of the status and thus the prognosis of loss there should be a worldwide inventory and cataloguing exercise as soon as possible (Section J 1.2).

Genetic diversity within crop species is distributed regionally in very different ways. Since both generation and preservation of this diversity depend on human intervention, important political and economic questions arise with regard to the equitable distribution of burdens and tasks (Section I 3 and Chapter J).

D 3.4.4 Agrobiodiversity under threat

Agriculture uses just a small portion of the entire species spectrum in the form of planned biodiversity, but over the 10,000 or so years of its existence has brought forth an enormous diversity of varieties and breeds *within* the species it has used.

There are a number of different reasons for the decline in anthropogenic agrobiodiversity. The FAO (1996b) cites population growth, wars, extreme weather conditions (especially drought), pollution, unsustainable agriculture, statutory regulations and economic factors in particular. Hammer (1998) determined that the main causes of loss of agricultural species were overuse, disuse and neglect, mistakes in determining species and displacement by other species.

From this list we can derive the following issue areas that have a direct influence on agrobiodiversity:

1. change in demand for agricultural produce,
2. agricultural management,
3. development of plant breeding technology,
4. agricultural and economic policy (impacting, in turn, on the first three points).

Issue area 1: Change in demand for agricultural produce

Agro-ecosystems are defined as systems that were created to produce certain goods and services. Demand for the products and a services of an agro-ecosystem therefore has a crucial influence on the shape and structure of the system.

Although in principle only relatively few *species* were originally suited to agricultural use (Diamond, 1998), even these are far from universally used, certainly not to any significant extent (Fig. D 3.4-2). One main reason for that is the fact that many species provide similar products, eg carbohydrates, fat, protein, milk, meat, wool, bedding, fuel, etc. In most regions, however, one species – often the one with the highest yield in those circumstances – becomes the main supplier of such product categories; so for example in a given region in general one of either wheat, maize or rice is planted as the main provider of carbohydrate (FAO, 1996b).

New technological developments allow agricultural products to be altered to such a degree in the process of their preparation as foodstuffs that very few basic raw materials are required. For example, using biotechnological methods, it is possible to manufacture isoglucose from starch. Currently, the food industry in the USA is meeting a great deal of its sugar needs from maize starch. This has led to a strong decline in the importance of raw sugar imports (Knerr, 1991).

Another approach tries to deliver differing product qualities with a regionally well-adapted species. So, for example, varying qualities of oil from oil seed rape (*Brassica napus* L.) are produced in order to dispense with having to plant other oil plants or import oils. Transgenic rapeseed with high lauric acid levels in the oil could take over from coconut and oil palms in the future as the supplier of lauric acid (Sovero, 1996) and reduce demand from the industrialized countries.

Varieties are also often not primarily cultivated because they are most ecologically suited to the prevailing conditions, but because they provide a certain quality of product. With the increasing requirements upon non-perishability, suitability for storage and transportation, there has been a distinct impoverish-

Box D 3.4-2

Genetic variability at the level of varieties in selected regions

In a given region often only a very few varieties of a crop species will be planted. The actually cultivated genetic diversity within that species is then very low. Just a few examples to illustrate that point:

- In 1983/84 on 67 per cent of the land under wheat in Bangladesh and 30 per cent of the area under wheat in India, just one variety (Sonalica) was planted.
- In 1972 and 1991 studies carried out in the United States demonstrated that of the eight main cultivated species fewer than nine varieties each were being planted on 50–75 per cent of the acreage.
- A study in the Netherlands found that of the nine main cultivated species just three varieties were planted on 80–100 per cent of the acreage (FAO, 1996b).
- In 1985 60 per cent of the acreage under winter wheat in Germany was planted with five varieties that all had the Capelle variety as a parent or grandparent (Becker, 1993).

ment of the range of varieties available. One example of this trend is strawberries, where many particularly delicious varieties have disappeared completely from farming because they spoil so soon after they are picked.

Commercial demand and demand from the manufacturing industry for large batches of uniform goods also contributes to the decline in diversity at the variety level. Currently, approximately five varieties of brewing barley meet a considerable portion of the worldwide demand from malthouses. Other suitable genotypes (some of which may be better in agronomic terms) are available in the various regions of the world but a small number of varieties lowers the costs of trade registration and for the malthouses (P. Franck, personal communication); thus there is little interest from the demand side in increasing diversity.

Often agricultural policy measures also lead to a distinct drop in diversity. Guaranteed sales and minimum pricing sever the link between supply and demand and thus prevent a transfer of information regarding desired and new product qualities.

Issue area 2: Agricultural management

Often there are substitution links between the ecological functions of agrobiodiversity and the external inputs (eg fertilizers, pesticides). This means that external inputs take on the functions of agrobiodiversity and *vice versa*.

In homogeneous systems of *high-input* agriculture more intensive management and external inputs offset the ecosystem functions that are missing as a result of low biodiversity. This happens (in an incomplete fashion) in intensive grain monocultures with no crop rotation; here, most of the functions that, in more diverse systems, would be assumed by various species are replaced by external inputs, such as mechanical earth loosening, or the addition of nitrogen in the form of fertilizer.

As a result it is particularly those components of agrobiodiversity whose functions can be replaced more cheaply that are at risk. The influence of such measures on species diversity in agricultural systems is clear. For example, in the past many different fodder crops were planted in Germany (eg oats, barley, beans, clover grass, lucerne/alfalfa, forage beet and potatoes), but today on many farms maize is the sole fodder base, possibly supplemented by purchased soya flour as a protein component. Each of the 'replaced' species founders in its own way. For example, lucerne's nitrogen fixing characteristics as a forecrop are now substituted by chemical and technical means, while forage beet has become unprofitable as a result of higher labour costs.

There are also many examples of loss of diversity as a result of changed management intensity at the variety level. For example, the use of cereal varieties with shorter straw allows for distinctly higher doses of nitrogen (NRC, 1993; Becker, 1993). Short-straw varieties are so superior to the longer varieties that in just a few years the latter have been pushed out almost completely – at least where use of fertilizer was possible and profitable.

Many functions and interactions of substituted agrobiodiversity are not yet known. This has the consequence that we can neither estimate how good a substitute will be in the long term, nor what consequences there will actually be from removing a component of diversity from the system.

Issue area 3: Technological developments in plant breeding

At the *species level*, breeding plants is more valuable when a given cultivar is cultivated on a larger scale; at the same time, the species being planted is generally more competitive the more intensely it is processed and bred.

Worldwide, both private and publicly-funded plant breeders are therefore concentrating on a relatively small number of species. The correlation between investment in breeding research and the increase in yield of a given species is positive and as a rule fairly close. Production of intensively processed wheat rose in developing countries by 5 per cent annually from 1963 to 1986, millet by just 1 per cent (Becker, 1993).

Biotechnology and genetic engineering appear, however, to reinforce this trend even further. Investments are concentrated worldwide on maize, rice, soya and rapeseed. Other important species such as wheat, barley and sunflowers follow behind, but at a considerable distance. There are (generally publicly financed) activities where the more important 'minor crops' are considered, but to a much smaller extent. Many species that are basic foodstuffs, particularly in regions that have lower levels of agricultural productivity, are almost never processed and are also not being conserved systematically (Brown et al, 1989).

At the *variety level* the main reason given almost worldwide for the loss of genetic diversity is the replacement of local varieties by new breeds (FAO, 1996b). All regional reports came to this conclusion, with the exception of Africa. The Green Revolution contributed and continues without doubt to contribute to the loss of genetic diversity, even though according to Wood and Lenne (1997) one cannot give the simple formula: 'green revolution = loss of genetic diversity'. It is not just the high-yielding varieties from the first or second green revolution that are causing these losses. Particularly in areas in which the varieties of the green revolution had and continue to have the greatest success are, according to

Wood and Lenne (1997), generally favourable agricultural sites and tended not to be centres of diversity.

The farmer's varieties of various species are often only superior, or at least competitive, under poorer ecoclimatic conditions. Most of the studies that have looked at these issues come to the conclusion that yield (or rather potential yield) is the most important criterion from the farmer's perspective for selecting a variety alongside the actual product (Heisey and Brennan, 1991). However, Brush (1995) found that many farmers plant high-yielding varieties without giving up on the traditional farmers' varieties altogether; mainly because the latter are of a particularly high quality (protein content, taste).

Having said that, one can assume that the replacement of old varieties by new ones will continue. It is crucial to note that the continued substitution of old varieties does not automatically have to lead to a loss in genetic diversity if one takes timely and sustained conservation measures to take care of the genotypes, that have at that stage become 'genetic resources' (Heisey et al, 1997)

Issue area 4: Agricultural and economic policy

Behind the direct causes of change in agrobiodiversity (issue areas 1–3) are the causes that were cited in the introduction to this section such as

- extreme weather conditions and climate fluctuations,
- disappearance and degradation of resources,
- pollution,
- population growth,
- political unrest and war.

Different policy areas intervene here. Agricultural and economic policies set the parameters for market activities and technological development in the agricultural sector. Areas for action include protection of intellectual property rights (eg variety protection, patent rights), promotion of research, agricultural pricing policy, subsidies, food laws or foreign trade policies. The agricultural sector is therefore an economic area in which most states in the world intervene to a particular degree in a regulatory fashion. In light of the diversity of the possible instruments available to agricultural and economic policy, it is evident that the influence of these policy areas on agrobiodiversity is extremely complex.

It also appears necessary in this context in future to examine agricultural and economic policy measures with regard to their influence on

- management intensity in agriculture,
- diversity of species breeding,
- diversity in procurement and trade, and
- level and use of public funding in agricultural research.

Generally it can be stated that agro-sciences must tackle as a priority the task of informing political decision makers with regard to which individual measures will have what potential impact on agrobiodiversity. In many areas there is a need for fundamental research since we have only just scratched the surface in terms of even *recording* agrobiodiversity.

The biggest problem, however, is that biological diversity in agro-ecosystems is generally not the goal of an individual farm and is rarely even the goal of agricultural policy. That applies particularly wherever the elements of agrobiodiversity have (today) no known 'function' or where they do not contribution towards increasing or stabilizing agricultural production. Maintaining current and latent agrobiodiversity must be made a particular policy goal as is demanded in the Convention on Biological Diversity.

D 3.4.5
Measures to conserve agrobiodiversity

Strategies for conserving agrogenetic resources

Modern agriculture has profited immensely from the diversity that has arisen during the history of land use (Box D 3.4-3). Its success, however, has essentially contributed to the loss of that diversity (Miller et al, 1995). In order to be able to adapt to changing environmental conditions and to achieve sustainable production increases (Section E 3.3.4) agricultural systems are, and will remain, dependent on biological diversity. Strategies that make active use of the ecological functions of agrobiodiversity should be pursued as a matter of priority, since measures to preserve genetic resources have no more than a precautionary character, even when organized in an optimum fashion. If current biodiversity cannot be maintained, conservation measures must attempt to preserve the biological diversity of plants, animals and microorganisms.

According to Frankel (1983), there are two options in response to the question of what is the appropriate strategy for preserving a species:

1. Establish or conserve a habitat in which the species can survive and evolve further, without being actively influenced in that respect. This option is rarely open to components of agrobiodiversity. It will become more limited in future (Brush, 1995).
2. If these habitats are not available, but the species or their varieties and breeds are to be prevented from dying out, then they must be transferred to collections, eg botanical gardens or gene banks.

Box D 3.4-3

The gene pool concept

Harlan and de Wet (1971) first put forward the idea of the gene pool. The concept divides cultivated plants and their relatives and wild species into a primary, secondary and tertiary gene pool. The measure of relationship is the possibility of crossing the species:

- The *primary gene pool* contains all representatives of the cultivated species.
- Plants in the *secondary gene pool* can be crossed with the cultivated plant species under consideration and produce fertile hybrids; the plants do not however belong to the cultivated plant species under consideration.
- The *tertiary gene pool* comprises species that can no longer be crossed in the classic sense with the cultivated species, but only with the help of *in-vitro* techniques such as embryo rescue or protoplast fusion.

Since genes can be transferred across species barriers using genetic engineering methods, the gene pool concept has been 'diluted'. The ability of a species to hybridize with another is no longer the exclusive criterion for whether gene transfer is possible. Callow et al (1997) therefore discuss whether hybridization with 'cultivated species' is still a suitable criterion for regarding a species as a genetic resource since genetic engineering methods in principle allow us to see any organism as a source of valuable genes. The gene pool concept however, does continue to provide a basis for designing collection and conservation strategies for genetic resources.

Theoretically, the following strategies may be derived form those two options (Table D 3.4-3):

1. *In-situ* conservation in the case of agricultural crops means more or less intensive management. There are gradations of difference from 'no management' (eg core zones in a national park), over 'minimal management' to 'intensive management' (when conservation is only possible if the present human-influenced state is also preserved at the same time). *In-situ* or *on-farm* conservation relate to conserving genetic resources in agricultural or horticultural situations, such as the traditional household garden ('conuco').
2. *Ex-situ* conservation takes place in gene banks, botanical and zoological gardens and aquaria. For the conservation of plants, there are many different available measures. These include seed collections, field collections, *in-vitro* tissue cultures, pollen conservation, protoplast cultures and cryoconservation. Animals are kept in captive populations; sperm, eggs and embryos can be conserved cryogenically.

With regard to conservation strategy, one can differentiate between crops and livestock on the one hand and the wild portion of agrobiodiversity on the other hand. Whilst the latter have to be kept *in situ*, this approach is only possible for the former in exceptional cases since these generally depend on human assistance for survival. Their long-term preservation is possible *in situ*, *on farm* or *ex situ* (Kosak, 1996). *On-farm* conservation generally only takes place in 'traditional' agriculture that is characterized by crop diversity. In modern or industrial agriculture that is characterized by genetically homogeneous high-yielding plant varieties and animal breeds of just a few species, diversity must be conserved *ex situ*.

Brush (1995) proposes that in isolated areas in the centres of domestication, in which small-scale farming is still the only possibility, systematic *in-situ* and *on-farm* conservation could be introduced to supplement *ex-situ* conservation. This is not just the conservation of the *status quo*, but rather allows evolutionary processes to continue.

Examples of conservation strategies for particular cultivated plant species

- *Wheat*: Worldwide almost 800,000 wheat (*Triticum*) accessions are being kept *ex situ* (FAO, 1996b). Many of the accessions are historic farmers' varieties. Although there are certainly some duplicates among the 800,000 accessions, sheer numbers clearly show that systematic *in-situ* or *on-farm* preservation of this diversity would be impossible from an organizational standpoint. Two biological characteristics predestine wheat for *ex-situ* conservation strategy:
    1. Wheat is self-fertilizing; that means elaborate measures to manage pollination or isolate plots can be dispensed with.
    2. The samples have only to be planted every 25 years for regeneration. That is sufficient to preserve germinating capacity.
- *Cassava*: Cassava (manioc) is a species that reproduces by vegetative propagation. Worldwide there are around 28,000 accessions in *ex-situ* collections, 23 per cent of which are historic farmers' varieties, and 9 per cent are modern varieties or nucleus stocks (FAO, 1996b). It may be assumed that the collections constitute more of a random selection than a complete collection. Furthermore, the cassava clones have to be replanted every year. The conservation of habitats in which a large diversity of cassava is cultivated is therefore the best strategy for conservation.

The two examples indicate how one might proceed in order to define the optimum conservation strategy for a given species.

Table D 3.4-3
Advantages and disadvantages of various conservation measures.
Sources: Frankel, 1970; Brush, 1995; Miller et al, 1995; FAO, 1996b; Hammer, 1998

Conservation measure	Advantages	Disadvantages
In situ	– Interaction with other species and organisms possible – Inter- and intraspecific variation can be combined – Also for vegetatively propagated species or those with recalcitrant seed (characterization, property rights)	– Requires a great deal of space for conservation – Only a small number of genotypes can be managed this way. No good protection against epidemics, disease, etc. Loss possible. – Organization of preservation via networks required – Access to material is difficult
In situ or *On farm*	– Further evolution through natural evolution and variety selection	– No *Status-quo*-conservation, but selection – Genetic erosion possible
Ex situ		
Seed banks	– Seed (accessions) always available – Catalogue – Little space required (small seeds) – Genetic status quo of stored seed can be preserved if appropriate reproduction strategies applied – Only a limited section of variability is collected and preserved – Change in the population structure at regeneration to smaller population sizes	– No continuous evolutionary development. Dependent on the surrounding environment – Problems in conserving recalcitrant and vegetatively propagated species – Large space required (large seeds) – The original surrounding flora is not conserved along with it – Regeneration requires space and needs a long time and much money
Tissue culture	– Little space – Good for vegetative propagation and recalcitrant species – Minimizes incidence of disease	– High technical effort – Somaclonal variation – Related species not conserved along with it
DNA	– Requires little space – Applicable everywhere – Future method of final resort in individual cases	– Not a germ plasm conservation method *per se*

Evaluation, pre-breeding and use

In order to make appropriate use of the material maintained *ex situ* in gene banks or other collections, it is necessary to characterize and evaluate the material. That means recording the passport data of an accession (origin, name, taxonomy) and in the secondary evaluation recording data on resistance, constituent substances or particular features. Indications on how to record features are given in, for example, the IPGRI description lists. Since it is very time-consuming to evaluate the entire material, it has become standard practice for the gene banks to investigate certain parts of the overall collection in more depth. Frankel and Brown (1984) proposed to that end the concept of the 'core collection' (Box D 3.4-4). When applying this model, it is important to ensure that accessions which are not part of the core collection are not neglected. The *raison d'être* of these 'leftovers' often comes into play when they have characteristics (eg resistances) that are not present in the core collection. A classic example of this is the screening for resistance to the Grassy Stunt Virus in rice at the International Rice Research Institute (IRRI) in the Philippines: of the 30,000 accessions examined (varieties, historic farmers' varieties, wild rice) just one single wild rice (*Oryza nivara*) was found that had the urgently required resistance (Khush and Beachell, 1972). There are various other such examples (Chang, 1989) that clearly demonstrate the need to preserve sufficiently large collections.

The further high-yielding varieties develop, the more they differ in many characteristics from the historic farmers' varieties and certainly from the wild species. Since when hybridizing into elite material one transfers not only interesting, but also many less desirable features, the use of gene bank material is problematic if it is too far removed from the current range of varieties. In this case, pre-breeding programmes are essential. A famous example of successful pre-breeding is given by Harlan and Martini (1938). They ascertained that the 5,000 barley accessions that were at that time stored in the US gene banks were not very usable for the breeding purposes

Box D 3.4-4

The principle of the core collection

Frankel et al (1995) formulated the concept of the 'core collection'. According to this principle core subsets should be formed in large genebank collections comprising the genetic diversity of the cultivated plant species and their related wild species. The basic collection of a cultivated plant species therefore comprises this core subset and all other related accessions.

To establish this core subset and to minimize the time-consuming and costly evaluations and characterization steps, representative excerpts from the whole collection of a given species are made (NRC, 1993). Problems arise in defining the appropriate size. An approximate guideline is 10 per cent of the total collection (Brown, 1989). There are various approaches to the composition of the core subset: non-overlapping, by origin, particular characteristics (resistance, ingredients, etc).

The disadvantage of this approach is described as follows by the NRC (1993): 'One disadvantage of the Core Concept is the possibility or the probability that the other elements of the basic collection that are held in reserve will still erode and disappear as a result of neglect.' Furthermore, they could be viewed by certain decision makers as less valuable and thus dispensable in the interests of the economy. In order to minimize this disadvantage as much as possible, Frankel et al (1995) emphasized that these 'reserves' must remain an integral part of the basic collection. They have at least two functions:

1. as alternatives if the characteristic or feature sought is not found in the variation represented in the core subset,
2. as a source of diversity for other allele of a gene already found in the core subset (NRC, 1993).

of the time. They therefore selected 28 outstanding accessions from the main barley cultivation areas of the world and crossed them with one another. Seed of the F2 generation of all of the hybrids were mixed and planted worldwide as a segregating population called 'Composite Cross II'. From this population many superior varieties were developed (NRC, 1993). The fact that gene bank material has to first go through pre-breeding for current breeding purposes cannot be used as an argument against the Noah's Ark principle, as is sometimes done: the example of Grassy Stunt resistance is an example of this.

D 3.4.6 Conclusions

In Sections D 3.4.2 (Functions) and D 3.4.4 (Threat) we have illustrated that, in the course of agricultural development, historic varieties have constantly been pushed out by new ones since these were more able to fit the prevalent requirements. Thanks to the uniformity that has been achieved in agriculture in many areas in Europe and North America, the associated biodiversity at the level of plants and animals has been pushed back further and further. The example of the Grassy Stunt virus in rice was used to illustrate how quickly a particular characteristic from one single place of origin or accession can become important and valuable.

The precautionary principle recommends that we *conserve as much material as possible.* There are currently – except for the identification of duplicates – no scientific methods that would allow us to state which parts of a collection we could safely do without.

Whereas in the political debate (FAO Global Plan of Action, Leipzig 1996) and in scientific circles (Brush, 1995) greater activity in the field of *in-situ* conservation is being called for, the large numbers in the collections (Section D 3.4.5) demonstrate that *in-situ* conservation alone often *simply cannot* be the main means of preservation. Virchow (1999) comes to the conclusion in the case of plant genetic resources that '*in-situ* conservation programmes should only receive limited support ...' and bases this statement on the relatively high costs of *in-situ* conservation.

In the discussion surrounding the suitable conservation strategy the decision should therefore be based on

1. the reproductive biology of each species,
2. the reliability of each method of conservation and each institution (including the sustainability of their funding and the quality of access for enquirers).

When deciding in favour of *in-situ* conservation, it must be borne in mind that the possible benefit that is derived from conserving the genetic resource will not necessarily go to the person or institution investing in conservation. Therefore a system of targeted incentives must be created for the *in-situ* conservationist. Furthermore, targeted conservation strategies and monitoring systems must be developed.

On the whole, promoting *in-situ* or *on-farm* conservation measures for genetic resources, that is for latent, currently no longer desired biological diversity, should not be considered a substitute for diverse agriculture. The maintenance or creation of sustainable agrarian systems that make active use of 'as much biodiversity as possible' must be the focus of our efforts. Furthermore, the active use of agricultural biodiversity is ensured by multifunctional land use (Section E 3.3.4) and makes it easier to conserve the used components *in-situ*. Accordingly, the ecosystem services of biological diversity in agrarian systems can contribute towards agriculture being shaped in as environmentally sound and sustainable a manner as possible.

D 3.4.6.1 Research needs

Identifying the functions of agrobiodiversity

External inputs in agriculture are sometimes in substitutional relationships to biodiversity services. Starting from the idea that we can best guarantee the protection of agrobiodiversity by its sustainable use, the following primary research needs arise:

- Identifying the potential and actual contribution agrobiodiversity makes to the productivity, stability and sustainability of agro-ecosystems.
- The targeted contribution or use of biodiversity as 'means of production' requires urgent examination. This area includes development of methods for identifying the ecological services provided by agrobiodiversity and identifying the economic value of agrobiodiversity.

Recording and characterizing agrobiodiversity

Recording agrobiodiversity *on farm* must be tackled and promoted worldwide. As a priority, domestic plants and animals at the variety and species levels as well as microorganisms, particularly soil dwellers, should be considered. In particular, the crops that do not feature in the 'Top 30' should also be included (Section D 3.4.2).

The systematic investigation and evaluation of the stocks of genetic resources in *ex-situ* collections is also of fundamental importance and requires support. Important specific issues are:

- Examination of genetic diversity on the basis of molecular and morphological markers is often based on less than 100 gene loci (out of an average of approx 10,000–100,000 genes in higher organisms). It is necessary to examine the genetic variation in the loci that control the agronomically important features.
- For the conservation and use of diversity within the particularly richly subdivided crop species it is absolutely necessary for the classic morphological-systematic systems to be further developed.

Optimizing conservation strategies

The Global Plan of Action (GPA) adopted at the 4th International Technical Conference of the FAO in Leipzig in 1996 gives *in-situ* conservation of agrobiodiversity priority over *ex-situ* measures. However, the development of optimum conservation strategies must take place in a species-specific way and requires that a number of different factors be considered. The following should be addressed as priorities:

- Investigation of the suitability and reliability of *in-situ* approaches for the preservation of genetic diversity under various ecological conditions must press ahead.
- Investigation of costs and benefits of various conservation approaches with due regard for the fact that agrobiodiversity, at least partially, has the character of a public asset. It should also comprise analysis of the distribution of costs and benefits, both geographically and within society.

Three individual questions in the area of 'Optimizing conservation strategies' should receive priority treatment:

1. The development of efficient transfer mechanisms to finance conservation and to share the benefits arising from the use of agro-genetic resources.
2. Establishment of practical, affordable reproduction methods.
3. Ascertaining necessary population sizes in *ex-situ-* and *in-situ* conservation approaches in order to avoid genetic drift wherever possible.

Analysing social, economic and political parameters

The agricultural sector is very highly regulated in most national economies. At the international level, too, there are already certain sets of rules that touch on the conservation and use of agrobiodiversity. The primary focus should be placed on:

- Investigations of social and economic factors that influence the way relevant actors make use of agrobiodiversity.
- Analysis of the (national and international) existing parameters for the conservation and use of agrobiodiversity and the long-term consequences resulting from that use.

Important sub-areas are:

- The impact of the life sciences industries on agrobiodiversity. Can the breeding of 'minor crops' be assured for the future?
- The question of the extent to which different systems for the protection of intellectual property have an impact on the availability of genetic resources.
- Do the international rules (primarily the Convention on Biological Diversity and the IUPGR of the FAO; Section I 3) guarantee effective protection of agrobiodiversity? How could they be improved?

D 3.4.6.2
Action

Sustainable use of agrobiodiversity as a primary policy goal

Agrobiodiversity is immensely important for the nutritional security of future generations and for the sustainability and stability of the Earth's agro-ecosystems, as well as providing the basic material for innovations in breeding and biotechnology. This must find an appropriate expression by conservation and sustainable use becoming a priority goal in all relevant areas of policy (Section I 1.2). The active use of agrobiodiversity as a first option must stand at the forefront of preservation and be applied in the most diverse agrarian production possible. Particular attention should be placed on the reliable, sustainable funding of usage and conservation strategies. Time delays or interruptions can lead to *irreversible losses* if, for example, necessary regeneration measures cannot be implemented and accessions lose their ability to germinate, or if ecosystems that provide the habitat for rare agrobiodiversity components are destroyed. This irreversibility in the case of loss distinguishes biological diversity fundamentally from most other environmental problems and must be given due consideration in the context of any measures adopted. Early warning systems, such as CGRFA (Commission on Genetic Resources for Food and Agriculture) hopes to introduce for plant genetic resources, are particularly important in this respect.

The services of, as well as the major threat to, diversity in the agrarian systems of the Earth must form a central aspect of practical and academic training courses. In the academic context, there is a particular need for high-quality training in taxonomy, agro-ecology and genetics.

Preserving agrobiodiversity

Worldwide the preservation of a considerable portion of *ex-situ* collections is considered at risk. Thus, a priority task is to safeguard and provide financial support to existing collections. In particular, regular regeneration measures must be made possible.

Collections that have been built up by various non-governmental organizations (eg community gene banks in developing countries, NGO collections in industrialized and developing countries) should be included in this support; these include gene banks like the ones at the CGIAR research centres (Consultative Group on International Agricultural Research). For reasons of efficiency and cooperation, the collections should be coordinated into one global network. Existing collections must be augmented in accordance with the precautionary principle. By way of priority the collections in the diversity centres of the various species should be completed. Drawing up a red data book for endangered plant cultivars as a basis for the creation of appropriate conservation measures and funding of the same should be aimed at. Preserving endangered domestic animal species and breeds must form a further focus of efforts towards preserving agrobiodiversity.

Since in many cases *in-situ-* and *on-farm* conservation are the only means of preventing the total loss of certain components of agrobiodiversity, these measures must be supported. On the basis of their decentralized distribution, of course, political will in making this happen is crucial. In many cases, it is merely necessary *not to disturb* the locally organized *in-situ-* and *on-farm* conservation and use of agrobiodiversity. In the past this often happened through restrictive provisions governing the seed market or one-sided agricultural extension focussing on 'modernization'.

In the context of the utilization of agrobiodiversity, financing the secondary evaluation of genetic resources or characterization of currently used agrobiodiversity is crucial. In particular, the investigation of resistances and specific quality features must be considered.

In order to add valuable genes from genetic resources to elite material and expand its genetic basis, alongside basic evaluation work there is also a need for comprehensive, publicly funded pre-breeding (where possible in association with a gene bank).

Diversity of landscapes and ecosystems E

E 1.1
Classification of landscapes by geography and function

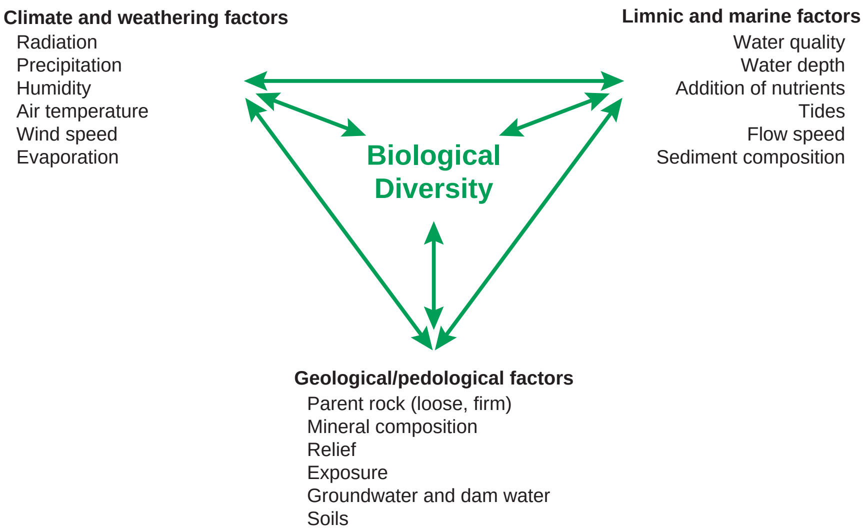
Ecosystems, that is webs of biotic communities and their abiotic environment (Section D 2.3), can be described as three-dimensional physiographic units (Leser, 1997) aggregated to varying degrees, whose boundaries are defined by humans and cannot be precisely determined – unlike those of organisms. They range from ecotopes through to ecotope webs (landscapes) and ecoregions (biomes) right up to continents, the ocean and the globe. Like organisms, they have structures and an ability to reproduce and mutate (Section D 2).

Here, landscapes are viewed as ecosystems at a higher degree of aggregation, ie as a mosaic or web of various ecotopes that may have different sizes, structures, functions and configurations. Landscapes can be understood roughly as units that can be delimited geographically and are largely independent of each other, but are connected with each other via the atmosphere, biosphere and hydrosphere. It is not possible to make a clear delimitation here, since in the longer term even apparently insignificant indirect interactions between the units can lead to radical changes.

Ecosystems with their various communities of plants, animals, fungi and bacteria (Box E 1.1-1) developed in an adaptation process under the influence of the climatic, geochemical and biological conditions of each site (Fig. E 1.1-1). In turn, however, the biotic communities change their environment. If we consider the diversity of site conditions worldwide, ie climatic and geogenic diversity, it is hardly surprising that a large number of ecosystem types can be identified within which the characteristic living communities have formed.

One example of such a large-scale global typification is the categorization into biomes, such as that undertaken by Prentice and Kaplan (1999). This is a grouping of terrestrial ecosystems according to the dominant plant types in each case, based on the old observation that there is broad correlation in the geographical distribution of plants and climates. The result is a highly aggregated division into 28 biomes that is suitable for showing the heterogeneity or homogeneity of the global distribution of ecosystems.

Figure E 1.1-1
Structure and function of site factors that shape natural ecosystems.
Source: WBGU



Box E 1.1-1

Organisms

Organisms are characterized by four properties. They have a specific structure, ie they have outer limits that clearly separate them from the outside world. They have a metabolism that provides energy and nutrients to maintain the functions of life. They can reproduce, ie they are capable of ensuring, by division or by creating offspring, that ageing or dying organisms are replaced by younger, fitter ones. Furthermore, thanks to the ability to mutate (changes in genetic information) organisms are capable of adapting to changing environmental conditions (Section D 2). Moreover, higher organisms are capable of learning. By means of individual information stored in neurones they have another very effective adaptation mechanism.

In order to maintain their structures and life processes, organisms have to be fed usable energy in the form of radiation or chemically bound energy as well as nutrients. Excreted products from organisms, which are released into the environment as heat and wastes, cannot be further used by the same species. Organisms are thus 'flow through systems' whose existence is only ensured by the continued supply of usable energy and substances from outside sources.

These ecosystems are subject to major internal modification by varying geological, pedological and orographical site factors as well as human intervention. The degree of aggregation to be used in each case is determined by the question being addressed. Questions concerning global biogeochemical cycles, for example, are dealt with at the biome level, whereas studies on the ß-diversity of plants (change in the number of species in a habitat) are carried out at an ecotope level. In Germany, for example, 509 biotope types have been identified for questions of biotope conservation and land use planning (UBA, 1997a), whereas the above-mentioned global breakdown according to Prentice and Kaplan names only a few biomes for Germany.

The consideration of landscapes as geographical or functional units can be done at different hierarchical levels. The following is a brief description of landscape-forming elements in their hierarchical organizational form.

E 1.2 From natural to cultivated landscapes

Over millennia, humankind has increasingly intervened in natural landscape diversity and, in the process, has changed its habitat by chance or consciously redesigned it. In the last few decades, humankind has developed into an environmental factor that accelerates the exchange of matter between ecotopes, landscapes, biomes and continents in previously unknown ways. As a result, there are major changes in biological diversity at the species, population and ecosystem level that are hard to quantify and whose consequences cannot be reliably predicted (WBGU, 1998a).

Viewed ecologically, humans are extremely competitive, heterotrophic consumers. With the help of their intellectual abilities, they have considerably developed their biological characteristics and have enriched them culturally. As a being endowed with reason, it is possible for them to foresee events and to design their environment. With these human abilities that have developed over biological evolution, 'culture' has appeared as a new factor in the biosphere. Since then, cultural evolution has accompanied biological evolution and overshadowed it at times, but it has never cancelled it out or replaced it. Cultural evolution can be explained in terms of humans' need to free themselves from the constraints placed on them by nature. If we look at the development of cultural evolution, we can make a rough categorization into five stages that can be identified to varying extents and at different times in all human habitats:

1. Hunter-gatherer stage,
2. Stage of agricultural and forestry land use,
3. Stage of urban cultures,
4. Industrial and high-energy use stage,
5. Information and communications stage.

These five stages came about at different times and characterize the periods named after them, but they have not completely replaced each other. Rather, they can be found next to each other or linked together to differing extents, and they all have a combined effect on the biological diversity of ecosystems. People still hunt and gather today, albeit with different equipment and techniques. Similarly, agriculture and forestry are practised alongside industrial technologies and information technology. Humankind's natural environment was largely changed into a cultivated landscape in the course of this development. In this process, self-organization, reproduction and evolution were replaced to a varying degree by the targeted regulation and control by mankind. The existing structures and internal cycles were frequently destroyed and decoupled during this process. Ecosystems shaped by humankind are therefore often similar to the flow-through systems that are characteristic for organisms. Humankind did not find it satisfactory to confine the adaptation of its needs and wishes to the natural productivity and utility of its habitat. In order to elude the constraints posed by nature, people developed collection, concentration, reinforcement and distribution processes and created the systems associated with these actions. The perfection of hunting and catching methods, the keeping and rearing of similar highly useful animal populations (domesticated animals), the cultivation of high-yielding plants to acquire nutrients or raw materials, the intervention in the water cycle for water supply, irrigation, fish farming or flood protection and the generation of energy from collecting regenerative biomass (wood, peat) are examples of such interventions in the ecosphere. These interventions have increased enormously in the last two centuries as a result of the use of fossil fuels and the spatial and temporal partitioning of biogeochemical conversion processes associated with population growth and compaction in conurbations. In the process, ecosystems were created that were influenced by humankind to varying degrees (Table E 1.2-1). A definition of 'ecosystem' in a broad sense that also includes ecosystems that do not conserve or regulate themselves is used as a basis here. To examine the functional contexts of landscapes, it is essential to understand the linkages among natural, anthropogenically influenced and technological ecosystems.

Ecosystems do not occur in complete isolation of each other; they interpenetrate each other spatially and temporally, with varying intensity, and, in this way, characterize the visual appearance of specific cultivated landscapes (Section E 3.9). With increasing numbers of people and a corresponding increase in the demands they make, cultivated landscapes will continue to expand to the detriment of the natural landscapes that still exist. If this is to be done at a tolerable level, sustainable forms of use will have to be developed for the cultivated landscapes (Section E 3.3).

The interactions that exist at different levels between the biological and technological ecosystems in landscapes are very important for the understanding of their structures and functions. Not taking these dependencies into account can lead to serious errors in the sustainable development of landscapes and make the required measures considerably more difficult. In particular, it is the influence of the constantly growing anthropogenic ecosystems that urgently need further analysis because the majority of emis-

Table E 1.2-1
The most important ecosystem types arranged according to increasing human influence.
Source: Haber, 1993 based on SRU, 1987

A. Biological ecosystems	Ecosystems largely made up of natural components and characterized by biological processes: 1. *Natural ecosystems* Not or hardly influenced by humankind, capable of self-regulation. Examples: Tropical rainforest, sea, rivers, lakes. 2. *Semi-natural ecosystems* Influenced by humakind, but very similar to type 1; hardly any change when the influence ceases, capable of self-regulation. Examples: Many Central European broad-leaved forests, highland moores, shallow seas, rivers, lakes. 3. *Semi-natural ecosystems* Come from human use of type 1 or 2, but not deliberately created; change when the usage stops. Capable of self-regulation to a limited extent; maintenance needed. Examples: Heaths, dry grassland, litter meadows, coppices, dams, ponds, canals and channelled rivers.
Boundary between natural-appearing and anthropogenic ecosystems	4. *Agricultural and forest ecosystems, aquaculture* Commercial ecosystems deliberately created by humankind for the generation of biological food and raw materials made up of crops and domesticated animals, completely dependent on human maintenance, self-regulation undesired, functions are controlled from outside. Examples: Fields, forests, vineyards, plantations, meadows, pastureland, fishponds, fish farms.
B. Technological ecosystems	5. *Technological ecosystems* Deliberately created by man for cultural-technological activities, not capable of self-regulation but completely dependent on external control (with high levels of energy and substance additions) and the biological ecosystems that go through them (type A). Characterized by: - Construction, durable and consumer objects, - Extraction, manufacturing and use processes, - Emissions, - Use of space. Examples: Villages, towns, industrial areas

sions originate from them and they have a decisive impact on the decoupling of biogeochemical cycles.

E 1.3
Anthropogenic influence on the biosphere in terms of landscape – case studies

In order to illustrate the biological changes caused by man, four examples from the terrestrial and aquatic sphere have been chosen from among the large number of existing ecosystems. On the one hand, different factors act on the particular site (Fig. E 1.1-1) and, on the other hand, they have differing use durations and intensities. *Central Europe* (Section E 2.1) serves as an example of a historic cultivated landscape with a changing history of use under temperate climatic conditions favourable for the development of the landscape. Industrial development and high population densities have led to Central Europe largely being shaped by humankind and the natural landscape has given way to an intensively used cultivated landscape whose biological diversity is today falling sharply, after an initial human-induced rise. Shaped by the last Ice Age in many areas, Central Europe has soil rich in nutrients and high landscape diversity because of a changing initial starting situation over a small area. In contrast to the relatively high landscape diversity, the natural biodiversity is on the low side.

Amazonia, the largest area of tropical rainforest in the world, provides an example of a historic natural landscape on largely nutrient-poor soil, but with very high biodiversity (Section E 2.2). After millennia of just marginal human influence, in recent decades this region has been undergoing revolutionary change. The existence of the once largely impenetrable primary forest area has been threatened by immigration, population pressure and development measures that are only controlled by government to a very small degree. The rapid destruction of the fragile ecosystems, large areas of which have not yet been researched, is continuing apace.

As the third largest inland lake in the world *Lake Victoria* represents an isolated, species-rich limnic ecosystem that for centuries was only used extensively to a slight extent. In the last few decades this lake has been undergoing a drastic change as a result of human interventions (Section E 2.3). It serves as an example of how nutrient status and species diversity can be changed or destroyed within a very short time by intensifying land use and introducing alien species.

The *Java Sea,* as a warm, tropical shallow sea, represents an extremely species-rich area typical of shelf areas that are exposed to high use pressure because of their high productivity and the high population density of the surrounding coastal regions (Section E 2.4). Tourism, uncontrolled and unsuitable use of fish populations and coral reefs as well as the intensification of land use, fish farms and advancing urbanization in the coastal area are threatening this habitat.

Development of landscapes under human influence E 2

E 2.1 Development of the cultivated landscape in Central Europe

A steady high has developed over Germany. The weather forecast is predicting warm and sunny days for the late summer; the viewers are wished a pleasant weekend. To illustrate this, pictures of the flowering heather at Wilseder Berg with white flocks of sheep are shown. On the next day, many people from the urban areas around Hamburg, Bremen, Hanover and even the Ruhr region get into their cars in order to experience the 'natural spectacle' of the heather in flower in Germany's oldest nature reserve, after a car journey of one to three hours on the motorway. On their subsequent walk on sandy paths between flowering heather and dark green juniper bushes, only very few are aware that the protected landscape is not a natural landscape at all. This is what is left of a cultivated landscape that was still widespread in north-west Europe 150–200 years ago that came about because of an economic practice that lasted for centuries, if not millennia – heath farming. The basis of this agriculture on the low-nutrient soils of the Ice Age deposits was to remove the nutrients accumulated in the humus from large areas in order to spread them as fertilizer on the small arable fields close to the farm, after they had been used as bedding in the barns. This meant that it was possible to practise subsistence farming on poor soils over a long period. However, this was to the detriment of the areas from which the nutrients were removed, which were around 10–30 times larger than the arable land. These areas lost nutrients and acidified, with the result that in the end only the undemanding *Calluna* heather and a few juniper bushes would grow there. The heather provided the primary grazing for the *Heidschnucke* breed of sheep and the primary source of nectar for bees, that together provided the main products of this type of agriculture: wool, meat, honey and wax. These forms of landscape created by humans, which took up wide expanses of Europe, disappeared after honey was replaced by sugar beet, wax by petrochemical products and finer imported wool pushed rough *Schnucke* wool out of the market.

This example illustrates various aspects. On the one hand, it can be seen that mankind is capable of radically changing landscapes – and this is not just a recent development. On the other hand, it shows that landscape forms created through use and the living communities that shape them can only be conserved when the use that brought them into being is also maintained. However, it is not only the use that has to be continued; the climatic conditions have to continue. Thus, in order to conserve these sites, eutrophication resulting from nitrogen deposits also has to be avoided, a process which the visitors who come by car play a part in. Landscapes and their communities of organisms are thus dynamic ecosystems that can quickly adapt to changing environmental conditions. For millennia humankind has been a shaping factor in all of this.

E 2.1.1 Background

At the end of the Tertiary period, ie around 2.5 million years ago, an extraordinarily species-rich, warm-temperate woody flora had developed over large areas of Europe. It comprised a wide variety of deciduous broad-leaved trees and many conifers. Sclerophyllous evergreens grew in the Mediterranean area and an Alpine flora established itself in the newly-formed high mountains. As far as the fauna of the Tertiary is concerned, the evolution of mammals is most worth a mention, including the emergence of human ancestors. Radical changes for the plant and animal communities came with the Ice Age, the Pleistocene 2.3–2.5 million years ago and the associated temperature decreases. A lasting process of adaptation by the biosphere took place over several cyclical cold and hot periods (glacial and interglacial periods).

During the cold phases there was large-scale glaciation, especially in Scandinavia and the British Isles. The young high mountains running from the

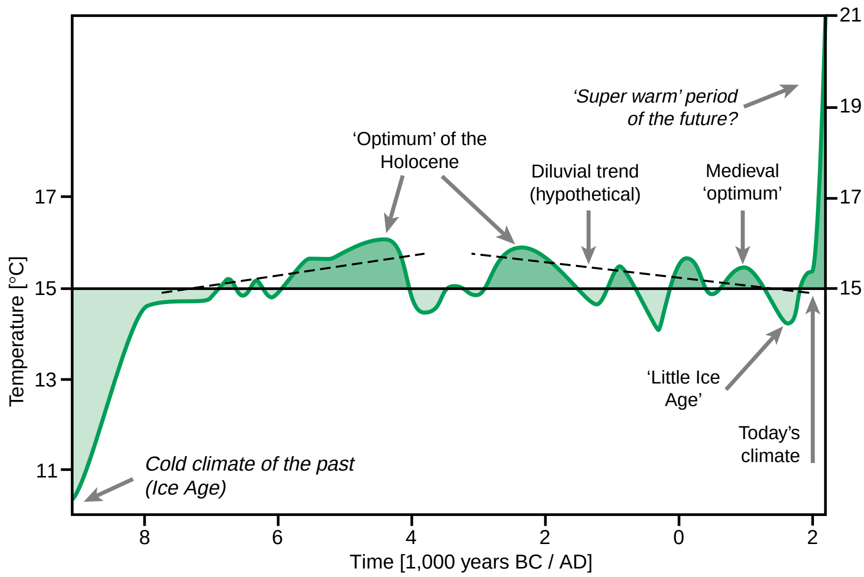


Figure E 2.1-1
Fluctuations of ground-level air temperature in the Holocene with glacial-interglacial transition (approx 11,000 years ago) and predicted warming (human-induced intensification of the greenhouse effect).
Source: WBGU, amended after Enquete Commission, 1990; IPCC, 1992; Schönwiese, 1992a

west to the east (Pyrenees, Alps, Carpathians) carried mighty glaciers and in the south they formed temporarily insurmountable barriers that stood in the way of the migration of plants and animals and, after the ice had melted, made return migration from the southerly or south-eastern refuges difficult.

The wide variety of tree species from the Tertiary was severely reduced in the process. A few species survived in very small, isolated populations. Return migration of the genetically impoverished organisms took place from these refuges. As with the vegetation, the animal kingdom was also affected by the radical change. The cold periods were characterized by steppe and tundra fauna. Mammoths, steppe elephants, woolly rhinoceroses, musk-oxen, steppe bison, horses, giant deer and reindeer were the characteristic representatives of these animal communities. In the warm periods forest fauna dominated, with forest elephants, aurochs, water buffalo, red deer, fallow deer and wild boars.

Modern humans (*Homo sapiens sapiens*) arrived in Europe 30,000–40,000 years ago, probably coming from the East. The humans of the Old Stone Age, who were at the cultural stage of hunters and gatherers, appeared only in very small groups and did not at first have a noticeable influence on the vegetation and the animal communities. At the beginning of the late Weichsel glacial period 15,000 years ago, large parts of Scandinavia and the British Isles were covered by extensive ice sheets; the remaining areas were characterized by tundra, steppe tundra and steppes. Central Europe was almost devoid of forests. At the end of the late glacial period over 11,000 years ago, the steppes and steppe tundra were replaced by a birch-spruce forest in many areas. After several climatic setbacks, a continuous period of warming started 11,000 years ago: today's warm period, the Holocene, began. Fig. E 2.1-1 illustrates that there have been considerable temperature fluctuations over the course of the Holocene. These mainly had an effect on the distribution and structure of the ecosystems.

With the increasing warming during the Holocene climatic optimum, deciduous broad-leaved trees spread north across their current areas of distribution. They were hazel and elm, followed by oak, lime and maple. Alder and ash grew in meadows. Beeches and firs migrated from south-eastern Europe, which became the dominant tree species in the second half of the Holocene. The hornbeam appeared very late on the scene from the south-east. Larch and spruce occurred in mountainous regions. The latter advanced as far as Scandinavia, via Russia. The spread of tree species led to the characteristic and often temporally delayed shaping of forest ecosystems in the various landscapes (Pott, 1993; Lang, 1994). Their modification by the simultaneous change in the site conditions has been identified by Ulrich (1996), for example.

It was not only forests, but also marshes that underwent far-reaching changes over the course of the Holocene. When the ice melted, many lakes formed in the north and in the area surrounding the southern mountains. Initially species- and nutrient poor, water vegetation developed that sometimes resulted in the silting up of the shallow waters. Lowland moors and wooded swamps formed. Marshy moors with sedges and bryophillum mosses formed in waterlogged hollows. Ombrogenous, ie highland moors with sphagnum mosses dependent on precipitation, did not appear until the mid-Holocene and are restricted to certain climatic regions. Their extent

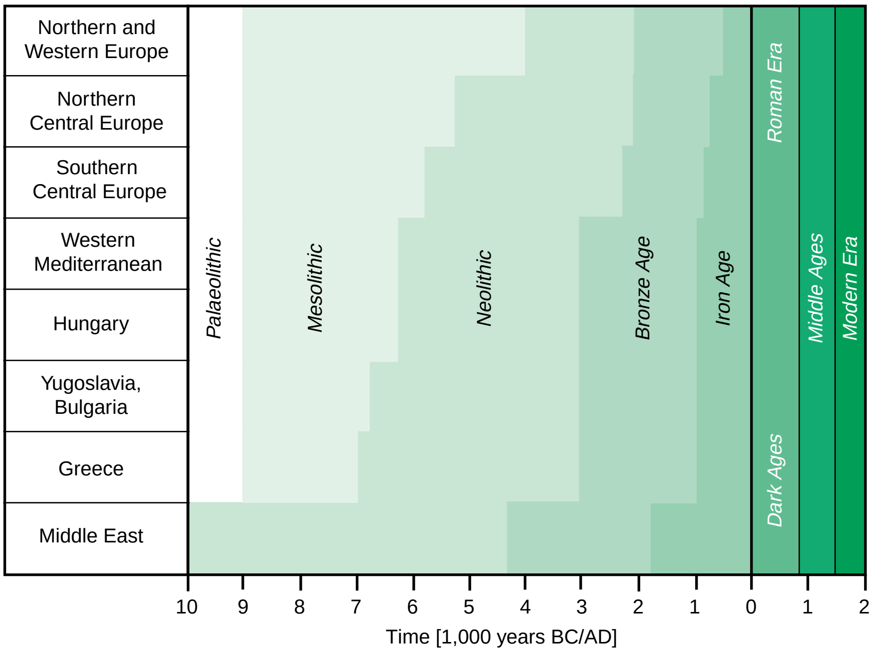


Figure E 2.1-2
Time-delayed development of cultural phases during the Holocene in Europe and the Mediterranean region.
Source: WBGU, 2000a

has already been clearly influenced by humans (Moore, 1975; O'Connel, 1990).

Throughout these times humankind lived as hunter-gatherers for tens of thousands of years. The human population was very small and has been estimated at around 10,000–100,000 people for the whole of Europe.

E 2.1.2
Human influence

During the Holocene, human influence on ecosystems increased. In the first half subsistence-farming forms of land use, characterized by sedentary culture, crop cultivation and animal husbandry, gradually spread over the entire continent from Asia Minor and southern Europe (Fig. E 2.1-2) The 'Neolithic Revolution' saw the start of the claiming of land in the form of forest clearances, grazing and arable farming.

This claiming of land followed a characteristic pattern. During the clearance phase the elms, limes and ash trees decreased first of all and grass and cereal land increased. During the arable farming phase, the fall in numbers of limes, ash and oaks continued, whereas willows, poplars and birches increased, which results in clearance by fire. After a few decades to centuries, the settlements were abandoned. A regeneration phase followed, where the original situation re-established itself.

In the Central European Neolithic Age, the main species of corn grown were emmer (*Triticum dicoccum*) and one-grained wheat (*Triticum monococcum*), and later naked wheat (*Triticum aestivum/durum*), more rarely barley (*Hordeum vulgare*). Only in the northern Alpine foothills and in eastern Central Europe were broom-corn millet (*Panicum miliaceum*) and foxtail millet (*Setaria italica*) grown. Other widespread crops of this period were the pulses peas (*Pisum sativum*) and lentils (*Lens culinaris*) as well as the oil plants flax (*Linum usitatissimum*) and opium poppy (*Papaver somniferum*). At the beginning of the Bronze Age the grain spelt (*Triticum spelta*) and the pulse broad bean (*Vicia faba)* began to be cultivated.

In the coastal regions of western Europe extensive heaths and blanket bogs were formed under human influence. Not only did even prehistoric humans intervene in the vegetation system, they also changed the flora and fauna species assemblage. Along with arable farming many 'weeds' came to Europe alongside alien crops. These then established themselves in the cultivated landscape as archaeophytes. While interventions during the Neolithic Age were limited to relatively small areas of settlement, the influence of mankind grew from the Bronze Age and the Iron Age onwards. On the one hand this is probably associated with population growth, on the other with the further technical development of tools. In southern Europe there was increasing deforestation, even in the mountains, in the pre-Roman Iron Age due to population growth. This development continued during the Roman Empire. The Romans introduced fruit trees originating from the Middle East all over the Mediterranean region and, later, even north of the

Alps. They did the same for viniculture. During the Roman era the preferred crops in the occupied territories were naked wheat, spelt, one-grained wheat and barley. However, rye (*Secale cereale*) also became more widespread. In the areas that were not occupied by the Romans, oats (*Avena sativa*) were cultivated in coastal regions. In the Mediterranean region there was a tremendous reshaping of the ecosystems because peasant agriculture was rejected in favour of large-scale latifundia and pasturage that better satisfied the needs of Rome and the other major cities. Processes that partitioned biogeochemical conversion (Section E 3.2), in conjunction with erosion, led to the large-scale soil degradation that made constant expansion of land use necessary.

During the Dark Ages Central Europe remained settled, but reforestation was not total. However, population density decreased considerably and the remaining population was usually not sedentary, but moved its settlements from time to time. This behaviour did not change until the start of the Middle Ages (AD 800–1500) although even then settlements were founded and then abandoned. A fundamental change in the structure and function of cultivated landscapes was associated with the emergence of fixed rural settlements. As a result of the fixed settlement, permanent land use systems developed around the settlements, which had common land used for set purposes and the 'three-field' system, in which spring and winter corn cultivation were followed by a fallow year. In the latter, the field was left alone to recover, but was also used as grazing land for animals and parts of it were used to grow pulses. Forests, too, were managed very differently by the permanent settlements. Firewood was now always taken from the same place and then re-taken after it had grown back. Individual tree species such as the beech could not withstand this treatment and were pushed back. Others, such as the previously rare hornbeam, became more widespread and oak-hornbeam woods developed instead of the beech or beech-oak woods. As a result of woodland grazing, there were also large-scale interventions in the composition of the stands and living communities, with beech and oak in particular being favoured as mast trees. During the mediaeval climatic optimum from around AD 1150–1300 (Fig. E 2.1-1) towns were founded and grew. In the 13th century, there were already over 2,000 such settlements in which around 20 per cent of people lived in the high Middle Ages. This was the period with the greatest expanse of arable land (Bork et al, 1998). After the major plague epidemics in the mid-14th century, the pressure on the countryside fell considerably (Rösener, 1993). Later, the use of higher land also had to be given up due to the climate (Little Ice Age, AD 1550–1700). Around one-third of the land was left to the forests. It was mainly the land that was least favourable. They were either too wet, too rocky and flat, too poor in nutrients, too steep or climatically unsuitable for the land use. However, the pressure of use on the remaining woods did not ease (Table E 2.1-1). In addition to agricultural use there was now greater removal of wood for building and for fuel for the expanding settlements. Added to this was the growing commercial need for charcoal and wood for saltworks, foundries, mining and glassworks, as well as for potteries, brick-makers and lime kilns. Leaf ash burning and potash mining as well as the growing use of bedding by farmers from AD 1750 onwards were other reasons why the woods were destroyed in many places, as was clearly the case in the 17th and 18th centuries.

The increase in the population and the settlement concentration was closely linked to technical improvements in land use. The head yoke for oxen and the horse collar, just like the use of the horseshoe, allowed better exploitation of the working strength of the animals. Thanks to these inventions, the lightweight top soil plough could be replaced by the heavier wheeled plough. This meant that not only could the soil be ploughed more deeply, but more nutrient-rich loam and clay soils could be cultivated, as a result of which yields clearly increased. The harrow, as a new implement for preparing seed beds, also allowed more intensive combating of the weeds that grew in competition with the crops. All of these measures not only had a positive impact on yields; they were also instrumental in the development of the flora and fauna in the cultivated landscapes. This form of land use that lasted almost 1,000 years led to a great variety of cultivated landscapes and it can be determined that biological diversity reached a maximum in the mid-19th century (eg Kretschmer et al, 1997). Biogeochemical partitioning and interventions in the living communities of fragile ecosystems meant that in many cases 'stability' developed at a very low production level that could only be maintained by constantly adding nutrients from neighbouring systems (woodland, grassland). In the process, it could be seen that progressive degradation of the 'removal area' could quite well go hand in hand with an increase in biological diversity. Typical ecosystems of this period include:

Atlantic heathland characterized by dwarf shrubs. In the north-western European coastal area with precipitation levels of over 1,200mm year^{-1} landscape-shaping marshes, consisting of sphagnum mosses, can be found in close contact with the Atlantic heaths. This is natural vegetation, which, however, underwent an increase in distribution at a very early stage because of deforestation.

Table E 2.1-1
Land use systems and biodiversity in Central Europe.
Source: after Kretschmer et al, 1997

Period	Land use system	Land use designation	Biotope diversity	Species diversity
Post Ice Age to Middle Ages	Natural landscapes without or with limited use	Large primary forests as well as bogs and swamps dominating; large-scale use for hunting; animal husbandry and crop growing starting here and there	Very high in large areas; more or less high in small areas, depending on the landscape type and natural dynamics	Very high in large areas; in small areas usually restricted woodland species; open land species only at special sites (bogs, riparian mea-) dows, cliffs, etc)
Approx 9th century to approx 1750	Mediaeval agricultural system	Large-scale forest clearance; strip farming and grazing (very extensive). Oligotrophication of entire landscapes, very low productivity and some declining soil fertility	Very high in large areas; in small areas increase due to the appearance of diverse oligotrophic open land and successions biotopes (meadows, dry grassland, grazed forests, etc); loss of many types of primary forest	Very high in large areas; suppression of many woodland species (loss of large mammals), spread of open land species, migration of archeotypes and the first neophytes
Approx 1750 to 1950	Modern extensive peasant farming and managed forestry	Separation of agriculture and forestry from large-scale afforestation; replacement of strip farming withversatile crop rotation; better nutrient balances (cultivation of legumes and the use of manure), moderate productivity with improved soil fertility	Still a high biotope mosaic in large and small areas; further destruction of natural biotopes (bogs, swamps, etc); great restriction of mediaeval open land biotopes, some replaced by extensive meadows and forests	Decline beginning in some small areas; continuing very high in large areas; risk to species in previously unused biotopes (eg bogs); start of the suppression of species on oligotrophic sites; increased migration of neophytes
1950 to 1990	Industrialized, intensive farming and forestry	Farming and forestry becoming technical; extensive use of input materials (fertilisers, plant protection agents, melioration); large-scale eutrophication as a result of mineral fertilisers and, in some cases, excessive livestock levels; very high productivity in arable and animal husbandry with high soil fertility	Many cases of loss of the small-area biotope mosaic in agricultural areas; large-scale destruction of entire biotope types (eg highland and lowland bogs, riparian meadows, etc); only small reminders of mediaeval open land biotopes; large-scale levelling of water and nutrient conditions	Large and small scale decline in indigenous species; country-specific 30–70% of all plant and animal species are in the Red Data Lists; greatest losses among the species of oligotrophic sites; some neophytes suppress indigenous species
Since 1990	see above	Management appropriate for the soil; 'damage threshold concepts'; multifunctional land use	Further losses	Genetically modified crops

Woodland as pasture. Initially, humankind had only limited grassland to feed its animals, so woodland was used for pasturage. As a result of the use of leaves as fodder (lopping system) certain tree species were indirectly encouraged. In the Middle Ages, a regulated system of extensive agricultural woodland use with mast, and leaf litter collection for stabling, developed in the woods. In the process, cultivated landscapes with woodland fragments (grazed forests) developed, in which the preferred tree species (oak, beech) were dominant. They also contained communities at their fringes and borders as well as oligotrophic grassland communities that give the misleading impression of a species-rich natural landscape.

Meadows and pastures. They could be found as natural vegetation in Central Europe in only a few sites unsuitable for trees, on the shores of lakes and the edges of marshes as well as at the coasts. The meadows and pastures that exist today originated as a result of grazing and mowing. Over very long periods these were extensively used, unfertilized rough meadows that were subjected to progressive nutrient depletion and acidification. It was only at the end of the Middle Ages, especially in the last two centuries, that intensively fertilized and managed rich meadows appeared.

Field-weed communities. With the start of human settlement 8,000 years ago in the Neolithic period, and with the development of farming, not only crops, but also many accompanying plants, were unintentionally imported, from southern and south-eastern Europe (Fig. E 2.1-3). Depending on the way in which they were used, typical field-weed communities developed that characterized the arable strips. In the areas settled by humans nutrient enrichment and disturbance of the natural vegetation occurred. Ruderal communities developed here, eg mugwort and cotton thistle communities. From AD 1500 onwards, at the start of the Modern Era, plants were imported to Europe. Their regions of origin encompass the globe and their appearance is directly linked to the intensification of trade (Section E 3.6). However, only a few species were able to permanently establish themselves in the natural ecosystems. Although a total of 57 plant species have been proven to have become extinct in Germany, the total species diversity has continuously increased. However, some of the imported plants have spread to such an extent that they are being controlled again because they are a threat to natural or semi-natural ecosystems or are an impediment to agriculture and forestry – and sometimes also to human health (WBGU, 2000a; Section E 3.6).

The composition of the animal world changed fundamentally with the vegetation. The large inhabitants of woodland, such as aurochs and bison, almost died out or became completely extinct; the wild horse disappeared. Elks, brown bears, lynx and wolves retreated to inaccessible areas. The large predators also preyed on domesticated animals and were therefore hunted intensively. The disappearance of natural habitats accelerated this process of exclusion. Birds, in particular, reacted positively to the opening up of woodland and the rigid structure of the field strips. Partridge, quail and skylark can be cited as examples

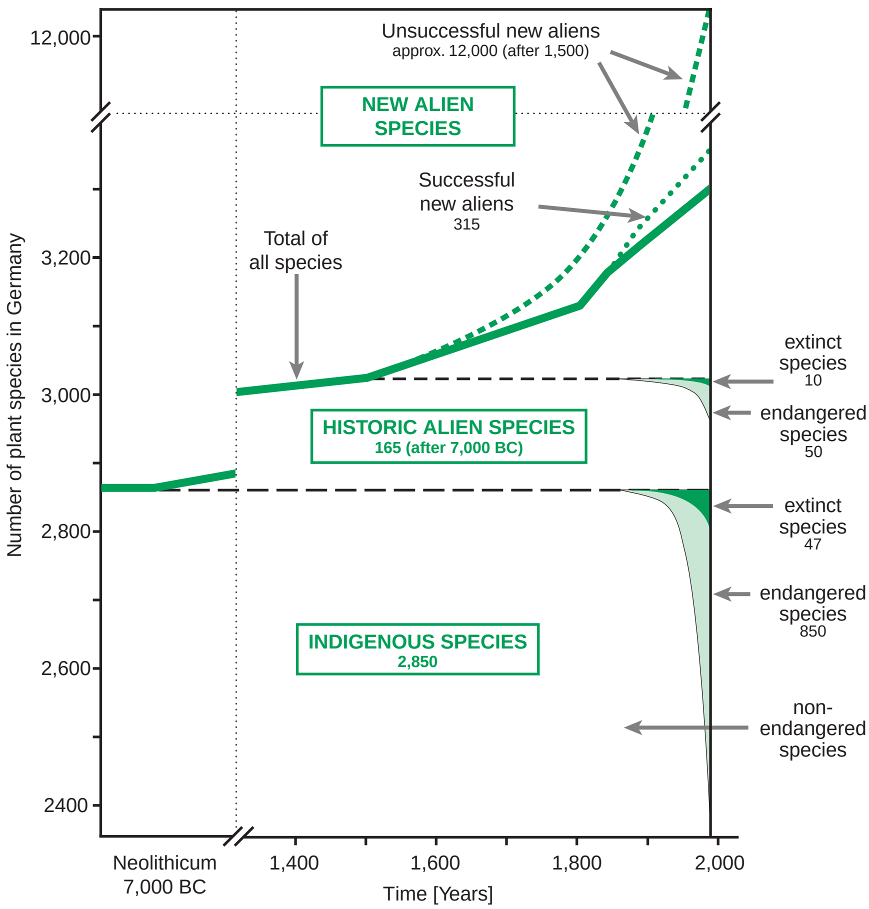


Figure E 2.1-3
Development of plant diversity in Germany.
Source: Scherer-Lorenzen et al, 1999

here. Without the cultivated landscape, around one-third of today's species would not exist.

Many open landscape species are now red-listed as endangered species. The reasons for this are much less the direct impact of agrochemicals than the destruction of habitats and staple diets associated with the change in use. Land uses in the Middle Ages and the first half of the Modern Era led to a diverse landscape in Central Europe, but nevertheless there were clear signs that the landscapes were being overburdened. In the fields yields declined; the potato introduced from South America and the later widespread cultivation of turnips could only make up the deficits to a certain extent.

The Industrial Revolution was humankind's response to the desperate situation. Because of the use of fossil fuels, less wood needed to be used as a fuel, resulting in reprieve for the overexploited forests. The development of modern agriculture with self-contained crop rotations and the cultivation of legumes that started in the early 19th century greatly increased yields. The increasing use of mineral fertilizers and improved plant breeding that had taken place since the mid-19th century also both had a positive impact on yields. As a result, a system based on stabling with fodder grown on the farm (potatoes, turnips, hay) and bedding made of straw from the farm's grain crop became established. These developments led to reprieve for the forests and to an improvement in nutrients for the agro-ecosystems.

The improved management methods in agriculture initially changed relatively little in the biological make-up of the agricultural landscapes, although the increased cultivation of root crops (potatoes, sugar beet and maize) considerably increased the intensity of soil management. Although machines were used more and more, the structure of predominantely small farms was conserved, and – with very few exceptions – the work was done by people and animals. Small fields, varied crop rotations, work processes spread over the whole year, hedges and boundary strips, unpaved cart tracks, moderate applications of fertilizer and drainage characterized the picture. Plant and animal production were still largely linked together in the farms. In addition, the proportion of so-called wasteland such as heaths, marshes, quarries, etc was still relatively high.

A fundamental change did not occur until after 1950, with the increasing mechanization and chemicalization of agriculture. In the subsequent period, ie in just 40 years, animal and human labour was largely replaced by machines. The efficient use of these implements required larger fields. Hedges and boundary strips that were in the way were removed; drains were built and ditches deepened to make the fields dry out more evenly. 'Wasteland' was cultivated, marshes drained and made fertile by the use of fertilizers. By contrast, fertility was increased in sandy soils with irrigation. Crop rotations were simplified until they became monocultures; sowing and harvesting took place on only a few days in the year in all locations. Herbicides destroyed weeds, fungicides the fungi and insecticides the animal pests. In many cases the link between arable and animal production was severed. Concrete or asphalt cart tracks and heavily used transport routes criss-cross the agricultural land.

These measures have raised the productivity of the soils to previously unprecedented levels. It was not deficits that characterized the situation in Europe, as they had previously done so for long periods of time; rather it was surpluses. However, the security of the food supply was bought at the price of a sharp decline in biological diversity and other environmental changes. With the use of genetically modified crops, a completely new factor is coming into play, the ecological risks of which have not yet been fully estimated (WBGU, 2000a).

In contrast, modern technology can be used to largely avoid abiotic pollution. The relief of the pressure on forest soils, or even their regradation, did not result from the specific forestry measures practised for 200 years of the development of agriculture, because increasing levels of acid-forming substances and heavy metals were emitted during the incineration of fossil fuels. These accumulated in the forest soils.

Conifers, in particular, have proved to be effective in filtering out air pollutants. Even in the second half of the 19th century quantities of acid were emitted per ha and year that were above the soil's mean internal buffer rates from the weathering of silicates. Only where there were limy substrates or where flying ash was deposited in the vicinity of the emitters could the input acids be compensated for without the release of ecotoxic cationic acids such as Al^{3+}, Mn^{2+} and Fe^{3+} (Godbold and Hüttermann, 1994; Beese, 1997).

In the second half of the 20th century it was mainly nitrogen, normally a limiting nutrient in forests and other natural ecosystems, that was released and deposited in large quantities. On average, the deposition rates today are around 20–40kg N ha^{-1} $year^{-1}$ (UBA, 1997a). Around 40 per cent of the nitrogen comes from transport, where NO_x is formed during combustion at high temperatures, which is then converted into nitric acid (HNO_3) in the atmosphere. Another 40 per cent of the emitted nitrogen comes from agriculture, where the nitrogen escapes as ammonia in conjunction with livestock farming and the use of slurry, is converted mainly into NH_4^+ in the atmosphere and is then deposited (Lammel and Flessa, 1998). These deposits lead to large-scale nutrient depletion and acidification with simultaneous N eutrophication. Both processes work against biodiversity because they remove locational differences in the landscape or differences generated by man. Thus, today around two-thirds of forest soils can be classed as highly acidified (BMELF, 1997) and receive excessive nitrogen deposits at the same time.

This digression about the development of ecosystems in Central Europe makes it clear that this ecologically 'favourable area', which developed in areas with young, little-weathered substrates and a temperate climate, has undergone an extremely dynamic development over the last 11,000 years. Natural changes in the climate and the soils meant that living communities had to constantly adapt. However, human interventions were especially serious; over millennia humans had deliberately shaped the landscape and, in the process, created a cultivated landscape. In the species-poor region of Central Europe, 'disruptions' caused by humans initially led to an increase in biodiversity, which reached its peak around 100–200 years ago. Today there are 509 biotope types in Germany. Of these, 69 per cent are at risk, whether by the reshaping of landscapes during economic intensification or by the abandonment of conventional use forms (UBA, 1997a). In addition, completely new ecosystems have developed that are still evolving. In this environment, the challenge of biotope and species conservation can only be met by allowing conservation and use to co-exist (Section E 3.9). Protecting processes alone would change this landscape into one consisting almost entirely of woodland, with a corresponding loss of diversity. However, if we want to conserve the cultivated landscape of the past, we will also have to conserve the associated use. All other solutions lead to biological changes whose results cannot always be precisely predicted, but that need to be assessed if the cultivated landscape is to be developed sustainably and in a way that is environmentally sound.

E 2.2
Amazonia: Revolution in a fragile ecosystem

Fine smoke is wafting through the rainforest, blurring outlines under a blue-grey veil and making the sun appear as a milky disc. It started a few weeks ago, intensified, diminished and intensified again, but the smoke, that makes your eyes water and affects your breathing was always there. The fire, with which the small-scale farmers wanted to clear their plots of weeds, wood, scrub and pests as usual, has got out of hand this year. An unusual drought has kept the rain away that would otherwise keep the fires under control and, therefore, large areas of the forest have been burning in many places and for many weeks now. But who is bothered about these fires in the parts of Amazonia far from the major cities? Although the Governor has declared a state of emergency, there is no money for the deployment of fire-fighting helicopters and planes. Because no cities, no international transport routes or even centres of tourism are affected by the smoke, the central government is not very interested in the fires and the international public takes no notice whatsoever of the catastrophe.

Every year 300–500 million ha forest burn down around the world, and it is only reported by the media reports it in exceptional cases. Forest fires are natural and have always destroyed large areas of woodland at certain intervals. Exceptional climatic conditions greatly heighten the risk of forest fires; just lightning striking a dry tree can be enough to trigger an extensive fire. However, forests can regenerate and revert to the original situation from before the fire, but this can take decades to centuries.

People, too, have over the millennia used fire to clear their settlements of vegetation or to clear the forest in order to grow crops. However, this burning down also brought other advantages; the ash fertilizes the soil and neutralizes the acid stored in it, greatly improving the growth of crops. The Indians in the Amazon basin also know this, and they have been using this technique, shifting cultivation, since they migrated to this area about 8,000 years ago. However, they also know when they can burn so that the fires do not get out of control. They also chose such small areas that the interventions would not lead to long-term changes in the overall ecosystem. Because the soil's nutrient reserves are exhausted after around three years, it is no longer worthwhile to grow crops on it. The forest regrows over the cleared area and the settlers migrate to another place, to return 30–100 years later. However, this rhythm has changed. Slowly at first when the first conquerors and colonists appeared at the start of the Modern Era, but then with increasing speed. Today concessionaires, big land owners, gold-diggers and small farmers intervene in the forests, largely without control. The changes induced by the use of the forests, right up to the conversion of the forest into grassland or arable and plantation land, exceed the forests' regeneration capabilities, with the consequence that large areas of primary forest are disappearing.

E 2.2.1
Geological and climatic features of the Amazon basin

What makes the interventions in the tropical rainforests different from interventions in the temperate forests of Europe, North America and Asia, which, are, after all, also being cleared on a large scale? What makes the loss of the rainforests so dangerous for the Earth? To answer this, we need to look back into history. When seen from a plane, the enormous area of the Amazon basin appears like a gigantic green leaf; rivers cut through the area like the veins on a leaf and flow into the Amazon. Its catchment area is 7.2 million km^2, 40 per cent of the area of South America. The Amazon Lowland, the core area, occupies around 50 per cent of this and is less than 200m above sea level. The 5 million km^2 rainforest territory stretches far beyond this lowland area and also covers areas of the central Brazilian mountain and table land in the south and parts of the Guyana massif, the Guyana coastal land and the Orinoco basin (Kohlhepp, 1987).

The Amazon basin is an ancient rift zone that stretches 3,500km from east to west and 2,000km from north to south between the old crystalline shields of Guyana and Brazil. After the Andes were thrust up, the rift was blocked off to the west and an enormous inland lake was formed that then drained into the Atlantic to the east. The soil was formed by clayey and sandy late Tertiary sediments, the 'terra firma', into which the river system cut. When the sea level rose in the Pleistocene, broad flood meadows formed along the rivers, the 'Várzeas' (Sioli, 1984). The homogeneity that can be seen from the air is therefore only an illusion. If we look carefully, a great diversity of physiographic units can be seen.

The Amazon is not homogeneous from a climatic point of view, either. The annual mean temperatures are around 25–27°C, but the daily fluctuations can be as much as 10°C. In the south and south west, incoming cold air can cause the temperature to fall to 15°C. Precipitation is not spread evenly over time or space. In the north west it is around 3,600mm $year^{-1}$, falls to 1,800mm in the central region, only to rise back up to 2,500mm on the Atlantic coast. The precipitation falls in short warm storms in the afternoon or as zenithal rain in enormous quantities. The increase in a weak dry period can be detected from west to east; it lasts up to two months and increases to up to four months to the south.

A distinction is made between white, black and clear water flows, depending on the area of origin. White water flows come from the Andes and carry large quantities of nutrient-rich sediments with them. After deposition, they build up the majority of the Várzeas, which, as flood meadows, have great potential for agricultural use. The black water flows carry very little sediment and do not form any meadows. The black colour comes from humates, the layers of nutrient-poor soil and the vegetation types that form them. The clear water flows come from the already heavily weathered and eroded crystalline massifs, which are also very poor in sediment loads. During the rainy season the rivers and streams of the lowland flood their banks every year for 6–7 months. In the process, they flood the forests to a level of 10m. Ground vegetation and small trees are completely submerged by water. Although flooded forests con-

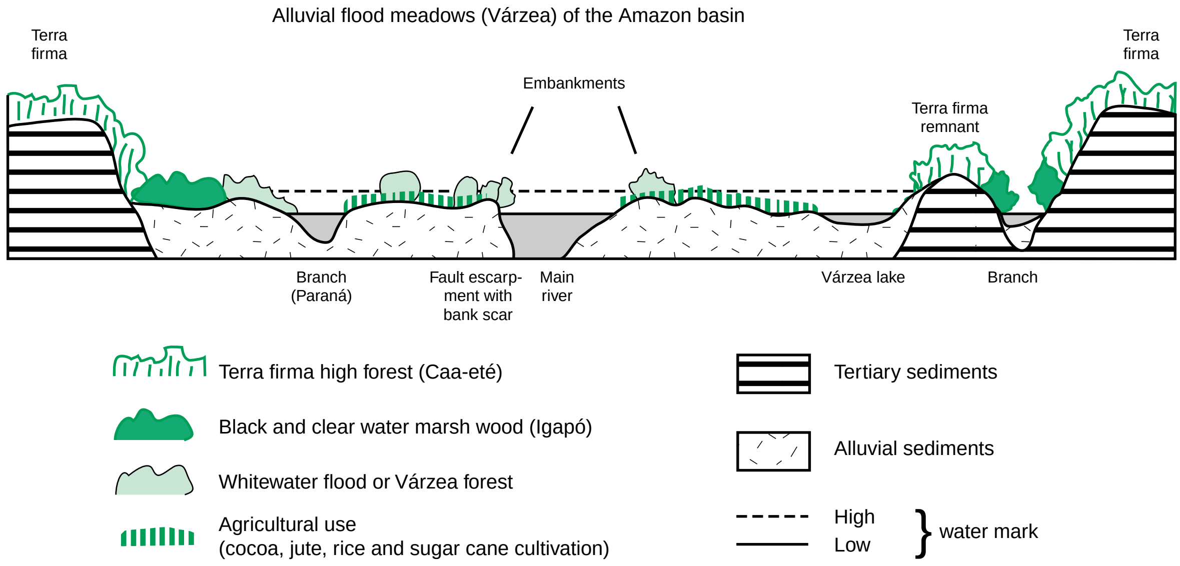


Figure E 2.2-1
Schematic profile through lower Amazonia.
Source: after Kohlhepp, 1987

stitute only some 3 per cent of the rainforest, they make a great contribution to biodiversity (Goulding, 1990, 1993). Fig. E 2.2-1 shows a schematic cross-section through the lower Amazon, indicating the various, site-specific vegetation types and crops.

E 2.2.2
Emergence of biological diversity in the Amazon basin

The Amazon rainforest is considered to be one of the most complex and species-rich ecosystems on Earth. The remarks above show that some of the complexity and diversity results from the locational diversity. With the exception of the nutrient-rich Várzeas, this biodiversity has developed on mostly nutrient-poor and acidic soil, upon which humus layers developed as a refuge for decomposers. Very high ecosystem productivity is achieved by the formation of almost self-contained, internal nutrient cycles, involving a large number of organisms. This depends on the maintenance of the geochemical cycles. Disruptions to these cycles can have catastrophic consequences that can only be balanced out over extremely long periods.

For a long time it was assumed that this diversity was the result of a process of adaptation that had been going on for millions of years. However, this idea has been revised in recent years, because the climate was not constant and there were repeated local or regional disasters. For example, during the Ice Age the climate was colder in the Tropics as well; occasional fires and floods led to temporary, locally limited destruction of the forests. However, these phenomena did not destroy the flora and fauna, as the Ice Ages did in Europe or North America; through the destruction they led to an increase in biodiversity. The entire ecosystem is, as was shown, by no means uniform. Differences in the soils, precipitation, floods and geochemical inputs, linked to differing dry periods, caused evolution that varied greatly from place to place. All of this meant that the Amazon basin is a colourful mosaic of the most varied ecotopes with living communities in varying stages of succession, but which has hardly been researched to date in terms of its multifaceted structures and functions.

The question as to why there is such high diversity in the Tropics has not been completely answered. This fact makes its difficult to develop strategies to conserve diversity. The ecological factor of 'diversity' not only contains the number of species in an ecotope, but also their relative frequency. This diversity is called α-diversity. Here, a distinction is made between β-diversity, a measure of the differences of species compositions in living communities in neighbouring and similar habitats and the γ-diversity of large regions with very different habitats and ecosystems. The prevailing opinion is that in the Tropics, in addition to favourable conditions for the formation of species, there are also, above all, favourable conditions for the conservation of species. The question is why the many species, which are mostly extremely rare, do not become extinct or why individual species do not become superior in terms of competition at the expense of others.

In this respect, two basic hypotheses are discussed (König and Linsenmair, 1996). In the deterministic equilibrium models it is assumed that the available resources are partitioned by means of competition between species with similar demands. In the stochastic models it is assumed that the occurrence and frequency of individual species is determined by random processes. Gaps in the ecosystems come about through disruptions that cannot be spatially and temporally foreseen. The latter models expand the spectrum for explanation, but the former models also appear justified. The factors that promote diversity definitely include habitat richness and heterogeneity in the ecosystems. The various storeys of the forests and soil diversity offer many structurally and microclimatically differentiated niches. The size of the area and the age of the system also correlate positively with biodiversity. But diversity is also characterized by the establishment of varied relation between the species. There are many examples of this in the tropics. The nutrient-poor status of many tropical soils promotes diversity of primary producers, ie green plants. In turn, this diversity promotes diversity of consumers and decomposers in the subsequent trophic levels. There are many factors that promote the great diversity in tropical ecosystems. Nevertheless, it is currently not possible to satisfactorily explain the diversity that occurs in the various ecosystems.

E 2.2.3
Human intervention

The Amazon basin is an ecosystem that was subjected to continuous change. However, the disruptions always took such a form that large parts of the ecotopes remained because of the geographical differentiation and subsequently interlinked with the developing systems in the disturbed zones. The appearance of the forest Indians around 8,000 years ago is an example of disruptions in history that remained within the sphere of internal 'scope for repair'. Cultivation techniques and hunting possibilities were of such limited extent that the original inhabitants did not pose a threat to the viability of the ecosystems. In 1500, the colonization of Amazonia started. The eastern part was assigned to the Portuguese by the decree issued by Pope Alexander VI, the western part to the Spaniards. The entire area subsequently became a Portuguese colony. Whereas the forest was soon cleared and settlements in which agriculture dominated were formed in the eastern part, settlements for military reinforcement and to convert the Indians to Christianity were established along the Amazon and its major tributaries. This form of 'development' had very little impact on the ecosystems and took place over centuries. Amazonia was considered to be hostile to life, a 'green hell'.

This changed in the 19th century. It had been discovered that the juice of a tree (*Hevea brasiliensis*), which was called latex, was suitable for impregnating fabrics and for the manufacture of rubber. The invention of the rubber tyre by Dunlop in 1888 led to a veritable boom in rubber tapping, as a result of which around 500,000 tappers migrated into Amazonia from the arid areas in north east Brazil. Once the Brazilian rubber monopoly had been broken, the development stagnated around 1910. This situation changed only in the second half of the 20th century when Amazonia was placed at the heart of government development strategies to put a value on the natural resources of the rainforest region. Moving the capital to the newly established Brasilia as well as the construction of the Transamazonian Highway and other roads are an expression of this intention.

The social tensions in the densely populated north east of the country are pushing development further. Improvement in the infrastructure, major agro-colonization projects, the promotion of the use of wood, the expansion of beef production and plantation management as well as the use of minerals were all associated with this. Whereas during the rubber boom the interventions in the rainforest were low due to the relatively small number of rubber-tappers, the new measures taken have a different quality that lead to a destruction of large areas of rainforest. The roads and paths that were established for the development of the forests are the lesser problem here, since they only take up a relatively small area. However, they are a prerequisite for the subsequent intervention in the forest, ie the removal of less valuable trunks, causing major damage to the remaining stands. Although there are rules for the sustainable use of the forest and there are also export regulations for tropical hardwood, it is suspected that 80 per cent of the high-grade timber felled in the rainforest is smuggled out of the country (Overexploitation Syndrome; Chapter G).

However, it is not only the mining companies that exploit the major minerals in this region that cause damage, but also the *garimpeiros*, the gold-seekers who devastate the forest with their heavy equipment or contaminate the soil and rivers with the mercury that they use to mine gold. Roads and paths are also the entry points into the rainforest. Whereas large land-owners destroy the forest in order to practise large-scale grazing or plantation farming, with the cultivation of soya for export currently being favoured, the small farmers clear the forest to survive.

Most of the planned agricultural reform is being realized in Amazonia. In this process, families are allocated a piece of land. In order to be able to develop it, they set fire to it. However, the majority of primary forest soil is extremely poor in nutrients, meaning that it is only possible to grow crops for 3–5 years. As a result, the farmers are forced to move on and to clear new areas, while the old land either becomes grazing land or regenerates and becomes a secondary forest within decades. As shown at the start, these clearances by fire, which are officially banned, can get out of control and lead to terrible primary forest fires that change entire landscapes. The 'Landless Movement' is playing an increasing role in the destruction of the rainforest because of the growing population. On the one hand, the conversion of the rainforest is legitimized with the argument of reducing poverty; on the other hand the movement is also used as an argument to oppose protected areas or reserves for the indigenous population. On the whole, well over 500,000km^2 have undergone deforestation by clearance and fire; that is over 15 per cent of the original extent.

New studies from Amazonia show that large areas have also suffered preliminary forest fire damage that to date could not be identified by conventional satellite evaluations. These very slowly progressing small fires below the canopy lead to the ground vegetation and the younger trees dying off. The remaining dead biomass forms the seat of subsequent fires. Studies show that this is how large areas can be destroyed within a few years. The fire risk is further amplified by the El Niño effects. Around 980,000km^2 are at great risk in this way (Cochrane and Schulze, 1999).

Often degraded soils remain, on which the original vegetation can no longer develop – or can only develop over very long periods. The land cleared and then abandoned by the small farmers is frequently taken over by the big landowners, who then convert it into grazing land for cattle husbandry. Poor, dense grazing land is formed where the precipitation cannot penetrate into the soil, but runs off the surface, leading to erosion. As a result, the degradation process that has started continues, with the result that new arable and grazing land is constantly needed. This is a vicious circle that could only be interrupted if the necessary development were to concentrate on the more fertile 'favourable areas' of Amazonia and if the existing knowledge concerning sustainable, multifunctional land use (Section E 3.3.4) were used.

E 2.2.4
Comparison of intervention in tropical and temperate forests

Now what is the cause for the different behaviour of tropical and temperate forests after human intervention? If we ignore the soils in the flooded areas, whose sediments mainly come from the western mountainous regions – these are, as outlined above, frequently old and heavily weathered soils that are barely capable of storing nutrients or supplying them from minerals. The nutrients needed for the plant populations come from the humus, which is decomposed over relatively short periods of time at high temperatures and high soil humidity, but is constantly regenerated from the population waste. The biodiversity of the ecosystems has meant that an internal nutrient cycle has been able to develop, although the very high and intensive precipitation, the high turnover speeds and the extreme shallowness of the soils counteract the maintenance of the biogeochemical cycles. If humankind intervenes in this complex process chain, it breaks up the biogeochemical cycles, nutrients are washed out quickly and there is a dramatic increase in soil erosion and loss of living communities.

The much younger soils of the temperate zone are, by contrast, generally much less sensitive to interventions. They have weatherable minerals, which can supply nutrients in the event of disruptions, and thus have stronger buffers against external pollution. As a result of the seasons, the lower winter temperatures lead to slackened vegetation growth and phases with greatly reduced conversion rates. During this time human interventions are largely harmless. Furthermore, the level and the intensity of the precipitation are much lower, causing less nutrient leaching and erosion.

As shown in the previous case study for Central Europe (Section E 2.1), human interventions have extended over a period of 6,000 years, whereas the large-scale intervention in Amazonia has only been taking place for 50 years. Nevertheless, the origins of the phase currently being undergone there can certainly be compared to the clearance phase of the Middle Ages in Europe, even though the intensity of the change is much greater today. The consequences for biodiversity are, however, completely different. In Central Europe the use of land in young, species-poor ecosystems led to an increase in diversity because of the creation of zones of disruption and nutrient depletion. In the old Amazon region with its great diversity and rare species, the opposite effect is being achieved (Box E 2.2-1)

Many scientists see no future for the rainforest. Even before the biological wealth of this region has been recorded, the majority of it will have disappeared. The fact that we are particularly worried about the forests of Amazonia is because this is the region with the highest species diversity in the world and 'only' 15 per cent of the area has been destroyed, meaning that it may be possible to conserve it. In a country with rapid population growth, however, an attempt to save nature will certainly fail if the economic and social situation of the people is not improved at the same time. To do this, appropriate land use strategies will have to be developed and put into practice (Section E 3.3).

The sooner a start is made on linking use to the protection of the ecosystems by means of bioregional management (Section E 3.9), the greater are the chances to conserve large parts of this irreplaceable region that is so important for the world's climate.

E 2.3
Introduction of the Nile perch into Lake Victoria: a Pyrrhic victory in economic terms?

Around 35 years ago a bucketful of Nile perch from nearby Lake Albert was tipped into Lake Victoria in order to give the local population a new source of food. This was successful, at least in the short term. However, the contents of this bucket had the effect of releasing a genie from a bottle, because it was enough to extinguish well over half of the approx 400 tilapia (cichlid) species only present here (endemic) within just two decades (Goldschmidt, 1997). Their biomass fell by 99 per cent to below 1 per cent of the entire fish biomass in Lake Victoria (Stiasny and Meyer, 1999). The Nile perch (*Lates niloticus)* became one of the most important sources of food and income for the populations of Kenya, Uganda and Tanzania. In 1994 almost 400,000 tonnes Nile perch were fished and sold – probably even more. However, since this record year yields have been falling and the water quality of Lake Victoria has deteriorated drastically. The recent history of Lake Victoria is a lesson in the conflict between the needs of the local population to survive and the conservation of the world's natural heritage.

The changes to the Lake Victoria ecosystem can be ascribed to natural and anthropogenic effects, with no agreement on the relative importance of the individual factors:

Box E 2.2-1

Significance of the Species-Area Relationship for different habitats

The number of species per unit of area is termed species diversity. However, this diversity is not a fixed factor for an ecosystem; it is greatly dependent on the size of the area. The larger the area, the higher the number of species and vice versa. MacArthur and Wilson (1967) were the first to recognize this relationship, which applies to all groups of organisms. It can be shown in the equation

$$S = C\,A^z$$

The relationship is exponential, S is the number of species, A is the size of the area, z an exponent, which is also called the 'exponent of insularity', and C is a factor that depends on the species richness of the animal or plant group concerned. Fig. E 2.2-2 uses the example of Central European breeding birds to show the course of the species-area relationship for extensive rural areas. The function of this relationship is represented in logarithmic extrapolation by a rising straight line between points L and O. Below point L, which marks the limit value of the area size of around 1km² for Central European breeding birds, investigation results show the exponential decline in species diversity in smaller areas. If there is an over-proportional increase in the number of species in relation to the species-are relationship in the investigation results, as marked by point O, this is an indication that area limits have been exceeded and another area type has also been incorporated. Minimum sizes of areas that are necessary for certain animal or plant groups can be determined with the species-area relationship, and biotope boundaries can be checked. It can also be seen whether compound systems still function as a unit or not. 'Expected values' can be derived with the help of species-area relationships if factor C and exponent z are known.

The expected values can be used to evaluate the actual state, ie their deviations above or below the expected value.

If the situation in Central Europe is compared to Amazonia, it can be seen that the number of species rises much less with increasing area in Europe than in Amazonia, in the case of breeding bird species, for example, by a factor of five (Reichholf, 1998). The reason for this is the greater insular occurrence. This has far-reaching consequences. Whereas in Europe a few per cent of protected areas are enough to largely protect the population of a species, the areas in the tropics have to be much larger to achieve the same effect. The European biotic communities are characterised by much greater 'cooperative living', those of the tropics by much greater 'coexistence'.

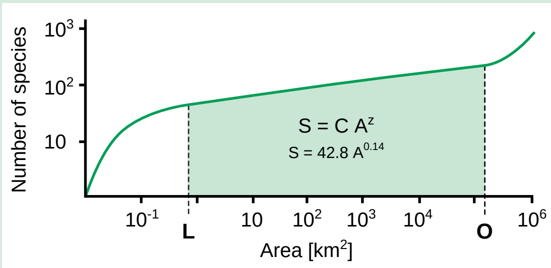


Figure E 2.2-2
Function of the species-area relationship.
Source: Reichholf, 1998

– Eutrophication as a result of changes in land use and sewage,
– Changes in the biotic communities as a result of the introduction of an exotic species,
– Short-term natural climatic fluctuations.

E 2.3.1
The eutrophication of Lake Victoria

With an area of 68,460km² Lake Victoria is the third largest inland lake in the world and the largest in Africa (Herdendorf, 1990). In the past, differences in precipitation led to considerable fluctuations in the lake level (Nicholson, 1998). Since 1960 the lake has risen and the surface water temperatures have increased by 0.5°C. Whereas in the early 1960s the water was always aerated at depths of up to 55m, the water's oxygen content now decreases sharply below 30m (Hecky, 1993). Two factors are held responsible for the oxygen depletion at depth: the eutrophication and stabilization of the water column as a result of greater heating of the surface water.

The rise in the water level in recent years has led to the washing out of flooded soils in the immediate vicinity of the lake. Since these soils are rich in apatite, large quantities of phosphorus get into the lake. This means that, in contrast to most other lakes, nitrogen is the production-limiting nutrient (Holtzman and Lehman, 1998). The nitrogen mostly comes from diffuse discharges from the surrounding land as a consequence of the concentration of the population near the shore and the intensification in animal husbandry. The widespread burning of forests and savannahs, also in the further environs of the lake, leads to considerable nutrient discharge via precipitation (Hecky, 1993). In the early 1960s the algal plankton mainly comprised diatoms (*Aulacoseira* [*Melosira*] *nyassensis* var. *victoriae*, Kilham, 1990). Today, the nitrogen-fixing cyanobacterium *Anabaena* is dominant. The disappearance of the few suspended large diatoms is possibly a consequence of the stabilization of the water column as a result of the warming of the water surface. The appearance of *Anabaena,* however, is a clear indication of the eutrophication of Lake Victoria. At the same time, primary production increased considerably (Hecky, 1993). Every year around 20kg of organic matter is produced per m² (by way of comparison: the figure for Lake Constance is 3kg). As a result of the shallower water (on average

40m) and the long water residence time (approx 100 years), the lake is especially sensitive to eutrophication (Vollenweider, 1968).

E 2.3.2
Formation of the tilapia species as a textbook example of the theory of evolution

MacArthur and Wilson (1963) explained the number of species on islands by establishing a balance between the invasion of new species and the extinction of existing species, with the resultant number of species increasing with the size of the island. Barbour and Brown (1974), Magnuson (1976) and Eckmann (1995) were able to show, with a statistical analysis of many lakes, that this regularity can also be applied to lakes and the number of fish species does actually increase with the size of the lakes studied. For Lake Victoria this would thus mean a theoretical number of around 100 fish species (Magnuson, 1976). However, there are actually almost 400 cichlid species. As a result of the molecular-biological examination of their genetic material we can conclude that all tilapia in Lake Victoria have descended from a single ancestral form that migrated from Lake Tanganyika (Barel et al, 1977; Meyer et al, 1990). These tilapias are a textbook example of the process known as 'adaptive radiation', comparable to the Darwin finches on the Galapagos Islands. Adaptive radiation describes a process in which new forms develop from an original form after colonizing a habitat, by adapting to the different biological conditions. In the case of tilapias this process was favoured by low population sizes, intensive brood care and the genetic isolation of individual populations (Stiasny and Meyer, 1999). Since it is probable that Lake Victoria almost completely dried out around 12,000 years ago, it can be assumed that this species diversity has developed over an extremely short period of time for a speciation process (Stiasny and Meyer, 1999). In contrast to this, the large number of endemic species in Lake Baikal in Siberia (around 2,000) is due to the great age of this lake (approx 35 million years) (WBGU, 1998a).

E 2.3.3
The changing face of Lake Victoria's ecosystem

The population in the catchment area of Lake Victoria used to mainly live by subsistence farming and animal husbandry; fishing played a subordinate role. In 1962 the Nile perch from Lake Albert was released at Entebbe; another release took place in 1963 (Lowe-McConnell et al, 1992). The Nile perch is a fast-growing predatory fish that reaches a weight of up to 200kg. One of the people who knew the east African lakes best had warned against such stocking measures (Fryer, 1960). The Nile perch really did reproduce rapidly in Lake Victoria and caused the extinction of many tilapia species. In the open water 93 per cent of all tilapia species were eliminated; on the rocky coasts around 70 per cent, and in shallow areas 30 per cent (Goldschmidt, 1997). Only species that live in areas that cannot be sought out by the Nile perch were protected (Kaufmann, 1992). Fears initially expressed that the Nile perch population could collapse after eliminating the tilapias, which were their original source of food, have not been realized. In particular, the following changes to the food web in Lake Victoria arose (Goldschmidt et al, 1990):

- The Nile perch has replaced most of the fish-eating tilapias as well as the catfish that feed on tilapias (*Bagus dokmae* and *Clarias gariepinus*).
- The prawn *Cardinia nilotica* has replaced the previously numerous, particle-eating cichlids and is the most important food source for young Nile perch. Furthermore, 30 per cent of the food of the Nile perch is mosquito larvae of the genus *Chaoborus*. During the day both species flee to anoxic deep water layers, which the Nile perch cannot reach because of its need for high levels of oxygen (Branstrator and Mwebaza-Ndawula, 1998).
- Some of the ecological niches previously inhabited by tilapias have not been occupied by other species. This means that in today's ecosystem there is lack of species that feed on phytoplankton. As a consequence, the biomass of the algal plankton increased greatly. Tilapias that eat insect larva were not replaced either, meaning that mosquito larvae, above all, reproduced rapidly (Goldschmidt, 1997; Lehman et al, 1998).

E 2.3.4
Is the transformation of Lake Victoria a blessing for the local population?

With its high fishery yields, the Nile perch has led to a radical transformation of the economy around Lake Victoria. Since 1980 the annual catch of Nile perch has risen to 362,000 tonnes, 29 per cent of which are caught in Kenya, 27 per cent in Uganda and 44 per cent in Tanzania. The income of the three riparian states from the export of Nile perch (marketed as 'Victoria perch') are around US$140 million per year. The Nile perch has become one of the most important export products for Uganda and Tanzania. The main buyers are Europe, Israel and Australia. In the EU, imports of Nile perch rose form 4,000 to

18,000 tonnes between 1990 and 1994 alone (Megapesca, 1999). Initially, fishing was done from small boats. The rapid development of Nile perch fishing since 1990 was largely possible thanks to improved catching methods. As a consequence of the advancing centralization of the fisheries industry in East Africa jobs are being lost and the local fishing industry is becoming much poorer again (O'Riordan, 1997). Therefore, the question of future development is raised from a socio-economic point of view. However, the emerging ecological problems may be even more serious in the long term:

- *Overfishing*: The future prospects for fishing on Lake Victoria appear to be favourable only at first glance. The slight drop in fishing yields since 1994 indicates that the populations are already being overfished. The hauls from small boats fell from 50kg to 10kg per boat. The practice of using pesticides to catch Nile perch, which has only recently become known, could be an indication of catches that are already falling dramatically (Chapter B). In spite of the extremely high primary production, fish production in Lake Victoria is comparatively low.
- *Ecosystem degradation and eutrophication*: The rapid eutrophication of Lake Victoria is another uncertainty factor in the future of Nile perch fishing. As a result of the introduction of the water hyacinth (*Eichhornia crassipes*) in 1990, which spread rapidly as a consequence of the lake's high nutrient content (Twongo, 1993), the fishing situation has deteriorated further. The water hyacinth shades the water below it, greatly impairing or completely preventing the photosynthesis of the phytoplankton due to a lack of light. As a consequence, oxygen-demanding processes dominate even near to the surface. With the high water temperatures, the oxygen may be used up completely within a very short time under these conditions. In recent years there have therefore been several incidents of mass fish deaths.
- *Destabilization of the trophic structure*: The destruction of the endemic tilapia populations not only resulted in the extinction of a unique, extremely species-rich biological community. It also meant that a complex and finely-balanced food web was replaced by a simple food chain dominated by just a few species. Due to the loss of oxygen as a consequence of the heavy eutrophication there is a growing restriction on the Nile perch's habitat. The tilapias compensated for their low numbers of young with marked brood care behaviour (K selection) and had a varied food spectrum that protected resources. In contrast to this, the food web is now dominated by the rapidly reproducing Nile perch (r selection). Ecologists fear that this food web, which is dominated by a single keystone species, is unstable, especially when the future existence of this single species is under threat.

E 2.3.5
Loss of world natural heritage: destruction of native fish populations in favour of a alien species

The introduction of the Nile perch into Lake Victoria put the food security and economy of the riparian states Kenya, Uganda and Tanzania onto a new footing within less than 20 years. This was done at the expense of the extinction of a significant proportion of the tilapia species that lived there. A unique piece of world natural heritage was destroyed in this way. However, it is suspected that at least some of the tilapia species that have disappeared would have died out anyway as a consequence of the eutrophication of Lake Victoria, regardless of the introduction of the Nile perch. The destruction of the native fish populations has caused a drastic change in the natural structure, which is now dominated by a single species. As a result of overfishing and the continuing eutrophication of the lake and the associated loss of oxygen, there may be a collapse or a major impairment of the fishing industry. What started as a success story at the expense of a unique piece of natural heritage could prove to be Pyrrhic victory within a few years.

E 2.4
The Indonesian shallow sea: destruction of an ecosystem through overuse and mismanagement

Just like every evening, the elegant restaurants of Hong Kong are overflowing. Rich business people want to offer their trading partners from overseas something really special today: the lips of the Napoleon fish (*Cheilinus undulatus*). This luxury is worth up to US$300 per guest to them, but first of all the colourful fish, weighing up to 30kg, has to be admired in the restaurant aquarium while it is still alive. The Napoleon fish is the emperor of the coral reef fish, and its exorbitant price is by no means least due to the rapidly dwindling populations. Would the guests from Chicago, Düsseldorf or Tokyo enjoy their dinner quite as much if they knew how the fish is caught? A few hours earlier the fish was anaesthetized by a diver with a cyanide solution in one of the extensive coral reefs off the coast of Indonesia. Since the fish had retreated into one of the countless cracks in the reef, the reef had first of all to be destroyed with a crowbar. Only then could the anaesthetized animal be caught. Many other smaller organisms died from the dose of cyanide.

Cyanide fishing was only introduced in the Philippines in the late 1950s, but today it has great economic significance in the entire Indopacific region. 20,000– 25,000 tonnes $year^{-1}$ are exported, mainly to Hong Kong and primarily from Indonesia. However, many of the fish caught never reach the market because they die as a result of the cyanide dose being too high. The catch figures are therefore higher than the export quantities. Every year turnover in the trade in the precious food fish is around US$1 thousand million in the Indopacific and another US$200 million are earned for aquarium fish, which are mainly sold to customers in the USA and Europe (Tomascik et al, 1997). It is estimated that there are no more than 20,000 cyanide fishermen; in other words a small guild that lives dangerously: for many hours each day they pursue their difficult work at depths of 15–20m, equipped with a spray bottle with cyanide solution, supplied with air to breath through a compressed air hose that has a strong smell of exhaust gases. The cyanide fishermen have comparatively good incomes; the real money is earned by others, though: the local dealers and those in far away Hong Kong.

Cyanide fishing is only one of the many threats to the coastal ecosystem of Indonesia. 45 per cent of Indonesia's coastline is covered by coral reefs, corresponding to an area of $86,000km^2$ (greater than the area of Austria). Mangrove woods cover a total area of $25,000–38,000km^2$ (Tomascik et al, 1997). As a result of the heedless exploitation of its marine resources, not only are precious ecosystems being destroyed in the whole of Indonesia, but in the medium term an important basis of the life of the population is being thrown into question. In the following, the burning issues involved in this problem are outlined: the overuse and destruction of the coral reefs and mangroves as well as the Indonesian fishing industry.

E 2.4.1
Coral reefs

Because of their high temperature requirements, corals are limited to the tropics and the subtropics. According to recent analyses, their worldwide extent in shallow water is estimated at $255,000km^2$ (Spalding and Grenfell, 1997). With a share of around 15 per cent of the worldwide area covered by coral reefs, the Indonesian coral reefs are the most extensive in the world. Corals are typical of low-production (oligotrophic) seas. The occurrence of reefs in relatively productive waters, as in Indonesia, is an exception. With 700–4,500g C m^{-2} $year^{-1}$ (Tomascik et al, 1997) their productivity is almost twice as high as that of the surrounding shallow sea (180–2,600g C m^{-2} $year^{-1}$; Gieskes et al, 1990). Their biological productivity based on self-contained geochemical cycles is among the highest in marine habitats and is the basis for the high fish yields that can be achieved here. Alongside the tropical rainforests, coral reefs are among the most species-rich ecosystems on Earth. To date, 800 reef-forming species of corals have been described. In addition, reefs house a characteristically species-rich biotic community, eg around 4,000 fish species (Paulay, 1997). In total, 1–9 million species are thought to be associated with coral reefs (Norse, 1993). In the areas between Southeast Asia and the Great Barrier Reef alone, over 700 coral, 1,500 fish and 4,000 mollusc species have been described. It is suspected that the species diversity of coral reefs is actually much higher (Wilkinson and Buddemeier, 1994).

Economic significance of coral reefs

The annual worldwide actual net output from coral reefs is estimated at around US$375 thousand million (Costanza et al, 1997). Around 25 per cent of fisheries in developing countries are based on coral reef fish with a total value of US$50–100 thousand million (Kaufmann and Dayton, 1997). As a result of overfishing and destructive fisheries practices, in Indonesia alone there is annual damage of US$10 million. With careful management, profits of US$320 million could be achieved in this country and 10,000 fishermen employed. Around 15 tonnes fish and other marine animals can be harvested per km^2 of coral reef (Cesar, 1996). Organisms in coral reefs are regarded as a promising source of natural substances for the production of medicines (Birkeland, 1997; Section D 3.3). Another important function of coral reefs is coastal protection (erosion and flood protection).

The threat to coral reefs

Coral reefs are threatened directly by construction measures and damage from divers' fins (Jameson and Smith, 1997). Added to this are damage from sedimentation and the eutrophication of shallow water areas near coasts resulting from discharges from the land (fertilizers, sewage). As a consequence, corals are shadowed by the developing algae plankton. The occasional large-scale development of algae that cover the reefs and kill them is similarly serious (Dubinsky and Stambler, 1996). Overfishing also often makes major changes to the structure of the reef biotic community, especially when keystone species (Box D 2.4-1) are eliminated. Thus, for example, sea urchins gain the upper hand through their

Table E 2.4-1
Threat to coral reefs.
Source: Bryant et al, 1998

Region/Marine area	Low risk potential [%]	Medium risk potential [%]	High risk potential [%]
Middle East	39	46	15
Caribbean	39	32	29
Remaining Atlantic	13	32	55
Indian Ocean	46	29	25
Southeast Asia	18	26	56
Pacific Ocean	59	31	10

Table E 2.4-2
Evaluation of the state of the Indonesian coral reefs.
Source: Tomascik et al, 1997

State	Coverage rate with living corals [%]	Proportion of total area of Indonesian coral reefs [%]
Intact	75–100	7
Good	50–75	22
Moderate	25–50	28
Badly damaged	<25	43

natural enemies being fished and they then destroy large coral populations. Destructive fisheries practices (cyanide and dynamite fishing) destroy practically all the organisms in coral reef ecosystems. Pollution from the sea comes from the release of ballast water from ships containing oil and from oil accidents. As a consequence of these negative influences it is not only the biodiversity of the biotic communities is under threat; important use functions are also impaired (Bryant et al, 1998).

Increased water temperatures lead to dramatic changes in coral reefs, the bleaching of the coral. In the process, the corals lose 60–90 per cent of the symbiotic single-celled algae. By means of this mechanism, a change in the climate can have a direct impact on the worldwide existence of coral reefs. This important connection is dealt with in detail in Section F 4.2.4.

A worldwide analysis of the degree to which the reefs are threatened, in which their use intensity, instead of their state, is used as a basis in a combined indicator, revealed that worldwide 27 per cent of reefs can be classed as at great risk, 31 per cent as at risk and 42 per cent as not at great risk (Table E 2.4-1). This evaluation correlates with the actual state of rates in about 80 per cent of all cases. Worldwide 36 per cent of reefs are at risk from overuse, 30 per cent from coastal development, 22 per cent from pollution from land and erosion and 12 per cent from marine pollution (Bryant et al, 1998).

In addition to knowledge of the risk potentials, analysis of the actual state of the coral reefs (monitoring) is a major prerequisite for effective protective measures. Indirect influences from land and sea are usually more difficult to recognize and to control than are direct impairments resulting from overuse, mechanical stress and biotope conversion. The proportion of area covered by coral animals within the reef is frequently used as a basis for the quantification of the actual impairment of reefs because it is relatively easy to determine (Table E 2.4-2). However, the evaluation of coral reefs on the basis of the degree of coverage is problematic: high coverage rates are usually also achieved in areas in which a few species are dominant (low biological diversity). By contrast, species-rich coral reefs, which should therefore be classed as especially valuable, can have coverage rates of only 50 per cent or less.

Conservation and use of reefs

The prerequisite for the conservation of coral reef ecosystems is 'that all uses and impacts be brought within and maintained at levels which do not exceed these systems natural capacity for production and regeneration' (International Coral Reef Initiative Framework for Action, 1995). For coral reefs, a system of gradated use intensities (Section E 3.3.1) could be aimed at, similar to the one for landscapes. This concept has already been realized at the Great Barrier Reef in Australia (Box E 3.9-3). In line with the principles developed in Section E 3.3.1 the principle of sustainability will also have to be taken into account in the intensively used reefs.

- Type N ('Nature conservation'): In order to conserve biodiversity, every use is ruled out. At the Great Barrier Reef, 20 per cent of the reef area has been placed under complete protection (Box E 3.9.3). Only research is allowed to a limited extent in this area.
- Type E ('Economic use'): These are areas in which controlled economic use is allowed. The prerequisite for the use of living resources, above all by

coral reef fishing, has to be the avoidance of destructive practices (eg cyanide and dynamite fishing). Endangered fish species should also be placed under complete protection here.

- Type M ('Mean protection requirement'): This form of use should only allow use for research, tourism and recreation, but prohibit fishing. Tourism, in particular, offers the advantage of an environmental education function. Otherwise, the same criteria have to apply to the selection of the reefs as apply to use type N. In addition to conserving biodiversity, the establishment of no-fishing zones (ie types 'N' and 'M') also serves the purpose of securing the stocks of other economically useful resources by the creation of refuge and breeding areas.

E 2.4.2
Mangroves

The term 'mangroves' is used to describe woodland ecosystems in the tropical tidal zone. Mangrove forests stretch over the tidal area of shallow coastal areas and can reach as much as 30km inland. In spite of the adverse environmental conditions, mangroves are extremely productive. Their net primary production is 300–1,250g C m^{-2} $year^{-1}$. Mangroves are complex and finely balanced ecosystems with high biodiversity. This is where terrestrial and marine biotic communities meet. Both the high productivity and the high biodiversity are responsible for the high use value of mangroves (Lalli and Parsons, 1997). The ecological and economic significance of mangroves was classified as relatively low until recently. It is only in recent years that their importance has been recognized. Because of their sediment-accumulating effect mangroves contribute to the stabilization of banks and coasts in the tidal area and are thus an important factor in coastal protection. As a result of the wave-weakening effect, the coast is protected from erosion through waves and storm damage. In areas where mangroves are being destroyed, the coastline is receding quickly. Alongside Nigeria and Mexico, the Indonesian coasts are the most mangrove-rich areas on the Earth. However, the figures on the total extent of mangroves are even more uncertain than those for coral reefs (Tomascik et al, 1997). Although quantitative figures are very imprecise here, it can be assumed that many mangroves have been destroyed in Indonesia in the last 15–20 years; the losses for Java alone have been estimated at 98 per cent. The most extensive and least impaired mangroves can be found on the coasts of Irian Jaya.

The construction of settlements and industrial facilities as well as of fish breeding ponds (Tambaks) are considered to be the most important factors in the destruction of the mangroves (Tomascik et al, 1997; Section E 3.4). In addition to the destruction of biotopes, non-sustainable use poses the greatest risk for the Indonesian mangroves. For example, prawn fishing had yields of 29,000–133,000 tonnes $year^{-1}$ between 1973 and 1979. By 1996 this value had increased slightly to 144,000 tonnes, corresponding to a trading value of US$597 million. However, no more increases are to be expected. In addition, the wood from the mangrove trees is used to build boats and houses, as well as for cellulose production and as fuel (charcoal). An annual profit of around US$20 million is made from the wood for cellulose production (Tomascik et al, 1997). The local population has also been using the mangroves for a long time. Annual income of around US$10 million is expected from this form of use. In addition to wood, the local population also harvests honey and medicinal natural plant materials from the mangroves (Tomascik et al, 1997).

E 2.4.3
Fisheries

The comparatively high productivity of the Indonesian shallow sea as well as its easy accessibility and the usually favourable weather conditions creates excellent conditions for fishing. Currently, around 60 per cent of the Indonesian population's protein requirements are met by fish. In some parts of Indonesia up to 22 per cent (Ropelle, 1995) of the protein requirement is met by coral reef fishing, in ASEAN states the average is 6 per cent. Between 1969 and 1995, fish yields in Indonesia practically quadrupled. However, a further rise can hardly be expected. The majority of the catches are used to cover domestic requirements (FAO, 1993). The country's proportion in world catches stands at around 3 per cent today.

E 2.4.4
Conflict between economic use and the preservation of biotopes and species

With respect to the total coastline length as well as to terrestrial and marine biodiversity, Indonesia is unique in the world. In this country, however, there are also a large number of urgent environmental problems, especially pollution and destruction or degradation of marine ecosystems, mainly in regions near the coasts. It is therefore all the more important to promote the sustainable use of the coastal zone and to balance out the interests between ecological and socio-economic requirements (Yong, 1989). The country has one of the most comprehensive sets of laws on conserving the environment and on the sustainable management of natural resources. It is the Government's stated intention to designate a total area of 10 million ha throughout the country as marine protection areas in a total of 85 nature reserves. But this objective is faced with sober reality: the reserve Kepuluauan Seribu in western Java was set up as a protected area as early as 1982, but habitat destruction continues there. In general, plans to designate protected areas are not implemented. One major reason for this is the lack of financial resources since the major economic and currency crisis, both at state level and among the administrations of the port cities. There is a lack of management plans, infrastructure and know-how for the implementation of effective environmental management, insufficient knowledge among the local population and among decision-makers as well as inadequate information on living marine resources. Added to this is the lack of monitoring programmes and the existing uncertainties with respect to evaluation criteria that can be objectified for the ecological state of designated protected areas.

E 2.4.5
The future

The concentration of the population in the coastal area of Indonesia will probably continue to increase considerably in the next decades. In the short term, however, it is to be expected that the use conflicts in the coastal zone that already exist will become more acute. On the one hand, the coastal zone is an area where there are ecosystems with the highest species diversity. However, these are not only physiographic units of global significance that are worthy of protection, they also house an immense potential for economic use. On the other hand, the coastal area is already a preferred region for industry, trade, agriculture and urban development. Only when the understanding gains ground that a balanced strategy for the use and protection (Section E 3.9) of these valuable bioregions can safeguard their sustainable use in the future, is there a chance to prevent an ecological collapse that would inevitably bring economic collapse in its wake.

E 3 Focal issues

E 3.1
Perception and evaluation

E 3.1.1
Introduction

For millennia, human beings have been shaping their environment and changing natural conditions according to their needs and interests. If the call for sustainable development is accompanied by a desire to reflect on and change mankind's current relationship with nature, it is necessary to analyse in more detail the factors that determine this relationship. From this analysis, two things emerge which must definitely be considered in efforts to conserve the biosphere:

- There is no uniform, universally applicable relationship between humankind and nature; this relationship has different regional and culture-specific expressions.
- Apart from monetary interests in use, ideal, symbolic and aesthetic aspects determined by cultural factors are also key considerations.

E 3.1.2
People-nature interfaces

Human life and the natural world are interwoven in a variety of ways. Three basic functions can be crystallized out of these relationships (Markl, 1986):

- Human beings are products of natural evolution.
- They depend on the natural world and its products in order to stay alive: nature is the foundation which sustains all human life.
- Human beings use nature; in doing so they bring about major changes, in many cases with destructive force.

The way in which nature is used as a foundation of life is determined both by natural conditions and cultural factors (Fischer-Kowalski and Weisz, 1998). These two elements are in a relationship of mutual dynamic exchange. At the interface between culture and nature, human actions can have a wide range of impacts on biological diversity.

The constitution of the natural environment that surrounds human beings provides the framework for how they treat nature. For humans, different landscapes, such as tropical forests, the Arctic, steppes, savannahs, evergreen broad-leaved forests, oceans, deserts, etc, represent different prospects for development and special challenges which must be met if they are to survive there (Bargatzky, 1986). However, human development is not exclusively dictated by the natural habitat; there are also many opportunities to interact with this environment. For this reason, when we characterize the relationship between humans and the environment we do not use the term 'adaptation' but culturally conditioned interaction between humans and the environment. Human beings can drastically alter their environment and thus adapt the environment to their needs. This is illustrated by cases from history, such as the conversion of forest landscapes into arable and pasture landscapes in Central Europe since the 10th century (Gleitsmann, 1989; Section E 2.1). More recent examples also provide evidence of this reciprocity, for instance the conversion of rainforests into savannah (Primack, 1993; Section E 2.2) or the diversion or drainage of rivers and lakes with the resulting consequences for the landscape (WBGU, 1995a). However, less drastic examples of cultural landscape shaping can also be cited. Although Amazonian landscapes appear 'wild' to Western Europeans, they show evidence of much human impact as a result of the cultivation methods of the Kayapó Indians in Brazil, for example. They extend the vegetation, both by planting nut and fruit trees in the forest's various ecological zones and by creating new woodland islands in savannahs (Posey, 1982).

The significant influence of cultural factors can also be seen from the example of the Meo and Karen, two population groups local to the mountainous region of Northwest Thailand. Both groups inhabit the same biome (evergreen primary forest), but live very differently (cultivation techniques, modes of housing). The Meo carry out tillage based on primary forest clearance, initially by starting large-scale fires and then practising deep soil cultivation to eradicate tree remnants. The soil is used for a number of years to the point of complete depletion. Because of the resultant soil erosion, the Meo have no choice but to move their settlements repeatedly.

By contrast, the Karen maintain the natural resources around their settlements and restrict themselves to clearing the secondary forest. The fields created likewise by fire clearance are used for one year only and are then left fallow until the secondary forest regrowth can be harvested again without depleting the soil. The primary forest conserved in this way offers protection against erosion and serves at the same time as a 'seed store' for the regenerating secondary forest. The Karen usually keep to the same settlement location. These different ways of life are caused by cultural factors: for the Karen, concepts of local harmony are of central importance. They wish to remain settled and therefore keep to this method of cultivation, in spite of the higher levels of work involved and poorer yields (Bargatzky, 1986).

Cultural factors can contribute both to the conservation and the destruction of biological diversity. In traditional societies in particular (pre-industrial and pre-colonial), which operate within tight feedback loops with nature, the relationship between philosophy of life, religion, economic patterns and treatment of nature are clearly revealed (Section E 3.5.2). In more complex industrial societies, by contrast, the cultural factors are varied and sometimes contradictory. As a key cultural building block of many western societies, Christianity is ascribed with both positive influences on natural conditions (respect for God's creation and for living things) and negative consequences ('Subdue the Earth!') (Gardner and Stern, 1996). Hinduism, conceiving of man, nature and God as a unity (Krieger and Jäggi, 1997), has helped to preserve many habitats regarded as holy in an unspoilt state, so that today they remain sites of high biodiversity (Sinha, 1995). However, in India as a whole or other Hindu countries, this has not led to conservational treatment of nature because other factors, such as economic interests, also have a role to play.

The distinction made by Dasmann (1988) between 'ecosystem people', whose well-being is largely dependent on long-term availability of the natural resources in their immediate environment, and 'biosphere people', whose resources are obtained from further afield, often also transformed by industrial processes, provides an apt illustration of the differing nature of the interface between humans and the environment in industrialized and non-industrialized societies.

E 3.1.3
Traditional societies ('ecosystem people')

The relationship with nature of many 'indigenous peoples' has hardly changed over long periods of time. They have not experienced the technological, economic and social upheavals of the western world and were often considered to be 'primitive' by western conquerors or observers. Changes only came along with waves of western conquest and destruction starting in the late Middle Ages, many of which wiped out entire peoples or robbed the survivors of their cultures and ways of life and destroyed their traditional settlement areas. The indigenous communities that still exist today (Box E 3.1-1) acquire a key position in the conservation of biodiversity because of their special relationship with nature. This is also explicitly recognized in Article 8(j) of the Biodiversity Convention (CBD; Section I 3.2). In furtherance of efforts to conserve biodiversity, much can be learned from the peoples who have been familiar with these concerns for millennia. The historical example of two indigenous peoples demonstrate those cultural control mechanisms which allow natural resources to be used successfully without destroying them in the process (Box E 3.1-1).

From case studies of this kind, four principles can essentially be derived which, in the form of social rules and restrictions, lead to the sustainable management of nature and thus to the protection of biodiversity in many traditional and indigenous societies (Berkes et al, 1995):

- The designation of specific habitats or ecosystems completely protected : examples of this are mountains, meadows, forests, rivers or lakes declared to be holy.
- The designation of specific species, the use of which is forbidden or restricted: for example, in many parts of the Old World *Ficus* trees are protected by taboos. In Amazonia certain fishes that are viewed as important for medical care are not permitted as a food source.
- The obligation to protect animals in certain critical phases, such as the incubation and reproductive periods.
- The organization of resource use under the supervision and control of local experts.

Many indigenous and traditional societies that are heavily dependent on the long-term functional capacity of their immediate surroundings have – in contrast to western cultures – developed a lifestyle that does justice to the idea of sustainability from an ecological perspective. In making this assertion, two key aspects must not be overlooked: on the one hand, it does not imply that indigenous or traditional soci-

Box E 3.1-1

Case studies of indigenous communities

North-West American Indian tribes

The traditional way of life of the old Indian tribes settled on the coasts of North-West America is very well documented by ethnological studies. They were hunter and gatherer communities whose main food base was the salmon from the coastal rivers. This unstable ecosystem can be easily disturbed when the fish cannot reach their spawning ground because of insurmountable obstacles or they are caught beforehand.

The Indian tribes using this resource have developed a system of keeping stocks with a religious foundation and avoided overfishing through hunting taboos and rituals. The time required to conserve food was much longer than that taken to actually catch the fish, needed sophisticated technologies (drying, smoking, boiling, steaming, etc) and demanded a strict division of labour. The means of production (eg smoking houses) and the products of labour were owned individually, surplus production and the accumulation of private property were highly regarded as cultural assets: increasing what one owns means gaining prestige and moving up the social scale. Keeping stores was not defined as an adaptation strategy to prevent possible food shortages, but as an element of the cultural system, as a religious requirement whose upholding was ensured by rituals. The reason why this system, which was not unlike the western capitalist cultural system, nevertheless did not lead to the overuse of the fish stocks is due to the fact that the duration of the catching season and the size of the catch were prescribed in the religious system of values. The catch was led by a master of ceremonies who determined the size and timing of the catch. Winter was defined as the season where it was forbidden to procure food. This season was dedicated to festivals. This meant that the growing young fish moving downstream in winter were protected very efficiently. This restriction on the size of the catch and the limitation on the catching season motivated with religious values and as a religious purpose prevented the exploitation of the resources beyond the natural regenerative capabilities of the ecosystem (Weichhart, 1989). The system of values also regulated social relationships: the norm of increasing private possessions was kept within limits by the 'potlach' ceremony. Potlach is a ceremonial distribution of gifts with which conflicts about social status were fought out without the shedding of any blood.

New Guinea: The Chembas

Another example that clearly illustrates the control of the people-environment system by means of cultural values and rules is that of the Chembas, a native tribe in New Guinea, which also lives in a highly sensitive ecosystem that is susceptible to destruction: the tropical mountain forest. To produce their food the Chembas grow various crops and keep pigs on the basis of slash-and-burn, migratory felling cultivation. Their diet is supplemented by hunting and trapping. The Chembas' use of the natural resources is also regulated by a sophisticated system of ritual rules. Only a fraction of the available tribal territory is used for building. Soil erosion can be effectively prevented by means of long fallow periods (up to 45 years) as well as protective cultivation methods, such as leaving young saplings in the fields or a specific arrangement of the cleared tree trunks. Furthermore, the population density is kept stable and low by cultural norms. The central component of the Chembas' ritual cycle are regular fights at long intervals between the individual tribes where the main aim is power over the land. The herds of pigs play an important role here and at the climax of the cycle, the pig festival, large numbers of them are slaughtered. With the outbreak of war a number of strict taboos come into play, such as a ban on eating certain foods, drinking, a ban on sexual relations, etc. These taboos reduce the extent of the fights and the loss of human life is kept very low. Overall, the fighting takes place only over a very few weeks and for a few hours per day, then the defeated group seeks sanctuary with neighbouring tribes. The victors destroy the homes of the defeated and retreat. After the fights the entire pig herd, with the exception of the young ones, are slaughtered. The meat is prepared and dedicated to the ancestors, who are thus being thanked for the victory. They eat only a small proportion of the meat themselves, the majority is given to friendly groups. In the period that then follows, there is another series of taboos: the conquered land may not be entered; the catching of otherwise popular prey animals is also forbidden. In this phase, the Chembas are still obliged to thank their ancestors and all further actions of war are prohibited. Only when the pig festival can be celebrated can new fights be waged. But for this there have to be enough pigs. The regeneration of the herd depends on the available food in the territory and can take five to ten years. Furthermore, the regeneration period is artificially extended because the boars are castrated – fertilisation is possible only with wild boars – and the piglets are born in the wood, not in stables meaning that their chances of survival are much lower. So, it is only when the pig population is considered to be large enough after the first ritual slaughtering that the animals – with the exception of the young animals - are slaughtered as part of the pig festival. With the festival, which lasts for a total of around a year, the taboos against the catching of certain animal species and the entering of the conquered land are also lifted. Both the land and the animal populations were able to regenerate in the taboo period. During the pig festival intensive contacts with other groups are maintained (trade, marriage, festival). Once again, the majority of the pork is given to friendly groups. Only now does the cycle end and new war-like actions can start again.

eties are intrinsically 'good and noble'. Even these societies, with their affinity and bond with nature, have historically contributed to the extinction of animal species and the devastation of entire regions (McNeely et al, 1995). Some had and still have social structures and practices which are completely unacceptable from a western point of view, such as slave trade and other grave human rights abuses. The one-sided portrayal of aboriginal peoples as 'noble savages' may be an expression of the longing for a better world or a natural paradise, but it usually bears little relation to the everyday life of indigenous societies. Secondly, the indigenous or traditional form of sustainable lifestyles that conserve biodiversity cannot simply be imposed as a model for western societies to copy, because neither the cultural nor the natural prerequisites for this are in place. Above all, indigenous lifestyles are most consistent with societies of low population density and low mobility. Today there is virtually nowhere where these preconditions can be met.

E 3.1.4
Industrial societies ('biosphere people')

Over the centuries, the relationship of industrialized societies with nature and the biosphere has undergone a major change and today is characterized by serious, in some cases irreversible, destruction by humankind. This time, a human-induced wave of extinction of biodiversity can be seen, prompting questions as to the consequences for the whole planet (Chapter B).

The historical development of perception and evaluation patterns as well as modes of interaction with the natural world is critical to understanding the modern relationship with nature. Since empirical research on these issues has only recently commenced, help may come initially from analysing environmental history, the philosophy of nature and ethics, landscape painting and literary testimonies (Box E 3.1-2). As part of their social differentiation and technological development, since the Middle Ages western societies have felt the need to conquer 'hostile nature', and have used it as a resource, in the process creating new forms of landscape that today appear familiar and natural to us. Only 'tamed' nature shaped by human hand was deemed to be acceptable; the wilderness was abhorrent. It was not until the early 19th century that nature was regarded with the 'romantic view' that is still familiar today. The beauty of nature and an affinity with the landscape were new themes. The establishment of the 'touristic view', today both an opportunity and a risk for the conservation of biodiversity (Section E 3.7), was only possible after the discovery of the perfection of nature (from around the 16th century). By the late 19th century, industrialization was no longer seen in terms of unmitigated progress. 'Freedom' and recreation were only to be found in nature, especially in those parts considered to be unproductive, eg on the moors or in high mountains. The protection of nature and animals became an issue; this could be seen, for example, in restrictions on the long-established practice of bird trapping (Ritter et al, 1995). The radical changes in technology and society in the 20th century also bring the discovery of the 'environment' in their wake. However, issues of environmental conservation and degradation have only really been placed on the agenda in the last 30 years. Analysis of the worldwide network of causes and effects and the recognition that environmental damage occurs as an accidental side effect of technological and economic progress are the central elements in today's debate about nature and the environment. So far, making environmental damage an issue has not been able to halt the continuing destruction of biodiversity. What is therefore needed – in analogy to and as a supplement to the 'romantic view' – is the development of a 'biospheric view' (Section E 3.1.4.2) that 'sees' the need to conserve biodiversity and guides human action accordingly.

What nature is and what it means is construed and perceived differently in different eras and by different cultures (Graumann and Kruse, 1990). Even today, even within one form of society, we cannot assume that there is a uniform relationship with and understanding of nature (Jahn and Wehling, 1998). In the following, we shall deal with the question of what significance and functions 'nature' has today for people living in western industrialized countries. To date this question has been studied more philosophically than empirically, with the result that any answer provides only fragments of an incomplete mosaic. It should be remembered that each piece of research outlined below into the perception and evaluation of nature and landscape is selective, artificially extracting certain data, which will reflect only a small part of people's real lives. Human perceptions and actions are not usually specifically directed towards the protection or conservation of nature, landscapes or the environment, but rather towards the diversity of goals, particularly in highly differentiated societies, that provide social contexts (eg performing tasks in the world of work, establishing and maintaining social relationships, satisfying material needs, etc). In this respect, the destruction of biodiversity is partly unintentional but partly a consciously accepted secondary consequence of actions directed towards other goals. Human actions are influenced by a host of factors (WBGU, 1996), but the perception and conception of nature is an essential backdrop against which other factors, such as cost-benefit calculations, which are then directly linked to actions, take full effect.

E 3.1.4.1
Pluralistic lifestyles and the perception of nature

Modern industrialized societies are characterized by a high degree of internal differentiation and complexity. There are often conflicts of aims and values between components of the system that have become largely independent of each other (eg economic growth and environmental protection). The consumption of natural resources and the associated depletion of biodiversity by industrial societies remain high. Programmes for sustainable manage-

Box E 3.1-2

Historical development of the perception of nature and the landscape in western industrialized countries

There have been repeated incidents of environmental destruction in history, both in non-western and in western cultures, and not just since the Industrial Revolution, causing deep-seated changes in the people-nature relationship. The first major annihilation of a natural habitat in Europe was the large-scale clearance of the forest (Section E 2.1).

Forest and hostile wilderness were synonymous for a long time (Zirnstein, 1994) and the fight against the forests was considered to be a 'work to please God' in the times of Charlemagne (Heine, 1989, quoted after Heiland, 1992). The idea of the inexhaustibility of nature, which is shown in the German proverb 'wood and misfortune grow every day' (Gleitsmann, 1989), may also have contributed to the fact that forest cover diminished considerably in the late Middle Ages. The very existence of forests, which were mainly used as a resource for construction materials and firewood, seemed to be under threat. They were probably saved by the tragic plague epidemic of the 14th century because the utilization pressure on them was reduced as a result of the drastic drop in the human population (Gleitsmann, 1989; Section E 2.1). However, nature continued to be viewed mainly as a resource for technological and civilizational progress. Serious protection efforts, with the objective of conserving these resources for as long as possible, were being practised as early as the 17th century. The environmental damage caused during the Industrial Revolution and the severe pollution and risks to people were deemed to be unavoidable and sometimes accepted in the following manner: 'Daringly and with complete awareness of early death the newcomer stepped into the grinding shops, firmly decided upon fully utilizing the reprieve granted to him as well as possible in good living and exploits of all kinds and thus to hurry all the more quickly to his tragic end' (quoted after Bayerl, 1989).

Nature had to be subjugated and dominated. 'Untamed' nature was considered to be 'dreadful'. In his 'History of Nature' (translated into German in 1769), De Buffon, a natural historian who became famous as a biologist, wrote: 'Crude nature is dreadful and an image of death; I, I alone can make it attractive and alive; let us dry out these morasses, let them be made into streams and canals' (Zirnstein, 1994). The increasing destructive exploitation of nature since the Middle Ages is constantly ascribed to the influence of Christianity (on this: Berner, 1996). Certainly, this cultural development has greatly contributed towards changing the feelings of unity with the elements of the cosmos that could be found among the Greeks and the early Romans and thus to arriving at different ways of dealing with nature. But the spread of Christianity was just one of many social changes in the western world and cannot therefore be considered to be the sole reason for the exploitative stance towards nature. The essay by Lynn White (1967) that is often cited for this argument actually makes the connections much more subtly than is often discussed. Ascribing all of the complex social developments in science, technology and the economy to the one sentence 'Subdue the Earth' that has become symbolic of the influence of Christianity is too simple.

Interestingly, at around the same time as when many people were expressing their deep unease with intact nature, the first effective nature conservation efforts by Europeans came into being – although not actually in Europe, but far away in the colonial tropical islands that they had destroyed. On Mauritius the discrepancy between the idea of the exotic paradise and the actual environmental situation had become so obvious that French scientists, followers of the social critic Jean Jacques Rousseau, drew up regulations (1769) to protect the tree cover and to prevent water pollution in order to prevent soil erosion and the reduction of fish stocks (Grove, 1994). On the one hand economic interests were to the fore, on the other moral and aesthetic aspects also played a role. However, these efforts came too late for the dodo, which used to be native to this island. It had already fallen victim to the seafarers and the pigs, dogs and rats that they had introduced and which had now become wild (Zirnstein, 1994).

Nature as a landscape, as an aesthetic experience was only paid more attention by a broader public in Europe in the Romantic Age. This turn towards nature can be seen in different ways: wilderness and exotic animals were considered to be an expression of a sound world, a symbol of adventure. Wilderness brought the 'emotional kick that no longer existed in Europe' (Spehr et al, 1995). The establishment of nature conservation parks in the colonies (1866 by the British Government in South Africa) can be viewed in this vein. However, nature conservation was practised without any consideration for social concerns: the African population was forbidden from hunting in the park to protection the game population for the colonial hunting interests. In addition to the establishment of nature parks in the colony, in Germany the demand for exotic nature led, for example, to the founding of large zoos in Hamburg (Hagenbeck) that also offered – and are still offering – corresponding experiences of nature to the 'simple masses'. In Germany, above all, the nature conservation and homeland preservation movement developed, supported and driven by 'classes of the bourgeoisie and aristocracy threatened with social descent' (Spehr et al, 1995), whose efforts caused the Lüneburg Heath nature conservation park to be founded in 1921.

The example of the Lüneburg Heath in particular is a good illustration of the cultural change towards the 'romantic view' of nature. For around 200 years this area had been notorious as 'wild, bad, desolate, evil, monotonous, sinister, miserable' (Eichberg, 1983). In 1801 Caroline Schlegel described the journey from Braunschweig to Harburg via Celle in a letter: 'The urgency was the best part of the journey because Heaven help such a land! I became seasick from the monotonous sight of the heath and the sky, and from Braunschweig to here it is like that for 18 miles, dry brown heather, sand, crippled trees coated with moss and mould, every mile a village instead of milestones that seems to have grown out of the soil' (Eichberg, 1983).

The Lüneburg Heath is a part of that cultivated landscape created by man that came about as a by-product of the exploitative use of nature since the Middle Ages and that today is quite naturally 'magical, pleasant, beautiful, green and full of life' (Section E 2.1). The view of what is beautiful in nature and the fascination with the moods of nature are normal today and do not need the discovery of the 'new view' of nature, which had to distance itself from the old image, as becomes clear in the quotation of the two writers: 'There is the life-size Lüneburg Heath in front of us, which, by the way, is not as bad as is generally assumed' (Baggesen, ca 1800). 'I looked upon the large Lüneburg Heath, which is decribed as ugly. My God, how people do talk!' (Andersen, 1847, quoted after Eichberg, 1983).

ment of natural resources have been drawn up, but not yet implemented to any great extent. In line with high internal differentiation, the life contexts of groups and individuals also vary greatly. As a result of the breakdown of society-wide norm systems, they are less homogeneous than is the case with traditional societies. The pluralization of lifestyles (Reusswig, 1994) can be seen in the various attitudes to the environment and its use. It can be clearly seen in differential patterns of consumption with respect to goods, mobility, energy and landscape use. In addition to the trends towards pluralization, at the same time in the age of globalization, unifying factors are taking effect that can lead to a levelling out of culture-specific differences ('McDonaldization'). Another unifying effect is exerted by the environmental discourse in the media, which gives the different social groups access to the same information, information that would normally lack relevance in terms of the local reference points of their lives. Without the information from the media most people would know nothing about the existence of the hole in the ozone layer or about endangered species worldwide. This information must be returned to the subgroups for interpretation and vesting with relevance, however (WBGU, 2000a). With the discovery of the environment and the development of an explicit environmental awareness in the last 30 years, the relationship with nature is about to be redefined for most social subsystems and groups. In view of the technological options available to industrialized societies, ethical evaluations are a vital element in resolving this issue (Chapter H).

The following typology of 'environment-related mentalities', the result of a study among a random German sample (Poferl et al, 1997), illustrates the plurality of relationships with nature and the environment as they may apply to western industrialized countries, but not to developing countries:

- *Personal development project*: inward orientation, an alternative lifestyle, and ascetic renunciation (eg of consumerism) are experienced as personal enrichment.
- *Civil duty*: a normative obligation for environmental protection is perceived, there is a willingness to act in principle, but major upheavals and radical steps are not endorsed.
- *System or state orientation*: the efforts of individuals are viewed as meaningless, a willingness to act is not exhibited, arguing that structural barriers make this futile.
- *Indifference*: the problem of the environment is perceived as a normal component of social reality, but individuals report that they are not personally affected. Correspondingly, people feel no pressure to take positive action or to justify actions harmful to the environment.
- *Maintaining the status quo*: ecological reorientation attempts are experienced as a threat to the established order and are rejected.

E 3.1.4.2
Towards a 'biospheric perspective'

It is conspicuous that the current research into environmental awareness has largely 'forgotten' the subject of nature. The perception of nature and the landscape and the subject of biodiversity scarcely play a role in the most recent representative surveys conducted by the German Federal Environmental Agency. Everyday patterns of consumption and product use (shopping, waste, energy-saving, car use) are at the forefront of the national surveys. Only when recording knowledge about the environment are people asked which animals are red-listed (Preisendörfer, 1996, 1998). In the large-scale international Gallup Health Poll one of the questions concerns an assessment of environmental quality with respect to the natural environment (air, water, land, plants and animals) and the built environment. All aspects are combined in one question, meaning that no differentiated information is available (Dunlap, 1994).

The neglect of classic nature themes in public may be due to the fact that, at first glance, habitat and species conservation do not contribute to safeguarding the necessities to sustain human life. Thus far no connection has been made between maintaining quality of life and conserving biodiversity. Whether or not certain insects become extinct or not apparently has no direct consequences for people's lives: the loss cannot be perceived or experienced and it does not affect people personally. What is happening is too far away for people to experience it themselves. Correspondingly, no personal responsibility is felt for the protection and conservation of natural and landscape resources; sole charge of these is transferred to the governments responsible (Karger and Wiedemann, 1994b). The feeling that one is personally affected, which can, for example, be triggered by emotional reactions to a specific species, is of central importance: thus the destruction of far-off regions, even if it cannot be perceived or experienced directly, can give rise to a high degree of personal feeling. Many people follow the deforestation of the tropical rainforest with great concern because they fear serious consequences for their own lives resulting from climate change. However, the extinction of animal and plant species is evaluated as a symbol of the state of the environment in general, meaning that the support of groups committed to the conservation of certain species can be a (symbolic) contribution to the conservation of the environment. More consternation with regard to the extinction of species was found in a study in which older children were questioned on which people or living beings they most sympathized with, and in response most frequently cited animals because they become ill or because they are threatened with extinction (Szagun et al, 1994). However, in the public perception not all species carry equal status. Some species are given a symbolic significance because many people feel emotionally touched by their fate. These are animals that are usually especially attractive or appealing (often childlike), eg seals, or 'cuddly', eg koalas, or stand out due to other special characteristics (Box E 3.3-3). Many campaigns by environmental and conservation groups have been successfully based on this principle. They have an impact on the public and enjoy the support of the mass media. Examples of this type of campaign include Greenpeace's commitment to save the whale or the WWF campaign to protect the tiger, the panda or the forest elephant.

In the past, the loss of biodiversity has not been explicitly discussed in most of the studies on perceptions of nature and the environment. This is also reflected in a small media analysis of online daily and weekly newspapers conducted by the Council (in the first quarter of 1999), in which only 4–7 per cent of all articles that appeared on the subject of the environment and nature contained the key words 'biodiversity', 'biological diversity', 'species conservation' or 'biosphere'. However – as in national or international environmental awareness polls – issues relevant to conservation of the biosphere were frequently addressed. For example, it can be seen that environmental problems, such as air pollution, water pollution, marine pollution and the destruction of natural landscapes, are deemed to pose a high potential risk for humankind (Karger and Wiedemann, 1998). A problem awareness exists concerning many causes of damage to the biosphere, but the specific importance of biological diversity has not been an issue to date.

Social science research has not only concerned itself with the perception of environmental problems, but also more generally with the perception of the landscape and nature. This branch of research is concerned with the question of what nature really is, the position that nature occupies in human life, which landscape forms are preferred for recreation and leisure, etc. Thus it is primarily concerned with the symbolic and use value of nature and the landscape (Chapter H). These issues gain practical importance when it is necessary to estimate likely changes in evaluation of the landscape, for instance in the context of environmental impact assessments (eg for landscapes used for tourism or for landscape management interventions). Here, too, the fact is that it is impossible to make sweeping statements about which landscapes people generally prefer, but at any rate people can be categorized into types with different preferences for certain landscapes (sea, high mountains, etc).

Even the various survey methods on perception and evaluation of nature and the landscape produce very different results (Schwahn, 1990). A perception analysis of landscape reveals large differences depending on whether the survey is interested in preferences for use (eg a leisure trip) or an aesthetic appreciation of the landscape. In an aesthetic evaluation, landscapes are preferred which appear natural, ie which have no features showing human influence (Mausner, 1996; Kaplan and Kaplan, 1989; Gareis-Grahmann, 1993). In this assessment, quite apart from cultural variations, group-specific differentiation also operates. For example, town-dwellers still consider rural landscape pictures as wild and natural, whereas the inhabitants of rural areas regard them as having been influenced by man (Lutz et al, 1999). Depending on experience, the 'threshold' for what is considered to be natural seems to shift. Age, sex and familiarity with certain landscape forms also play an important role in preferences (Kaplan and Kaplan, 1989). Various models have been drawn up in which an attempt is made to cluster the large number of factors that influence perception (eg Berlyne, 1974; Wohlwill, 1976; Kaplan and Kaplan, 1989). According to these, landscapes become more pleasing, the more diverse and natural they are. In this respect, diversity refers to various aspects such as relief diversity, vegetation diversity (colour impressions, diversity of flowers, foliage, fruits), diversity of water bodies and diversity of use (Gareis-Grahmann, 1993). The attractive aspects of diversity are a certain degree of mystery and the possibility of discovering new aspects and information holding out the prospect of variety to the observer. However, it still has to be possible to instil order into complexity and diversity and make them comprehensible to the observer; they have to offer orientation points and exhibit recognizable features (Kaplan and Kaplan, 1989).

Attention is paid not just to preferences for certain landscapes, but also to fear and abhorrence of nature – albeit to a much lesser degree. Here, people differ with regard to their 'level of sensitivity to disgust', their wish for comfort or their fear in certain situations. These are factors that are relevant both to the evaluation of nature and to dealings with nature. People who have a negative perception of nature and the wild (become disgusted readily, eg at the sight of spiders, snails, slime, dirt), want high levels of comfort (showers, air-conditioned rooms, sanitary facilities) and are easily frightened (darkness, animals, noises), prefer tidy parkland to 'natural' landscapes and prefer indoor leisure pursuits to outdoor activities (Bixler and Floys, 1997).

In spite of all the variation in the details, it can generally be said that the perception of nature and landscapes, with their aesthetic and emotional qualities, fulfils important functions for human beings. These qualities are elements of 'belonging to a place' and 'place identity' (Tuan, 1974; Proshansky and Fabian, 1987; Altman and Low, 1992). Experiencing nature and natural pursuits as a source of recreation and stress reduction are decisive for quality of life (Kaplan, 1995).

E 3.1.5
Summary

- The terms 'biological diversity' and 'biosphere' have not gained great currency so far in everyday usage, nor in the studies that have dealt with the theme of 'nature'. Although making an issue of the destruction of nature is not a new phenomenon *per se*, the extent, the speed and irreversibility of the damage are new phenomena that could be combated by developing a 'biospheric perspective', incorporating acknowledgment of the need to conserve biological diversity and, thus, the establishment of sustainable development (Chapter B).
- The prerequisites for the development of the 'biospheric perspective' are in place since there is already a high degree of sensitization to damage to the biosphere. But we must not expect this perspective to be uniform in its details. On the contrary: it has to leave scope for the images of nature that exist in different cultures and subgroups.
- The selection and further development path of the lifestyles concerned have to be left to the social communities in question – taking account of certain framework conditions, such as those provided in AGENDA 21. In particular, the guiding principle of social justice must also be taken into account here (right to development, right to self-determination).
- On the other hand, ways also need to be found by which cultures can learn from each other, such that 'highly developed cultures' can learn from the knowledge bases, potential for innovation and practices of indigenous cultures.
- The necessary planning strategies (designation of protected areas, habitat conservation, etc), should include involvement of the relevant population groups in order to prevent conflicts and to gain acceptance (Section E 3.9).

E 3.2
Spatial and temporal separation of biogeochemical turnover processes in ecosystems

As part of the planetary system, the biosphere not only plays a major role in the composition of the atmosphere, but also in the condition of soils, inland waters and seas. Global biogeochemical cycles are decisively influenced or even 'controlled' by the biosphere (Section F 1). This complex tapestry of biogeochemical cycles, energy flows and linked effects developed in the evolutionary interaction between development of organisms and their physical and chemical environment over thousand millions of years of the Earth's history. By way of contrast, human interventions in this system have only reached dimensions that can be felt all over the world in the last few decades and could, in future, lead to serious disruptions to chains of processes with global consequences. Examples of this are the conversion of forests into fields and pasture or the emission of pollutants. In particular, this section will deal with the political challenges of the causes and effects of regional – and, now, global – decoupling of biogeochemical cycles by trade fluxes.

E 3.2.1
Biogeochemical cycles in ecosystems

With regard to biogeochemical fluxes in ecosystems, the primary producers capable of photosynthesis and the secondary producers reliant on organic matter as an energy source as well as consumers and decomposers act against each other. On this basis, biogeochemical turnover in the ecosystem can be described with the following biogeochemical equation (Ulrich, 1994):

$$aCO_2 + aH_2O + xM^+ + yA^- + (y\text{-}x)H^+ + \text{Light} \Leftrightarrow (CH_2O)_aM_xA_y + aO_2 + \text{Heat}$$

where:

$\Rightarrow$ Photosynthesis, ion absorption and phytomass production,

$\Leftarrow$ Respiration, decomposition and mineralization.

In this equation M^+ stands for the various cations and A^- for the anions; a, x and y are the extent of the reaction.

The equation is based on the law of conservation of matter and the principle of electron neutrality. From the equation it can be seen that conversion of the protons is associated with the conversion of the cations and the anions, which can be calculated when the extent of the reaction of the cations and the anions is known. In the formation and depletion of organic matter, the generation of protons means acidification, their consumption deacidification or alkanization of soils of water bodies.

The balance of many opposing processes can be recorded at the level of the annual biogeochemical cycle. The fluxes into the ecosystem or ecosystem compartments (input) and out of the system are measured or calculated. Depending on the knowledge of the processes and resolution with regard to the fluxes measured and the compartments, information can be gained about whether certain processes are in dynamic equilibrium (input = output) or whether they lead to linear (same annual difference between input and output) or non-linear changes (growing annual difference between input and output) of material stocks in the system. In terrestrial ecosystems, input-output differences usually reflect changes in quality, eg in biomass, in the soil's humus content and in the composition of the organism communities. If, however, the new production of biomass and its destruction are balanced in the long term, this is usually associated with a characteristic, site-related species composition expressed in the plant community and the humus formation (as an expression of the decomposer community).

E 3.2.2
Biogeochemical fluxes in the soil

In the stationary, that is balanced, state the net turnover of protons is also zero: the outputs of material correspond to the inputs; the state of soil does not change. However, it is not possible to achieve absolute equality of input and output because a small amount of the assimilated CO_2 is always washed out with the leached water as hydrogen carbonate together with Ca^{2+} ions, which causes alkalinity in the water body. This process is necessarily linked to the dealkinization or acidification of the soils, which is therefore a natural, very slow process. The dealkinization can be compensated for to a certain degree by the weathering of silicates or by inputs from the atmosphere. However, this presupposes that silicates are still present in the soils. In very old soils, eg in the tropics, this is frequently no longer the case.

In this context, the soil plays a decisive role because it is the reaction medium in which the two major processes in terrestrial ecosystems, biomass production and biomass decomposition (mineralization) meet. The soil acts as a nutrient pool (weathering) and nutrient reservoir (mineralization, exchange) and allows a connection between nutrient absorption and mineralization to take place under changing environmental conditions. Biomass production also always means an accumulation of substances that are temporarily being removed from the environment. But the material 'depletions' of the environment take place on a very small scale, eg in the area of the rhizosphere, and they are compensated for by the decomposition of biomass. The biogeochemical gradients that originate in this process are weakened again by burrowing animals, with the result that on average the conditions for root growth do not change. Only thanks to this property is it possible for ecosystems, even in climates characterized by excess precipitation and marked seasons, not to deplete nutrients quickly and to ensure luxuriant plant growth.

In natural terrestrial ecosystems, which are more or less in a state of dynamic equilibrium, the internal nutrient cycle is largely closed. Nutrients that are absorbed by plants return to the soil by the process of organic decomposition. The principle of the biological cycle presupposes that a balance is maintained between nutrient output and input and, consequently, also the size of the internal pool of matter. Nutrient losses through soil erosion, leaching, evaporation or the removal of living or dead organic matter are considered to be insignificant under these conditions. Above and beyond this, it is assumed that these losses are compensated for by nutrient influxes with precipitation, mineral weathering, biotic fixing or nitrogen from the air and inputs of mineral or organic matter from other systems (Fig. E 3.2-1). Because of their different structures, terrestrial and aquatic habitats are fundamentally different from each other with regard to the biogeochemical cycles that take place within them.

E 3.2.3
Biogeochemical fluxes in water bodies

Under constant conditions there may be a quasi-stable dynamic equilibrium in inland aquatic ecosystems, just as in terrestrial ecosystems. The main reason for this is that the vast majority of the conversions take place in the open water, which has a vertical temperature stratification during the growing season, and the biogeochemical conversions are therefore distributed asymmetrically along the gradients. Only in water layers near the surface is there sufficient light for the photosynthetic production of living organic matter (primary production). The thickness of the productive (euphotic) layer in inland waters fluctuates between a few centimetres and 20m; in the ocean it reaches a maximum thickness of 80–100m (Wetzel, 1983; Lalli and Parsons, 1997). As a result of the use and subsequent remineralization of

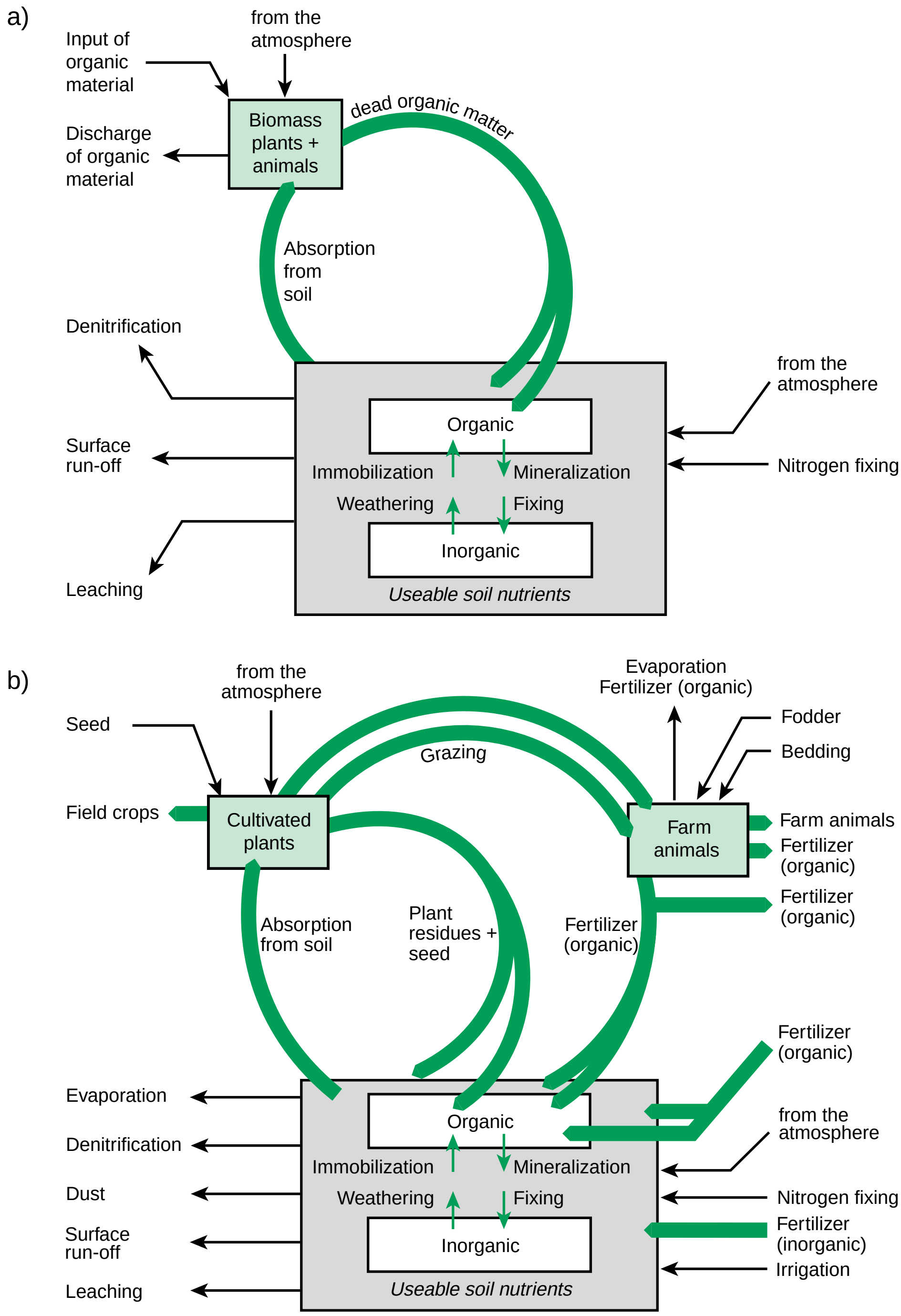


Figure E 3.2-1
Nutrient cycle in (a) unmanaged ecosystem and (b) agro-ecosystem.
Source: Tivy, 1993

the organic matter in the euphotic zone, usually only 80–90 per cent of the nutrients are regenerated; the rest of the organic matter sinks to the bottom. In the ocean and in extremely deep inland lakes, 90–99 per cent of this material is depleted in the water column; the nutrients it contains can therefore be returned to the illuminated water layers during the winter mixing of the water body (circulation) (Tilzer, 1990; Lalli and Parsons, 1997). In these cases there may be a quasi-stable dynamic equilibrium. In contrast to this, in inland lakes, which are mostly small (< 100 ha) and shallow (< 20m), 10–20 per cent of the organic matter formed in the euphotic zone is stored in the lake bed (Wetzel, 1983). Even without the increased anthropogenic introduction of nutrients from the catchment areas, organic material accumulates in the bottom sediment. As a consequence, fewer nutrients leave the system via the run-off than are introduced to it from the catchment area. As a result the total nutrient content of the water body progressively increases. Even under natural conditions lakes eutrophy slowly and are eventually filled up by the accumulation of sediment (Ruttner, 1962).

Within the bottom sediment, even in oligotrophic lakes anoxic conditions with extremely negative redox potentials dominate. A characteristic microbial biotic community has adapted to these conditions.

E 3.2.4
Biogeochemical fluxes in agro-ecosystems

Dynamic equilibrium or a balanced nutrient cycle is neither characteristic of nor easily created for agro-ecosystems. The extent and rate of the nutrient turnover depend on the type and intensity of the management methods. Biogeochemical conversion is associated with large inputs and outputs.

In most intensive agriculture systems the aim is for higher agricultural yields, linked to large material exports and a corresponding demand for nutrient inputs. The need for nutrients varies not only with the plant species and its yield potential, but also according to the nature of the parts harvested and the length of the growing period available for its production. For example, cereals in temperate zones absorb fewer nutrients per unit area than leafy vegetables or root crops. High-yielding C_4 plants in warm climates, such as sugar cane and maize, have even higher requirements. Similarly, there are many varieties of a single plant species that can vary in their yield potential and their nutrient requirements.

The removal of plant and animal biomass leads to a continuous removal of nutrients from the soil pool. On the whole, the loss of nutrients is lower when arable farming is combined with animal husbandry on the farm and the animal excrements are returned to the soil. However, even with this type of management, export-related nutrient losses cannot be avoided. In all agro-ecosystems the losses caused by farming have to be balanced out in order to maintain or increase productivity. Depending on the type of use, this input of nutrients can be in organic or inorganic form and come from the farm itself or entirely or partially from outside. The example of heathland farming, with its centuries of gradual nutrient removal from the large, increasingly heather-covered areas and accumulation on small-scale arable plots described in Section E 2.1, clearly illustrates the dilemma of the spatial and temporal disruptions to biogeochemical conversion through agricultural use.

E 3.2.5
Impact of settlement growth on biogeochemical fluxes

This trend underwent considerable acceleration as a result of the founding and growth of settlements and towns, since not only were large catchment areas now needed to meet food and raw material requirements, but the nutrient-rich waste was also in most cases not returned to the production land. As a result, the differences between biogeochemical depletion and accumulation zones became increasingly obvious in the landscape.

From an ecological point of view, towns are not self-sufficient and are dependent on the surrounding natural ecosystems and the agro- and forest ecosystems (Section E 3.8). A major ecological problem for the cultivated landscape that came about in this way is the severance of the ecological links. Food and raw materials are increasingly being produced in gardens, fields and forests that are geographically separate from the consumers in the towns.

Decomposers remain in agro- and forest ecosystems and exercise their function of biogeochemical depletion in the formation of humus. They are largely absent from settlement ecosystems and this leads to the accumulation of waste and sewage. This means that separate decomposer systems in the form of composting and sewage treatment plants as well as landfills have to be set up with the environmental risk of pollution and eutrophication.

In order to maintain or increase the metabolism, special transport devices or systems have to be created between the agricultural, urban and depletion systems. To date, however, there has only been partial success in converting these biogeochemical fluxes into closed cycles, just like their predecessors in natural ecosystems.

Maintaining or increasing productivity in the production zones is achieved by, on the one hand, depleting fossil nutrient deposits (eg phosphate or potash seams) and compensating for the losses with external fertilizers and, on the other hand, by converting the nitrogen in the air into mineral fertilizers using fossil fuels. In all of these cases the use of energy is absolutely essential for acquisition, provision (transport) and application.

E 3.2.6
Spatial and temporal separation of biogeochemical turnover processes in ecosystems: The future

With the start of the Industrial Revolution, not only was it possible to acquire larger quantities of fossil and renewable raw materials more efficiently, but their transport over long distances also became much easier (ships, railways, trucks). However, as a result of the improved transport possibilities, the spatial and temporal separation of the biogeochemical turnover processes was further accelerated and extended to a global dimension. In addition to the substances bound up with biomass, gases such as CO_2, NH_3, NO_x and SO_2, were now emitted at higher levels, resulting in a direct or indirect impact on the biosphere and pollution of inland waters and shallow seas in coastal areas, as a result of sewage from built-up areas and agriculture (Paerl, 1993). Since most inland waters are phosphorus-limited, phosphorus-rich sewage and sediments make an especially high contribution to eutrophication. Whereas the eutrophication of inland lakes has considerably fallen in the industrialized countries as a result of improved wastewater treatment and the substitution of phosphates in detergents, the problem is becoming much worse in developing countries due to population growth and the intensification of agriculture (Section E 2.3)

The dense transport network on land and water and in the air allows the transport of very large quantities of raw materials and food from all parts of the world into the industrialized countries. Fig. E 3.2-2 shows the proportion of nitrogen used by the import of fodder to EU agriculture.

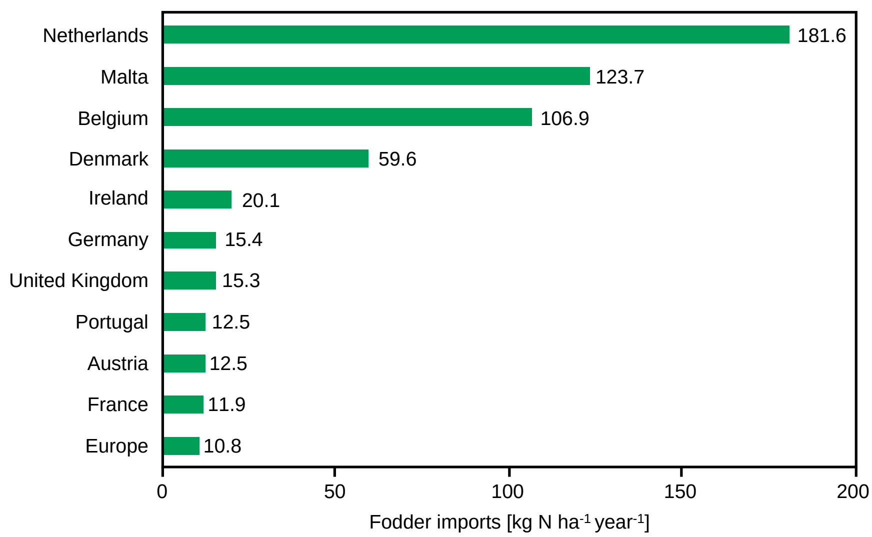
The exporting countries thus suffer constant biogeochemical depletion (the loss of phosphate is especially serious) and, as a consequence, the acidification of the soils, which is in contrast to a situation of ecologically unsound biogeochemical accumulation in the industrialized countries. Wilhelm Busch illustrated this phenomenon very aptly in his picture story *Maler Klecksel* (Painter Splodge) (Fig. E 3.2-3).

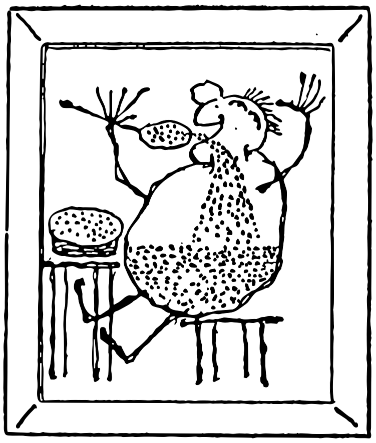
Another threatening trend can be seen in the developing countries: the rapid emergence of megacities is often linked to a rapid neglect of the rural areas. People's material need in rural areas leads to serious symptoms of ecosystem degradation, whereas in the built-up areas the uncontrolled accumulation of waste is leading to eutrophication, is poisoning soils and water bodies and is pushing out the characteristic communities of organisms.

The geographical separation of chemical turnover processes on the mainland leads to an increase in nutrient inputs into water bodies. In this respect, the natural eutrophication described above is exceeded by several powers of ten (WBGU, 1998a). As a result of the deterioration of the living conditions there is a reduction in biological diversity, usable fish populations are put at risk and other water functions are impaired.

Viewed in terms of biogeochemical cycles, the 'recipient regions' have developed into flowthrough systems by decoupling cycles at the expense of 'donor regions'. In the process, large quantities of exhaust gases, wastewater and solid waste arise that pollute and change the environmental media that surround them. The order of magnitude reached by human influence can be seen in the global chemical conversion of nitrogen and sulphur, which are already dominated by man, and in the key changes to the carbon and phosphorus cycles.

Figure E 3.2-2
Feedstuff imports into the European Union in 1997.
Source: Mund, 1999





Hier thront der Mann auf seinem Sitze
Und ißt z.B. Hafergrütze.
Der Löffel führt sie in den Mund,
Sie rinnt und rieselt durch den Schlund,
Sie wird, indem sie weiterläuft,
Sichtbar im Bäuchlein angehäuft.–

So blickt man klar wie selten nur,
Ins innre Walten der Natur.

Figure E 3.2-3
'Painter Splodge' as a decoupled system.
Source: Wilhelm Busch, 1884

The knowledge about the effects of these interventions in ecosystem chemical conversion processes is essentially available, but so far it has not been sufficiently evaluated or translated into political action at a local or global level. There is a need for urgent clarification as to the extent to which the evident or latent disproportion of biogeochemical fluxes and stocks leads to intolerable changes of biodiversity and its associated functions. Furthermore, preventive and compensatory strategies have to be developed and used that mainly aim at closing biogeochemical cycles. Economic practices that are based on the overexploitation of natural or managed ecosystems shall be avoided on all levels (Chapter G). Management directed towards sustainable use should be identified by labelling schemes or promoted via other measures in order to offset the higher costs incurred by these strategies. Education must engender an awareness that the sustainable use of terrestrial and aquatic ecosystems has its price.

A further instrument for avoiding material-related changes in biological diversity is the development of bioregional management (Section E 3.9), with the help of which geographical disparities can be reduced and regional cycles strengthened. In order to preserve the necessary scope for action for the sustainable use of natural resources, there is a need to address more intensively the numerous interactions among production, consumption, trade and environment at different geographical levels. Because of the ever-closer global links, greater attention needs to be paid to this issue at national and international level. At the international level, UNEP could take on the requisite coordination tasks.

E 3.3
Sustainable land use

E 3.3.1
Types of landscape use

Man uses practically all terrestrial landscapes in a diverse way. Only around 5 per cent of temperate and tropical land area is absolutely uninhabited and subject to no direct anthropogenic influences. It is simply neither possible nor, in many cases, desirable, from an economic or – as will be seen – from an ecological point of view, to protect the biosphere completely from human influences (Miller et al, 1995). For example, in Germany only 35–40 per cent of native species live in protected areas (SRU, 1985). Marine and coastal ecosystems are also largely to be found in areas where fish are caught or other human activities making use of nature are carried out. Against this background it is clear that maintaining the functioning of the biosphere depends on the extent to which it is possible to use biosphere services sustainably and to minimize negative impacts on the biosphere (Miller et al, 1995; WRI et al, 1992).

The deliberations in this section should be understood in the context of the development of a concept for the implementation of the 'sustainable land use' model. Section E 3.3 deals with a broad range of problems that occur in many forms of land use. What guides the findings for the implementation of sustainable land use is the differentiation between various types of landscape use outlined in Section E 3.3.1, which differ with respect to their varying extent of economic use interest and protection requirement. On the basis of this differentiation, a 'system of differentiated intensities of use' (Haber, 1971, 1998) should be developed for the various forms of land use – in each case adapted to the regional conditions – that specifies procedures for implementing forms of land use based on sustainability considerations. Opportunities for this will be addressed in the individual parts of this section. In the process, the discussion covers a continuum, ranging from areas to be strictly protected (Section E 3.3.2), through extensive land use (Section E 3.3.3) right up to intensively used arable land (Section E 3.3.4). Finally, within the context of regional management, there is a discussion as to how these various forms can be integrated (Section E 3.9).

E 3.3.1.1
Fundamental idea: The development of a 'system of differentiated intensities of use'

Humankind makes a wide range of demands on ecosystems and the biosphere. These reflect the diversity of values assigned by humankind to the biosphere. The values are derived and categorized in detail in Chapter H; only a few examples will be named here: tourism and local recreation, a mountain forest that prevents landslides, aesthetic enjoyment of nature, wheat production, the construction of an insect's wing as a model for engineers, flood protection through the storage capacity of a wetland, rattan harvest from the rainforest in Kalimantan and, at the same time, its significance for the world's climate, the production of paper from the conifer wood of boreal forests, mangrove forests that protect the coast against erosion by wind and waves. This list could be carried on *ad infinitum*. When we look at this list it immediately becomes clear that many of these demands are mutually exclusive. Competition between various possible uses is one of the central problems in dealing with the biosphere. It is completely impossible to set out to construct an ecosystem type that does justice to all of these requirements. For this reason, a division of tasks or specialization makes sense: a field planted with wheat is very efficient for the production of food, but can hardly prevent soil erosion or offer a habitat to a wide variety of organisms. However, this advantage of specialization does not always apply: For example, a mixed forest is capable of combining a soil protection function and the storage of precipitation with recreational use and, not least, wood production.

In principle, therefore, two strategies emerge (Haber, 1998):

1. Integration of conservation with use. Here a compromise between yields and habitat quality should always be aimed at.
2. Segregation of conservation and use. This strategy aims at dividing the landscape into highly productive, ie intensively used, ecosystems on the one hand and protective ecosystems on the other.

However, the relationship between these two fundamental strategies is complementary rather than substitutive, because the two can be merged to form one – at least in the majority of landscapes. With the (partial) incorporation of strategy (1) 'Integration of conservation with use' into strategy (2) 'Segregation of conservation and use', the objective being pursued is that of developing a 'system of differentiated intensities of use' (Haber, 1971, 1998; Uppenbrink, 1998). In order to implement a strategy of this kind it is firstly necessary to differentiate between different types of landscape use.

E 3.3.1.2
Differentiating between individual forms of land use

From an economic point of view, the problem of sustainable land use is usually presented as a conflict between the economic use interest – in this case especially the use of landscapes for biomass production – on the one hand, and the necessary protection of the biosphere on the other hand. Progress towards goals on either one of these dimensions is frequently at the expense of the other. Thus, at first glance, the idea of nature conservation is in opposition to unlimited private use. However, this supposed conflict can be put aside in most cases. On the one hand, in spite of economic use it is possible to take account of protection targets and, on the other hand, differentiated strategies of use can be developed because the level of the conflict described varies depending on the land use type. Thus it makes a difference whether a rare composition of flora and fauna in an ecosystem that is unique in the world is destroyed or converted by human activity, or whether a landscape with ecological characteristics found in many regions of a country or the world is given over to (limited) human use. For this reason, in a first, pre-structuring approach, an initial distinction should be made between the following types of landscape use – differentiated according to intensity of use:

Landscape-use type 'N' ('nature conservation' type – 'conservation before use' principle):
This type categorizes landscape which is accorded special status for its environmental characteristics. This is important landscape from a biological point of view, characterized, for example, by the fact that landscape-use types with a similar biological inventory are rare in the world. Landscapes that house such unique ecosystems with global significance are also called 'world heritage sites' and are considered to be humankind's heritage. These may be tranches of landscape or ecosystems that provide regionally important ecosystem services (Box D 2.5-1) and must therefore be protected against unlimited economic use. In this landscape-use type, the environmental policy protection interest predominates, whereas the economic use interest recedes.

Landscape-use type 'E' ('economic use' type – 'conservation despite use' principle):
This landscape type forms the other end of the scale and is characterized by especially good private utility. For example, it covers highly productive agricultural land or areas where mass tourism is of great economic significance. In this landscape-use type the

economic use interests prevail and the implementation of environmental policy protection strategies would give rise to high economic costs in the form of the non-use of important economic development potentials. Hence the economic use interest dominates with this landscape-use type.

Landscape-use type 'M' ('mean protection requirement' type – 'conservation through use' principle):
The intermediate position between the two types 'N' and 'E' described above is characteristic of this landscape type. This type of landscape indicates intermediate sensitivity in respect of the capacity to assimilate human interventions in such a way that the main system properties and services remain maintained. Furthermore, the economic utility of the landscape is in an average range. Thus, for example, only average productivity can be obtained from the soil, or natural or infrastructural circumstances leave only limited scope for large scale touristic use of the area.

The categorization into various types of landscape use provides a heuristic method in order to facilitate the argumentation. Of course, these three types do not exist *de facto* in the pure form described. Much rather, a continuum is set up with the two criteria 'economic use interest' and 'protection requirement', along which an ideal-typical arrangement of the types described can be accomplished.

As an aid to classification of the landscape use types, the criteria of Johnson (1995), for example, can be used to set biodiversity protection priorities in order to gain an idea of the need for protection and the protection worthiness of landscapes. This is based on biological criteria such as abundance, rarity, threat, unique features, representativeness and functional importance. Section E 3.3.2.4 will deal in particular with areas of type 'N'. In order to estimate the economic use potential it is necessary to determine the corresponding yield potentials (eg agricultural productivity, fish abundance, etc; Section E 3.3.4 and E 3.4).

E 3.3.2
Protected areas: conservation before use

The varied demands that man makes of the landscape cannot be combined without conflict. For example, areas cannot perform certain ecological services (such as maintaining the water cycle, soil protection, flood control) if the land is being used intensively. Nor can the protection of the option, symbolic or existence values of biodiversity be easily combined with other uses. If, for example, a species or even an ecosystem type that is valuable to humankind for these reasons is threatened, its disappearance from the domestic landscape or even its worldwide extinction will not be tolerated. The demands have to be weighed up alongside the needs of production and development.

For various reasons, functions or services that are made available by species, ecosystems or landscapes (Box D 2.5-1) are very difficult to monetarize and to internalize into economic accounts. Because of their character as public or partially public assets, they are frequently undervalued on the market and this can subject them to greater degradation than is commensurate with human preferences (Section H 5).

This gap must be bridged by nature conservation. Conservation has the task of correcting the missing or distorted market valuation of the biosphere and complementing it with scientifically justified and politically desired measures in order to preserve the services and functions of the biosphere for present and future generations. This can only be achieved by a mixture of private and government initiatives: nature conservation is a task that needs as broad a social base as possible (Reid and Miller, 1989; McNeely, 1997).

The most important instrument of nature conservation is the conservation of areas where there are still natural or semi-natural ecosystems. This is the prime objective of landscape-use type 'N' ('nature conservation' type – 'conservation before use' principle; cf Section E 3.3.1) in which nature conservation has priority over all other interests. This type is not limited to terrestrial areas; it can also cover limnic systems, coastal zones and marine areas. We could speak of priority for 'nature conservation use': if we use the Council's moderately anthropocentric stance as a basis (Chapter H), nature conservation is ultimately also a form of biosphere use. Against this background, exclusion of humans from conservation areas on principle does not make sense, and other uses are not fundamentally ruled out (Dierssen and Wöhler, 1997). Use for scientific purposes, the experience of nature ('low-impact tourism') and even hunting and gathering activities can take place in conservation areas when this does not contradict the priority purpose of nature conservation (case studies can be found in Section E 3.3.3.4). In historic cultivated landscapes, the continuation of traditional land use may even be a decisive prerequisite for the conservation of the landscape and for meeting nature conservation objectives; the landscape of the Lüneburg Heath is a classic example of this (Section E 2.1). In yet other cases it will be necessary to completely preserve the areas from human influences, eg breeding colonies of protected seabirds must remain undisturbed during the breeding season (Box E 3.7-1). The relationship between land use and nature conservation is therefore heavily dependent on the historical, biogeographical and ecological circumstances, and general rules cannot be applied.

So if the subtitle of this Section is 'Conservation before use', it refers to use in the narrowest sense, ie the use of land as a site for infrastructure, settlement, industry, mining, etc as well as economic use of resources that are obtained from the biosphere. The latter usually affects intensive biomass extraction from 'artificial' agricultural or forest ecosystems that came about from the conversion of natural ecosystems and can be operated only with considerable inputs of nutrients and energy (Section E 3.3.4). These types of use are usually incompatible with nature conservation and are therefore in direct competition with it. However, this contradiction is defused to a certain extent by virtue of the fact that – in global terms – land that is especially productive for agriculture is of comparatively minor importance for nature conservation and vice versa. So, much of the remaining biological diversity could be preserved without necessarily incurring very high costs, eg there is no need to sacrifice agricultural productivity (Huston, 1993; James et al, 1999).

Space will be devoted not only to land or ecosystem conservation but also to species conservation in this section because – with the exception of Section D 3.1 on the trade in endangered species – it is very difficult to deal meaningfully with it in isolation. Other important subjects, such as dealing with conflicts in conservation areas or the increasingly important discussions about the restoration of natural ecosystems cannot be dealt with here for reasons of space.

E 3.3.2.1
Tasks and functions of protected areas

The most effective strategy for the conservation of biodiversity is to avoid the conversion or degradation of natural ecosystems. That is why the designation of protected areas is the strongest weapon in the fight against progressive biological impoverishment of the Earth (WCMC, 1992). Such areas safeguard valuable ecological services (eg drinking water or soil protection), conserve biological diversity and landscape beauty and protect the habitat of interesting or valuable species (Box E 3.3-1), objectives which usually complement each other (Soulé and Simberloff, 1986). In large areas, conservation areas should serve to maintain representative or unique segments of biological regions. As already mentioned, certain forms of use (eg research and learning, recreation and tourism, the sustainable manufacture of products, safeguarding opportunities for development and use) can be combined with the purpose of nature conservation by imposing appropriate conditions in many cases (McNeely et al, 1994).

The World Conservation Union (IUCN) defines 'protected areas' as areas of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN, 1994a). This implies that protected areas correspond to land use type 'N' pursuant to Section E 3.3.1 in which priority is given to nature conservation.

The IUCN and its World Commission on Protected Areas (WCPA) have developed a categorization of conservation areas that can be used all over

Box E 3.3-1

In-situ conservation of genetic resources in protected areas

The protection of valuable genetic material, eg related wild species or traditional farmers' varieties of especially economically important species, can mainly be achieved by protection of the relevant natural ecosystems or traditional cultivation methods (*on farm*) (Section D 3.1; Begemann and Oetmann, 1997). In this respect, particular attention should be paid to population-biological aspects because it is not just a matter of the survival of a wild population but also about the conservation of as much genetic diversity as possible within the population and about the maintenance of the natural evolutionary processes in the populations – which may also include possible selection pressure by traditional human use.

In spite of the great value of genetic resources, only a few protected areas have been specifically set up or optimized for the purposes of the *in-situ* conservation of genetic resources (Heywood, 1993). The basic data are very sparse, with respect to inventories, monitoring and knowledge about the ecological needs of these resources. The FAO has only carried out a study of the protection requirements of the related wild species of the most important food plants.

Protected areas are the most important instruments for the protection of genetic resources for forestry. As far as the wild species of plants related to agricultural crops are concerned, *in-situ* conservation is usually just an accidental side effect of general nature conservation measures. Protected areas could and should therefore play a greater role in the conservation of plant genetic resources in future (McNeely, 1995), but there is still a need for much greater efforts to make the conservation of plant genetic resources in protected areas more effective. The protected areas approach alone is not enough: most valuable plant genetic resources are outside established protected areas, meaning that it is necessary to develop an integrated approach with other forms of land use (on-farm conservation) and, above all, *ex-situ* instruments (Section D 3.1) for their conservation.

Box E 3.3-2

The modified IUCN system of protected areas categories agreed at the 4th World Congress on National Parks and Protected Areas

I. Strict Nature Reserve/Wilderness Area.
Areas of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring; or large areas of unmodified or slightly modified land, and/or sea, retaining their natural character and influence, without permanent or significant habitation, which are protected and managed so as to preserve their natural condition.

II. National Park: Protected Areas Managed Mainly for Ecosystem Conservation and Recreation.
Natural areas of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for this and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.

III. Natural Monument: Protected Areas Managed Mainly for Conservation of Specific Features.
Areas containing one, or more, specific natural or natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.

IV. Habitat/Species Management Area: Protected Areas Managed Mainly for Conservation Through Management Intervention.
Areas of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.

V. Protected Landscape/Seascape: Protected Areas Managed Mainly for Landscape/Seascape Conservation and Recreation.
Areas of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, cultural and/or ecological value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.

VI. Managed Resource Protected Area: Protected Areas Managed Mainly for the Sustainable Use of Natural Ecosystems.
Areas containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

Source: McNeely et al, 1994

the world but does not always concur seamlessly with national or regional categories (McNeely et al, 1994; Box E 3.3-2). In turn, some international agreements contain lists of conservation areas that can usually be incorporated into this category system without any problems (eg World Heritage Convention, Ramsar Convention; Section I 3).

There are conservation areas in which only total protection will be effective in conserving biological diversity and in which hardly any other form of use can be compatible with the conservation objective. The IUCN categories I-III represent this end of the scale (conservation areas in the stricter sense; Box E 3.3-2). At the other end of the scale there are cultivated landscapes with a large number of ecosystem types that have come about through the interaction of man and nature as a consequence of traditional land-use and settlement forms (categories V and VI). Here, too, is the priority for nature conservation objectives, but these categories form a fluid transition to type 'M' (conservation through use; Section E 3.3.3). Land use is not ruled out in principle. The endeavour is towards synergies of conservation and use. Total conservation can even be harmful in cultivated landscapes if the existing diversity can only be conserved by the continuation of traditional types of use.

Biosphere reserves (Section E 3.9) cannot easily be integrated in this system since this form of area protection has already been integrated into the various land use types (for the relationship between biosphere reserves and conservation areas see IUCN, 1998a).

E 3.3.2.2
Species conservation versus ecosystem protection?

For many reasons the species is not the only key 'unit of nature conservation'. Species conservation is only a meaningful concept in conjunction with ecosystems and landscapes; the conservation of biological diversity has to concentrate on these levels (Bridgewater and Cresswell, 1998).

As already mentioned at another point in this report, the identification and taxonomic description alone of the many millions of species on Earth is a monumental task. It is utopian to identify all endangered species in order to then develop species-specific plans of action (Heywood, 1993). The resources available to nature conservation are by no means sufficient for this (Myers, 1993).

Box E 3.3-3

Categories of species

Species can be especially valuable for people for the most varied reasons. Here, a definition of terms for the various species categories is proposed on the basis of the value categories in Chapter H (cf Simberloff, 1990).

Functional value: keystone species
Species that occupy a keystone position in the ecosystem, the loss of which would bring about major changes to the ecosystem structure (Box D 2.4-2; Paine, 1966). Occasionally, the large flagship species simultaneously occupy a keystone position (keystone species, eg elephant; Western, 1989).

Economic use value: economically important species
Species with high economic use value. Above all these are animal and plant species for use as food and fibre that are important for agriculture and forestry, fisheries and the pharmaceuticals industry.

Symbolic value and existence value: flagship species, umbrella species and indicator species
Surveys reveal a large majority in favour of the conservation of certain *flagship species*, eg tigers, elephants, pandas, whales, etc. These are often large animals (but also trees or especially popular ornamental plants such as orchids) with considerable significance to humankind, whether as a symbol or as a cultural-spiritual or mythical symbol (eg heraldic or totem animal), the extinction of which would be considered a major loss. The symbolic value of these charismatic species ensures high levels of attention and, thus, a higher weighting in the arguments about competing uses and therefore often serves as an 'anchor' for the nature conservation campaigns organized by NGOs.

Umbrella species are species that need a large natural habitat and whose protection 'automatically' benefits other, less noticeable species with a lower existence value (eg in Europe the white stork serves as a 'peg' for the protection of wetland meadows or in the USA the spotted screech owl is a 'peg' for the protection of the primary forest). Umbrella species typically have a high existence or symbolic value; frequently they are also keystone species.

Indicator species are characteristic species of certain ecosystems and have a representative function because they are also indicators of their condition. Here, therefore, it is not the value category that is to the fore, but the function for nature conservation.

Option value: potentially important species
These are species whose value, although high, is still unknown. This unknown value can manifest itself in all categories (functional, economic use, symbolic and existence value; cf Table H 5.6-1). Mostly, the economically important species *in spe* in the narrower sense are meant, eg the related wild species of crops or plants with possible medicinal effects (Section D 3.3.).

Species conservation will therefore not succeed without a prior weighted evaluation: only species with 'special conservation status' can benefit from sophisticated species conservation programmes. There are no uniform criteria for the decision as to which species are to be given 'special conservation status' (eg Simberloff, 1998). The various categories of values (functional, use, symbolic, option and existence value; Chapter H) clearly show that it may not just be a matter of a decision based solely on ecological-scientific consideration, but that many socially defined evaluations play a role (Box E 3.3-3). Thus, for example, Lufthansa promoted species conservation programmes for its symbol, the crane, and the USA makes very costly efforts to protect its national bird, the American bald eagle, from extinction. These examples of a high estimation of the symbolic value could be replaced by others in which, for example, the existence value (whales) or the option value (wild related species of crops) are given a high assessment. Another important criterion concerns the extent of the concrete threat.

One advantage of the species approach is the fact that status, trends and degree of threat can be assessed more easily ('Red Data Books'; IUCN, 1994b; BfN, 1997a) and the motivation of 'protecting a species from extinction' can be easily conveyed to the public at large. One disadvantage is the fact that the justification of land use restrictions by means of conservation status for just a few, or even only one, species gives the local public a simplified, distorted image, with the result that in extreme cases contradictory interests can lead to the species that is being protected becoming a focus for enmity. The actual objective of protection – the conservation of natural ecosystems with their abundant inventory of species, their dynamics and their varied services – can fade into the background in the process.

Conservation programmes that are fixated on the management of individual species can also expose themselves to conflicts of objective. Measures for the well-being of one endangered species usually have ecological consequences that may very well be at the expense of another, possibly equally endangered, species. If the funding is concentrated on elaborate protective measures for individual 'charismatic' species, the question as to the efficiency of the measures for the overall objective of 'conserving biodiversity' may arise.

In order to solve conflicts of this kind it is essential for those responsible to evaluate the species and ecosystems consciously and transparently, rather than implicitly, as is usually the case at the moment. This indirect assessment can be seen clearly, for example, in the fact that species conservation programmes are mostly dedicated to the visible and popular symbolic species – usually vertebrates and mostly mammals or birds. For example, species con-

Box E 3.3-4

Overview of ex-situ nature conservation

In the *ex-situ* conservation of species or genetic resources components of biological diversity are removed from their natural context and kept alive in an artificial environment. This includes collections of living biological material of all kinds: botanical gardens and arboreta, zoos, aquaria, museums, collections of microorganisms, gene banks, etc. These institutions are not all state-run: there are major private collections and, not least, collections of valuable resources in the agricultural industry. These institutions are frequently multifunctional, ie they not only serve as 'archives' but also offer space for research, teaching, awareness-raising or a sophisticated leisure activity for visitors. The link to applied research should be emphasized in particular because successful *ex-situ* conservation strategies can only be developed on a sound scientific basis.

Ex-situ conservation, eg in gene banks, plays an indispensable role in the protection of genetic resources for food and agriculture. For many species and varieties they are currently the only practicable way of preventing the extinction of the genetic diversity of these resources. Section D 3.4 deals with this subject in more detail.

The genetic material currently protected *ex situ* is limited and very distorted in comparison to conditions in nature. The *ex-situ* range is best for higher plants: around 80,000 species of higher plants are represented in botanical gardens all over the world, that is around one quarter of the estimated number of species in the world. The situation is incomparably more difficult for zoos: the *ex-situ* conservation of animals is expensive and difficult. For example, the conservation of elephants or rhinoceroses in zoos is approximately 50 times more expensive than in national parks (Leader-Williams, 1990). Under the current conditions, of the approx 3,000 species currently in zoos throughout the world, only a maximum of 900 animal species can be permanently preserved from extinction: this is only a tiny proportion of the total number of species. If the long-term conservation of the genetic diversity of these species were also to be made possible, the figure would be much lower still (Conway, 1992). The situation is similarly unsatisfactory for microorganisms: of an estimated 2 million species, only approx 4,000 have been described. These few described species are, however, well represented in *ex-situ* collections because the description has to be accompanied by the storage of the type master in a public collection. There are phylogenetic data for 90 per cent of the described genera and for 805 of the species, but access to this information needs to be improved (Stackebrandt, 1998).

Ex-situ measures are valuable aids and an indispensable supplement to the efforts of *in-situ* nature conservation, but they can by no means replace it. *Ex-situ* nature conservation is always associated with problems of the small population and the different selection vis-à-vis natural populations: genetic diversity is lost, natural behavioral patterns change and the evolution of the species is given new impetus (Loeschke et al, 1994; BfN, 1997a). For this reason, many components of biological diversity cannot be protected *ex situ* (plant genetic resources are an important exception; Section D 3.4). Above all, the dynamic processes (eg abiotic and biotic interactions in ecosystems and natural evolution) can only be conserved *in situ*. For restoration ecology projects, such as the reintroduction of species, *ex-situ* conservation through genetic material, targeted preparatory programmes and scientific findings can, however, provide essential prerequisites (Box. D 2.4-1; IUCN, 1995).

servation programmes to prevent the extinction of an obscure insect might be equally justifiable, eg on the strength of ecological keystone functions, but they are rarely carried out.

In spite of the problems and conflicts, species conservation programmes are nevertheless necessary in many cases – and are often successful, too. For example, where the conservation or reintroduction of keystone species or especially charismatic species are concerned, which, in turn, can be a prerequisite for the conservation of the ecosystem concerned, special species conservation programmes are appropriate. In this respect, knowledge of the minimum area or minimum viable population (MVP) of the species to be protected is vital. Species conservation programmes are especially effective when the factors threatening endangered species are known and can be specifically influenced, eg hunting, gathering activities, conversion or fragmentation of essential habitats or trading in endangered species (Section D 3.1).

In practice the following rule still applies in many cases: 'A species is whatever a competent systematist says it is' (Regan, 1926). In the long term this will not be enough. For this reason, scientific clarification of the importance of the species concept remains an important question for research. Since evolution and adaptation to the environment takes place at the level of the individual and the local population and not at species level, there are no natural mechanisms in ecology or evolution that have the function of benefitting the survival of species (Williams, 1966; Section D 2). The nature and survival of a species is therefore inseparable from the biological concept of a population and its integration in the ecosystem concerned. Population biology research – and here, in particular, the importance of diversity within species – is therefore an important pillar for the scientific justification of species conservation and should be promoted more intensively (Chapter J; WBGU, 1997).

Efforts to conserve species should begin with an evaluation based on methodology that takes account of both ecological and social criteria. There is still a considerable need for research here. The foundations can be the conscious and transparent application and weighting of the various value categories explained in detail in Chapter H. On the basis of these categories, the various 'roles' of the species for ecosystems and human society can be defined and considered in decision making (Box E 3.3-3). Thus, we can identify the species or populations for which a special conservation programme will have to be designed. The shape that such a programme will take obviously depends on the demands and the endangerment status of the target population; usually a mix of various instruments has to be put together. In this connection, the incorporation of *ex-situ* measures also has to be examined (Box E 3.3-4). But above all, the programme has to be closely linked to measures to protect the ecosystems upon which the target species depends. The close integration of species conservation and ecosystem protection is decisive: it opens up the prospects for synergies and can help to resolve conflicts between different protection goals.

E 3.3.2.3
Situation of protected areas worldwide

Status

Every ten years the IUCN organizes a World Congress on protected areas. One of the objectives of the 4th Congress (in Caracas in 1992) was to simplify the category system for protected areas (Box E 3.3-2) and to draw up a current overview of the status of and trends in the worldwide protected area system (Table E 3.3-1; McNeely et al, 1994).

Currently approx 5 per cent of the world's land area is under protection, although the regional spread is very uneven: it ranges from less than 1 per cent to over 10 per cent. However, these statistics are distorted by the fact that the only protected areas included were those in Categories I–V which were larger than 1,000 ha and in public ownership (IUCN, 1998b). For example, this means that the situation in Europe is not reflected appropriately, where many protected areas are smaller than 1,000 ha. Table E 3.3-1 therefore provides a conservative estimate of the actual situation for land protection. A complete list of all protected areas has been compiled by the World Conservation Monitoring Centre (WCMC, 1999a), Fig. E 3.3-1 provides a worldwide overview.

Trends

Fig. E 3.3-2 shows that the protected areas system is growing globally: in five out of 13 regions in the world, over half of the protected areas have been designated since 1982 (McNeely et al, 1994). However, the annual growth rate of protected area designation has been falling continuously since 1970.

Representativeness

The worldwide protected area system is intended to reflect the different biome types as representatively as possible. In order to estimate this representativeness, Udvardy (1975) classified the biosphere into eight regions and 193 'biogeographical provinces' so that each province is characterized by one of 14 biome types. The aim of the 'Bali Action Plan' adopted at the 3rd World Congress on Protected Areas (McNeely and Miller, 1984) of placing at least

Table E 3.3-1
Area of protected areas according to IUCN management categories I-V (data from 1992, category system from 1978). For these statistics, the minimum size of areas is 10km^2, except in the Pacific and the Caribbean where it is 1km^2.
Source: McNeely et al, 1994

	Protected area categories I	II	III	IV	V	Protected area size (I–V)	
	[km^2]					[km^2]	[%]
North America	19,724	1,452,628	184,705	696,293	207,150	2,560,502	10.9
Europe	31,070	55,130	3,422	66,138	306,473	462,231	9.1
North Africa and Middle East	22,958	139,429	62	232,788	45,487	440,724	3.4
East Asia	3,746	72,866	0	309,387	38,153	424,151	3.6
Northern Eurasia	218,493	16,444	0	18,403	1,176	237,958	1.1
Sub-Saharan Africa	25,824	758,064	189	439,090	24,831	1,247,997	5.2
South and South-East Asia	73,555	176,508	211	232,493	4,670	487,437	5.5
Pacific	1,948	1,281	12	1,543	76	4,858	0.8
Australia	25,835	633,210	15	105,679	49,374	814,113	10.6
Antarctica and New Zealand	8,858	21,710	210	3,558	0	34,335	0.3
Central America	3,558	31,012	175	11,057	67	45,871	8.5
Carribean	494	8,697	13	6,758	6,896	22,857	9.6
South America	83,896	546,325	28,076	281,189	206,404	1,145,894	6.4
Total	519,939	3,913,304	217,090	2,387,816	890,757	7,928,928	5.3

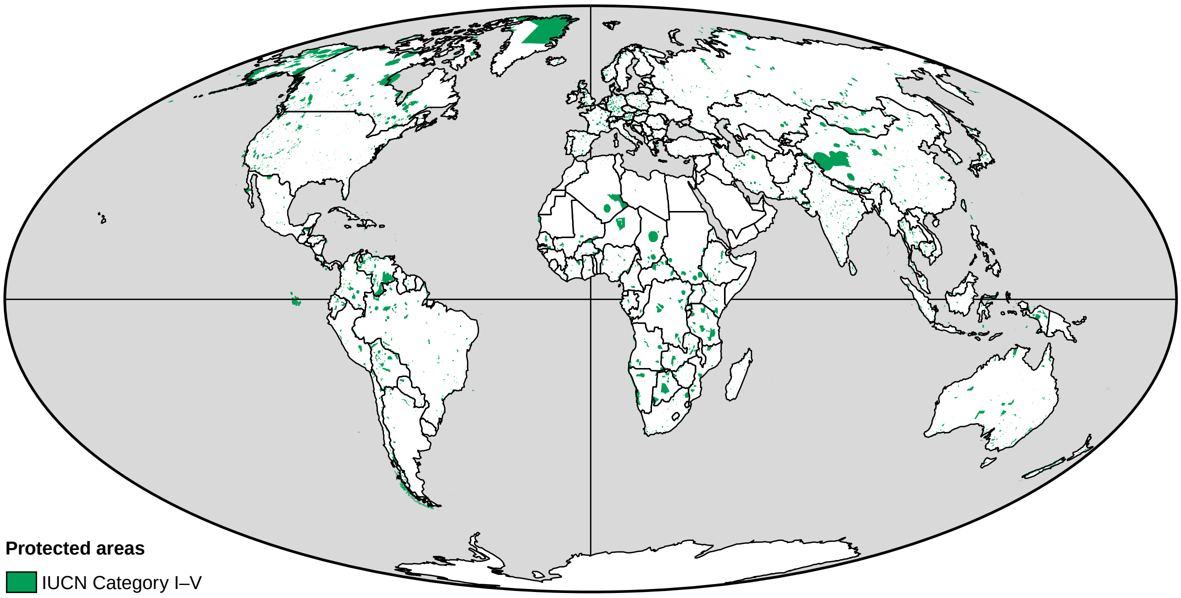


Figure E 3.3-1
The worldwide system of protected areas.
Source: WCMC, 1998

10 per cent of each biogeographical province under nature conservation has been achieved in only a quarter of the provinces to date. In most of the provinces, less than 2 per cent of the land is protected (Fig. E 3.3-3). If the protected areas are compared with the biome types, today 0.8–9.9 per cent of the areas of the biomes are protected. To date, therefore,

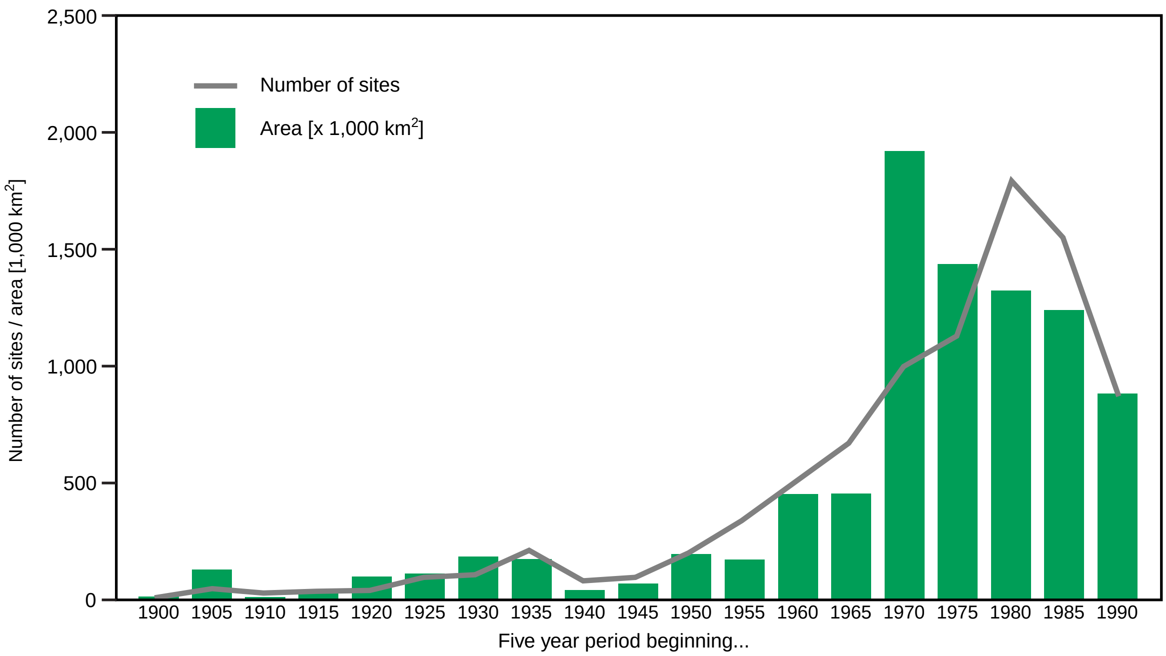
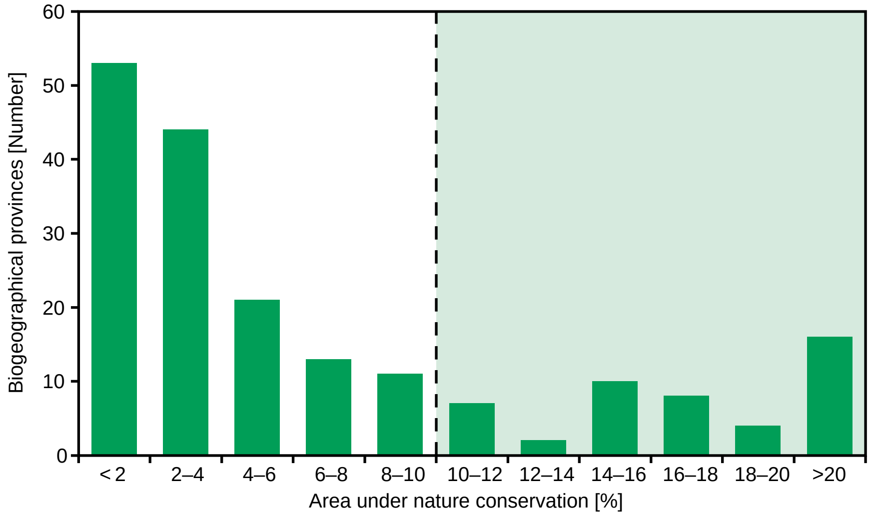


Figure E 3.3-2
Growth of the worldwide system of protected areas (not cumulative).
Source: McNeely et al, 1994

Figure E 3.3-3
Distribution of the proportion of biogeographical provinces that is under nature conservation. Only protected area categories I–V are considered (1978 category system). Only the provinces to the right of the broken line meet the criteria of over 10 per cent nature conservation area as called for by the Bali Action Plan.
Source: McNeely et al, 1994



no biome type is satisfactorily represented in the worldwide protected areas system (Table E 3.3-2).

The protection of the marine environment and its biodiversity is lagging far behind that of the terrestrial sphere (Kelleher and Bleakley, 1994). The biogeographical representativeness of the worldwide 1,182 protected marine areas is unsatisfactory: no integrated approach for the management of the global marine ecosystem has yet been made. Above all, there is an urgent need to carry out a systematic classification, on the basis of which a representative whole-area protection strategy can be developed.

A large proportion of terrestrial biological diversity (approx 50 per cent) occurs on a very small proportion of the Earth's surface (approx 2 per cent), the 'biodiversity hotspots', many of which are in tropical developing countries (Myers, 1998; Mittermeyer et al, 1998; Fig. D 1.2-2). The representativeness of the protected area system with respect to the hotspots has not been satisfactorily examined; there is a need for research here. By improving the available data and making use of modern information technology, progress can be expected with this in future. A study by BirdLife International, for example, shows that around 20 per cent of the territories of endemic bird species include no protected areas (Stattersfield et al, 1998). Well thought out prioritization can certainly help to improve the effectiveness of a protected area system on the same level: there is an acute need for action here.

E 3.3.2.4
Planning and selecting protected areas

The correct choice of the sites for protected areas is a decisive prerequisite for success in conserving biodiversity (Caldecott, 1994). There are a number of

Table E 3.3-2
Analysis of the worldwide representativeness of protected areas according to biome types.
Source: McNeely et al, 1994

Biome type	Area biome [10^6 km²]	Protected area [10^6 ha]	Protected area [%]
Tropical rainforest	10.5	53.8	5.1
Subtropical / temperate rainforest	3.9	36.6	9.3
Temperate coniferous forest	15.7	48.7	3.1
Tropical forest / steppe	17.3	81.8	4.7
Temperate deciduous forest	11.2	35.8	3.2
Evergreen sclerophyllous forest	3.8	17.8	4.7
Warm deserts / semi-deserts	24.3	98.4	4.1
Cold deserts	9.3	36.5	3.9
Tundra	22.0	164.5	7.5
Tropical steppes / savannahs	4.3	23.5	5.5
Temperate steppes	8.9	6.9	0.8
Mixed mountain systems	10.6	85.2	8.0
Mixed island systems	3.3	32.3	9.9
Lake systems	0.5	0.6	1.3
Total	145.6	722.6	5.0

approaches and criteria (eg Johnson, 1995; Miller et al, 1995; Dinerstein et al, 1995; Annex I to the CBD). These criteria can be summarized as follows:

- *Distinctiveness*: Priority should be given to sites with a high proportion of rare, endemic or taxonomically unique biodiversity ('biodiversity hotspots'; Mittermeyer et al, 1998; Williams, 1998).
- *Usefulness*: Species or ecosystems whose loss would harm humans – for example as a result of lost use or ecological services – should be given preferential protection.
- *Representativeness*: All ecosystem types should be represented in a protected area system.
- *Redundancy*: It must be ensured that planning errors, disasters or climatic change in a protected area do not put at risk the supraregional or even worldwide existence of an ecosystem type that occurs there.
- *Threat*: It is especially urgent to assign protection status to species or ecosystem types threatened with local or even global extinction.

These (and other) criteria have their weak points and their application is no simple task because, for example, there are not even uniform indicators of biodiversity.

NETWORKS: CORRIDORS AND CONNECTIVITY

Protected areas are usually fragments of the original ecosystems. This fragmentation not only means a simple reduction of site size, but also has many ecological effects (eg upon genetic drift, edge effects; Section C 1.1). It therefore makes sense to connect the remaining fragments with corridors in order to create an interlinked compound system (eg Noss and Harris, 1986). These corridors should improve the mobility and the genetic exchange of certain species and, thus, their probability of survival, but they are more prone than usual to edge effects and are therefore more sensitive. They are particularly effective when they mirror the known migration routes of animals. One large-scale example is the vision of a 'biological corridor' comprising protected areas or biosphere reserves stretching from Mexico to Panama (MAB, 1999). Given anthropogenic climate change and the fragmentation of natural ecosystems, corridors have an additional significance in order to allow the climate-related shift of ecosystem types (Section F 4.1; Peters and Darling, 1985). However, given the current state of knowledge, it is not yet possible to make general recommendations or rules for the establishment and design of corridor systems. Their effectiveness varies too greatly from case to case to provide a basis for this (Dawson, 1994), and the benefits of corridors as well as the prerequisites for their success have not yet been sufficiently studied (Plachter, 1991; Simberloff et al, 1992; Meffe and Carroll, 1994). Nature conservation research should be dedicated to this important matter to a greater extent. In Europe, the implementation of the Habitats Directive and the NATURA 2000 network can provide a framework for this research.

E 3.3.2.5
Effectiveness and management of protected areas

No matter how impressive the number and the size of the worldwide protected areas may appear at first glance, this says very little about their quality and effectiveness. Designation alone of a protected area does not remove the threats to biodiversity. There is no doubt that many of the areas exist only on paper, with local implementation either non-existent or fraught with major problems (eg poaching, illegal use of timber, settlement, fisheries and agriculture; Brandon et al, 1998).

The question of the effectiveness of protected areas can only be answered unsatisfactorily: even in countries with a well established protected area system there are too few data and studies. Two examples will illustrate the problems:

- All US National Parks are too small and insufficiently linked with each other and the surrounding area to conserve the entire mammal fauna present there when they were founded. Thus in the 20th century, particular mammals have become extinct in all of the National Parks (with the exception of the biggest one), with the loss of species decreasing in a linear relationship to increasing Park size (Newmark, 1987).
- The situation in Germany is similar: species loss cannot be halted by the current system of protected areas (Ssymank, 1997). A study of a representative selection of protected areas in southern Germany comes to the conclusion that only 18 per cent of the areas have a good state of conservation, whereas in 75 per cent there is a risk or an acute threat to the protection objectives. 5 per cent of the areas had already been destroyed (Haarmann and Pretscher, 1993).

For the first time, the worldwide study of protected areas by the IUCN ('Regional Review') provides an overview of these problems, from which recommendations for region-specific improvements were derived (McNeely et al, 1994). In the following, two mutually complementary approaches will be emphasized that are especially important to nature conservation.

MANAGEMENT IN THE BIOREGIONAL CONTEXT

The effectiveness and success of protected areas is not achieved by shielding them as far as possible from external influences and changes. Natural ecosystems, too, are rarely in equilibrium but tend rather to be influenced by external disturbances ('non-equilibrium paradigm', Pickett et al, 1997).

These dynamics have to be taken into account with every conservation strategy; the effect of fire in natural ecosystems and their changed evaluation from the point of view of nature conservation is a good example of this (Johnson and Gutsell, 1994). Stability (in the sense of 'freezing' a state) is not a goal to be achieved or even aimed at for ecosystems. Reserves are not only characterized by the internal dynamics of ecological and evolutionary processes that have to take account of nature conservation ('process protection', eg Knapp, 1998). They are also exposed to many influences and disturbances from the surrounding landscape, which influence the species composition within the area and, in many cases, cannot be stopped. For this reason, nature conservation strategies that concentrate on individual protected areas and ignore the wider context of the surrounding landscape, the history of its use and its current uses, are unrealistic, especially as only a small proportion of worldwide biodiversity can be found in protected areas (Noss and Harris, 1986; Miller, 1996).

An integrative strategy encompassing the entire landscape is therefore needed (SRU, 1996). The protected areas (as 'islands' of biodiversity) and the surrounding areas ('matrix'), that are managed extensively or intensively, have to be seen in context. This finding is increasingly being accepted throughout the world and it forms the basis for concepts such as bioregional management (Miller et al, 1995; Section E 3.9) or UNESCO biosphere reserves (MAB, 1996). AGENDA 21 also calls for the introduction of integrative concepts. Accordingly, the initiatives for Local AGENDA 21 processes should increasingly take up this subject. The Convention on Biological Diversity also states that the Parties should incorporate the integrative approach for the conservation and sustainable use of biodiversity into the various sectoral strategies and measures and ensure implementation along these lines (Article 6 CBD; Section I 3).

ADAPTIVE MANAGEMENT

Adaptive management is an approach for the management of biological systems that takes account of the fact that, firstly, there is only incomplete knowledge about these systems and, secondly, that change represents a fundamental reality of biological systems (Holling, 1978 and 1994; Walters, 1986 and 1997). A major challenge for the future will be to adjust and adapt to – often unexpected – changes and processes (McNeely, 1997; Section F 4). Adaptive management does not therefore attempt to define objectives or strategies 'once and for all' (Gunderson et al, 1994). Instead, a wide variety of possible hypotheses and strategies are permitted, which take account of the perspectives of both biological and social sciences.

Adaptive management uses an experimental approach:

1. If interventions are necessary, they are if possible planned and implemented in the form of scientific experiments so that they not only deliver a direct benefit, but also reduce uncertainty about the function of the system.
2. The precondition for this is adequate, long-term monitoring before, during and after the intervention.
3. The findings are used to improve management strategies (performance monitoring).

This type of feedback, a general aversion to irreversible interventions and a general preference for high biological and cultural diversity, should improve the adaptability of the ecosystems concerned vis-à-vis changes (Ludwig et al, 1993). Adaptive management is shaped as an iterative learning process and therefore has a beginning, but no end: it survives on continuous assessment and innovation (Meffe and Carroll, 1994). Since monitoring and assessment are important elements of adaptive management, the availability of indicators on condition, pressure and reaction are a key requirement for its application: there is still considerable need for research here (Section J 2.1). This flexible approach is suitable both for the management of regenerative biological resources and for nature conservation tasks. It is especially helpful when direct social or environmental change is inevitable.

E 3.3.2.6
Conclusions and recommendations

Protected areas are an important pillar of every strategy for the conservation of biodiversity. The task of conserving biological diversity cannot, however, solely be 'delegated' to socially and ecologically isolated protected areas: only integrative approaches hold out a prospect of success. This integration has to take place in various ways:

1. *Ecological integration*: Ecological systems can be influenced and, in many cases, controlled by external factors; they are not screened off from the outside world and are only rarely in balance. The conservation of biodiversity in protected areas must take into account the fact that disturbances and dynamics are fundamental, natural processes in ecosystems. This also means that the spatial contexts of ecological processes are recognized and taken into account, above all the relationship

between the protected areas themselves as well as their context within the surrounding landscape. The system of gradated land-use intensities used in this report is helpful for this task (Sections E 3.1 and E 3.9).

2. *Social integration*: Conveying and instilling the objectives of nature conservation into various groups in society, especially at local and bioregional level are key requirements for successful implementation or enforcement. Important points are the link between nature conservation and cultural protection (Section E 3.5), the importance of environmental learning (Section I 2.5) and the arbitration of the divergent interests of the local population, users of the land and nature conservation objectives (Section E 3.9). This task is a major social challenge: the problems and conflicts concerned with nature conservation and conservation areas will be increasingly difficult to solve in the future (McNeely et al, 1994).
3. *Economic integration*: protected areas provide important services for society. These services, some of which can be maintained only by foregoing exploitative use or by management that entails costs, should appear in the societal account (Section H 5). Incentive structures should promote and not hamper the conservation of biodiversity (Section I 2.4).

These points are frequently mentioned in international agreements. But they have to be implemented at national or bioregional level; there are also still considerable deficits in implementation in Germany (cf Chapter I).

Objectives for landscape type 'N': conservation before use

There is widespread agreement on the fundamental objective: a worldwide, effective and representative system of protected areas should be established. It should not only reflect the range of biomes, bioregions or ecosystem types – including the limnic and marine sphere – it should also take account of areas with high species diversity (hotspots) or endemism (Mittermeyer et al, 1998). This system can overall be termed a 'guard rail' which it would be unacceptable for the international community to cross (Section I 1). The question as to how much land is needed for this, however, cannot be answered scientifically with the current state of knowledge and certainly cannot be averaged over various bioregions. Important ecological findings, a sufficiently precise definition of the objectives of nature conservation policy and the economic methods for estimating the biosphere values are still inadequate for this and should be improved as a matter of urgency (Section J 1.4). For this reason, setting objectives for area protection is currently more of an art than a science. The objectives are always the result of negotiations in which expert opinions or assessments, the application of the precautionary principle and economic and political interests all play an important role.

Nevertheless, experts from various committees and bioregions independently come to the conclusion that the proportion of land designated for nature conservation should be in the order of magnitude of 10–20 per cent (eg 'Bali Action Plan', McNeely and Miller, 1984; Haber, 1972, 1986; Heydemann, 1980, 1981; LANA, 1991; IUCN, 1993; SRU, 1996). In the process, the following simple relationship applies: the larger the nature conservation area and the better they are chosen, the more certain it is that it will be possible to conserve biodiversity.

Obviously, this percentage is heavily dependent on the regional circumstances and will vary greatly in practice. It also depends on the scale considered: the smaller the scale, the more the target will vary. There will be regions where 100 per cent protection is needed and others where just 1 per cent appears appropriate. A rough estimate of this sort can therefore only ever be a first guideline; a more precise study is always necessary for the region concerned in each case.

The Council agrees with this assessment and recommends as a rough indicative guide that 10–20 per cent of the world's land area should be reserved for nature conservation, selected according to substantive criteria.

Planning protected areas

Discussions at the national and bioregional level to specify the objectives and strategies for nature conservation are needed for the selection of the protected areas. Planning protected area systems, selecting protected areas representatively, gaining acceptance for and communicating policy, as well as monitoring status, trends, threats and conflicts are important elements of this process, and may make apparent some considerable deficits in the taxonomic or ecological knowledge base. The various protected areas should be viewed in context and be developed in the direction of a system of protected areas. This applies not only to the size and interlinkage of the areas among themselves, but above all also to how well the natural capital of a landscape is represented in the protected areas and how well the respective protected areas are integrated into the surrounding landscape use. In this context, the European directives are of key importance. The Habitats Directive offers great opportunities to nature conservation that have unfortunately not been used to date (Section I 3.3.4). In this respect, Germany is anything but a pioneer. The status of implementation of the

Habitats Directive, and of the EU-wide NATURA 2000 network envisaged in that directive, must be considered very unsatisfactory in Germany. The deficit in enforcement has already led to Treaty infringement proceedings at European level. The Council refers to recommendations made in previous annual reports for the need to amend the Federal Nature Conservation Act and once again strongly recommends speedy implementation with due political decisiveness.

Managing protected areas

Protected areas not only have to be properly selected and designated; their success also depends above all on appropriate management and long-term security. Here, too, a deficit in implementation can be seen: the loss of native biodiversity has now been sufficiently documented; the causes are known. There is a great lack of funds, specialist staff and general impetus to implement nature conservation.

Correlations with work in the behavioural and social sciences should increasingly be recognized and considered in the attempt to solve current problems in connection with acceptance and conflicts in protected areas (eg Stoll, 1999). Participatory and discursive approaches are key instruments for improving the presentation and communication of nature conservation so as to achieve the all-important public acceptance. The interlinking of nature conservation management with educational activities as well as with environmental learning and experience is particularly important. Above all, the bioregional context offers scope for cooperation between local nature conservation initiatives and local educational institutions (Sections E 3.9 and I 3.3). These approaches should not only be advanced in applied research (corresponding conclusions drawn for the management of protected areas); they are also an important subject for the basic and further training of nature conservation experts.

Access to information on nature conservation is unsatisfactory. Improved organization, standardization and easier access to data would allow nature conservation work to take place in a much more efficient manner. It would also be helpful to promote better informational interlinkage of the – governmental and non-governmental – nature conservation institutions, facilitating the exchange of experience and the spread of new concepts, eg from the field of international nature conservation, among the nature conservation community. This could be an important task for the German Clearing House Mechanism.

The link between new scientific findings in ecology and the practical on-site management of conservation areas should be improved. The aim should be to improve cooperation and exchange of expertise and technology between scientists and practitioners of nature conservation, on the one hand, and resource use on the other, in order to convey to practitioners the paradigm shifts in modern ecology and, vice versa, to inform scientists about the current questions affecting practitioners. German nature conservation research has an urgent need to catch up and should therefore be promoted more intensively. It is also necessary to develop this interface so that research in the direction of a 'scientific theory of nature conservation' (Pickett et al, 1997) can be further developed.

In the international sphere, the particular contribution of German development cooperation to the creation and management of protected areas in developing countries has to be mentioned (Section I 3.5.3).

Financing protected areas

The funding of biodiversity conservation measures presents major challenges. An effective system of protected areas covering 15 per cent of the worldwide land area would cause annual costs of approx US$27.5 thousand million (including land purchases and compensation for loss of use), a large proportion of which would be incurred in developing countries (James et al, 1999). If this figure is compared with the existing worldwide expenditure on protected areas (US$6 thousand million per year) or the total GEF (Global Environment Facility) expenditure on biodiversity (approx US$1 thousand million since 1992), the large funding gap becomes apparent, which mainly affects compensation payments for developing countries.

It will not be possible to close this gap with a simple call for improved funding for the existing public nature conservation institutions. Economic incentives and subsidies are an important starting point for redistributing funds (Section I 2.4). A rough calculation shows that – in comparison to the agricultural subsidies that are standard practice in many industrialized countries – financing the expansion and operation of the worldwide protected area system is by no means an impossible task. Estimates of worldwide subsidies with a harmful impact on biodiversity are in the order of magnitude of US$1,450 thousand million year^{-1}, of which approx US$460 thousand million year^{-1} are agricultural subsidies (Myers, 1998). Whereas US$82,500 km^{-2} year^{-1} are spent on subsidizing agricultural land in the EU and US$16,100 km^{-2} year^{-1} in the USA, support for national parks and protected areas in these countries is less than US$2,000 km^{-2} year^{-1} (James et al, 1999). Reducing and partially diverting agricultural subsidies by paying for ecological services would thus offer major opportunities for the conservation of biological diversity.

An important requirement for this is the development and testing of a methodology for assessing and evaluating the ecological services provided by protected areas in particular and the landscape in general, and for incorporating the outcomes into societal decision-making processes (Section H 4). The existing biosphere reserves are especially suitable for pilot projects of this kind because they comprise not only protected areas (core zones), but also buffer zones and development zones (Box E 3.9-1).

However, the subject of financing cannot be treated in isolation for protected areas alone; it must be viewed in conjunction with biosphere policy as a whole – especially North-South policy. Hence this area (incentive instruments, funds, international cooperation) will be dealt with later in a section of its own (Section I 3.5.3.2).

E 3.3.3 'Conservation through use' as a strategy

E 3.3.3.1 The problem: the (alleged) conflict between conservation and use

The (alleged) conflict between conservation and use has already been referred to in the pre-structuring Section E 3.3.1 'Types of landscape use'. In this respect it has been argued that in many cases there is not much hope of success in attaining the objective of environmental policy if every use of biosphere services is prohibited. Much rather, a 'system of differentiated intensities of use' gradated according to the relevant landscape-use type should be developed.

The advantages of such a 'system of differentiated intensities of use' become clear upon consideration of empirical experience with respect to the effectiveness of nature conservation areas in which all use of biological resources is prohibited (Lewis, 1996). Protected areas, especially in developing countries, usually provide only low yields for the local population. At the same time, enormous costs for the protection of the biosphere are imposed on local population groups, mostly in the form of opportunity costs arising from non-use (Section E 3.3.2; McNeely, 1988). This imbalance of costs and benefits among the local population leads to serious problems for protected areas because a conflict arises between the objective of nature conservation and the promotion of economic development (Miller et al, 1995). Environmental policy is therefore well advised to limit the prohibition of all use, especially in countries with weak local implementation potential, to rare cases where the conservation of ecosystem components is really not possible in any other way.

Measures to place a value on biosphere services create scope for using ecosystems or their elements and functions for earning individual incomes. This approach corrects the imbalance between costs and benefits among the local population in favour of the benefits. This fulfils an important requirement, ie that protection goals can also be realized effectively and adhered to locally. In contrast to management of landscape-use type 'E' ('economic use'), intensive land use is not in the foreground (Section E 3.3.4), the strategy with land-use type 'M' ('mean intensity of use'), which is in the foreground here, is to implement the protection concept and aim for extensive land use by permitting certain types of use.

E 3.3.3.2 Fundamental idea: 'Conservation through use'

The fundamental idea of the 'conservation through use' instrument is to give private individuals – especially the local population but, under certain circumstances also companies, NGOs, etc – the possibility to use the ecosystem, which is to be protected in principle, for the purposes of earning individual incomes. Excessive use, that endangers protection, is to be prevented by relevant sanctions.

One example of the 'conservation through use' concept is the protection of crocodiles in Australia by permitting trade, ie sales of crocodile eggs or young crocodiles to breeding farms. This financial gain, for example benefitting farmers whose cattle are otherwise threatened by the crocodiles, guarantees tolerance and protection of the crocodiles (Heidinger, 1998).

Such an example of 'valuation of nature' – in the example cited it is valuing a species of animal – gives private actors an incentive to use the ecosystem, but not to such an extent that it is overused and thus loses its protective properties. With regard to their own scope for earning income, private actors should have an incentive to conserve the ecological efficiency of the ecosystem in the future – as a basis for earning private incomes in the long term. This can also be seen in the example of the protection of the crocodiles. Here there was a change in consciousness to the effect that when the native Aborigines kill the crocodile in a legalized process, they take care to spare the egg-laying females (Heidinger, 1998).

In principle, a distinction can be made between two different methods for placing a value on biosphere services:

1. On the one hand, there are cases in which individuals are willing to pay for the use of the biosphere services. It would then be the task of state nature conservation policy to license the available possibilities for use. In this case there is thus an established (economic) value. A typical example of the existence of a willingness to pay and the marketability of certain biosphere services is the discussion about the trade in endangered species (Section D 3.1). Experience with CITES has shown that strict regulation of trade has often led to legal trade being replaced by illegal trade. A flexible mechanism to specify the permitted scope of the trade in endangered species can, in many cases, prove to be an appropriate strategy for conservation and use.
2. On the other hand, there are many cases where economic values are not established and individuals are not willing to pay for biosphere services. In such cases, the state must first create a willingness to pay. This can be done, for example, if the relevant demand for biosphere services comes from the state itself. The payment of subsidies to safeguard access to cultivated landscapes can be interpreted in this sense.

When we look at the economic reasons for the loss of biodiversity, the importance of the approach of raising the status of protecting biosphere services within individual cost-benefit calculations by placing a value on individual sections of the biosphere becomes clear. Thus, Swanson (1994) points out the important point that species conservation is so difficult for terrestrial inhabitants because nature conservation competes with other forms of land use. Because of the low value usually placed on nature conservation, especially vis-à-vis agricultural use (expansion of subsistence farming as a result of population pressure; industrial, export-oriented agriculture) it is very difficult to implement biodiversity protection (Swanson, 1994). Placing a value on biosphere services is thus an important instrument for influencing the distorted value relationship in favour of nature conservation without completely ignoring economic considerations.

The use of this strategy also complies with the philosophy of Article 11 of the Convention on Biological Diversity that calls upon the Parties to adopt incentives for the conservation and sustainable use of biological resources. The need to create incentives becomes especially clear against the background of the developing countries' limited financial and institutional scope to afford conservation areas adequate protection against human intervention. The example of species conservation shows that wild animals – regardless of the existing statutory regulations – are hunted and their populations are threatened when people are poor or if the effective implementation of protective measures cannot be guaranteed. For this reason, for national nature conservation policy to be effective and efficient – especially in developing countries where both the administrative capabilities for implementing protection measures and the financial resources needed are scarce – two conditions have been proposed (Miller et al, 1995):

1. The local population that lives with the biotic resources must have incentives to protect them.
2. Users of resources must be responsible for their actions.

This approach also takes account of the finding that the biosphere cannot be protected in the long term solely by the establishment of protected areas (Section E 3.3.2). For the implementation of sustainable treatment of the biosphere, the issue is far more to accomplish nature conservation outside the protected areas as well. This can be achieved only by active participation of the rural population in nature conservation and by the granting of economic advantages. It is precisely this thought that corresponds to the strategy of 'conservation through use' in which the opposing conservation and use interests are neutralized (Miersch, 1998; Krug, 1997; Merz, 1995). The 'conservation through use' strategy is thus a central component for projects where protection and development goals are to be achieved side by side (Integrated Conservation Development Projects – ICDP; Wells and Brandon, 1992).

In spite of advocating this strategy in principle, it is necessary to make a differential assessment of the conditions in which it can be applied. Protecting all sections of the biosphere with this instrument is not recommended. Instead, a more detailed and differentiated analysis is needed that refers to the different land-use types previously introduced (Section E 3.3.1). Thus, with extremely rare, varied and species-rich landscapes ('world heritage'), forms of human use should be entirely – or at least predominantly – excluded in order to retain their uniqueness.

Finally, we should make a linguistic note. The concept of 'conservation through use' (*Schutz durch Nutzung*) should not be understood in the sense of 'maintenance through use' (*Pflegenutzung*) as practised in current nature conservation efforts in Germany. In such efforts, the main concern is that cultural landscapes shaped by human influences can only be conserved by continuing the traditional land use. By contrast, at the heart of the strategy of 'conservation through use' advocated by the Council is the idea of combining economic use interests with the protection of natural landscapes. The analogy to current practice therefore rather pertains to permitting agricultural activity in nature conservation areas or semi-natural areas in Germany. This also illustrates the conflicts, because agriculture and forestry may be compliant with statutory provisions and yet often in considerable conflict with the conservation goal.

E 3.3.3.3
General conclusions with regard to applicability of the strategy

Within the issue at the heart of this section – the extent to which the biosphere can be protected through use – type 'M' ('mean intensity of use') is the category most relevant to the theme (cf Section E 3.3.1 for the landscape-use types). Whereas with type 'N' ('nature conservation') and type 'E' ('economic use') the prime political goal to be pursued is relatively clearly stated in the typological characteristics – protection objectives with type 'N' and economic development goals with type 'E' – type 'M' offers the greatest potential for application of the strategy of 'conservation through use'. Here, protection reduces private use only slightly, due to lower productivity (in comparison to type 'E'), and, in turn, private use impairs the quality of protected environmental resources only to a very slight extent. However, the other two types also contain considerable potential that will first be addressed.

Landscapes where the protection objective is dominant (type 'N')

The dominant position of a political objective when dealing with a landscape of type 'N' or type 'E' – protection goal or economic use – does not automatically mean that only a certain instrument can or should be used. This has already been demonstrated with reference to type 'N'. As already argued in the introduction, a government ban on the use of a landscape can prove to be ineffective when the prohibition is to be implemented by a central government body against the interests of the local population (McNeely, 1988). In many cases such measures only lead to poaching and illegal cultivation of the land. For this reason, use can be permitted here to a very limited extent in order to maintain the local protection interests (Section E 3.3.2).

In this context, McNeely points out that many conflicts which arise during the designation of protected areas can be avoided if the local population is viewed as a partner instead of an opponent. The importance of this circumstance is obvious when we consider that for thousands of years the indigenous population may well have been a harmonious component of the ecosystem from which they are now to be excluded (McNeely 1990, cited after Lerch, 1996, Section E 3.5).

Landscapes where the use objective is dominant (type 'E')

In type 'E' landscapes, too, measures can also be taken for biosphere conservation. On the one hand, this is shown by experience in the field of urban ecology (Section E 3.8; Ritter, 1995; Weigmann, 1995). On the other hand, not every anthropogenic intervention into the natural environment is a threat to diversity *per se*. Thus Central Europe has been ecologically enriched by the thousands of years of human influence (Section E 2.1). As the forest was forced back and a diverse spectrum of open landscape and successional habitat types was created, in combination with large-scale soil nutrient depletion, the conditions were put in place for the spread of plant species which required light or were uncompetitive in other circumstances (Hampicke, 1991).

The greatest reservations with respect to the opportunities for biosphere conservation of type 'E' certainly concern intensive agriculture. Although in principle it is possible to argue that every environmental policy measure in intensive agriculture is an attempt to harmonize the targets of protection of use, economic use dominates so much that this issue is treated separately elsewhere in the report (Section E 3.3.4), and the same applies to intensive aquaculture (Section E 3.4).

Landscapes with mean protection requirements (type 'M')

Without a doubt, type 'M', ie the landscape with mean protection requirement, is the category that is most relevant to the subject of this section because here the scope for achieving the protection and the use objectives is the greatest. Both the other types are characterized by a broad conflict between conservation and use. This conflict corresponds to typical trade-off problems, such as those that are frequently encountered in economic theory, ie the achievement of one objective (protection goal) is often at the expense of the other objective (use goal). However, in addition there are also large portions of the biosphere in which the two goals are not in major conflict, but protection goals can be achieved more easily by permitting (limited) use. The strategy of 'conservation through use' will be presented below using case studies – mainly concerning type 'M'.

E 3.3.3.4
'Conservation through use': Case studies

Game management in the Selous Reserve in Tanzania

The Selous National Park is in the south-east of Tanzania and at 50,000km^2 is the largest nature conservation area in Africa. Although UNESCO has recognized the area as a 'World Heritage Site', the conservation of this area is threatened by increasing population pressure and a greater need for agricultural land. The greatest damage is caused by commercial poaching and illegal logging. So far, the authorities have not succeeded in planning and implementing an effective system of nature conservation management.

The abundance of game is a tourist attraction and the key factor for booming tourism, which is one of the most important sources of income for the country. However, the losers from the economic upturn brought about by tourism were the local population on the periphery of the protected area, which, on the one hand has no share in the income from tourism and, on the other hand, has to suffer financial losses from the constant damage to its agricultural land caused by the game. This is, therefore, the classic case described above where the local population groups have to bear the costs of nature and landscape conservation without having a share in the benefits.

The introduction of regulated hunting is now set to help the local population to benefit from the abundance of game in its home territory. Regulated hunting should serve both conservation and use objectives. On the one hand, the inhabitants are given permission to use wild animals for meat and, on the other hand, regulation is used as a tool for minimizing the negative impact on the natural population. Game wardens monitor whether the specified quotas are adhered to and no protected species are killed. Since the introduction of this system, poaching has fallen considerably. In spite of the (limited) permission to hunt elephants, the population increased from 30,000 to 52,000 animals as a result of the almost complete eradication of poaching.

Furthermore, there are plans for promotion of restricted hunting tourism and ecotourism, which will induce a further increase in the economic value of the species living *in situ* (BMU, 1998).

The Campfire Programme in Zimbabwe (Communal Areas Management Programme for Indigenous Resources)

During the British colonial period, the black population was pushed back into regions with unproductive agricultural soils. These communal areas cover around 42 per cent of Zimbabwe's total land area. Hunting for wild animals was not only banned in the protected areas, but also in the communal areas and the large private farms. Furthermore, the wild animals are significant competitors for the food of the domestic cattle. This meant that neither the indigenous population nor the farmers had any interest in safeguarding a large enough game population. Since the distribution of costs and benefits from the protection of wild animals was unfavourable to the local population, there was no support among the population with regard to effectively combating poaching. A turnaround has been achieved in species conservation – and, associated with this, in landscape protection – by means of the Campfire Programme, trying to create incentives for long-term species conservation in agricultural land via the use of wild animal species (Grimm, 1996). The Campfire Project is based on three fundamental principles:

1. Strengthening the responsibility of the rural local authorities with respect to access to and control of their natural resources.
2. Transferring to the rural local authorities the right of independent decision-making on management of their natural resources.
3. Income from the use of the natural resources should go directly to the local authorities.

The Campfire Programme provides the legal basis for the rural population to use their natural resources sustainably and to directly improve their financial position. The following possibilities for earning income by using the available biotic resources are allowed (Campfire Association, 1999):

- *Renting out hunting licences*: Over 90 per cent of Campfire 's income comes from selling licences to foreign hunters who want to shoot elephants, buffalo, lions or other wild animals, with elephant hunting alone accounting for 64 per cent of the income earned (Metcalfe et al, 1995).
- *Use of natural resources*: The municipalities collect, harvest and sell natural products, such as crocodile eggs, wood, river sand, etc.
- *Tourism*: Some of the income from communal areas comes from renting out land for nature tourism. At the same time, some municipalities maintain their own tourism facilities. Many local people are available as guides.
- *Sale of live animals*: In areas where the game population is very high, live animals are sold to private game reserves and national parks.
- *Sale of meat*: In some communal areas wild animal meat is sold to neighbouring municipalities and towns.

It is very important for the success of the project that the income must not be diverted to central government. Instead, the majority of the money earned remains at local level. The earnings are mainly either invested in local economic development or go directly to private households (Barnes, 1994).

The success of the Campfire Project can be seen from an economic, ecological and social point of view, in other words in all three dimensions of sustainability. The World Wide Fund for Nature (WWF) estimates that household incomes in the communal areas have risen by 15–25 per cent (Campfire Association, 1999). From a nature- and species conservation point of view, the designation of new protected areas as a result of Campfire activities should be deemed to be a success. It is especially important that Campfire efforts have led to a re-opening of traditional migration routes for wild animals as a result of the creation of interlinked protected areas (Nuding, 1996).

In addition to the economic and ecological successes of the project, positive effects can also be seen from a social point of view. The development and learning process triggered by the initiative led to an increase in local self-awareness and responsibility (empowerment, collective self-reliance). This form of wild animal use thus simultaneously combats poverty and promotes resource conservation and investment in human capital (Nuding, 1996).

E 3.3.3.5
Implementing the strategy of 'conservation through use'

Choosing the form of use

With regard to a landscape's protection requirement and its protection worthiness, an appropriate use or combination of various forms of use has to be chosen. In principle, a distinction can be made between non-consuming use (photo-tourism and the trade in living game) and consumptive use (subsistence hunting, trophy hunting, game harvesting). The right form of use cannot be selected abstractly, but only on the basis of the local socio-economic conditions (Krug, 1997).

Some forms of use, which are particularly suitable for the 'conservation through use' strategy, include the use of wild animals and plants, tourism, and scientific use. In principle, various forms of use are therefore suitable for implementation of the 'conservation through use' strategy. However, the use of landscapes for extensive biomass production is at the fore in this section, meaning that the use of wild animals and plants in particular is considered here.

In this form of use, landscape protection can be realized by placing a value on individual animal or plant species. Many species produce multiple economic benefits. For example, an elephant can be used to provide meat, open up opportunities for game hunting and function as a general tourist attraction (Miller et al, 1995). Because a species usually has to be kept *in situ* for this form of use, species conservation is simultaneously associated with an incentive also to conserve the ecosystem necessary for the species. Experience in Africa with the legalized use of wild animals – especially in Zimbabwe (Campfire Project), Zambia, South Africa and Namibia – illustrate that the use of game clearly has positive impacts on species conservation and the spread of game species. Species of game and plants that are not used also benefit from the noticeable enlargement of the habitats for wild animals. Nature conservation in this form thus makes ecological sense and is an economically attractive form of land use (Krug, 1997).

Organization of instruments

The various forms of use, the likely criteria that could be used to determine the protection worthiness and protection requirement, and the task of combining use and protection make it clear that the 'conservation through use' strategy cannot be organized according to one blanket, generally applicable blueprint. Instead, as mentioned above, an individual case study is needed for every object of protection, for which the incentives for sustainable management are to be raised by increased use. Only then can instruments be used.

Against this background, implementation of the idea of 'conservation through use' requires a combination of various instruments. It is extremely important to equip potential beneficiaries with property rights or rights of disposal. Only in very few cases does the complete privatization of biological resources lead to an allocation result in which higher protection goals are adhered to. There is therefore a need for precisely tailored rights of disposal that usually have to be subject to a certain degree of public – not necessarily centralized/state – control (cf Section E 3.3.3.6 for the importance of local authority resource management).

This fundamental idea that a gain in efficiency goes hand in hand with the allocation of private rights of disposal has long been discussed in the economic theory of property rights (Demsetz, 1967) and can also be used for many environmental media – in addition to air and water, possibly also for more subtle media, such as the biosphere (Wegehenkel, 1981). However, an individual case study has to decide on the appropriateness of the desired environmental policy goal in each case because the possibilities for combining the protection goals with the use objectives are heavily dependent on the section of the biosphere, the local conditions, etc.

The instrument 'creation of *ex ante* limited rights of disposal' is a key prerequisite for overcoming the problem that the majority of local authority land can be used by anyone for any purpose (open access resource). In many cases this leads to overuse and the ecosystem degradation (Hardin, 1968; Krug, 1997). This central instrument, 'creating rights of disposal', should then be combined with other instruments (Bromley, 1994). On the one hand, economic incentive instruments such as taxes and subsidies can be used in pursuit of conservation and use goals and, on the other hand, in some cases stipulations under administrative law, such as the specification of catch quotas or adherence to allocated use territories, cannot be avoided.

As already mentioned, many previous nature conservation strategies suffer from the fact that too little account is taken of the local population and the intended protection goals are circumvented for this reason. The 'conservation through use' concept draws attention to the importance of incentives for the local population to protect the biosphere. In addition to the 'allocation of rights of disposal' instrument, further economic incentive instruments should be developed in order to provide incentives for conservation as well as promote the acceptance of this new nature conservation regime. Instruments at local, national and global level should be developed for this purpose (McNeely, 1988). It is especially important to deploy incentive instruments at a local level so that the philosophy of protection is not circumvented by permitted use. For this reason, some possible instruments of this type are briefly presented below.

Direct financial incentives – including negative incentives, for example in the form of penalties – use monetary behaviour control to influence the goal of preserving or sustainably using the stock of biological resources. Instruments of this kind could be, for example, the reimbursement of entry fees from protected areas used for tourism, monetary rewards for behaviour which protects the environment, penalties for the illegal use of biological resources and compensation payments for damage caused by wild animals. In addition to financial incentives of this kind, material incentives in the form of food, animals and access to areas where sustainable use is practised could be considered (McNeely, 1988).

In addition to these 'direct' incentive instruments, indirect incentives can also be used to promote local authority interest in biosphere conservation, for example in the form of tax relief, especially for major land owners (core) protection areas, insurance payments for failed harvests and social security payments (McNeely, 1988).

A very interesting instrument in this connection is the proposal of Panayatou (1995) to use development rights in the designation of protected areas. For example, a procedure of this kind is used in Puerto Rico. Here, the coastal regions are divided into areas worthy of protection which are not intended for further economic development, and development areas which are to be kept available for settlement, transportation and commerce. Owners of land in the protected areas are granted tradeable development rights and can use them themselves in development areas or sell them to the highest bidder. The development right, which permanently increases the value of the land, allows certain contraventions of building regulations which are to be defined in corresponding statutory regulations. It therefore represents an economic value that can financially compensate inhabitants whose economic use has been restricted without the need for the state to take responsibility for these compensation payments (Panayatou, 1995; Bizer, 1997).

It has become clear that implementation of the 'conservation through use' strategy will have to be achieved by a combination of a number of different instruments which, in individual cases, should be checked with regard to their applicability and cannot be presented in full here. An OECD study about the economic incentive instruments in biodiversity policy comes to the conclusion that a combination of several instruments is needed to achieve the objective of the Convention on Biological Diversity, the conservation and sustainable use of biodiversity, with the help of economic incentive instruments (OECD, 1998; Section I 3.5.1).

E 3.3.3.6
Concluding remarks: decentralization as a necessary institutional condition

The discussion so far has shown that transferring rights of disposal to individuals or farmers, legalizing the use of elements of the biosphere – in most cases the use of wild animals – and creating opportunities for trade in natural products creates the prerequisite for placing a value on biosphere services and the basis for implementation of the 'conservation through use' strategy. However, the accompanying institutional framework is also of central importance to the success of this approach. Alongside this, corresponding local institutions also have to be set up which not only supervise use, impose sanctions and ensure a fair distribution of income, but should also be integrated into the entire planning and decision-making process of the 'conservation through use' strategy implementation. Control and monitoring mechanisms that build upon local institutions are an important prerequisite for guaranteeing the ecological dimension of the sustainability goal (Krug, 1997; Section E 3.9).

The need to gain distance from a biosphere policy based unilaterally on centralist approaches becomes especially clear from the point of view of the economic federalism theory. Many biosphere services affect cost and benefit factors at the local level, and for this reason this is also the appropriate place for the planning and implementation of conservation and use strategies (Döring, 1998; Fromm, 1999; Lerch, 1996; Kiss, 1990; Section E 3.9). These theoretical arguments are supported by empirical experience, for example within the context of the Campfire Project, where the participatory and democratic involvement of the local population in Campfire activities is an important condition for the success of the project (Miller, 1996). Other case studies also show that local communities are mostly capable of using their biological resources sustainably, and that the establishment of strong and powerful institutions at local level to monitor adherence to conservation and use targets is an important prerequisite for establishing effective incentives to protect the biosphere (McNeely, 1988).

E 3.3.3.7
Required research and action

The action-oriented statements on the questions relating to 'conservation through use' can be kept brief. A concept is called for which – where it is applicable – has advantages both for the biosphere and for people's use interests. For situations where improvements are simultaneously possible for two objectives, there can only be one recommendation: more of them.

This entails identifying those situations in which such advantageous conditions are latent. In this section two examples are discussed and many others can be found in the literature. Research should now concentrate on developing typologies that make it possible to discover such situations. This is a difficult task because, depending on the landscape-use form, social organization, government organizational power (eg assignment and safeguarding of property rights) different solutions are needed.

German development policy should consolidate the existing approaches which firmly place the valuation of nature, and thus conservation through use, at the service of integrated promotion of economic development and the protection of the biosphere.

E 3.3.4
Conservation despite use: sustainable production of biological resources

Increasingly productive land use – basis for the conservation of biodiversity

The use of terrestrial ecosystems for the production of food of plant and animal origin, fodder, regenerative raw materials such as wood, fibres, oils, waxes, etc as well as biomass as a fuel is not only the foundation which sustains human life today; it will play an even greater role in the future when there will not only be a further 3–5 thousand million people to feed but also a need to substitute renewable for non-renewable resources.

To accomplish the adequate nourishment of an estimated world population of 8.25 thousand million people in the year 2025 (United Nations, 1993), the FAO is assuming a required increase in food production of 75 per cent. At this point in time around 83 per cent of the world population will be living in developing countries. Even today around 800 million people there are affected by hunger and malnutrition. At the same time, ever increasing quantities of grain, which used to feed people directly, are now used for animal production with less energy efficiency. Around 21 per cent of the world grain acreage is used to produce fodder and around 22 million km^2, or some 17 per cent of land surface, is dedicated to grazing systems (Steinfeld et al, 1997). Furthermore, around 100 million people in developing countries cannot currently meet their daily firewood needs. Another 1.3 thousand million people are facing increasing fuel bottlenecks because they consume more firewood than is grown (Lean et al, 1990). In 1994 the worldwide consumption of firewood was around 1.9 thousand million m^3, of which over 85 per cent was consumed in developing countries. The potential per capita firewood supply in developing countries will halve by the year 2025 (Schulte-Bisping et al, 1999).

There are the following three options for meeting the increasing demand for usable biomass in the next 25–30 years:

1. The production level remains the same or falls. As a consequence, agricultural land would have to be considerably extended at the expense of natural or semi-natural ecosystems (such as forests and grasslands).
2. If the agricultural land area remains the same, productivity per unit area will have to be increased. This would require almost a doubling of yields.
3. By substituting the products of land use, future needs are secured on the available land within the given productivity. This could be done by reducing the consumption of meat, by acquiring more food from the sea (Section E 3.4) or by using biotechnology in food production.

These options apply to the globe as a whole. From the point of view of biodiversity and the conservation of biological resources, options two and three should be implemented with priority. There will be no uniform worldwide solution. Much rather, regionally varied combinations of these options will have to be developed in order to cover the growing demand. This results from the fact that the starting positions with

Table E 3.3-3
Agricultural land 1994, sub-divided according to arable and permanent grassland.
Sources: WRI, 1998a; FAO, 1998b; World Bank, 1998

	Arable land	Grassland
	[ha per inhabitant]	
North America	0.79	0.9
Latin America	0.36	1.5
Africa	0.27	1.3
Europe	0.43	0.24
Germany	0.15	0.07
Asia	0.18	0.3
China	0.08	0.33
Developing countries	0.18	0.49
Developed countries	0.57	1.0

respect to agricultural land vary greatly in the different regions, as shown in Table E 3.3-3.

If we look at the supply of individual regions or countries, this does not always have to be secured from their own agricultural land. As a result of a disproportionate increase in production in favourable areas, shortages in deficit regions can be balanced out if trade and distribution systems enable this.

E 3.3.4.1
Extending agricultural acreage

Over the last few years various estimates of potential arable land have been published. The estimates worldwide amounts to 2–4 thousand million ha (Alexandratos, 1995; Luyten, 1995; Fischer and Heilig, 1998). Of these, around 1.5 thousand million are already being cultivated today (FAO, 1998b). This total agricultural land has *remained more or less constant* over the last twenty years *in spite of additional cultivated land*. As a result of soil erosion, salinization and the spread of settlements, transport routes and deserts, almost as much land has been lost as has been claimed.

Fig. 3.3-4 shows some scenarios of how the need for agricultural land will develop worldwide with a growing population and varying production levels. A required area of 0.28 ha per person was used as a basis to calculate the scenarios shown in the diagram; a value that already today cannot be reached in large parts of Asia and on average throughout the globe for developing countries (Table E 3.3-3). The calculation also presupposes that in future no agricultural land will be lost to soil degradation. This is an optimistic assumption because soil degradation is currently taking place on a large scale (WBGU, 1995a).

On the basis of existing productivity, the potential land area would be sufficient to feed 12 thousand million people. However, this calculation is deceptive for several reasons. The current annual expansion of agricultural land is only 0.1 per cent of the acreage because at the same time similar quantities of land have to be taken out of production due to severe degradation (Alexandratos, 1995; Young, 1998). Around 40 per cent of food production today comes from irrigated farming, which accounts for around 17 per cent of acreage (FAO, 1996a). The area dedicated to this type of farming has increased by a factor of 2.5 since 1950 (Young, 1998). However, the growth of irrigated land will not continue at the same rate as in the past because of limited land availability, high development and maintenance costs, increasing impairment from salinization and limited availability of water resources. On the contrary, over the last two decades the growth rates have fallen markedly. In Asia, the most significant region of the world for irrigation farming (62 per cent of acreage), 85 per cent of water extraction is already used for agriculture, and in the countries with the highest populations, China and India, the available water potential has already been exhausted by over 80 per cent (Kulshreshta, 1993; WGBU, 1998a).

The expansion of agricultural land is far from being a certainty and is possible to varying degrees in different regions. Whereas in south-east Asia or north Africa around 85 per cent of the potential areas are already being used, the proportion used in South America is only 20 per cent (Young, 1998). Under the outlook of conserving biodiversity, a strategy of major expansion of agricultural land should be viewed extremely critically; after all, it aims at continued progressive intervention in natural ecosystems, increasingly encroaching on more marginal sites and thus also destroying sites of high biodiversity. In particular, in addition to their high genetic, species and habitat diversity, the fragile tropical and subtropical ecosystems play a significant role as gene pools (gene centres) for many domesticated plant and animal species (Section D 3.4). The expansion of agricultural use in these areas would therefore be associated with considerable risk because previously unused resources would be destroyed and the genetic basis of cultivated plants would be threatened.

The following conclusions can be drawn from this brief overview:

- All possible steps must be taken to put a stop to the global degradation of soils so that the land already under cultivation does not lose its productivity (WBGU, 1995a).
- The expansion of the agricultural land at the expense of natural ecosystems should take place only to the extent that is unavoidable following exhaustion of the production potential on land areas already cultivated.

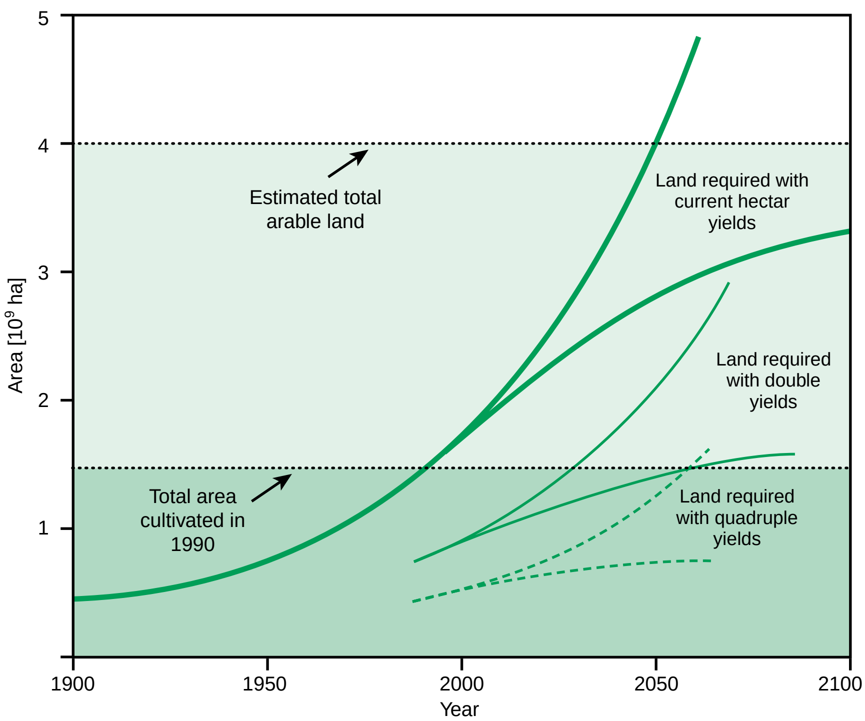


Figure E 3.3-4
Need for arable land with a growing population and different production levels. Bold lines: land required at current hectare yields. The divergence of the lines from the year 2000 onwards results from UN population forecasts. Bottom line: minimum scenario, top line: maximum scenario of population development. Thin lines: land required if harvest yields can be doubled (solid lines) or quadrupled (broken lines) in the future. Shaded areas: estimates of the total land area that was cultivated in 1990 or could possibly be cultivated in the future – a large proportion of this land is wooded areas and wetlands. Cf. description in the text.
Source: Meadows et al, 1993, modified

- The loss of plant crops during storage, transport and processing, which amounts to a considerable proportion, must be reduced further.

Balanced nutrition including a high proportion of plant foodstuffs is the means to reduce losses in processing and improve supplies.

E 3.3.4.2
Scope for increasing agricultural production in various regions

In *North America*, with a comparatively sparse population and favourable climatic and pedological conditions, there is no shortage of agricultural land. From the point of view of the slowly rising population, there is no acute need to increase land productivity. However, because of the increase in labour productivity, there is a growing trend towards intensification of use and thus to further structural homogenization and eutrophication of the agricultural landscapes.

In *Latin America* and *Africa*, too, the amount of land per head of population is still relatively favourable. In spite of significant increases in production in these continents, however, there are still large deficits in food provision because of rapidly growing populations in certain regions, largely extensive use, unfavourable climatic conditions as well as political instability. But there is still considerable scope for an ecologically sound, site-appropriate increase in production. In view of the spreading destruction of ecologically significant natural areas, the exploitation of this scope is urgently required and needs support from outside that goes far beyond the levels achieved so far (WBGU, 1995a, 1996, 1998a).

Slash and burn and the destruction of rainforests cannot be the answer to land shortages while considerable spare yield capacity on existing agricultural land could be activated by improvements in land management methods and the implementation of social reforms.

The conditions in *developing countries in the Far East* are completely different. Today around 1.5 thousand million people live there (29 per cent of all people) but with around 305 million ha they have scarcely 22 per cent of the agricultural land in the world. The area per inhabitant here is only 0.18 ha. But in most of these countries, in spite of some severe poverty, there is no extreme shortage of food, ie food production can meet modest demand. The key lies in the fact that the climate in this region allows two or even three harvests per year. The staple food in this region is rice, the cultivation of which has always been one of the most intensive and traditional forms of agriculture. At the same time, it is an example of the fact that intensive land management and environmental protection are not mutually exclusive, although rice is cultivated in a 'monoculture'. However, this was only possible on highly nutritious soils where nutrient exports and acidification could be

Box E 3.3-5

Cotton: Intensive monoculture of an important crop

The production of fibre plants is a special form of intensive agriculture. The cultivation of cotton dominates here, accounting for around 80 per cent of global production of fibre plants, well ahead of its rival such as sisal, hemp, jute or flax (FAO, 1997a). Cotton is not only the most important textile fibre, but – because of its wide usage spectrum – it is also a strategic crop and a cash crop par excellence. Around 86 per cent of today's cotton production is concentrated in the northern hemisphere, with China, the USA and India being the main producers, together accounting for around 56 per cent of annual production. For many years world production has been at a high and constant level of around 19 million tonnes (FAS, 1999). Over the last 50 years yield has more than tripled (Reller and Gerstenberg, 1997). In addition to the above-mentioned major producers, cotton is produced in another 115 countries, of which Uzbekistan, Pakistan, Turkey, Australia and Brazil should be mentioned. Together with the three major producers, these countries are responsible for around 80 per cent of annual cotton production.

Around 85 per cent of the cotton grown throughout the world is produced in dryland farming, the remaining 15 per cent come from irrigated farming. In some countries, such as Sudan, Senegal, Uzbekistan or Israel, it only became possible to grow cotton thanks to comprehensive irrigation systems. In irrigation farming in particular there are great differences with regard to the efficiency of the cultivation systems. Whereas, for example, in Sudan or the Aral Sea basin around 29m^3 water are needed to grow 1kg of raw cotton, in Israel only 7m^3 are needed. At the same time, in Israel yields of raw cotton (1,750kg ha^{-1}) are twice as high as in Egypt (Reller and Gerstenberg, 1997). Efficient irrigation methods show the scope for savings here with much higher yields at the same time. In spite of these successes, the cultivation of cotton poses a high risk to the environment because of many unfavourable production locations with poor climatic conditions and insufficient water resources. The very high increases in yields were only possible with the intensive use of pesticides, insecticides and artificial fertilisers as well as irrigation measures. Cotton cultivation accounts for around 2.4 per cent of world farmland (around 33 million ha – roughly the size of Germany), but around 10 per cent of the pesticides produced in the world and some 25 per cent of the insecticides are used for cotton production, which are applied at intervals of 1–2 weeks in conventional cultivation methods. A conservative estimate comes to the conclusion that at least 119,000 people are poisoned each year as a result of accidents with plant protection agents and at least 2,270 of them die (Knirsch, 1993). A quarter of these cases are related to cotton cultivation. Estimates from the World Health Organisation (WHO) are much higher.

In addition to the increasing pollution from pesticides and the decreasing fertility of the soils from non-adapted production, there is another problem with cotton cultivation in the competition to food production because in many countries the land that would really be needed for food production is currently used for cotton. Heavily rising costs from the constantly increasing use of agro-chemicals and the loss of land from soil degradation increase the trend to convert cotton production to ecological or integrated cultivation, but around 99 per cent of production is still in conventional cultivation.

In spite of the development of various synthetic fibres that have achieved high market growth, the per-capita consumption of cotton has also risen sharply. The fibre proportion of cotton among textiles throughout the world is still around 48 per cent (Höschle-Zeledon, 1996). The negative consequences of cotton cultivation in intensive monoculture are well-known, but the path towards sustainable cotton cultivation is very difficult because of the complex socio-economic, political and ecological contexts. Nevertheless, there are approaches to increasingly move towards integrated cultivation, biological plant protection or organic cultivation, as can be seen from examples in Egypt, India, Peru or Nicaragua. The solution to the problem, however, cannot be found just in alternative forms of cultivation or substitution by other fibre plants, such as hemp or flax. The production and real net output chain of cotton has to be recorded completely and incorporated in changed strategies. This needs the cooperation of producers, scientists, commerce and politics in order to secure the usage scope of cotton under the relevant cultural and ecological marginal conditions.

compensated. Over the centuries the cultivation of rice without any crop rotation has also meant that specialist rice pathogens and pests have become a limiting factor for yields. It is only thanks to efforts by international breeding research that high-yielding rice varieties adapted to specific locations have been made available. Improved cultivation methods and the targeted deployment of agrochemicals also help to secure high yields. The favourable sites in the region are already being used intensively; further expansion of the land is limited. Intensification of use and preservation of soil fertility require increasingly large amounts of capital (Box E 3.3-5).

Small amounts of land, highly developed agriculture and high production costs characterize the picture in *Europe*. Farmers have to produce high yields on small quantities of land in order to be able to compete on the world market, where market prices are largely determined by American farmers with their abundance of land. The best response is to harvest optimum yields on the land available. This is the reason why European farmers have to make every effort to obtain top yields with all of the crops they cultivate: they are increasingly following this trend, while also maintaining soil fertility.

On the one hand, this was achieved by returning the nutrients to the soil that the harvest removed from it. This is done with organic and mineral fertilizers. Secondly, plant breeding has made available varieties that are adapted to the location and largely meet the relevant production objectives. Thirdly, soil management and mechanization have been optimized, and fourthly the yield potential created in this way has been secured with plant protection.

This adaptation process did not take place without a negative impact on the environment. Incorrect handling of agrochemicals and the creation of landscapes suitable for machinery were a considerable burden on the biota of the agricultural landscapes and their diversity. In the meantime, there has been a rethink to take more account of the multifunctionality of land use.

E 3.3.4.3
Intensity features of agricultural production

The different levels of intensity of agricultural production are achieved with different proportions of capital and labour deployment depending on the site conditions. Whereas, for example, the industrialized countries in Europe and North America have comparatively high intensities of fertilizer use and mechanization, the example of China shows that, firstly, the intensities of the industrialized countries have already been reached or surpassed with regard to the use of fertilizers, but, secondly, the low degree of mechanization and labour-intensive management require extremely high labour input per unit area (Table E 3.3-4). However, the average figures here overlay the strong regional variations that result from local differences and different use strategies. But they do illustrate that there is considerable, if varying, potential to increase agricultural production in all regions. So that the increase in agricultural production (Box E 3.3-5) does not lead to the degradation of the land use, a guiding principle will have to be developed upon which the use strategies can be based. The Council considers 'multifunctional land use' to be such a guiding principle (Section E 3.3.4.9).

In order to safeguard yield capacity, management priority should be given to sites with a low tendency for degradation. To do this, the agro-ecological foundations of planning have to be improved all over the world. The development of adapted strategies for exploitation must be promoted. This should take place primarily 'locally' involving scientists and institutions. The promotion of breeding should not concentrate on just a few crops (Section D 3.4.5). In order to stabilize agro-ecosystems, the diversity of crops should be increased (Section E 3.3.4.6). Targeted breeding programmes should be promoted for this purpose.

E 3.3.4.4
Forestry

In the last 30 years the worldwide consumption of wood has risen by approx 50 per cent. The rise was especially marked in the field of paper and veneer production. However, in terms of quantity, the consumption of building wood and firewood are at the fore. In future, the demand for wood and wood products will rise because wood is a regenerative raw material which is a suitable substitute for various fossil raw materials. Unlike in agriculture, the rising demand has so far not been met by expanding forest acreage or intensifying use, but by clearing primary forests and overexploiting woodland. Only a comparatively small proportion of production takes place within regulated forestry based on multifunctionality and sustainability. This means that practices are being continued on a wide scale that in the past have already led to anthropogenic destruction of 45 per cent of the forests that covered the Earth after the Ice Age. This overexploitation is dealt with in detail in Chapter G.

Table E 3.3-5 shows that there are considerable regional differences with regard to deforestation. Forest destruction is practised on an especially large scale in Asia, Africa and Europe, where 65–70 per cent of the forests have already disappeared. Worldwide the destruction continues apace; only in North America, Europe and Russia has a reverse in this trend been seen in recent years. At the same time the fragmentation of the forests is also continuing. Of the remaining forests, only between 20 and 65 per cent can be considered to be primary forests of a sufficient size.

	Labour [km^{-2}]	Proportion of irrigation farming [%]	Tractors [km^{-2}]	Fertilizers [$t\ km^{-2}$]
Europe	22	0.12	3.6	10.1
Former CIS	10	0.05	1.0	2.5
North America	11	0.09	2.4	9.2
China	531	0.52	0.8	30.1
Asia	196	0.29	1.1	13.5
Africa	138	0.06	0.3	1.8
Latin America	36	0.10	1.1	5.9
World	104	0.17	1.8	9.4

Table E 3.3-4
Intensity features of agricultural use (1994).
Sources: WRI, 1998a; World Bank, 1998; FAO, 1998b

Table E 3.3-5
Regional change in forest cover.
Source: Abramowitz, 1998

Region	Original forests [10^3 km^2]	Remaining forests [10^3 km^2]	Annual net change (1990–1995) [% year^{-1}]	Proportion of primary forest [%]
Africa	6,799	2,302	-0.7	23
Asia	15,132	4,275	-0.7	20
North America	10,877	8,483	0.2	44
Central America	1,779	970	-1.2	18
South America	9,736	6,800	-0.5	65
Europe	4,690	1,521	0.3	1
Russia	11,759	8,083	0.1	43
Oceania	1,431	929	-0.1	34
World	62,203	33,363	-0.3	40

Today the mean annual change in the forest acreage in the species-rich tropical forests is especially large. It is extreme in Brazil and Indonesia. Both countries together have annual forest losses of over 3.6 million ha, that is a third of the forest acreage of Germany for each country. With deforestation rates of over 0.4 million ha each, the losses in countries such as Zaire, Mexico, Bolivia, Venezuela and Malaysia are also considerable. In Russia, which does not provide any official figures, experts estimate that approx 4 million ha of taiga are cleared per year. These figures do not include the insidious changes resulting, for example, from small, repeated fires that escape detection by satellites over a long period (Cochrane and Schulze, 1999).

The relationship of forest acreage to population figures is influenced both by the development of deforestation and by population growth. In 1950 around 2.55 thousand million people lived on the Earth; the figure had more than doubled to 5.7 thousand million by 1995. In 1950 there was an average of 1.6 ha forest available per inhabitant of the world; this figure had fallen to 0.6 ha by 1995. The forecasts predict another halving to 0.3 ha per inhabitant for 2025. However, it is not only the conversion of the forests that is changing biodiversity (Box E 3.3-6), but also the increasing conversion of primary forests into secondary forests or plantations. Here, the uncontrolled exploitation of primary forests, in particular, has a negative impact.

The further destruction of the forests can only be stopped by:

– ceasing uncontrolled conversion of the forests into arable and grazing land and into areas for transport infrastructure and settlement;
– regulating forest use, in a manner incorporating existing knowledge and geared to sustaining timber increment (sustainability principle);
– establishing segments of regulated, highly productive plantations in order to produce the required quantities of certain wood qualities while protecting natural forests;
– halting the use-related degradation of the biotic and abiotic components of forest ecosystems;
– reducing the deposition-related stresses upon forests from acids, nitrogen and contaminants.

E 3.3.4.5
Substitution of land-use products

Nutritional statistics show that in North America today the food supply per head of population is 15,181 kJ per day, 34 per cent of which comes from animal production. The figures for western Europe are 14,424 kJ, 33 per cent of animal origin. In the developing countries of Latin America 11,438 kJ are available to every inhabitant per day, 17 per cent of animal origin. In the Far East the figures are 9,285 kJ, 7 per cent from animal production, and in the developing countries of Africa 8,872 kJ, only 5 per cent of which is of animal origin.

The oversupply of food in the industrialized countries, coupled with a surplus of animal protein, holds the potential to relieve shortages in the global food supply. However, because of the relatively small proportion of the world's population that is oversupplied in this way, the relief that can be achieved by reducing the proportion of animal foods should not be overestimated, especially when we remember that the world's population is growing by over 80 million per year. Substitution is also limited because only feedstuffs that are also suitable for human consumption can be considered. Moreover, it must also be considered that ruminants sometimes graze grasslands which cannot be used for any other purpose.

Animal production and its rapid growth in recent years (Table E 3.3-6) exerts an enormous influence on the biodiversity of our world. This influence is not only due to the fact that 22 million km^2 are used as grazing land, but also that animal feed is produced on 21 per cent of arable land. If, on the one hand, the demand for food from animal sources is to be met and, on the other hand, ecological side effects are to

Box E 3.3-6

Forests and biological diversity

The loss of forest biodiversity results both from the loss of forest land (Section E 3.3.4.4) and from the degradation of existing forests. Both processes continue apace and, after centuries of forest destruction in temperate and boreal areas, since the mid-twentieth century they have taken place particularly actively in the tropics. With regard to the loss of biological diversity, special importance is attached to the loss of tropical forests and forest degradation because the tropical forests are disproportionately richer in species than temperate and boreal forests and the agro-ecosystems that result from the conversion are much more fragile.

The best contribution to the conservation of forest biological diversity can be made by the biodiversity of forests being understood as a carrier of biological resources. The value of these biological resources comes to bear at various levels, ranging from the household level (firewood, food, medicine), local (food, firewood, medicine, building materials), national (wood products, water, firewood, etc) and international markets (wood products, resins, oils, tourism, etc) (Section H 5). Forest biodiversity gains global significance as an important carrier of information for future options on technological or medical developments (Section D 3.3). Further importance may be attached to the biodiversity of forests regarding their stabilising effect on the global climate (Section F 2). The importance of forests as biological carbon sinks is currently the subject of international discussion (WBGU, 1998b).

The information on the number of species in forests is highly unreliable and fluctuates between 2 and 80 million species. The mean value of the estimates is around 10 million species, and it is assumed that the vast majority of these are arthropods (WCMC, 1992; Heywood and Watson, 1995). In turn, around 50–90 per cent of arthropods are to be found in the tropical forests and this emphasizes their high fauna diversity. With respect to plant biodiversity the much quoted example form Borneo can be used, where 700 tree species have been identified on 10 ha of forestland, in other words more species than occur in the whole of North America (Rodgers, 1996).

In light of the pressure on land use described above, further losses of forests in the tropics will be inevitable (Chapter G). The majority of the conversion will continue to be for agricultural use. It is therefore all the more important to integrate the land use changes into comprehensive concepts that are anchored at regional level (Section E 3.9). The maintenance of the agricultural productivity of the converted forestland or increasing the productivity on existing agricultural land must be an important objective (Section E 3.3.4.2).

Although most national policies emphasize that the remaining forestland should be protected, deforestation continues on a global level. From this, it can be seen that the causes of forest destruction are multi-faceted and differ from region to region. Not only direct reasons, such as the spread of slash and burn, but also indirect reasons due to the failure of policies, such as rural poverty, lead to the continuing destruction of forests (NNA, 1998; Jepma 1995; Pearce and Moran, 1998; Chapter G).

Since the existing biological diversity of the forests cannot be preserved as a whole and species are becoming extinct more quickly than all the existing species can be recorded (Pimm et al, 1995; Section D 1), special significance is attached to the functional evaluation of biodiversity alongside recording habitats. Two questions can be asked:

- How much biodiversity is needed to conserve multifunctional forests (Section E 3.3.9)?
- Can this question be answered on time?

The first steps along this route have been made with the identification of hotspots of biodiversity, the designation of indicator taxa and the mapping of the usage pressure on existing forest ecosystems (Global Forest Watch; WRI, 1999). An accompanying measure that could help to reduce the predatory exploitation of forest resources is the certification of wood products and forms of management (Box E 3.3). A legally binding regulation for forest protection is long overdue (Section I 3.4.4). The instruments and means of implementation currently available are, however, so limited that it is extremely doubtful whether the dynamics of the current trend can be decisively influenced.

be minimized, far-reaching changes in eating habits and in the way we keep and use animals will have to be effected.

- Overnutrition with foods of animal origin must be reduced because it is inefficient on the one hand and has a negative impact on health on the other.
- The productivity of domesticated animals should be optimized because large unproductive stocks have a disproportionate negative impact on biodiversity. This should also include 'improvement' of traditional livestock breeds.
- Grazing practices should be more oriented towards the carrying capacity of the grasslands in order to prevent the degradation of the grazing areas.

Switching to animal foodstuffs from the sea is also limited because some natural fish populations are already being overexploited. Although aquaculture is a possible alternative, high-quality feed must be used, which – in turn – mostly comes from terrestrial ecosystems. Also, establishing cultures of this kind in lakes and shallow seas is problematic from the point of view of environmental pollution and the impact on the biodiversity of aquatic ecosystems (Section E 3.4).

The production of food using biotechnological methods has not yet progressed to a level where it can relieve shortages. Although there is great potential for the biological conversion of plant wastes or residues into feedstuffs and foods, only a few approaches have so far proved to be economically sustainable. New information and conversion methods should be developed for the better use of plant biomass (such as wood or straw) as feed and food. In this respect, molecular biological methods could open up new opportunities.

Table E 3.3-6
Global overview of domesticated animal populations and animal production (1994).
Source: FAO, 1997a

Animal category	Number [10^3]	Meat [10^6 kg]	Milk [10^6 kg]	Eggs [10^6 kg]	Wool [10^6 kg]
Cattle	1,296,907	52,739	464,380		
Buffalo		149,591	2,569	48,310	
Camels	19,017				
Horses	60,715	493			
Sheep	1,089,749	7,188	7,782		2,675
Goats	613,227	3,150	9,983		
Pigs	883,386	78,537			
Chickens	12,568,000	51,223		45,007	
Total	16,680,592	155,899	530,455	45,007	2,675

E 3.3.4.6
Influence of intensified land use on biological diversity

The biological diversity of used ecosystems is determined by four influencing factors:

1. the diversity of the vegetation in the ecosystem and its surroundings,
2. the nature and duration of crop cultivation,
3. the intensity of management,
4. the isolation of the ecosystem from natural habitat types.

Various combinations of factors result in ecosystems with differing degrees of biological diversity. Fig. 3.3-5 shows a schematic classification of agricultural and forestry use systems with respect to their biological diversity.

The type of use influences biodiversity at several levels. It takes effect directly in the ecosystems themselves as an 'on-site effect'. However, this use-related biodiversity, whether planned or associated, is always subject to indirect effects from the surrounding or neighbouring habitats with a relationship to the ecosystem concerned. These influences are called 'off-site effects'.

The extent to which 'associated biodiversity' in the system used is determined by the 'planned biodiversity' is largely open, because both tilling and crop rotation have an influence and, furthermore, the off-site effects in the neighbouring ecosystems feed back into the used ecosystem. It has been shown for agricultural use that the reduction of planned on-site biodiversity often brought about a reduction in off-site biodiversity (eg Paoletti and Pimental, 1992; Vandermeer, 1996, Jedicke, 1997). As an on-site effect, the tilling determines the composition and abundance of the associated diversity (Matson et al, 1997). This, in turn, is fed back to the crops via many functions (Fig. E 3.3-6). In this respect, the functional links are non-linear both for the on-site effects and the off-site effects (eg Perfecto et al, 1997; Vandermeer et al, 1998).

E 3.3.4.7
Loss of agrobiodiversity

Intensive agriculture in the industrialized countries and, increasingly, in newly-industrializing and developing countries is characterized by modes of production with high capital and energy inputs per unit area and product. The high management intensity, the decoupling of plant and animal production and regional concentration processes led to high materials input per area as well as an increasing decoupling of biogeochemical cycles (Section E 3.2). Formerly largely closed in-farm cycles with low losses were replaced by biogeochemical cycles with high throughput rates. As a result of intensification, operational conditions and stock management have changed markedly; they are listed together with their impact on biodiversity in Fig. E 3.3-6.

In the following, some examples of the loss of biological diversity due to agricultural use are outlined. To this end, examples of on-site effects are given and off-site effects from neighbouring ecosystems are considered. A global overview of the loss of plant and animal genetic diversity is given in Section D 3.4.

On-site effects

The concentration on just a few high-yielding crop varieties has led to the displacement of a large number of traditional and locally adapted native varieties (Auer and Erdmann, 1997). This fall in biological diversity goes hand in hand with a loss of cultural diversity (Guarino, 1995). This means that the loss of native varieties is often combined with loss of knowledge about this material and its usefulness (Section E 3.5).

The population density of crops generally rises with increased intensity of arable measures and plant protection. The number of species and the degree of coverage of the attendant flora shows the opposite trend (Braun, 1991).

Mechanization is associated with the homogenization of plant populations and the reduction of crop rotations, and also reduces the diversity of the invertebrates linked with them (eg Altieri and Liebmann,

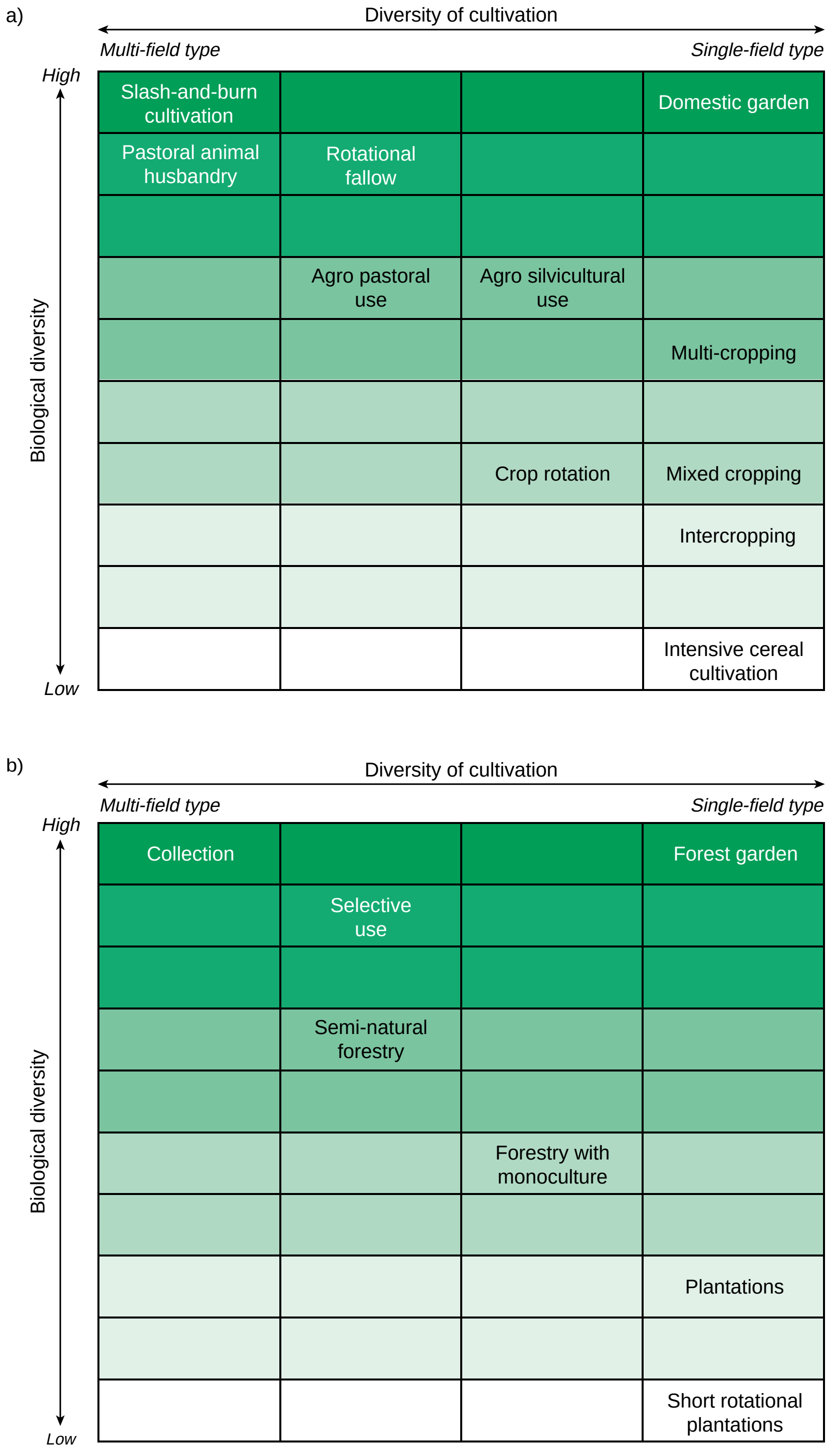


Figure E 3.3-5
Classification of (a) agricultural and (b) forest systems on the basis of their biological diversity and diversity of cultivation systems.
Sources: Swift and Anderson, 1994, modified

1986; Perfecto et al, 1997). An intensification of use encourages generalists, while stenoecious specialists (ie surviving only in a narrow range of environment) become ever less competitive. Reduction in the quantities, or imbalanced composition, of harvest residues that remain on the field, reduces the available food and the size and species composition of soil organism communities (eg Hendriz et al, 1989; Swift and Anderson, 1994, Altieri, 1995). Monocultures favour the mass reproduction of pests by providing a glut of food specific to their requirements, while simultaneously causing a reduction in regulatory competitor organisms. This was impressively shown in the USA, where between 1945 and 1975 the use of

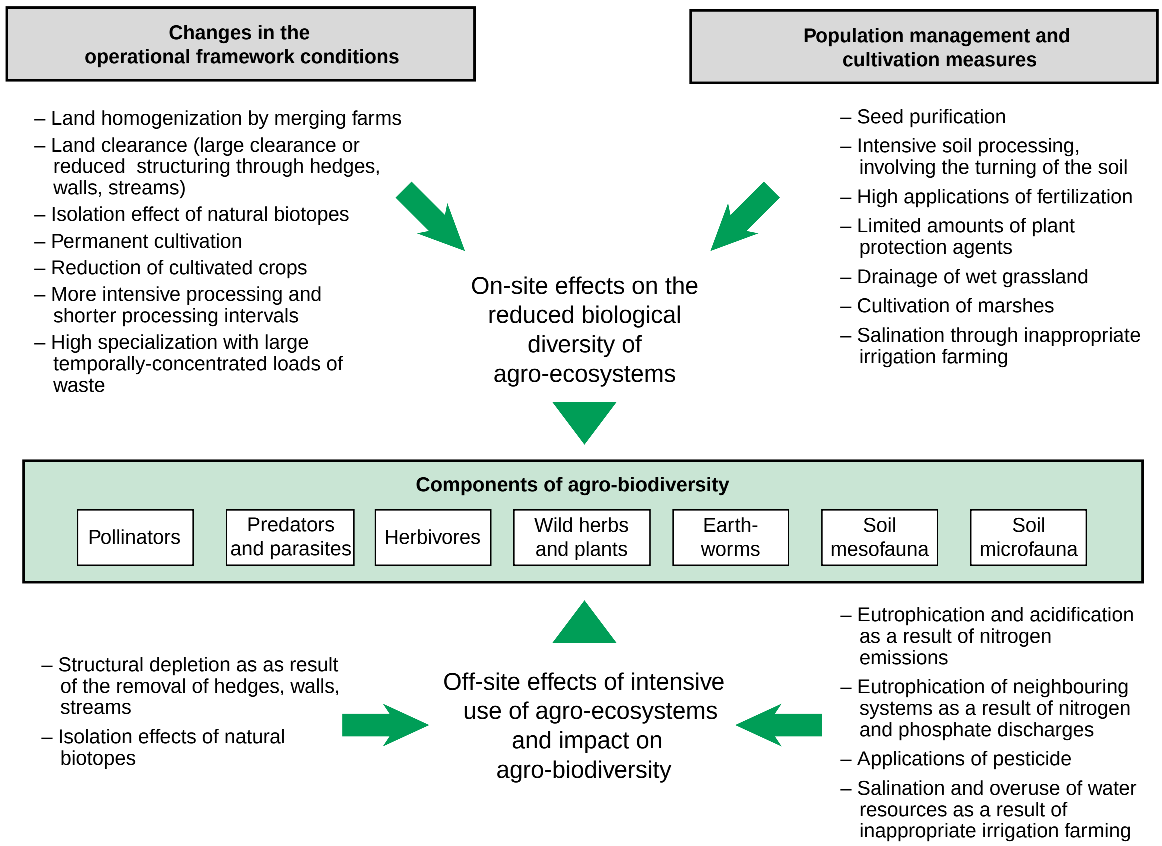


Figure E 3.3-6
Intensive agriculture and the loss of agrobiodiversity.
Source: WBGU, 2000a

pesticides rose ten-fold, but at the same time the harvest losses to pests rose by 100 per cent (Botrell, 1979).

High applications of fertilizers bring about falling abundances in animal populations (eg van Wingerden et al, 1992; Basedow et al, 1991). Crop production and livestock production modify plant association on the agricultural land and, via the quality and quantity of the harvest residues, the timing of the harvest and grazing intensity, also influence the diversity and quantity of soil organisms (Vandermeer et al, 1998; Stary and Pike, 1999). One important reason for the falling populations of arthropods is the absence of organic fertilizers coupled with the use of imbalanced mineral fertilizers. Poor soil structure also limits the habitat of the soil fauna dependent on gaps and cavities (Bathon, 1997).

Although intensively turning the soil favours the biological requirements of specific aerobic fungi and bacteria (Stahr and Stasch, 1996), it reduces biomass and the diversity of soil fauna, as has been shown repeatedly with earthworms or millipedes (eg Paoletti, 1988; Friebe and Henke, 1992; Claupein, 1994; Fragoso et al, 1997). The populations of microarthropods are also severely affected by soil being turned (Bathon, 1997).

In contrast to the clear evidence with respect to the loss of diversity among soil macrofauna and mesofauna, there are no clear indications of losses of microbial diversity from pesticide and fertilizer inputs or intensive soil management (Giller et al, 1997; Buyer and Kaufman, 1997; Zelles et al, 1997). The reason for this could be the lack of knowledge about the diversity of microorganism communities in the soils.

Off-site effects

The increase in field sizes, the homogenization of cultivation conditions by irrigation and drainage and the removal of landscape elements that provide structure, such as hedges, borders, walls or streams, reduces the diversity of the habitat types that are available as a habitat for useful organisms. In the federal states of the former West Germany, for example, between 1950 and 1985 around 85 per cent of all third order rivers (streams, ditches) were straightened, made deeper or given artificial beds; this corresponds to a length of around 360,000km and led to a drastic loss of wetland habitats (Engelhardt, 1997). Another example is the eutrophication or acidification of neighbouring habitats for plants and animals as a result of substance discharges (leaching, emissions) from agriculture. Agriculture accounts for over 90 per cent of ammonia emissions in Europe. Per hectare of agricultural land this corresponds to an average emission of around 24kg NH_3-N $year^{-1}$, whereby emissions in countries with intensive animal production can be several times this figure (ECETOC, 1994). This means that agriculture also makes a major contribution to nitrogen loading of around 30–60kg N ha^{-1} per year in central European forests (Augustin and Andreae, 1998).

In addition to eutrophication, salinization as a result of inappropriate irrigation plays an important role in the degradation of neighbouring ecosystems and the loss of habitats and species diversity. A prominent example of this is the Aral Sea, which has lost three quarters of its volume since 1960 and where the 24 fish species, now extinct, formed the basis of the livelihood for 60,000 families (WBGU, 1998a).

E 3.3.4.8
The functions of agro-ecosystems and biological diversity

In order to be able to assess the significance of the loss of agrobiodiversity for agro-ecosystem services, we have to be able to assess its role for long-term productivity and the stability of the system used. To do this, we have to clarify what functions agrobiodiversity fulfils in agro-ecosystems, or rather what functions could be lost by the reduction of agrobiodiversity (Section D 2). The functions of agrobiodiversity and their connection with individual components of agro-ecosystems are listed in Fig. 3.3-7.

Functions of plant diversity

The importance of the diversity of historic cultivated plants (native breeds), which have undergone an process of adaptation lasting centuries or even millennia, is their function as a resource for breeding (Section D 3.4). With the loss of the genetic variety of these cultivated varieties irreplaceable genetic resources will be lost, as a result of which breeding research will find an ever narrower basis of genetic resources, which can block the new development and further development of resistant and high-yielding agricultural varieties (Section C 1.3.1). According to estimates by the FAO, in the next ten years the genetic diversity of 90 per cent of the main grain species (rice, maize, wheat and sorghum) is greatly at risk (Esquinas-Alcazar, 1996). This makes us pause for thought when we remember that around 60 per cent of the world's food needs are met by these four grains. In particular, the constantly changing situation with regard to pests (eg by 'development of resistance') leads to the need to improve varieties constantly by breeding in new features from cultivated and wild varieties. Furthermore, biological diversity in the landscape is an important regulatory factor in the mass reproduction of pests. Variety diversity, species diversity and their spatial arrangement have a negative impact on the distribution of pests and diseases.

The conservation of plant genetic resources is a priority task to secure food and to meet demand for

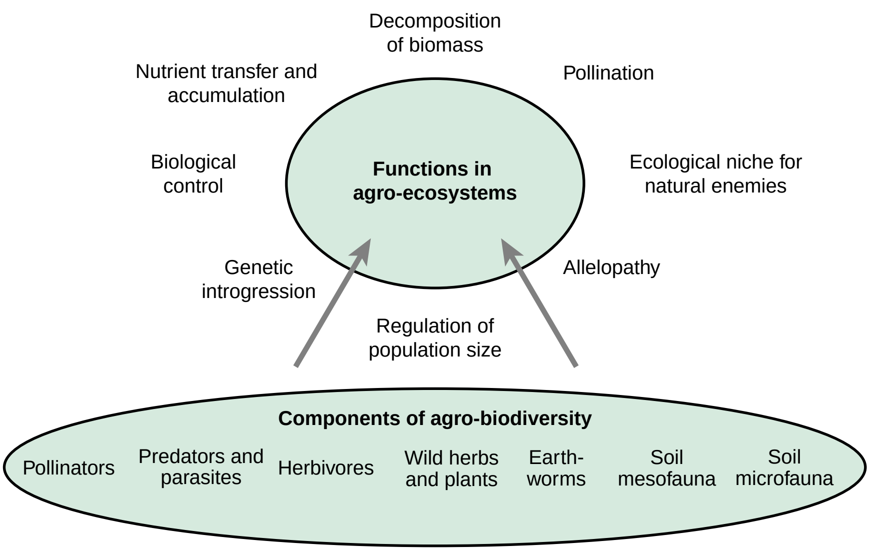


Figure E 3.3-7
Functions of biological diversity in the agro-ecosystem.
Source: Altieri and Nicholls, 1999, modified

renewable raw materials (Sections D 3.4 and I 3.3.2). It is important to conserve the genetic diversity of the wild forms or farmers' varieties in order to introduce their genetic information into cultivated varieties, where appropriate. Since the original gene centres of many cultivated plants are outside national cultivation boundaries, worldwide collections are needed as an important basis for the search for material with better or new properties (*ex-situ* conservation). To do this, the biotechnological capacities have to be extended in developing countries. In addition to *ex-situ* strategies, it is absolutely essential for *in-situ* and on-farm conservation to be continued and extended because this is the only way for the natural selection process to continue (Section D 3.4; Koshoo, 1996, Brush, 1995; Hammer, 1998; FAO, 1999c). Proposals for the conservation of plant genetic resources have been included in the FAO's Global Plan of Action (1996c) and have been implemented with varying degrees of intensity (Section I 3.3.2).

Functions of faunal diversity

The function of herbivores and the predators associated with them is mainly to regulate the incidence of pests and this has been repeatedly documented in the literature. Loss of biodiversity and declining populations reduce the self-regulatory scope of the system (Altieri and Nicholls, 1999). The extent to which biological diversity can maintain this internal regulatory function has largely not been clarified because, for example, the importance of various species with the same or similar functions for system stability is not known (Section D 2; eg Hawkins, 1994; Kogan and Lattin, 1993). However, it is undisputed that a diverse assemblage of natural antagonists is essential for the natural control of pests and diseases.

Various studies provide evidence of the influence of permanent cropping and monocultures on the increased occurrence of plant diseases. The reasons for this can be seen in changes to microbial organism communities and the one-sided encouragement of pathogens. Crop rotation or intercropping can recreate the hygienic functions of the microorganism communities and aggressive pathogens can be suppressed (eg Olsson and Gerhardson, 1992; Johnson et al, 1992).

Interactions between soil organisms and plants

The composition and activity of soil organisms is influenced both directly and indirectly by the crops. Four factors play a decisive role here: the quantity, quality, timing and distribution of the organic matter formed by harvest residues, root mass or root exudate. Microclimatic effects of the vegetation influence the metabolism dynamics of the waste. Since the biotic community of the decomposers is specialized on parts and substance groups of the organic matter, cultivation in monoculture or permanent cropping also changes the composition and the population size of the decomposer community. But to date there are no systematic studies that provide reliable proof of a loss of functions as a result of these interventions. However, it is assumed that the diversity of the decomposers is responsible for the stability of the biogeochemical cycles and their spatial-temporal coupling of the processes involved (eg N and P) (Collins et al, 1992; Potthoff, 1999).

Function of production methods

Many comparisons between intercropping methods and cultivation in monoculture (eg Trenbath, 1974; Francis, 1986; Vandermeer, 1989) prove that when several species are grown yields can reach 90 per cent of the yields of monoculture or exceed them – even though fewer agrochemicals are used. One explanation for this is thought to be direct plant interactions, while the positive influence on herbivore and decomposer subsystems is considered to be the reason for increased productivity (Vandermeer, 1989; Vandermeer et al, 1998). Above and beyond this, there are positive effects with respect to wind erosion (McLaughlin and Mineau, 1995) and water infiltration. It is therefore possible to maintain higher biological diversity alongside high yields. However, the optimum ratio between the number of plant species grown and system stability on the one hand and productivity on the other is barely known to date. Hypotheses assume a hyperbolic function where the optimum could be around 5–30 plant species grown (Swift and Anderson, 1992). However, not only the number of plants grown, but also their species composition is of key importance for the productivity and the stability of the ecosystems.

In addition to these on-site effects, the loss of γ-diversity in the cultivated landscape, for example as a result of the loss of habitat for useful organisms in ecotones or island biotopes, has an impact on the self-regulatory capacity of agro-ecosystems as an off-site effect (eg Holling et al, 1995; Baudry, 1989).

E 3.3.4.9
Animal production and biological diversity

Domesticated animals make a major contribution to securing human food (Tab. E 3.3-7), but they also have a major impact on terrestrial ecosystems and sometimes pose competition for plant-based food needed by humans.

Around 22 million km^2 or approx 60 per cent of the world's permanent grasslands are characterized

Grazing systems	Area [10^6 km^2]	Population [10^6]	Cattle [10^6]	Sheep and goats [10^6]
Arid and semi-arid grazing land	9.89	182	116	280
Temperate and tropical highlands	5.13	189	81	185
Sub-humid and humid savannahs	6.06	332	197	146

Table E 3.3-7
Grazing systems and animal populations in various ecozones.
Source: FAO, 1998b

by grazing systems. Large parts of the grazing land, approx 6.8 million km^2 or around 28 per cent have already been degraded as a result of overgrazing. Grazing comprises around 360 million cattle (around half of which are in humid savannahs) and around 600 million sheep and goats (mostly on semi-arid/arid grasslands). Worldwide, only around 9 per cent of beef production and 30 per cent of lamb, mutton and goat meat production are accounted for by grazing. However, animal production is a major source of survival for around 100 million people in arid regions.

In many regions grazing systems only have a comparatively low potential for intensification and production increases because the risk of degradation is very high. Intensive, highly-productive grazing reduces biodiversity as a result of high fertilizer applications, high stocking density and few, nutrient-rich forage grasses and also harbours the risk of negative impacts on the biological diversity of neighbouring ecosystems through eutrophication or acidification.

Animal breeds adapted to low-yield sites are not as productive and are frequently replaced by highly productive or exotic breeds. Of a current 2,719 recorded breeds of domesticated animals, 391 are classed as endangered (Tab. D 3.4-1). The proportion of endangered native breeds is especially high in Europe and North America.

The need for food from animal sources is growing constantly, and the trend towards spatially concentrated, intensive production methods goes hand in hand with this. Industrial animal production in specialized operations underwent a double or six-fold rate of increase in comparison with traditional mixed farms between 1990 and 1995 (Sere and Steinfeld, 1996). This can also be seen in the particularly marked increase in poultry production. In 1996 over half of pork and poultry production and 10 per cent of beef production came from intensive production systems. This corresponds to around 43 per cent of global meat production.

Although this trend made it possible to do without additional grazing land, these production methods called for high quality feed, some of which is drawn from the human supply. This trend is likely to continue in order to satisfy rising demand. This means that the link between this sector of production and native resources is being increasingly severed and the sector becomes dependent on fodder imports.

The need for concentrated feed rises with the increasing intensification of animal production and the move towards pig and poultry production as the main consumers of concentrate. Fodder is mainly grown on land with high production potential and in intensive cultivation systems. Around 3 million km^2 or 21 per cent of arable land is used to grow animal feed. 32 per cent of grain production (maize, barley, wheat) serves as animal feed. However, this 32 per cent is grown on only 20 per cent of the land used for grain cultivation, ie at more productive sites (Steinfeld et al, 1997).

Because some of the productive sites are used to grow fodder, food cultivation has to move to lower-yielding sites. This and the rising demand are leading to increased utilization pressure on neighbouring natural ecosystems and the loss of biological diversity.

Animal production is, to a large extent, partially responsible for the loss of tropical rainforest by conversion into grazing and arable land. However, this applies only to South America where, according to Bruenig (1991) around 44 per cent of land losses are attributable to livestock farming, whereas conversion into arable land is responsible for most of forest loss in Asia and Africa (Chapter G).

But animal production can also aid biodiversity. In tropical agricultural systems with few nutrients, animal production can help to secure the harvest and increase the productivity of the arable land because it provides nutrients and organic matter for the fields. The creation of mixed farms allows diversified cultivation systems, an improvement in the nutrient cycles and, thus, higher yields per area. This reduces the expansion onto neighbouring fields. A diversification of cultivation also increases the diversity of the biotic communities associated with it. However, with this form of management, it is possible to contribute only to improving the nutrient cycle within a husbandry system and not to increasing the actual nutrient contents. The latter was described in Section E 2.1 for the heathland farmers. Here, the diversification of cultivation generated as a result of nutrient concentration was a consequence of far reaching degradation phenomena among grazing and forest land.

E 3.3.4.10
Multifunctional land use

With a current population of 6 thousand million and 10–12 thousand million in the foreseeable future, the need for biomass for food is enormous. For countless years to come, every year thousand millions of tonnes of plant and animal matter will have to be made available. These masses are provided by just a few plant and animal species, requiring large areas of cultivable land (Sections D 3.4 and E 3.3.4.1). To survive, people are forced to use state-of-the-art technology in order to develop and maintain highly productive, but also sustainable, land use. In this respect, the degradation of soil has to be prevented and the competitor organisms that are constantly developing through evolution, such as weeds, pests or pathogens, have to be kept under control.

In the past this was achieved by the selection and breeding of high yielding and resistant varieties as well as the use of plant protection agents and fertilizers. But in future, 'green' genetic engineering will have to be examined without any prejudice as a possible way of solving the growing problems. The risks that may be associated with it should be minimized by appropriate testing procedures and controls (WBGU, 1998a). New methods of soil tilling will have to be found to reduce physical and chemical soil degradation. In this process, above all the use of the turning plough, which has been used for millennia to prepare for sowing and combat weeds, will have to be replaced by other implements that make the soil less susceptible to erosion.

As shown in the previous sections, the potential for increased production of biological resources lies largely in increasing area productivity or in substituting terrestrially-generated raw materials and foods.

One means of assessing the yield potential of various sites and regions at global level is offered by the net primary production of the natural vegetation. Net primary production (NPP) refers to the biomass per unit area formed in a year by the primary producers. This is a net factor because the losses that occur through the plant's gas exchange are deducted from gross production. NPP is a good indicator of the site's yield potential because the natural plant communities of the ecosystems concerned have adapted to the site conditions over very long periods and have optimized biomass production in the process.

The NPP of natural ecosystems is not spread evenly over the land surface; it has zones of varying productivity. The inner tropical area, with the exception of the Horn of Africa, is a zone of high to maximum productivity of the terrestrial biosphere. In the subtropical and temperate zones there are also large regions with high and very high primary production, but the picture here is more subtly differentiated. Fig. E 3.3-8 shows the global distribution of NPP. These are modelled data that represent an average of 17 global vegetation models. This procedure minimizes the differences in the geographic and temporal allocation of net primary production that occur with the different types of vegetation models. In addition to solar radiation, temperature, precipitation levels and distribution, NPP is heavily dependent on the fertility of the soils. Carbon is closely linked to soil's organic matter content (humus) and can be seen as an indicator of the organic providers of soil fertility. It can be seen that the fertility of the soils in the tropics is largely based on organic matter, whereas in the temperate zones great importance is attached both to the mineral and the organic components. This has consequences for the productivity of agricultural and forestry cultures because the organic matter in soils reacts more quickly and more intensely to human interventions than does mineral matter. The reasons for the marked fall in NPP after man has started cultivation (grazing, crop growing, plantations) include the following:

- The cultivation of monocultures or very simplified crop rotations leads to the decoupling of biogeochemical cycles and, thus, to nutrient depletion or acidification.
- The removal of biomass and its limited return accentuates the above processes.
- Soil tilling leads to humus depletion and, thus, to the depletion of water and nutrient stores as well as soil stabilizers.
- Infestation with pests increases with monocultures.
- Increasing homogeneity reduces beneficial organisms.
- Intensive grazing reduces diversity and the density of plant stocks.
- The adaptation of crops to site conditions is usually not as good as that of native plants.
- Symbioses are destroyed.
- Adapted crop plants are increasingly being replaced by higher yielding, but less well adapted cultivars.
- Periods without plant coverage and the thinning out of plant stocks increase soil degradation.
- Burning vegetation litter leads to nutrient losses and the reduction of biodiversity.
- Machine use compacts the soil and destroys its regulatory function for the hydrological and biogeochemical regimes.

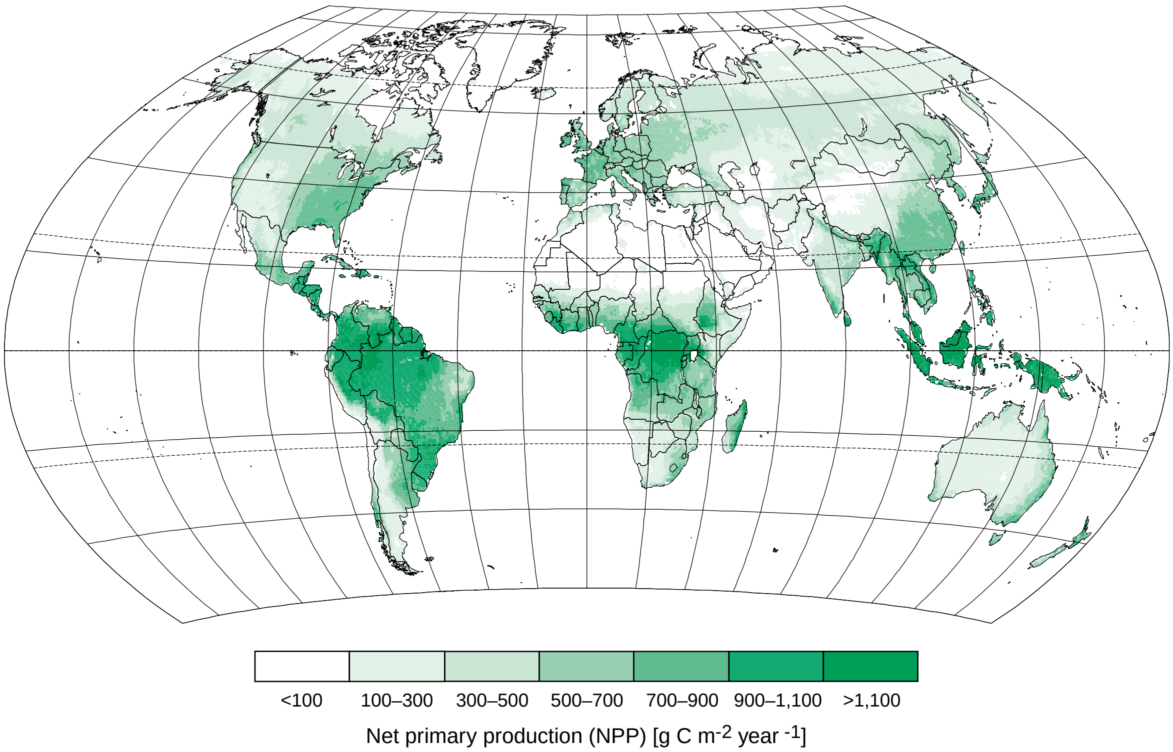


Figure E 3.3-8
Global distribution of net primary production (NPP), represented as an average of 17 global vegetation models.
Source: Cramer et al, 1999b

Comparing the actual biomass yields achieved with the crops to that of the natural vegetation makes it clear that in large parts of the world the NPP of the crops reaches only around 10–20 per cent of the production potential of the natural vegetation (Esser, 1993). Only where fertilizers, plant protection agents and suitable varieties are used is the level of the natural NPP reached or even surpassed. However, in these regions the rises in productivity are frequently associated with additional environmental pollution and a clear fall in biodiversity.

There is, therefore, considerable potential for increases in yield worldwide without the need for major expansion of agricultural land at the expense of other ecosystems (WBGU, 1995a). Therefore, for ecological reasons, we have to demand that the increasing need for food and renewable raw materials be primarily met by the site-appropriate intensification of land management on existing agricultural land. This is the only way to prevent the destruction of further natural ecosystems, with negative consequences for biological diversity and the biogeochemical cycles of the Earth and risks for the biosphere as a whole.

The distribution of the NPP also illustrates that the fertility of the sites in developing countries is frequently very low and, furthermore, is largely based on the organic soil matter, ie an unstable pool. This means that human interventions in these easily-harmed systems are often problematic. A direct comparison with the interventions in more stable systems in the temperate climate zone is therefore deceptive. For this reason, the clearance of temperate forests in the past must not be compared with the clearance of the tropical rainforests or even used as an argument for the deforestation of the latter.

On the other hand, however, we must counteract the myth that the soils in the tropics are generally not suited to intensive and sustainable land use (FAO, 1993). With a precise analysis of the site and taking account of site-specific factors it is certainly possible, even in these regions, to practice large-scale sustainable and environmentally sound land management. Around 57 per cent of soils in the tropics are not typical 'tropical soils' such as oxisols and ultisols; the proportion of tropical soils classed as fertile is around 24 per cent. In comparison, their proportion in the temperate zone is only around 27 per cent.

The worldwide assessment of potentially cultivatable soils ('favourable soils') will therefore have to be pursued and improved as a priority. To speed up the assessment process, field-based surveys should be combined with modern remote sensing methods. Only on such a basis is it possible to develop site-appropriate, sustainable and environmentally sound soil use with high yield potential. Accompanying monitoring programmes will have to be developed and realized in order to guarantee the implementation of site-appropriate and sustainable land management. These programmes have to be designed for the long term because this is the only way that gradual changes to the biosphere can be recognized.

E 3.3.4.11
Model of multifunctional land use

If the goal of highly productive land use is to be harmonized with the principles of sustainability and environmental protection, a general model will have to be developed to provide guidance on the use strategies to be developed.

This model must not, as in the past, be largely oriented to production or, as was frequently the case, be limited just to individual components or organisms; it must include all ecosystem functions equally, ie it must be *multifunctional*. Furthermore, the pollution of neighbouring terrestrial and aquatic systems and of the groundwater and the atmosphere emanating from the intensively used ecosystems also has to be taken into account. Future uses should not only be economically sustainable; they must also be environmentally sound and socially compatible. This can only be the case if they are appropriate to the site. However, it is not enough merely to come up with a model; practicable sets of instruments also have to be developed that make it possible for the objectives to be implemented. To do this, indicator systems must be developed which take account of the regionally varying mechanisms of cause and effect and thus go well beyond the approaches pursued to date. It is only then that they are suitable for the evaluation of multifunctional land use.

The Council has deliberately chosen the term 'multifunctional land use' because it contains all the elements of use that the Council considers to be important. Future forms of land use have to respect the diversity of abiotic and biotic factors at the site and be geared towards long-term usefulness. Specific uses must not excessively pollute neighbouring systems, ie they must be environmentally sound. Multifunctionality means that natural functions (habitat and regulation of the biogeochemical cycles and energy flows) and cultural functions (production and social services) have to be given equal treatment. Other terms, such as 'ecological land use' or 'organic husbandry' are not used because they are either not identical to the approach suggested here or because they have been defined differently at an international level. A keyword summary of the guidelines to this multifunctional use of regenerative resources can be found in Box I 1.1-1.

The worldwide introduction of such land use strategies promises to be all the more successful the sooner these practices are also realized in the industrialized countries and the sooner their ecological and economic benefits can be proved there. The approach of multifunctional land use also has a place in the international discussion as the FAO 'MFCAL Approach' (Multifunctional Character of Agriculture and Land) and was a central theme of the conference held in Maastricht in September 1999 (FAO, 1999a). The Council recommends that the Federal Government should support the transfer of multifunctional land use principles throughout agricultural and forestry practice. Furthermore, it should support changes to the system of national accounts so that assets which have not previously appeared in the balances, such as biological diversity, the quality of groundwater and surface water and the fertility of soils, should also be taken into account. Above and beyond this, we should examine how the 'Convention to Combat Desertification' can be expanded to become a comprehensive convention to protect all soils (WBGU, 1995a; Box E 3.3-7).

The strategies of use that are to be developed are characterized by a high deployment of labour dependent on the site. In large parts of the world, the required increase in yields with simultaneous soil and environmental protection can only be achieved by combining integrated arable and livestock farming and forestry with the required deployment of adapted agricultural technology, adapted crops and domesticated animals and the optimized use of agrochemicals. A complete renunciation of the latter production factors would mean operating production at low yield levels and thus, automatically, being responsible for an additional expansion of the agricultural land at the expense of natural forest and grass landscapes (Walker and Steffen, 1997). Multifunctional land use should not be ruled by dogma but needs to be pragmatic, results-oriented and flexible enough to integrate new findings from research.

In this regard, it is essential that multifunctional land use and the associated institutions, land improvement schemes and protection measures be linked to long-term investments. This means that the large-scale implementation of this use strategy can only be expected given low capital interest rates, appropriate wages and prices which cover costs. If we look at the situation on the Earth today, it can be seen that in many countries these conditions do not prevail.

Box E 3.3-7

Expanding the Desertification Convention into a global Soil Convention: problems and perspectives

Several times in the past the Council has noted that public awareness of soil degradation is very low (WBGU, 2000a). However, as the Council has repeatedly stressed and explained (WBGU, 1995a, 1998a, b), soil degradation is a global problem. Whereas global conventions have already been negotiated for climate protection and biodiversity conservation, the 'United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa' (Desertification Convention or CCD) covers only part of worldwide soil degradation. Although the CCD is global in terms of accession scope (eg it has been signed by Germany), its scope of application is limited to arid areas. For this reason, in its 1994 report the Council recommended that the Desertification Convention be further developed into a global soil conservation convention (WBGU, 1995a). The Tutzing Initiative for a Soil Convention (TISC) took up this proposal and in 1998 submitted a first draft, in four languages, of a Convention on the Sustainable Management of Soils (Tutzing Project 'Contemporary Ecology', 1998). This draft is currently being debated and further developed. Options include the adoption of a protocol to an existing convention, the expansion of the CCD into a global soil convention or the creation of a soil convention alongside the CCD. However, it would not be expedient to create a global soil convention alongside the CCD for reasons of efficiency and effectiveness. In the following, therefore, opportunities and problems for the expansion of the CCD into a global soil convention will be identified – undoubtedly an innovation in the history of environmental conventions. At all events, whether a protocol or expansion is chosen, an initiative of this kind cannot be achieved against the interests of the developing countries.

Of the three 'Rio Conventions' the Desertification Convention is the most important in terms of development policy. In addition to soil protection in arid areas its central element is the alleviation of poverty (Pilardeaux, 1997, 1999). Since no other United Nations Convention has such an express development policy mission (after all, there is no 'United Nations Development Convention'), the concerns of developing countries have to be taken into account, i.e., the development aspect and, thus, the possibility to call for financial support from the North needs to be integrated. Without early involvement of the developing countries in these deliberations, the prospects for success of the Tutzing Initiative are slight.

It runs counter to the interests of developing countries that the further development of the Desertification Convention into a global convention would increase the prospect for soil degradation receiving its own 'window' at the Global Environment Facility (GEF). This would mean that more funds would be available for this issue than previously. Since the adoption of the CCD there have been repeated calls for such a 'window' for soil degradation at the GEF. Unlike its two 'sister conventions' the CCD is mainly dependent on the use of existing funds from bilateral and multilateral development cooperation. Although there is theoretically greater potential for financing as a result of bundling and better focusing of bilateral and multilateral development cooperation according to the 'multi-source' funding principle, the tangible increase of funds for combating desertification expected by the developing countries has not yet emerged.

The industrialized countries also have reservations. The main reason for this is the fear of growing financial commitments. With a convention applicable worldwide it would be very difficult to deny the global dimensions of soil degradation. This would then have a direct impact on GEF policy. In spite of these reservations, trends are emerging that show that the CCD is already on the way to becoming a global soil protection convention. On the one hand, a 5th Annex for the Eastern and Central European Region was proposed at the COP-2 of the CCD upon the suggestion of Russia, Armenia, Romania, Azerbaijan, Uzbekistan, Tajikistan and Turkmenistan and under the critical observation of the developing countries. At the COP-3 in Recife (Brazil) in 1999 a draft of this kind will be submitted. There are therefore indications of an expansion to regions that no longer just comprise soil degradation in 'arid, semi-arid and dry sub-humid zones' (i.e. mainly in arid areas).

On the other hand, the new GEF initiative for combating desertification is a further indication of the growing perception of the global importance of soil degradation. Since 1994 the GEF has also been able to provide funds to combat desertification if the climate or biodiversity are affected by it. In Dakar (1998) this change of direction in the GEF, which presented new initiatives on the subject of soil degradation, was confirmed once again. According to this new GEF approach there are global connections in two respects: on the one hand in the interactions between soil degradation and the formation of biological sinks and sources for greenhouse gases and, on the other hand, in the special significance of biodiversity in arid areas (Section I 3.4.2). The GEF views the latter as a key factor for sustainable development. The Council welcomes the discussion about the establishment of a global soil convention and recommends that soil-related issues increasingly be brought up in the UNCED follow-up process and especially in the context of forthcoming COPs. By identifying potential areas of conflict and objections among the international community, the obstacles to be expected in the implementation of this endeavour can be appraised, and strategies identified for creating a convention for global soil protection.

One urgent requirement for the worldwide introduction of multifunctional land use is therefore for pricing to include the costs of soil protection, environmental protection and the conservation of biological diversity.

Use-related interventions in ecosystems are always made with the aim of producing yields of plant or animal origin. Depending on the desired objective, the interventions can be extensive or intensive and they can have a promoting, conserving or destructive effect on parts of the system. As a result of interventions, depending on the site, diversity can be increased at species and ecosystem level, as was shown in the example of Central Europe, or it can be drastically reduced, as is the case in Amazonia.

Box E 3.3-8

Certification of sustainable forest management

Solely concentrating forest use on wood production has reduced the ability of forests to also provide other ecosystemic services and supply products upon which humankind and the biosphere depend. There is no doubt that the forests or large parts of them will have to be used for wood production in the future, too. However, if this use is to be sustainable, the other forest functions will also have to be considered (habitat, regulatory and social functions).

In the early 1990s, stimulated by the prior boycott on tropical woods, principles for environmentally sound forest development were adopted in Article 11 of AGENDA 21. This led to the development of various initiatives that set out multinationally or internationally applicable principles of sustainable forest use. In addition to government initiatives and the forestry policy level, systems for the independent certification of forest management were developed at the level of the management unit (eg forest).

The basis of all of these initiatives is to make a contribution to the promotion of sustainable forest management. In this respect, sustainability should not just mean that wood is produced in the long term and the forestland is conserved, but that natural functions are linked to cultural functions. Certification is intended to emphasize examples of good management in the above vein with the objective of

- improving forest management,
- improving the attractiveness of wood from sustainably managed forests as a raw material,
- securing the authenticity of the origin of the certified product.

There are currently differences of opinion as to whether state or 'independent' institutions should carry out certification.

In 1993 the Forest Stewardship Council (FSC) was founded in Toronto, supported by environmental organizations, the wood trade, forestry experts, organizations of indigenous peoples, forest corporations and certification organizations. The FSC is an independent, non-commercial NGO. By 1999 the FSC had certified approx 13 million ha. Three quarters of this forestland is in Europe and the USA. Although this area may appear large, it is only just a few 100ths of a per cent of global forest area.

At the 1998 Ministerial Conference in Lisbon the 'Pan-European Guidelines for Sustainable Forest Management' were adopted. They are the foundation for the Pan-European certification initiative (PEFC) proposed by the German Forestry Council. To date, organizations from the forestry and wood processing industries from various European countries with approx 100 million ha forestland have taken part in this initiative (Ripken, 1999). Other approaches, such as ISO 14001 or bilateral and multilateral agreements have not had any noteworthy influence as yet.

To date, these two certification systems have been irreconcilable. In the interests of the intended promotion of sustainable forest management it is necessary for agreement to be reached in order to achieve a breakthrough for certification, which is, as such, undoubtedly a useful instrument.

The NPP was used as a 'benchmark' for the potential of a site to accumulate biomass. It provides a reference for calculating the theoretical yield potential. Whether the latter is achieved or not depends on the cultivation method chosen and the available resources.

Operational conditions, choice of variety, stock management and the measures for reducing losses all have an effect on the biological diversity of the site in question. An impact assessment should estimate the secondary effects of new strategies of use prior to their introduction (Article 14 CBD).

To assess the effects of land use at the level of ecotopes, landscapes or regions, the approach of critical loads, interventions and outputs, introduced by the Council (WBGU, 1995a), is suitable. The criticality of the three factors is measured against critical states or functions of ecosystems or their components. The future aim must be to derive similar critical states and functions for biological diversity which may not be exceeded during use. On this basis, the approach could be integrated into the WBGU's guardrail concept (1998a) (Section I 1).

The necessary measures for the conservation or restoration of biodiversity also include afforestation and reafforestation of degraded woodland landscapes. The Kyoto Protocol enables the promotion of forest restoration via certification of CO_2 sinks. These measures should therefore be supported on an ecologically useful scale.

One way of promoting multifunctional land use is to certify appropriate use strategies and label their products (Box E 3.3-8, Section I 2.4). This means that consumers would be able to promote multifunctional land use by buying labelled agricultural and forestry products. In the past, the success of this approach has been limited or only had a local or regional effect because consumers still prefer the cheaper product, even when they are aware that it does not come from a sustainable source. More education is needed here to bring about more environmentally sound consumer behaviour.

But problems also result from the increasing and uncontrolled concentration of people and their activities in relatively few conurbations. The associated spatial and temporal decoupling of biogeochemical cycles and the concentration of biogeochemical and energy flows are a key factor in the loss of biodiversity. The incorporation of bioregional aspects into planning projects (Section E 3.9) and decentralization of activities with a network of smaller centres should also be advantageous for multifunctional land use.

Human intervention in the biosphere in the course of land use constitutes one of the biggest threats to biological diversity on the Earth. The dynamic with which the use-driven loss of biological diversity is progressing leaves the impression that the 'race against time' has already been lost and cannot be won. From the point of view of the Council it therefore appears urgent for policy to make it a priority to address the problem of exploitation-driven loss of diversity and support those activities at international level which might contribute to a solution of the problem.

Little time remains in which to halt this risk-laden development; its potential impacts escape full assessment. Swift and effective action is urgently required.

E 3.4
Sustainable food production from aquatic ecosystems

Whereas fish is regarded as a welcome change on the menu in western industrialized countries, in eastern and south-east Asia it is the main source of protein for over one thousand million people. Unlike land ecosystems, even today the majority of food obtained from aquatic habitats comes from naturally renewable populations. World fisheries production has increased five-fold since 1949 and currently provides around 15–20 per cent of the protein consumed by humans (Alverson et al, 1994). Its annual growth rate has thus clearly exceeded population growth (Alden, 1999). The raw value of world fishery production in 1996 was US$131.3 thousand million (fishing US$84.7 thousand million, aquaculture US$46.6 thousand million) (FAO, 1998d, e).

Aquaculture thus accounts for around 25 per cent of the total aquatic biomass used. Currently according to official FAO statistics 121 million tonnes of fish, crustaceans and molluscs are hauled in from the sea every year (FAO, 1998d), of which 87.1 million tonnes are from the sea, 7.5 million tonnes from rivers and lakes and 26.4 million tonnes from fish farms (aquaculture, mariculture). Approx 20–27 million tonnes of discards as well as an unknown quantity caught by small fisheries for which insufficient data is recorded should be added to these figures, meaning that the total world fisheries are probably currently over 150 million tonnes year^{-1}. The world fisheries industry thus already largely exploits the yields which might be expected given the theoretical production potential of the ocean (Hubold, 1999b).

The increases in fishing yields from naturally regenerative populations achieved in the last few decades were solely based on the development of more efficient methods for detecting living marine resources as well as improved catching methods. The subsequent overfishing of many important populations is now increasingly endangering food security. In particular, the populations of some species that live in coastal regions are threatened. Even if the populations were to recover and fishing were to be optimized, higher fishing yields for the future can be expected only within tight limits.

A substantial increase in aquatic food production is therefore only possible by an intensification of aquaculture. However, there are also already fundamental problems here: in aquatic habitats, the addition of nutrients with the aim of increasing production leads to a degradation of the ecosystems affected and neighbouring ecosystems to a greater extent than is the case on the land (eutrophication; WBGU, 1998a).

E 3.4.1
Deep-sea fishing

Of the 20 most important fished species only Alaska pollack, herring, skipjack, cod, swordfish, yellowfin tuna, squid and hake are pure food species; the others are partially or completely utilized for industrial purposes. In total, at the start of the 1990s 28.5 million tonnes fish year^{-1} were used for the manufacture of fishmeal and fish oil. Approx 6.5 million tonnes fishmeal and 1.5 million tonnes fish oil with a value of US$3–4 thousand million are produced each year, principally from small, pelagic schooling fish species not suitable for direct human consumption, from bycatches and from fish-processing wastes (Barlow, 1996). Among those fish, by far the most important is the Pacific anchovy (*Engraulis ringens*), catches of which account for up to 10 per cent of world fishing yields but which are subject to extremely strong fluctuations and can collapse in El-Niño years (Arntz and Fahrbach, 1991; Lalli and Parsons, 1997). Over 50 per cent of the fishmeal is used as animal feed in poultry keeping, 20 per cent in pig rearing and 25 per cent in aquaculture. 70 per cent of fish oils are used as high-quality carriers of Ω3 fatty acids in the food industry (eg margarines, baked goods) and around 25 per cent are used in animal food production (mainly for aquaculture). In Europe, Denmark is the main operator of significant industrial fishing in the North Sea (Hubold, 1997).

The development of overfishing
In an assessment of the 200 most important fish populations used in the world (77 per cent of the catch) the FAO comes to the conclusion that 35 per cent of the populations are overfished today and that yields are falling (FAO, 1997a). 25 per cent are being fished

at maximal, consistent levels and scope for a rise is conceded for 40 per cent of populations. In a new study the American National Research Council comes to the conclusion that marine fishing is 'close to or possibly already above the maximum sustainable level' (NRC, 1999). In its autumn 1997 session, the International Council for the Exploration of the Sea (ICES) judged the situation of the populations of plaice, sole, redfish, pollack, Greenland halibut and mackerel in particular to be highly critical in the North Sea and the Irish Sea.

Overfishing of the north-west Atlantic cod, for example, led to the almost complete abandonment of cod fishing in Canada; the total catch has fallen by 75 per cent since 1988 and 35,000 fishermen have lost their jobs since 1991. Another valuable population with rapidly dwindling catches in recent years is the bluefin tuna (*Thunnus thynnus*) in the Atlantic, yields of which have fallen by 87 per cent in the last 20 years. In 1999 the International Commission for the Conservation of the Atlantic Tuna (ICCAT) responded by setting a total catch quota of only 2,500 tonnes for the western Atlantic and, at the same time, fixed this quota for the next 20 years. In the eastern Atlantic (including the Mediterranean) the permitted catch of this species was only 32,000 tonnes (1999) and 29,500 tonnes (2000) respectively (Anonymous, 1998).

Longline fishing for the Patagonian toothfish (*Dissostichus eleginoides* and, more recently *D. mawsoni*) in the Southern Ocean, which has come about in recent years, has quickly developed into a largely illegal fishery in which 60–90 per cent of the total catch is caught by unlicensed ships. In addition to the foreseeable destructive impact on this very slow-growing ocean fish, unlicensed fishing practices will also kill large number of endangered seabirds (especially albatrosses) which bite into the bait, get caught and drown (BfA, 1998, 1999). Disregarding the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), due to the size of the marine area concerned and the hesitant stance of some member states (including member states of the EU) no effective measures to end these practices have yet been introduced.

The example of the North Sea herring, on the other hand, shows that even a short-term cessation of fishing in potentially fast-growing populations can lead to their rapid recovery (Fig. E 3.4-1).

Development of fishing capacity

The world fishing fleet doubled to an estimated 3.5 million units between 1970 and the 1990s and its efficiency was further enhanced by technical and organizational measures. Today's high-technology fishing vessels can locate fish over great distances, monitor the catching processes until 'nets full' is displayed and keep to good catching positions with precision. The fleets often operate in large associations and can be directed to promising catching territories at short notice from all over the ocean. Modern catching equipment, such as the large pelagic trawl nets for catching redfish have a length of over 3.5km, are 150m high and 220m wide (Anonymous, 1997). Factory ships can process bycatches alongside the target species and thus help to reduce the discards. However, the extent of this increase in capacity considerably exceeded the increases in catches of the last 20 years. As a result the total economic balance of deep-sea fishing deteriorated greatly, with the result that the fleet is operating with losses of at least US$15 thousand million year^{-1} which are compensated for by subsidies (Milazzo, 1998). Overcapacities in the fisheries fleets are considered to be the most important reason for worldwide overfishing. Currently, worldwide subsidies in the fisheries sector amount to US$11–21 thousand million, around US$1.5 thousand million in the EU (WWF, 1998). Some fishing nations, such as Iceland, and NGOs, are therefore calling for the removal of government subsidies for fishing vessels, which are principally blamed for the maintenance of overcapacities (Paulsson, 1999). The FAO considers a reduction of 30 per cent in fishing capacities to be necessary in order to achieve worldwide sustainable deep-sea fisheries. A WWF study even calls for the reduction of the world fishing fleet to one third of its size.

Bycatches and discards

One of the main unsolved problems in the fisheries industry is the bycatch of unwanted species and the consequent discarding of these catches back into the sea. These can be fish, ground-dwelling fauna, marine mammals, turtles or seabirds (BfA, 1999). According to the most recent estimate, the worldwide discard of unwanted bycatches is around 20 million tonnes year^{-1} and it thus comprises around 25 per cent of marine fish catches (Hubold, 1999a).

Bycatches of marine mammals can be reduced considerably by adaptation of the catching methods. For example, in the eastern tropical Pacific around 350,000–654,000 dolphins were killed each year until 1973. As a result of a strict monitoring programme this figure has fallen to approx 3,000 year^{-1}, which is no longer considered significant (Hall, 1996). However, the bycatch of harbour porpoise in Danish set gill-net fishing in the North Sea is still around 7,000 year^{-1} (Kock, 1999). The use of the net can result in incidental mortality, eg due to injuries received when passing through the mesh. The use by fisheries of the target species must therefore be organized with

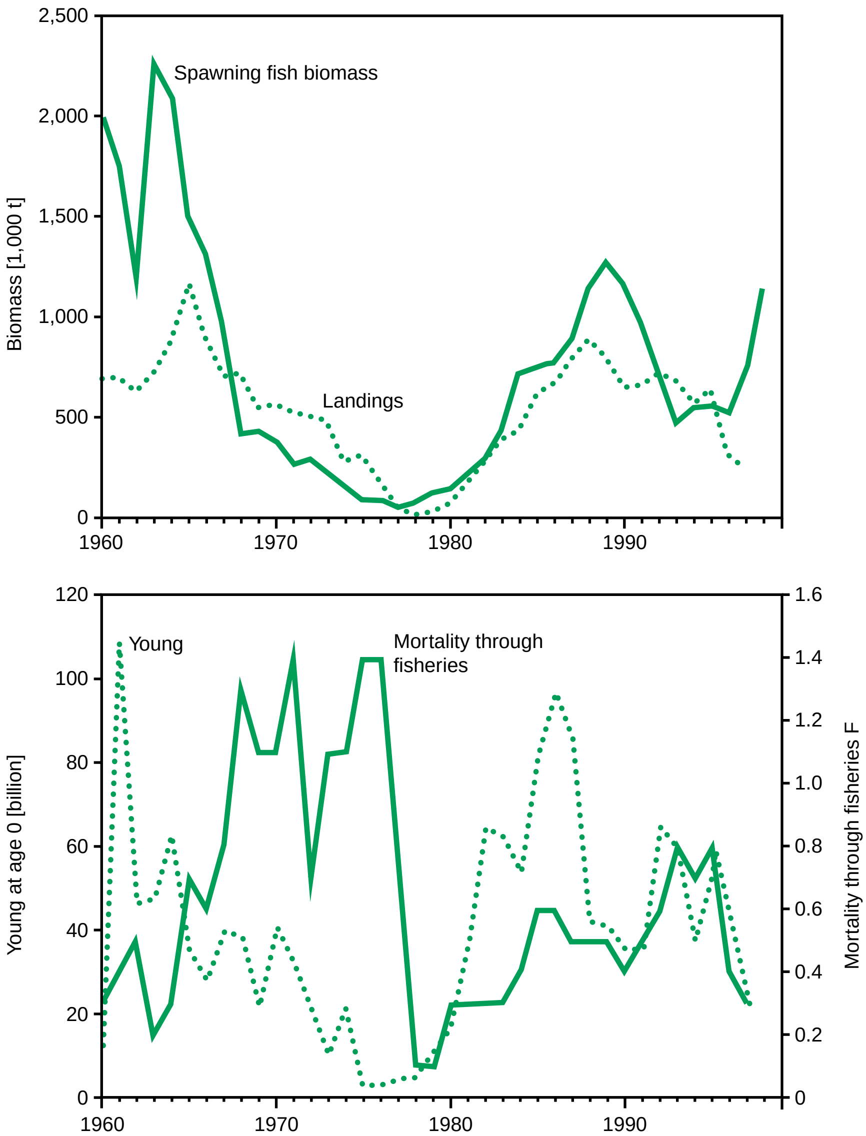


Figure E 3.4-1
Development of herring stocks in the North Sea and how they were fished between 1960 and 1998.
Source: Hubold, 1999a

greater selectivity of catching methods in order to protect fish stocks and the environment.

Effects of overfishing on the continued viability of species

In spite of the heavy overfishing, the risk that species of pelagic bony fish will become extinct is rather low because of the wide geographical distribution of these species. However, more recent studies show that there are widespread pelagic fish species from isolated populations that can vary greatly in genetic terms. It can therefore not be ruled out that some of these are already true species. Overfishing can therefore lead to a loss of genetic diversity (Malakoff, 1997). In any case, fishing results in a shift in the species spectrum from long-lived to short-lived species and to a reduction in biological diversity.

The situation among fish in coastal waters is much more critical. For example, some coral fish species are already endangered from heavy overfishing (Section E 2.4). The situation is similar with regard to fishing for cartilaginous fish, which reproduce slowly and make up for their small numbers of young with intensive brood care (K selection). Worldwide catches of the 400 shark species, 500 skate and 35 chimera species rose from 272,000 tonnes in 1950 to 760,000 tonnes in 1996. Currently, 20 shark species are considered to be overfished, including the spiny dogfish in the North Sea and the north-west Atlantic. However, improved statistics would be desirable for a more detailed analysis of the situation.

As far as the marine mammals are concerned, above all the fall in the numbers of large whales as a result of whaling is alarming. With residual populations of 100–10,000 individuals, the genetic diversity and the survival of some species of baleen whales are immediately endangered.

E 3.4.1.1
Scientific foundations for safeguarding utilizable populations

The starting point for combating overfishing and for the regeneration of fish populations is the determination of sustainable fish yields. Whereas the technological options for fishing have continuously improved in the last few decades, biological and ecological data on the subjects being caught are still largely inadequate.

The marine food chain

Although the oceans cover 71 per cent of the Earth's surface, only around half of the organic matter formed on the Earth is produced in them, around 45–60Gt carbon per year (Longhurst et al, 1995). This means that on average the oceans produce only around half as much per unit area as the land. The food chain comprises the microalgae (phytoplankton) floating in the water as primary producers, phytoplankton-eating zooplankton, fish, predatory fish, squid and whales. However, with every transfer stage within the food chain, 80–90 per cent of the energy absorbed with the food is lost. Since plankton algae in nutrient-rich, and thus production-rich, buoyant areas are usually larger than those in low-production areas far from the coast, the food chain here is shorter and therefore the total transfer-efficiency rate from the microalgae to the fish is up to 4 per cent higher than in waters far from the coasts, where is it is usually well below 1 per cent (Lalli and Parsons, 1997).

Determining sustainable fish yields

Because of the large difference in the structure of marine food chains, only rough statements – based on assessments of the ocean's primary productivity – can be made about potential mean fish yields, and only for limited marine areas, usually based on correlation analyses. However, in individual cases these do not provide a sufficient foundation for the management of fish populations. Sustainable fish yields can only be achieved if the natural rate of increment at least balances out the total mortality of the fished population. Total mortality is made up of natural mortality (of which only a rough assessment is possible) and fisheries-related mortality. In the case of fish species with large number of young (high-recruiting), high fisheries mortalities can be tolerated, without endangering the continued existence of a population. The recruitment and, thus, the annual size of populations available for fishing are subject to strong interannual fluctuations (Box E 3.4-1). These annual sizes therefore have to be identified and considered for sustainable fishing quotas to be set. This requires considerable technical, logistical and administrative effort. Unfortunately, data availability on the population development and recruitment of important commercial fish species has deteriorated in recent years, due to cuts in research funding.

Box E 3.4-1

Why do the annual sizes of fish populations fluctuate?

The reasons for the major fluctuations in the annual sizes of commercial fish stocks have not yet been identified, in spite of intensive research efforts. This knowledge deficit is one of the main reasons why the long-term forecasts of population sizes and, thus, the determination of long-term sustainable fishing quotas has not been possible to date. Most bony fish produce very large numbers of eggs or young larva. But usually only a very small proportion (at most just a few per cent) of the hatched young reach sexual maturity. Relatively small fluctuations in the mortality of the larvae therefore have a great impact on the population size of the young fish concerned (so-called recruiting). The following attempts at explaining the variability of recruiting have been made so far (Lalli and Parsons, 1997):

- *Hunger hypothesis*: First of all, fish larvae eat the yolks of their eggs before they start to feed. If no food is available then, the young larvae die off.
- *Predator hypothesis*: Below a certain minimum size young fish larvae are easily eaten, there is then a high mortality rate in the populations. With unfavourable feeding conditions the fish grow more slowly than when the feeding conditions are favourable. For this reason, the time in which they can be eliminated by being eaten is longer.
- *Advection hypothesis*: As a result of sea currents fish larvae can be drifted into areas abundant in food – or poor in food – and recruiting reflects this.
- *Growth hypothesis*: In higher water temperatures the fish reach sexual maturity sooner with a smaller body size. Moreover, their growth depends on the nutrient value of the food (above all the protein content) and their metabolic intensity (eg the energy required for acquiring food). A change in the food spectrum therefore generates different growth rates that have an impact on the fish yields that can be achieved.

Experimental findings support all the hypotheses that do not necessarily rule each other out. A great deal of research is needed to clarify these questions that are essential to fisheries and to draw up forecasts for the longer term.

E 3.4.1.2
Sustainable fisheries management at international level

The guidelines for sustainable fisheries management are the principles on marine environmental protection and the long-term use and conservation of living marine resources laid down in Chapter 17 of AGENDA 21, in the Convention on the Law of the Sea and in the Biodiversity Convention. The FAO voluntary code of conduct on responsible fisheries and the binding United Nations Convention on Conservation and Management of Straddling and Highly Migratory Fish Stocks, which has not yet come into force, are important foundations for the sustainable management of fish populations, and expressly include consideration of the precautionary principle. A lack of or (as yet) inadequate scientific studies should not therefore be a reason for postponing or omitting the introduction of measures to conserve fished and unfished species and their habitats. However, the precautionary principle is still not used enough throughout the world. This lends all the more importance to the judgement of August 27, 1999 by the International Tribunal for the Law of the Sea on provisional measures to conserve the bluefin tuna, which took the precautionary principle as a basis. Moreover, another important step on the way towards international sustainable fisheries management is the rapid ratification and implementation of the UN Convention on the Conservation and Management of Straddling and Highly Migratory Fish Stocks, especially by the EU states that have not yet done so. This would bring the number of ratifications to the 30 needed for the Convention to come into force.

Safeguarding stocks of commercial fish

An internationally recognized and organized system of research and administrative institutions is needed for the annual specification of sustainable fishing quotas. Under the scientific coordination of the International Council for the Exploration of the Sea (ICES), the Advisory Committee for Fisheries Management (ACFM) submits annual management analyses for over 100 fished stocks in the North Atlantic. The Federal Government should push for the specification of the total annual catch in the EU to be based more on the scientific recommendations of the ICES than on politically motivated demands. Where there are no scientific findings, the precautionary principle should take effect and research should be intensified at the same time. Furthermore, the Council feels it is necessary to extend the management analyses to cover further stocks. Internationally recognized fisheries protection zones and moratoria have proved to be effective instruments for the protection of endangered stocks; their use continues to be advocated and should be expanded. For example, the American National Research Council recommends that permanent fisheries protection zones should be established in the coastal area of the USA, which should comprise 20 per cent of the potential fisheries zone (NRC, 1999).

Adapting fisheries capacities to needs

In order to achieve the sustainable use of the available resources, the FAO code of conduct calls for the reduction of excessive catching capacities, amongst other things. The Council feels that this is a key instrument for sustainable fisheries management because the continuing overcapacity of the fishing fleet is the main reason for the overfishing of stocks. Furthermore, the reduction of capacities can assist with better adherence to quotas, which so far have been undermined in various ways which are difficult to police, eg by neglecting to land catches, but trading them immediately on the high seas (passing the catch on to refrigeration ships).

The targets for reducing the fleet segments laid down within the context of the EU's Common Fisheries Policy (CFP) have been too low in the past to counteract overfishing effectively. Moreover, not all of the member states have fulfilled the requirements. The Council is also critical of the possibility of limiting the catching activities of fishing vessels instead of permanently setting them aside. The Federal Government should press for the necessary dismantling of overcapacities to be pursued more rigorously and to be accompanied by structural measures.

In a continuation of this approach, the reduction of capacities should also be attempted worldwide, within the context of appropriate conventions and conferences. The problem of flags of convenience ('outflagging'), with which the actual world fleet is just shifted around but not reduced, can also only be solved at international level.

The abolition of subsidies for fishing fleets is a key requirement for the reduction of overcapacities. The funds that are freed up in this way can be used to establish proven environmentally sound fishing and to finance technical measures and institutions to control compliance.

Preventing degradation of aquatic ecosystems

In view of the fact that the vast majority of marine pollution comes from land-based sources, concepts and measures that also take account of terrestrial sources of pollution are urgently required to protect the ecosystems concerned. Whereas some substantial improvements have been made in the highly developed industrialized countries in the last two decades as a result of sewage treatment, the problem of water pollution continues to grow in the developing countries. Here, there is usually a complete lack of sewage treatment installations. The discharge of untreated or insufficiently treated sewage leads to the eutrophication, pollution and contamination of the surface water with pathogens. The loss of oxygen and accumulation of pollutants that consequently occurs can seriously endanger fish populations (incidents of mass fish deaths; WBGU, 1998a). In light of the increasing concentration of the world population in coastal regions, this problem will be exacerbated in the near future. The Council therefore considers support for projects to intensify the protection of rivers, lakes and coastal regions, especially in conurbations in developing and newly-industrializing countries, to be a priority.

The large-scale fertilization of the ocean (addition of iron) to increase phytoplankton growth with the aim of reducing atmospheric carbon dioxide concentrations was seriously considered (Chisholm and Morel, 1991). This would have been extremely difficult technically and logistically and does not appear to be reasonable for ecological reasons. Although the eutrophication of inland lakes and shallow coastal waters leads to an increase in production, it simultaneously leads to a reduction in water quality. As a consequence, the habitat and usage functions of the ecosystems concerned are impaired. A maximization of productivity by means of fertilization, such as is possible on land, is not therefore a promising option for water bodies.

Securing the continued viability of species

Whereas current deep-sea fishing for widespread bony fish hardly endangers their continued existence as biological species, the intensive fishing of slow-growing species (eg cartilagenous fish such as sharks and rays) is already threatening stocks. Some fish species in coral reefs and mangroves are also threatened by overuse. The use of poison (cyanide) or explosives for catching the fish also destroys the habitat (Section E 2.4). Regional fisheries protection zones, international import bans for endangered species (eg within the context of CITES; Section D 3.1) as well as the international certification of harmless catching methods (ecolabel) could help towards conserving endangered species and ecosystems. Initiatives for the independent certification of environmentally sound fisheries and catching methods, such as the Marine Stewardship Council, should be supported.

Minimizing bycatch

More attention must be devoted to the problem of the bycatch. Whereas the bycatch of mammals generally arouses great public interest and has now largely been reduced in most areas by international agreements, the bycatch of fish and soil-dwelling organisms is still problematic. Measures to improve the selectivity of catching methods have to be reinforced by creating incentives and by statutory initiatives (bans on discards, order to change catching locations). Considerable efforts in research and development are still needed, that taking particular account of the typical behaviour of bycatch species. This applies in particular to organisms on the sea bed. For example, attempts are currently being made to prevent the bycatches of small whales in set gill nets by means of acoustic signals or by using electrical stimuli or hydraulic scaring to reduce the bycatches of soil-dwelling organisms in flatfish fishing (BfA, 1998).

Optimizing the EU Common Fisheries Policy

Considering the recommendations above, the Federal Government should continue to gear its policy-making opportunities towards an optimization of the practical elaboration of EU fisheries management. With respect to the forthcoming reform of the EU Common Fisheries Policy in 2002, the Council advocates the further implementation of the resolutions and conclusions of the 1997 Ministerial Meeting on Fisheries and the Environment in Bergen as well as the establishment of a group of experts on 'Fisheries and the Environment' at EU level. Furthermore, the EU should consider the adoption of flexible management instruments which could react suitably swiftly to acute deteriorations in the state of individual fish stocks.

In addition to the programme for reducing the fisheries fleet and the further deployment of technical provisions to reduce the bycatch, new types of approaches should be tested. To date it has not been the total catch, but just the catch brought on to land that is offset against the set quotas depending on the fisheries, fishing territory and nets used. As a result, the catch of depleted or otherwise protected species is legal if the catches are not landed. Another example of the measures needed, in line with biological findings on the protection of young fish, would be the specification of minimum lengths in roundfish fishing. A number of concrete proposals for improvements in the management of European fish stocks have already been drawn up (Hubold, 1994) and these have been introduced into the international discussion by means of the scientific bodies of the ICES, as well as in dialogue with the EU's Directorate General for Fisheries Policy (GD XIV) and the relevant German Federal Ministry. Implementation of these should be moved forward quickly.

Finally, the EU-wide implementation of the amended Control Regulation on the Monitoring of Fisheries within and outside EU waters that entered into force on July 1, 1999 should be promoted. In particular, the objectives of the increased openness of fisheries monitoring in the individual member states, the improvement of cooperation between member states with regard to controls and the better control of third country ships can help to achieve higher acceptance among fishermen by reinforcing equal treatment.

E 3.4.2 Aquaculture

When obtaining food from breeding systems, a distinction must be made between industrially-operated intensive and extensive aquaculture, the latter of which is frequently combined with agricultural production. Whereas industrial aquaculture primarily produces luxury products such as salmon, lobster or prawns for export, extensive aquaculture integrated in small farms in developing countries makes a contribution towards local and regional food security (WBGU, 1998a). In aquaculture, there is increasing use of transgenic fish, which are equipped with additional growth hormones to increase fish production. This leads to shifts in the population composition, changes in behaviour and changes in the food web. The use of quantities of growth hormone that is alien to the species question in predatory fish species is considered to be especially critical (UBA, personal communication). The following three case studies are designed to reveal the scope and problems of the various aquaculture systems. These are cases in which aquaculture has already reached a relatively advanced state, so that experience gained thus far can be used to derive approaches for increasing efficiency and for the social and environmental compatibility of aquaculture.

E 3.4.2.1 Integrated carp breeding as an example of freshwater aquaculture

There are many years of experience with the cultivation of carp in China, India and other south-east Asian countries in particular. The distinguishing characteristic of integrated carp aquaculture is its combination with the most varied plant crops (sugar cane, bamboo, fruit trees, flowers), depending on the local conditions, and frequently also an internal waste recovery system. The integrated breeding of herbivorous species such as carp also offers small farmers economic advantages thanks to relatively low technical requirements for production. The Chinese and Indian carps are usually kept in mixed crops of 2–3 species drawing on complementary food spectrums, which allows more efficient use of the available food and thus a corresponding increase in fish yields.

In India, Indonesia and Bangladesh many naturally hatched young larvae are still being used for rearing, whereas in China and Europe the brood material is produced artificially. The stocking rate of carp ponds fluctuates between 4,000 and 5,000 larvae ha^{-1} with a length of 2.5–5cm or 2,000–3,000 larvae ha^{-1} with a length of 5–10cm. The rearing time to achieve a fish weighing 1–1.2kg is around two years in Europe. In the tropics, fish are harvested with a weight of 0.6–1kg, which need only one year for their development.

Fertilizers are added to the fish ponds in order to maximize the yields, with slurry and compost being primarily used in Asia. However, this harbours the risk of infections through bacteria, fungi and viruses. The mortality of grass carp can be 70–90 per cent in China. In addition to diseases, parasite infestation is widespread.

E 3.4.2.2 Shrimp farming as an example of industrial aquaculture of crustaceans

Between 1982 and 1994 the annual production of prawns (shrimps) from aquaculture rose from 100,000 to 900,000 tonnes. Production takes place mainly in developing and newly-industrializing countries (eg Philippines, Thailand, Indonesia, China, India and Ecuador) and is largely exported to industrialized countries as a cash crop. In south-east Asia, 1.2 million ha of coastal land areas are currently being used for ponds; in the western hemisphere this figure is around 0.2 million ha.

In the Latin American countries in particular, the larval material is largely obtained from natural stocks because they are considered to have higher resistance to infection. By contrast, the majority of prawns in south-east Asia are reared from larvae produced by humans. They are mainly reared in ponds created in salt marshes, wetlands or mangroves. But these are areas traditionally used by farmers (for rice) and inland fishermen, meaning that in many places the interests of farmers, fishermen and prawn breeders collide.

A distinction can be made between three rearing models: in the extensive or traditional method, the prawns are cultivated in rotation with rice crops and are enclosed in flooded fields with other fish and shellfish during the monsoon. With this sort of production no food or fertilizers are added. Yields during the 100–120 day development period are less than 1,000kg ha^{-1} and are intended for local people's own needs and the local market (Friedrich-Ebert-Stiftung, 1997; Boyd and Clay, 1998).

In the case of the semi-intensive and the intensive method, the prawns are reared in permanent ponds created for several years. Production ranges from 2,000kg ha^{-1} in semi-intensive installations to over 8,000kg ha^{-1} in intensive crops. Here, the prawns are fed on pellets made of fish or plant products. The utilization efficiency of the food given is usually below 50 per cent. The rest is deposited as waste, decomposes and leads to eutrophication of the ponds, in the same way as inorganic nutrients added as fertilizers. In intensive husbandry particularly, where large quantities of food are added, the degradation of the ecological conditions in the culture basins can restrict the length of the life of the rearing systems, which leads to increased land appropriation for new aquaculture installations. If the prawns are fed at shorter intervals with lower individual portions, the utilization efficiency of the nutrient uptake can be increased and, thus, the amount of waste can be reduced (Boyd and Clay, 1998).

Worldwide, the destruction of mangroves by aquaculture accounts for approx 10 per cent of the total destruction of these biotopes. But regionally it reaches much higher percentages, for example on Java (Section E 2.4). In the case of inland ponds, seawater has to be supplied via a pipeline system. The leakage of saltwater from faulty pipes leads to salinization of the groundwater. The addition of freshwater also threatens the already scarce freshwater reserves in the coastal area. This leads to strong conflicts of interest. In intensive crops, in particular, there is the risk of the spread of viruses and bacteria. However, the addition of antibiotics pollutes the environment and harbours the risk that resistances will develop to pathogenic bacteria (Boyd and Clay, 1998).

E 3.4.2.3
Marine macroalgae as an example of plant aquaculture

Above all, marine macroalgae settle in the tidal zones and the areas just below low tide. They are characterized by high biomass and growth rates. In some east Asian countries (Japan, China, Korea, Philippines and Taiwan) they are bred on a larger scale in aquaculture systems. In 1993 total production was 2.4 million tonnes or around 22.8 per cent of total aquaculture production. The most important macroalgae bred in aquaculture is the red alga *Porphyra* spp. In addition, the brown algae *Undaria pinnatifida, Laminaria* spp. and the green algae *Enteromorpha compressa* and *Monostroma* spp. are cultivated.

Macroalgae are primarily bred for food, but also to meet industrial demand for products such as agar, alginates or carrageen, where they are used as swelling agents or emulsifiers or for the production of chemical fibres. The nutritional value of macroalgae is sometimes better than with land plants, but consumption is so far limited to countries in the Far East. The breeding of macroalgae in aquaculture systems could, without a doubt, be increased greatly, but this would be dependent on a change in consumption patterns in regions where macroalgae are not part of the traditional diet.

E 3.4.2.4
Environmentally friendly and low-resource aquaculture management

These case studies clearly show that a differentiated, locally and regionally adapted consideration of the various aquaculture systems is needed. Whereas integrated carp rearing is not technically very sophisticated and is comparatively environmentally friendly with low to medium stocking rates, the intensive rearing of carnivorous species in particular causes considerable ecological problems. This is especially the case for the rearing of prawns and salmon. In addition, their supply with live food (usually animal plankton), whether caught from wild populations or making use of bred material, is very complex. The preferred alternative method of feeding – with protein-rich fishmeal and fish oil – is a further burden on marine stocks that are already overfished or threatened with overfishing.

Aquaculture systems should take up areas that are as small as possible and cause little environmental pollution. However, it is very difficult to harmonize these two demands and this causes a dilemma: although extensive crop systems are environmentally friendly, they require large areas, which means that other uses are lost or valuable ecosystems are converted (above all mangroves and wetlands). Although intensive installations take up less land, they generate considerable environmental problems. The only way to make feasible compromises here is to consider the local ecological and socio-economic conditions. One important strategy which is always effective is to reduce land appropriation by undertaking measures to prolong the life of existing installations.

PROMOTING CONVERSION TO SUSTAINABLE AND WELL-ADAPTED FORMS OF AQUACULTURE

The Council considers it to be reasonable to continue to promote conversion to environmentally friendly, long-term and well-adapted forms of aquaculture by means of international programmes or bilateral cooperation, eg within the framework of Federal Ministry of Economic Cooperation development projects. Partnership research projects should contribute not only to solving specific ecological problems, but also to training local specialists (capacity building). In many of the poorest countries (for example, in Bangladesh) aquaculture has so far only been used to earn export profits. In order to improve the diet of the local population, especially with proteins, it would make sense to promote the additional production of food from aquaculture for domestic consumption. In particular, rearing herbivorous freshwater fishes, such as carp, can make a contribution to the growing need for protein in developing and newly industrialized countries with little technical effort. In the field of prawn rearing there are already some approaches towards adapting the present crops and depleted areas to the principles of sustainability and environmental compatibility. One possibility is to combine integrated mangrove forest culture with brackish water aquaculture ('silvofisheries'). This form permits the maintenance of relatively high integrity mangrove forests alongside extensive cultivation of fish, prawns and shellfish.

ESTABLISHING INTERNATIONAL CRITERIA AND LABELLING SYSTEMS FOR ENVIRONMENTALLY FRIENDLY AQUACULTURE

The development and implementation of international criteria and labelling systems for sustainable aquaculture is urgent. In the above-mentioned code of conduct the FAO has already set out requirements for the environmentally compatible development of aquaculture and drawn up guidelines for their implementation. Within this context, the establishment of internationally valid labelling schemes also merits attention. Research in this direction must adopt differentiated approaches for the various aquaculture sectors. A decisive criterion for all forms of aquaculture is the stocking rate and the lifetime of the rearing systems.

E 3.5
Conserving natural and cultural heritage

E 3.5.1
Cultural change and heritage conservation as preconditions for successful biosphere policy

THE ENVIRONMENTAL CRISIS AS A CULTURAL CRISIS

The previous sections outlined human interventions in the landscape and the consequences of this for biological diversity (Section E 1–E 3). Under the guiding principle of sustainable use of the landscape and resources, proposals for various types and intensities of use of terrestrial, aquatic and urban ecosystems (Section E 3.8) have been discussed, and used as a framework for weighing up use and conservation interests. 'Conservation before use', 'conservation through use' and 'conservation despite use' designate prototypes of human activities relating to land and water. Their purpose is to help introduce sustainable, environmentally sound development – here with particular emphasis on the conservation of the biosphere.

With reference to the three-dimensional sustainability concept, the *ecological* and *economic* dimensions were the focus of analysis here. In the process, links to activities, demands and value scales of human communities were repeatedly created and thus to the third dimension of the sustainability triangle: the *social* aspect. This dimension refers to all social or, more accurately, socio-cultural conditions of humanity – including but also extending beyond the economic dimension – but is often abbreviated to the aspects of intra- and inter-generational social justice and equality of opportunities. For this reason, some sustainability theoreticians consider another dimension to be necessary, which holds the other three together or upon which these three depend, ie the cultural dimension. The three dimensions are structured, linked and weighed up against each other by cultural schemata, values and practices.

Since its first report (WBGU, 1994) the Council has tried to analyse environmental problems such as climate change, soil degradation, the freshwater problem and now the risk to the biosphere as a global complex of relationships (WBGU, 1995a, 2000a; Chapter C), which is characterized by multi-faceted direct and indirect interactions between the natural sphere and the anthroposphere. In the process it can be seen how and to what extent humans cause changes in the environment with their cultural activities, but that they are also affected by natural changes. The role of humankind in overcoming environmental problems, in the sense of adapting to changes that have already occurred or in avoiding, reducing or slowing down anticipated undesirable changes is not explicitly visible in the network of interrelations, but it should be analytically separated from the two roles of polluter and affected party.

To underline the importance of human awareness and action, for some time now it has been emphasized repeatedly that environmental problems are the result of maladaptive action and should therefore be viewed as problems of culture, or resulting from the development of civilization. Hence, both causes and solutions must be sought in this sphere. The environmental crisis is a crisis of culture; talking about a crisis of nature would be a 'cultural misunderstanding' (Glaeser, 1992). Overcoming 'environmental problems' thus depends on people recognizing these problems in the first place and seeking ways and means of solving them. Solutions will require changes in maladaptive methods of managing nature and, especially, in the perceptions, knowledge, values and attitudes upon which these are based; in other words a complete change in lifestyles. Another promising approach, at a different level, concerns institutional regulations, balancing out the differences between the North and the South, and technical developments (Section I 3).

In Agenda 21, and even more strongly in the Convention on Biological Diversity (CBD), it is pointed out that for centuries many indigenous peoples and traditional communities have practised a way of managing nature and natural resources which does not lead to the degradation and destruction of the biosphere (Section E 3.1). If these indigenous and traditional communities, previously often called 'natural peoples', only rarely practised maladaptive action, what is the explanation for this? Furthermore, can conditioning factors for their actions be identified, since some strategists would like to shape these into a guideline for sustainable treatment of biodiversity?

Protecting the biosphere by changing the patterns of cultural action

If the subject of biological diversity has been gaining increasing amounts of (political) attention since the negotiations for the CBD, there is a parallel process that places the protection of cultural diversity at the fore. In 1997 the 'World Decade for Cultural Development' designated by UNESCO came to an end. In this context the President of the World Commission, Perez de Cuéllar, submitted the report 'Our creative diversity' in 1995. This report and the associated plan of action not only calls for the conservation of cultural diversity, but also for the elaboration of 'culture-sensitive development strategies', in which cultural diversity should be brought to bear as a creative source in the definition and design of development.

In this context, the plea is made for conservation of the environment and biodiversity as the bearers of cultures but also, in the same vein, for the conservation of linguistic diversity. The fear that by the end of the next century 95 per cent of the approx 6,500 languages in existence could have disappeared is not only placed frequently alongside biological diversity as a 'second critical loss', but is also viewed as causally connected with it. Consequently the relationship between biological and cultural diversity becomes a matter for reflection, and the symbiotic character of this relationship is taken as a basis for further action. Ultimately, the way in which humankind comes to terms with nature is what we call culture. This is where there are possible points of departure for political action.

If the human race is still to have a future, a change in cultural awareness and action with respect to nature and its resources is essential (Section E 3.1). Its (cultural) patterns for action must also change accordingly if humankind is to live more sustainably than before and survive in the future. But the cultural diversity of societies, and the associated linguistic variations, systems of beliefs and patterns of action with respect to nature and the environment, should also be protected because they are considered to be an important precondition for the conservation of biodiversity. In general it can be assumed that cultural diversity strengthens the capacity of societies to withstand and deal with environmental crises.

This apparent contradiction between the call for both cultural change and cultural conservation can only be resolved if the general subject of this report (humankind and the biosphere) is reflected upon once again, so as to examine the hypothesis of a close relationship between nature conservation and the preservation of cultures implied in the heading of this section. This requires us to reconsider the traditional relationship between nature and culture which we have inherited in our own society.

E 3.5.2 Human adaptation of nature

Humans are increasingly destroying their environment and the natural foundations which sustain their lives. This statement refers to a more comprehensive set of problems that concerning the relationship between humankind and nature. Many generations of cultural philosophers have thought about the 'place of man in the cosmos' (Scheler, 1928). Traditionally, the relationship between humankind and nature is a subject studied in geography, cultural anthropology, ethnology and human ecology. The relationship between nurture and nature has always been an issue in psychology and is currently gaining renewed attention as a result of the arguments in behavioural biology (eg biological basis of people's preference for natural stimuli).

Like all living beings, humans are a product of biological evolution. However, of all species man has traditionally always been given a special position because he has unique physical and psychological properties as a result of his 'biological endowment'. Through intelligence, long-term memory and the ability to speak he is able to order his world by imposing his own categories, to interpret it and act accordingly, and also to transmit this knowledge to his offspring.

Although in the past it was usual to consider humans (unlike animals) as cultural beings as opposed to part of the natural world, our modern insight into the interaction of nature and culture no longer allows such a dichotomy. Much rather, we must clarify the processes and activities by means of which, and the extent to which, nature and culture are related to each other. The former view has been superseded and today we do not see nature as a world 'untouched' by man, left to itself that is 'strange' because of its autonomous laws, but as a world constructed and appropriated by mental and physical human activities.

In the tradition of the Russian school of cultural history (Leontyev, 1973) appropriation is understood to be man's interactive coping with his environment, by means of which man changes or defines his environment for his own purposes, thus making it into a human environment (Kruse and Graumann, 1978; Graumann and Kruse, 1990). This is a dialectical process: in the extent to which man, whether as a species or an individual, appropriates something from his environment and thus makes it his own (*humanum*) by processing or use, ie into an object that ultimately mirrors human activities, it will reflect back on to man as a changed environment. Man who has such an impact on his environment also changes in the process.

This makes it clear that the term 'appropriation' refers to two distinct processes that coincide here: one is the historical process of appropriation of nature (its raw materials and forces) and resultant products, which leads to extremely different philosophies and practices over many generations in different cultural and ethnic groups (eg mediaeval societies in Europe). The other inherent process is biographical and individual learning that starts afresh for every life history. The subject of the first process is humankind, differentiated according to peoples, tribes and their various cultures and languages. The subject of the second process is the individual who has to learn the achievements of his or her culture afresh.

Appropriation certainly takes place in a historical and culture-specific perspective through the conversion of nature into culture through work: converting slopes into rice terraces, removing stones and soil to build houses, developing transport routes on water and land, breeding plants, domesticating animals, but also appropriation of other humans and peoples through conquest and subjugation. One essential part of this process is the symbolic appropriation of nature, by depicting it artistically and naming its parts linguistically (categorization). In this symbolic appropriation, differences in religion, myths, general beliefs and knowledge play a key role. Closely linked to symbolic appropriation is value formation. This is culture-specific, giving rise to the problem that valuations of natural and cultural assets and states of affairs (material culture), and the attitudes and stances taken with respect to them, are so divergent from one culture to another that intercultural communication often becomes difficult, if not impossible.

E 3.5.3
Reappraisal of indigenous and local cultures: importance in the context of biosphere policy

New interest in indigenous societies

A (negative) example of cultural appropriation is the way in which representatives of western cultures once relied on their own systems of beliefs and knowledge about indigenous cultures (Box E 3.5-1), even classing them as inferior ('primitive', 'naïve', entirely based on subjective opinion). Only in recent times has new interest been expressed in the knowledge and practices of these peoples, most of whom live in tribal societies. Around 5,000 such groups exist, encompassing a total of 200–300 million people, frequently living in rural or semi-natural areas with high biological diversity, half of them in China and India. There are various reasons why that is the case.

- Since the 1960s it has been increasingly recognized that the consumption of energy and resources that go hand in hand with western cultural patterns and lifestyles, the destruction of ecosystems, and other processes of degradation, lead to global environmental problems.
- It is also recognized that many indigenous and traditional societies have succeeded in conserving the biosphere or managing it sustainably. In the process, they use practices that are supported by a complex interaction of knowledge, philosophies and religious belief systems developed over long periods of time. To what extent can this knowledge

Box E 3.5-1

Indigenous peoples

Indigenous literally means 'born into something', 'within a line of descent', or simply 'native'. Instead of this last term, which is felt to be discriminatory, the term indigenous has established itself uniformly at international level. In order to distinguish between indigenous and non-indigenous peoples several criteria always have to be considered, as illustrated by the definitions below. The definition of the International Labour Organisation (ILO) is the only international legal agreement to date with respect to indigenous peoples. The definition of the United Nations Special Rapporteur has also met with broad international acceptance.

United Nations Special Rapporteur
Definition by the Special Rapporteur of the United Nations Sub-Commission on Prevention of Discrimination and Protection of Minorities of the Council for Economic and Social Affairs:

'Indigenous communities, peoples and nations are such that have developed in a historical continuity with pre-invasion and pre-colonial societies on their territory, and view themselves as being different to the other sectors/parts of the society that now dominate in these territories. They now form non-dominant sectors/parts of society and have a firm resolve to preserve, develop and pass on to future generations their continuing existence as peoples, in accordance with their own cultural arrangements, social institutions and legal systems.'

International Labour Organisation
According to Convention 169 of the International Labour Organisation indigenous peoples are:

1. Tribal peoples in independent countries whose social, cultural and economic conditions distinguish them from other sections of the national community, and whose status is regulated wholly or partially by their own customs or traditions or by special laws or regulations.
2. Peoples in independent countries who are regarded as indigenous on account of their descent from the populations which inhabited the country, or a geographical region to which the country belongs, at the time of conquest or colonization or the establishment of present state boundaries and who, irrespective of their legal status, retain some or all of their own social, economic, cultural and political institutions.

Self-definition as an indigenous or tribal people should be considered the key criterion for the determination of the group which the provisions of this Convention should apply to.

be used for nature conservation? Can indigenous and traditional practices be a model for sustainable management to conserve biological diversity (Section E 3.9)?

- There is growing interest in the use and profitable recovery of the genetic resources available in these habitats and of the associated knowledge of the indigenous and traditional communities. How can we use these materials? How can we let the 'owners' of this potential participate in its economic use (Section I 3.3.3)?
- The frequent abundance of resources (eg iron, copper, bauxite, gold or silver) in the territories inhabited by indigenous and traditional communities has often meant that they have had to give way to large-scale projects; they have been dispossessed or resettled. Within a very short time knowledge was lost that had been passed down orally over many generations and had thus defined not only a language, but also the social fabric of the communities and their identity. Is cultural diversity a guarantor of the conservation of biological diversity as well as a value *per se*? Can the loss be accepted and should it be further advanced by the globalization of western patterns of consumption and production, by the 'McDonaldization' of standards and lifestyles (Chapter H)?
- The indigenous communities themselves also make demands and assert rights (Dömpke et al, 1996). The growing extent of 'contact' with westernized culture, eg via scientists and representatives of industry looking for useful knowledge, as well as tourists, the media, etc increases the fear of indigenous peoples about the use or exploitation of their traditional knowledge without the equitable sharing of benefits, and about the imminent loss of their identity and their culture. They are calling for the protection of their intellectual property and the conservation of their habitat where they can retain their traditional lifestyles, including their economic, cultural and religious habits as well as self-determination and co-determination with regard to the use of their habitat (Section I 3.2.9).

Traditional or indigenous societies, which are often located in areas rich in biodiversity, have always been forced to manage with the resources in their immediate habitat. Over many centuries these communities have developed reserves of knowledge and practices that have ensured their survival and whose rules are passed on orally from generation to generation. Complex processes of adaptation to their living conditions transmitted as knowledge and spiritual practices have meant that many, but by no means all, indigenous and traditional groups have maintained the foundations of their lives and the abundance of their flora and fauna. There are not just many different mythical ideas about indigenous peoples, but also an impressive array of scientific, mostly ethnological and cultural-geographical, case studies on the philosophies of indigenous and local cultures and the way they live. 'Myths' begin with the discriminatory understanding of indigenous peoples as people with 'little mastery of nature', peoples apparently 'without culture'; they continue via the concept of the 'noble savage', a paragon of ecological virtues, through to the projections of esoteric and New Age groups on their 'ethnic trip', craving the 'natural' untamed way of life, the ability to gain access to other planes of consciousness and the wisdom of indigenous peoples (Herzog-Schröder, 1991).

The scientific analyses of indigenous and local cultures reveal a much subtler picture. They show the remarkable interdependence of nature and culture, with culture meaning more than interaction with the landscape, flora and fauna, but also including interaction of members of society with one other. Thus traditional ecological knowledge (TEK) is a characteristic element of all of these cultures termed indigenous. However they also bear testimony to failed adaptation, the rise of conflicts and the collapse of cultures which come about with the 'infiltration' of the industrialized, western world.

Many landscapes, especially in South America, that were long regarded as a 'wilderness' and were considered to be virgin territory have since proved to be carefully managed. Thus, for example, the Kayopó Indians established herbs and medicinal plants in sheltered spots in seemingly – to the European eye – wild savannahs and forest areas (Posey, 1982; Herzog-Schröder, 1991). The Tukano in the north-western Amazon basin care for an amazing variety of plants and animals. What the western world sees as the largest remaining 'wilderness' in the tropics is the home of the Tukano who extract their livelihoods out of this apparently inhospitable landscape in extremely varied ways. The Tukano accept their 'wilderness' as man-made, ie transformed in the past and structured by the symbolic significance that linked their ancestors to the available resources. The Tukano know that they cannot harvest more from their forest than it will produce again. They have a profound knowledge of individual species and their uses. Their daily struggle for survival has led to a long tradition of continual observation of animal behaviour and has shown them possible ways to survive. In their myths there are stories of animal species that were punished by the spirits for gluttony, boastfulness, foolishness and aggression. These myths serve as examples to human society; the animals are metaphors for life. By watching the behaviour of the animals, the Tukano create for themselves an order to the physical world within which human activities can be adapted (Reichel-Dolmatoff, 1976, cited in McNeely and Keeton, 1995). The relationship of the Tukano to the animal world is a typical example of how these people manage the resources available to them. Firm in their knowledge of the population density and ecological linkages and backed by their traditional ethical norms, they restrict hunting of the animals upon which they live. 'Such people walk lightly on the landscape' (McNeely and Keeton, 1995) – in fact so lightly that one could think no one had ever lived or farmed in this wilderness.

Indigenous and traditional systems of knowledge are adapted to specific local conditions. Possible risks with respect to food security are minimized by the combination of various land use and cultivation methods. This understanding of agricultural methods as well as the varied knowledge about native fauna was long overlooked. The interrelationship between management of the immediate habitat, social structures and the patterns of labour division are also part of indigenous systems of knowledge and practice.

In the course of human history not all local communities have developed sufficient knowledge and technology to be able to survive over very long periods of time by following a way of life adapted to the limits of their habitat. One example of this is the deforestation of Easter Island in the Pacific Ocean 800–1,200 years ago, which was tantamount to an ecological disaster and signified the end of the megalithic culture which had erected the famous statues on the island.

Moreover, it must also be pointed out that a sustainable way of life can continue only for as long as

- the societies live at subsistence levels,
- the groups do not become so large that carrying capacity is exceeded,
- the societies have full control over their local resources,
- there is sufficient group cohesion.

Differentiated practices of resource use and protection, eg woodland and grazing management, comprise issuing ownership titles to forests and meadows, rotating hunting grounds, banning hunting on certain species, restricting felling, designating 'Holy Groves', shifting residential settlements and controlling tribe sizes. These conditions often quickly cease to apply when external influences (eg colonization) or the offers of the market economy and the global consumption culture 'infiltrate' in the form of trade, television, tourism, etc.

The fate of the Tuareg in West Africa is well known. Their nomadic way of life, with migrations adapted to the availability of water and grazing land, was destroyed in the course of French colonization. The ban on travelling, the specification of territorial borders, customs obligation and other instructions from the government, which wanted to turn the Tuareg into sedentary arable farmers, led to them losing their traditional lifestyles and their economic foundation and thereafter suffering greatly as a result of droughts. In the early 1970s, drought disasters drove thousands of Tuareg to Nigeria and Niger.

Traditional cultural patterns and forms of managing natural resources therefore prove themselves to be highly vulnerable and are increasingly jeopardized in an ever more globalized world.

The 1999 World Conference on Science: Encouraging the recognition of indigenous knowledge

However, the observation that many indigenous and traditional communities have contributed with their knowledge and practices to the conservation and sustainable use of the biosphere and maintained highly complex ecosystems, the functioning of which has not yet been explained by ecological research, has for some time increasingly led to discussion on how indigenous knowledge differs from scientific findings, especially from the natural sciences.

This question played a major role at the World Conference on Science in Budapest (1999) and the discussions about it were highly emotional at times. Some representatives of the indigenous peoples feel that their identity is severely threatened and call, among other things, for their indigenous knowledge bases to be recognized as a science. Others favour a 'de-mythification programme', differentiating between the 'rational core' and the spiritual belief systems and practices associated with knowledge systems.

Traditional knowledge systems do in fact impinge upon many areas of science, such as astronomy, meteorology, geology, ecology, botany, agriculture, physiology and medicine. But there is no clear separation of knowledge and belief systems in these knowledge systems (Berkes et al, 1995; Gadgil, 199). In one region of India the indigenous population protects and honours fig trees (practice treatment) because of their knowledge (qualitative understanding of the importance of fig trees as food for birds, bats, squirrels and monkeys) and their belief that fig trees are abodes of nature spirits. By contrast, according to the example cited by Gadgil (1999), science also comes to the decisions that some fig trees should be protected (practice dealings), on the basis of quantitative findings about their importance as a keystone species. Added to this is the belief or value that the comprehensive conservation of biological diversity is a desirable objective (Table E 3.5-1).

Berkes et al (1995) cites further similarities and differences between scientific and indigenous knowledge: both systems of knowledge are philosophies or interpretation systems aiming to make the world comprehensible. Both are based on observations and conclusions derived from them. But the knowledge systems also differ in that traditional ecological knowledge (TEK)

- refers only to restricted geographical areas,
- largely relies on qualitative rather than quantitative information,
- lack of built-in drive to collect more and more facts,
- accumulates facts much more slowly,
- trusts in trial-and-error more than in systematic experimentation,
- only has limited scope to the verification of predictions,
- has little interest in developing general principles and theories.

In future, the debates about the dignity and recognition of these two knowledge systems will go even further – including in the negotiations on the CBD. In addition to the more 'academic' aspects of this discussion and the question as to how far the ecological knowledge of indigenous and traditional communities (or its rational core) is superior to the somewhat rudimentary findings of scientific ecology, as proved by the increasing interest of the pharmaceutical industry (Section D 3.3), these traditional knowledge systems have another important function.

Since TEK not only contains cores of knowledge, but also information on managing natural resources, this knowledge is most definitely of practical relevance, especially when the precautionary principle is

Table E 3.5-1
Natural resources in traditional and scientific knowledge systems.
Source: Gadgil, 1999

Knowledge system	Practice	Knowledge	Belief
Traditional	Strict protection and worship of the fig tree	Qualitative understanding of the trees' fruit as food for birds, bats, squirrels, monkeys	Fig trees are the abode of natural spirits
Scientific	Partial protection of the fig tree	Quantitative understanding leads to the concept of a key resource	Comprehensive conservation of biological diversity is desirable

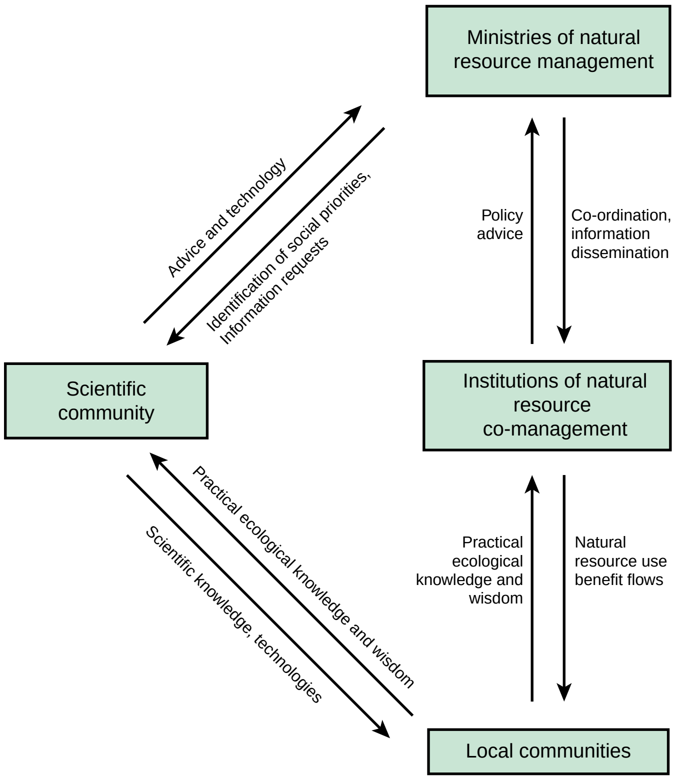


Figure E 3.5-1
Co-management system.
Source: Gadgil, 1999

prioritized over the desire for complete scientific clarification in protecting biodiversity.

Further importance is assigned to TEK where the conservation of biological diversity at regional level is concerned (Section E 3.9). From this emerges not just the opportunity, but the virtual necessity for participation of the local population. Sustainable use and adaptive management in a bioregion are only possible if all the available information about the habitat, its ecosystems and its socio-cultural structure is used. This means that the incorporation of indigenous and traditional knowledge is all but imperative, even if this knowledge is to be modified in the course of the management process or if its importance is to be played down (if other findings prove to be more important). Gadgil (1999) reported from India on an example of 'co-management' that incorporates the local community just as much as the scientific community, and where the relevant environment ministry ensures that both knowledge systems are heeded (Fig. E 3.5-1).

E 3.5.4
Conserving nature, preserving cultures – a necessary alliance

'Culture determines people's relationship with nature and their environment'. This sentence from the report by Perez de Cuéllar (1995) not only applies to indigenous communities, but also to the human race as a whole. However, it can also be seen that this 'symbiotic' link between cultural and biological diversity, as it can still be found in indigenous and traditional communities, is hardly ever encountered in a secular and increasingly technological world. The technologically shaped environment, once called 'second nature' by Gehlen (1940), the creation of which was necessary for the survival of humans, the 'deficient beings', has long been 'first nature' for many people and it has attained the character of something that is unquestioned and natural. For example, to judge from biographical accounts of appropriation processes, words for cars and machines are now learnt sooner than those for meadow, wood and water. It has been sufficiently documented that children growing up in American cities do not know the plants on which tomatoes, potatoes or coconuts grow; even 'natural products' come from the supermarket shelf. Emancipation from natural living conditions has frequently reached the point of distant alienation.

The urban culture described so pithily here is surely not best suited to take sole responsibility for the necessary protection of biological diversity. But by demonstrating the effects of out-and-out 'domination of nature' and exploitation oriented only to benefits and use, it may help people to come to the conclusion that different lifestyles are needed if this planet is to continue to function as a habitat for man. Life in a completely man-made world founded on concrete and asphalt is most definitely not sustainable because it is a world which relies on resources produced elsewhere and imported to meet its needs. The fact that modern man is forced to think about nature more than ever (Seel et al, 1993; Meinberg, 1995) is a feature of culture. Just as nature can be characterized as a construction of indigenous communities through the indissoluble relationship between empirical knowledge and spiritual belief systems, the construction of nature has also changed among industrialized peoples. Today's understanding goes beyond nature as boundless and self-regulating, the cradle of the elemental and the familiar, but also the frightening and the terrible (Section E 3.1); today the discourse is dominated by nature as under threat, in need of protection or at least 'management'. The relationship between biological diversity (and diversity in jeopardy) and cultural diversity is also reflected in those conceptualizations of nature and in discourses that are increasingly taking their place on the agenda – and not just in the context of environmental education. The call for a 'biospheric perspective' (Section E 3.1), the search for new conceptions of human nature (Meinberg, 1995) or new lifestyles (BUND and Misereor, 1997; UBA, 1997b; Enquete Commission, 1998) are examples of such efforts towards a new 'culture' that reassigns greater importance to nature. Such concepts have to enter into socialization and education processes as part of 'education for sustainable development' (BLK, 1998; Section I 2.5). Furthermore, greater efforts should be made to carry out empirical research on the issues relating to lifestyles and conceptions of human nature; to enhance the synergies, it is essential that this should be transdisciplinary.

If awareness of the interdependence of nature and culture, biodiversity and cultural diversity has largely been lost in modern industrialized societies, by contrast the example of indigenous communities has highlighted this interdependence, which is obviously not limited to these narrowly defined groups. After all, beyond these indigenous communities there are many other local communities all over the world who have developed patterns of cultural diversity in historical continuity, layer by layer as it were, under conditions of great geographical, biological, social, linguistic and behavioural variability and by means of countless adaptation processes. These patterns are known today and manifest themselves in multifaceted knowledge systems and ways of treating the natural environment but also in extremely variable ethical, philosophical, religious or mythical interpretations of the relationship between man and nature.

Cultural conservation is therefore a condition of success for environmental protection. At the same time global environmental protection is inconceivable without cultural change. A successful biosphere policy must be geared to both. It must try to strengthen the ability of society to cope with global change by preserving cultural diversity. At the same time, cultures have to face up to the necessary changes, especially with regard to non-sustainable lifestyles and patterns of consumption. Conversely, cultural diversity and, thus, the survival of many societies is at risk when the ground is pulled from under its feet through environmental destruction. These aspects are addressed in the CBD; however, they can only be implemented locally through the inclusion of the actors concerned and affected. The Council therefore calls for reinforcement of learning and educational processes to convey clearly the special features of the learners' own environment and its cultural use. Starting with the principle that biological and cultural diversity are interdependent, it can be concluded:

- Protection of nature and its biological diversity as the foundation of life is in man's interest because he is a natural and cultural being and cultural diversity builds upon biological diversity.
- The protection of cultural diversity is required because humans as a part of the biosphere must not be reduced to mere biological entities, but must be fully included as cultural beings. However, protection must not be understood as a licence to preserve all values and practices – eg if these infringe human rights.
- Furthermore, the protection of cultural diversity is a guarantor and instrument of the conservation of biological diversity, especially in the bioregions where local and indigenous communities have successfully conserved this diversity.
- Which measures must be taken to ensure the continued existence and development of these communities, taking account of their right to self-determination in the face of further globalization?
- Which specific cultivation, harvesting and hunting methods of indigenous peoples can offer models, even if not fully transferable, to stimulate 'culture-sensitive development strategies' and sustainable management practices when adapted to the contexts concerned?
- Going beyond the indigenous knowledge systems and practices – how important are traditional, mainly village-based knowledge structures, values and ways of managing natural resources for the sustainable conservation and use of biological diversity?

Clarification of the individual factors of interdependence between cultural and biological diversity is a research programme that is only known sketchily, but the progress of efforts for the worldwide conservation of biodiversity depends on its realization.

E 3.6
Introduction of alien species

The term alien organisms is used for those organisms that have been directly introduced by man or have indirectly migrated since the start of the modern era (since 1492). A distinction is made between neozoa (animals), neophytes (plants) or neomycetes (fungi) (Barthlott et al, 1999; Geiter, 1999; Kinzelbach, 1998; Kowarik, 1999; Scholler, 1999). The start of the modern era signalled a previously unseen worldwide exchange of fauna and flora elements which led to the transfer of organisms into regions well beyond the limits of their natural ranges. If organisms reproduce in the new habitats, there may be far-reaching ecological and economic consequences as well as impacts on human health (Section C 1.3.2) (Loope and Stone, 1996; WBGU, 2000a). The spread of alien organisms has accelerated rapidly in the last 20 years as a result of increasing world trade pathways and global mobility. In aquatic habitats, for example, only 1.5 per cent of the species present had been introduced before 1800, during the 19th century 4.3 per cent and from 1900 to 1939 10.0 per cent. In the following 40 years, the proportion of introductions rose to 35.5 per cent and in the period from 1980–1998 it was 19.2 per cent (FAO, 1999d). Some regions of the Earth, especially islands, have an extremely high proportion of alien species, which is often over 50 per cent (Vitousek et al, 1996).

Seen from a world perspective, the introduction of alien species is the second greatest threat to biological diversity – after the loss of habitats (Sandlund et al, 1996). If all biogeographical barriers were to be dismantled, in theory 70 per cent of all plants, 65 per cent of all mammals and almost 50 per cent of all bird species could become extinct (Brown, 1995). In the past, the 'services' provided by ecosystems, such as the maintenance of biogeochemical cycles, the self-purification of waters, local climate compensation or coastal protection have not been considered in estimates of the damage caused by alien species (Costanza et al, 1997; Box D 2.5-1). But the economic losses are already considerable. Just the direct costs for the damage to agriculture in the USA by alien weeds are estimated at US$2–3 million. Together with the losses that are incurred in animal husbandry, horticulture and forestry, there are annual costs of US$3.6–5.4 million, of which herbicides alone account for US$1.5–2.3 (OTA, 1993).

E 3.6.1
Appearance and impact of alien organisms

Mass developments of introduced species in new habitats cannot usually be predicted. Many alien species probably arrive in a range several times before they can become established there. Sometimes, alien species need decades in order to adapt to the new conditions. Only then can there be an explosive increase (Bright, 1998). Latent periods are probably widespread among plants (Crooks and Soulé, 1996; Shiva, 1996). However, the population density of alien species can fall again after a few years or decades once a new equilibrium has established itself, as was seen in Europe for the earlier introductions of the Canadian pondweed (*Elodea canadensis*), the mitten crab (*Eriocheir sinensis*) and the zebra mussel (*Dreissena polymorpha*) (Spicer and Catling, 1988; Walz, 1992). The rise in predators and self-regulating mechanisms appears to have led to a fall in the population densities of the above-mentioned species after a certain period. In the case of the zebra mussel the position of the mussels in several layers on top of each other, for example, means that the animals lower down can no longer open their shells (Walz, 1992). In recent times *Dreissena* has also migrated into the North American Great Lakes and is undergoing rapid reproduction there (Ludyanski et al, 1993). Knowledge about previous distribution histories and the autecology of the species concerned can serve as a basis for forecasts about the possible spread of alien species and its consequences. Experience from well-documented introductions in the past can be helpful here (eg Carlton, 1996; Williamson and Fitter, 1996). Especially successful, cosmopolitan species should be catalogued in a similar way to the 'Dirty Dozen' persistent organic pollutants.

Data about the causes and impact of the introduction of alien organisms are available only in exceptional cases because science has only been intensively dealing with this problem since the 1980s (eg Mooney and Drake, 1984; Drake et al, 1989; Vitousek et al, 1996). Our knowledge about the impact of introduced species has therefore been very patchy in the past and restricted to a few, well investigated case studies. The introduction of alien species can have a serious impact on the structure and function of biotic communities. There may be a redistribution of species and their population densities and this means that there may be changes in species spectrums, biomass and biogeochemical processes (Doyle, 1999).

In detail, the following effects have been identified so far:

- The introduction of an alien species often initially increases species diversity. But this is often followed by a reduction in the number of individuals within native species due to an altered predator-prey ratio, competition and introduced diseases; later there is a reduction in the total number of species. If the eliminated species occur only in the habitat concerned (endemic species), they can become extinct as biological species (Section E 2.3). In Lake Baikal with an approx 80 per cent proportion of endemic plant and animal species, the introduction of alien species may have an especially serious impact and is considered to be at least as serious a threat to this unique ecosystem as the degradation of environmental conditions through eutrophication and/or the discharge of pollutants (WBGU, 1998a). Some neophytes can be made directly responsible for the population reduction in some species: non-native organisms have been largely implicated in the disappearance of 43 plant species which have become extinct in Germany or classed as endangered (Korneck and Sukopp, 1988).

- The uninterrupted exchange of fauna and flora elements leads to a worldwide homogenization of ecosystems (Ritzer, 1995). An important factor here is overcoming previously existing barriers to spread, which used to cause genetic isolation of populations. The crossing of populations which used to be genetically isolated (introgressive hybridization) can lead to the loss of certain, genetically specified features. Hybridization with alien species can lead to the extinction of species with site-specific adaptation to certain environmental changes because of the introduction of new allele (Tautz and Schliewen, 1999). So far, the consequences that the homogenization of flora and fauna may have on the emergence of new species have hardly been studied (Vermeij, 1996).
- The invasion of alien species can influence the speed, or even the direction of succession, ie the temporal sequence of various organism groups as a consequence of changed environmental conditions. For example, this can happen as a result of changes in the chemical conditions in the soil, such as the acidification of the soil in southern Germany as a consequence of planting Douglas firs (*Pseudotsuga menziesii*) (Knörzer et al, 1995) or in Berlin/Brandenburg as a result of the spread of the equally alien false acacia (*Robinia pseudoacacia*) led to an accumulation of nitrogen in the soil (Kowarik, 1992).
- Of the interactions of alien species among each other, the focus of research interest used to be mainly on negative interactions, such as competition for resources. So far, there are only a few direct indications for the assumption that interactions between various alien organisms actually prevent further introductions (biotic resistance hypothesis). A new analysis of the literature (Simberloff and von Holle, 1999) tends rather to show that interactions between introduced organisms at least as frequently have self-reinforcing effects (facilitation). Positive interactions between introduced species can thus accelerate the negative impact on these ecosystems affected (invasional meltdown hypothesis). Synergistic effects between alien species could lead to an unexpected, sudden acceleration of further movements. In this case, the prevention of introductions should be given a higher status than previously.

The Council has already shown the negative impacts of alien organisms on human health, the economy and further, indirect influences on ecosystems (WBGU, 2000a).

More comprehensive studies according to more generic aspects would have to be carried out to draw up effective strategies to combat undesired invasions or their impacts (Vermeij, 1996). The many individual items of information about alien species should be brought together in central databases and made generally accessible in order to allow quick analysis of the problems associated with the introduction of an alien species. Coordination, standardization and simplification of the worldwide or national databases already in existence or at the planning stage could lead to more consistency and help to avoid duplication of effort. Concrete proposals already form a foundation for work with regard to the specifications for databases of this kind (Simberloff et al, 1999).

Findings from the aquatic environment should above all illustrate the mechanisms which are generally important for the problem of alien organisms (Box E 3.6-1): of the approx 3,000 recorded introductions of alien species into aquatic systems, almost half of them have already become permanently established in open nature (FAO, 1999e). The main cause of such introductions, at 38 per cent, is aquaculture. As in agriculture, species introduced into the aquatic area also account for a considerable proportion of production. Worldwide, around 10 per cent of the production generated by aquaculture is by means of introduced organisms. In Asia, where aquaculture had its origins with native organisms, the proportion is low, but in other continents it may be significant. Thus, 97 per cent of the production of prawns in Europe, 96 per cent of fish production in South America and 85 per cent in Oceania comes from breeding introduced organisms (FAO, 1999f; Section E 3.4). Worldwide, 10 per cent of all introductions in the aquatic sphere resulted from government programmes. The private sector was responsible for 6 per cent of cases. Other sources, individuals and international organizations were responsible for around 8

Box E 3.6-1

Species introductions by ships

Shipping moves species by means of the ballast water, sediment deposits in the ballast tanks and growth on the ships' hulls. Since the end of the 19th century around 170 alien species have been introduced into the North Sea and the Baltic Sea (Gollasch and Dammer, 1996).

Introduced pests (pathogens, parasites and toxic algae) reduce the yields from aquaculture and sports' fishing. Algal blooms impoverish the water quality and can have a negative effect on tourism and other forms of use for the ecosystems concerned. The introduction of growth organisms can, furthermore, lead to higher cleaning costs, eg of coolant water and harbours as well as ships.

The most important vector for the worldwide transfer of marine species is the ballast water in ships. Every year, an estimated 10 thousand million tonnes ballast water are transported; in this water 3,000–4,000 species reach a new location every day. In a first European inventory of 211 ships a total of 404 alien species were found in the study period of 1992–1995. The spectrum ranged from microscopic algae via mussels, snails and crabs to 15cm long fish in the ballast water (Gollasch et al, 1995; Lenz et al, 1999). Each individual ship transported in its ballast water, growth on the hull and the sediments in the ballast tank potentially enough organisms to establish a new species in our waters.

An extrapolation of the ballast water emptied into German ports to waters outside Europe resulted in entries of around 2 million m^3 per year. On average 1 individual per litre ballast water was found in the examinations of the ships. This results in organism introduction of several million individuals day^{-1} from ballast water alone.

In order to keep the organism content in the ballast water as low as possible chemical treatment has been proposed, such as chlorination, which is already common practice in some South American ports because of the risk of cholera. In addition to this environmentally harmful method, other methods, such as filtration or heating the ballast water, are currently being developed. Since it is assumed that deep-sea plankton cannot survive in coastal waters and organisms from coastal seas die in the deep seas, the International Maritime Organization (IMO) in London recommends complete ballast water changes be carried out at high sea in the 'Guidelines to Minimise the Introduction of Undesired Aquatic Organisms and Pathogens from Ships' Ballast Water' (IMO, 1998). If applied all over the world, this measure could lead to a considerable reduction of accidental introductions of alien species in the aquatic ecosystem. For this reason, the implementation of these guidelines should be further advanced at global level.

per cent of introductions. However, in most cases (76 per cent) a source could no longer be identified (FAO, 1999g). In the case of negative consequences, therefore, no one could be held liable for damage, even if the national legislation concerned allowed this. An analysis by the FAO revealed that the impact from the introduction of alien species could not be assessed in 80 per cent of cases, both with respect to aquatic ecosystems and socio-economic aspects. However, the classification of the cases that can be evaluated showed that 407 introductions were assessed positively with regard to their socio-economic effects (eg fish yields), but only 94 as clearly negative (FAO, 1999h). This ratio was reversed with regard to the impact on the natural environment. 213 of the cases had a negative ecological impact. In 129 cases the impact on the environment was evaluated positively (FAO, 1999). These figures illustrate the dilemma between potentially positive economic aspects and frequently negative consequences for the environment (Section E 2.3).

E 3.6.2 Case studies

Germany

In Germany the number of neozoa is estimated at 740 species, 190 of which are considered to be permanently established. The clear taxonomic focus is on fish, molluscs and crustaceans in limnic ecosystems as well as on mammals and birds. Furthermore, there is evidence that 35 fungus species have been introduced. However, making an inventory of the animals and fungi that have been introduced lags far behind the inventory for plants. At least 417 alien plant species have been permanently introduced and, at around 12 per cent, represent a significant proportion of the total number of species (WBGU, 2000a). Many neophytes characterize disturbed sites, such as urban and industrial land as well as fields and meadows created by man. Currently, 20–30 neophytes are classed as problematic and are being dealt with (eg, giant hogweed, Canadian goldenrod). Nevertheless, the question must be asked as to how far general prevention or control is justified in each case (Kowarik, 1999). There is a need for research here in order to monitor the harmful effects of neophytes on the biotic communities where they settle. The monitoring must comprise the benefit as well as the implementation and environmental compatibility of any measures that may have been introduced and it must be the basis for the management regime required.

Islands with large numbers of endemic species

The biotic communities on islands with large numbers of endemic species react especially sensitively to the introduction of alien species. Since 1840 over 80 mammal species have been introduced to New Zealand. They include opossums, cats, ermine, rabbits and red deer. The 2,700 native plant species taxonomically recorded so far represent only a comparatively small proportion of the flora alongside the 20,000 alien species. 200 of the introduced species cause serious ecological damage (Bosselmann, 1999).

On Hawaii the introduction of insects, snakes, weeds and pest, dubbed the 'silent invasion', is considered to be the greatest economic and ecological threat (HEAR, 1998). The damage caused by diseases introduced with these organisms is estimated at many millions of US dollars. The extinction of endemic species, the destruction of native forests and the spread of diseases are cited as the most serious consequences for the ecosystems. Trade and tourism have greatly speeded up the introduction of alien organisms. In spite of considerable efforts, the relevant authorities expect the situation to become even worse because of the loopholes in the current prevention system and the lack of public awareness of the problem.

E 3.6.3
International agreements

At the international level today there are 18 agreements that deal with the problem of biological invasions (Table E 3.6-1). However, the regulations have extremely varied consequences. The Protocol to the Antarctic Treaty on Environmental Protection (Madrid Protocol) contains an especially strict, directly applicable provision – it categorically excludes all alien species with the exception of a very few organisms, which are listed in an annex (Bright, 1998). Above all, the following agreements are of global significance to the issue of the introduction of alien species:

1. *International Plant Protection Convention*, IPPC: in 1951 this convention was agreed on the protection of plants and plant products against the spread and introduction of pests that result from international trade and thus lead to considerable losses of income. The Parties agreed on regular inspections of the most important export commodities and on measures to control and eradicate the causes of new diseases. Furthermore, collateral agreements on certain areas, pests or forms of transport were made. In 1997 an attempted amendment tried to harmonize the IPPC with the provisions of the World Trade Organization's 1994 *Agreement on the Application of Sanitary and Phytosanitary Standards* (SPS): measures intended to counteract a disease must not restrict the flow of goods. On the other hand, the SPS makes provision for measures to restrict trade under certain conditions if life or human, animal or plant health could be affected.

Table E 3.6-1
Multilateral agreements which refer to alien species, ordered according to the year of signing. Agreements on genetically modified organisms and human diseases are not considered. Agreements which are not in force yet are set into square brackets.
Source: Glowka and de Klemm, 1996; Bright, 1998

Year	Agreement
1951	IPPC – International Plant Protection Convention
1958	Convention Concerning Fishing in the Waters of the Danube
1964	Agreed Measures for the Conservation of Antarctic Fauna and Flora
1968	African Convention on the Conservation of Nature and Natural Resources
1976	Convention on the Conservation of Nature in the South Pacific
1979	Convention on the Conservation of European Wildlife and Natural Habitats
1979	CMS – Convention on the Conservation of Migratory Species of Wild Animals
1980	Convention on the Conservation of Antarctic Marine Living Resources
1982	UNCLOS – United Nations Convention on the Law of the Sea
1982	Benelux Convention on Nature Conservation and Landscape Protection
1985	[ASEAN – Agreement on the Conservation of Nature and Natural Resources]
1991	[Protocol of the Antarctic Treaty on Environmental Protection]
1992	CBD – Convention on Biological Diversity
1992	[Convention for the Conservation of the Biodiversity and the Protection of Wilderness Areas in Central America]
1994	[Agreement on the Preparation of a Tripartite Environmental Programme for Lake Victoria]
1994	Protocol for the Implementation of the Alpine Convention in the Field of Nature Protection and Landscape
1994	[North American Agreement on Environmental Cooperation]
1995	[Agreement on the Conservation of African-Eurasian Migratory Waterbirds]

2. *Convention on the Conservation of European Wildlife and Natural Habitats*: the Convention signed in Bern in 1979, which despite its name is not restricted to Europe but also open to other countries, is for the worldwide protection of wild plants and animals and their habitats. To this end, every Party is obliged (Article 11 II lit. a) 'to encourage the reintroduction of native species of wild flora and fauna when this would contribute to the conservation of an endangered species, provided that a study is first made in the light of the experiences of other Parties to the Convention, to establish that such reintroduction would be effective and acceptable'.
3. *United Nations Convention on the Law of the Sea*, UNCLOS: this convention was agreed in 1982; it requires all Parties to take all necessary measures to prevent, reduce and control the intentional and accidental introduction of alien or new species (Article 196 I). This clause includes genetically modified organisms. There is also a call for the development of methods to prevent migrations and to research control methods. This Convention provides the basis under international law to effectively counteract marine invasions, eg for regulations concerning ballast water (IMO guideline, cf Box E 3.6-1) or aquaculture (OTA, 1993).
4. *Convention on Biological Diversity*, CBD: Within the CBD there are provisions for effectively combating the introduction of alien species (Article 8 lit. h; Section I 4). Here, the Parties undertake 'as far as possible and as appropriate, to prevent the introduction of those alien species which threaten ecosystems, habitats or species and to control or eradicate these species'. The Parties are developing strategies for this. Some states are revising their quarantine provisions and practices and have introduced controls that take account both of the deliberate and accidental introduction of alien species. One area of focus is on the public relations work relating to this issue.

Within Europe, the following regulations are significant: the Convention on the Protection of the Alps, and within the EU the Habitats Directive and the Directive on the Conservation of Wild Birds.

At the political level the ratification of the abovementioned agreements in 1996 was followed by international conferences, such as the Norway/UN Conference on Alien Species in Trondheim and the OECD Workshop on the Ecology of Introduced, Exotic Wildlife: Fundamental and Economic Aspects in Ammarnäs/Sweden. Since 1996 the Scientific Committee on Problems of the Environment (SCOPE) has been working with UNEP, IUCN, UNESCO and the International Institute of Biological Control within the context of the Global Invasive Species Program (GISP) on a global strategy for dealing with alien species. In addition to a plan of action, this programme also contains clear, fundamental declarations of intent that underline the urgency for action (Mooney, 1996). As a supplement, further guidelines have been drawn up by the IUCN Invasive Species Group (ISSG) (Clout and Lowe, 1996). Furthermore, the COP of the CBD commissioned its Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA) to elaborate recommendations for action on preventing the impact of alien species. An item on the agenda of the 4th meeting of the SBSTTA (SBSTTA-IV) in June 1999 determined the most important measures for geographically and evolutionary isolated ecosystems and, after evaluation by the GISP, also made proposals for the further development of this programme (SBSTTA-IV, 1999). In future, the Secretariat of the CBD will cooperate on these items with the abovementioned organizations, which have developed recommendations for dealings with alien species. Important elements of the recommendations are dealt with in Section E 3.6.5.

E 3.6.4
Examples of national legislation

In *Germany* there is a central provision on the treatment of alien species in the Federal Nature Conservation Act (Article 20 d II). But this regulation is not definitive. On the one hand, this is due to the division of legislative action between the Federal Government and the federal states; on the other hand regulations can be found within specific legal provision (genetic engineering, animal protection, fisheries on the open seas and coastal fisheries, navigation) (Ginzky, 1998). Above and beyond this, there are insufficient regulations in the following areas (Fisahn, 1999):

- Although the deliberate and intentional export of alien organisms is prohibited or subject to licensing, there are no regulations for accidental introduction.
- There are exceptions to the limits on exporting alien organisms for agriculture and forestry.
- In German legislation to date the regulations apply almost exclusively to animals and plants. However, microorganisms are not expressly considered.

In *New Zealand* the environment, health and safety are defined as assets to be protected under the Biosecurity Act of 1993 and the Hazardous Substances and New Organisms Act of 1996. The import, breeding or release of alien organisms are prohibited and are subject to licensing. The term 'new organisms' covers animals, plants and microorganisms as well as subspecies and genetically modified organisms. The strength of the Act lies in the control of the deliberate and accidental introduction of new organisms as well as in established instruments for the eradication and control of undesirable organisms. In spite of the exemplary nature of the existing Act, its implementation is made difficult through the division of administrative responsibilities amongst a large number of ministries and the limited expertise of individual enforcement bodies (Bosselmann, 1999; Fisahn and Winter, 1999).

In the *United Kingdom*, after the Convention on the Conservation of European Wildlife and Natural Habitats had been signed in 1979 it was implemented as part of national law in 1981, in the form of the Wildlife and Countryside Act. Although this legislation is regarded as far-reaching in the European and international sphere, in practice the Act is considered to have little effect because there is no independent body in the licensing procedure, the public still has an underdeveloped awareness of the problems, there are no fixed penalties and the source of an introduction is identified only in rare cases (Purdy and Macrory, 1998).

E 3.6.5
Conclusions for required research and action

- *Create scientific databases on introductions*. A generally accessible database on alien species must be created through coordination with the GISP, which will centrally gather all information on this issue.
- *Develop methods for the eradication of undesired introductions*. The prerequisites and opportunities for the environmentally sound eradication of undesired alien species must be examined. These species may include infectious diseases as well as plants and animals with sufficiently long generation cycles.
- *Improve prognostics on the possible effects of introductions*. Future research will have to show the extent to which the successful establishment and frequency of alien species in the country of origin and other indicators, which have yet to be identified, are generally sustainable. In the process, the interactions between introduced species must also be examined. Efforts will have to be taken to use new techniques (eg remote sensing and GIS) to discover alien species.
- *Define relevant terms and incorporate into national legislation*. Clear definition and standardization of the terms in connection with the introduction of species at global level within the context of the CBD by the COP (with the help, for example, of GISP, FAO, IMO, WHO) with the aim of a uniform use of these definitions in national laws. Harmonization of the provisions in connection with the introduction of natural species alien to the territory and genetically modified species, since numerous issues in the two cases are similar.
- *Improve the scope for checking regulations on intentional release*. In many countries there is already an obligation to obtain approval for the introduction of alien organisms; deficits prevail in many countries with regard to the scope for checking existing regulations and the possible sanctions for violations. The precautionary principle should be the basis on which the release of alien species is treated. Therefore, prior to any intentional release, environmental impact assessments must be carried out, as called for in SBSTTA-IV. These provisions must also apply to releases in the context of agriculture and forestry.
- *Prevention and management of accidental introductions*. Those responsible for the accidental introduction of alien species must be identified. On the one hand, the people responsible for such 'accidents' should be made liable and on the other hand, international and national authorities must be selected to take responsibility for prevention and for management in emergencies. Accidental introduction should be prevented by border and seed controls, logistical measures (governed by the IPPC) such as shorter waiting times in container transport (Simberloff et al, 1999), but also awareness-raising in the population and important target groups (tourists, hunters, fishermen, aquarists, foresters, farmers, garden owners, etc). An early warning system should be developed for emergencies. Already today, analyses of introductions in various areas can indicate similarities and differences (eg Williamson and Fitter, 1996; Carlton, 1996) and can be employed for the purpose of early warning and prevention.
- *Introduction through shipping: continue to apply IMO directive*. The implementation of the IMO Guidelines 'on the minimization of the introduction of undesired aquatic organisms and pathogens in ships' ballast water' should be further promoted at global level.

E 3.7
Tourism as an instrument for the conservation and sustainable use of the biosphere

E 3.7.1
Sustainable tourism to protect the biosphere – defining terms

In the Council's opinion, the objective of sustainability is a challenge for all types of tourism and should not be limited to niche markets such as eco-tourism. That is why strategies to protect the biosphere for all forms of tourism are at the heart of this Section. Here, sustainable tourism is understood as a higher-level concept that concerns itself with the question as to how the negative ecological impacts of tourism (eg mass tourism and nature tourism) can be reduced to an acceptable level. This concept is guided by the principles of the Rio de Janeiro Declaration on Environment and Development and by the recommendations of AGENDA 21. The Council would put forward a tentative definition of sustainable tourism as a form of tourism that does not go beyond fundamental ecological, social, cultural and economic guard rails, ie is geared towards conserving resources and increasing local employment, is culturally adapted, is characterized by locally effective welfare effects and helps to balance out economic disparities.

There is no internationally uniform concept of 'sustainable tourism'. For example, the Council of Europe has defined 'sustainable tourism' as a form of tourist activity or development

- in which the environment is respected,
- in which the long-term conservation of natural and cultural resources is safeguarded, and
- which is socially equitable and economically viable (Recommendation R(95)10).

Nature tourism is another term that is often used. This refers to a form of leisure activity that concentrates specifically on semi-natural areas or protected areas, such as observing nature or animals (safari), fishing and hunting or scientific tourism. Nature tourism plays only a minor role, as a sub-section of general tourism, in the degradation of the biosphere. A special form of nature tourism is eco-tourism: eco-tourism refers to 'forms of nature tourism that aim at minimizing negative impacts on the environment and socio-cultural changes, contribute to financing protected areas and create sources of income for the local population' (BMZ, 1995b). From the Council's point of view the starting point for developing a global tourism concept, which is only outlined here and which concentrates on protecting the biosphere, could be the allocation of regionally varied intensities of use for tourism. In this context a distinction would have to be made between (cf Sections E 3.3.1 and E 3.9):

- Landscape type *conservation before use*: no interventions or changes to a semi-natural ecosystem are allowed in this zone.
- Landscape type *conservation despite use*: mass tourism is allowed, or even desirable, in this zone. Accepting congested but bounded (coastal) tourist landscapes prevents the much more harmful 'dispersal' over large areas. Accommodation in central hotel complexes, concentration in certain regions (eg islands, valleys) makes more ecological sense that the individual dispersal of floods of tourists all over the natural landscape. The aim is to make this form of tourism as sustainable as possible.
- Landscape type *conservation through use*: regional-specific concepts of protection and buffer zone management have to be developed for this zone. Tourism in these areas remains limited in terms of numbers and, at the same time, serves the protection and conservation of the environment (Section E 3.3.3). Many small island states practise controlled tourism: the spread of tourist infrastructure is subject to stringent controls in the Seychelles. Bermuda has limited the number of daily visitors from cruise ships. In Vanuatu, tourism usage has been concentrated on three islands. Other countries demand a tourism tax or a visitor's permit prior to admission.

E 3.7.2
Current trends in global tourism

Tourism is one of the fastest growing economic activities in the world. In 1997 it accounted for around one-third of all worldwide services. According to the World Tourism Organization (WTO), world tourism traffic is growing at around 4 per cent every year and doubles around every twenty years. We are in the age of mass tourism: in 1998 there were over 625 million international tourists.

In addition to cultural and historical sights, nature is at the heart of tourism in an increasingly urbanized world (the Mallorca club scene is proof that there are also other objectives on holiday). Since the main aim of tourism is recreation in most cases, intact and attractive natural surroundings are fundamental. Accordingly, tourism today concentrates on

- coastal areas and islands,
- mountainous regions,
- 'natural areas' such as forests, wetlands, inland waters, steppes and deserts as well as Arctic and polar regions.

Box E 3.7-1

Breeding birds under stress

In birds, just like people, permanent stress results in a higher susceptibility to illnesses and parasites, low success in breeding and a lower life expectancy. In the Wadden Sea the birds are not only disturbed by people, but dogs or kites flapping in the sky are also an important cause of disruption. It is often difficult to assess the consequences of disruptions. Even animals of the same species react to walkers, for example, very differently – not even an individual animal always behaves in the same way.

An important measurement factor for the level of excitement of the animals is the pulse rate. The pulse rate of breeding oystercatchers increases when people, cars, wild animals or dogs approach them. Natural disruptions by birds of prey or grey heron put the oystercatchers on maximum alert. Oystercatchers are also capable of learning: walkers along the same paths trigger only a little excitement. But if they walk at the same distance but alongside the path, an oystercatcher feels directly threatened. It can no longer 'predict' the direction in which the walker will continue his route. Passers-through who stay only a short while at one place, on the contrary, are much more susceptible to disruption because they cannot benefit from such a 'habituation effect'. This means that some breeding birds are capable of adapting to disruptions, others not. This means that it is very hard to specify generally valid distances for disruptions. In many cases it is not enough to require walkers to stick to certain paths. Because of the special susceptibility of passers-through to disruption it is therefore necessary for there to be a seasonal route prohibition in the relevant breeding areas of the Wadden Sea (Landesamt für den Nationalpark Schleswig-Holsteinisches Wattenmeer, 1994).

The majority of tourist flows move within the industrialized countries. Over 70 per cent of international travel takes place in Europe (59 per cent) and North America (14 per cent). However, the number of long-distance trips to developing countries is rising. The greatest increases were in eastern Asia and the Pacific region. In 1975 the proportion of international travel in this region was 3.9 per cent, in 1997 14.7 per cent (measured in numbers of arrivals). The current proportion of the international tourist stream amounts to 3.8 per cent in Africa, 2.4 per cent in the Middle East and 0.8 per cent in southern Asia (World Tourism Organization, 1997). Without South America, for which there are no separate figures, the developing countries' share of international tourism is 21.6 per cent. Overall, we must assume that the developing countries have a 25–30 per cent share of international tourism today.

Damage to the biosphere and socio-economic problems

The biosphere is damaged by tourism in many ways. The degree of impairment not only depends on the intensity of the intervention, but also on the sensitivity of the site and the existing pollution. In the process the biosphere is impaired directly, by the loss of habitat for rare plants and animals to make way for tourism, and indirectly as a result of damage to other environmental media, such as the climate, water, soil or the ozone layer, caused by tourism.

Tourism can speed up the loss of biological diversity; it can contribute to soil degradation and soil sealing and exacerbate the problems of freshwater supply (lowering of the groundwater level and saltwater intrusion in coastal areas). Furthermore, there may be disposal problems for waste and sewage. A key driving force of this development is the land required for tourist infrastructure, caused by hotel and holiday complexes, golf courses, sports facilities and transport connections (airports, roads, cable cars, car parks, etc). In particular, semi-natural activities such as trekking, skiing, diving, safaris and even hiking affect animals and plants. If an eagle's eyrie is disturbed by just one person this could be enough to endanger or expel this animal (Box E 3.7-1). Zones with seasonal access bans for visitors have therefore been designated in European and North American national parks. Added to this are the environmental problems caused by rising volumes of travel worldwide. The number of holiday flights is rising; they already account for 40 per cent of flight volumes (Stock, 1998).

The socio-economic problems which can be caused or exacerbated by tourism are many and varied. Typical examples are conflicts about the use of scarce resources (water, land), insufficient resulting local income, displacement of the local population through building projects, displacement of traditional forms of income, monofunctional direction of the regional economy towards tourism with susceptibility to crises and cultural conflicts.

This phenomenon that the Council calls the *Mass Tourism Syndrome* (WBGU, 1997) has its origins in the rising increase in global tourism over the last few decades and has been a major contributory factor to environmental degradation and social conflicts in the regions concerned.

Tourism as development potential

Tourism can also 'place a value' on the biosphere and – if it is managed according to sustainable principles – protect it. Income from international tourism rose twenty-fold to US$445 between 1971 and 1998. After the USA, Italy, France, Spain and the United Kingdom, China occupies place 6 on the international scale. According to information from the World

Travel and Tourism Council tourism accounts for over 10 per cent of global GNP. At over US$650 thousand million, it is the most important source of tax revenue. That is why many developing countries are counting on tourism as the motor of economic development. Tourism is frequently the most important source of foreign currency and thus, alongside the exports of raw materials or agricultural products, it contributes to paying off debts. Tourism has many connections to other branches of the economy and can have an effect on incomes and employment. It can only be 'automated' to a limited extent due to its service orientation and is therefore one of the most labour intensive branches of modern industry. Throughout the world 255 million people are employed in tourism. However, in many cases only a small proportion of the profits earned remain in the country because the majority of the tourism industry is based in western industrialized countries. This means that the local welfare effects remain limited. Furthermore, tourism is heavily dependent on the economic fluctuations in the home countries of the tourists, the political situation and the security situation in the destination countries as well as weather extremes. Moreover, the holiday regions are increasingly interchangeable, meaning that demand for a holiday destination can cave in from one day to the next.

E 3.7.3
Political initiatives to promote sustainable tourism

At the 1992 UN Conference on Environment and Development (UNCED), the subject of sustainable tourism played only a marginal role, with the consequence that this aspect is only mentioned in passing in Agenda 21. Nevertheless, in recent years a number of political initiatives to promote sustainable tourism have been introduced. An overview of recent developments makes it clear that the subject has now entered the international debate. In particular, discussions are being held within the context of the Convention on Biological Diversity on the establishment of global tourism guidelines (Section 1.3).

Declarations, codes of conduct and action programmes

In 1995 the International Conference on Environmentally Sound Tourism was held in Lanzarote – it was organized by UNEP, UNESCO, the Spanish Government and the World Tourism Organization (WTO). In the Charter on Sustainable Tourism adopted there, 18 general principles are listed, including the multi-dimensionality of the sustainability principle (ecological, social, economic, cultural), the preservation of cultural heritage, the participation of the actors concerned, special consideration of local economic cycles, an equitable sharing of benefits, the development of alternative forms of tourism, possibly by internalizing the environmental costs and the development of codes of conduct. In the same year, the United Nations Environment Programme (UNEP) produced a worldwide code of conduct for sustainable tourism for the first time.

Two years later an international conference on the subject of 'Biodiversity and Tourism' was held in Berlin on a German initiative, in which 24 ministers (including ministers from developing countries with especially high levels of tourism) participated. The 'Berlin Declaration' adopted there starts out from the premise that the essential goal of global environment and development policy cannot be achieved without the sustainable development of tourism (Steck et al, 1998). In its content, the 'Berlin Declaration' focuses on five main issues: 1. Sustainable tourism as an instrument for the conservation and sustainable use of biodiversity; 2. The need for controlled tourism development; 3. Special consideration of protected and buffer zones; 4. The role of the private sector and voluntary commitments; 5. The importance of local communities. Generally, the 'Berlin Declaration' calls for gradated and regionally adapted concepts of use. It is therefore emphasized that nature and biodiversity represent a key resource base for tourism that must not be overexploited. In areas where there is already strong pressure on nature, an additional load should be limited and, where necessary, avoided. In areas where the carrying capacity is exceeded by tourism, it should be brought back in a sustainable direction. Tourism in protected areas should be regulated so that protection objectives can be adhered to.

With the help of the Berlin Declaration, which is not binding under international law and which mainly serves as a frame of reference for other tourism initiatives, ongoing processes within the Convention on Biological Diversity (adoption of tourism guidelines) and the Commission on Sustainable Development (CSD) should be advanced. At around the same time the CSD was commissioned by the Special Session of the UN General Assembly to submit a measure-oriented international programme of work on the subject of 'sustainable tourism' in order to minimize the negative impacts of tourism and to promote its positive contribution to sustainable development. At the 7th CSD session in 1999, at which the EU took on a pioneering role, a programme of work of this kind was adopted, which is to be evaluated in 2002. Among other things, the governments were called upon to promote small and medium-sized tourism enterprises, taking into account their effect on employment, to exploit the full potentials of tourism to combat poverty and, within the framework of the CBD, to develop guidelines for sustainable tourism for especially important vulnerable ecosystems. However, no agreement could be reached during the discussions on a definition of sustainable tourism and eco-tourism.

The private sector has also now become involved in sustainable tourism. The 'Green Globe' initiative of the World Travel and Tourism Council (WTTC), which came into existence in 1994, is an initiative of tourism companies who have signed up to the sustainability principle. Voluntary undertakings are to be used to adhere to fundamental standards for the protection of the natural environment. A 'Green Globe' logo signals to the consumer that a tour operator has undertaken to adhere to these environmental standards (WTTC, 1995). There is an annual check to ensure that these 'Green Globe' guidelines are still being adhered to. The 'Green Globe' Prize is awarded to outstanding positive examples.

The United Nations is also active in the tourism sector. The World Tourism Organization, a subsidiary organization of the UN Development Programme (UNDP), promotes tourism projects worldwide. Among other things, it cooperated in the development of a tourism master plan for Ghana (1996) and an action plan for sustainable tourism in Uzbekistan (1997). Some examples of short-term projects were pilot projects on eco-tourism in Congo, hotel classification in Ecuador, the development of new tourism legislation in Nicaragua, reservation management in the Maldives, the protection of historical sites in the Philippines or for the marketing of reserves in China. In addition, the World Tourism Organization has developed a series of manuals for the tourism industry and tourism planners, such as:

– Sustainable Tourism – Manual for Planners,
– What Tourism Managers Have to Know: Indicators of Sustainable Tourism,
– Incentives for Better Coastal Zone Management: The Example of the 'Blue Flag',
– Agenda 21 for the Travel and Tourism Industry,
– Bilateral and Multilateral Sources for Financing Tourist Development,
– Guidelines for the Development of National Parks.

Above and beyond these concrete implementation activities, the World Tourism Organization also documents all developments in worldwide tourism through statistical analyses.

Finally, the European Union is also involved in the promotion of tourism. The EU Commission has its own tourism department. Since 1990 around ECU 18 million have been spent in the EU tourism programme, mainly in ACP states (Steck et al, 1998). The much-criticized programme (ineffectiveness and low significance of environmental protection) is currently undergoing restructuring in order to bring about greater emphasis on sustainability aspects.

Conventions

Under applicable international law, sustainable tourism has not been specifically and comprehensively regulated. Only in a few cases are there indirect and regionally limited agreements (BfN, 1997b). One example of such a regionally limited regulation is the 'Convention on the Protection of the Alps' (hereafter referred to as the 'Alpine Convention') that the Alpine states concluded to protect the Alpine environments and that entered into force in 1995. There is a Tourism Protocol among the seven protocols that have since been negotiated. The aim of the protocol is to contribute to the sustainable development of the Alpine areas by means of environmentally sound tourism. This protocol is remarkable because it is the first instrument for sustainable tourism that is binding under international law and that identifies the possible deficits in regulation, even if it does refer only to the Alps (BfN, 1997b). However, to date there is no example to show that regulations of this kind can be used to prevent the non-sustainable spread of the tourism industry (Box E 3.7-2). On the contrary, after a temporary 'pause' in the 1980s, where there was a wave of protected area designations, since the early 1990s building activity and land conversion in the Alps has been rising again. For example, some municipalities increased their bed capacities ten-fold for the 1992 Albertville Winter Olympics. Over all, the number of French ski resorts rose from 120 in the late 1970s to around 280 today.

In 1998 the expansion ordinance to the Environmental Audit Act came into force in Germany. This means that the environmental audit system is open to many service providers. Tour operators, travel agencies, the hotel trade and municipalities reliant on tourism can now have their environmental commitment certified and be awarded the coveted EC Environmental Management Emblem. Now that some environmental verifiers have already received their accreditation for the new sectors, this process can now commence in earnest for tourism destinations, among other groups. However, the scope of local authority public administration does not cover the entire area of the municipality, but rather individual properties, in line with the definition of 'site' in the EC EMAS Regulation.

A general international law instrument for sustainable tourism should be launched within the context of the Convention on Biological Diversity (CBD). However, the Parties at the COP-4 of the

Box E 3.7-2

Obergurgl: Why one of the world's first ecosystem management projects failed

One of the first projects within the context of the Austrian MAB programme (Section I 3.3.2) was the 'Obergurgl project' in the upper Ötz Valley, which started during the years of the International Biological Programme and was officially called into being as a MAB project in 1971 (Price, 1995). This project had the objective of researching, in an integrated and interdisciplinary approach, the ecological and socio-economic consequences of the change of a previously agricultural alpine village into a tourism centre and to shape a sustainable future for the region together with the population (Moser and Moser, 1986). In particular, the impact of tourism on the vegetation, soils and pasturage was to be examined. Another central issue was the perception of 'environmental quality' by the locals and tourists. As a priority objective, the land use by tourism was to be designed in such a way that traditional land use forms and biological diversity were conserved while a sustainable economic upturn was supported. The analysis showed two economic alternatives for this region: mass tourism with high turnover, large-scale job creation, but major risks for the environment (high profit with foreseeable negative consequences for the environment) or exclusive, expensive individual tourism on the basis of division of labour and income between farmers and hoteliers with foreseeable environmental sustainability. Controlled by a comprehensive socio-economic model, the compensation payments between the hotel owners and the farmers, who maintained the conventional alpine pasture landscape, were to be regulated, for example. Even details like the waiting times at ski lifts, which on the one hand were to deal with the tourists quickly and, on the other hand, offer the opportunity for communications between the people waiting, were taken into account in the model.

The project started with euphoria and a division of roles and income among the locals that was planned down to the very last detail. The hotel owners saw rising incomes, the farmers a sustainable support for their otherwise not very profitable activity. However, in spite of the euphoric start, the project was prematurely abandoned in 1979. Superficially this was because of the withdrawal of funding from the Austrian MAB Committee. But the reason was internal disagreements between hoteliers, farmers and environmentalists. This was about the avalanche protection on the eastern slope at the southern edge of the village, where the owners of large hotels planned extensions that would otherwise have been at risk from avalanches. But the avalanche protection was just an excuse to build a road on the alpine pastureland region above the slope at risk of avalanche and to build a lift system there in a region that was reserved for the protection of the native flora and fauna in the land use model. In addition, there were arguments between the hotel owners and the farmers concerning appropriate compensation payments to the farmers who were supposed to design the alpine landscape for exclusive tourism. The hoteliers wanted ever bigger hotels but were ever less willing to honour the services of the farmers and to take the environment into account. The decision to secure the slope at the upper edge of the village against avalanches, to build the road on the upper alpine pasture and to build another ski lift in the nature reserve led to removal of the MAB status. The initiator of the MAB project emigrated to Canada (due to bitterness about the failure of 'his' project), accepted a chair at the University of Alberta in Edmonton and today, as an emeritus, he runs a farm in the Canadian Rockies.

In spite of the obvious failure of a plan originally started with great commitment and with the consensus of all the groups involved, the Obergurgl project provided a number of important results: it was a pioneering achievement to formulate an integrated and comprehensive ecological and socio-economic model. This was only possible with close contact between scientists, locals and decision-makers (Prince, 1995). Many of the results laid down in the comprehensive final report (Patzelt, 1987) later found their way into the concepts of the Swiss and German MAB programmes. But the most important experience remains the fact that ultimately the efforts by individuals to make a profit can, after all, ruin sustainable planning if internal regulation is disenfranchised because the avalanche protection was authorized and financed by external sources.

CBD in 1998 could not agree to enter into an international exchange of information and experience about issues relating to tourism and biodiversity (Steck et al, 1998). Nevertheless, the subject of sustainable tourism remains on the agenda in international environmental and development policy.

The aim is for a legally binding regulation on the basis of existing 'soft' obligations, such as the UNEP code of conduct for sustainable tourism and the adoption of a measure-oriented international programme of action within the context of the 7th Session of the UN Commission on Sustainable Development (CSD-7) in 1999. Additional regulations within the context of existing agreements are conceivable for this. The subject of 'Sustainable Tourism and Biodiversity' is to be dealt with at the 5th COP of the CBD in the year 2000. The aim is for a mandate to draw up tourism guidelines. In the long term, these guidelines should allow the negotiation of an additional agreement (protocol) to the CBD. The Federal Agency for Nature Conservation has already submitted a draft for such a 'Tourism Protocol' (BfN, 1997b).

E 3.7.4 Recommendations

Guidelines for sustainable tourism: examine options for over-arching regulation

The initiative for a supplemental arrangement to anchor tourism guidelines within the CBD is, in the Council's view, a step in the right direction since a 'Tourism Protocol' does not currently seem internationally enforceable. The directive approach, more flexible as a result of its non-binding nature, is more suited to activating the requisite incentive systems for sustainable tourism than a protocol would be, since for the actors there is more scope and room for dynamic adaptation to current developments. Having said that, this process is too focused on biological diversity although the Framework Convention on Climate Change (foreseeable increase in air traffic) and the Convention to Combat Desertification (concentration of tourism in arid and semi-arid areas) are both affected. However it does not seem practicable to thrash out guidelines or protocols for all of the 'Rio Conventions'. Therefore, the Council recommends examining whether the process launched under the auspices of the CBD could constitute an element in a future over-arching international regulation on sustainable tourism.

Eco-tourism and development cooperation

The Council welcomes the fact that German development cooperation has once again taken the first steps towards promoting sustainable tourism, after it had largely withdrawn from this area in the 1980s. Tourism is not a focus of work in development cooperation. The Council believes that within the context of development cooperation the available control scope should be used to steer the growing global tourism in a sustainable direction to protect the biosphere. Action areas within the context of development cooperation include the promotion of favourable framework conditions within the context of policy advice, management of protected areas and buffer zones, rural regional development, basic and further training, private sector cooperation and assistance with financing.

Above all, development cooperation concentrates on nature tourism because the conflicts between the protection of the biosphere and the daily survival of people are most marked in the protected and buffer zones. The aim is to make nature tourism in developing countries sustainable, ie gear it towards the concept of eco-tourism. Eco-tourism is an important instrument for nature conservation. The Working Group on eco-tourism has put forward a number of funding criteria here. According to these, eco-tourism projects within the context of development cooperation should be promoted only if the living conditions of the local population are improved, innovation potentials arise that can be used to solve regional or sectoral problems, distribution mechanisms are in place or can be developed that secure and safeguard as high a share of revenue as possible for the local population, tourism development is carried out by 'responsible' operators and the environmental and social compatibility of tourism can be verified (BMZ, 1995b).

In development cooperation more commitment is desirable in the promotion of eco-tourism projects. The Council feels that tourism promotion should be used as a development opportunity and a way of protecting the biosphere. Bilateral and multilateral donor organizations (eg the World Bank, IMF) should also be committed to the principles of sustainable tourism. Governments should be supported in drawing up master plans for the tourism sector to provide strategic orientation for the actors. In this context, the active involvement of the local population is a major prerequisite for success.

Use institutional diversity

It is far from easy to restrict, much less to ration, mass tourism. Instead, ways to promote sustainable tourism have to be developed, ie mass tourism has to be steered onto sustainable paths in order to protect the biosphere or it has to be reduced to a supportable level. Added to this is the fact that tourism is a sector of the economy which is particularly at the mercy of the rules of a globalized and increasingly dynamic market – with corresponding consequences for the instruments to be used. The starting point for the development of management options for tourism compatible with the biosphere should be orientation towards the subsidiarity principle.

The current European Union revision of the EU Commission's tourism programme to favour the greater integration of aspects of sustainability is to be welcomed. Since Europe is one of the most visited regions, the need for action is especially great here. A first step in the right direction is the 'Blue Flag' campaign by the Foundation for Environmental Education, which denotes clean beaches in Europe and is now to be spread all over the world with the support of UNEP and the World Tourism Organization. However, campaigns of this kind should primarily aim at the prevention of beach pollution rather than the removal of waste with tractors and rakes, which destroys beach life in the process. However, as yet there is no evidence to confirm the environmental effectiveness of the Blue Flag.

Private initiatives, such as the 'Green Globe Initiative' of the World Tourism and Travel Council, are also essential for the development of sustainable tourism. For this reason, the Council recommends that the Federal Government support the noticeable trend towards voluntary commitments among tourism companies in the form of product labelling schemes or seals of quality. This also includes help in the introduction of environmental management systems, such as life cycle assessments and staff training. In this context, the 'Environment Declaration' issued in 1997 by the central organizations and associations within German tourism is an important document:

support for the tourism industry in the drawing up of a uniform environmental quality seal in Germany will be the next focus of work.

INDICATORS: IMPROVE COMPARABILITY

As yet there are no globally uniform definitions on data collection and observation of developments in tourism. In order to be able to record and compare this all over the world, the relevant stipulations issued by the UN Statistics Commission in 1993 should be adopted or harmonized with existing regulations. In this context, the external environmental costs induced by tourism should be entered on the balance sheet as part of the national tourism statistics. The United Nations World Tourism Organization should be strengthened in its role (continuation and updating guidelines, statistical surveys and monitoring as well as global reporting). International nature conservation NGOs (IUCN, WWF, etc) should also be involved.

E 3.7.5
Investigating the limits of carrying capacity for tourism

There is a great need for knowledge on regional carrying capacity limits for tourism, especially with respect to designating zones of specific intensity of use. Studies should therefore be conducted into whether carrying capacity limits can be determined for individual natural landscapes on the basis of 'disturbance rates' for animals and plants (Box E 3.7-1).

E 3.8
The role of sustainable urban development in biosphere conservation

Settlements and, in particular, urban conglomerations are particularly intensively used by people. Under the aspect of sustainable land use geared towards the protection of the biosphere they should be assigned to the landscape use type 'Conservation despite use' (Section E 3.4). The link between towns and the biosphere can be seen in their reciprocal significance: the quality of the biosphere has an important function for towns, and at the same time towns also perform functions for the conservation of the biosphere. Towns have the greatest influence on the biosphere through their high consumption of resources and emission of pollutants, which also makes them an important starting point for biosphere policy.

E 3.8.1
The key role of towns and cities in sustainable development

Towns play a key role with regard to global sustainable development. 60 per cent of global GNP is produced in towns, and corresponding quantities of resources are consumed. In absolute figures, for example, a European city with 1 million inhabitants has an average daily consumption of 320,000 tonnes water, 11,500 tonnes fossil fuels and 2,000 tonnes food. By the same token, every day 1,600 tonnes waste, 300,000 tonnes sewage and 1,500 tonnes air pollution are produced (Forum Umwelt und Entwicklung, 1996). The import and export of resources and waste products brings additional pollution, meaning that there is an externalization of urban environmental problems which harm the biosphere.

In addition, towns are becoming ever more important with regard to the social dimension of sustainable development. Whereas 45 per cent of people in the world lived in towns in 1995, in 2025 this figure will probably be 61 per cent (WRI, 1996). At the same time, urban unemployment, homelessness, crime, social disparities and environmental pollution will increase. Hence concepts for sustainable development will have to prove themselves equal to these issues. Approaches for a biosphere policy will therefore have to aim at sustainable urban development. This not only comprises the conservation and sustainable use of the biosphere within towns, but also a long-term change of urban processes and lifestyles. To do this it is first of all necessary to describe the special features of the urban ecosystem, especially with regard to the differences from non-urban or biological ecosystems (Table E 1.2-1).

E 3.8.2
Special features of urban ecosystems

There are causal and functional interactions between the system elements of an ecosystem (Section E 1.1), which determine the processes within an ecosystem and, at the same time, demarcate it from other ecosystems ('functional ecosystem'). However, ecosystems can also be demarcated from one another on the basis of a naturally bounded, coherent space, eg a lake or a forest ('geographic ecosystem'). Due to its significant fragmentation, a town is not a functional ecosystem, but as an ecosystem complex and a demarcated space it corresponds to a geographic ecosystem (Trepl, 1994). Even if cities cannot be considered as independent functional ecosystems, they

Table E 3.8-1
Differences between non-urban and urban ecosystems with respect to the biosphere.
Sources: WBGU, 2000a; Trepl, 1994; Rebele, 1994

	Non-urban ecosystem	Urban ecosystem
System limitation	• functionally limited by the weakest intrasystemic relations • but also geographically limited (forest periphery, bank of a lake)	• geographically limited, eg town limit, settlement boundary
Biogeochemical and energy flows	• energy received mainly from the sun • self-contained biogeochemical cycles	• import of fossil fuels, inorganic and organic resources • high biogeochemical turnover and generation of large quantities of wastes and emissions • export of wastes and emissions and import into the environmental media
Degree of integration (System interconnection, whereby each system is functionally linked with the sphere of influence of another)	• causal and functional • heavily integrated ecosystem • corresponds to functional ecosystem	• living creatures in the area not necessarily linked by causal and functional relationships • in an extreme case completely disintegrated ecosystem feasible • system elements do not maintain any 'ecological' relationships • corresponds to geographic ecosystem
Succession (Sequence of various stages of development, succession of plant communities in certain ecosystems over a period of time)	• successions of ecosystems mainly caused internally or controlled • succession deterministic, ie targeted, repeatable and predictable to a certain extent • final community often predictable	• successions of urban biocenoses have a historical character and are subject to anthropogenic influences • succession not deterministic, not repeatable, not predictable, most on the basis of social science studies • final community not predictable
Invasion (Invasion of living creatures into habitats that they otherwise do not inhabit)	• generally relatively resistant to the invasion of alien species • number of species is generally limited to a certain level	• particularly large number of alien species because of favourable distribution and naturalisation conditions
Stability and equilibrium	• estabishment of a dynamic equilibrium under natural conditions and over a long period (decades or centuries)	• states of equilibrium in urban biotic communities more or less ruled out because the system will probably be destroyed before the state of equilibrium can be attained
Biodiversity	• species abundance 'normal'	• high diversity of sites, organisms and biotic communities

can be studied in ecological terms, summarily characterized and demarcated from non-urban ecosystems (Table E 3.8-1). However, a clear separation cannot be made because human settlements vary in density and intensity of use, and there are transitional forms and overlap areas between ecosystem types in the peripheral areas.

E 3.8.3
Importance of a high quality biosphere for the urban environment

The following functions of a high quality biosphere can be cited for the urban environment:

- *Urban climate function*: green areas absorb excess precipitation and contribute to cooling by means of evaporation. With the production of oxygen, the absorption of CO_2 and the removal of dust and pollutants they help to improve air quality (Häckel, 1990).
- *Function of conserving urban nature*: high diversity, eg in the tree population, prevents the loss of the populations in the case of disease. In this way, the ecological and climatic functions of urban nature are preserved (Reduron, 1996).
- *Aesthetic and psychosocial function*: urban green areas are used for recreation and contribute to the experience of biodiversity (Gebhard, 1993). Because of the increasing urban population, the

biosphere in urban areas is the only way for a large number of people – and in future the majority of people – to experience nature in their everyday lives (Folch, 1996).
- *Educational function*: urban biodiversity is suitable illustrative material for environmental education (Reduron, 1996).

E 3.8.4 Function of cities for conserving the biosphere

Because of the fragmentation of landscapes and the emission of pollutants, the effects on the biosphere emanating from towns are mainly negative (Chapter C). On the other hand, towns also contribute to the conservation of the biosphere and its diversity:
- Because of the high population concentration and its central functions, towns are usually the key forums for the development of environmentally relevant opinions and consciousness. From the towns, for example, scientific findings are 'exported' horizontally into peripheral areas as well as vertically, eg by NGOs, into the political arena (Reduron, 1996).
- Furthermore, the heterogeneity of use forms and lifestyles in towns enable the formation of high degrees of 'socio-diversity', which provides niches for experimentation with, and subsequent establishment of, unconventional and often sustainable lifestyles (Feindt, 1997).
- Towns directly contribute to the conservation of the biosphere through zoological and botanical gardens (LNU, 1997).

E 3.8.5 System linkages – the biosphere, towns and global development

There are fundamental system linkages between the biosphere, towns and global development (Chapter C). Characterization of important global development trends is the starting point for biosphere-centred system analysis. Many of these biosphere trends (conversion, fragmentation, damage and substance overload of ecosystems) also occur in urban systems. Furthermore, the development of transport routes, for example, or the increasing globalization of the markets is characterizing the relationship between towns and the biosphere. An important trend is the increase in alien species in towns, which is encouraged with favourable immigration conditions and low resistance to the infiltration of alien species, as well as advantageous conditions for the spread of these species towards the urban biotic communities.

'Naturalization conditions' are critically determined by the combination of natural and social factors of the location. The natural locational factors (meaning the abiotic environmental factors not modified by living creatures) of most areas on the Earth would allow a higher number of species than in fact are found (Trepl, 1994). Town dwellers promote the increase of alien species by direct import and high demand. In Vancouver, the migration of the Chinese led to a complete reshaping of gardens; goat farming is gaining in significance in the Toronto area because of the increased demand for products of this kind from immigrants from the Caribbean (Keil, 1998). Barriers to expansion, such as geographical obstacles, missing habitat elements or competing demands among the species, prevent an 'explosion of species' in natural ecosystems. However, in urban settlements not only are the geographical barriers to expansion increasingly being removed, but the competition between species is less important. Added to this is the fact that the great number and diversity of crops and ornamental plants constantly create new living conditions for animal species adapted to them.

Assessing the increase in species in towns

There is a lack of good information for assessing the increase in species in towns in spite of the growing number of biotope mapping projects in Germany (Schulte, 1997). In particular, the increasing dismantling of geographical barriers (Rebele, 1994) speaks for the fact that in future there will be a further rise in the number of species in towns (Trepl, 1994). However, the number of species says nothing about the 'success' of the immigrant species. Thus, for example, the proportion of naturalized species is below 2 per cent of the plants introduced by man to semi-natural vegetation (Lohmeyer and Sukopp, 1992), but this proportion is much higher in towns (Kowarik, 1991). On the other hand, towns are characterized by local extinction of species because of the frequently dynamic nature of urban development (Rebele, 1991). However, no precise information can be made about these contradictory trends because as far as the human-induced capacity to overcome barriers to dispersal is concerned, there can only be speculation about the duration of the migration process.
- It is not known whether the introduction of alien species has already reached its peak in urban areas. On the one hand it is noted that the peak of the influx was already exceeded in the 19th century (Jäger, 1988). On the other hand, some people are of the opinion that invasions will increase due to the better developed transport systems and climate change (di Castri, 1990).
- There are differing evaluations of the consequences of disturbances to urban ecosystems.

Grime (1979) assumes that urban biotic communities are subject to great disturbances and that this generally favours the penetration of alien species. By contrast, Newsome and Noble (1986) note that most invaders are highly specialized and could not cope with disturbances.

- There is also uncertainty about whether, as a general principle, high species diversity increases (Brown, 1989) or decreases (Simberloff, 1989; Trepl, 1993) resistance to invasion.
- The ratio of species-increase to species-extinction varies from region to region. Although the increase in the number of species resulting from invasions in Central Europe clearly exceeds the fall resulting from extinction, this ratio cannot necessarily be transferred to other regions.

Studies on the number of ferns and flowering plants in Central European cities are at least one point of reference. They reveal that the number of extant species correlates to the population figures and density. Whereas 530–560 species are found in small to medium-sized towns, the figure rises to over 1,300 species in cities with over 1 million inhabitants (Sukopp, 1998).

Relationship to the syndromes of global change

The susceptibility of urban ecosystems to the invasion of species can be illustrated by various syndromes of global change (Chapter G; WBGU, 1997, 1998a). Two of the 16 syndromes identified by the Council refer to environmental degradation as a result of different forms of urbanization (Table E 3.8-2).

1. The *Favela Syndrome*, which the Council has already described in detail (WBGU, 1998a), describes the process of unplanned, informal and consequently environmentally harmful urbanization. It is characterized by poverty, such as slums.
2. The *Urban Sprawl Syndrome* (WBGU, 1997) describes the process of urban expansion with far reaching environmental consequences. New spatial structures arise from the formation of urban conglomerations, and there is a corresponding need for adaptation.

In particular, the spread of settlements to the peripheries of towns in both syndromes leads to a reduction of the ecological potential in the area surrounding the town. However, the reasons for this vary greatly. Whereas there is economic pressure for use in the Urban Sprawl Syndrome, the Favela Syndrome is a matter of ensuring the survival of poverty-stricken people. In the inner cities this pressure for use can still be kept at bay, to a certain extent, in respect of open space by measures under administrative law. Because of the frequently low degree of organization in the planning, monitoring and enforcement bodies it is very difficult to prevent the occupation of open space on the outskirts of towns. The ecological concerns are relegated to the background when faced with securing livelihoods.

The development radiating from towns in industrialized countries often leads to damage to the landscape as a result of the expansion of urban structures and infrastructure. With regard to the biosphere, the key issues are the conversion of natural habitat into farmland and an increase in soil pollution resulting from traffic emissions. As the disadvantages of urban conglomeration increase, eg high land prices or heavy traffic pollution, the wish for semi-natural living leads to urban sprawl in the environs of the towns. The associated expansion of the infrastructure divides recreation areas and natural habitats. As a consequence of the conversion of the natural habitat (in Germany alone around 90 ha day^{-1}) there is a severe loss of biological diversity. For example, it can be assumed that the conversion of agricultural land in the United Kingdom has led to the permanent loss of around 30 per cent of animal and plant species (WGBU, 1994).

Whereas spatial expansion is crucial in the Urban Sprawl Syndrome, in the Favela Syndrome the extent and speed of poverty-induced influxes of people into existing settlement structures leads to damage to the biosphere. Losses of biological diversity and varying conditions for the invasion of alien species can be seen with both development patterns.

Table E 3.8-2
Development trends of the Favela Syndrome and the Suburbia Syndrome.
Sources: WBGU, 1995a, 1997, 1998a

Favela Syndrome	Suburbia Syndrome
Population growth, rural exodus, waste accumulation, contamination, sealing, collapse of traditional agriculture, reduction of cultural diversity, social and economic marginalisation, troposphere pollution, freshwater depletion, eutrophication, reduction of the groundwater level	Higher aspirations, individualisation, sectoral structural change, economic growth, urban sprawl, fragmentation of ecosystems, conversion of semi-natural ecosystems, sealing, emergence of new economic areas, deregulation, increasing traffic volumes, expansion of traffic routes

E 3.8.6 Models and concepts for sustainable urban development

In order to reverse the urban development trends described above, new models have been developed and gained currency in the German-speaking world, known variously as 'ecological urban redesign', 'the compact city' or 'the ecology of time'. Agenda 21 expressly calls for sustainable development which respects economic and social development as well as incorporating the environment. Chapter 28 emphasizes the importance of towns to sustainable development. Associated with this is a call to local authorities to draft Local Agenda 21 processes together with all groups in society (UNCED, 1992). This procedure is different from the conventional planning methods because all relevant groups in society are involved.

Another important principle of sustainability is formulated in the Aalborg Charter. According to this, town may not temporally or spatially export their ecological, economic or social problems. Instead, attempts should first of all be made to solve these at local level. Only when this has proved to be impossible should temporal or spatial balancing mechanisms be sought (ESCTC, 1994; Kuhn and Zimmermann, 1996).

The Conference on Human Settlements HABITAT II was held in Istanbul in 1996 (WBGU, 2000a). The difficulty of establishing the term of 'sustainable development', anchored in Agenda 21 in 1992, as a basic principle for the development of human settlements was overcome by the compromise wording: 'Sustainable development equal to economic development, social compensation and ecological compatibility' (BMBau, 1997). This is motivated by the concern of developing countries to exercise their right to 'catch-up' in development terms. At national and local authority level the HABITAT II process has taken some effect, especially as a result of the comprehensive involvement of local authorities, scientists, business and NGOs (Sibum, 1997). In Germany, a national report on the HABITAT II Conference has been compiled (BMBau, 1996) as well as a national plan of action based on the Global Action Plan of HABITAT II (ARL, 1996). Although the declaration of intent for sustainable urban development signed by the governments is not legally binding, it can be invoked politically.

At the URBAN 21 international conference to be held in Berlin in 2000, the aim is to work towards concrete solutions tying in with the results of Rio de Janeiro and Istanbul. The focus will be on the problems of the growth of megacities in the developing countries and non-sustainable urban development in the industrialized countries. The URBAN 21 international commission will submit the 'World Report on the Urban Future' to the Conference. Finally, the Conference is to adopt a declaration that will outline the cornerstones of future worldwide urban policy and point out the way for urban development in the 21st century (BBR, 1999).

Recommendations for action to promote sustainable urban development

In terms of urban planning, ecological concerns are at the forefront with respect to biosphere conservation – however, without the integration of social and ecological concerns, the positive effects of purely ecological urban planning will remain marginal. An adequate foundation for evaluation is initially of central importance for the protection of the urban biosphere. In order to ensure a fair assessment of the conservation and use requirements of the biosphere, it is necessary to make a comprehensive inventory and valuation of existing biotopes. This requirement is accommodated in Germany by the nationwide mapping of biotopes, which now comprises over 200 maps, especially in small and medium-sized towns (Schulte et al, 1993). Since 1990 there has been international cooperation with Brazil to see whether the methods developed in Germany can be transferred to other countries and preliminary results have already been achieved (Schulte et al, 1994).

For sustainable urban development geared towards the protection of the biosphere, the following points of departure for town planning also emerge: (Becker, 1992; Loske, 1996; Birzer at al., 1997):

- Creation of structures for supply and disposal (energy and waste) that allow the efficient exploitation of resources used and the introduction of biogeochemical cycles (Section E 3.2).
- Prevention of urban sprawl in urban peripheral zones. However, subsequent population concentrations should not take place to the detriment of open spaces. Soil sealing should be reduced and ecological building should be promoted.
- Drawing up concepts for inner city open spaces in order to increase the proportion of open spaces and to interlink them, for example, as habitat-type compounds (Fachdienst Natur und Umwelt der Stadt Neumünster, 1999). The aim should be to secure biological diversity and its functions in towns. Special significance is given to fallow land, gaps in building and green spaces. With fallow land in particular, there is usually special pressure for economic use, for which land use plans have frequently already made provision although this is in conflict with existing, often informal, uses.

- Identifying ways to reduce motorized private transport and the use of the most environmentally friendly form of transport (by means of individual incentives). Land use and emissions from road transport should be cut in the process.
- Promotion of smaller structures in order to reduce traffic flows and allow local means of identification.
- Promotion of cooperation with the surrounding area. Movement away from a system of town planning that is biased in favour of investments and expansion.
- Incorporation of social aspects in environmentally oriented town planning. In addition to public participation in the planning and decision-making process based on new forms of dialogue, styles of argument and procedures and the promotion of sustainable lifestyles, this also includes the removal of social inequalities, which are often a background reason for the implementation of ecological objectives (Dangschat, 1997).

Biosphere-oriented model of future urban development

A system of town planning geared towards biosphere conservation must pursue balanced development of settlement structures. The model of the compact town frequently pursued in recent years leads to an impairment of biological diversity because of the increased internal compaction by means of 'open space recycling', and building on fallow land and open spaces in addition to the increasing social burden. Starting from the previous considerations, the Council recommends the model of polycentric urban development, which reflects the concept of decentralized concentration (BMBau, 1993; Spiekermann, 1999): within the urban area development concentrates on settlement types, ie the city centre and the secondary centres in which there is a complex mix of different uses. New areas of settlement are planned subject to the proviso of a high degree of multifunctionality and ease of accessibility by public transport. Between the areas of settlement, the building is relieved by interlinked green spaces. Whereas the hubs of settlement are linked by an efficient system of local public rail transport, journeys within the urban centres are made on foot or by cycle. The green spaces between the areas of settlement are of an adequate size and are linked to each other as well as the surrounding area. The stipulation 'of an adequate size' means that, firstly, they can serve the population as a recreational area and fulfil urban climate functions, and secondly, they provide a refuge for species typical to urban habitats. Furthermore, the interlinkage of the green spaces to the outer environs helps to diminish the barrier effect of urban agglomerations.

The model of the polycentric town aims at protecting open spaces in the outer and inner area. Although this model is less economically efficient than the compact town, the social and ecological gains are disproportionately higher. This is the best way to integrate the beneficial function of the biosphere for towns, on the one hand, and the towns' function in the conservation of the biosphere, on the other.

E 3.8.7
International research programmes on urban ecology

The Council's 1996 report contains an overview of urbanization research (WBGU, 1997). The international research programmes that deal with urban ecology with the emphasis on biodiversity will be presented in the following sub-section.

Within UNESCO's MAB programme, sub-programmes 11 (Ecological Aspects of Urban Systems) and 13 (Perception of Environmental Quality) are related to urban ecology. Studies within the context of sub-programme 11 (from 1972) initially concentrated on the subjects of energy and water in towns. Later, the focus of research, especially in Europe, shifted to the maintenance and development of urban open spaces.

Within the International Association for Ecology (INTECOL) there is a working group on 'Urban Ecology' that was founded at the 1st International Congress for Ecology in The Hague in 1974. A research programme that is better known in North America is the Urban Forestry Programme of the International Union of Forestry Organizations (IUFRO), which aims at studying and developing urban forests. More recent programmes and projects have been initiated by the OECD (The Ecological City, since 1994) and the EU (Sustainable Cities and Towns Campaign with the Aalborg Charter, from 1994) and are increasingly dedicated to the aspect of sustainability (eg including the Urban Sustainability Indicators Project of the International Institute for the Urban Environment, 1993–1995).

Many applied research projects of the United Nations (UNCHS), various institutions and NGOs call for the application of best practices of sustainable development. This means that worldwide a number of databases with access to the internet have been set up from which applicable examples can be found relating to the most varied aspects of sustainable urban development which have been tried in practice (DIFU, 1997; UNCHS, 1998, 1999). For example, at the HABITAT II Conference, the regenerated Freiburg district of Vauban was introduced and presented among the 'best practice' projects. The follow-up process to HABITAT II should be considered to be a successful strategy for overcoming negative environmental changes that is worthy of imitation and support because of the quality of the results and the resultant interlinkages between international, national and local institutions.

The current EU research programmes attach high importance to sustainable urban development. Although we are still far from an efficient and creative European network of scientists, local politicians and authorities, the most recent report by the European Commission on the results of research in 160 projects in the 3rd and 4th Framework Programme provides many new findings on the socio-economic aspects of environmental changes, which open up good perspectives for integrated sustainability research in European cities (European Commission, 1998).

E 3.9 Integrating conservation and use at the regional level

E 3.9.1 Experience and deficits

The case studies from the Central European cultivated landscape, Amazonia, Lake Victoria and the Indonesian shallow seas described in Section E 2 showed how complex these landscapes are and how varied the intensity and extent of human interventions in these ecosystems can be. The examples also clearly demonstrate that an exploitation of biological resources which ignores the long-term impacts leads to overexploitation and mismanagement, jeopardizing the resource base in the long term (Chapter G).

In the cases described there is a discrepancy between the lofty aspirations at global level, for example as worded in Article 1 of the Biodiversity Convention (Section I 3), and local practice. First of all, the Parties are directly responsible for implementation of the Convention. However, deficits in the application of the principles of the Convention can be seen both in industrialized and developing countries. In the following, two extreme examples will be taken from the continuum of different institutional and natural geographic framework conditions.

In the case studies on the use of biological resources in *developing countries,* it can be seen that national governments in countries with large land areas frequently have too little interest in events a long way away from the capital (Amazonia, Section E 2.2) or lack the power to effectively implement statutory provisions locally (Indonesian shallow seas; Section E 2.4). The property rights for the biological resources are often in the hands of the state or a small number of private owners. An adequate knowledge base as well as structural, personnel and financial capacities for planning are unlikely to be in place and planning decisions are usually made centrally and not locally. Due to the great distance separating the decision-making from the implementation, there is no feedback of locally available knowledge to spatial planning authorities. Poorly-equipped and insufficiently linked institutions have no way of reviewing or enforcing the implementation of planning objectives. This 'implementation vacuum' leads to action being taken on the basis of short-term economic interests, disregarding the sustainability of use.

By contrast, even well-developed systems of regional planning in *industrialized countries* extending down to local authority level and including the designation of protected areas with a clearly defined status have not been able to guarantee adequate implementation of the objectives of conservation and sustainable use of the biosphere. One problem here is that, in practice, the burden of proof necessary to demonstrate the need for proposed interventions on economic grounds is frequently much lower than that demanded for nature conservation to ensure the prevention of an intervention or the designation of a protected area. The piecemeal and small-scale conversion of ecologically valuable land into intensively used areas, is still common and persistent, with woefully inadequate regard for the ecological contexts (eg networks of protected areas). The different planning disciplines are often poorly coordinated with each other and neglect the perspective of regionally significant ecosystem services. One reason for this is that the geographic areas under consideration are often small, and either the multi-faceted functions of ecosystem complexes have not yet become visible or the causes for local events are beyond the local institutions' sphere of influence and action. Even where industrialized countries are taking these functions into account – eg in managing protected forests in the alpine area – other tourism or infrastructure plans are frequently still being operated in parallel, completely divorced from these ecosystem functions. The land is in the possession of many different owners with contradicting interests, which is reflected in the highly divergent and conflicting demands being made of the landscape and land use.

In both cases there is a lack of practical application of the principle formulated at global level that both conservation *and* sustainable use of biological diversity must be integrated at local level. This raises the question as to which approach might best be used to achieve this difficult task most effectively, and at what level.

A global biosphere policy based on the regulatory approach, which aims at implementing objectives in the region exclusively through state measures, quickly realizes its limitations, as the above extreme cases show, and is described in more detail in Section I 2. A successful approach should therefore also seize the opportunity that the motivation approach (Section I 2.4) has to offer for application at the regional level. In this process, it is much less a matter of regional implementation of the rigid objectives of a central governing body than – applying the subsidiarity principle – allowing a variety of institutional approaches and regional experiments so as to organize a process of enquiry, which can better integrate the diverging ideas of the individual actors from the region.

If the intention is to link the protection of landscapes and ecosystems with sustainable use, then a concept is needed that also does justice to the complexity of the various local requirements for conservation and use. In the process, the various ecosystem types and land use forms cannot be viewed separately from each other because they are linked via interactions, impinge upon each other or even overlap. In view of the global diversity of the ecosystems and forms of use, the specific design of such an approach obviously has to be adapted to the local conditions. This applies not only to the natural factors (terrain, soils, climate, etc) but also to the social conditions (culture, settlement density, structure of state institutions, etc). Mutually contradictory conservation and use demands lead to conflicts that make the protection and the sustainable use of the biosphere much more difficult.

The relationship to existing planning is of particular importance: the approach with its principles and instruments should help to incorporate the perspective of integrating conservation and sustainable use of the biosphere into spatial planning. In this context, on the one hand the area must be large enough to be able to implement effective measures for ecosystem protection and, on the other hand, small enough to develop locally adapted concepts that do equal justice to the ecological, economic and social framework conditions locally.

Another important spatial criterion results from the fundamental considerations of biosphere policy (Section I 2): the spatial equivalency principle. The greater the spatial separation between the benefits and costs of biosphere conservation, the more difficult it will be to reach a consensus. Therefore, the level that should be chosen for political action should be the one that is best suited to balance the beneficiaries with the bearers of the cost. This does not always have to be the global level: the regional level discussed here can also offer an interesting approach – in line with the subsidiarity principle.

The task of central importance is therefore the following: in the use of biological resources there must also be a comparison of the three components of sustainability (economic, ecological and social component). In rural areas, it is of prime importance to consider the different needs of intensive agriculture and forestry, the conservation of natural ecosystems and the interests of the local population.

In this respect, the main concern cannot be to give one of the three components priority over the others. There should not be a knee-jerk reaction to the destructive exploitation of biological resources in the form of a concept in which every economic use of biological resources is informed by nature conservation aspects alone. Much rather, all three aspects have to be considered as integrated from the outset. A successful concept will therefore be tailored more to rural regions, which are characterized by the use of biological resources, and less to regions where industry or settlements are the predominant influences. In the process, it is imperative to avoid bureaucratic over-regulation within the context of local and nationwide use-planning, in order to give the local actors flexibility and to open up scope for action, within the limits set by the guard rails (Section I 1) and guidelines (Box I 1.1-1) which must still be observed.

The following section introduces the principles and instruments for a regional approach of this kind for integrating the conservation and use of biological resources. Obviously, these are not universally valid and cannot be used as a template in all regions of the world; they rather form building blocks which must be assembled locally to form a 'well-adapted' and flexible concept, given the particular local framework conditions.

E 3.9.2
The proposal of bioregional management: principles and instruments

The World Resources Institute (Miller, 1996) proposes 'bioregional management' as a method for practically shaping the integration of conservation and use; this term will be described here and evaluated with regard to its suitability for the implementation of these objectives in spatial and regional planning.

Bioregion refers to a geographically definable area with a predominantly rural structure, characterized by its typical ecosystems, its culture and history and comprising several ecosystem and landscape use types (eg water catchment areas, forests, pasture and arable land). The term bioregion is actually defined too narrowly because here we are considering parts not only of the biosphere, but also the hydrosphere, the geosphere and the atmosphere. 'Ecoregion' would certainly be the more appropriate term, but since 'bioregion' has already been introduced in this context and 'ecoregion' already has a different definition, we will keep to the term 'bioregion'. Bioregions are a suitable framework for the management of biological resources because they facilitate the overview of the ecosystems in a region with their interlinkages and biogeochemical flows and ensure immediate feedback on measures and their impact. As a result of the transparency of the region and the close link between the local population and the political sphere, conflicts of interest can be better solved.

Bioregional management attempts to develop and implement a gradated protection and usage concept for a bioregion's biological resources using a varied mix of instruments under participation of the relevant groups and institutions. Since the bioregion is delineated by natural borders it can comprise several political and administrative units (eg local authorities, provinces, and states) and span the corresponding borders.

Examples of bioregions are the Great Barrier Reef in Australia (Box E 3.9-3), the Serengeti ecosystem in Kenya and Tanzania or the mudflats of the Netherlands, Germany and Denmark. The size of bioregions can vary according to the conditions; in areas with little ecological diversity and a more or less uniform settlement pattern, bioregions tend to be larger than in areas with high landscape and cultural diversity. It is therefore difficult to find generally valid criteria for the definition of bioregions. In the Serengeti ecosystem the migratory movements of the wild animals may be decisive, whereas in the mudflats or the Great Barrier Reef it makes sense to include the agriculture in the coastal zone and the navigational routes. The concrete form of bioregional management can rely on the experience of different nature conservation and development programmes, such as UNESCO's MAB programme (UNESCO, 1996b; Section I 3.3.2) or the concept of integrated conservation and development projects (ICDPs; Miller, 1996).

The most important *elements* of bioregional management are:

- to consider regions which are large enough to sustain habitat and ecosystem functioning in the long term,
- to use a zoning concept which divides the landscape into a gradated pattern of different intensities of use,
- to involve the relevant actors in shaping and implementing the concept, using comprehensive information schemes and other methods,
- to back up the management process with research, monitoring and the use of traditional knowledge,
- to introduce flexible, adaptive management structures which allow objectives to be corrected when the knowledge-base changes,
- institutional integration in order to close existing gaps and avoid unnecessary duplication of effort,
- international cooperation on ecosystems or protected assets that extend over several countries.

In order to organize sustainable management of a region's biological resources, certain *principles* have to be taken into account and implemented. These principles include:

- Management of biological resources must not solely be dominated by economic uses, but must take place within the meaning of the sustainability principle while weighing up economic, ecological and social aspects and giving greater emphasis to the long term view (Chapter H).
- Bioregional management takes account of imports and exports of nutrients or sediments and their distribution within the bioregion in order to counteract the decoupling of biogeochemical cycles (Section E 3.2).
- In addition to the immediately obvious use values, ecosystem services also have to be taken into account. This also includes services for local recreation and tourism, but above all services that cannot be easily put into monetary terms and economically valued, such as the regulatory services of natural ecosystems (Section D 2.5). The bioregional approach includes values from all five categories: not only the use values (value of biological products such as wood) are considered, but also the functional values (eg flood protection from alluvial woodland) as well as the option, existential and symbolic values (as a major justification for the conservation of biological diversity). These multi-faceted values of the biosphere and the methods for arriving at valuations are presented in Chapter H (and, in more detail, in a Special report on this subject prepared by the Council; WBGU, 2000b).

A number of instruments are available to implement these principles practically. Some of these instruments are already being used in some countries, therefore they are not specific to this concept of bioregional management.

Zoning

Bioregional management uses a zoning concept – similar to that reflected in the breakdown of Section E 3.3 – which distinguishes between nature conserva-

Box E 3.9-1

Zoning in biosphere reserves

Since 1976, 'biosphere reserves' have been established within the context of UNESCO's Man and the Biosphere Programme (MAB) (Gregg 1991; UNESCO, 1996a). In total, today there are 356 MAB reserves in 90 countries (UNESCO, 1999). They are established in industrialized and developing countries alike, where they are brought into line with the relevant national conditions.

The fundamental idea of the biosphere reserve concept is to integrate people in the protection and maintenance of specific ecosystems for the development of sustainable land use. Biosphere reserves are designed as area systems that, on the one hand, are made up of areas of untouched, natural or semi-natural ecosystems and, on the other hand, areas characterized by human activity (Erdmann, 1997). In geographical terms, biosphere reserves are made up of three elements:

Core area. Here conservation objectives have priority. At most, observation of largely undisturbed ecosystems and research that is not harmful to the environment are allowed. This zone corresponds to landscape use type 'N' (Section E 3.3.1).

Buffer or maintenance zone. This zone buffers the core area from the development area. The use of this zone is restricted to environmental education, recreation, ecotourism and naturally adapted research activities. This zone corresponds to landscape use type 'M'.

Development area. This is the population's area for living, engaging in economic activity and seeking recreation. This area corresponds to landscape use type 'E'. The aim is to develop a sustainable form of land use that strikes a balance between the needs of human society and the natural environment (UNESCO, 1996b).

This illustrates the main functions of biosphere reserves: (1) protective function, (2) development function and (3) support and demonstration function, as established by the Seville Strategy of MAB (UNESCO, 1996b). The biosphere reserve concept is thus a strategy that anchors the protected areas in their regional context and pursues gradated, broad-scale conservation and use objectives.

tion land (landscape use type N, 'conservation before use'; Section E 3.3.1), areas of extensive land use (landscape use type M, 'conservation through use') and areas of intensive land use (landscape use type E, 'conservation despite use'). The biosphere reserves of the UNESCO programme 'Man and the Biosphere' (MAB; Section I 3.3.2), which serve as trial and demonstration areas for the integration of different demands made of the biosphere, similarly use a breakdown into core (conservation), buffer (maintenance) and transition (development) zones (Box E 3.9-1). However, biosphere reserves have so far mainly been designated in areas with a high proportion of supraregionally or globally significant biosphere elements (eg biological diversity), meaning that conservation is generally the overriding concern.

Because of their location, orography or biological diversity, nature conservation areas (Type 'N') may perform valuable ecological services for the region which are difficult to value in monetary terms and would be lost if the land were used for agriculture or forestry (Section D 2.5). These areas are, as it were, 'regional guard rails' that would jeopardize the sustainability of the region if their economic use continued unimpeded. These areas have to be identified by suitable methods. Implementation of the protection objectives also has to be guaranteed. It is sensible, at least for reasons of ecology and landscape husbandry, to surround these nature conservation areas with 'buffer zones' where there is extensive economic use (Type 'M'). The proportion of remaining land – in many regions the majority – (the 'matrix' of the landscape) can be used according to market forces for intensive methods of sustainable agriculture and forestry provided account is taken of the guidelines for sustainable use (Box I 1.1-1; Section E 3.3.4).

This leads to the formation of a mosaic of areas with varying intensities of conservation and use, whose matrix is mostly characterized by agriculture and forestry, whereas the protected areas and their buffer zones and corridors form a network within them, supplying the bioregion with ecological services that can only be provided by intact natural or semi-natural ecosystems.

Guidelines for intensively used land

Bioregional management must keep more than the global guard rails in mind (Section I 1). With land for intensive use (Type 'E'), where the use value from the production of biological assets is at the forefront (intensive agriculture and forestry) care must also be taken to ensure that the ecosystems perform their use, regulatory, habitat and social functions and the limits of sustainability are not exceeded. For example, in Germany provisions have been passed against the excess application of slurry or plant protection agents. These guidelines are listed in detail in Box I 1.1-1.

Irreversible processes should be avoided here so that several options can be kept open for the future and the option is retained, in principle, to convert types of area. This is also desirable when economic factors are considered, because preventive measures are often much cheaper than the restoration of destroyed and degraded land (Box D 2.4-1).

Involvement of stakeholders

If the implementation of statutory provision or the monitoring of protected areas – eg in developing countries – is inadequate, this gap will have to be closed, for example with a 'bottom-up approach'. Then, the involvement of stakeholders is a key element of decentralized approaches for the conservation and sustainable use of biological resources, meaning that the responsibility for management of the resources must be gained via directly negotiated solutions, voluntary commitments and incentive systems and may in certain circumstances be placed in the hands of the former users (eg Campfire Project, Section E 3.3.3).

However, with participatory approaches the question as to who is a stakeholder always arises, ie who should be involved and who should not. In relation to bioregional approaches, stakeholders can be understood as individuals, groups or institutions who are directly affected by decisions, represent an understandable and justifiable interest or whose action has an obstructive or promoting effect on dealings with the biological resources in the region, or may have such an effect in the future. Involvement does not therefore mean that the opinion of every individual is asked and considered because this would quickly lead to an inability to act or would make the results arbitrary. One important task is therefore to identify those interest groups in a region who are involved in the use of the biological resources or influence that use. Often motivational and informational work is necessary to move institutions, individuals and groups to get involved, where their action (or inaction) plays a key role in the use of biological resources. The range of participation may extend from agreements on adhering to certain management practices right through to mediation of conflicts between conservation and use (Lewis, 1996). Because there is often a lack of detailed planning structures in many developing countries, such participatory approaches are often the only way to develop resource use concepts and thus combat unhampered predatory exploitation without sacrificing the economic use of biological resources. NGOs in particular often perform the informational task of building the capacities for involvement of the local population into the planning process.

In contrast, it can be seen in many industrialized countries that sovereign planning frequently meets with considerable resistance among those involved, and that early involvement of the local population is therefore an important prerequisite for success. This is why there is provision for the participation of actors in, and people affected by, planning procedures in many industrialized countries. With this constellation, bringing together the various actors whose actions have a direct or indirect effect on the biosphere can help to sort out interests and conflicts in the early stages of state planning processes.

However, the state implementation of measures has to remain guaranteed, even if the discussion processes fail. If, for example, stakeholders refuse in principle to participate in the discussion, state action becomes imperative: this is where the participatory approach comes up against its limits.

Financing and incentive systems

Financing and incentive systems, as provided for in the Convention on Biological Diversity (eg GEF; Section I 3.5) are important elements of biosphere conservation that can also come into play at regional level. Financial compensation (positive incentives) or the development of alternative perspectives for groups of people affected (eg farmers) can make inevitable restrictions on use and changes in use easier to accept. In the Rhön biosphere reserve, noticeable improvements in income and additional opportunities and perspectives, especially in the fields of catering and tourism, were by no means insignificant in bringing about a clear increase in acceptance of the MAB project (Ott, 1994). Measures that concur with the interests of certain groups have a better chance of taking off. For example, this can be achieved by the introduction of quality seals for quality products and associated marketing strategies.

Alongside the question as to how incentive and financing systems can be established *within* a region there is obviously also the question as to how financial balancing can be achieved *between* regions. If a region has a high proportion of ecosystems worthy of protection and can make a contribution to the conservation of nationally or globally important biological diversity by renouncing economically attractive development that is incompatible with the principles of sustainability, the question should be posed of supraregional compensation, perhaps in the form of additional grants. This is especially important in the biodiversity hotspots.

At the national level, the German Council of Environmental Advisors (SRU) has already pointed out the possibility of financial compensation between local authority districts and regions with different biogeographical endowments (SRU, 1996). Following the model of urban partnerships, a programme to establish regional partnerships between regions with a high proportion of biological diversity (mostly in developing countries) and regions with a low proportion (mostly in industrialized countries) but a high interest in the conservation of biological diversity would be conceivable. Within the context of Local Agenda 21 processes, urban partnerships between industrialized and developing countries have already been initiated with great success, and through direct contacts and identification with a particular region instead of confrontation with an abstract problem, they ensure a high degree of commitment.

Adaptive management

The introduction of flexible, adaptive management can be of great assistance to the implementation of the goal of 'integration of conservation and use'. Adaptive management takes account of the fact that knowledge about biological systems is imperfect (Section E 3.3.2.5; Holling, 1978; Walters, 1997). The setting and achieving of targets is hampered by this lack of knowledge. Adaptive management recognizes change as a fundamental reality and does not attempt to define objectives or strategies 'once and for all' (Gunderson et al, 1994). Instead:

– interventions are designed as experimens so that the result not only brings a direct benefit, but also reduces uncertainty about the function of the system,
– the results are used in order to improve management,
– adequate monitoring is carried out before, during and after the interventions.

Bioregional management makes provision for interdisciplinary research efforts to concentrate on applied aspects and on the relationship between man and the environment: the development of innovative, sustainable and socio-economically viable technologies and methods for the use of local resources, but also the protection of species and ecosystems within the region.

E 3.9.3
Case studies

In large parts of the USA, Canada and Australia, and increasingly also in New Zealand and Europe, bioregions are already defined as the foundation of planning for administration and resource management. So far, experience has been gathered on this under various conditions with respect to the ecosystemic circumstances, administrative prerequisites, economic framework conditions and the involvement of stakeholders. Three case studies will be used to show how the above-mentioned considerations have been implemented and the special challenges which result for the design of these projects (La Amistad, Costa Rica: Box E 3.9-2); Great Barrier Reef Marine Park, Australia: Box E 3.9-3; Rhön, Germany: Box: E 3.9-4). These case studies were consciously chosen as a comparison to the situations described in Section E 2 (Amazonia, the Indonesian shallow sea and the Central European cultivated landscape). Furthermore, reference is made to other regional projects in this report that can also be seen as a case of application (Campfire, Section E 3.3.3; Obergurgl, Box E 3.7-3).

E 3.9.4
Evaluation and application

In the Council's guard rail concept, areas are defined where it can be assumed that precept of sustainability is being violated (WBGU, 1998a). In analogy to the global guard rails (Section I 1), guard rails can

Box E 3.9-2

Case study: La Amistad in Costa Rica

The 'La Amistad' biosphere reserve covers an area of over 600,000 ha (approx 12 per cent of the country's total area) in the south-east of Costa Rica with a large number of unique ecosystems from the Atlantic coast right up to high mountain forests. Around 30–40 per cent of the flora are endemic in the entire area. Within Costa Rica this region is one of the last where the indigenous population still lives. In 1982 Costa Rica and Panama set up a cross-border national park and in the same year the area was recognized as a biosphere reserve and extended. In 1983 declaration as a 'World Heritage Site' followed (Gobierno de Costa Rica, 1990). Overall, the reserve comprises several areas with different protection status (national parks, biological reserves, forest reserves, game protected areas and protected water areas as well as 'protected areas' for the indigenous population.) A commission, which was financed by a 5-year debt-for-nature swap (Section I 3.5.3.2) and in which all of the institutions already present in the region were represented, was entrusted with coordinating and managing the region. After initial difficulties (including financial difficulties) this commission, together with international organizations, developed a joint strategy for institutional development. What is especially important here are strategies to resolve conflicts, recognition of indigenous territorial claims, the development of management plans for the protected areas and the specification of priorities for future development options. The commission also makes recommendations for development projects, such as the extension of roads, mining activities and generating electricity. The incorporation of indigenous groups proved to be difficult because the required skills had to be developed here first and organizational structures had to be built up. An indigenous NGO (KANEBLO) has taken on these tasks with the support of various national and international aid organizations. A critical phase of the project was reached when, after five years, the funding from the debt-for-nature swap ran out and transitional financing could only be secured with extreme efforts (including funding from GEF, the Netherlands, Sweden and UNEP). The project is now financed for the long-term by a national environmental fund.

Box E 3.9-3

Great Barrier Reef Marine Park, Australia

The Great Barrier Reef extends along a 2,300km-long coastline and is the largest continuous coral reef in the world. It is made up of individual reefs, islands and sandbanks and provides a habitat for around 400 coral species and 1,500 fish species. The main use of this region, recognized as World Heritage in 1981, is tourism with a large number of different leisure and sport activities. Every year, around US$1 thousand million is earned. Raw material depletion, fishing and shipping are other, but less important, economic activities in this area.

Two factors are currently threatening this unique ecosystem:

- Disruptions from tourist activities, such as diving, shell collecting, boat trips in sensitive areas.
- The tremendous increase of starfishes in some places, which is probably linked to pollution and eutrophication and which destroys the corals.

In 1975 the Great Barrier Reef Marine Park was founded with the aim of protecting the marine and coastal ecosystems and promoting the appropriate use of the resources in this area. The Great Barrier Reef Marine Park Authority is responsible for the management of this region. The government authority with close contacts to the Environment Ministry has built up many contacts to local authorities, governments and other interest groups via an agreement with the Federal State of Queensland. The authority's main task is to bring together and spread information and to carry out studies and projects on ecosystem management. A committee for the regular exchange of information between the Park administration and other institutions, experts and citizens was set up for the involvement of important groups.

The main conflicts in this region were oil pumping in the 1960s and lime extraction in the coral reefs. Australia has clearly decided on protection here: the country is prepared to do without these uses in favour of conserving this unique reef.

The Marine Park Authority uses two important instruments to avoid conflicts: on the one hand a seven-stage system of zoning lays down precisely what activities in which areas are allowed, not allowed or allowed only with a special licence. On the other hand, the Authority is in regular dialogue with companies who (want to) use the reef – whether for the removal of raw materials, fishing or tourism. These users then voluntarily undertake to adhere to certain rules. For example, sport anglers may not fish in fish breeding areas and they supervise each other in adhering to this prohibition; tough sanctions await anyone who does not stick to these rules. Ships carrying mineral oil and travelling through parts of the reef are now accompanied by specially trained pilots who guide the ships through the highly sensitive areas.

The example shows that effective instruments can be developed as a result of the cooperation of a national authority with local authorities and interest groups that do justice to the different protection and usage requirements. Existing institutional capacities have been used and supplemented by the national authority. The general appreciation of the ecosystem by all involved as well as the knowledge that the state national park authority can introduce more stringent restrictions on use at any time ensure that there is high acceptance and effectiveness for voluntary commitments.

also be identified at regional level. This concept can be very well combined with the above-mentioned approach for bioregional management: designating areas for placing under protection or restriction on use defines 'sustainability limits' which must not be exceeded.

In this respect, the term 'bioregional management' could suggest that biosphere conservation should be accorded priority over economic biosphere use from the outset. This is not the case: in a successful concept all three aspects of sustainability must always be regarded as integrated. Bioregional management should therefore create a balance between the interest in intensive land use and the protection interest without one of the two interests being granted *a priori* priority over the region as a whole. No user should be prescribed a use plan right down to the individual field. Only a network of ecosystems is identified, each of which is of major important for biosphere conservation.

The zoning concept provides a differentiated foundation for this (Section E 3.9.2). There will be type 'N' areas in every region (Section E 3.3.2) in which important ecosystem services are performed, which are undervalued when viewed from a purely market point of view, and would be lost if used for economic purposes – conversion and subsequent intensive land use – (eg core zones of protected areas as a habitat for endangered species, high-slope forests without economic use because of their importance for erosion prevention, water protection areas). These protected areas are of regional importance and can also be designated at this level. Added to these are protected areas of supraregional or global importance, such as areas of natural heritage or areas of importance to the global protected areas system (Section E 3.3.2). These are agreed at national or global level, but also have a binding nature for the region concerned. The regions can vary greatly with respect to their share of the three landscape-use types. This means that this concept is ultimately a geographical implementation of the guard rail concept for the regional integration of conservation and use of the biosphere: after a network of protected and buffer areas has been designated, there remains some 'leeway' within which economic search processes can run their course – while adhering to the guidelines for intensive sustainable use (Section E 3.3.4) – and a market-oriented use is possible and desired, eg with respect to the goal of safeguarding adequate supply of food.

Box E 3.9-4

The Rhön biosphere reserve

The Rhön biosphere reserve was recognized by UNESCO in 1991 and is located in the three German states of Bavaria, Hesse and Thuringia. It represents the Central European cultivated landscape type and is characterized by diverse habitats, such as woodland, hedges, orchard meadows, matgrass, highland heaths and dry grassland. The specific target species of the protection efforts is the black grouse, whose habitat is in the open landscape of the heaths and matgrass. Historically, the matgrass and dry grassland came about as a result of sheep grazing and the constant removal of nutrients; today they are important refuges for rare animal and plant species. However, their continued existence depends on extensive forms of use, such as sheep grazing or late mowing.

Small farm structures in Hesse and Bavaria led to a great breakdown of the landscape characterized by villages, whereas in the Thuringian part the landscape are characterized by large farms. The previous marginal location on the inner German border, the low economic power and the sparse settlement made the Rhön into a poorly developed area, which, for example, received EU funding. Agriculture, the manufacturing industry and tourism characterize the economic structure. Agriculture mainly provides a second income. However, many farmers are giving up their farms, meaning that the maintenance and conservation of the ecosystems dependent on extensive use is at risk.

The basis for the development of the biosphere reserve is a framework concept drawn up by a planning office that contains proposals for zoning the landscape and, thus, linked concepts for the conservation and maintenance of the different habitat types (Grebe and Bauernschmitt, 1995). The sponsors of the framework concept include the nature parks of the individual German states (Länder), the Rhön Club, landscape maintenance associations and local authorities. For example, various marketing strategies were tried to make the care of the cultivated landscape economically attractive. This includes the 'Rhön sheep', a regionally adapted breed of sheep whose meat is marketed together with restaurants as a regional speciality, or the conservation of orchard meadows by a merger of farmers, fruit pressers, innkeepers, mineral water companies and nature conservationists called 'Rhön Apple Initiative'. The proportion of regional produce in catering in the Rhön is 10 per cent and is thus more than twice as high as the national average of 4–5 per cent. The proportion of regional drinks in catering rose within five years from 30 per cent to over 50 per cent (Popp, 1997). Farms, including former collectives, are supported in the conversion to organic farming and new tourism opportunities, such as farm holidays, are being developed. Further training courses, such as 'training women for rural tourism' offer further prospects for second incomes in farming. Alternative sources of energy are being promoted, eg on the basis of regenerative materials from the region.

Within the biosphere reserve there are some considerable conflicts of use: after German reunification the region became attractive as a transit area for long-distance transport routes; hunting, sport and tourism as well as the desire for economic development and the settlement of industry are in conflict with the objective of conserving the diverse cultivated landscape. There are some acceptance problems among the population, which fears that the biosphere reserve will curtail their traditional rights or future income opportunities (Cramer von Laue, 1997). Within the context of a study, it is currently being examined how nature conservation and sport can be brought into harmony in the ecologically sensitive areas of the slopes and hills. With the involvement of the stakeholders, sites are to be sought for flying model planes, hang-gliders and gliders that are acceptable both to the sport of flying and other people seeking recreation as well as to nature conservationists. What is interesting here is the fact that the project was called into being on the initiative of Deutsche Aeroclub e.V. (German aeronautical club), which actively sought the dialogue with the nature conservationists.

A decisive question for the application of the bioregional approach is the institutional relationship to existing plans. The starting points in the various countries are very different administrative role allocations, ecological circumstances and social framework conditions. For this reason, using the examples already shown in Section E 3.9.1, here we will show how the ideas and approaches of bioregional management can be integrated in the existing structures.

There is already a well-developed planning system in many *industrialized countries*. In Germany, for example, this extends from framework Federal Government legislation in the form of the Federal Spatial Planning Act to the various systems of federal state planning right down to local authority planning. Setting up a parallel nationwide system of planning relating to the biosphere with the appropriate institutions, sanctions, connections to the democratic representative bodies, etc would be inefficient, especially since the trend in recent decades has been to incorporate environmental protection and nature conservation and participatory elements into these planning systems.

However, the scope for action to promote the integration of conservation and use objectives should be improved, even in countries with planning systems that work well in principle (Gruehn and Henneweg, 1998). Particularly in the case of areas which do not coincide with administrative boundaries and the planning systems that relate to them, there is a risk that the peculiarities of an ecologically defined region such as the North Sea mudflats or the Rhön region receive insufficient consideration. For this reason, it has proved expedient to define special regions with different boundaries and to give them their own, albeit limited, scope for action (Box E 3.9-4).

For the most part, the existing system of regional planning in industrialized countries has the nature of administrative law. In Germany this problem has been countered in recent years with approaches of 'regional management', which is charged with implementation of the key objectives and concepts for the spatial development of a region right up to specific measures and projects in areas where there is a need for action (Strunz, 1998). In this respect, an important task is assigned to the regional manager, who must have both expertise and good access to the actors in the region so that he can achieve higher-level objectives relevant to the area by consensus-building and gaining acceptance in spite of limited powers. In this respect, attention must be paid to the democratic legitimization and control of the institutions with planning powers. Regional management not only refers to economic and social aspects, but also to ecological reorientation, which is based on integrated environmental protection as opposed to remedial environmental protection (Fürst, 1995). In this respect, it is important that there is a level playing field: interventions for economic purposes and the prevention of interventions or designation of protected areas for nature conservation purposes should bear the same burdens of proof. These responsibilities could be extended as the bioregional management approach takes off, and should be supported by the consolidation and decentralization of the various sectoral funds.

In many *developing countries* a planning system with effective decentralized entities is not yet in place. The option is open from the very outset to set up planning entities geared towards the biosphere. The proposal of bioregional management, presented in Section E 3.9.2, could then be realized directly. Here, first of all, the required capacities will have to be built up in the regions and at national level in order to perform the varied tasks of integrating conservation and use. In most cases, this work requires the establishment of institutions and planning bodies. The specific implementation has to be geared towards the relevant prerequisites and circumstances in the region – there cannot be a cure-all. The most important steps for the start of the regional planning process are shown in Fig. E 3.9-1.

Of course, the two types overlap somewhat; the examples described represent planning extremes. For both types it can be said that bioregional management is brought to bear predominantly in rural areas because it refers to the management of biological resources. It is also important that decisions made at bioregional level do not take place in isolation from the higher and lower levels, but are anchored in them. This becomes especially clear when bioregions span borders and the cooperation of various states thus becomes necessary. The efforts to clean up Lake Constance are an example of a successful form of such cross-border cooperation.

The national and international framework conditions are of major importance to the success of the bioregional approach. Many of the decisions that have an effect at regional level are taken centrally and not locally, or they are taken in policy areas that apparently have no connection to the biosphere. For example, the constant discharge of nitrogen from various sources, such as industry and transport, can cancel out the regional protection and management efforts to conserve rare or species-rich ecosystems (Flaig and Mohr, 1996). In these cases, clear signals and information about such regional effects and the need for action must flow from the regions affected to the superordinate (national or international) levels.

Greater decentralization and shifting of decisions to the regional level as a prerequisite for protection efforts has already been discussed in Section E 3.3.3 (cf Miller et al, 1997) and is recommended at this point, especially in developing countries with a centralized state structure. The Council is in favour of a reinforcement of the regional level as a decision-making body. In this respect, the opportunities that the motivation approach has to offer should be seized for work at the regional level. The diversity of approaches and regional experiments should be promoted along the lines of systemic competition: this also opens up new opportunities for the integration of conservation and sustainable use at bioregional level (Section I 3.3).

Cooperative involvement, the incorporation of stakeholders and the interlinkage of the institutions cannot, however, be implemented overnight. Frequently, it requires effort to gain the trust of stakeholders, whose involvement is desirable within the framework of a comprehensive concept, and individually tailored proposals of participation have to be developed. For this reason, a suitable time horizon should be made available for project financing and evaluation of success: the example of La Amistad (Box E 3.9-2) shows that the time frame of five years targeted within the context of the debt-for-nature swaps was much too short to make sufficient impact on the complex planning process (Section I 3.5.3.2). The Council therefore welcomes the fact that in its sectoral concept on the conservation of biodiversity by nature conservation, the Federal Ministry for Economic Cooperation and Development expressly points out that project terms of 15 years, well beyond the standard time frame, should be the aim for projects of this kind (BMZ, 1997).

There are already successful projects, such as Campfire in Zimbabwe (Section E 3.3.3) that have been able to bring about a measurable increase in previously endangered wild animals by means of a comprehensive management concept that takes account of the interests of the local population. The successful projects are characterized by the fact that

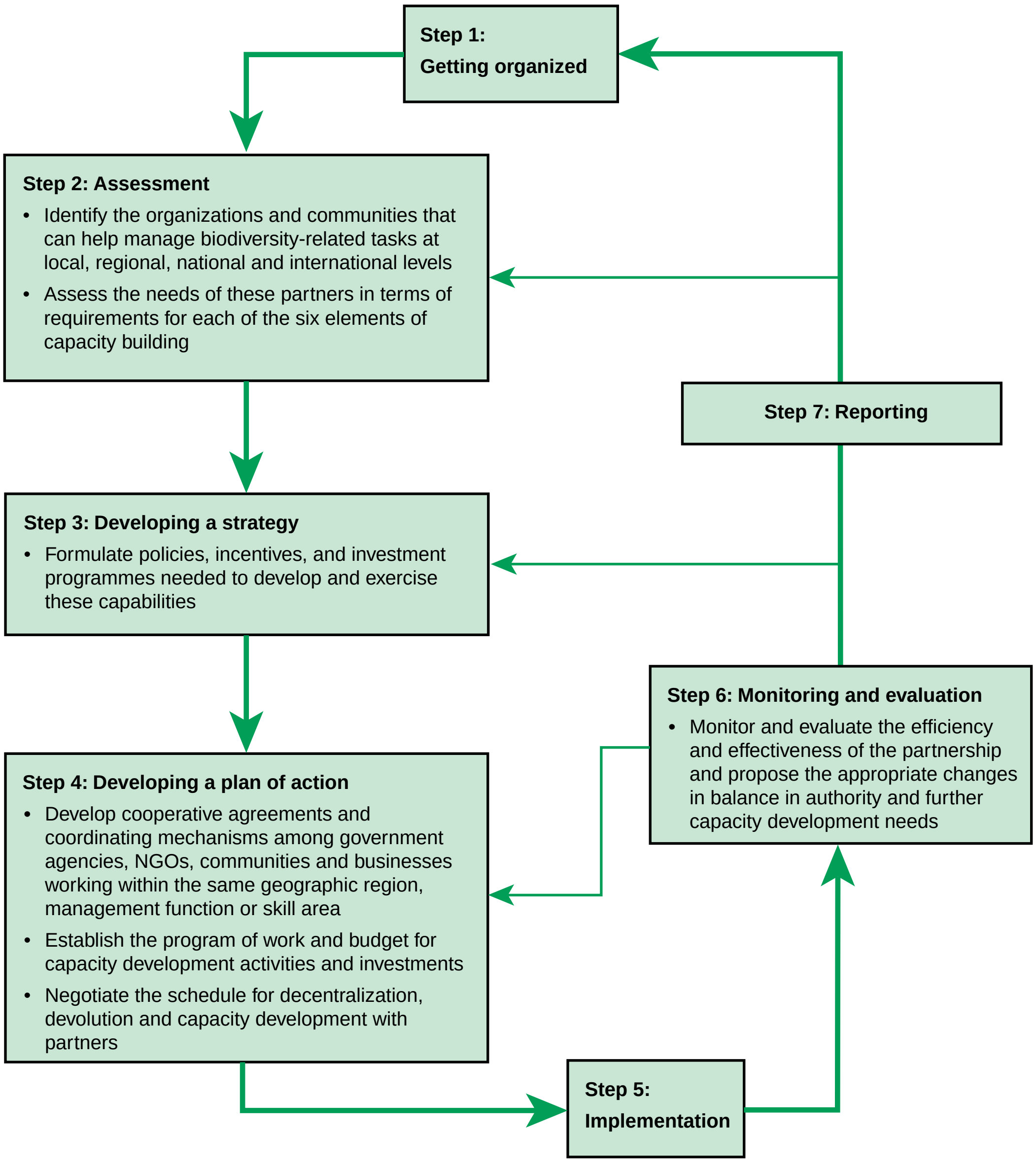


Figure E 3.9-1
Biological resource management in the regional planning process.
Source: Miller et al, 1997

– a large number of groups are integrated in the planning process and independent and responsible action is thus encouraged,
– resistance to efforts for sustainability can be specifically defused via timely conflict resolution strategies,
– nature conservation interests can be linked to the interests of various actors and thus placed on a sound – also economic – footing in the long term (SRU, 1996).

The Council is in favour of this integrative approach since it makes available a pragmatic mix of instruments that can allow implementation of a guard rail concept at regional level. The aim of sensibly linking conservation and use and finding solutions for the varied and, sometimes, contradictory, demands made of ecosystems can undoubtedly be better achieved with bioregional management under suitable framework conditions than with management of bioregional resources decreed 'from above'.

E 3.9.5
Recommendations for action

- The extent should be examined to which the bioregional approach is already sufficiently anchored in the German planning system and whether it can be coupled with a regional management system that extends regional planning and is oriented towards implementation. In this respect, attention must in any event be paid to the democratic legitimization and control of the institutions with planning powers. The Council does not recommend setting up a second planning system in the form of bioregional management alongside the existing planning system. Instead, the fundamental ideas of this approach are to gear the integration of the objectives of conservation and use to the natural conditions and not just to the political and administrative borders, and to incorporate them into the existing planning system. This also includes considerations for consolidating sectorally oriented funds with respect to the conservation of the biosphere, and allocating them regionally.
- Within the context of development cooperation, the options should be examined for integrating the various forms of bioregional management into the concept of rural regional development – and thus into an important instrument of technical development cooperation. In this connection, particular attention should be paid to projects geared to the long term (at least 15 years). When assigning funds, the scope for correcting objectives should be allowed in line with adaptive management principles.
- In nature conservation, large-scale, integrative regional concepts should be given priority over the designation of isolated protected areas (Section E 3.3.2). In the environs of existing protected areas, support should be given to developing buffer zones with corresponding management concepts, as already happens in biosphere reserves.
- Following the model of international urban partnerships, the feasibility should be studied of initiating a programme to promote international regional partnerships between countries of high and low biological diversity, eg initially via a few pilot projects.
- Various financial compensation and incentive mechanisms at national and international level should be tested and evaluated with respect to their effectiveness in promoting bioregional approaches (Section I 3.5). These also include models for financial compensation between regions with a high proportion of land relevant to nature conservation (type 'N'; Section E 3.3.1) and regions with a high proportion of intensive land use (type 'E'), both internationally and nationally. When assigning funds for regional assistance programmes, care must be taken to specify sustainable biosphere management as a prerequisite for eligibility for assistance.

The biosphere in the Earth System F

From BIOSPHERE I to BIOSPHERE III

F 1

F 1.1
Life in the Earth System: BIOSPHERE I

If one could take a look at the planets in our solar system from way off in space, a scientific Sherlock Holmes would immediately be able to diagnose which planet sustains life and which does not. James Lovelock in his early days as a scientist developed this idea when, as part of the NASA programme for early flights to the moon, he was confronted with the analysis or at least the possibility of discovering extraterrestrial life forms (Lovelock, 1998). In response to the key question of what makes our planet so special he found the solution in the facts and data that were already known about our atmosphere. The composition of the atmospheres of the other planets are apparently very similar to one another and are in a particular state of chemical balance: high carbon dioxide levels, small amounts of nitrogen and no methane or oxygen are all clear indicators for abiotic worlds. But the proportions on the Earth are reversed. Relatively high concentrations of methane, nitrogen and oxygen would signal to a visitor approaching Earth that he would find a biotic world far removed from chemical balance. Flora, fauna and microorganisms have not simply left their finger prints in the atmosphere, they also seem to determine its composition to a significant degree. The biosphere is part of the planet's system, with the emphasis firmly on the word 'system'. Incorporated into a complicated labyrinth of feedback loops and compensatory balancing processes, from what we know today, the biosphere influences the composition of the soil and the seas, in addition to that of the atmosphere (Nisbet, 1994). Furthermore, the global biosphere not only regulates biogeochemical cycles, but also seems to move that regulation in a significant direction. This 'Gaia hypothesis' states strictly speaking that life on a planet is capable of controlling its own conditions of subsistence and modifying those conditions to its 'advantage' (Lovelock and Watson, 1982). This hypothesis, which the Council considers debatable, stands for a new way of viewing life on Earth. An important aspect is the cooperation of living organisms in shaping their environmental conditions, a cooperation that does not contradict the natural selection according to Darwin. A large number of studies on specific elements within the Earth's system seem to confirm this hypothesis (Schneider and Boston, 1993). The role of the biosphere in forming and weathering carbonate rock, the most important CO_2 sink, the importance of the albedo of boreal forests or the influence of algae in cloud formation and thus global temperature regulation are just a few examples that reveal astonishing connections.

As a result of their dark colour boreal forests have a strong temperature-regulating influence not just in the Northern regions, but on the world's climate as a whole. The spread of these forests is determined therefore not just by specific climatic conditions, rather they themselves raise the winter and summer temperatures in large areas of the northern hemisphere as a result of their low reflectance. Interestingly, reforestation on the same cleared area might not be feasible since it would possibly be too cold and the water regime might have changed too much.

Even more puzzling is the role of the biosphere in global temperature regulation as influenced by the formation of clouds. Certain clouds raise the albedo and thus lower the intensity of the sun's rays. For a long time it was known that marine algae released a certain substance, dimethyl sulphide (DMS), which, in the form of condensation nuclei, significantly increases cloud formation. Thus, these organisms can lower the temperature particularly in regions with high irradiation and thus high evaporation rates (Nisbet, 1994). It was largely unknown, however, what advantages this relationship brought in terms of the evolutionary process. Only recently Hamilton and Lenton (1998) demonstrated that cloud formation also generates an updraft that allows the algae to rise up in the vortex and spread out over large areas 'by air'. This phenomenon gives the algae enormous competitive advantages and is possibly also advantageous for the stability of the entire Earth System.

It seems therefore that this type of win-win combination is given preference in the evolutionary process. Individual advantages as a result of changed environmental conditions seem only to be advantageous in the long term if others to which there is a relationship of dependency also benefit. The network of interactions and linkages between the biosphere and the environment is therefore important for understanding the living conditions on Earth. How did this system of coevolution of life and the planetary environment develop? Answers to this key question can probably only be given for artificial, reconstructed 'worlds' that as complete systems provide a platform for this type of system analysis. Such systems are intended to simulate BIOSPHERE I, ie the ecosystem not yet disrupted by humankind.

F 1.2 A constructed environment: BIOSPHERE II

The idea of an artificial world created by man as a closed and autonomous station that sustains itself and provides all necessary resources for humankind is not new. This vision is pictured in forms that range from the Garden of Eden to Noah's Ark through to ideas of sustainable development that are meant to enable the life (and survival) of man in a harmonious relationship with creation. And in the search for survival options on other planets, space travel has planned concrete projects to this end. One of the best known projects is BIOSPHERE II, an experiment that emerged in the Arizonan desert. It was created as the smallest possible biosphere that was self-regulating and inhabitable by man. The system should be compact enough to be managed, but sufficiently complex and diverse to serve as a reasonable laboratory for the investigation of natural ecosystems. Two main goals were set: first of all, to investigate biogeochemical cycles in closed systems that have a significant influence as regulatory processes on the inhabitability of a planet and secondly to gain a deeper understanding of the possibility of human survival in permanent balance with the biosphere (Kelly, 1994).

F 1.2.1 How much nature does a civilization need?

The most obvious, but probably most trivial strategy for creating an artificial biosphere is to include a miniature replica of each ecosystem and each climate zone. The questions 'How much nature is necessary for survival?' or 'What kind of nature is necessary from a human standpoint?', if one could answer them, would probably have led to a different construction principle. For the design of BIOSPHERE II, however, the global biosphere constituted the model that one hoped to approximate as fully as possible. On an area of 1.6 hectares, hermetically sealed, five natural and two artificial habitats were created: tropical rainforest, savannah, desert, swamp, sea, an area with intensive agriculture and a living and working area for eight inhabitants. Of course, in an experiment of this sort not every detail can be incorporated. An artificial geosphere is as impossible to realize as would be glaciers or large ice-covered regions. However, the endeavour was to come as close to the model as possible. In the rainforest, for example, a more than fifty meter high mountain was constructed on which fog machines produced a realistic mist veil and a river with a waterfall created the illusion of a real tropical mountain forest.

F 1.2.2 Constructing balance and its limitations

Whereas on Earth (ie in BIOSPHERE I), climatic and hydrological cycles were driven by the sun, these environmental conditions could not be created in BIOSPHERE II. A high degree of technical input with cooling, heating and pumping systems was designed to at least reproduce the most important aspects of the environmental conditions on Earth. A salt water sea with a volume of 250,000 litres, drainage systems, additional water reservoirs and a host of sprinkler systems and mist machines demonstrate what sort of effort is required to 'make weather'. One should not forget that precipitation and temperature had to be prepared for the various ecosystems. A large number of monitoring and control systems were therefore used to maintain all of the major environmental parameters such as temperature, humidity, air and water quality within the specific levels required. At the same time, these devices also made it possible to permanently store the environmental data. A 'sniffer system' consisting of over 1,200 sensors took air and water samples every 15 minutes. In that way all developments could be reconstructed. They thought they had thought of everything, but of course it turned out differently. The good news was that the air quality was better than in a space craft. The bad news was that no one knows why. The assumption was an unknown microbial mechanism. But that was not the only unusual message. The carbon dioxide levels in the air behaved completely erratically. The highest concentrations recorded of up to 3,800ppm were not threatening to the life of the inhabitants of BIOSPHERE II, in a submarine up to 8,000ppm is admissible, but they were concerned about the so painstakingly created coral reef since carbohydrate dissolved in water breaks down lime as carbonic acid. The oxygen concentration fell from 21 per cent to 15 per cent, a level to which the inhabitants of Lhasa (Tibet) are accustomed, but which would cause a North American difficulties. Tiredness and lethargy were the consequence. The question now was, what happened to all the oxygen? (Even in Biosphere I the oxygen cycle is not fully understood; Kelly, 1994). Overall, Biosphere II seemed to be collapsing. Since the insects as pollen carriers were not surviving, important crop plants were dying. 19 of the 25 species of vertebrates became extinct. The clear winners were the cockroaches and busily multiplying ants. The desert became steppe, the ocean dead sea and the eight human inhabitants lost a great deal of weight.

The conclusion of this experiment is that currently, no one knows how to construct stable, life-sustaining systems that are characteristic of the natural terrestrial ecosystem. Salt water aquarists are familiar with the problem. Even in that mini biosphere it can take months to form stable microbial food chains and harmonize the communities. For a long time there is imbalance, fish or plants die, putrid gases form. The system meanders until apparently all of a sudden and without cause it 'locks in' and is stable. There is no recipe so far of how to achieve this more quickly or possibly in a more controlled manner. Just like the aquariums there is only one thing to do: do nothing and wait. Possibly, this is a trivial insight, but one which may be transferable. In Biosphere II they did exactly the opposite. When things became critical, the attempt was made to control events, for example, by lowering the temperature (in order to store carbon dioxide in sea water) or changing the pH values. All possible environmental levels were tinkered with to stabilize the system and possibly it was precisely those actions that prevented stabilization.

Whatever the case, in the wake of that experiment, the ability of life in Biosphere I to control its environmental conditions for its own well-being can be seen in a completely new light. The key to understanding 'pre-stabilized harmony' in the Earth's system and the failure of Biosphere II may well lie in more recent research on the Gaia hypothesis.

F 1.3
A closer look at Biosphere I

The essential difference between Biospheres I and II is certainly not the composition of the two systems. The structure of the regulatory systems seems much more significant. In the case of Biosphere II the adjustments of the environmental levels took place via simple regulatory systems. The principle of variance compensation of individual variables as a rule only takes into consideration to a small degree linkages between the correcting variable. In light of the large number of regulatory levels and the associated degrees of tolerance, however, such a system is extremely difficult to stabilize. Particularly, if no detailed climate or more general environmental model is available that would allow for a short-term prognosis, intervention on the principle of trial and error can have disruption rather than balance as the outcome and lead to fatal consequences.

F 1.3.1
Homeostasis as a fundamental regulatory principle

In our natural environment, however, homeostatic principles appear to dominate. Homeostasis means in this instance that a system controls itself to achieve balance and remains within a limited stable area (Rampino, 1993). Minimal disruptions do not change the character of the system because they can be neutralized. This observation demonstrates parallels to physiological systems: temperature regulation in the human organism as a physiological system demonstrates the phenomenon of homeostasis. There is no objective target temperature, rather the participating processes are linked to one another via negative feedbacks with the result that they more or less automatically establish a stable balance. A simple model by Watson and Lovelock (1983) aims to illustrate this effect. Picture a planet that is covered exclusively in black and white daisies. Their growth rate reduces as temperatures rise. At a given level of solar radiation the black daisies effect a higher temperature than the white ones as a result of their colour. If the rays lessen, however, the probability of the black daisies reproducing falls as the temperature rises. The more reflective white daisies are therefore more competitive and increase. The overall temperature of the planet remains more or less constant. The relationship between black and white daisies may be said to adapt in a self-organized manner to the increased radiation levels and regulates the disruption into non-existence. But if the planet were just an uninhabited lump of soil, it would warm up as the sun warms up. The competition between black and white daisies in the form of a Darwinian selection process therefore results for the individual in the possibility of controlling its environment together with other individuals. From this fundamental idea of 'Daisy World' far more complex and realistic models may be formed which show the homeostatic capacities and improve them (von Bloh et al, 1997). Self-regulation is therefore an extremely robust principle.

F 1.3.2
The metabolism of the Earth System

Seen in that light, the particularities of the Earth's atmosphere mentioned at the beginning may now be explained. Except for the inert gases, all other components are regulated by a complicated interaction of biological and geological processes. Photosynthesis plays a very important role in that context. The 'waste product' of this process, oxygen, is the second most important element in the atmosphere by about 20 per cent. This proportion is maintained at astoundingly constant levels. At an oxygen concentration below 15 per cent even dry wood will not ignite. But at levels over 25 per cent a rainforest will catch fire (Nisbet, 1994). Interestingly enough, nitrogen is involved here, too. It is fire retardant and protects plants. At the same time its 78 per cent share in the atmosphere also appears astonishingly stable: nitrogen fixing and nitrogen releasing processes hold one another in balance. Above all bacteria, but also processes such as lightning, fix nitrogen and other bacteria then release it. But the release is very important: all food chains on land and in the water are dependant on the availability of nitrate. Without this Gaia metabolism the nitrogen concentration in the atmosphere would reduce distinctly over the course of several million years.

This is, however, just one small slice of the physiological-metabolic interplay that goes on in the Earth System. The concentration of oxygen is closely linked to that of carbon dioxide and phosphorus. More carbon dioxide would increase the oxygen levels via photosynthesis and thus increase the possibility of forest fires. This would result in a negative feedback that would stimulate algae growth in the seas through the release of phosphorus from the land's biomass and at the same time defunct biomass would be deposited more quickly on the sea floor. From this withdrawal of phosphorus and the lowering of carbohydrate content in atmosphere the original ratios would be re-established.

Phosphorus itself is a limiting factor for the biosphere, but one which when sufficient carbon dioxide is available can possibly be 'harvested'. An increase in the amount of carbon dioxide in the air leads via the greenhouse effect to increased precipitation that can above all speed up the erosion of minerals both chemically and biologically (via the increased activity of soil organisms and plants). The erosive process then in turn releases nutrients (eg phosphorus, sulphur) that further increase the activity of the biosphere until the atmospheric carbon dioxide levels are re-established. From what we know today, this closed-loop cycle appears primarily to have an effect over long time scales in the form of a biologically moderated silicon-carbon cycle (Berner et al, 1983), and not just to determine the 'life expectancy' of Gaia, but also appears to have controlled its early development (Franck et al, 1998). It is known that the sun in its early phase radiated about 30 per cent less energy than it currently does. Given the same atmospheric conditions, the Earth would have been an ice planet then that would never have thawed because of the high reflectivity of ice. At low solar radiation levels the silicon-carbon cycle however stabilizes a higher CO_2 concentration in the atmosphere thus ensuring through the greenhouse effect that the oceans flow and the hydrological cycle continues (Walker et al, 1981). And above all, the latter is extremely important for the metabolism of Gaia: almost one quarter of the energy absorbed by the Earth System is used to drive the water cycle which – note the clear analogy to the living organism – produces nutrients for the biosphere, distributes them globally and makes them able to be absorbed, and regulates the energy regime by distributing thermal energy globally and directing energy to certain regions while keeping others cool with the help of clouds (Volk, 1998). The analogy to the living organism is self-evident. A host of organisms participate in each part of this terrestrial air-conditioning system: the sun may be the driving force, but it is controlled and structured by biological control mechanisms.

It appears that evolution has not just kitted out individual species with harmonious, self-stabilizing physiological regulatory processes, but the entire biosphere also. This should not in any way be taken as an all clear for the greenhouse experiment 'staged' by humankind. Minimal fluctuations and disruptions can be regulated very easily it seems by the Earth System. But simple geo-physiological models show that there is a limit to the disruption beyond which homeostasis is overwhelmed and apparently collapses without prior warning. We do not know how far we are still away from that point and only know a handful of the less important regulatory elements. The International Geosphere Biosphere Programme (IGBP) has for this reason made analysis of these aspects a central research focus. The biological aspects of the (global) hydrological cycle or the analysis of biogeochemical metabolic and energy cycles are in activities within this international joint programme that, in the light of the Gaia theory, should provide additional key information towards understanding the Earth System.

F 1.4
Towards global control: Biosphere III

With hindsight, the essential failure of the Biosphere II experiment was anything but a surprise. The physiological and metabolic complexity of Biosphere I, which was given a broad-brush outline in the last section, is after all the result of thousand millions of years of evolution in the interaction of opportunism and functionality. Spurred on by variously intense external and internal disruptions somewhere between the two extremes of chance and purpose, a system has organized itself that, perhaps, is only possible just once in the entire universe.

Despite the failures, NASA is pushing forward under its CELSS programme (Controlled Ecological Life Support Systems) to develop artificial agricultural ecosystems that are intended to secure maximum food production in extra-terrestrial conditions (Volk, 1996). And 'geo-engineering', the science that is seeking to 'repair' the unintentional ecological faux pas of the industrial society (such as the thoughtless release of CFCs and CO_2) on a grand scale, can already look back on initial successes. For example, fertilizing the tropical ocean west of the Galápagos Islands with just 500kg of iron sulphate triggered a large bloom of algae (Coale et al, 1996). This demonstrated that the marine 'biological pump' can be strengthened in a targeted fashion to precipitate carbohydrate from the water column (at least for a short period).

The quality of such experiments to control habitats is still very low, but is there really an alternative to progressing on the road to Biosphere III, a controlled global environment? Humankind is already rebuilding the planetary ecosystem with rapidly growing depth and scale of intervention, so far it has to be said without any kind of comprehensive blueprint! For example, in Biosphere I approx 40 per cent of the area able to sustain vegetation is covered with forest (Burschel, 1995; WRI, 1997); this proportion has shrunk in the landscapes shaped by humankind to a current average of some 27 per cent (FAO, 1997b). And the great CO_2 atmosphere enrichment experiment 'staged' by the burning of fossil fuels will ultimately impact the biosphere less *indirectly* through the 'side effect' of climate change, but more *directly* through the overfertilization shock.

Compelling evidence for the CO_2 fertilization effect is the observation that the annual respiration of planetary life is becoming deeper (Box F 1.1-1). The impact on the composition of terrestrial ecosystems as a result of changed competitive conditions cannot be predicted clearly, but will no doubt be considerable. The older C_3 plants (which include wheat and rice), older in terms of evolutionary history, have adapted in an optimum fashion to the carbon-dioxide-rich atmosphere and could deny the 'younger' C_4 plants (such as maize, sorghum and sugar cane, but also many natural grasses) of their place in the rankings in terms of nutrient use. This tendency is however countered by the fact that a warmer ambient temperature tends metabolically to favour the C_4 plant (Taiz and Zeiger, 1991; Monson and Moore, 1989).

There is much that would speak in favour of transferring this largely erratic process into a well controlled process in the sense of biosphere governance, just as at the latest with the advent of the Kyoto Protocol, management of the Earth's atmosphere became a project of the modern age. But what would that type of governance be like? A grand typology of possible strategies can be sketched out in advance. There are three main roles from which humankind must chose: the role of the preserver ('Noah'), the nurturer or steward ('curator') and the shaper/architect ('demiurge'). The modern Noah would not just try to save all species in creation, but also every type of landscape and ecosystem, too. The biosphere curator, mindful of his responsibility, would carefully and after great thought select or transform individual elements from the existing biotic world. The demiurge of the Third Millennium would by contrast try as an architect to 'improve' the biosphere and its conditions of subsistence – ameliorative aspirations ranging from key agrarian plants to a global land use concept.

Proponents of the demiurge principle are ultimately motivated by the insight that today's biosphere is only operating at around 30 per cent of its true potential as a photosynthetic energy reservoir (Volk, 1998). As indicated above, this could change very quickly, if the industrial society understood how to make intelligent use of the combination of human-induced environmental trends, CO_2 enrichment in the atmosphere, nitrogen enrichment in ecosystems and global warming. The American agroscientist S B Idso waxes lyrical at such thoughts: '... for we appear to be experiencing the initial stages of what could truly be called a *rebirth of the biosphere*, the beginning of a biological rejuvenation that is without precedent in all of human history, but which is not atypical of great periods of our geological past, where the CO_2 content of the atmosphere was several times greater than it is today. Biologically speaking, those bygone eras of high CO_2 were truly "the good old days" [...] Fortunately for us, and for all of the other life forms with which we share the planet, the mounting array of evidence [...] suggests that humanity may well be in a course that will carry us back to such

Box F 1.1-1

The breathing of the biosphere

The famous Mauna Loa Curve (Fig. F 1.1-1) shows how under the influence of an industrialized society, the CO_2 content in the Earth's atmosphere is increasing almost exponentially.

The clearly visible long-term trend is modulated by annual oscillation of 6ppm amplitude on average, as is clearly seen if the curve is sufficiently enlarged (Fig. 1.1-2). This oscillation is a spectacular expression of the 'living' planet Earth. When the vegetation in the northern hemisphere begins to grow in the springtime, it consumes so much CO_2 from the air that the CO_2 concentration in the air is reduced by several ppm. In the autumn, when a large part of the plant tissue produced in the summer dies off or rots (eg the leaves from many trees), sufficient CO_2 is released to more or less offset the springtime loss.

A closer analysis of the Mauna Loa data (Keeling, 1994) reveals that the seasonal 'inhalation' and 'exhalation' by the biosphere is becoming more and more pronounced with the long-term increase in atmospheric carbon dioxide levels (Idso, 1995). Fig. 1.1-3 shows that the 'breath of planetary life' has become about 20 per cent stronger in the last few decades. This is probably a consequence of the combined carbon dioxide-nitrogen fertilization effect due to unabated material inputs into ecosystems from the anthroposphere.

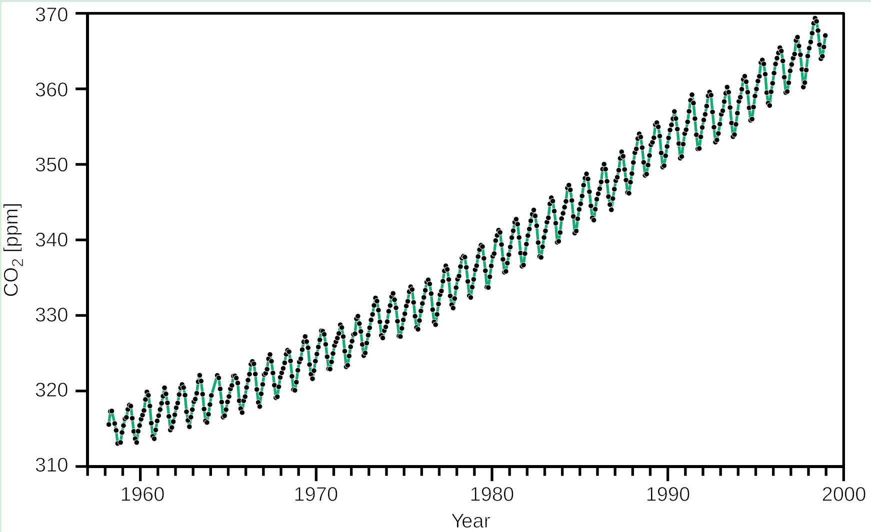


Figure F 1.1-1
CO_2 concentration in the atmosphere of Mauna Loa (Hawaii).
Source: Keeling and Whorf, 1999

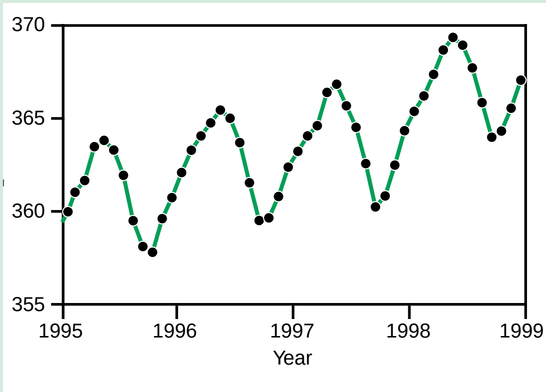


Figure F 1.1-2
CO_2 curve on Mauna Loa, Hawaii, for the 1994-1998 period.
Source: Keeling and Whorf, 1999

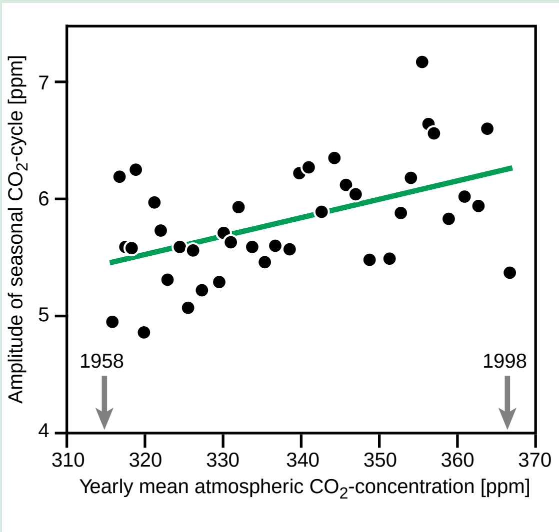


Figure F 1.1-3
Increase in the 'breath of planetary life'.
Source: WBGU (data from Keeling and Whorf, 1999)

times ... back to a more productive future' (Idso, 1995).

This assessment, which the Council views as unrealistic, cannot be lent serious consideration on the knowledge we possess today. But even if biosphere governance were to contain elements of the demiurge strategy (and certain elements would speak in favour of that), then these elements should be implemented with less heart and more calculated reason. The debate on this very issue has already begun (Schellnhuber and Kropp, 1998; Schellnhuber, 1998).

F 2 The global climate between forest and desert – two extreme scenarios

Given its control over the processes on the surface of the land and seas, the biosphere is a central factor in the global climate system. The biosphere influences climate in that it regulates the water balance, thermal balance and the balance of radiatively active (ie climate-relevant) gases (WBGU, 1998a). In the following, the importance of the biosphere for atmospheric circulation and the Earth's climate will be demonstrated using two hypothetical and extreme model scenarios: complete lack of biospheric control of the land surface is represented by the 'Global Desert' scenario, maximum control by the 'Global Forest' scenario.

F 2.1 Interaction between biomes, atmosphere and climate

The climates of the Earth (Köppen, 1923) can be characterized by the broad-scale distribution of the natural biomes adapted to the given soil and climate (vegetation types) (Box F 2.1-1; WBGU, 1994). On the other hand, biologically controlled processes and parameters of the land's surface such as degree of forest coverage, leaf area index or soil water storage capacity also influence the climate. Unlike the surface of the sea, the climate-relevant characteristics of the land surfaces are dominated by the biosphere; eg land surfaces only demonstrate similar energy balance and evaporation to the sea surfaces if there is sufficient access to soil water. The biologically controlled parameters are generally interdependent and represent different aspects of vegetation.

The aims of linking biosphere and climate models consist in being able to represent changes in the geographic distribution of vegetation as a result of climatic changes, record the main influencing factors that affect the interaction between biosphere and climate and evaluate quantitatively the influence of the biosphere on climate. The linkage between biogeographical and atmospheric systems on varying scales (Gutman et al, 1984; Henderson-Sellers, 1993; Claussen, 1994; Foley et al, 1996) provides insight into the importance of the biosphere for the circulation of the atmosphere and the global hydrological cycle. In that respect the biosphere may influence cli-

Box F 2.1-1

Biomes

The coincidence of the geographic distribution of plants and climates is an old observation from plant ecology, vegetation geography and climatology on the basis of which a classification of various global formations of vegetation – now expanded ecologically to be termed 'biome' (Section E 1) – emerged. On the basis of Köppen's climate classification (1923) numerous models and schemes to divide the Earth into delineated biomes were developed further where the borders of climate zones were equated with the borders of potential natural vegetation types. Biomes offer the opportunity to analyse the biosphere on a global scale in a structured manner and allow the regional 'assignment of processes and balances' (WBGU, 1994). The relevance of the close connections between plant growth and the regional distribution of certain species on the one hand, precipitation, temperature and air humidity on the other, led above all in light of global climate change to numerous attempts to introduce biomes as integral parts of climate models. In that context both the influence of climate change on vegetation zones and the impact of biosphere elements on the climate system are analysed (eg Prentice et al, 1992; Foley et al, 1996; Claussen et al, 1998).

Biomes are defined as a grouping of terrestrial ecosystems according to the dominant plant type in each case in order to model the reciprocal influence of climate and biosphere on the global scale and make prognoses regarding global environmental change (Prentice, 1998). In further developed biome models the terrestrial biosphere is made up of bio-physical, physiological and ecological processes with their respective developmental timelines.

The influence of humans in the zones used most for agriculture reduces the capacity of the models in relation to real vegetation in these regions, ie for these regions they only show a climate-dependent, potential natural vegetation.

mate to a greater extent than has been assumed until now (Foley et al, 1996; Section F 1).

Sensitivity analyses of these linked systems show that current biome distribution and extension clearly correlate with the current climate and that this is relatively independent of the original geographical situation, with the exception of West Africa and the Southern Sahara (Claussen, 1998). However, most studies concentrate either on individual processes (also in the paleoclimate) or regional aspects (cf review by Pielke et al, 1998), such as the deforestation of the Amazon region (Henderson-Sellers, 1993), the boreal forests (Bonan et al, 1992), the change in soil albedo in sub-tropical savannahs (Charney, 1975), evaporation (Shukla and Mintz, 1982), water storage capacity (Milly and Dunne, 1994) or the root depth of vegetation (Kleidon and Heimann, 1998). There is now some knowledge with regard to short and long-term interaction between vegetation and atmosphere, hydrological and metabolic cycles and the energy and radiation levels. Furthermore, the man-made impact through such activities as overgrazing and desertification can also be felt. Only few studies are looking at the connections between vegetation and climate system on a global scale.

Mechanisms and feedback effects

Plant cover modifies the global energy and water balances by means of two main effects (Fig. F 2.1-2): (1) Plants and forests, compared with land surfaces with no vegetation, effect higher transpiration since they draw on soil water and groundwater and (2) they absorb more solar radiation because of their lower albedo. Both mechanisms work together and (3) increase evapotranspiration at the Earth's surface. The direct consequences of this are (4) a reduction in surface temperatures and (5) an increase in humidity in the atmosphere. Three feedback effects from the water and radiation balance of the atmosphere change the direct impact of vegetation: (6) The hydrological cycle is increased through greater humidity in the atmosphere; it favours cloud formation and precipitation and can therefore lead to more evapotranspiration in arid areas. (7) An increase in humidity and clouds also increases the long-wave counter-radiation of the atmosphere and thus the water vapour-induced greenhouse effect. (8) The radiation available at the Earth's surface also

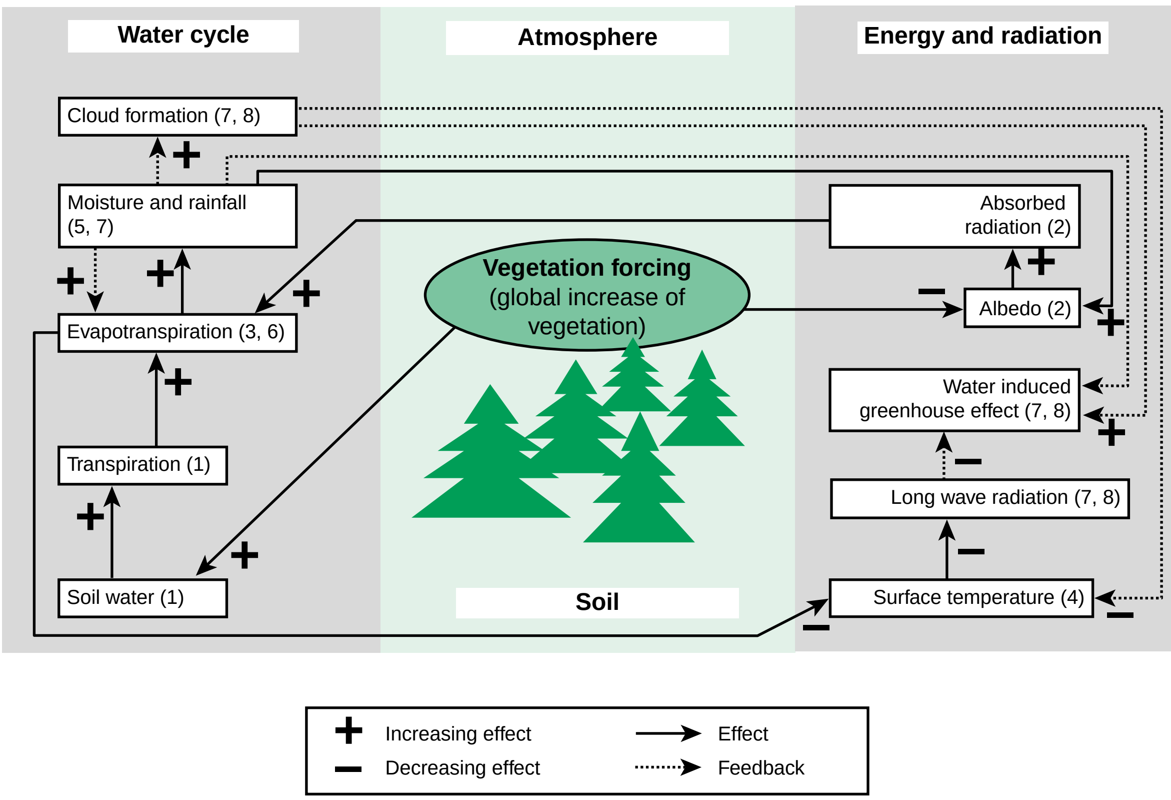


Figure F 2.1-2
Mechanisms and feedbacks between biosphere and atmosphere. Numbers are explained in the text.
Sources: WBGU and Meteorological Institute Hamburg

changes: superficial cooling is caused by lower solar radiation penetrating the clouds and higher evaporation. The cooler surface lowers the long-wave radiation of the soil and thus substantially attenuates the water vapour greenhouse effect. Both feedback effects work contrary to one another but as a whole vegetation reduces the greenhouse effect (Fig. F 2.1-2).

F 2.2
The biosphere between forest and desert: a simulation

The Hamburg-based climate model ECHAM 4 is used (Roeckner et al, 1996) to evaluate the maximum effect that vegetation can have on the atmosphere (Fraedrich et al, 1999) and on the processes at work on the land surface (Kleidon et al, 1999). It is a model that simulates parts of the Earth System in high-resolution detail. To that end, maximum ('Global Forest' scenario) or absent ('Global Desert' scenario) biospheric control are ascribed to the continents. Integral components of the climate models are parameterizations of physical processes at the land's surface. They describe the interaction between atmosphere and subsoil through the exchange of heat, water and momentum. For instance, the water balance of the ground includes surface run-off, but does not take into consideration site-specific inhomogeneities, slow or fast drainage dependent on the water levels in the root regions of plants or the overall evapotranspiration which in turn comprises the evaporation of snow, uncovered soil, transpiration of vegetation and the evaporation of water in the tree crowns (WBGU, 1998a). In detail, the following surface parameters characterize the influence of the vegetation in the climate columns that form each of the grid points in the global model: (a) background albedo, (b) forest fraction, (c) vegetation cover, (d) leaf area index, (e) roughness length and (f) soil water storage capacity. Each climate column at a grid point represents a surface of approx 2.8° x 2.8°; communication one with another is performed by atmospheric circulation. The one extreme, the 'Global Desert' scenario, is made up of desert features with its bright, even surface and the low capacity of desert soils to store water. The second extreme, the 'Global Forest' scenario, is made up of parameters that correspond to a high net primary production of vegetation as found in the tropical rainforests (with dark, rough and evaporating surfaces). The 'Global Forest' scenario is characterized by an albedo of 12 per cent, 100 per cent vegetation and forest cover, a leaf surface index of 10, 2m roughness and optimum water storage capacity. The following set of parameters makes up the 'Global Desert' scenario: albedo of 28 per cent, vegetation and forest cover, leaf surface index and roughness are all zero and soil humidity was ascertained on the basis of 10cm deep soil and the global data set of water availability of plants according to Batjes (1996). In the Global Desert scenario there is no biospheric control of the land's surface at all, whereas this is at the maximum level in the Global Forest scenario. The biosphere is seen in the sensitivity analysis as a comprehensive, global entity and no differentiation is allowed according to differing biomes. The features and strength of its control over the phenomena of the land's surface are therefore represented on a scale that ranges from 'no biospheric control' to 'maximum possible control'. The features of the land's surface for the two extremes form the input for the two climate simulations. These allow a quantitative evaluation of the impact of the biosphere on the climate system. In the following discussion the Global Desert scenario has been chosen as a reference point and the difference expressed as Global Forest scenario minus Global Desert scenario is intended to demonstrate the extent of the extremes.

The results show that the global hydrological cycle in the Global Forest scenario is significantly more active over land than in the Global Desert scenario: Precipitation is approx 100 per cent higher, evapotranspiration approx 250 per cent greater and median atmospheric humidity is around 30 per cent higher over land (Fig. F 2.2-1a). The highest levels are to be found over the continental regions of the tropics and during the summer in the more temperate latitudes (Fig. F 2.2-2b).

The substantial increase in evapotranspiration in the Global Forest scenario is linked to a reduction in the sensible heat flux by 30 per cent and thus changes the energy balance at the Earth's surface. Thus, the Bowen ratio (sensible heat flux to evapotranspiration) falls over the land regions from 1.25 to 0.12 with the effect that the land and ocean surfaces adjust to match one another. As a result, evapotranspiration in the Global Forest scenario leads to a cooling down of the Earth's surface by around 1.2°C over land with the highest cooling rates of up to 8°C in the tropics and up to 6°C in summer in the mid-latitudes (Fig. F 2.2-2a). The solar radiation absorbed at the Earth's surface only increases insubstantially, by less than 5 per cent. This small difference is a result of the increased cloud formation (+16 per cent) that emerges as a negative feedback effect. Since the long-wave radiation of the surface falls by around 30 per cent, the available radiation balance at ground level increases considerably. This strong reduction in thermal radiation (and the associated temperatures) which emerges as a difference between forest and

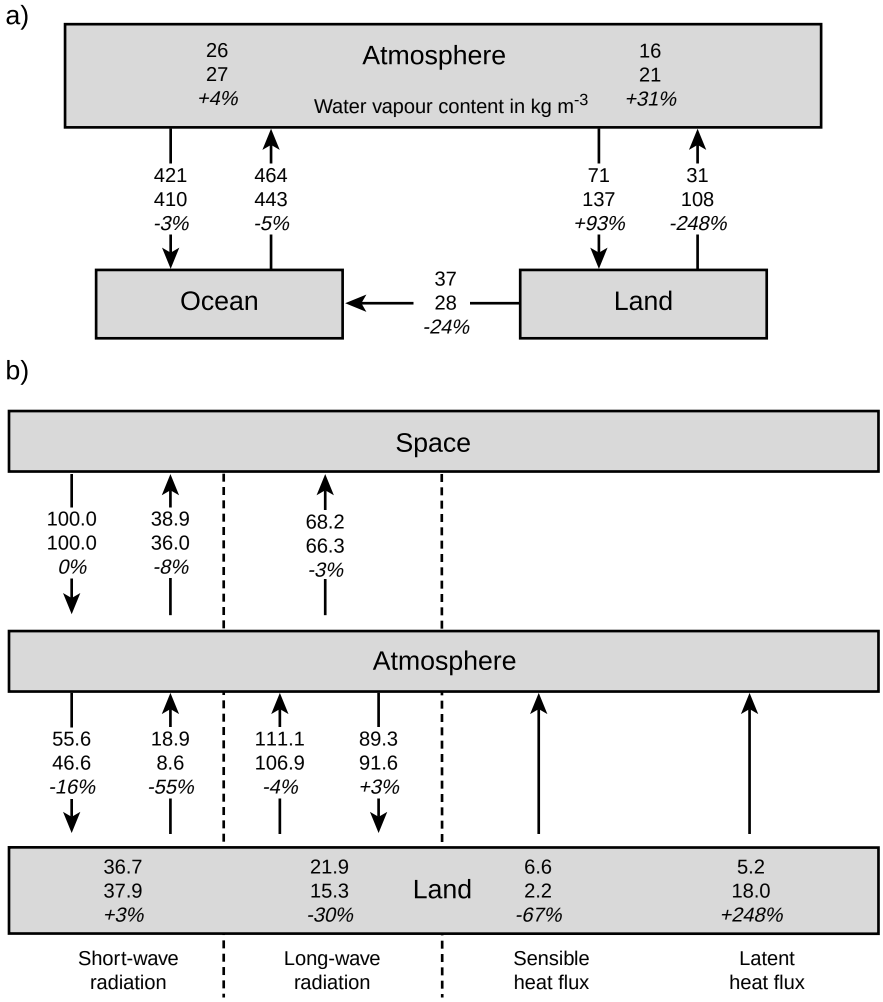


Figure F 2.2-1
a) Global hydrological cycle in 10^{12} m^3 year^{-1}
b) energy levels over land as a proportion of solar irradiation (100 per cent = 341.3W m^{-2}) for climate simulations with and without vegetation control of the processes on the land surface: 'Global Desert' scenario (upper figure), 'Global Forest' scenario (middle figure) and the difference between the two (in per cent, lower figure). At maximum biospheric control, evapotranspiration is three times as high, precipitation on land is twice as high and temperatures close to the surface are reduced over land by 1.2°C. Source: after Fraedrich et al, 1999

desert comes about as a result of the increased ability of the soils to store humidity and release it in drier times. Furthermore, there is the increased radiation balance at the surface that is available for evapotranspiration (Milly and Dunne, 1994; Eltahir, 1998).

The differences between the two extremes can be understood through the mechanisms described above as a direct consequence of the change in evapotranspiration. They are particularly striking in regions and in times of maximum solar radiation (summer) (Fig. F 2.2-2c).

Atmospheric circulation is influenced considerably by increased levels in the hydrological cycle: Increased evapotranspiration increases the Hadley circulation in the Tropics (tropical cell in which warm air masses rise at the Equator and lower in the Subtropics) and leads to a general warming of the mid troposphere in the sub-tropics (by around 5°C). The increase in the North-South temperature gradient associated with that phenomenon increases the intensity of the mid-latitude West wind drift. Consequently, the East-West asymmetry is reduced in the quasi-permanent high and low-pressure areas. These global changes in atmospheric circulation cause regional and seasonal weakening of the Aleutian Depression, warming in Eastern Asia and cooling in Alaska (Fig. F 2.2-3). Furthermore, the influence of the forest on the snow albedo leads to large-scale warming in the boreal regions during the Spring that is in part compensated by Summer cooling. Overall, a warming is noted in certain extra-tropical regions in the middle of the year.

Maximum influence of vegetation on the CO_2-induced greenhouse effect

The atmospheric greenhouse effect is weaker in the Global Forest scenario than in the Global Desert scenario because the layers of near surface air cool off more and the troposphere is more stable. The greenhouse effect can be quantified by calculating the difference in terrestrial net radiation between the upper and lower borders of the atmosphere (land

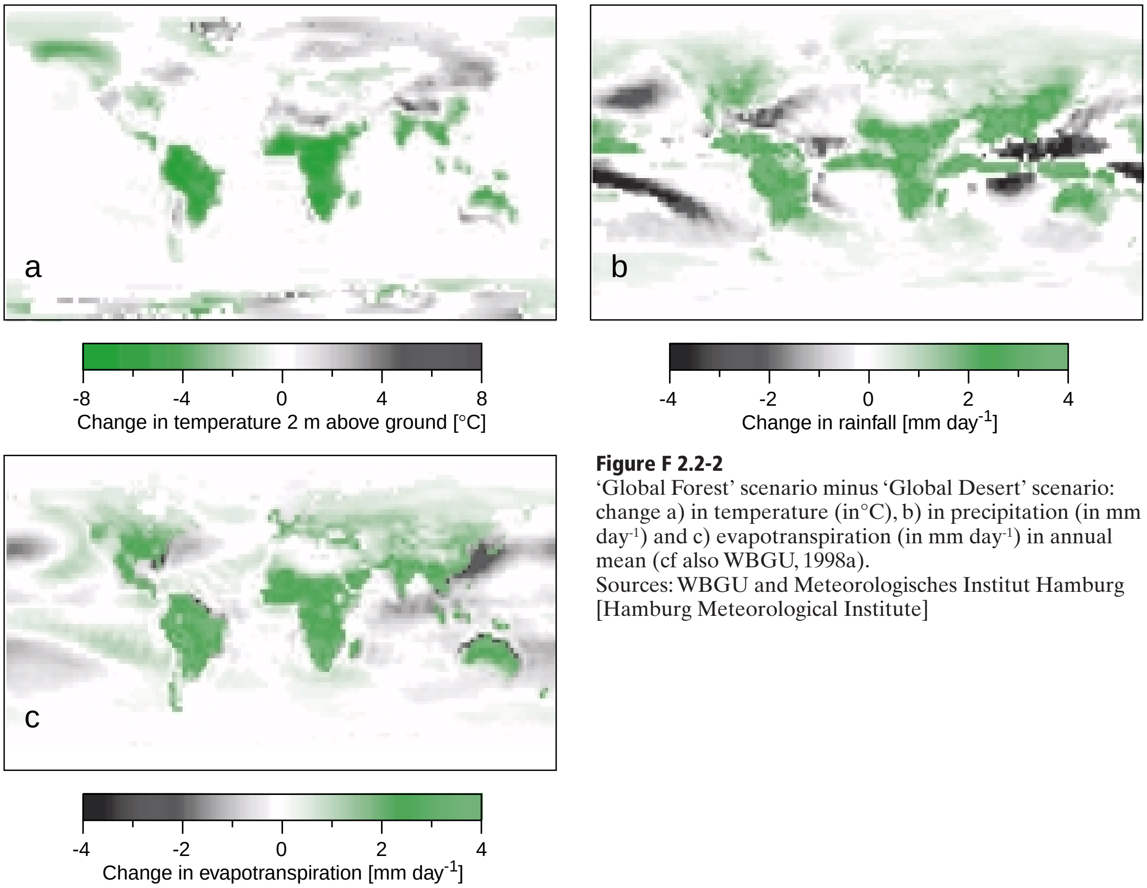


Figure F 2.2-2
'Global Forest' scenario minus 'Global Desert' scenario: change a) in temperature (in°C), b) in precipitation (in mm day^{-1}) and c) evapotranspiration (in mm day^{-1}) in annual mean (cf also WBGU, 1998a).
Sources: WBGU and Meteorologisches Institut Hamburg [Hamburg Meteorological Institute]

and ocean). For the Global Forest and Global Desert scenarios this difference is 160.3W m^{-2} and 163.7W m^{-2}. The maximum vegetation reduces the greenhouse effect therefore by 3.4W m^{-2}. This figure is comparable in scale to the increase of the greenhouse effect when the concentration of CO_2 is doubled, that is 2.6 to 7.9W m^{-2} (Kleidon et al, 1999). The calculated effect of maximum vegetation may possibly in part mitigate CO_2-induced warming, as calculated in the IPCC scenarios (IPCC, 1996a).

Possible influence of the oceans

In this experiment the annual variability of the sea surface temperatures is set in accordance with our current day climate. The energy balance in the Global Forest scenarios demonstrates an imbalance in the thermal exchange between the oceans and the atmosphere. The oceans compared to today's climate experience a net gain of $1.2 \cdot 10^{15}$ W. By contrast, the oceans in the Global Desert scenario show a loss of $0.6 \cdot 10^{15}$ W. The high regional differences between the two scenarios, up to 100W m^{-2} along the Western boundary currents, can be explained by the transportation of moister and cooler air from the Eastern parts of the continents in the Global Forest scenario.

Comparative regional analysis

Regionally speaking, the climate zones shift between the modelled extremes of the two scenarios. In order to evaluate their geographical patterns, the five main

Climate type according to Köppen	'Global Desert' Scenario [%]	'Global Forest' Scenario [%]
A Tropic	18.1	19.4
B Dry	28.2	9.1
C Moderate	12.2	29.4
D Snow	27.3	23.5
E Ice	14.2	18.5

Table F 2.2-1
Proportions of climate types according to Köppen (1923) as a proportion of the total land surface for the scenarios 'Global Desert' and 'Global Forest'.
Source: adapted from Kleidon et al, 1999

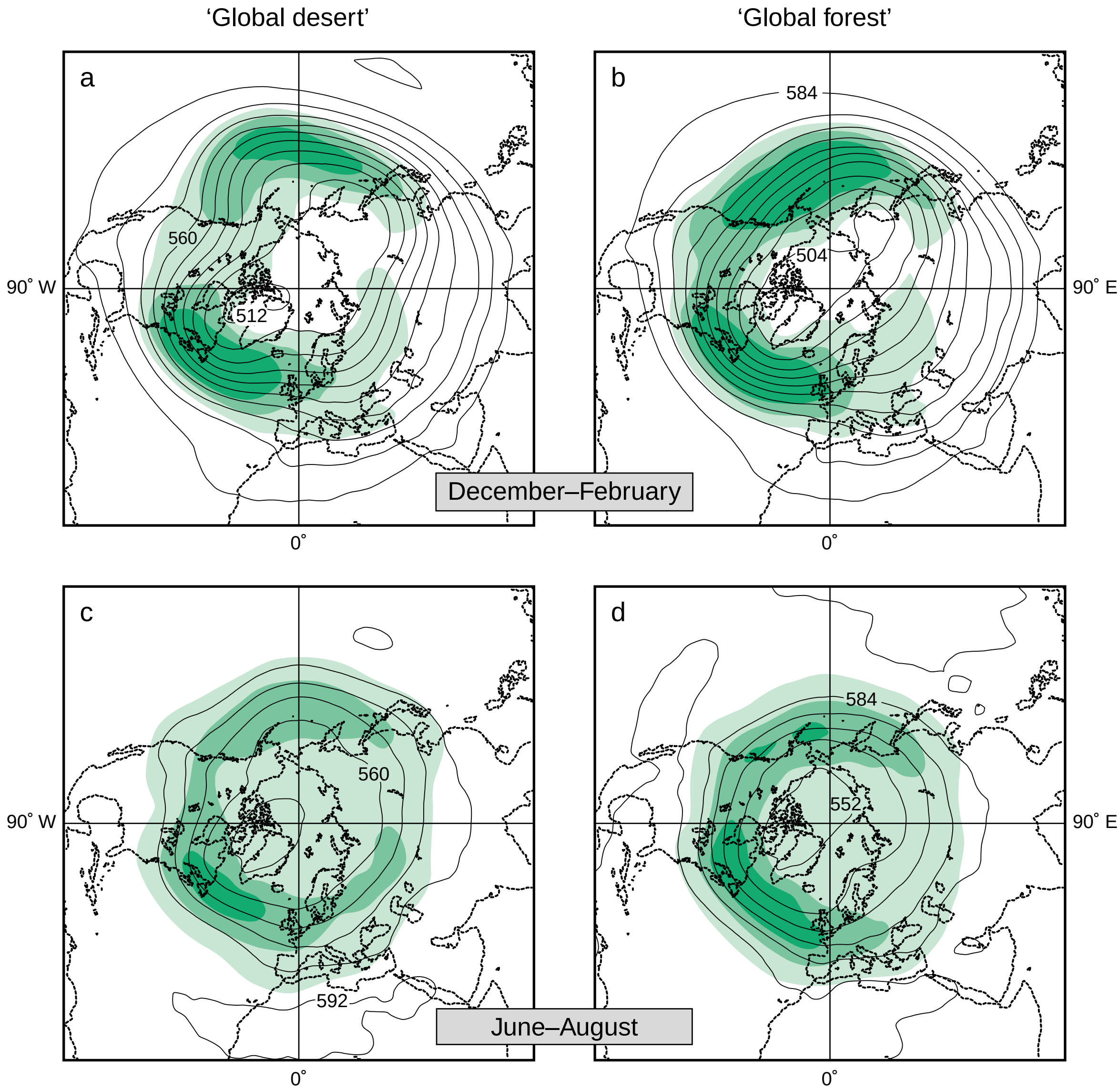


Figure F 2.2-3
'Global Forest' (b, d) and 'Global Desert' (a, c): Changes in mean current of atmosphere along the contours of the 500 hPa land area in winter (a, b) and summer (c, d) and the synoptic activity (in green). It includes dispersion levels (high-pass filtered) of daily fluctuations in the height of the 500hPa area that exceed 30gpm.
Source: after Fraedrich et al, 1999

climate zones are identified following Köppen's climate classification (1923) (A to E; Table F 2.2-1): tropical, arid, temperate, snow and ice climates. Thanks to their simplicity, these categories allow conclusions to be drawn with regard to the shifts in biogeographical borders. The experiments with the Global Forest and Global Desert scenarios are examined, and further comparisons are made possible by the ECHAM control run (simulation under current conditions) and a variant of the observed climatology (Fig. F 2.2-4).

The proportion of climate types on the global land surface is illustrated in Table F 2.2-1. About one-fourth (22.9 per cent) of the total land area demonstrates a change in climate type. The greatest differences between the Global Desert and Global Forest scenarios are located in the arid and temperate climatic regions; whereas in the Global Desert scenario the arid (steppe and desert climates) and snow climates (cold-boreal summer dry and cold-boreal winter dry climates) dominate, in the Global Forest scenario the proportion of temperate climates (summer

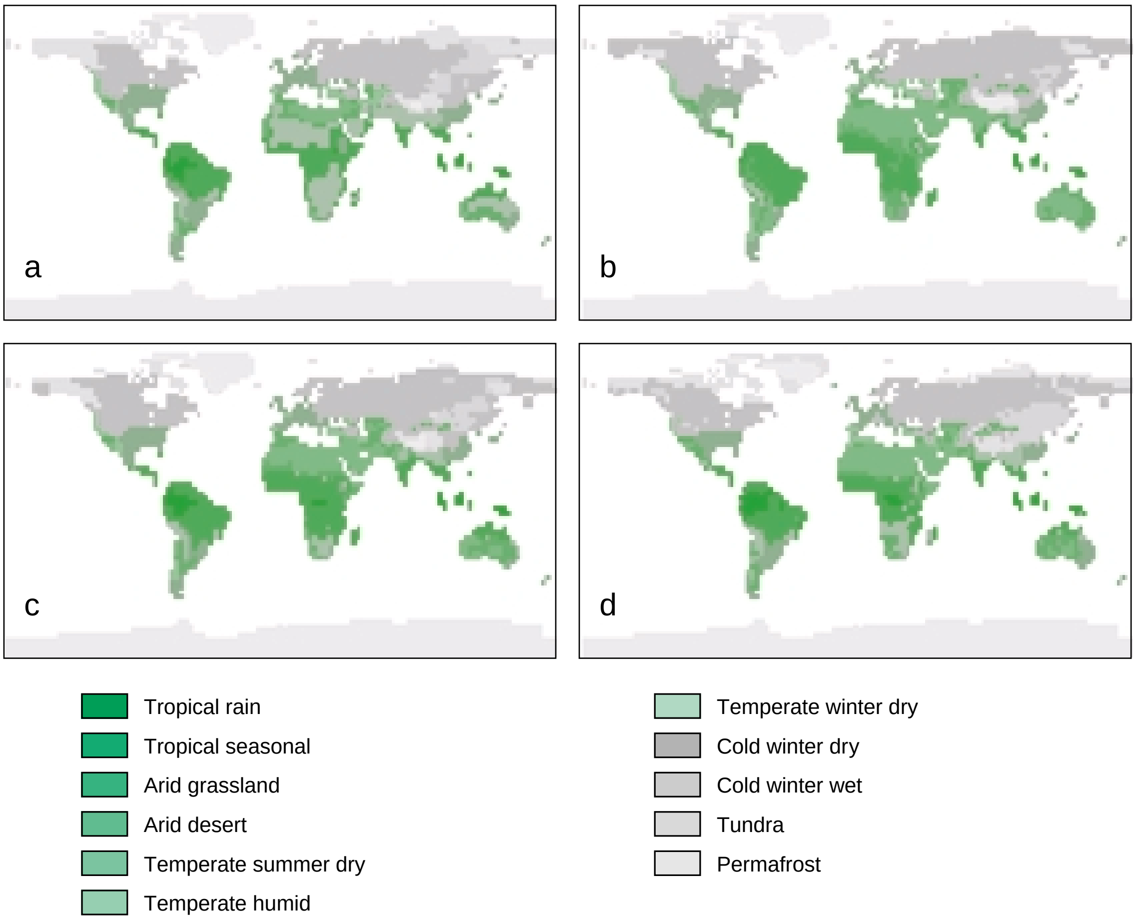


Figure F 2.2-4
Global distribution of climate zones according to Köppen: a) 'Global Forest' scenario, b) 'Global Desert' scenario, c) ECHAM control simulation, d) data measured on the basis of Cramer and Leemans (1992).
Source: adapted from Kleidon et al, 1999

dry, year round humidity and winter dry climates) increases.

Two regional changes are worthy of particular mention since their causes cannot be derived from the dominant global effect. This predominates in most of the extra-tropical regions and a large part of the inner tropics where the atmosphere close to the ground warms up in the transition from the Global Forest scenario to the Global Desert scenario because the dominant cooling effect from evapotranspiration is absent.

- The arid areas in the regions impacted by the monsoons are pushed back considerably in the Global Forest scenario. These are large parts of Africa, South and Central Asia and Australia. The cause is the intensification of the monsoon in the case of increased evapotranspiration and its far-reaching transportation of water vapour far inland. Supported by the reduced albedo and increased roughness accompanying afforestation this mechanism seems to be the reason for the stability of vegetation in the sub-tropics in the Global Forest scenario. This was also characteristic for the climate in the Sahel-Sahara region during the mid-Holocene.
- Compared with the Global Desert scenario, the Global Forest scenario leads to cooling over Alaska and to a warming over East Asia (Fig. F 2.2-4). The reason for this is the zonalization of the storm-tracks (Fig. F 2.2-3) that reduce the trough over the North Pacific which in turn reduces the heat flux to Alaska and increases it to South East Asia.
- As a result of the sea and ice areas that cover 70 per cent of the Earth's surface, there are still climatic conditions in the Global Desert scenario where forests grow (Fig. F 2.2-4). In particular, the scenario demonstrates an expansion of desert, steppe and savannah areas. But most agrarian, forest and settlement areas remain under the influ-

ence of climatic conditions favourable to their existence. It does become problematic however for the whole Northern part of the Indian sub-continent, the North of China and Southern Siberia, the Australian steppes and the savannah zones in Africa, the Western parts of North America and the Andean region.

- In the Global Forest scenario the forest regions increase dramatically and the current core areas of desert and steppe retain their original form: the desert belt of the ancient world from the Maghreb and the Sahara over the Middle East into portions of the Thar and Gobi deserts, Western Australia and Western South Africa, Patagonian, the Atacama and the south western part of North America. There, no favourable climatic conditions can be established for forest. Changes cannot simply be maintained by afforestation and climatic conditions alone. Irrigation is a provisional option, but not a sustainable solution for these areas.

F 2.3
Biospheric control over the climate system and the global hydrological cycle

These new simulations provide an initial evaluation of the maximum biospheric control over our climate system and the global hydrological cycle. What was not considered is the exchange of many greenhouse gases such as carbon dioxide that are controlled by the biosphere. Also left unconsidered are the exchange processes between ocean and atmosphere that would influence many of the results. However, the general conclusion that may be derived is that the biosphere does indeed exercise an extensive control function over the climate system. This control is particularly strong in the global energy levels as a result of the cooling effect of vegetation and in the global hydrological cycle through increased evaporation, determined by evapotranspiration. Its influence is on the same scale to the changes that are anticipated as a result of doubling the CO_2 concentration (IPCC, 1996a).

The geographic and temporal effect of the biosphere is seen above all in the fact that the biological influences are strongest during periods of maximum solar radiation, whereas the increased carbon dioxide concentration influences above all the winter period in the upper latitudes.

F 3 The biosphere in global transition

F 3.1
Global human impacts on the biosphere

Humankind began reshaping the Earth centuries ago; no ecosystem today is free of human influence (Vitousek et al, 1997). These interventions achieved a global dimension in the form of industrialization and, since that time, have changed biogeochemical and biogeophysical cycles and disrupted the regulatory function of the biosphere which is so essential to the Earth (Chapter C). In earlier times, too, humans intervened deep into the biosphere with their land use changes and reshaped whole swaths of land by deforestation (eg the Greeks and Romans in the Mediterranean, Aborigines in Australia). The climate reconstructions indicate for those periods climatic modifications by regions in terms of precipitation and temperature, but a constant CO_2-concentration. On the other hand, the data analysis from ice cores extracted in Greenland show that even without human influence within just a few decades dramatic temperature fluctuations occurred and that the climate changed erratically.

The new dimension of human intervention in the biosphere and the climate is therefore less an issue of such modifications being unprecedented in Earth's history, and more about the dramatic collision of a world globalizing at breakneck speed with highly divergent societies. On the one hand, there are the highly developed sensitive civilizations with high resource and energy consumption, on the other hand societies in poverty in which the generally prevalent high population growth increases the pressure on the environment. At the same time, the population of the Earth is larger than it has ever been before. It is also largely unknown whether humankind can respond appropriately to the changes it has itself caused and can adapt without major social upheaval.

Against the background of the debate on climate policy, and specifically on the reduction of greenhouse gas emissions, the following section will discuss above all the role of the biosphere in the carbon cycle and consider the question to what extent intervention by civilization, and the global modifications associated with such intervention, can be reduced to a sustainable level (IPCC, 1996b).

F 3.1.1
Direct intervention in the biosphere: global trends

The conversion of natural ecosystems into pasture and agricultural land and the shift from agricultural to industrial land use are global trends of extraordinary quantitative dimensions. It is estimated that 40–50 per cent of the land surface has been converted or degraded by humankind so far (Leemans, 1999; Fig. F 3.1-1). Although humankind uses only approx 6 per cent of terrestrial net primary production (NPP) directly through harvesting plants to gain food, fuel or building materials or for paper manufacture, it is estimated that as a result of anthropogenic forest and steppe fires and air pollution, the potential natural global NPP is reduced by up to 25–40 per cent (Schlesinger, 1997). Since 1860 humankind has destroyed around 13 per cent of the pre-industrial biomass (Schlesinger, 1997) and thus amongst other things has caused the recorded increase in CO_2 in the atmosphere.

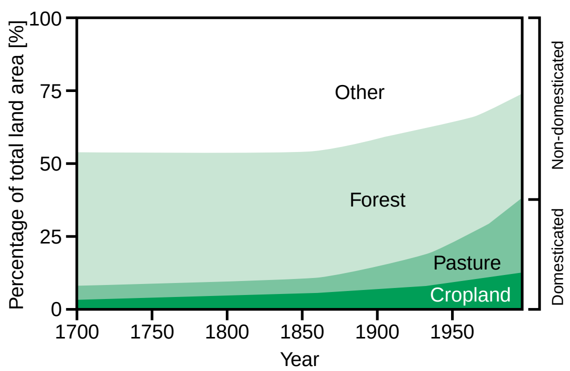


Figure F 3.1-1
Estimated changes in global terrestrial ecosystems between 1700 and 1995 (proportion of total land surface).
Source: Leemans, 1999

In addition, there is a global trend towards the *fragmentation of natural ecosystems* which amplifies the impact of land use changes on a global scale and weakens the capacity of the biosphere to adapt to global environmental changes (Chapter C). Equally, the *damage to ecosystem structure and function* and the *substance overload of natural ecosystems* are global trends that result today from local and regional impacts and also from human intervention in the biogeochemical cycles (Fig. C 1.3-3). Land use changes, such as deforestation or the drainage of wetlands, lead directly to the loss of carbon sinks in the biosphere and the increase of biospheric sources, for example for greenhouse gases; they can even directly change regional and widespread climate patterns, such as monsoon systems. Through these interventions in the biosphere, human activities also modify the carbon cycle. As a result of the albedo increase related to deforestation and the quantitative changes associated with that in regional water levels, man is also intervening directly in regional climate systems. For example, in Colorado the conversion of large areas of prairie into irrigated agricultural land over the last few decades has led to regional cooling of 2°C (Couzin, 1999). In the Amazon catchment area the felling of the tropical rainforest and conversion into grasslands has brought about a regional warming and a reduction in precipitation of up to 30 per cent (Couzin, 1999; Section F 5.2.1).

Land use and land use changes are currently the strongest factor influencing the biosphere and will presumably remain so for the next few decades (Walker et al, 1999). Estimated population growth of one thousand million people per decade will make an annual increase in food production of approx 2 per cent necessary. This will lead in Africa, Latin America and Asia to yet more conversion of natural ecosystems into agricultural land and to an intensification of production on developed crop land (Alcamo et al, 1999). Both processes can, seen in general terms, be assessed as interventions into the natural cycles and as a trigger for global environmental changes. They lead to a loss of plant-related carbon in the atmosphere and a reduction in the carbon sink potential of the biosphere.

F 3.1.2
Intervention in biogeochemical cycles

The reasons for the increased concentration of greenhouse gases in the atmosphere (carbon dioxide, methane, dinitrogen oxide) are not only to be found in the industrial, transport and heating-related burning of fossil fuels, but rather in the changes of biosphere use by agriculture and forestry. This leads to human-induced global climate change that with great probability can already be felt today (IPCC, 1996a).

Intervention in the global, biosphere-influenced biogeochemical cycles

The burning of fossil fuels and biomass also increases the global emission of aerosols: 10–20 per cent of all aerosol pollution in the atmosphere is attributable to humans (Schlesinger, 1997). Aerosols are of great importance in the context of the regional and global climate, since they influence the radiant features of the atmosphere and the formation of precipitation. Intervention in biogeochemical cycles also has a direct impact on the biosphere in that it makes profound changes in the structure and function of ecosystems. The Council has analysed the risk of destabilizing natural ecosystems through intervention in global biogeochemical cycles as an example of the Cassandra risk type (WBGU, 2000a). This risk type describes damage that has a high probability of occurring *and* high damage potential but which is of an insidious nature and has a complex configuration of causes making the threat not immediately recognizable.

The burning of fossil fuels has doubled the global input of sulphuric gases into the atmosphere (Schlesinger, 1997). Intervention in the nitrogen cycle through the use of fertilizers and the burning of fossil fuels has also increased fixation of atmospheric nitrogen and therefore doubled the amount entering ecosystems when compared with natural inputs. Two-thirds of the global nitrogen oxide and ammonia emissions are due to human activities (Vitousek et al, 1997) and cause nitrogen inputs into numerous regions of the world which in turn triggers shifts in the range of species and changes in semi-natural ecosystems. For example, the growth of forests is increasing in the mid-latitudes of the northern hemisphere. In combination with the acidification the availability of nutrients can be impaired and due to functional disruptions in the ecosystems a loss of biodiversity (Vitousek et al, 1997; WBGU, 2000a). And finally, we are faced with an increase of the global concentration of the greenhouse gas dinitrogen oxide, the fourth most important greenhouse gas after water vapour, carbon dioxide and ozone.

Through emissions of the precursor substances for the formation of ozone into the troposphere (NO_X, CO), humankind is increasing the ozone concentration in this layer of the atmosphere that determines our weather. Ozone is a key compound in the biogeochemical cycles: ozone and the hydroxyl radicals formed from it (OH^-) oxidize many of the biogenic trace gases (Schlesinger, 1997), and ozone is also the third most important greenhouse gas.

Humankind intervenes in biogeochemical cycles with additional materials, such as CFCs and halons. These substances trigger degradation of the stratospheric ozone that forms a protective layer against the UV-B radiation that is dangerous to the biosphere. The increase in UV-B radiation reduces, for example, plankton production in Antarctic waters, and there is speculation that it also plays a role in the worldwide observed reduction in the reproductive capability of amphibians (Schlesinger, 1997). Other chemical substances are very effective and long-lived greenhouse gases (HFC, PFC, SF_6). The emission of a large number of persistent organic pollutants now poses a further global danger for the biosphere. The Council has described this as an example of the Pandora risk type (WBGU, 2000a).

Intervention in the global hydrological cycle

Half of the freshwater available annually is used either directly or indirectly by man, the large part in agriculture (WBGU, 1998a). Approx 6 per cent of global run off evaporate as a result of human intervention, eg from irrigated agriculture or reservoirs (Vitousek et al, 1997). The Council has investigated in detail the worldwide freshwater crisis and issued recommendations for the sustainable use of water (WBGU, 1998a). Direct intervention in the biosphere changes the hydrological cycle and climate patterns at regional level in such a way that a negative impact on the biosphere may result. For example, the destruction of forests close to the coasts in West Africa causes low evaporation from these areas and a tangible decline in precipitation in the northern Sahel regions. After such an interruption of the long-distance transportation of equatorial masses of humid air the entire regional hydrological cycle is modified and the ecosystems are in danger of desertification (Nicholson et al, 1998).

It is expected that as the global climate changes, the intensity of the hydrological cycle will increase (IPCC, 1996b), ie there will be increased precipitation, evaporation, and perhaps run off worldwide. There will however be a different impact on the hydrological cycle depending on the region. Whereas for certain regions climate scenarios indicated increased precipitation, it may fall in large parts of Brazil, South West Africa, Western and Northern parts of Australia and Southern Europe. With the help of a procedure that, whilst recognized by most scientists, is still full of major uncertainties, it is estimated that the climate warming of the last 100 years has led to a thermal expansion of the water in the oceans, a melting of glaciers and a global rise in sea level of 18cm (with an uncertainty of 10–25cm) (Warrick et al, 1996). For the coming 100 years, a further sea level rise is expected. Because of the great thermal inertia of the oceans, the sea level may even continue to rise in centuries after that, even if we manage to achieve stabilization of the greenhouse concentration before then.

Intervention in the carbon cycle

As a result of the burning of fossil fuels, particularly in the industrialized and takeoff countries, and the destruction of forests, humankind has increased the concentration of carbon dioxide in the atmosphere by 30 per cent over just 100 years. Together with the emissions-related increase in the concentration of other greenhouse gases (methane, nitrous oxide, CFCs, sulphur hexafluoride), it is 95 per cent probable that human-induced global warming of near surface air has occurred, causing an increase of approx 0.8°C since 1860 (Hegerl et al, 1994; IPCC, 1996a). The largest share of anthropogenic emissions of carbon dioxide (7.1Gt C $year^{-1}$ in the 1980s) is accounted for by the burning of fossil fuels, after that deforestation in the tropics at 1.6Gt C $year^{-1}$. Just around half of these emissions currently remain in the atmosphere, one-quarter ends up in the ocean and one-quarter as far as we know at the moment enters the terrestrial biosphere. Whereas ocean absorption of around 2Gt C $year^{-1}$ is corroborated by various model studies and observations, only a minimal amount of the presumed terrestrial sink can be measured directly (Sections F 3.2 and F 3.3).

F 3.2 The terrestrial biosphere in global transition

F 3.2.1 The terrestrial biosphere in the carbon cycle and the climate system

The terrestrial biosphere is an important global carbon store, it could bind a portion of the atmospheric CO_2 and therefore in the Kyoto follow-up negotiations is accorded central importance with regard to afforestation, reafforestation and deforestation as well as the planned trade in carbon certificates (WBGU, 1998b). Therefore, in the following sections we shall elucidate and discuss in more depth the links between biosphere, the global carbon cycle and the atmosphere.

Plant-based biomass and organic soil material contain globally 2,200Gt C, more than twice as much as the atmosphere (Cao and Woodward, 1998). The largest proportion of this storage is located in the ground (1,358Gt C). Forests contain around 46 per cent of the total terrestrial carbon, 39 per cent in forest soils and their organic cover alone (WBGU, 1998b). Half of worldwide forest carbon is located in the boreal forests of Russia, Canada and Alaska, and 84 per cent of that is in the soils. But grasslands and wetlands are also important carbon stores. Wetlands cover only around 3–6 per cent of the Earth's surface, but contain 10–30 per cent of global terrestrial carbon (figures vary depending on the definition of wetlands used; WBGU, 1998b).

Through photosynthesis the terrestrial biosphere absorbs approx 120Gt of carbon from the atmosphere every year (Gross Primary Production – GPP). And yet only half of that amount is stored briefly in the biomass through plant growth (Net Primary Production – NPP), the other half is immediately breathed out by the energy metabolism of the plant. The majority of NPP is broken down by soil organisms with the fixed carbon re-entering the atmosphere. The remaining 5 per cent of GPP is attributable to the net absorption of carbon by the ecosystem (Net Ecosystem Productivity – NEP). An assessment of global NEP assisted by a biome model (Box F 2.1-1) resulted in a seasonal fluctuation between – 0.6Gt C (October) and 1.5Gt C (July) (Cao and Woodward, 1998). Natural disruptions such as fire and also human intervention (eg harvesting wood) take biomass from the ecosystems which immediately or with some delay (for example, when the wood products rot) leads again to the release of CO_2 into the atmosphere. For time scales of decades to centuries and at biome level, the net biome productivity (NBP; Schulze and Heimann, 1998) is the suitable measure for carbon fixing (WBGU, 1998b). It accounts for just 0.5 per cent of GPP: This is the carbon that over several centuries is stored as charcoal and in stable humus. An ecosystem can have a positive NEP over several years even though the biome in which the ecosystem is embedded records a negative NBP over several decades, for instance when fires become more frequent as a result of the warming (Schulze and Heimann, 1998). For example, photosynthesis increased in the boreal forests of Canada between 1981 and 1991 (because of longer growth periods) and the NEP was positive in the growth period. As a result of clear-cutting, deforested areas convert from C sinks to C neutral systems – NBP decreases. By contrast, swampy forest areas and older forest stands have high C absorption rates and so merit particular protection in global terms and for the preservation of the regulatory functions in the Earth System. The boreal primary forests in Canada and Siberia with their moors and older coniferous stocks are included in that category (Section F 5).

The biosphere responds to the human-induced changes in the carbon cycle and the climate system in positive and negative feedback effects, about which too little is known as yet. Numerous studies and research programmes (eg IGBP) are currently investigating the interaction between the global carbon cycle, climate change and the biosphere. The increased concentration of carbon dioxide leads to increased photosynthesis ('CO_2 fertilization') and also to improved water availability. This represents a negative feedback and an attenuation of the warming of the Earth, though the sink effect of terrestrial biosphere is increased. The extended vegetation period triggered by climate change can also increase NPP. This does not however necessarily lead to an increased carbon uptake (Houghton et al, 1998). The deposition of nitrogen in nitrogen-limited ecosystems increases NPP further ('N fertilization'), in particular in forests of the mid- and higher latitudes of the northern hemisphere. On the other hand as the Earth warms respiration increases and so carbon dioxide is again released into the atmosphere.

Positive and negative feedbacks and interactions with other cycles impact on various time scales and are not linear (Houghton et al, 1998; Woodwell et al, 1998). Whereas CO_2 fertilization takes immediate effect, heterotrophic respiration (by soil organisms) responds to higher temperature, humidity and litter quality with some time lag. CO_2 and N fertilization also demonstrate a clear saturation with increased input of carbon dioxide and nitrogen, whereas the increased respiration may begin with some delay in comparison with photosynthesis, but then increases exponentially with the rise in temperature (Scholes, 1999; Fig. F 3.2-1).

The latest IGBP findings show that CO_2 fertilization has possibly been overestimated so far and that therefore also in models calculating the sources and

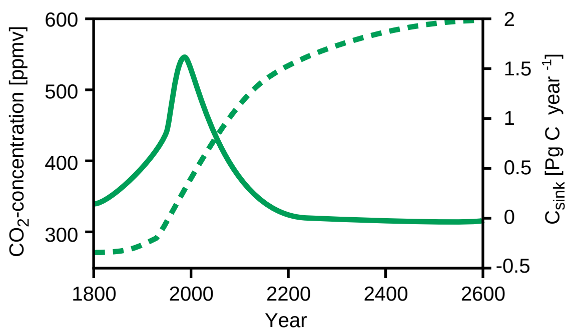


Figure F 3.2-1
Long-term development of atmospheric CO_2 concentration (dashed line) and biospheric sink capacity (solid line). The Scholes model indicates a stabilization of CO_2 concentration only after several hundred years at a level of 600ppm. It should be noted that the reduction of the carbon sink sets in long before the atmospheric CO_2 equilibrium concentration is reached.
Source: Scholes, 1999

sinks in the biosphere, miscalculations may occur (Walker et al, 1999). The swift growth of young trees under increased CO_2 concentration does not necessarily mean that the forests overall are taking in more carbon dioxide (Walker and Steffen, 1997). Often models only take into account CO_2 fertilization, but not other interventions in water and nutrient cycles and modified disruption frequencies. The influence of these changes on the functioning of ecosystems could however exceed that of CO_2 fertilization (Walker and Steffen, 1997). Also the pollution of the tropospheric air may possibly have an impact on carbon dioxide absorption by the biosphere: tropospheric ozone reduces photosynthesis for instance and increases respiration, therefore effecting a reduced NPP. Considerable research efforts are still required in this area.

In the global carbon balance for the 1980s the terrestrial biosphere comes out net as a sink: The emission of 1.6 (±1.0)Gt C year^{-1} from land use changes (predominantly in the tropics) is offset by a presumed absorption of 1.8 (±1.5)Gt C year^{-1} by the terrestrial biosphere (Schimel et al, 1996). From forest statistics it is concluded that 0.5Gt C year^{-1} is absorbed by the forests in temperate climates in the northern hemisphere that are still growing back after the deforestation at the beginning of the century. That the remaining approx 1.3Gt C year^{-1} (sometimes called the 'missing sink'; Houghton et al, 1998; Schindler, 1999) is absorbed by other processes in the terrestrial or marine biosphere can only be concluded indirectly. It is assumed that a large proportion of this missing sink is located in the forests of the northern hemisphere. CO_2 and N fertilization are classed as processes responsible for increased plant-based C absorption. Nadelhoffer et al (1999) conclude from measurements in Europe and North America that N fertilization can only explain a sink impact of a maximum of 0.24Gt C year^{-1}. The question remains therefore what processes and regions are responsible for the fact that the terrestrial biosphere was clearly a C sink in the 1980s (Schindler, 1999).

There are indications that a portion of the as yet 'unidentified' terrestrial sink is to be found in the tropics: possibly, the tropical rainforest in the Amazon basin plays a larger role (Phillips et al, 1998). River measurements have confirmed that the remaining rainforests in the Amazon basin possibly absorb as much carbon as is lost through deforestation (Prentice and Lloyd, 1998). This absorption rate is greatly variable however: in El Niño years for example, these ecosystems turn from C sinks to C sources as a result of high aridity (Tian et al, 1998).

Terrestrial ecosystems that are currently C sinks could convert in future to become C sources – even if land use changes are not taken into account (Cohen et al, 1996; Rapalee et al, 1998). The warming recorded in Alaska, Canada and Siberia has possibly led to reduced carbon storage in the tundra (Melillo et al, 1996; Walker et al, 1999). Goulden et al (1998) working in the 1990s measured losses of soil carbon from a boreal forest in Canada that thus turned from being a sink to a source. The permafrost soils of the boreal forests contain one of the largest terrestrial carbon stores. If this were released as a result of a thawing of these soils, the concentration of carbon dioxide in the atmosphere could double (Goulden et al, 1998).

F 3.2.2
Scenarios for the future

Using a terrestrial biogeochemical model, Cao and Woodward (1998) investigated the change in carbon fluxes for the simulated climate change in the 1861–2070 period. They calculated a considerable increase in the absorption of carbon by the terrestrial biosphere, but also a subsequent decline due to the saturation of the CO_2 fertilizer effect and the increased respiration by soil organisms. In the tropics, due to reduced precipitation, a weakened effect of CO_2 fertilization is seen. Biome models (Prentice et al, 1992) demonstrate that a doubling of the concentration of CO_2 in the atmosphere can be expected to cause a shift in vegetation zones: taiga shifting towards the poles, together with the temperate coniferous forests and warm evergreen forests. The tropical rainforests extend their surface area just a little (Melillo et al, 1996; Section F 2).

Depending on the speed of climate change, it is to be expected that certain ecosystems will disappear from a region quickly because they cannot adapt to the changed climate, but at the same time, new ecosystems that would be adapted to the new climate cannot develop quickly enough. The process of change in ecosystem structure and function will probably lead in a transitional phase to a release of a carbon dioxide pulse, whatever the new balanced biome may be (Walker and Steffen, 1997). This transitional period could last several decades or even several centuries. How large this transient carbon dioxide pulse would be hinges crucially on the speed of climate change and the speed at which ecosystems migrate. As an upper estimate we can take the model results of Smith and Shugart (1993), according to which a doubling of the concentration of CO_2 would cause approx 200Gt C to be emitted by the terrestrial biosphere until new forests had grown back.

Dynamic Global Vegetation Models (DGVM) simulate vegetation dynamics at scales of decades and centuries. They can therefore also take into account processes that do not begin until after a certain time lag: changed competitive balance, changed frequency of disruptions (fire, storms) or the migration rates of species (Walker et al, 1999). One example are simulations with the HYBRID vegetation dynamics model that takes into account increased CO_2 and N inputs: according to these simulations the biosphere could during the anticipated climate change between 2000 and 2050 constitute a sink of 2–3Gt C year^{-1}, but from 2050 onwards could become a source (2Gt C year^{-1}) (White and Friend, 1998).

However, these scenarios should by no means be understood as prognoses; the uncertainties and differences between the various models are too great at the present time. Nonetheless, the following general trends will in all likelihood be seen (Walker et al, 1999):

- Emissions from land use changes and intensified land use will increase.
- If climate change persists at the same rate in the second half of the next century, ecosystems that are today C sinks may switch to become C sources.
- Emissions of CO_2 from soils may develop in the course of the 21st century with increasing climate change to be net C sources.

F 3.3 The marine biosphere in the carbon cycle and the climate system

F 3.3.1 Interactions between marine biosphere, carbon cycle and climate system

For exchange processes on time scales of decades and centuries, the oceans constitute by far the largest global carbon reservoir: They contain an estimated 39,000Gt of dissolved inorganic carbon in various chemical forms. In addition there are around another 700Gt of organic carbon and approx 3Gt of carbon in organisms. Upon closer examination of the interactions between marine biosphere, climate system and global carbon cycle, however, the uncertainties and research gaps are just as great as they are in the case of the terrestrial biosphere. Today the ocean absorbs approx 2Gt C year^{-1}, that is around one-fourth of anthropogenic emissions. The absorptive capacity is limited by the fact that the carbonate system in seawater buffers the carbon dioxide content and thus reduces the effective reservoir size of the ocean to one-tenth (around 3,900Gt C). Furthermore, in the short term of just several years, only the surface layer of the ocean can absorb carbon dioxide (Denman et al, 1996).

At intervals from 500 to 1,000 years the majority of the ocean is mixed up by global thermohaline oceanic circulation. Above all in that process cold carbon dioxide-rich surface water in the North Atlantic is taken into the depths ('physical pump'). A weakening or even collapse of the thermohaline circulation, that is possible if certain critical (not yet known in detail) threshold levels of global warming were exceeded, might impair the effect of the physical carbon pump (Stocker and Schmittner, 1997; WBGU, 2000a).

The marine biosphere plays an important role in the global carbon cycle. Without the marine biosphere the atmospheric concentration even in its preindustrial balance would have been almost twice as high (Maier-Reimer et al, 1996). The phytoplankton absorbs carbon in the upper, light-filled layer of the ocean and uses it to produce biomass. A portion of the carbon thus fixed enters deeper water layers either directly or indirectly via the zooplankton and there it is broken down and dissolved. Just a small amount is deposited as sediment. This carbon transportation from the surface into the depths is termed a biological carbon pump. Calcifying organisms fix carbon also in the form of calcium carbonate which together with the shells is also transported into the depths (calcium carbonate pump). The production of calcium carbonate is associated, however, with the release of carbon dioxide in the surface layer (Wolf-Gladrow, 1994; Wolf-Gladrow et al, 1999).

Due to the nutrient limitation of the marine biosphere its absorptive capacity for additional inorganic carbon is limited. Together with the buffer effect of the carbonate system this explains why the biological pump is not directly changed as a result of CO_2 concentrations in the atmosphere. There are indications of higher photosynthesis rates in phytoplankton (Riebesell et al, 1993), but due to the nutrient limitation it is not clear that this leads to an increase in carbon absorption. However, an increased photosynthesis rate together with non-linear processes such as delinkage from zooplankton and a physical aggregation of phytoplankton can lead to an increase in the carbon intake at the surface layer of the ocean. Also, the possible change in relationship between carbon absorption and nutrient absorption and the possible reduced calcium carbonate production that was observed for increased CO_2 concentrations can increase the intake of carbon dioxide (Wolf-Gladrow, 1994; Wolf-Gladrow et al, 1999).

Phytoplankton production in the Southern Ocean is probably iron-limited, as in other regions, eg the sub-Arctic North Pacific, Eastern Equatorial Pacific and the South Pacific (Behrenfeld and Kolber, 1999). For that reason Martin (1990) suggested fertilizing these regions with iron in order to increase the amount of CO_2 absorbed by the oceans. It is, however, unclear whether the food chain would respond as expected, what amounts would be necessary and how ultimately the linked atmosphere-ocean system would respond. Initial experimental results show an effect on the marine ecosystem (increase in productivity and chlorophyll concentration) but not on CO_2 concentration (Denman et al, 1996). Model results show that the atmospheric CO_2 concentration after 100 years of iron fertilization could be reduced by at most 10 per cent of the concentration anticipated for 2100. The IPCC (1996a) does not therefore see iron fertilization as a suitable climate protection measure. Currently, however extensive *in-situ* experiments are being carried out (Coale et al, 1998; Section F 5).

F 3.3.2
Scenarios for the future

Coupled atmosphere-ocean models that are used to project climate change so far contain only very simple representations of marine biogeochemical and biogeophysical processes. The carbon cycle models used for the IPCC stabilization scenarios work on the assumption that the ocean's currents and the biological pump remain unchanged (IPCC, 1996a). Sarmiento et al (1998) calculate using a coupled atmosphere-ocean circulation model that the current carbon sink in the Southern Ocean can change dramatically in just a few decades: increased precipitation can lead to greater stratification so that less carbon is transported to the depths and less warmth is released from the ocean into the atmosphere. Both of these can result in the ocean absorbing less CO_2. This investigation shows that an improved model of marine processes is required in order to be able to evaluate the changes in the biological pump (Schimel, 1998). Arrigo et al (1999) show that the biological pump is weakened when there is increased stratification in the Ross Sea (in the Southern Ocean) because the composition of phytoplankton species is changed. This could also mean a reduction in the CO_2 absorption of the ocean, a positive feedback that has not been considered in any of the scenarios up to this point. In light of the critical influence of phytoplankton on the future CO_2 absorptive capacity of the ocean, about which too little is known, additional investigations with regard to the interaction between the carbon cycle, climate change and the marine biosphere remain essential.

F 3.4
Research requirements

In the IPCC stabilization scenarios (IPCC, 1996a) assumptions with regard to terrestrial and marine biosphere and the ocean currents were made that, although still very much up to date and having gained relevance in both policy and practical terms in the context of the Framework Convention on Climate Change, have since been supplemented. Above all, the complexity and diversity of feedbacks between atmosphere, organisms, soils and inorganic substances has been specified to a greater degree in such a way that the uncertainties with regard to the carbon cycle at global level are better evaluated and a new basis for calculation of scenarios has been created. The development of better models has been crucial to developing an understanding of the ecological processes on a global scale and thus to making sufficiently reliable prognoses of the response of ecosystems to climatic changes and increased carbon dioxide levels. Currently, in almost all individual questions with regard to biospheric C absorption there is a need for more research, but it is widely accepted that older forests, moors and wetlands merit particular protection from a global point of view.

For the Kyoto follow-up conferences and the calculation of biological sinks, it will be fundamental to define more precisely the absorption capacity of individual terrestrial ecosystem types as is envisaged currently in several research projects. It is also essential to clarify the behaviour of vegetation communities and of soils in specific geographic zones in the case of future warming. Whether the organisms in the sea will play a greater role in the future as C reservoirs and in which regions they could be influenced by fertilization will remain the task of further Earth System analyses. Before work can really begin in this regard on effective Earth System management, more precise scientific results should be awaited and above all evaluated in connection with socio-economic and politico–institutional findings. Be that as it may, it continues to be essential on the emissions side that countries meet their greenhouse gas reduction commitments as agreed in Kyoto – essential both for them and for the global environment.

Human-induced climate change: consequences for ecosystems and species F 4

For the biosphere human activities such as ecosystem conversions, landscape fragmentation, non-site appropriate management methods and the establishment of alien species constitute *direct*, local interventions with global consequences (Chapters C, E). Mankind can also jeopardize biodiversity and the functioning of ecosystems *indirectly*, for instance by changing the atmospheric composition and thus the climate, as well as modifying the distribution of biomes globally and regionally. The indirect consequences of climate change for the biosphere have been given little consideration so far in the international policy negotiations within the CBD and UNFCCC regimes (Markham, 1996). A direction of investigation has now been established in international research into climate impact that quantifies these effects more precisely. In particular climate impacts relevant to agriculture and forestry have been ascertained quite reliably in field experiments (McGuire et al, 1995; Peterson et al, 1999). On the basis of those experiments it is considered that ecosystems will reach a new stage of balance far more slowly than the climate which might considerably narrow their potential for services to humankind (Melillo et al, 1996). Furthermore, there are insights into the reactions of individual natural ecosystems and plant species in particular regions (Markham, 1998). What is not clear however is whether biodiversity will fall as a result of too slow migratory behaviour on the part of certain species (IPCC, 1996b). Additional studies are also necessary on the long-term impact on a global scale, such as the potential and real shifts in the biome borders which primarily will draw on model experiments (Claussen and Cramer, 1998). For that reason, most of the results achieved by IPCC working group II that is evaluating the current level of knowledge on the climate impact, are formulated very cautiously (IPCC, 1996b). The fact that no experiments on long-term changes in the biosphere can be conducted compels us to use models and allows for less reliable conclusions than would be possible in field experiments.

F 4.1
Reaction of ecosystems to global climate change

Ecosystems and species react directly to changes in climatic conditions and increased concentrations of carbon dioxide. Stratospheric ozone depletion, acid loading, dust particle deposition and airborne pollution all impact upon biodiversity (MacIver, 1998). Modified climatic characteristics (such as mean temperature, minimum and maximum temperature, precipitation, number of warm or frost-free days) have direct physiological impacts on plants, modify the length of vegetation periods and lead to modified ability of species to compete.

Plant growth and carbon dioxide concentrations

An example for structural changes in ecosystems are the shifts in the spread of C_3 and C_4 plants in the savannah and steppe zones in the light of higher atmospheric carbon dioxide levels. They are a well investigated example of climate impacts on natural ecosystems, agriculture and forestry (Hörmann and Chmielewski, 1998). C_3 and C_4 plants differ in terms of biochemical reactions during photosynthesis and in terms of their natural biogeographic distribution. A warming may increase the advantages of C_4 plants that use light more efficiently for photosynthesis at temperatures above 22°C. However, this temperature threshold rises as the concentration of carbon dioxide increases and in turn shifts the competitive balance in favour of the C_3 plants (Melillo et al, 1996). Furthermore, an increased concentration of carbon dioxide according to experimental observation favours photosynthesis and the growth of C_3 plants (Kirschbaum et al, 1998). This effect cannot however be proven in field experiments because complex interactions occur (Hörmann and Chmielewski, 1998). In prairie regions observation of changed species composition can be made. For example, it was found that the frequency of buffalo grass (a C_4 plant) in the short grass steppe of Colorado (USA) declines with rising daily minimum temperature, whereas native and imported plants (C_3 plants) increased in frequency (Alward et al, 1999). Buffalo grass is a very productive, arid-resistant grass and is an important food staple for the cattle in the region (Melillo, 1999). Since however in a field situation the impact of carbon dioxide cannot be analysed in an isolated fashion separate from all other factors, these insights cannot be generalized. However, according to the results of several studies, most prairies and savannah regions will extend further. Furthermore, the species shift in the grass communities will bring with an impoverishment of fodder yields and thus cause a migration of agricultural operations into more favourable areas (Allen-Diaz et al, 1996).

The various impacts of increased CO_2 concentration upon plant species also affect crops. Important field crops are C_3 plants (wheat, rice, soya beans). In the experiment, doubling the carbon dioxide concentration did allow for a yield increase of approx 50 per cent (Nisbet, 1994), but in the field these results are most certainly modified by numerous other factors. In addition, the warming-related shift of the Northern border of the cultivation zones (eg wheat by approx 500km) means the countries of the North are particularly favoured. By contrast, important traditional cultivars in developing countries (maize, sugar cane, sorghum and millet) are C_4 plants which one would expect to show only small increases in yield. If socio-economic and political parameters remain unchanged therefore a greater increase in the global imbalance of food supply is to be expected (Hörmann and Chmielewski, 1998).

Carbon dioxide increase and species migration

The aim of the Framework Convention on Climate Change is to stabilize the concentration of greenhouse gases at a level that poses no threat. This goal is to be achieved 'within a time-frame sufficient to allow ecosystems to adapt naturally to climate change' (Art. 2 FCCC). At the currently estimated rate of warming of 1.5–3.5°C over the next 100 years the climate and vegetation zones would move by about 1.5–5.5km year^{-1} towards the poles and 1.5–5.5m year^{-1} higher in mountain areas and cause species migration on the same scale (Kirschbaum and Fischlin, 1996). However, given the very different changes ultimately in regional temperature and precipitation patterns, the real vegetation zones will actually shift very far in some regions of the Earth and very little in others. A number of studies on past climatic changes show that in the case of trees migratory speeds of 40–500m year^{-1} were achieved, in extreme cases such as the white spruce even 1,000–2,000m year^{-1} (Kirschbaum and Fischlin, 1996). Most species cannot however adapt to a climate change rate of more than 0.1°C per decade. Seeds can be transported a long way by the wind and individual pioneer plants establish quickly in a new environment. Even barriers such as the Baltic or the Great Lakes have been overcome (Walker and Steffen, 1997). The effective migratory speed, however, is a great deal lower than the potential since the survival rate of seedlings and not the speed at which the seeds spread is the step that determines the speed (Howe and Westley, 1997). Paleostudies and model simulations show that many plant species can migrate quickly via natural landscapes, quickly enough in order to keep projected climatic changes in check (Walker and Steffen, 1997). The fragmentation and lack of networking of ecosystems however inhibits the migratory speeds. It is possible that the undesirable opportunistic species will be able to migrate quickly (Pitelka et al, 1997). Above all for large mammals fragmentation constitutes a great barrier to possible migration particularly since many 'migratory attempts' are necessary for a successful migration to take place (Walker and Steffen, 1997). Isolated protected areas can also change into 'traps' (Myers, 1993), particularly if the landscape is not hilly and therefore an escape to higher altitudes impossible. A model study for the mountain forests in Switzerland (Kienast et al, 1998) found that around 40–50 per cent of the protected territories would be retained with their species intact in the case of warming by around 1–1.4°C since there were sufficient height differences. At warming of over 2°C only around 20–30 per cent of the protected areas could guarantee such migration within its borders. In order to prevent the isolation of valuable protected areas, therefore, migratory corridors for fauna and flora need to be established (Section E 3.3.2.4).

Given the largely hypothetical nature of the knowledge we have with regard to the impact of climate change on the migratory patterns of species, a certain degree of scepticism with regard to the results seems appropriate. The forecasting methods used to ascertain future species distribution once warming and a CO_2 increase have occurred in the layers of air close to the soil, remain relatively uncertain (Davis et al, 1998). In order to be better able to forecast the momentum of populations, it is suggested that not just climate parameters be taken more closely into account but also interactions between species and their geographic distribution in the models. This direction of research should be expanded in light of its interdisciplinary nature. According to what we know today, generalizations with regard to *global* reactions of vegetation to increased CO_2 concentrations and changed climate are not possible (Kirschbaum et al, 1998). By contrast, statements with regard to the growth and response patterns of *individual* ecosystems may be made even though the work is being done on the basis of as yet unreliable prognoses on the regional manifestation of terrestrial warming (Graßl, 1999).

F 4.2
Impact of global climate change on individual ecosystems

For political decision-making processes under the Framework Convention on Climate Change, exact findings with regard to the sensitivity of certain ecosystems and agrarian regions are relevant above all because better regional strategies for the implementation of the convention can thus be developed. Moreover, quantitative results on the 'effects' of climate change on ecosystems remain essential for global food security, forestry, fisheries and not least biosphere conservation. The various IPCC working groups have therefore produced detailed analyses on the impact of global climate change on forests, grasslands, deserts and mountainous regions, lakes and rives, wetlands, coasts and oceans (IPCC, 1996b). Table F 4.2-1 provides an overview of these impacts for selected ecosystems.

F 4.2.1
Forests

The potential consequences of global environmental changes will vary for the approx 4 thousand million hectares of forest and bush ecosystems on the Earth as a function of their different reactions to temperature and CO_2 changes (Enquete Commission, 1994; Section G 4.1). The most certain consequence which all forests have in common is the shifting of forest borders towards the poles (Kirschbaum and Fischlin, 1996; Neilson and Drapek, 1998). In the northern

Table F 4.2-1
Selected studies on climatic effects upon sensitive ecosystems.
Source: Markham, 1996; IPCC, 1996b

Ecosystem type	Key climatic variable	Ecological effect	Source
Mangroves	• relative rate of sea level rise • storm frequency and strength	• lack of sedimentation	Rose and Hurst, 1991 Markham et al, 1993
Coral reefs	• relative rate of sea level rise • storm frequency and strength • surface temperature of the ocean	• bleaching • coral deaths	Rose and Hurst, 1991 Markham et al, 1993
Coastal marshes	• relative rate of sea level rise • storm frequency and strength	• change in structure of plant communities	Rose and Hurst, 1991 Markham et al, 1993
'Flat' islands	• relative rate of sea level rise • storm frequency and strength	• salinization	UNEP and WMO, 1992
Arid and semi-arid areas	• precipitation patterns • winter minimums	• decline of frost-sensitive species	UNEP and WMO, 1992
Tropical mountain forests	• cloud cover and sunshine duration • hurricane frequency and strength • drought frequency	• reduced biomass • decline in populations of commercial tree species	Markham et al, 1993 Hamilton et al, 1993
High moor land	• mean summer temperature • mean annual precipitation	• no formation of high moorland	Schouten et al, 1992
Alpine mountain lands	• mean annual temperature • snow fall and melting	• upwards migration of alpine plants	UNEP and WMO, 1992 Markham et al, 1993 Peters and Lovejoy, 1992
Arctic	• mean annual temperature • length of seasons • precipitation	• warming endangers group of Norwegian plants that require an isotherm of <–10°C in January	Chapin and Shaver, 1996 Peters and Lovejoy, 1992
Boreal forests	• mean annual temperature • frequency of fire • storm frequency and strength	• northwards migration of tree line	Shugart et al, 1992 Peters and Lovejoy, 1992

hemisphere growth at the Northern border of the forests is expected to be so slow that the losses at the Southern border will not be offset. Thus, the level of carbon absorption by forests could reduce (Hörmann and Schmielewski, 1998). In particular, the reactions of tropical and boreal forests have been investigated in numerous research projects since publication of the comprehensive report of the German Enquete Commission on the Protection of the Earth's Atmosphere and more detailed findings resulted (Enquete Commission, 1994). Due to market incompatibility and to a high degree of complexity no tangible global research findings have so far been achieved with regard to the climate impacts for functions that forests in general assume for humankind (timber production, conservation, water conservation, hunting, recreation) (Solomon, 1996).

Tropical forest ecosystems

Because of their comparatively small temperature modifications and increases in carbon dioxide content, while tropical forests will potentially demonstrate higher growth rates, limiting factors in the modified chemistry of tropical forest soils and water levels will mean a minimal real increase in their net primary production (Silver, 1998). In particular, limitation through the nutrient phosphorus must be researched further according to Silver (1998) in order to understand better the structural and functional reactions of the tropical rainforests and the changes in the global biogeochemical cycles. Further warming-related effects are expected, in particular a higher incidence of droughts as a result of the El Niño phenomenon and the associated greater frequency of fires and heavy tropical hurricanes with their significant local effects on forestry and biodiversity. Tropical forests will undergo significant changes in the composition of species as a result of changed precipitation patterns and greater aridity that may possibly lead to further extinctions in exposed ecosystems (Markham, 1998). In that context, fragmentation as a result of non-site appropriate forestry methods (clear cutting, monoculture, etc) and further direct human influences (conversion, road construction, settlements, etc) will have a negative impact on adaptability.

Boreal forest ecosystems

Boreal forests will be impacted harder by climate change in their structure and function than other forest types because the warming in higher latitudes will probably be greater and boreal forests react more sensitively to temperature changes in connection with increased carbon dioxide concentrations (Beerling, 1999). They will spread into regions that are currently covered by tundra if the groundwater level is not too high. At the Southern reaches of the area they currently cover the boreal forests will be pushed out by pioneer species of temperate forests and grassland because warming will probably lead to more fires and insect blights (Kirschbaum and Fischlin, 1996). The adaptive behaviour of boreal forest ecosystems in global change will be discussed and researched in particular on the background of the sink problem in the context of the Kyoto follow-up process. In that context, the long-term experiment CLIMEX in Southern Norway which has simulated under real conditions the assumptions about probable climate change scenarios and subjected a forest area to increased temperatures (+3°C in summer and +5°C in winter) and increased concentrations of carbon dioxide (560ppm) over a period of nine years. Ultimately it is clear that boreal forest areas under those conditions become net carbon sinks (Beerling, 1999). This calculation only applies, however, to areas in which the boreal forest remains despite warming. A detailed presentation of the current areas covered by forest and changes in that stand can be found in Section G 4.1.

F 4.2.2
Tundra ecosystems

The regional form that climate change has taken thus far in the Arctic has varied depending on the location. Areas with warming tendencies in winter and spring (such as Norway, Northwest Canada, northern Russia, Western Siberia, Yakutiya) contrast with areas that are cooling distinctly (such as north-eastern Canada). Furthermore, the results of most model calculations do not yet concur with the observed climate data (Hansell et al, 1998). One thing is certain, though, the mean warming experienced thus far of the very varied, very sensitive Arctic is still within the natural realms of variability (Maxwell, 1997). Several new biome models forecast a drastic decline in tundra acreage in favour of boreal forests in the case of a doubling of CO_2 concentration (Neilson and Drapek, 1998). That would not just change the local biotope structures and water levels in peatlands completely, above all and this is the fear, it would lead to feedback effects on the global climate in the form of large-scale thawing of the permafrost soils and the release of large amounts of the greenhouse gases carbon dioxide and methane, even though there are contradictory results on this question (Siegert and Hubberten, 1998; Section F 5). The indigenous population in Arctic regions (eg Inuit, Lapps) have to expect changes in the snow and ice coverage and new erosionary processes and adapt their already jeopardized lifestyle and economic livelihoods accordingly

(Fitzharris, 1996). Chapin and Shaver (1996) have proven by experiment a possible change in the composition of species in tundra ecosystems on the basis of increased CO_2 concentration and temperature. Over nine years the mean temperature of a tundra area in Alaska was increased by 3.5 ºC and the lighting strength and nutrient levels modified. The populations of the most common plant species increased, by contrast the lichen and herb species that form the main food source for caribous declined. The international tundra experiment has not yet been able to confirm such a clear reaction to climate change. The different reactions of individual plant species in Sweden, Canada and Alaska observed over many years varied to the point that no general conclusion may be drawn for growth or biotope composition in tundra regions (Henry, 1997).

F 4.2.3
Coastal ecosystems

Coastal ecosystems are particularly sensitive to climate change, such as for example mangrove forests, coastal marshes, estuaries and river deltas, dune systems, low islands and coral reefs; the latter are discussed in the next section (IPCC, 1996b; Markham et al, 1993). The rate of sea level rise is crucial in that context as is the strength and frequency of storms (Markham et al, 1993). However, the change in the transportation of sediment in the rivers by dam construction and other flood protection measures also influence coastal ecosystems. Over longer periods of time coastlines fall and rise as a result of geological processes. The Mississippi delta accounts for around 41 per cent of total coastal wetlands in the US and in this century an area of around 40 hectares has been lost every day. Climate scenarios (business as usual) predict in this context by the year 2100 an additional loss of 39 per cent of the current area (Reid and Trexler, 1991). This jeopardizes numerous animal and plant species and at the same time an effective CO_2 sink is being lost.

Mangroves cover an area of 20 million hectares or 25 per cent of the tropical coastline. The 34 known tree species from nine families form a unique habitat with typical adaptation such as air roots and other halophyte strategies. Reconstructions of past situations indicate that mangroves can only tolerate sea level rises of up to 12cm a century (Ellison, 1994) – at that rate they would have extreme difficulty adapting to the predicted sea level rises. Mangroves are also at risk, however, by increased water temperatures and changes in salinity and sediment levels.

Climatic changes also have far-reaching ecological consequences for other flat sedimental coasts, such as for example the German North Sea coast (Reise, 1993). First of all probably at a warming of 2–4 ºC there will be an influx via the English Channel of species that are similar to the Eem period in the last interglacial and could increase the diversity by 20–40 per cent. With temperature changes however there would not just be an expansion of the species, but also a change in their vertical distribution by tidal zone. The frequency of harsh winters has a particular impact on the populations in the Wadden Sea (initially mass extinction and migration of fauna, but then in the subsequent summer above-average settlement of young animals with high biomass). Warming would therefore tend to create high biodiversity, but lower biomass with crucially reduced food supply for fish and sea birds. Higher summer temperatures would probably intensify the impact of hypertrophy (green algae mats, oxygen deficiency in sediment) (Reise, 1993). Overall, the North Sea mudflats are expected to have a reduced capacity to store and remineralize organic materials.

F 4.2.4
Coral reefs

Coral reefs can exist at water temperatures between 18 and 30°C. They achieve optimum growth between 25 and 29°C, this being just barely below their upper lethal temperature limit. Increased water temperatures triggered by climate change could therefore impair the capacity of reefs to live and function or at least increase their vulnerability to other stress factors. The clearest impact of increased temperature is the bleaching of coral. The coral lose 60–90 per cent of their zooxanthels (monocellular algae) that live in symbiosis with them. The zooxanthels also lose 50–80 per cent of their photosynthetic pigments (Hoegh-Guldberg and Smith, 1989; Kleppel et al, 1989; Porter et al, 1989). Corals can recover again within a few weeks or months by regenerating zooxanthels if the stress factors are removed (Wilkerson et al, 1988).

Immediately after bleaching corals demonstrate reduced skeletal growth and interruption of their reproductive cycle. In addition, their resistance, for instance to coverage by algae, is strongly impaired. If external stress factors persist, the coral polyps ultimately die off. In Panama, Colombia and on the Galapagos Islands some rare coral species have already disappeared locally (Glynn and de Weerdt, 1991). When reef-forming corals die reefs are settled by other benthic fauna. Since animals that use coral as a food source are not impaired to the same degree by the stress factors, the feeding pressure on the corals can increase and bring about additional losses (Glynn, 1996).

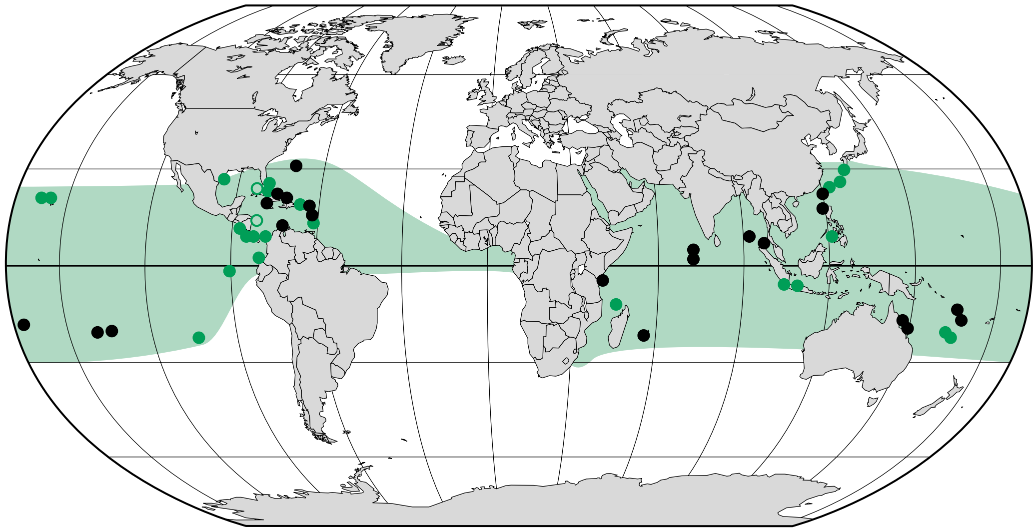


Figure F 4.2-1
Distribution of coral reefs (green) and coral bleaching from 1969 to 1996.
Source: adapted from Bryant et al, 1998

In principle, the bleaching of the corals is a non-specific reaction to various stress factors of which too high water temperature and extended summer temperature highs, as occur above all in El-Niño years are the most important. A decline in UV absorbing pigments in the corals was also observed at increased temperatures, thus increasing their sensitivity to UV radiation (Lesser et al, 1990; Glynn, 1993). In rare cases the addition of freshwater contributes to the coral bleaching. Pollutants such as copper or herbicides can also result in local bleaching (Glynn et al, 1984).

Coral reef bleaching was first observed in 1963 on the coral reefs off the Southern coast of Jamaica (Goreau, 1964). The large-scale bleaching in the years 1982/83 and 1991/92 was presumably caused by the persistent warming of the sea in connection with the El-Niño phenomenon in those years (Glynn, 1993). The large-scale bleaching in 1994 did not however coincide with an El-Niño occurrence (Fig. F 4.2-1; Glynn, 1996). The El-Niño year 1998 was the warmest in the last 600 years and in some areas resulted in bleaching from 60–100 per cent in the corals. Dead or acutely damaged corals occurred above all in the Caribbean, the Eastern Pacific and the Indian Ocean (Hoegh-Guldberg, 1999).

The accumulated occurrence of coral bleaching in the last few years indicates a connection with climate change. Given the great importance of zooxanthels for the process of forming the calcareous skeleton of the reef-forming corals, large areas of reef constructions could become weakened (Glynn, 1996) which would threaten numerous other species of flora and fauna that use the reef for protection, food and reproduction (Wilkinson and Buddemeier, 1994). In addition to an impairment of the habitat function of reefs, important use functions of the reefs would be affected such as coral reef fisheries, tourism and the erosion-inhibiting effect of reefs for coastal protection.

In the longer term the sea level rise constitutes another potential threat to the coral reefs. Under the climate scenarios that are currently in place, a worldwide rise in sea level of up to 1m for the next 100 years seems possible (IPCC, 1995). Although coral reefs were often impacted in the geological past by fluctuations in sea level and changes in the atmospheric CO_2 concentration (MacCracken et al, 1990) it is questionable whether they would ever be in the position in the foreseeable future to respond to swift changes in the sea level with increased growth. Particularly, the swift-growing shallow water coral species that could adapt well are particularly sensitive to temperature increases and increased feeding pressure (Glynn, 1990). The short time periods available are possibly not sufficient for the corals and their zooxanthels to adapt to the new conditions (Jokiel and Coles, 1990; Glynn, 1993).

F 4.3
Conclusions

For ecosystems, the anticipated climatic outcomes may either be catastrophic or mild, such is the wide range of known effects and so varied are the proven effects. As the final result of a structural change in the entire Earth System, small-scale and large-scale biotopes can in many instances be seen as the 'victims' of anthropogenic remote impacts (Graßl, 1999). In addition, they are subject to a whole host of direct human activities that cause long-term disruptions in the regulatory function they perform for the global Earth System (Chapter E, Section F 3).

To that extent, viewing the atmospheric impact on any ecosystem type in isolation is a scientifically necessary task, but the experimental findings are all too fragmentary and uncertain (Chapter J). For a realistic assessment of the 'behaviour' of the biosphere in global transition we lack the work that will put the individual pieces of the puzzle back together. And so, in the view of the Council, incorporation of all interactions into a comprehensive, coherent explanatory approach to global climate-biosphere-interactions remains the challenge for the research community. More exact results with regard to the reaction of individual organisms, their population momentum and the interaction between populations may be expected from a further development and combination of physiological and behavioural models (Orians, 1996). It is only via that route that in future effective prognostic theories on ecosystem reactions to climate change can be developed.

In light of the diversity of the individual effects within an ecosystem, only a few generalized, global recommendations for action may be made. First of all, the steps under the Framework Convention on Climate Change have certainly not been implemented sufficiently in order to demonstrate any recognizable impact on ecosystems. For that reason effective implementation of the Kyoto Protocol remains an urgent imperative. Secondly, since all measures to reduce greenhouse emissions help in principle to maintain the functionality of the biosphere, the full spectrum of local and regional climate protection projects should receive unqualified support.

F 5 Critical elements of the biosphere in the Earth System

F 5.1
Feedback mechanisms

In the history of the Earth there has never been a completely stable biosphere. Gradual changes in a seemingly unpredictable manner seem to have been succeeded by erratic and sometimes disastrous upheavals (Crowley, 1996). Cosmic disasters alone, such as meteors hitting the Earth, cannot explain these completely. Apart from the Milankovic Cycles (eg Broecker and Denton, 1990) which explain the majority of the semi-periodically occurring Ice Ages, the variability of solar irradiation may possibly actually play a relatively minor role. Although in the course of the Earth's history solar irradiation has increased by approx 30 per cent and demonstrates considerable variability in short timescales (Lean and Rind, 1996) the only similarities that have been found are those between the changes in the surface temperature of the seas and the intensity fluctuation of the sun's radiance. No such connection has been recognized between irradiation and the temperatures on land (Schönwiese, 1992b; Nisbet, 1994).

Even though these results certainly do not provide any definitive assessment of the role of external influences on the living conditions on Earth, they cannot explain the surprisingly sudden changes that are seen in the paleoclimatic data. Reconstruction of climate history by means of analysis of ice cores shows convincingly that climate activity often demonstrates abrupt changes. Within just a few years the temperature conditions seem to have changed completely although solar irradiation changed relatively slowly. The unmistakable message of the ice cores is that the climate is fragile, can change swiftly and drastically but also shows phases of high degrees of stability.

The climate system therefore seems to have a 'switch' that is moved at certain very specific thresholds. This image should not be pushed too far however. Of course it is not a switch in the sense of a simple electrical circuit. It is even doubtful whether any *single* element in the Earth System demonstrates that sort of inconstant characteristic. This is true in particular of the biosphere.

Non-linear systems theory provides appropriate explanations for the switch function: in its thermodynamic structure the Earth is a 'semi-open non-equilibrium system'. It permanently receives energy from the sun that drives a number of processes within the Earth System. From direct warming of the Earth's surface in accordance with the respective reflective capacity (albedo), absorption of long-wave thermal rays in the atmosphere, right through to balancing out thermal differences through transportation of heat there is a cascade of effects and processes. In this context, individual processes could demonstrate what is called a non-linear response behaviour. Minute changes in irradiation could have much greater impact for example on the hydrological cycle. If this were to be true generally, however, the climate system would be a great deal more unstable which, at least for the last 10,000 years, has not been the case. Therefore, the only explanation that remains is one of a systemic behaviour that results as a consequence of coupling various processes. And that sort of coupling usually involves the biosphere to a large extent.

Process coupling can in principle only manifest itself in two forms: two or more processes can attenuate one another, which is termed negative feedback, in the form of a regular process that attenuates the stronger external influence, or they can amplify one another. This leads to a greater overall effect and is termed a positive feedback (Section F 3). As a result of an external (or internal) disruption the timing of the system in both feedback effects and can demonstrate unstable behaviour in the form of dramatic effects.

F 5.1.1
Dramatic changes as marginal patterns of negative feedback effects

Through negative feedback loops, systems can be constructed that respond in a stabilizing fashion within certain limits. As an example, let us take the albedo-temperature linkage that is the regulating mechanism that ensures more stable environmental conditions in tropical regions. Rainforests release a large number of condensation nuclei into the air. As a result at times of high solar irradiation and corresponding high levels of water vapour formation, a low lying, even covering of cloud forms that has a diminishing effect on the high reflectance. Aerial shots of these cloud structures show that they reproduce with astonishing precision the geographic distribution of the rainforests. Even small river areas or small deforested areas are left uncovered by the clouds (Nisbet, 1994). Clearly this regulating balance is fragile in its spatial spread. Destruction even of fragments of the rainforest would it seems impair this apparently stable self-regulation of the local climate. It is possible that there is even a critical mass of deforestation beyond which the negative feedback via biogenic evapotranspiration and biologically controlled cloud formation collapses.

Even relatively simply designed Daisy World models (Section F 1.3) can reproduce this phenomenon of the catastrophic collapse of regulatory systems. In a two-dimensional model planet a negative feedback between climate and biosphere is simulated in which the plants influence local temperatures by means of the distribution of their albedo, thermal energy is spread via diffusion processes and the growth probability of plants is in turn dependent on local temperatures (von Bloh et al, 1997). By way of a disruption, the growth area is gradually fragmented. Fig. F 5.1-1 demonstrates the almost perfect 'thermostat effect' of the biosphere for the global temperature as shown. Although the degraded areas increase, the biosphere can maintain the 'climate' almost constant up to a critical fragmentation threshold through dynamic adaptation of the reflective capacity. When that threshold has been reached the model biosphere dies and a rapid change in global temperature occurs.

Here, a fundamental feature of these regulatory systems is seen. For a long stretch they 'tolerate' disruptions and make the system appear very stable. From a certain scale of disruption onwards – which can also be determined by their timing – the system collapses quickly and irreversibly. The 'switch' invoked above is flipped when the regulatory limit is reached. In the rainforest example that may happen precisely when through the gaps in the cloud cover in the case of high solar irradiation more thermal energy enters the vegetation system and the plants are forced to produce evapotranspiration to reduce it. Thus the intensity of the local hydrological cycle is reduced and the negative, stabilizing feedback collapses. Desertification, amplifying itself via negative feedbacks, could then set in and destabilize the system indefinitely. The regulatory limit functioning as the climatic switch also results here from a drifting apart of radiant balance, intensity of hydrological cycle and the ability of the biosphere to buffer the imbalances.

F 5.1.2
Positive feedback effects as elements in a critical Earth System dynamic

Unlike the upheavals in the climate system outlined in the last section that result in the collapse of an essentially stable dynamic, an abrupt change can also emerge when an 'unstable balance' is disrupted. For example, a brief intensification of a process amplifies a second process that in turn amplifies the first. This generates a positive feedback. The most well known

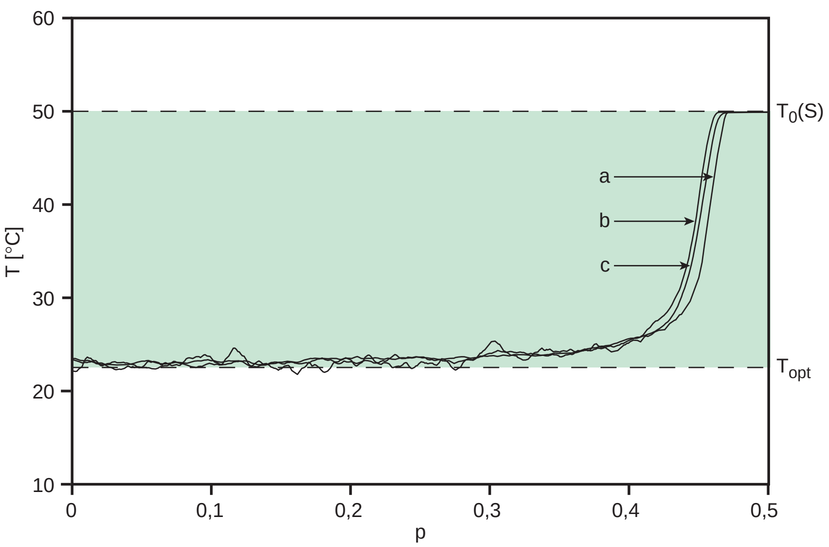


Figure F 5.1-1
Critical collapse of temperature regulation by biosphere in a simple biosphere-climate model. The parameter p designates the percentage of the fragmented area and T the global temperature. The letters a-c designate the simulation runs for model systems of differing size. Source: von Bloh et al, 1997

example of this phenomenon in the climate context is certainly the idea of the 'runaway greenhouse effect' that can be explained using the example of the greenhouse gases methane, water vapour and carbon dioxide.

Greenhouse gases in the atmosphere absorb the long-wave reflective radiance from the Earth's surface and radiate in accordance with their temperature part of that back to the Earth's surface. The warming associated with that process can initiate a series of feedbacks if organic (but also inorganic) sinks for greenhouse gases turn into sources because of higher temperatures, and additional greenhouse gases are released. The overall effect is certainly disputed. However, the frequent assumption is that the effect of (for example man-made) released carbon dioxide could be increased by a factor of 1.2–3.6 (Nisbet, 1994). This range shows the large degree of uncertainty that exists in evaluating reinforcing feedback effects. An extreme image would certainly be the nightmarish concept of warming releasing the entire complement of methane enclosed in the Arctic permafrost soils. The reinforcement factor would be immense. For this scenario there are estimates (Lashof, 1991) that indicate that the seasonality of weather conditions and the temperature-dependent activities of the methane-forming bacteria play a dominant role in the reinforcement of feedback effects.

The carbon dioxide-climate-biosphere interaction, by contrast, demonstrates a time-dependent feedback strength. Palecki (1991) assumes an overall positive feedback for periods under ten years. Only when CO_2 constitutes the short-term limiting factor for increased plant growth can it be absorbed to a certain extent. Climatic changes should however as a result of reduced biospheric activity lead to an increase in atmospheric carbon. Warmer years resulting from that process cause water stress and could increase the effects further. The key role here is linkage to the hydrological cycle. Higher temperatures tend to lead to higher precipitation levels. The characteristic effect is still unclear for the time scale. For longer periods (over ten years), however, a negative feedback seems to dominate since the biomass increase further reduces the amount of carbon in the atmosphere. This effect is also cited as a possible explanation for the current stability of the global climate (Nisbet, 1994). Growth of large forest stands in the last 10,000 years could have had a stabilizing effect on the basis of negative feedback.

F 5.2
Physiological and metabolic importance of the biosphere

The existence and growth of boreal forests has another important function. The temperature is increased through lower albedo of the forests. Deforestation would as a result of lower temperatures not necessarily lead to the emission of methane, but possibly set in motion a 'runaway cooling chain'. The snow-covered areas would increase and the temperature would drop further because of their strong reflective capacity. This is not a switch in the sense described above since it is triggered anthropogenically; but the effect indicates a possible critical element within the Earth System. In Table F 5.2-1 certain biomes are presented with respect to their physiological and metabolic significance for the Earth System.

F 5.2.1
Amazon Basin

The Amazon Basin is a crucial source of warmth and humidity for the global climate system on the basis of its size and its proximity to the equator (Pielke et al,

Table F 5.2-1
Qualitative assessment of the functional significance of biomes for aspects of global biogeochemical and energy cycles.
Source: Nisbet et al, 1994

	Forest			Grassland		Desert	Marine biosphere
	tropical	moderate	boreal	savannah	tundra		
Reflectance	low	low	very low	moderate	high	very high	low
Intensity of hydrological cycle	very high	high	low	low	uncertain	very low	low
Net primary production	very high	very high	high	moderate	low	very low	low
Long-term carbon storage	very high	high	high	moderate	high	low	very high
Nutrient transmission	low	uncertain	low	high	low	very high	uncertain

1998). For instance, there are estimates that 30–50 per cent of precipitation in the Amazon region stems from evaporation within that same catchment area. The region is home to half of the world's tropical evergreen forests and large expanses of tropical savannah (Tian et al, 1998). The forests produce around 10 per cent of global net primary production and provide around the same proportion of terrestrial carbon storage. Furthermore, they are probably an important carbon sink which currently more or less offsets the carbon extraction as a result of deforestation in the region (around 0.3Gt C $year^{-1}$; Fearnside, 1997; Tian et al, 1998). Net primary production in the Amazon Basin is determined essentially by soil humidity which in turn is a function of temperature and precipitation (Tian et al, 1998).

The direct regional-climatic impacts of deforestation of the Amazon Basin are the change in vegetation and soil, increase in albedo and decline in roughness. The exchange of water, energy and momentum between the atmosphere and vegetation is changing, with the effect that the local temperature is rising and evaporation and precipitation are falling, the latter by up to 30 per cent (Couzin, 1999). These changes are irreversible. From East to West 30–70 per cent of the precipitation in the Amazon Basin stems from 'biologically recycled' water – in other words, the region generates its own climate. Following deforestation it may be that no new rainforest could be established. The function of the rainforests as carbon sinks is further reduced through slash and burn. Furthermore, the emitted aerosols influence the climate by having a regional cooling effect. The patchwork deforestation going on could initially lead to increased recycling of water without influencing precipitation: only complete deforestation would initiate a globally perceptible decline in precipitation (Pielke et al, 1998).

F 5.2.2
Sahel region

The interactions between the land surface and the atmosphere in the Sahel have been studied and modelled in detail. Changes in the natural land cover resulting from conversion to agricultural land, overgrazing and other land use changes are the essential disposition factors of human-induced desertification (WBGU, 1997). Changed features of the land's surface can furthermore have a considerable impact on the atmospheric circulation at the meso-scale since they influence local evapotranspiration and water storage. A self-reinforcing feedback assumes a change in vegetation: reduced evapotranspiration ➜ lower precipitation ➜ falling soil humidity ➜ further reduction in evapotranspiration, etc.

These effects in combination with external influences possibly contributed to the decline in precipitation that was observed in the Sahel region from 1950 to 1955 (Hupfer and Schönwiese, 1998; Nicholson, 1998). Further influencing factors include the change in albedo and thus flows of tangible warmth and convection which are also triggered by vegetation changes in the Sahel. Certain hydrological effects resulting from those circumstances are: delayed start to the rainy season, fall in precipitation density, shift in the rain belt and reduced soil humidity. Taken together these effects have contributed to enhanced aridity in a region already suffering from water stress. At the same time however the vegetation increased its efficiency of precipitation use so that overall no loss of net primary production was diagnosed for the Sahel in the period between 1979 and 1996 (Nicholson et al, 1998). The desertification premise is not disarmed by this example, but it does mean that the consequences for agriculture and water supply do remain disputed.

The impact of changed temperatures for the global and regional ocean surface and of the El-Niño phenomenon on the length and extent of the rainy season in the Sahel was proven recently and is being researched further (Xue and Shukla, 1998). As a result of the strong variability of precipitation, the Sahel biosphere is not first and foremost a 'perpetrator' of global environmental changes, but rather a 'victim' of the same.

F 5.2.3
Boreal forests

A sensitivity study looking at the impact of a reduction in the boreal forests (Bonan et al, 1992) shows that deforestation leads to strong cooling in the summer and that the albedo increases to such a degree that in most of the deforested areas forests are unable to grow back. In boreal forests the vegetation-snow-albedo feedback develops a strong regional climatic and possibly global effect. In the Holocene on the basis of this effect and a change in the Earth's orbit boreal forests extended much further to the North than they do today (Foley et al, 1994). The snow and ice volume as a result of the lower reflective radiance of the vegetation was reduced by approx 40 per cent and the temperature increased regionally by 1–4°C. Today as a result of the reverse effect, the snow areas could increase, the temperature drop and the forest border shift southwards with all the consequences that would bring for the biodiversity of boreal forests and the tundra ecosystems

(Bonan et al, 1992). It is, however, more probable to assume that adapted forestry management methods will now be applied more consistently and as a result of the CO_2 related global warming, a renewed northwards migration with self-reinforcing feedbacks for the global climate will set in.

F 5.3 Biogeographical criticality

In the previous section certain regions were described whose biosphere has an important metabolic and physiological significance within the Earth System. The selection was unsystematic and based simply on expert assessment (Nisbet, 1994). In the following section we have attempted to list individual indicators which when linked demonstrate the regional significance of the biosphere for the Earth System. This approach also gives the first points of reference for performing a criticality evaluation in the case of existing or potential degradation and, at the same time, shows the particular protection merited by the biogeographical regions.

F 5.3.1 Evaluating the importance of the biosphere for the Earth System

A possible strategy for developing a criticality index for the biosphere is presented in the following. This index characterizes the importance of the *regional biosphere* for the Earth System. Here, therefore, features are identified that possess a function within the global ecosystem which is the Earth. Of course, such an approach is not clear *a priori* and the selection is certainly not complete. The Council emphasizes therefore explicitly that the following concept can only be *the first step* towards such an evaluation and indicates a *possible approach*.

The following parameters of the biosphere were selected: robustness or sensitivity (R) vis-à-vis a change in environmental conditions and a combination of important metabolic functions of the biosphere for the overall system which are characterized by the integral value F. The criticality indicator K is therefore derived from the quotient of these features, that is:

$$K = \frac{F}{R}.$$

It thus represents a simple, geographically explicit evaluation function into which suitable base indicators for the named characteristics (R, F) may be inserted. The global functions of the biosphere for the Earth System are subsumed under F.

For the *sample e*valuation in this section the primary energy uptake P, the distribution of the annual albedo of biosphere and the contribution that the biosphere makes to the global hydrological cycle were considered. Function P may be represented as productivity of the biosphere on the biome scale and as required may be defined more closely. As a suitable measure for P, the net primary production (NPP) may be used since it can be formulated as energy flux density (energy intake per unit area) and there is a relatively complete set of base data. By NPP we understand the amount of plant material that is formed by photosynthesis during a given year per unit area. The level of NPP describes the system in balance with its environment. Both for semi-natural and agricultural or silvicultural terrestrial ecosystems, plant primary production plays a crucial role. In the semi-natural ecosystem this plant material serves above all to promote the growth of the living biomass; furthermore, it replaces dead or eaten plant parts and forms reproductive organs. In ecosystems under agricultural use, the NPP forms the upper limit of the harvest yield, a level which is hardly ever reached because of the non-usable parts (root systems, stalks). In a global representation, the NPP distribution is a suitable measure for the regional energy intake of the biosphere and thus is immensely important for the Earth System. Through linkage with the worldwide representation of primary production in the marine biosphere – an important outcome of the Joint Global Ocean Flux Study (JGOFS) of the International Geosphere Biosphere Programme (Ducklow and Fasham, 1999) – this aspect can be identified worldwide.

Comparison of seasonal albedo distribution (Matthews, 1983) allows identification of regions where the albedo of the biosphere over the course of a year shows negative feedback if at times of lower solar irradiation in the winter months less is diffused. Of course, there is no complete compensation; however, foliage coloration and drop and the darker background of the soil soften the transition to the winter months in energy terms.

Also, the contribution of the biosphere to the hydrological cycle (Section C 2) can be understood as an important function of the global ecosystem. The transpiration output of plants exceeds the evaporation output from abiotic processes by far and thus makes a decisive contribution to the energy and nutrient transfer within the Earth System (Section F 1). This aspect can be demonstrated by linking global datasets on evapotranspiration and leaf area index. Both figures are necessary to be able to represent the regional biospheric transpiration output on a global scale.

F 5.3.2
Identification of biogeographic regions of importance for the Earth System

Taking all of the biospheric functions outlined above together in the form of intersecting thematic maps of biospheric 'energy intake', 'thermostat effect' and 'influence of the global hydrological cycle' already shows a rough approximation of the most important biogeographical regions of the Earth (Fig. F 5.3-1). Outstanding biogeographical regions are either characterized by high intake of solar energy, an important role within the hydrological cycle, a stabilizing effect on albedo in the local biosphere or a combination of these aspects.

By linking this representation with another value in the criticality function, robustness R, furthermore a particular protective merit of the regions may be derived. To assess R, which designates a stability criterion within the local biosphere, a worldwide representation of local sensitivity of net primary production for precipitation and temperature changes was used. From a random sample of NPP at over 62,000 locations and the associated climate (air temperature close to the ground, precipitation, light penetration with consideration for cloud cover, etc) a statistical correlation model was drawn up. To ascertain sensitivity of NPP vis-à-vis climatic changes it uses a neuronal network (Moldenhauer and Lüdeke, 1999; Lüdeke et al, 1999) that quantifies the functional dependency of NPP on certain climate values. The resultant global map shows in which regions of the world NPP is relatively stable in the face of climate fluctuations and where major effects are to be expected from minimal climatic changes. Combining this result with the map shown in Fig. F 5.3-1 then identifies those biogeographical regions that equally have an important function for the Earth System *and* react sensitively to changes in environmental conditions (Fig. F 5.3-2).

Certain critical regions are outlined below. In the Northwest of the United States, an East-West strip (circle 1 in Fig. F 5.3-2) was identified as critical running within the Rocky Mountains parallel to the Canadian border. The vegetation types in this region vary between boreal mixed forest, coniferous forest and grassland and are at risk from human influence particularly in the regions around Seattle and Portland, through deforestation (clear-cutting) or the spread of settlement (Urban Sprawl Syndrome; cf also Chapter G, Fig. G 4.2-3).

The Atlantic coastal area of the Amazon together with Guyana, Surinam and Brazil is another important and fragile region (circle 2 in Fig. F 5.3-2). In that

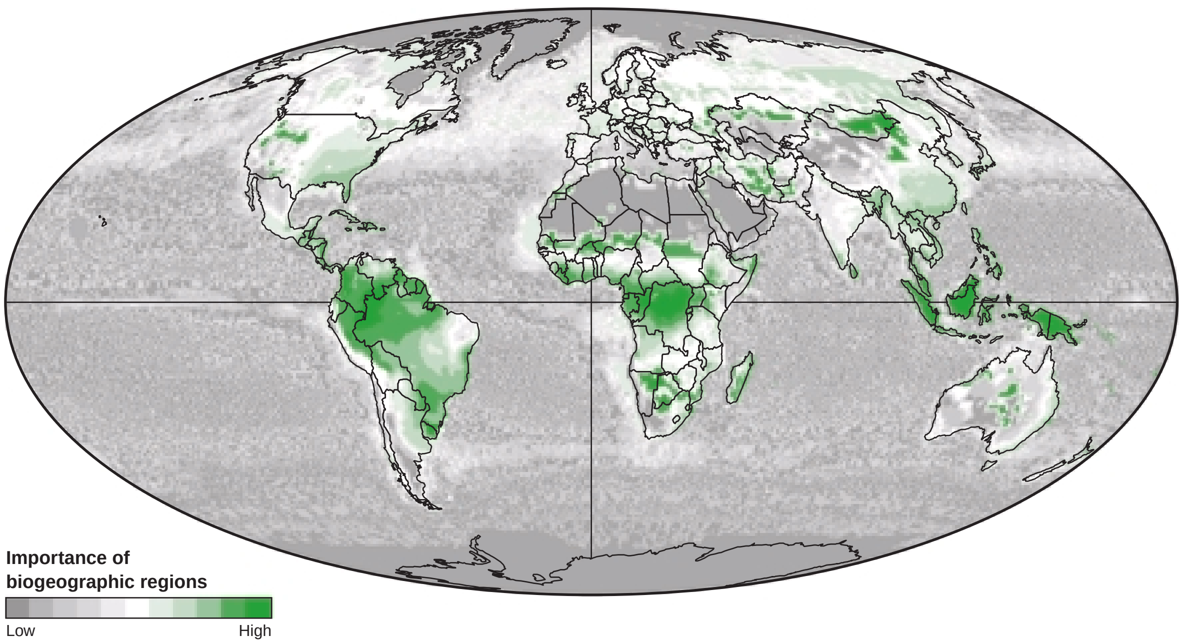


Figure F 5.3-1
The importance of biogeographic regions for the Earth System in the context of energy absorption, the thermostat effect and the hydrological cycle.
Source: WBGU

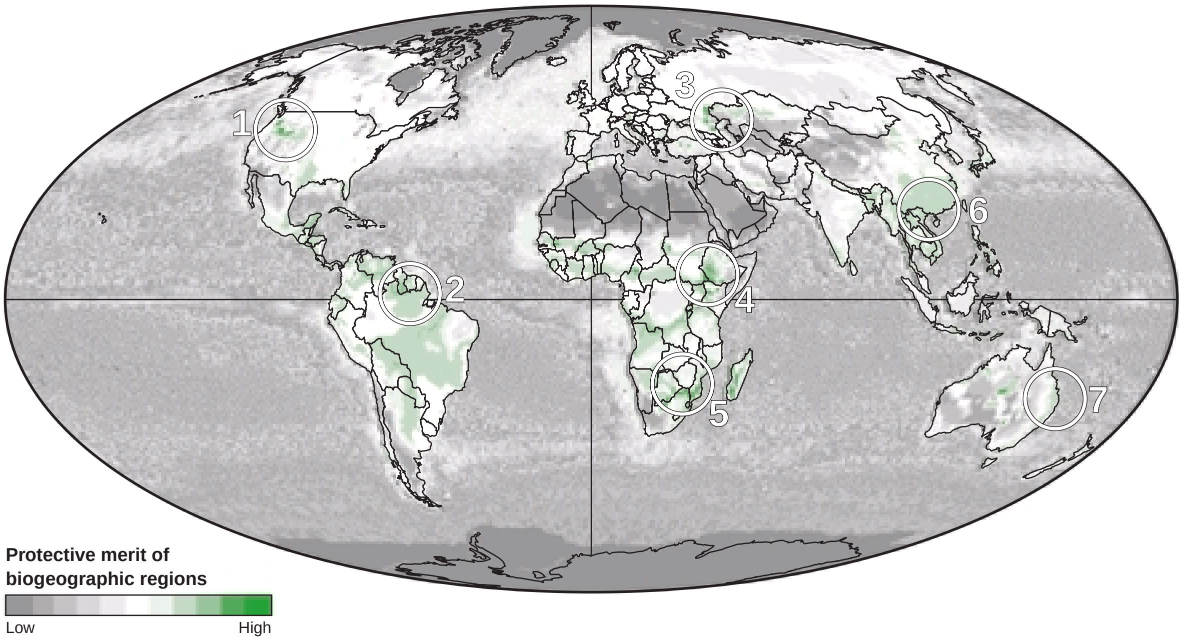


Figure F 5.3-2
Biogeographic regions with important functions for the Earth System (Fig. F 5.3-1) and, at the same time, high climatic sensitivity.
Source: WBGU

region there is a tropical rainforest at risk through logging, and steppe-like bush and grassland areas already suffering degradation. The coastal strip is used as an agriculture and settlement area. Similarly worthy of protection are large areas of Central Brazil and the Cordilleras of Venezuela. The chances of effective protection, however, are small in light of the weak state structures in those countries.

The critical areas on the northern edge of the steppes of Kazakhstan are located in a strip north of the Caspian Sea and the Central Asian deserts (circle 3 in Fig. F 5.3-2). Today there is primarily high-yielding agricultural activity there and hardly any of the original steppe. The conversion of steppe to arable land that has been performed here is, however, a comparatively small intervention.

The critical areas in Africa are in several swaths along the Sudan zone and the transition zones to the rainforests of West and Central Africa in Southern Congo, Mozambique and Madagascar (circles 4 and 5 in Fig. F 5.3-2). The use pressure is comparatively high but with the exception of Southern Nigeria the population density remains at a low level. Thus, agriculture and forestry are of only a medium to weak intensity in almost all of the regions. Only in exceptional areas such as the coastal forests of West Africa must we fear that an intensification of use will lead to a swift destruction of the biome functions.

Southern China and Indochina (circle 6 in Fig. F 5.3-2) are high density areas of land hardly covered by natural vegetation at all. Particularly in the mountain regions of Vietnam, Laos, Southern China, Thailand and Burma, as a result of the regulatory functions for the rivers, their high biodiversity and their climate functions are extremely important. Eastern Australia (circle 7 in Fig. F 5.3-2) is also in need of a great deal of protection because the original vegetation in particular in the Southern parts, has been replaced by agricultural land. Given the level of prosperity achieved in that region, however, there is the possibility of reducing the intervention in the biosphere to a tolerable level.

In general terms the data sets and maps allow the interpretation that critical biogeographical areas are characterized by strong environmental gradients with these areas often occupying marginal zones between large areas of biosphere elements.

The Council should like at this juncture to emphasize once more that these analyses are just *one first step* towards identifying functionally important biogeographic regions that merit protection. The evaluation of the global biosphere under the aspect of particularly important Earth System functions is only just beginning and should be the subject of redoubled research endeavours. Future research must take into account the reciprocal dependency of different biogeographical regions. Each of these important 'organs', as one could term the biomes within the Earth System, has its own ecology with characteristic and networked components. The forests of the boreal and the temperate zones, the grassland regions, the tropical humid regions and savannahs, the deserts and the mountainous regions are all distinguishable by each of their specific effects of albedo, evapotranspiration and carbon throughput. They form habitats whose borders to neighbouring biomes are distinct. The boreal forest in Canada or Siberia is for example separated by a narrow transitional zone of perhaps 20–30km marking if off from the grassland biome which has a completely different ecology.

Although these biomes are clearly delineated in terms of their characteristics, they are not independent of one another. At a higher level in the hierarchy they actually form a complex network of dependencies and are in the figurative sense the 'global players' in the biosphere-environment linkage. The tropical rainforests benefit for example from the desert regions through wind-borne dust and nutrient transportation: without regular fertilization with Sahara dust the leached soils of vast areas of the Amazon could not maintain their biological diversity. Similarly, dust and firestorms in the grassland biomes provide nutrients and soil material for the forests. Dependencies result not just from remote effects but also directly adjacent there is an interaction of cooperation and competition for nutrients, but above all for water. The importance of one biome for the others could therefore be evaluated on the basis of the number of interactions: whether a biome is in interaction with other biomes or whether it is organized in a relatively autonomous state gives an important indication of the possible further impact of local damage, and particularly for the impact on the system as a whole.

Biosphere-anthroposphere linkages: The Overexploitation Syndrome G

'Overexploitation' as a syndrome of global change G 1

Syndrome analysis (WBGU, 1995a–1998a) has already been mentioned at various points in the report. In this chapter, we provide a detailed analysis of a typical pattern of unsustainable use of the biosphere. The essential characteristic of this research method is the analysis of *linkages between natural and social factors*. We have selected the Overexploitation Syndrome.

G 1.1 Characterization

The Overexploitation Syndrome describes the rapid overuse – to the point of destruction or elimination – of renewable resources and the degradation or destruction of ecosystems on the basis of short-term use interests. Irreversible losses of biological diversity are the result. The losses to humankind manifest themselves sometimes directly, sometimes with a certain time lag and in a diffuse manner. The global forest ecosystems with the last remaining primary forests in the tropical and boreal regions are affected above all by this syndrome. The overgrazing of steppes and savannahs and the extinction of individual plant and animal species or the overfishing of the world's seas are other examples of unsustainable use of nature that follows the typical pattern of the Overexploitation Syndrome (WBGU, 1997, 1998a; QUESTIONS, 1996, 1998; Cassel-Gintz, 1997).

G 1.2 Manifestation

Both historical and present-day examples from various regions and environmental media describe the full range of anthropogenic natural destruction. They all have one thing in common: in what are at first glance very different cases the interaction of humankind and nature always follows at its core the typical pattern of the Overexploitation Syndrome.

Historical examples

The Overexploitation Syndrome emerges very early on in the history of human civilization development. Back in ancient times it was observed that a swift use of renewable resources beyond the resource's capacity to regenerate resulted in a whole range of negative consequences for nature and civilization. An early example is the deforestation of the Mediterranean in antiquity because wood was needed for shipbuilding and settlement construction. Plato, in his dialogue *Critias* (circa 350 BC), reports on the deforestation of the Attic slopes which left the soil unprotected and prone to water erosion and writes that of the once blooming and 'fat' landscape just a 'bare skeleton' remained. In the middle of the 19th century authors such as Carl Fraas or Georg Perkins Marsh drew attention to the exploitation of forest resources and the negative consequences of this (Schramm, 1984; Brüggemeier, 1998).

The almost complete eradication of the North American bison for its hide in the last centuries is an example in another form of the Overexploitation Syndrome. In this instance the stocks of an animal species were reduced to a minimum on the basis of short-term economic interests. In a similar fashion, industrial whaling in the first half of the 20th century led to the almost complete annihilation of certain species.

These examples already indicate the change of scale in the issue of the Overexploitation Syndrome. Whereas the consequences in earlier times were limited to smaller natural areas and were primarily regional in nature, today often large regions or even – as in the case of deforestation with feedback to the global climate – the entire Earth System is affected. Even if one does not take into account the losses for future generations, therefore, a great deal more people are confronted by the consequences of overexploitation today.

Regional examples

The Overexploitation Syndrome can in the present day be seen in, for example, Malaysia in various medial manifestations. With regard to the destruction of forest ecosystems, it has already reached the final phase: now that most of the forest stand of the economically valuable *Dipterocarpaceae* family (primeval trees up to 70m high) has been destroyed in Sarawak and Sabah through large-scale logging, timber companies from Malaysia have more recently been switching to buying up logging concessions in other southeast Asian countries, as well as in Guyana, Brazil and Surinam. This is one example for the geographic shift in the mechanism which, whilst ruinous in terms of the long-term social, ecological and economic consequences, is extremely lucrative in the short term from the individual perspective of the international timber industry. The persistence of important trends within the syndrome and the structures thus formed are particularly clear in this case: logging companies and the associated processing industries, supported by the generous awarding of concessions, have over decades built up a considerable technical, economic and human capital that still has an interest in being deployed profitably even when the local resource has dried up. Under the pressure of competition within the globalized logging industry this trend towards trans-continental spread of the syndrome is becoming more acute.

Another form of the Overexploitation Syndrome in the same region is fishing in Malaysia. Traditionally, it was less productive and restricted to the shallow coastal zones. In the 1970s, however, the fishing industry and fleet were modernized and mechanized and Malaysia became one of the leading fishing nations. Production reached its height in the 1980s and since that time is now primarily limited to the grossly over-utilized coastal regions (ECB, 1997). The Overexploitation Syndrome is therefore also active in the medium of 'water' in the Malaysian region in the form of heavy overfishing of coastal stocks and destructive fishing methods (eg dynamite or cyanide fishing, Section E 2.4) close to the ecologically highly sensitive coral reefs.

Negative social and economic consequences for a region in which the overexploitation existed in the past are visible for example in the Philippines. In the 1960s and 1970s, the country was one of the four largest timber-exporting nations in the world on the basis of an extremely unsustainable forestry policy. As a result, 90 per cent of the forests of the Philippines were lost within a very short time. The country became a timber importing country and approx 18 million people who had primarily lived in and off the forests became impoverished (Abramovitz and Mattoon, 1999).

Overfishing

Malaysia as a regional example gives some indication: not only forests or other landscapes but also the use of marine and limnic ecosystems is often taking place in a manner described here as the Overexploitation Syndrome. Overfishing has now become a serious threat to aquatic ecosystems (Section E 3.4).

The simplest explanation for overfishing is that this problem stems from the fact that (sea) fish are an 'open access' resource, for the maintenance of which no one has any particular interest, and they are overutilized because there is no individual advantage to be derived from sparing fish that are then going to be caught by the next fisherman. In this way, overfishing is to be seen as a classic open access problem, but that falls too short since that explanation fails to explain why so far only insufficient remedies have been taken for this wrong behaviour – even when as in the case, for example, of the EU waters one cannot talk about open access in the strict sense anymore. Furthermore, other factors should be included, one of the main causes is subsidies: various estimates indicate that fishing makes overall losses that are cushioned by subsidies, depending on the company and the region either partially, completely or even overcompensated. A particular case of mismanagement is the subsidies provided for the development of fishing fleets whose capacities have for years been increasing much faster than the catches themselves (Section E 3.4). Too large a fishing fleet demands further subsidies. This development, just like the overuse of forests, can be explained to a great extent by the influence of the fisheries lobby that, just like the timber lobby, seeks to prevent a loss of subsidies. The sustainable use of aquatic ecosystems is however more difficult to regulate than that of the forests, for several reasons:

- Monitoring is more difficult. One example is the landing practices: often more fish are caught than are 'landed' since the fishermen throw back overboard any fish that do not yield a particularly high financial return (Section E 3.4). This practice is actually promoted in a certain respect by the strict catch quota arrangements and is more or less impossible to monitor.
- It is more or less impossible to define ownership rights to fishing grounds for individual fishermen and thus to establish incentives for low-impact resource use. In practice, it is only governments that receive such property rights and fishing companies at most will own rights to certain quotas.
- It is relatively difficult to predict fish populations (Section E 3.4). This means that fishing quotas that are considered sustainable can change unpredictably within a very short time, which causes planning problems for fishing companies. On the other hand, use of sustainable fishing management is not immediately evident since there is hardly any way of proving a statistical connection

between the amount caught and the recruitment rate the following year. By contrast, in the case of forests the growth is calculable and the consequences of unsustainable management are immediately evident. Having said that the shorter life cycles of the most important fish caught also make it possible for relatively quick regeneration. Therefore, forward-looking strategies of risk minimization with higher uncertainties are particularly important here (WBGU, 2000a).

The Overexploitation Syndrome in the form of overfishing is also characterized by the fact that for a limited time there is the possibility of maintaining the capacities following overuse of a sub-region by shifting to another sub-region. The fishing fleets push out into ever-new fishing grounds and catch new species, mostly those that were not interesting until the 'superior' species had been overfished.

In the case of overfishing, geographic areas can be determined that are potentially prone to the Overexploitation Syndrome. This *disposition* is determined both by biogeographical factors and the socio-economic structures described above. With regard to the former, ecosystem factors include oxygen and nutrient content in the waters allowing high plankton production in the layer of water close to the surface. In that way, particularly the coastal and shelf regions as well as marginal seas can become vulnerable. In relation to the far larger habitats of the open seas these areas represent a small subsystem, but they account for approx 90 per cent of fish production. As a result of socio-economic factors areas that lie outside the 200 mile Exclusive Economic Zone are more likely to be affected since the direct influence of governments is much smaller. That also applies to the coastal waters of states that are not in a position to monitor their fishing rights effectively.

Annihilation and threat to individual species

The trade in individual animal and plant species has on a regional level led to considerable intervention in ecosystems, which is the reason why today approx 5,000 animal species and 25,000 plant species are protected by the Convention on the Trade in Endangered Species of Wild Fauna and Flora (Section D 3.4). (International) trade is often a reaction to very specific needs associated with culture, lifestyle or tradition. For instance, in Southeast Asia one can observe a severe loss of valuable animal species such as tiger and rhinoceros for the production of traditional remedies, particularly Chinese remedies. In more recent times the use of medicinal plants for pharmaceuticals commonly used in Europe has also endangered certain species. The desire for luxury goods continues to be a motive for trade in ivory, reptile skins or the furs of rare predators. For other species such as whales, hunting is lucrative simply because of the rich diversity of uses for the booty. Common to all cases is the short-term use disregarding necessary regeneration periods so typical of the Overexploitation Syndrome, which in many cases has led to the eradication of species, and indeed still does today.

G 1.3
Focus on global forest ecosystems

Cognizant of the diverse manifestations of the Overexploitation Syndrome, forest ecosystems will be subject to a syndrome analysis below in the following sections.

G 1.3.1
The forests of the Earth: Stocks and threats

Development of forest stocks

Global forest areas have in the course of history become ever more subject to humankind's influence. When agrarian cultivation was introduced around 10,000 years ago an estimated 6.2 thousand million hectares were covered by forest worldwide (Burschel, 1995; WRI, 1997). The current area covered by forest is given at around 3.45 thousand million hectares, of which half is tropical forest (1.76 thousand million hectares) and the other half boreal (0.93 thousand million hectares) and temperate forests (0.75 thousand million hectares; FAO, 1997b). This corresponds to a decline from 40 per cent to 27 per cent of the ice-free land surface over the last 10,000 years and documents the continuation of the process of deforestation. The global distribution of the present-day and historical forest resources is given in Fig. G 1.3-1.

Current forest area changes

Between 1980 and 1995 global forest cover declined by 180 million hectares (Fig. G 1.3-2). Above all in developing countries around 200 million hectares of forest was destroyed, primarily for agricultural use – a development which many industrialized countries went through in the early stages of their development (Brüggemeier, 1998). In that same period, however, a growth of the surface area of forest cover as a result of afforestation and set-aside agricultural land was recorded (FAO, 1997b).

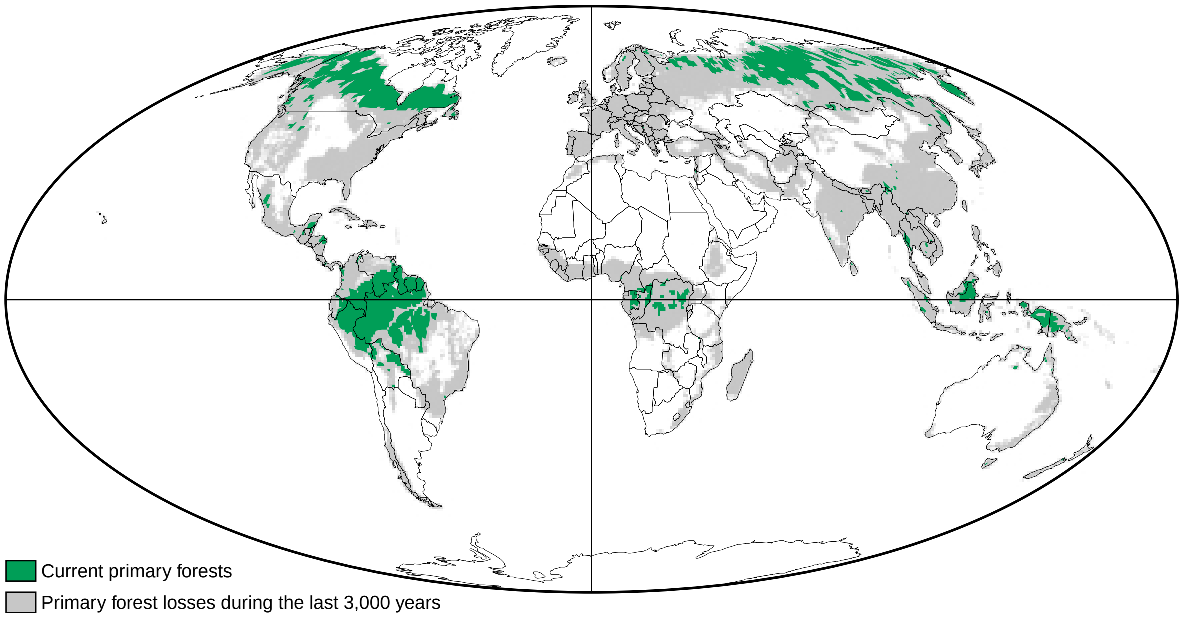


Figure G 1.3-1
Distribution of primary forest and forest types.
Source: Cassel-Gintz et al, 1999

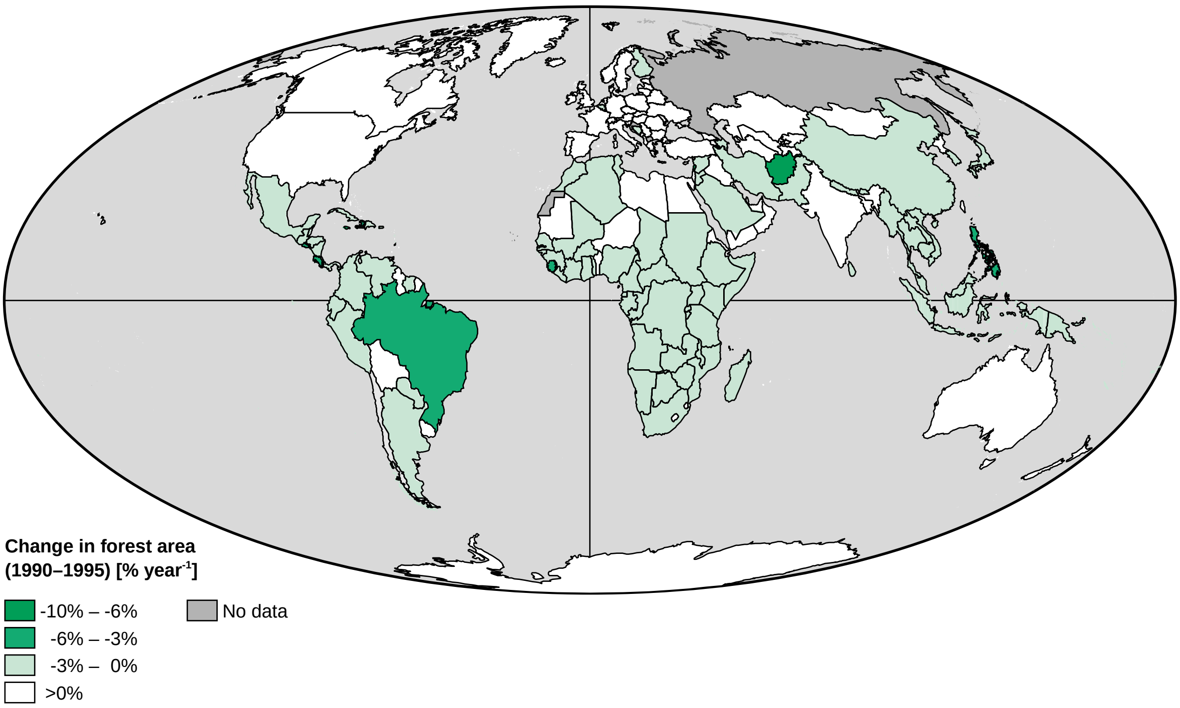


Figure G 1.3-2
Annual rate of forest cover change between 1990 and 1995.
Source: Cassel-Gintz et al, 1999

G 1.3.2
Placing the core issue of deforestation in the context of the syndrome

In the various regions of the world clearly distinguishable types of deforestation can be recognized (FAO, 1997b) that are attributable to different syndromes. Only a portion of global deforestation occurs according to the pattern of the Overexploitation Syndrome.

The predominant transformation in Africa of unfragmented forest areas via interim stages to bush and wasteland stems primarily from the expansion of subsistence farming as a result of rural poverty and population pressure (FAO, 1997b). This mechanism, which is also evident, albeit to a lesser degree, in Asia and Latin America can be understood as an expression of the Sahel syndrome (WBGU, 1997; QUESTIONS, 1996, 1998; Schellnhuber et al, 1997; Petschel-Held et al, 1999). The relatively swift conversion of unfragmented primary forests into other forms of land coverage dominant in Latin America is often due to government-organized measures (eg resettlement activities or construction of dams). The Council classifies this pattern as the Aral Sea Syndrome (WBGU, 1998a).

Large-scale conversion of forest areas to arable land with subsequent profit-oriented cash-crop (eg oil palm plantations) or intensive grazing use is by contrast termed the Dust Bowl syndrome. This conversion takes the form mostly of large-scale slash and burn and– in addition to an extraordinary El-Niño event that has a reinforcing effect – is also seen as the fundamental cause of the 'forest fires of the century' that occurred in Indonesia in 1998. To a lesser extent measures to harvest non-renewable resources (oil and gas, precious stones, ores, etc) are also responsible for forest destruction. The 'disruptive' forest is removed and the profit possibly made on the sale of the timber is a by-product. The Council has termed this the Katanga Syndrome.

Although the temperate forests of North America and Europe provide one-third of the world's timber, the forest areas in these regions have been expanding for some time. The main reasons for this expansion are the set-asides in agricultural production and afforestation with species-poor plantations. The threat to the forests in these regions also primarily emanates from the displacement of natural forest stands by structurally and biologically-impoverished monocultures (Schmidt, 1997). This displacement often takes place in the context of long-term forest management and constitutes a slow, insidious form of the Overexploitation Syndrome. Stresses arising from bioaccumulation of sulphur and nitrogen compounds leads to major damage in these forests (acid rain). This syndrome has been identified as the Smokestack Syndrome by the Council (WBGU, 1998a) and describes the remote impact of emissions. Noxious substances are disposed of through as fine a dispersal as possible in the air and water. They then have a direct impact in other regions on biotic communities or become enriched in the organisms.

G 2 The mechanism of the Overexploitation Syndrome

G 2.1
Syndrome core

In essence the Overexploitation Syndrome consists of the temporal discrepancy between human use and natural (re-)growth of the resource (Fig. G 2.1-1). The processes characteristic of this syndrome in the natural sphere are recognizable by the trends of overexploitation of biological resources and damage or conversion of the ecosystem. On the other hand, there are direct and indirect damages to extensive environmental areas: soil compaction or changes in the local groundwater levels are examples. The extraction of resources takes place to a degree that exceeds the reproductive capacity of the resource and, in the extreme case, is associated with the irreversible destruction of species or ecosystems. Thus, this syndrome threatens the functioning of the biosphere overall and changes the global regulatory and biogeochemical cycles. A particular feature of the Overexploitation Syndrome is that – provided the driving forces persist – it 'reproduces' itself in Region B when it has exhausted Region A through complete overuse ('sparkler effect'; Fig. G 2.4-1).

A major anthropogenic cause may be seen in the use of forests by local, and often by multinational players in the timber industry, use not designed for long-term management but for short-term profit maximization. Often these practices are tolerated or even actively promoted by the state. Alleged or actual advantages from this type of use (such as the generation of income, employment, tax revenues, hard currency) and public 'policy failure' (such as corruption, lack of resources for administration or executive) or shortcomings in infrastructure typically cause governments to even enact enabling policies such as awarding subsidies or tax breaks; thus they

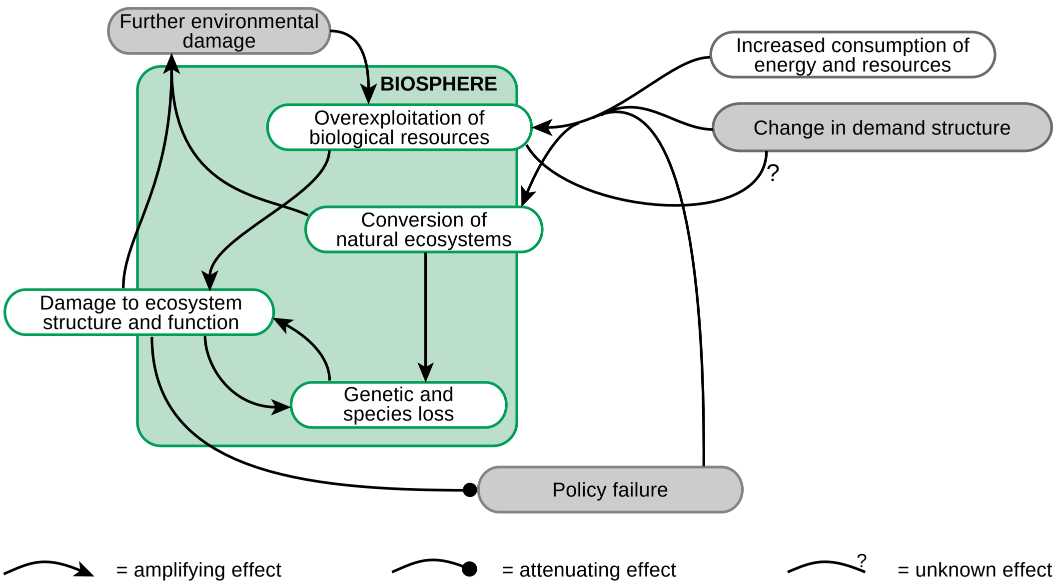


Figure G 2.1-1
The core of the Overexploitation Syndrome. Grey shaded ellipses indicate aggregate or ancillary variables that are not included in the global network of interrelations (see text for explanation of the mechanisms depicted here).
Source: Cassel-Gintz et al, 1999

are responsible for failure to adhere to the protective guidelines.

The overexploitation of biological resources that is not prevented, or is even promoted, by policy, is spurred on essentially by two factors: first of all increasing use of energy (firewood) and raw materials (wood products), and secondly a change in the demand structure (product spectrum). Whereas the first aspect is of a more quantitative nature, the second aims at qualitative changes in the composition of consumption. Overuse is not just promoted by 'policy failure' it also in turn feeds this driving trend. Here, the phenomenon of corruption that in many 'overexploitation countries' plays an important role as well as the importance of the timber lobby are significant here. In both cases social players that have profited from active overuse in the past, have accumulated a high degree of economic, social and political capital and are able to exert appropriate pressure on governments with regard to concession awards, legislative or interpretative practice which itself favours future timber extraction.

The political system acts in the context of the historically largely stable syndrome core in a way that would subdue the syndrome if the damage to the function and stand of the resource were so far advanced that no revenue could be achieved. The fact that political protest or scientific reservations can also be asserted at that stage is historically speaking a recent phenomenon that links in to the present network of interrelations rather than the classic core of the syndrome.

G 2.2
Syndrome trends and interactions

The *syndrome core* may be historically speaking a relatively robust description of unsustainable interaction of humankind and forest, nevertheless this does not do justice to the current form of global timber overexploitation and its importance for the biosphere. The *syndrome-specific network of interrelations* analyses the relevant trends and their interactions in a more detailed fashion and incorporates present-day factors (Fig. G 2.2-1).

Trends in the economic sphere

If one looks at the logic of the process of the Overexploitation Syndrome then its point of origin is a lucrative market, which is driven by increasing global demand (*globalization of markets*). In the case of the syndrome form 'forest' this is the market for timber and wood products (paper, cardboard, furniture, construction timber, veneer woods, particle board, kitchen fittings, windows, etc), in the case of 'fish' the market is for fresh fish and fish products (fish oil, fishmeal, frozen goods, etc). In the last few years, in addition to the high demand coupled with strong purchasing power in the industrial countries, there has been an increasing domestic demand from newly-industrializing and developing countries (eg Brazil, Malaysia) (*the spread of Western lifestyle and consumption patterns*). In that context, in addition to the number of consumers and their level of prosperity and expectations, the technology of resource harvesting and processing and the form of consumption play a crucial role in determining the amount in demand. On the one hand *automation and mechanization* of the syndrome, the wide availability of the chainsaw or heavy timber processing equipment are examples of this phenomenon. On the other hand, the technological progress also protects some resources. Lower spoilage rates and higher recycling quotas can in some cases lead to large timber savings and slow some of the demand hikes stemming from population and prosperity pressure. The substitution of wood products with other materials can also lower the extraction rate of these resources. This effect is taken into account in the trend to *develop new materials, material substitution*.

The dominant demand sectors in the timber industry are construction, industry, individual consumer goods sectors (eg furniture, paper, packaging) and various infrastructure areas (eg railway sleepers, telegraph poles) that are all linked to the macroeconomic development and technological and consumption structures of a country. In addition, above all in developing countries and newly-industrializing countries, the need for firewood plays an important role (*increasing consumption of energy and resources).* If conditions remain the same, a country's demand for wood will not be determined by population growth alone, but can also receive additional stimulus for growth with increasing prosperity.

In some industrial countries in the recent past demand for tropical hardwoods has been falling or at least stagnating, in part as a consequence of changed parameters in world trade (*increase in international agreements and institutions),* partly as a result of changed consumer behaviour (*growing environmental awareness*) and/or a growing *sensitization to global problems* in public opinion. The debate regarding the introduction of product classification (certification; Box E 3.3-8) is characteristic of that behaviour.

For the demand structure to have the effect of amplifying the syndrome there must be a timber sector that is economically significant in terms of turnover and employment. The sector encompasses logging companies, sawmills and paper factories through to furniture manufacturers and other manu-

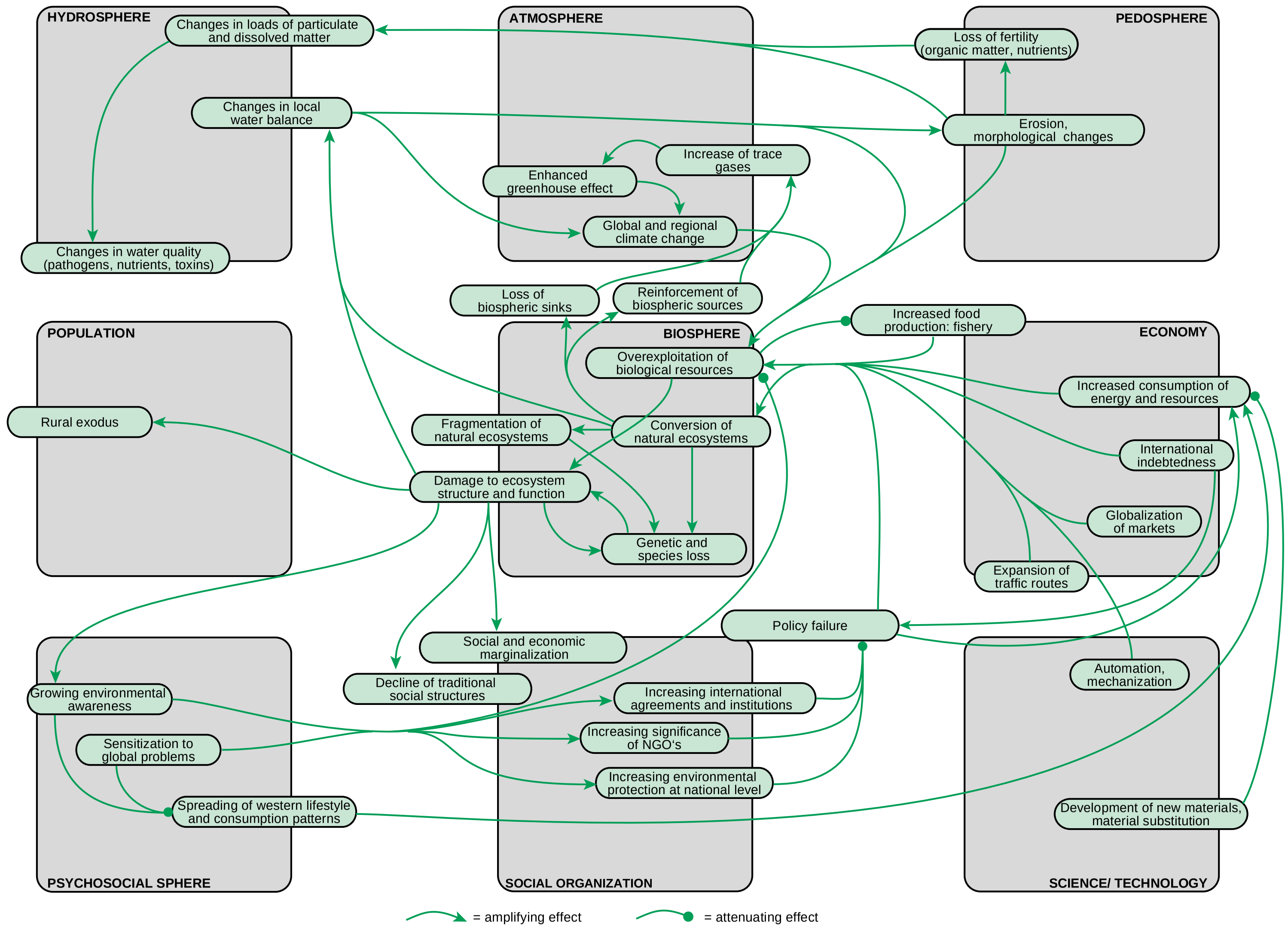


Figure G 2.2-1
Network of interrelations characterizing the Overexploitation Syndrome (WBGU, 1995a, 1997, 1998a, 2000a). Interactions are elucidated in the text.
Source: Cassel-Gintz et al, 1999

facturers of items or capital goods made of wood. The heterogeneity of the types of operations with regard to their technical equipment is great, both worldwide and within a country. The influence of a company in amplifying the syndrome is all the higher the more 'complete' is its coverage (eg international) and the more inefficiently it operates. In Indonesia, for instance, in the mid-1990s just 43 per cent of the logged timber was processed into products, the rest was waste. In other developing and newly-industrializing countries the ratio at 45 per cent waste is a little more favourable (Jepma, 1995; Dudley et al, 1996). There is therefore great potential here for a resource-saving efficiency revolution.

A key consequence of the Overexploitation Syndrome is the dampening effect it has on the trend of *economic growth* in the country of origin. Essentially this interaction reflects the threat to a country's very foundation of existence, one of the fundamental driving forces for the emergence of an environmental policy and the sustainability debate. Destruction and degradation of nature when the Overexploitation Syndrome emerges lead to the destruction or prevention of the growth-promoting functions of the habitat but also indirectly to loss of cleansing, production and absorption functions in the environmental commodities in questions (de Groot, 1992). Two further effects are just as problematic. Short-term focus on profit is normally conflictually juxtaposed in the Overexploitation Syndrome with the more long-term productive and low-impact management of forests. Often even in the medium term, but without doubt in the long term, the local population will suffer under negative management effects, openings for production and income generation (both for private individuals and the state) are destroyed and negative effects in terms of regional, growth and development policies result. With the destruction of ecosystems and species that have evolved over centuries irreversible damage is after all being wrought which should be seen as highly relevant in terms of growth. Quite apart from the difficulties in quantifying the level of damage in monetary terms, making estimations here is particularly difficult since the destroyed ecosystems are largely unresearched and their economic value therefore unknown. It is furthermore not unlikely that at a later point in time productive uses will be discovered for known, but as yet economically 'insignificant', animal or plant species (Option value, Chapter H).

Another much discussed driving force behind the Overexploitation Syndrome is the *international indebtedness* of many developing and take-off countries (Miller, 1991; Kahn and McDonald, 1995). It has more of an indirect impact and is only really brought to bear once the decisive political institutions that hold responsibility for the timber resources have failed. There are two reasons why that is the case. First of all, a waiver of debt in public budgets can only reach private-sector players via the contorted route of budgetary, fiscal or economic policy measures. These can, but certainly do not have to, lead to the decision of servicing the debt with the logging and export of native timber resources. Secondly, it must be considered that the state's restricted room to manoeuvre as a result of its indebtedness, scope it would otherwise hope to assert in exercising pressure on the natural resources, tends to lead to a situation where the infrastructure that is conducive to the overexploitation – for which generally speaking a cost-cutting input from the state is made available to private resource users – is no longer affordable. One example of this counter connection – ie debt having more of an inhibiting effect on the spread of the syndrome – is Ecuador from 1974 to 1982 (Wander, 1997). Even the Southeast Asian countries for many years (until the economic crisis in the autumn of 1997) recorded relatively low debt rates and at simultaneous high deforestation rates.

Trends in the organization of society

The timber-processing sector also has an indirect influence on policy. A permanent 'clear cutting economy' is as a rule associated with the formation of powerful lobby groups (individuals, groups, clans, associations, trade unions, etc) that, at least at regional level, place the political system under great pressure. This economic factor also plays a role in democracies in which the social interests of sections of the population erode or at least substantially weaken protective goals through media publicity, association power and the compulsion to re-elect decision makers. If demand and the economic importance of the forestry and timber sectors are great deforestation in the sense of the Overexploitation Syndrome need not follow automatically. Around 80 per cent of the tropical forests are government-owned (Jepma, 1995). More effective political protection can distinctly mitigate economic pressure on the forests and stimulate the search for alternatives (other materials, sustainable logging), and there are a number of positive examples that demonstrate this fact.

As a rule the Overexploitation Syndrome occurs when market forces and the economic pressure of use come to bear on the resource through *policy failure.* By 'policy' we mean here the omission or action of the legislative, executive and judicial branches at the various levels of the administration. By 'failure' we wish to denote the inability or unwillingness of the political system or individual political players with regard to the goals of sustainable forestry or conservation. It can therefore be either an inability (eg lack of financial resources) or an unwillingness (eg other political priorities or the aspiration of individuals or whole groups for personal enrichment). Policy failure in that sense has several aspects that broadly speaking can be categorized into two areas:

- A *direct* failure of policy can be noted wherever in areas relating directly to resource use or a forest region that is significant in biosphere terms is released for clear-cutting as a result of misguided decisions or the absence of policy decisions. This can happen by logging concessions being awarded at ecologically or fiscally unfavourable conditions (short maturities, too low fees, no invitation to tender, too large territories and no or few protective conditions) or by government forest policy inadequately protecting the resource (insufficient number of protected areas or laws and too few controls; poor financial or personnel situation in forest agencies). The illegal extraction of the resource, generally absent from official statistics and which is amongst other things a result of the failings of political institutions, merits particular attention here. It plays a particular role in the context of forestry in countries such as the Democratic Republic of the Congo (former Zaire), Brazil, Laos or Russia. This direct political failing extends to forest management in the broadest sense.
- If the legal and fiscal parameters are designed in such a way as to favour un-sustainable timber and forestry industries then we refer to this as *indirect* policy failure. For instance, this is how an infrastructure policy can be operated that aims at the aggressive and swift development of (remote) forest areas (construction and upgrading of routes of communications). Furthermore, subsidies, tax breaks or import protection measures for an ecologically and/or economically inefficient timber-processing sector belong in this category.

Corruption is in both cases a particularly dramatic form of policy failure. In that case individuals or groups with an interest in overuse try to stimulate the action of political decision-makers that would promote such use through more or less direct ‘gifts’ of money or payments in kind, or in return for other types of services (eg in return for the award of concessions or a ‘soft’ interpretation of protective regulations). In that respect profits gained from overexploitation in the past may be used to ‘safeguard the future’ of this unsustainable form of business, which is why in Fig. G 2.2-1 an amplifying arrow leads from *overexploitation of biological resources* to *policy failure*.

Forests are also the habitats of humans. Many indigenous communities do not just live in forests, but for centuries have been living off them – often, but not always, in a sustainable manner (Section E 3.1). With the pressure on wood as a resource, the habitat and cultural space of these peoples is also under threat. Often their traditional rights of use are annulled when the forest becomes government property, and not uncommonly the reserves conceded to them are not offered sufficient protection. Overuse and damage to ecosystems destroy the habitat of the indigenous communities and drive many of them away into urban or rural settlements where they are subject to social and economic marginalization. On the whole, clear- cutting of wood as a resource does not just bring with it a decline in biodiversity, but also a loss of culture and a reduction in cultural diversity (*decline of traditional social structures)*. This loss may be little felt today, but with a glance back through history it has gained great momentum and may bring with it unforeseeable cultural consequences.

Trends in the biosphere

The main consequences and interactions of the syndrome are located in the biosphere. It is here, in particular, that processes of natural succession and their influence in the form of too strong a human use of biological resources (Walter and Breckle, 1983) play a role. The crucial consequence is the *overexploitation of biological resources*, the direct consequences of which are the *conversion of natural ecosystems* and the *fragmentation of natural ecosystems*. If the overexploitation takes the form of clear-cutting, the ecosystem changes radically: primary forest then becomes grazing land, wasteland, settled areas, etc. If however only selective logging takes place (particular species or age groups, delineated areas) then the original system is fragmented. Many secondary forests are products of such fragmentation processes. Further overuse may convert them fully.

Both forms lead to a *genetic and species loss* and *damage to ecosystem structure and function*. The direct consequences of the overexploitation of renewable resources are the reduction or even destruction of species. For instance, just from selective logging, the stand of South American mahogany is declining at an alarming rate. These interactions also comprise other aspects such as the shifts in the composition of species: for instance, young forests can by damaged to a greater extent by herbivores (Schulze and Mooney, 1993). Similar arguments also apply to fishing. It is also important not just to look at the number of species, but also their quality compared with their original state in terms of the starting point and the functional relationship at the ecosystem and at landscape level (Dudley et al, 1996).

What is immediately seen is conversion-driven loss of biosphere sinks, in this case the loss of the carbon-storing function of the forests that contributes to the greenhouse effect and climate change (IPCC, 1996a, b). Overexploitation also has consequences in the area of soil; the biosphere and pedosphere are difficult to treat in isolation anyway, given the vast number of soil organisms. *Soil erosion and soil compaction* are the most visible consequences of the deterioration of the ecosystem. It is not just the erosion that follows clear-cutting that is in question here, damage from timber transportation routes or compacting by heavy machinery are also significant. For instance, in Finland large-scale overexploitation is done using scrap Soviet tanks. The *loss of fertility* occurs particularly in soils in which the nutrient cycle is determined to a significant degree by the biological occurrences in the vegetation, which is true of most tropical forest soils.

In addition to the direct consequences for the biosphere, eg reduced growth options, soil erosion also causes *changes in biogeochemical loads* and *water quality*, eg as a result of a distinct increase in sediment loads. This aspect of the Overexploitation Syndrome is seen, for example, in Bangladesh as one of the causes of the massive flooding they experience. Experience in Switzerland shows, however, that it is not possible to attribute causes in a way that will be applicable to all regions of the world (Christian Pfister, personal communication). A change in the local water levels takes place because, as a result of the *conversion of the ecosystem* and the *damage to system structures and functions,* there is less evapotranspiration (evaporation and release of humidity) with the effect of increased surface run-off. In that case, the terrestrial and limnic forms of the syndrome are coupled. The deterioration of the water quality in the catchment area as a result of deforestation leads above all to increased sediment being transported in the rivers and hence to a dramatic decline in the fish populations (particularly salmon species).

G 2.3 Possible syndrome scenarios

The core of the syndrome as described in Section G 2.1 was formalized using a new type of qualitative modelling approach in such a way as to be able to describe and forecast various scenarios compatible with this mechanism (Petschel-Held et al, 1999). This approach also makes it possible for example also to go beyond the categorization into boreal and tropical forests which, though the most obvious distinction, falls short of the truth in the light of the wealth of variations observed. What is crucial for this generally valid distinction is the use of certain principles such as the theory of ecological succession (Walter and Breckle, 1983; Tilman, 1993).

It should be emphasized that these various scenarios cannot be traced back to a different quality of interactions within the syndrome core. Rather they are the expression of the 'exemplary nature' of these relations, in other words it is precisely their general characterization in the form of statements, such as 'policy failure reinforces or stabilises unsustainable forms of management' (WBGU, 1994 and following), that permit such varied scenarios. And so this is not about divergent types of the syndrome but differing courses taken by the momentum of the syndrome that are possible as a result of conceivable and inherently consistent configurations of trends and interactions.

Two aspects must be distinguished from the outset: first of all, the question of what form of logging is being practised and, secondly, how the result of this form of logging is evaluated in ecological terms. Of course, both aspects, whether the technical-practical or the ecosystem-evaluating, are closely linked. For reasons of clarity the Council only distinguishes broadly here between Type A, in which the entire forest stand in an area is logged, and Type B, in which selective logging takes place (according to species, age group or proportional area). Accordingly, the result of these logging patterns is also only distinguished in two forms: first of all there may be a complete conversion of the ecosystem (eg from forest to grazing land), secondly, there may be various stages of degradation of the forest stand, from light clearance to species-poor residual forests with a distinct loss of functionality. Scenarios differing in qualitative terms only arise if the final result of human resource extraction is not just determined by the form it takes but also the speed at which it advances, and also in that case the reproduction rate of the natural vegetation. The following scenarios of the Overexploitation Syndrome typically occur in the 'forest' medium:

- *Type A conversion*: This, as it were, 'pure' scenario is characterized by an economically reckless exploitation of the ecosystems unchecked by policy. This would include, for example, clear cutting in the case of forest ecosystems where the natural succession is completely suppressed, whether by soil compaction or loss or fragmentation of predator habitats, so that an overpopulation of herbivores results that graze off even the young plant growth.
- *Type A degradation*: If, in an otherwise unchecked instance of resource use, consideration is given to a limited extent to certain ecological factors (selection of areas), then 'only' shifts in the structure of the ecosystem may be anticipated instead of a complete conversion of the ecosystem. For example, on certain clear-cut areas there is a rejuvenation process. However, the overall ecosystem

is degraded because the structure and the function of the ecosystem have been damaged. In the long term even this lightly arrested overexploitation scenario will lead to a complete conversion of the ecosystem in question. Most boreal forests in cultivated landscapes marked by long and intensive human intervention have gone through that scenario.

- *Type B degradation*: In this scenario also the resource is used selectively (cf *Type A degradation*), but the selection criteria are not primarily related to area but to certain species or age groups. If the logging exceeds the reproduction rate in the ecosystem the classic case of unsustainable forestry will occur. The severity of damage caused to the ecosystem then additionally depends on the degree of function and biodiversity loss, not just on the reproduction rate of the renewable resource. This scenario is typical for the majority of tropical rain forest areas that have been more or less transformed over time into degraded secondary forests.
- *Type B conversion*: In some circumstances, in the context of natural succession, there may also be conversion in *Type B degradation*. The transition to other syndromes is significant here; it can be triggered or promoted, for example, by the development and opening up of an area that usually comes hand in hand with resource use.

G 2.4 Interaction of the Overexploitation Syndrome with other syndromes

The significance of the Overexploitation Syndrome for the global deforestation issue varies from one forest type to another. In the boreal forests, the Overexploitation Syndrome describes the major component of deforestation. Other patterns of use, such as conversion of forest to agricultural use, play a secondary role. In the tropical forests the direct contribution of the Overexploitation Syndrome to deforestation is much smaller. The conversion to agricultural land accounts for the largest proportion of deforestation, with about 50 per cent attributable to small-farmers practising shifting cultivation (Herkendell and Pretzsch, 1995). This pattern was classified as an expression of the Sahel syndrome (QUESTIONS, 1996 and 1998; WBGU, 1997; Schellnhuber et al, 1997; Petschel-Held et al, 1999). Notwithstanding that fact, the Overexploitation Syndrome is also of great, albeit indirect, significance in the tropics in terms of the global core issue of deforestation: it functions simultaneously as a 'pioneer' or 'catalyst' syndrome for other patterns of forest destruction. As a result of the development of forest regions for or by timber companies the general access to a given region is always greatly improved. And along the newly built roads landless shifting-cultivation farmers and large

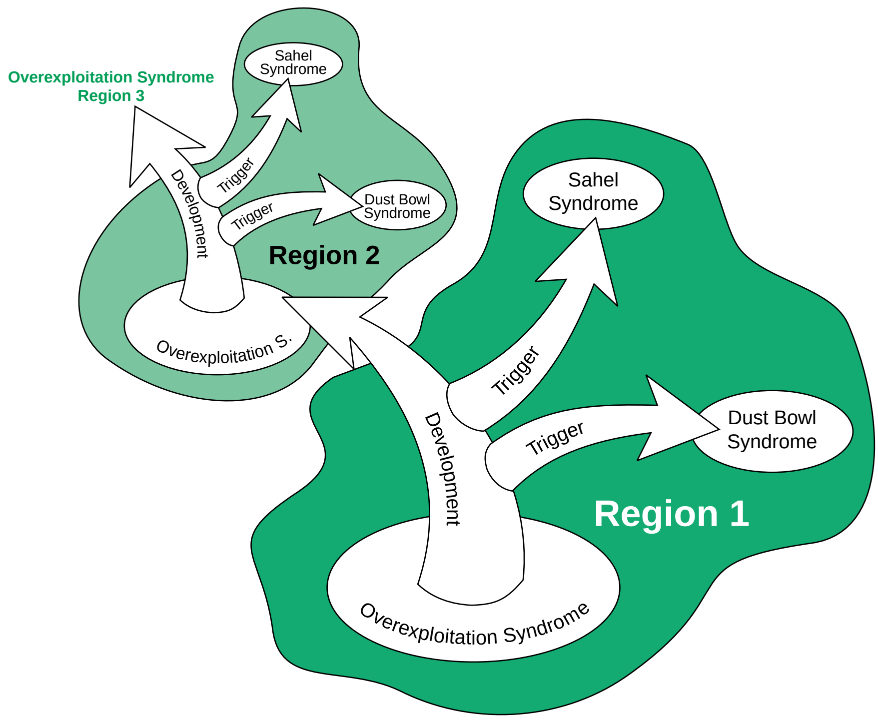


Figure G 2.4-1
The Overexploitation Syndrome as an element triggering the Sahel Syndrome and the Dust Bowl Syndrome.
Source: Cassel-Gintz et al, 1999

landowners arrive. These players, not really directly related to the Overexploitation Syndrome, can now transform large areas of forest into arable land. These areas are subsequently degraded by the outbreak of the Sahel or Dust Bowl Syndrome. In fact, in some cases at this stage the timber companies themselves take on the role of cattle ranchers on the converted forestland, for one thing to obtain long-term land rights and also to invest their profits in stable land assets.

This mechanism clearly shows the true potential for damage of selective logging. Since for selective logging of high-grade timbers (such as mahogany) routes of up to 500km first have to be developed (Verissimo et al, 1995), this form of forestry that in many cases is referred to as 'environmentally friendly', can cause considerable subsequent damage. 'Small' interventions of this sort generally lead to the large-scale development of forest areas, which are thus opened up to modern civilization and its various utilization interests. This type of degradation often triggers complete destruction of the usable soil layer. This effect of the Overexploitation Syndrome as the triggering factor for the Sahel Syndrome and the Dust Bowl Syndrome is depicted in Fig. G 2.4-1. This process is described in many case studies on tropical deforestation (Heilig, 1994; Walker and Homma, 1996; Mertens and Lambin, 1997; Lambin and Mertens, 1997; Rudel and Roper, 1997; WRI, 1997; Parayil and Tong, 1998; Stone, 1998).

This type of causal link also exists between the development of previously inaccessible regions and the upgrading of infrastructure for the construction of large-scale technical projects (such as dams) and the mining of mineral reserves. These patterns of environmental degradation were attributed to the Aral Sea Syndrome and the Katanga Syndrome (WBGU, 1998a), but the Overexploitation Syndrome can set these processes in motion.

G 3 Disposition of forest ecosystems to the Overexploitation Syndrome

For any analysis of the current dynamic, but above all to identify regions at risk in the future, it is important to ascertain what makes an ecosystem disposed to the Overexploitation Syndrome. In a formal manner, the concept of the area of disposition provides a response to the question of the conditions under which the interactions of the syndrome core are potentially present (QUESTIONS, 1998). Expressed in practical terms, the area of disposition covers those areas of the Earth in which there is a particularly high probability that the syndrome will emerge in the future.

Forests are seen as being disposed towards the Overexploitation Syndrome when the short-term, large-scale economic use of their wood products is both possible and probable. Other products of the forest ecosystems can be ignored in this context if their extraction does not bring with it the exploitation of the entire ecosystem. So the disposition is linked not just to the existence of forests but also to their potential economic use. This depends on a number of different factors which will be discussed below.

G 3.1 Disposition factors

The mechanisms characteristic of the Overexploitation Syndrome can only take hold if forest areas have a potential economic use. The potential economic use hinges on the density of the timber or biomass in a given area and on it being possible to reach those resources at as reasonable a price as possible. The relationship between transport costs, land use and deforestation is well documented (Lambin and Mertens, 1997; Cassel-Gintz, 1997; Stone, 1998) and can be explained in economic terms in the tradition of von Thünen's theory of land rents (Schätzl, 1988). The main premise is that land use is determined by the distance to the point of sale dependent on transportation costs (including development costs) and the sales price (Stone, 1998).

The density of biomass that can be put to economic use was estimated with the help of expert assessments (Kohlmaier et al, 1997) and a model on global vegetation dynamics (Sitch et al, 1999) and, using a compensatory AND-function, linked to accessible forest resources. A minimum biomass density required for economic viability is assumed.

The forest data used were taken from the World Forest Map (WRI, 1998b), that was transformed into 5' grid cells (around 10 x 10km at the Equator). However not all forest areas qualified as accessible are disposed to the syndrome to an equal degree. In many regions of the world the governments, from time to time under international agreements, have established protected forest areas with differing degrees of limitation on use. Areas with a protected status of Classes I-V according to the IUCN classification (Section E 3.3.2) are designated for political and legal reasons as non-usable. Protection against illegal logging through designation of protected areas (eg biosphere reserves under the MAB programme, Section E 3.9) may often be seen as inadequate and is dependent on local factors that vary with time. Thus the estimation of local legal certainty in these protected areas in the context of short-term influencing factors is assessed in the context of measuring intensity (Section G 4) and so is not significant here.

The accessibility of forests was simulated by means of a virtual cost calculation. The basic assumption was that forest areas that can be reached at a low cost are exploited before those that will take a large degree of technological and organizational input to develop and use. In order further to define that input, a fuzzy logic-based linkage operation was performed on the following factors:

– proximity to roads and railways,
– proximity to flat coastal areas,
– proximity to urban centres and dense areas of settlement,
– gradient in the topography of the terrain.

Permafrost areas and navigable rivers with no ice-free ports were categorized as accessible only with great difficulty. The map that was produced (5' grid) indicates the potential accessibility of forest areas and the relative costs required to develop the area

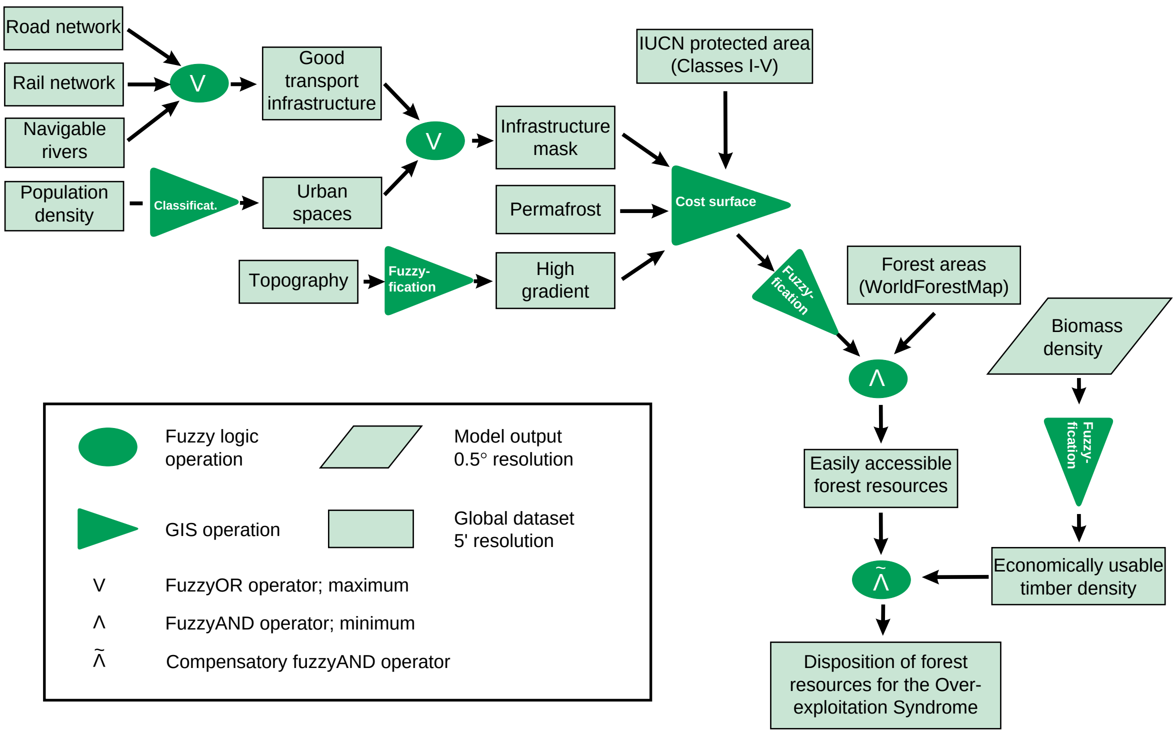


Figure G 3.1-1
Fuzzy logic evaluation tree used to determine the disposition of forest resources to the Overexploitation Syndrome.
Source: Cassel-Gintz et al, 1999

economically as well as the potential transportation costs for timber. The approach described here is depicted in the evaluation tree drawn up according to fuzzy logic in Fig. G 3.1-1.

G 3.2
Geographic distribution of disposition

Fig. G 3.2-1 shows the geographically explicit distribution of the various regions' disposition to the Overexploitation Syndrome as derived by this method. Below is a brief discussion of the disposition of the large unfragmented forest areas of the world.

The Americas

The forests in the densely populated regions of the east coast of the United States appear to be particularly highly disposed to the syndrome. There is an intensive timber industry here, particularly in the Northern New England states. In these regions the Overexploitation Syndrome had a particularly strong impact towards the end of the 19th and the beginning of the 20th century. Today, there is in places a dense secondary forest. In the Appalachians and Adirondacks overexploitation is still a feature of forest use.

In Canada it is primarily the regions along the St. Lawrence Seaway and the Great Lakes that appear to be highly disposed. The same is true of forest areas in Northern Ontario and parts of Quebec. The forest boundary in the Prairie Provinces and the west coast (British Columbia) also appear highly endangered. It is in these regions that a large part of Canadian timber production takes place. Above all, logging in the northern rain forests of the west coast on Vancouver Island and the mainland of British Columbia (Great Bear Rainforest, Clayoquot Sound) is currently significant (Diem, 1993; Soltwedel-Schäfer, 1997; Greenpeace, 1998).

In Central America, the Yucatán and the Caribbean coastal forests of Costa Rica and Nicaragua appear disposed. The remaining primary forests in this region are also categorized as high risk in the expert survey compiled on the basis of the study by the Frontier Forest Initiative (WRI, 1997). The forests of the Sierra Madre Occidental and the Maya Forest Region and along the Pan American Highway are described as at risk from logging.

In South America the accessible regions of the Amazon Basin and the Guyanan Shield are disposed. These regions have been identified in many case studies (especially about Rondônia) but also by the FAO as deforestation hotspots (FAO, 1999b). The

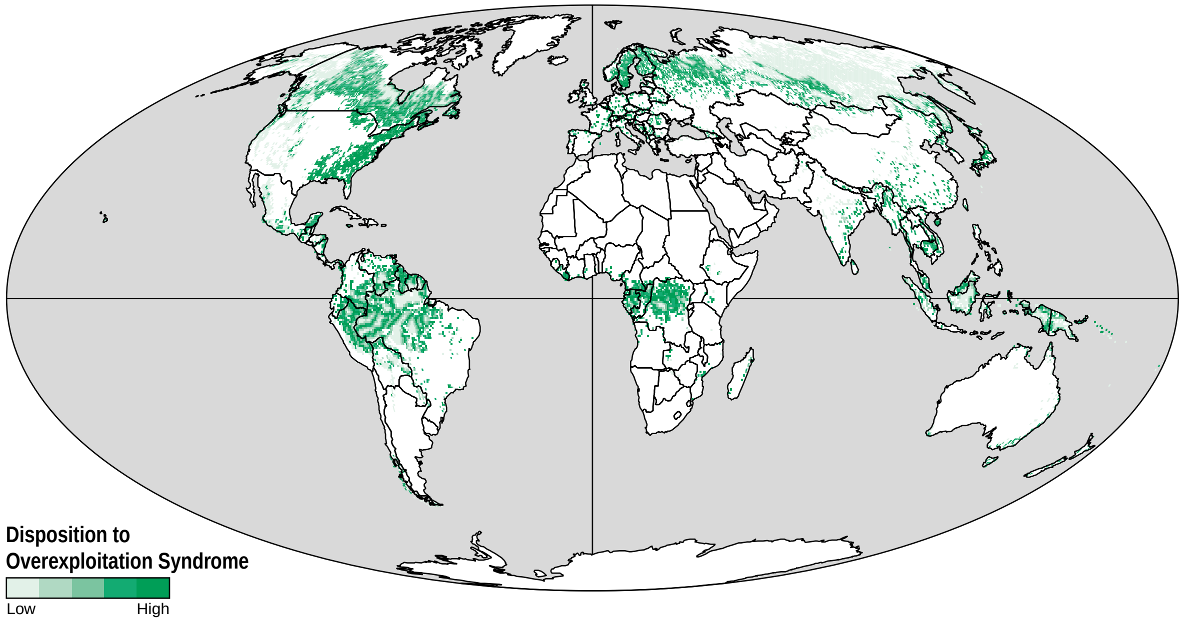


Figure G 3.2-1
Global area of disposition for the Overexploitation Syndrome for the example of forest resources (Mollweide projection true to surface area). White areas were not identified as having forest cover.
Source: Cassel-Gintz et al, 1999

smaller remaining areas of coastal rain forest also appear highly endangered (Dünckmann and Wehrhahn, 1998). The large, still relatively intact temperate coastal forests in Southern Chile appear to be disposed in places (Richter and Bäher, 1998).

Africa

In Africa the last great secondary and primary forest areas in the Congo basis are the main areas identified as disposed to the syndrome. These regions appear here to have been placed in too high a category since they do not reflect the wars and unrest over the last few years that are an inhibiting factor on the economy. Hence, in around 1960 the number of roads used for deforestation in the Congo area was a lot higher than it is today.

Asia and Oceania

Continental Southeast Asia demonstrates consistently high disposition levels, a result which is supported by many case studies (eg Krings, 1998). From 1960–1980 Asia lost around one-third of its tropical forests (Singh and Marzoli, 1995) and so takes up 'first place' worldwide. Even the remaining forest areas in Kalimantan and Sarawak on Borneo as well as in Irian Jaya and Papua New Guinea are highly disposed, although the disposition level seems to have been set a little too high for the latter. Most of the truly accessible forests in Borneo, Sumatra, Sulawesi and Irian Jaya have already succumbed to overexploitation leaving only forests in very inaccessible regions (WRI, 1997). The forests of Japan appear too highly disposed in the map when one considers their symbolic significance for Japanese society, an indication of resource use in changing cultural circumstances.

Europe and Russia

The very high disposition of the forests of Scandinavia and Finland can be explained in part by the fact that southern Scandinavia's timber plantations in particular have not been considered. The high categorization of the Russian forests is by contrast plausible. The economic problems Russia is experiencing in the transformation from a planned economy to a market economy are significant, as is the increase in corruption and crime and the loss of authority of many government offices. Overall, the pressure on forest resources is increasing under these conditions, amplified in turn by relatively inefficient logging technology (Greenpeace, 1998). In the southern forest areas of the Siberian taiga, the destructive influence of commercial logging is also well documented. Here, it is above all international, generally Asian, logging companies that see the forests of Siberia as a new and lucrative source to be tapped (WRI, 1997) and, in doing so, are endangering, amongst other things, the habitats of the Siberian tiger.

In this section we attempt to determine the geographic distribution of the various types of the Overexploitation Syndrome across the forest ecosystems. The first problem one faces is that the available data sorted by region on the nature, scale and cause of deforestation demonstrate clear deficits. Investigations using satellite and aerial images often underestimate the degradation of forest ecosystems since it is almost impossible to say anything about the degree of thinning in the forest. There can also be no details regarding the cause of deforestation, such as conversion for grazing, road or dam construction or arable cultivation. There are currently attempts to alleviate this general deficit through a global forest inventory, but the results are not expected for a few years yet.

G 4.1 Determining the basic types of the syndrome

These reasons lead to an indirect mode of determining the main types of degradation versus conversion (Section G 2.3). Studies were conducted in the period from 1990–1995 with reliable global data sets. On the basis of country-specific data-sets regarding the loss of forest areas, (LPJ: Lund Potsdam Jena Model; Sitch et al, 1999) the possible biomass extractions in the context of conversion were firstly estimated with the help of a global, dynamic vegetation model. However, neither the proportion of timber actually used in conversion or the location of conversion is known. Thus timber production in the context of conversion (full use in the most productive regions) can only be upwardly-corrected. The lowest estimate is zero corresponding to non-use of the timber in the converted forest areas.

If one compares in a second step the timber yield from conversion thus estimated with the corresponding empirical data for the total timber production of a country, the difference should be the degradation in existing forest areas (note: degree of degradation >90 per cent according to FAO definition). If one takes the proportion of timber use introduced above as an independent value, the result is the timber production for any given proportion that is associated with the degradation of the forest. The corresponding area of degradation may then be calculated with the assistance of the global vegetation model. Since, however, the location of the degradation is not known, here too just an upwards or downwards estimate is possible. Fig. G 4.1-1 demonstrates the result of this assessment in the case of Brazil. The line of upper estimate results when conversion and degradation take place on the most unproductive sites and the lowest estimate when it takes place on the most productive sites. The actual area of forest degraded by timber extraction should therefore lie somewhere between the two lines.

This type of estimate leads to characteristic differences between the tropical and temperate or boreal regions. The results of most tropical countries are similar to those of Brazil: for felling above a critical proportion of u_{crit} in the area designated as converted, the use of other forest resources should not be expected because of the carbon balance. For Brazil this level is at 25–65 per cent. Since however according to different sources the proportion of land conversion in Brazil accounted for by timber production is anywhere between 5 and 10 per cent, it may be

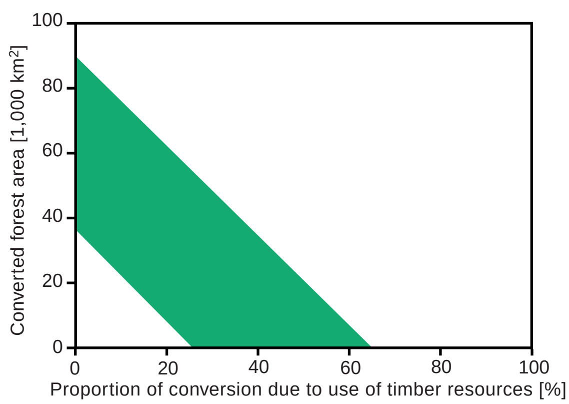


Figure G 4.1-1
Evaluating forest use for timber extraction without conversion of the forest area for the example of Brazil.
Source: Cassel-Gintz et al, 1999

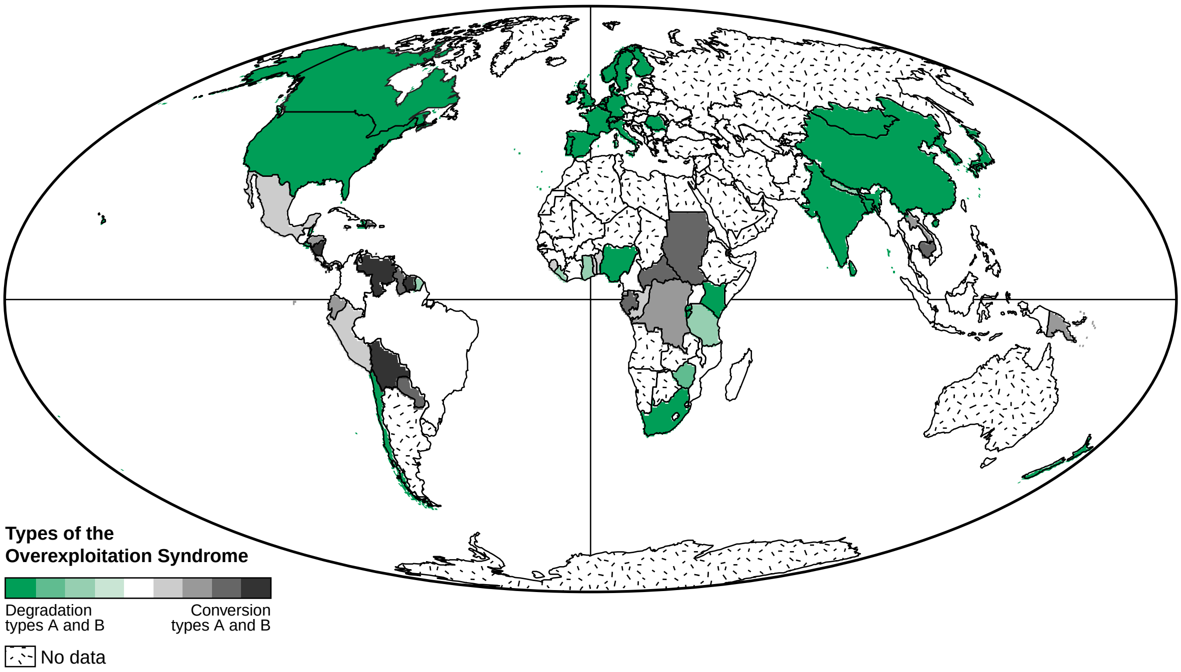


Figure G 4.1-2
Predominant types of the Overexploitation Syndrome by country without indication of the strength of the syndrome (blue = degradation types A and B; dark green = conversion types A and B; transition from blue to green = hybrid forms; grey = no consistent data sets available).
Source: Cassel-Gintz et al, 1999

assumed here (as also for other tropical countries) that a hybrid form between conversion and use coupled with continued existence of the resource prevails that may be linked to degradation. The scale calculated for the land used correlates in the case of Brazil with the figures given by Nepstad et al (1999) that gives an area damaged by logging in Amazonia in addition to deforestation of 10,000–15,000km^2 year^{-1}. By contrast the countries of the North all show a high degree of use without conversion. This difference may be summarized by the value u_{crit} (u_{crit} >1 for countries of the North). Fig. G 4.1-2 shows the geographic distribution of this indicator for hybrid use.

As may be expected most of the tropical countries demonstrate a hybrid form of timber use. Only very few countries, such as Bolivia or Venezuela, are characterized by a single conversion type. This is in contrast to the countries of the North where without exception it is not conversion but pure use of existing forest stands that can be observed. Having said that with this result one still has to take into consideration the issue discussed at the outset the fact that the data relate only to entire countries: thus, Canada as a whole actually records an increase in forest area, even though in large areas overexploitation is still in operation. This is where afforestation programmes weigh in that assure at the aggregate level of model calculation that the cleared areas are offset. Overall the measure given in Fig. G 4.1-2 may be taken as an indication of the type of Overexploitation Syndrome prevalent in a country, ie whether degradation or conversion, without indicating the severity of the syndrome.

G 4.2
Intensity of the Overexploitation Syndrome with regard to forest ecosystems

The intensity of a syndrome results from measuring all constituent trends and interactions (Section G 2.1). In the following we have tried to describe by way of a selective example of that sort of intensity measure in relation to two essential trends: the *overexploitation of natural resources* and *policy failure*.

G 4.2.1
Use of biological resources

Appraisal of the dynamics of use of biological resources draws on the statistics of the FAO, particularly with regard to the roundwood production of a country. Thus firewood is also included in the following discussion, which is difficult to integrate into the syndrome analysis. Firewood that is cut by impover-

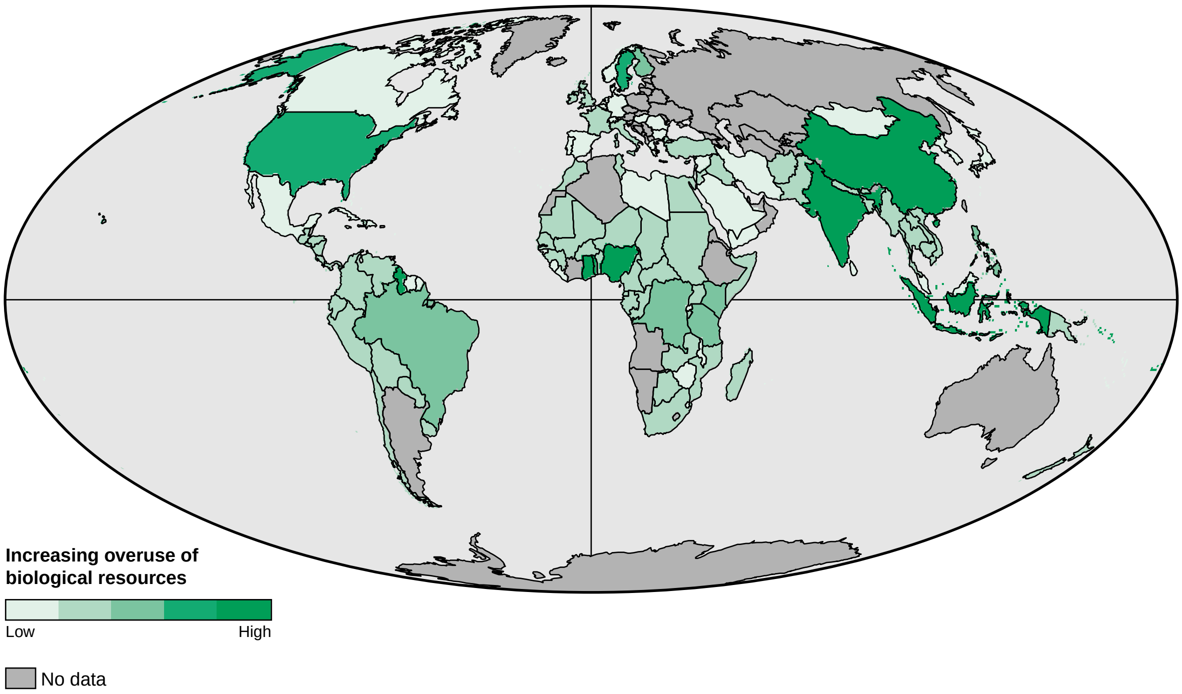


Figure G 4.2-1
Measure of the trend *overexploitation of biological resources*.
Source: Cassel-Gintz et al, 1999

ished subsistence farmers, for example, must be attributed to the Sahel syndrome. As soon as this timber is sold commercially it can also form part of the overexploitation logic. Thus the FAO figures on roundwood production have to a large extent been attributed to the Overexploitation Syndrome.

To determine the trend, first of all, the level of production was considered, and then also any changes in those levels from 1990 to 1995. The trend is especially relevant for the Overexploitation Syndrome if either a strong relative increase in production or a not overly strong decline in production at a high level is observed. This characterization was combined in line with the syndrome analysis (Schellnhuber et al, 1997) and the help of fuzzy logic on the basis of FAO statistics to form an overall indicator for these 'natural' components of the syndrome's intensity. The parameters that are required in the calculation were selected in such a way that the regions in which generally one speaks of 'overuse' were indexed accordingly.

Alongside the 'classic' deforestation countries of Brazil, Indonesia and Canada, others like China, India and Nigeria were also indexed as strongly affected by the trend (Fig. G 4.2-1). This is probably due to the high level of firewood use as an energy source in these countries. For instance, firewood production in China in 1990 accounted for 70 per cent of roundwood logging. However, since 1995 one can probably expect that proportion to fall as a result of the strong economic growth.

G 4.2.2
Measuring trends in policy failure

Policy failure relates in this context both to the inability of the government to enforce existing regulatory measures for the protection of forest ecosystems as well as to their unwillingness to even adopt such measures. The latter can be measured by the forest authorities/institutions that were in place during the period under analysis (1990–1995). The distinction was made between binding laws or merely action plans. This distinction is based on the details contained in the FAO forest report (1999b). In the case of an action plan one may pose the question to what extent the political and economic configuration in a given country allows one to expect implementation. Implementation can essentially be stopped by two mechanisms: corruption and lobbying (even, and in fact particularly, in democratic systems).

Corruption was calculated with the help of the corruption index of Transparency International (1998) both in terms of level of the trend and changes in the trend. This index currently measures the

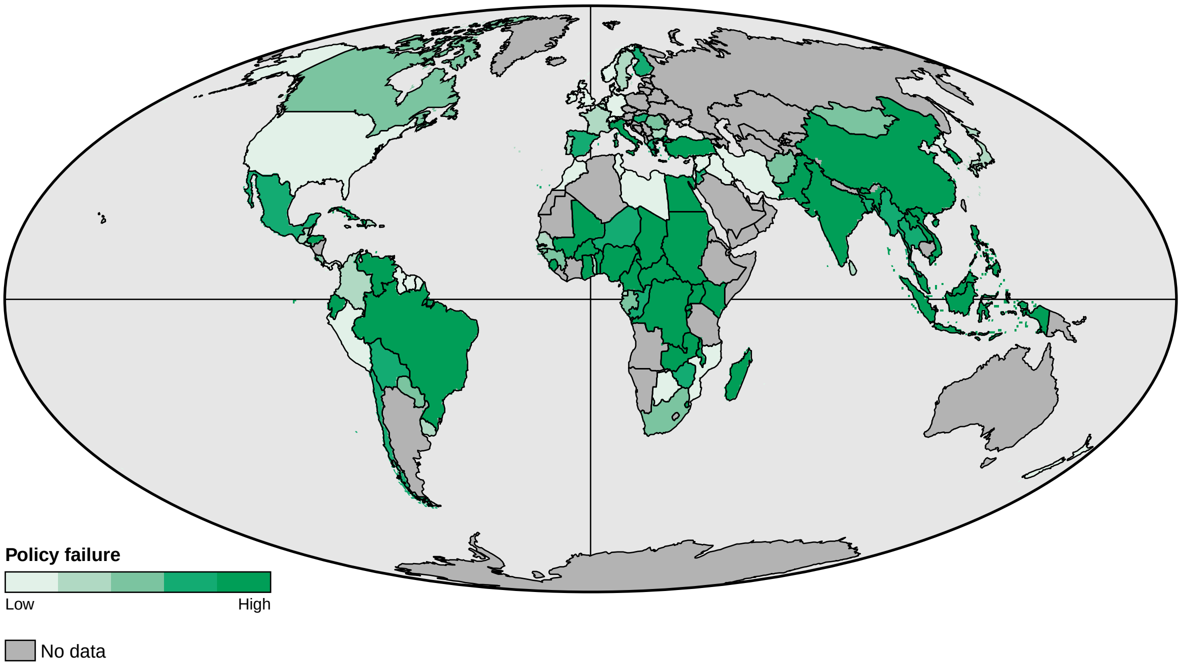


Figure G 4.2-2
Measure of the trend *policy failure with regard to forest resource conservation*.
Source: Cassel-Gintz et al, 1999

degree of corruption in state bureaucracy from the viewpoint of business and society in almost 100 countries. The basis for this is up to 12 different sources in which individual countries are evaluated independently of one another (eg the World Competitiveness Report or the Political Risk Service). To determine the resultant components of the trend in *policy failure* it was also taken into account that legally binding forest protection programmes are more difficult to circumvent than non-binding declarations of intent on the environment or conservation.

In order to estimate the degree of lobbying in terms of continued use of forest resources, an approximation of the forest sector as a proportion of the gross domestic product was used. Political decisions in provinces are not reflected in this indicator. This measure, combined with the composite corruption index, forms the indicator for policy failure given in Fig. G 4.2-2 with regard to the protection of forest resources for the period under analysis (1990–1995).

It may be recognized that in the tropical countries a high degree of policy failure is present, in particular in the classic 'deforestation countries': Brazil, Indonesia, Malaysia or the Democratic Republic of Congo. The trend is much less pronounced in the North. Exceptions are Canada and Sweden where lobbying long prevented, and indeed still prevents, implementation of forest protection measures. In the South there are only a few exceptions from the otherwise high level of policy failure. For instance, South African and Thailand demonstrate a somewhat weaker form of the trend.

G 4.2.3
Combined intensity

The individual indicators outlined above can with the help of a fuzzy logic AND operation be combined to derive an overall indicator for the Overexploitation Syndrome. This indicator, for which the geographic distribution is depicted in Fig. G 4.2-3, is the second component for measuring intensity alongside the 'type indicator' in Fig. G 4.1-2.

The map shows that the firewood-determined natural components in India, China and Nigeria are reflected in the intensity. The overexploitation of biological resources in these countries generally affects secondary forests and constitutes an oft neglected problem. The Council therefore wishes to emphasize that in the debate on global forest resources the secondary forests must not be disregarded.

In addition to these regions, the Overexploitation Syndrome emerges particularly in Indonesia, Brazil, Finland, Canada, Congo and a number of other countries. For this region or group of countries it is important to consider that the strong importance of the forestry sector generally speaking and in combina-

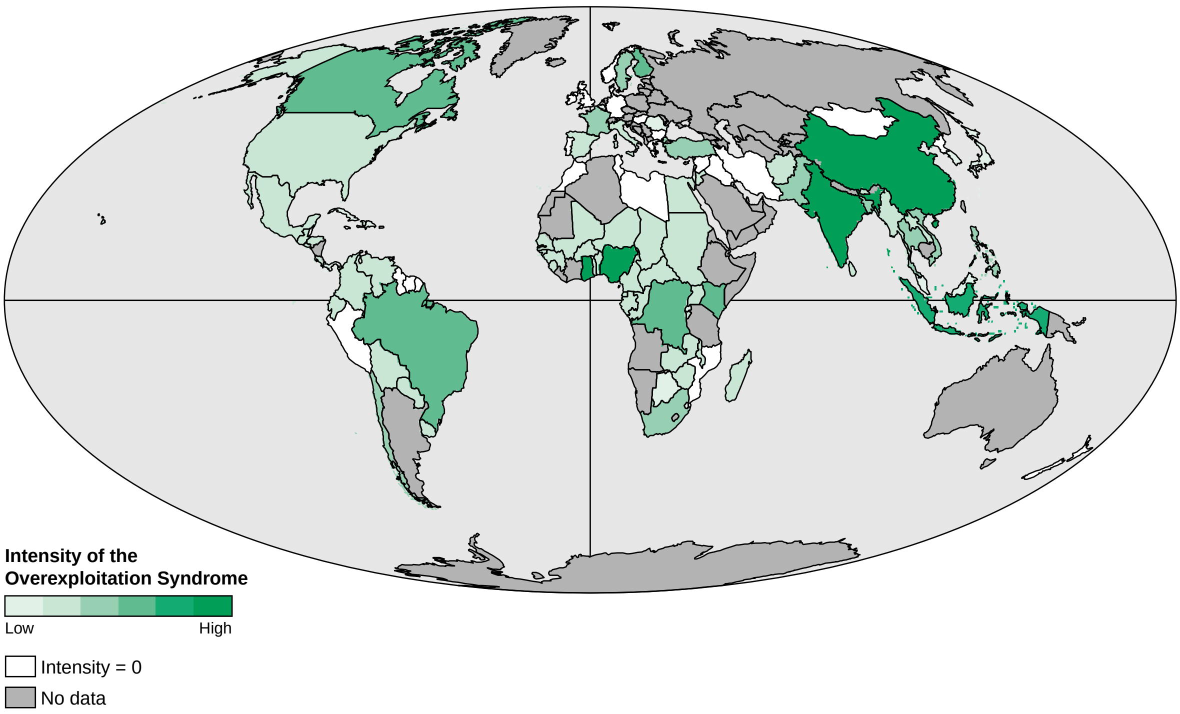


Figure G 4.2-3
Intensity of the Overexploitation Syndrome. See Fig. G 4.1-2 for type specifications.
Source: Cassel-Gintz et al, 1999

tion with corruption (in the South) and lobbying (in the North) constitutes a grave problem for forest resources. As long as there are no sufficient alternative sources of income, the tide cannot be expected to turn.

By contrast the syndrome is relatively weak in the US and large parts of Europe and North Africa. In the US and Europe in particular, well organized forestry industries with a long tradition ensure low intensity, ie long-term economic and thus also ecological interests dominate generally over short-term economic considerations. By contrast, in the other regions of Africa, particularly the Sahel region, the proportion of Overexploitation Syndrome in deforestation can be estimated to be very low. For here it is the Sahel Syndrome with its firewood collecting component that dominates.

G 5 Political implications of the syndrome analysis

Sobering assessment of nature and species conservation

An evaluation of policy to date to combat the Overexploitation Syndrome has found a sobering discrepancy between scientific findings and political endeavours on the one hand and concrete measures or ecological consequences on the other. Despite numerous status reports (by way of example we could name the FAO annual reports, the tropical forest reports issued by the German Federal Government or the work of the German Enquete Commission 'Protection of the Earth's Atmosphere') only very few political successes can be recorded, and the Tropical Forest Action Plan (TFAP) brought into life around a decade ago can truly be said to have failed. Political endeavours evidently appear to be a race against time. If one thinks of the continuing destruction of the African or East Asian tropical forests, the irrevocable loss of unique ecosystems such as alluvial meadows in Germany and the threat to fragile ecosystems such as coasts, rivers and mountains, it is clear that in many cases the outcome of that race has actually already been decided.

The interdependency of biosphere and anthroposphere as the basic premise for successful policy

As is evident in the syndrome analysis from the difference between the measurements of disposition and intensity, a consistent policy of protection in the interests of both nature and humankind is possible. The analysis indicates various potential openings for promising strategies. Integrated approaches and a clever allocation of political resources are the basic prerequisites. An essential result of the analysis is that policy can be successful if the *interconnectedness of the biosphere and anthroposphere is taken into consideration from the outset as a constitutive element.*

Sustainable development and growth strategies must take into account the cultural and economic manifestations of society. That means that even in the official agencies that do *not* primarily have environmental policy departments set up, institutional mechanisms need to be developed that identify and start to correct the crass violations of the model of 'sustainable development' and counteract existing contradictions in policies.

Implications from the syndrome analysis, however, also point in the other direction. 'Sustainability' should not be defined merely by the measure of ecological need and view of future generations. It became clear that protective provisions for the tropical forests could rarely be enforced in confrontation with the legitimate needs of the current population. The social, economic and political links, needs and interests of today's generations must also be placed at the foundation of any specific protective policies that are developed. The recommendations developed below are to be understood on the basis of both dimensions of this fundamental idea.

An integrated policy proposal to combat the worldwide momentum of overexploitation must attempt to address the crucial trends and interactions with suitable instruments and keep the political costs as low as possible. This can happen by means of various measures:

- Substitution and more efficient use of wood as a raw material and its derivative products, eg by increased recycling or new materials. Depending on the site and in light of a cost/benefit analysis, this may also mean an expansion of plantations.
- Changes in patterns of consumption and lifestyle, eg voluntary relinquishment or a new sense of quality to lower demand-side pressure upon non-certified tropical hardwoods.
- Conversion from firewood use to alternative energy sources (eg biogas, solar cookers) with due consideration for local conditions (appropriate technologies).
- Significant increases in efficiency in the least developed logging and processing operations (eg through technology transfer, improved employee training, participation and economic benefit-sharing for employees, support for modernization of the organization).
- Implementation of forms of sustainable forest management, in other words greater considera-

tion for ecological and social concerns in the forest areas designated for economic use. Here, there are a range of proposals from forest scientists and NGOs (eg selective logging, soil-friendly extraction, maintaining the 'green roof', leaving seed bearers standing, preferential use of native species for replanting, protection of watercourses, etc).

- Further development of an internationally accepted system of certification for sustainable timber production (Box E 3.3-8).
- Consideration of nature conservation quotas (ie not just criteria oriented exclusively on the technicalities of logging) and possible negative ecological and social consequences during the entire product chain (also includes processing in other countries).
- Strengthening democracy, transparency and other forms of good governance in order to roll back the influence of interest lobbies and corruption (eg when concessions are being awarded).
- Strengthening the transparency of forest policy measures. This relates both to the improvement of the data and scientific foundations and also the procedural forms and objectives (national environment and forest plans).
- Search for new interest coalitions and alliance partners (eg in the NGOs, trade unions, representatives of forest dwellers, etc) for as cooperative a political style as possible in the area of forest use and protection (Section E 3.9). Creation of communication forums for various user and interest groups. Securing land use rights. Search for solutions based as far as possible on the principle of subsidiarity.
- Break down subsidies and trade barriers that were erected to protect inefficient domestic timber companies.
- More restrictive concession awards for logging (stricter environmental conditions, higher charges, better controls, regulation of yield per unit area).
- Design the award of concessions and ownership rights in such a way that self-interest/-ownership in sustainable use is promoted (eg longer terms for a concession).
- Development and implementation of national forest laws with a forest protection component. Graded and ecologically sound conservation and use concept with core and use zoning (bioregional management, Section E 3.9).
- Improved financial, legal and organizational capacities for forest and conservation authorities. Training measures to integrate the sustainability idea into the forest administrations. Capacity building by industrial countries.
- Improved international forest policy (Section I 3.4.4 and Chapter K). Inclusion of selected tropical wood species in the CITES Appendices (Section D 3.1).
- Improvement of research and data on forest ecosystems and sustainable forest use. Broader communication of the results to include the education system.

Valuing the biosphere: An ethical and economic perspective

H

The fundamental issue H 1

Are people allowed to do everything they are capable of? We constantly come up against this question where the use of new technologies is concerned, such as genetic engineering or human interventions in nature, such as the clearance of primary forests so that the land can be used for agriculture. Intuitively, everyone answers this question with a definitive 'No'. In no way should people be allowed to do everything they are capable of doing. The same applies to everyday actions. Many options in daily life, from lying to minor deception, from breaking a promise to going behind a friend's back, are obviously actions that are seen by all well-intentioned observers as unacceptable. However, it is much more difficult to assess those actions where the system of values is not so obvious. Actions where there are conflicts between positive and negative consequences or where a judgement could be made one way or the other with equally good justification are especially common in environmental policy. After all, there is hardly anyone who wilfully and without reason desecrates the environment, releases toxic pollutants or is cruel to animals out of pure desire. Conscious desecrators of the environment are obviously acting wrongly, and every legislator would do well to prevent these people from acting in this way through the threat of appropriate punishments. But there is a need for clarification where people bring about a change in the environment with the best intentions and for good reasons and, in the process, harm the environment. In ethics we talk about 'conflicts of targets' here.

Most interventions in the environment are made for good reason: those who make such interventions may want to secure food for a growing population so that ever fewer people have to suffer hunger; they want to ensure long-term jobs and adequate incomes; they want to use natural resources for products and services that make life more pleasant for many people; they want to use nature as a receptacle for waste materials from production and consumption that are no longer needed. Of course, they do not do this out of pure love for humanity, but mainly for their own advantage without this being immoral on its own. The list of human activities that change the environment and are perpetrated for existential or economic reasons could be carried on into infinity. Human existence is bound to the use of nature. The more people populate the world, the more intensive this use will have to be.

Therefore, to be able to make a well-founded judgement of the ethically acceptable extent of the appropriation of nature through human economic activity, the range of products and services created by that appropriation of nature has to be considered in relation to the losses that are inflicted on the environment and nature. With this comparison it can be seen that the serious interventions in nature and the environment did not occur out of arrogance or indifference, but in order to provide the growing number of people with goods and services; these people need them to survive or as a prerequisite for a good life. However, at the same time it must not be forgotten that these interventions often inflict irreversible damage on the environment or deny future generations the possibility of use. Above and beyond this, for the human race, nature is a cradle of social, cultural, aesthetic and religious values, which, in turn, has a major influence on people's well-being. On both sides of the equation, therefore, there are important assets that have to be appreciated whenever interventions are made in nature. But what form should such an appreciation take?

If the pros and cons of the intervention in nature have to be weighed against each other, criteria are needed that can be used as yardsticks. Who can and may draw up such criteria? By what standards should the interventions be assessed? And how can the manifestations of the various options for action be compared with each other for each criterion? This chapter intends to provide answers to these questions. A deeper analysis can be found in the special report on ethical and economic assessment published by the Council (WBGU, 2000b). This special report deals in detail with the questions and problems that occur in the valuation of human interventions in the biosphere.

The following section gives a brief overview of the options for placing a value on environmental assets. In this process, a simple distinction is initially made between *categorical* principles, ie those that must under no circumstances be exceeded or violated, and *compensatory* principles, ie those where compensation with other competing principles is allowed. This distinction consequently leads to a classification of environmental values, which, in turn, can be used as decision-making criteria for weighing up options for the formation of environmental policies. In the second part, these ideas of valuation will be taken up and used to translate the value categories into economic behaviour. At the heart of the considerations here is the issue of how the goals of ethically founded consideration can be supported and operationally implemented through economic valuation methods. The last part continues the idea of the operational implementation of normative and factual valuations and describes a procedure that largely heeds the conclusions from the previous sections and integrates the ethical and economically determined valuation criteria into a procedural model of their own. The section ends with its own conclusions for the conservation and sustainable use of the biosphere.

Ethical fundamentals

H 2

In answering the question about which action is the correct one, we enter the field of practical philosophy or ethics. According to the usual view in philosophy, ethics describes the theory of the justification of normative statements, ie those that guide actions (Gethmann, 1991; Mittelstraß, 1992; Nida-Rümelin, 1996a; Revermann, 1998). A system of normative statements is called 'morals'. Ethical judgements, therefore, refer to the justifiability of moral instructions for action, which may vary from individual to individual and from culture to culture (Ott, 1999).

On what basis can the ethics of human behaviour or behavioural norms be assessed in a binding way that is also intersubjective? The answer to this question depends on whether the *primary* principles, in other words the starting point of all moral systems, or *secondary* principles or standards are subjected to an ethical examination. The first case is about the fundamental principles of moral action. Although many philosophers have made proposals in this respect, there is a broad consensus today that neither philosophy nor any other human authority is capable, beyond doubt and for all humans, of defining binding metacriteria by which to derive or examine such primary principles (Mittelstraß, 1984).

The problem of not being able definitively to derive ultimately valid principles, however, seems to be less serious than would appear at first glance. For, regardless of whether the basic axioms of moral rules are taken from intuition, observations of nature, religion, tradition, reasoning or common sense, they make broadly similar statements. Thus, there is broad consensus that each human individual has a right to life, that human freedom is a high-value asset and that social justice should be striven for. But there are obviously many different opinions about what these lofty principles mean in detail and how they should be implemented. In spite of this plurality, however, discerning and well-intentioned observers can usually quickly agree, completely in line with the WBGU guard rail concept (for details on this, see WBGU, 1998a), whether one of the basic principles has clearly been infringed. It is more difficult to decide whether they have clearly been complied with or whether the behaviour to be judged should clearly be assigned to one or several principles.

In particular they help to reveal the implications of such primary principles and standards. Unless primary principles (such as human rights) are concerned, the ethical discourse largely consists in examining the compatibility of each of the available standards and options for action with the primary principles. This is a matter of freedom from contradiction, consistency, coherence, adherence to structures and other broadly logical criteria (Gethmann, 1998). As the result of such an examination, it is entirely possible to arrive at different conclusions that all conform to the laws of logic and thus give rise to new plurality.

In order to arrive at binding statements or valuations here, the philosopher can either conduct a discourse of the 'mind' and let the arguments for various standards compete with each other (rather like a platonic dialogue) or engage in a real discourse with those people affected by the action. In both cases, the main concern is to use the consensually agreed primary principles to derive secondary principles of general action and standards of specific action that should be preferred over alternatives that can be equally justified.

The distinction between *categorical and compensatory standards* is especially important for the assessment of actions and instructions for action. Categorical standards must not be infringed under any circumstances, whereas, with compensatory standards, compensation with other competing principles is allowed. Protecting the life of a human, for example, is a categorical standard: sacrificing a human being for some other asset (such as money or a clean environment) is in the main rejected, no matter how great the gain. Only when the lives and assets of others are threatened can this categorical standard be transgressed (eg in the case of self-defence). An example of a compensatory standard would be the freedom to use property. Although an owner is entitled in principle to use his or her property as he or she thinks fit, other standards (such as environmental protection, social obligations) may restrict the applicability of the principle of the protection of property.

These preliminary considerations lead to some important conclusions in relation to the matter of the application of ethical principles to the issue of human action with regard to the biosphere. First of all, it is not consistent with the self-image of ethics to develop separate sets of ethics for different contexts of action. Just as there can be no different rules for the logic of deduction and induction in science, depending on what object is concerned, it does not make any sense to postulate an independent set of ethics for the biosphere (Galert, 1998). Justifications for principles and moral systems must satisfy universal laws (Nida-Rümelin, 1996b).

Secondly, it is not very helpful to call for a special moral system for the biosphere, since this – like every other moral system – has to be traceable to primary principles. Instead, it makes sense to specify the generally valid principles that are also relevant with regard to the issue of how to deal with the biosphere. At the same time, it is necessary to define those specific standards that are appropriate to the use of the biosphere and that reflect the principles that are valid beyond the biosphere.

Thirdly, it is neither helpful nor practical to contrast ethical with economic actions, as is frequently done in popular statements. Economic action is just as much determined by moral standards as environment-related action. Even the selfish pursuit of one's own personal interests may be ethically justifiable, for example as a means of freely developing one's own personality or as an incentive for an achievement that benefits society as a whole. With reference to ethical aspects, however, it must be asked critically whether this behaviour does not contradict higher standards or principles (such as the principle of sustaining the lives of other people) or whether it is in conflict with equally important standards or conflicts (equitable distribution of assets).

Fundamentals of environmental ethics

H 3

In our dealings with the environment, the traditional basic and human rights, as well as the civil rights that have in some cases been derived from them, should be just as much a foundation of our considerations as in the other areas of application of ethics. However, with regard to the issue of principles, there is a special problem relating to the use of nature and the environment: does the basic postulate of the sustenance of life apply exclusively to human beings or also to all other beings? This question does not lead to a new primary principle, as one may suspect at first glance. Rather, it is necessary to delineate the universally accepted principle of the sustenance of life that has already been laid down in the body of basic rights. Does this principle cover only human beings (this is the codified version valid in most legal constitutions today) or also other living creatures? And if so, which ones?

Should inanimate elements be included too? In answering this question, it is at first possible to take up two contradictory positions: *anthropocentrism* and *physiocentrism* (Taylor, 1986; Ott, 1993; Galert, 1998). The anthropocentric view places humankind and its needs at the fore. Nature's own fundamental rights are alien to this view. Interventions in nature are allowed if they are useful to humankind. A duty to make provision for the future and to conserve nature exists in the anthropocentric view of the world only to the extent that natural systems are classed as valuable to humankind and that nature can be regarded as the means and guarantor of human life and survival (Norton, 1987; Birnbacher, 1991b).

In the physiocentric concept, which forms an opposite pole to the anthropocentric view, the needs of humankind are not placed above those of nature. Here, every living being, whether human, animal or plant, has the same rights with regard to the basic opportunity to develop its own life within the framework of a natural order. In the physiocentric view, worthiness of protection stems from an inner value that is unique to each living being. Nature has an intrinsic value that does not depend on the functions that it presently fulfils or might later fulfil from humankind's point of view (Devall and Sessions, 1984; Naess, 1986; Callicott, 1989; Meyer-Abich, 1996; Rolston, 1994b).

Where the issues of environmental design and environmental policy are concerned, anthropocentric and physiocentric approaches in their pure form are found only rarely; rather, they occur in different mixtures and slants. The transitions between the concepts are fluid. Moderate approaches certainly take on elements from the opposite position. It may thus be in line with a fundamentally physiocentric perspective if the priority of human interests is not called into question in the conflict over resources. It is also true that the conclusions of a moderate form of anthropocentrism may approach the implications of the physiocentric view. The recommendations for action of a protectionist form of anthropocentrism, which sees nature as an object to be protected against human intervention and uses an existential value of nature desired by humankind beyond the conservation of resources, will not be far removed from those of the physiocentric view.

If we look at the behaviour patterns of people in different cultures, physiocentric or anthropocentric basic positions are rarely maintained consistently (Bargatzky and Kuschel, 1994; on the convergence theory Birnbacher, 1996). In the strongly anthropocentric countries of the West, people spend more money on the welfare and health of their own pets than on saving human lives in other countries; in the countries of the Far East that are characterized by physiocentrism, nature is frequently exploited even more radically than in the industrialized countries of the West. This inconsistency is not a justification for one view or the other, it is just a warning for caution when laying down further rules for use so that no extreme – and thus untenable – demands be made. Also from an ethical point of view, radical anthropocentrism should be rejected just as much as radical physiocentrism. If, to take up just one argument here, the right to human safety is largely justified by the fact that the causing of pain by others should be seen as something to be avoided, this consideration without doubt has to be applied to other beings that are also capable of feeling pain (referred to as: pathocentrism). Here, therefore, pure anthropocentrism is unconvincing. In turn, with a purely physiocentric approach, the primary principles of freedom, equality and human dignity could not be maintained at all if every part of living nature were equally entitled to use the environment. Under these circumstances, humans would have to do without agriculture, the conversion of natural land into agricultural land and breeding farm animals and pets in line with human needs. Nobody wants that. As soon as physiocentrism is related to species and not to individuals (which should be protected), human primacy is automatically implied; for where human beings are concerned, nearly all schools of ethics share the fundamental moral principle of an individual's right to life from birth. The extreme forms of both physiocentrism and anthropocentrism are therefore not very convincing and are hardly capable of achieving a global consensus. This means that only moderate anthropocentrism or moderate physiocentrism should be considered.

It would go beyond the remit of this chapter to consider in detail the arguments for and against one solution or the other here. Both points of view can be justified ethically; at this point we have to decide between exogenic criteria or one's own preferences. In this connection, making a decision does not have to be all that difficult because, in the final analysis, the two moderate versions hardly differ in their practical implications and concrete behaviour standards (Norton, 1991; Birnbacher, 1996; Ott, 1996). In practical terms, it usually makes no difference whether moderate physiocentrism or moderate anthropocentrism is pursued. In this matter, the Council has come to the conclusion that, for logical and pragmatic reasons, moderate anthropocentrism should be pursued. This is justified in detail in the special report (WBGU, 2000b).

Special principles and standards for the use of the biosphere H 4

H 4.1
The need for human interventions in the biosphere

Although some important conclusions for the ethical assessment of human use of the biosphere can be drawn from the specification of moderate anthropocentrism and the validity of the generally recognized primary principles of human coexistence, they are by no means sufficient for making a comparative assessment of competing standards of use.

Since contemporary society and the generations to come certainly use, or will use, more natural resources than would be consistent with a lifestyle in harmony with the given natural conditions, the conversion of natural land into anthropogenically determined agricultural land cannot be avoided (Mohr, 1995).

With regard to the issue of species conservation and the depth of human interventions in the biosphere, therefore, different assets have to be weighed against each other. Nature itself cannot show humankind what it is essential to conserve and what can be traded for valuable assets. Humankind alone is responsible for deciding and also for the arising conflicts between competing objectives. Appreciation and negotiation processes are therefore the core of the considerations about the ethical justification of rules for using the biosphere.

But this does not mean that there is no room for categorical judgements along the lines of 'this or that absolutely must be prohibited' in the matter of biosphere use. It follows on from the basic principle of sustaining human life now and in the future that all human interventions that threaten the ability of the human race as a whole, or of a significant number of individuals, to exist should be categorically prohibited. The Council calls such interventions *threats to the systemic functions of the biosphere*. Such threats are one of the guard rails that must not be exceeded under any circumstances, even if this were to be associated with great benefits. In the language of ethics, this is a categorical principle or, in the language of economics, an asset that is not eligible for being traded. The 'cudgel' of categorical prohibitions should, however, be used very sparingly, because plausible trade-offs can be thought up for most principles, the partial exceeding of which appears intuitively reasonable. In the case of threats to existence, however, the categorical rejection of the behaviour that leads to this is obvious and is probably also capable of achieving an international consensus.

H 4.2
The use of categorical principles in biosphere conservation

But what does the adoption of categorical principles specifically mean for the political shaping of biosphere conservation? In the past, a number of authors have tried to define the minimum requirements for an ethically acceptable moral system with respect to biosphere use. These so-called 'safe minimum standards' specify thresholds for the open-ended measurement scale of the consequences of human interventions that must not be exceeded even if there is a prospect of great benefits (Randall and Farmer, 1995; Randall, 1988). In order to be able to specify these thresholds in more detail, the breakdown into three levels proposed in Chapter B is helpful (WBGU, 2000a). These levels are:

- the global biogeochemical cycles in which the biosphere is involved as a generator, modulator or 'beneficiary',
- the diversity of ecosystems and landscapes that have key functions as bearers of diversity in the biosphere, and finally
- the genetic diversity and species diversity that are both 'the modelling clay of evolution' and also basic elements of ecosystemic functions and dynamics.

Where the first level is concerned, in which the functioning of the global ecosystem is at stake, categorical principles are obviously necessary and sensible, provided that no one wishes to question the primary principle of the permanent preservation of the human race. *Accordingly, all interventions are categorically prohibited in which important biogeochemical or energy cycles are significantly influenced at a global level and where globally effective negative impacts are to be expected.* Usually, no stringent causal evidence of the harmful nature of globally relevant interventions is needed; justified suspicion of such harmfulness should suffice. The Council has already laid down in detail in its 1998 risk report how the problem of uncertainty in the event of possible catastrophic damage potential should be dealt with (Cassandra risk type; WBGU, 2000a).

On the second level, the protection of ecosystems and landscapes, it is much more difficult to draw up categorical rules. Initially, it is obvious that all interventions in landscapes in which the global functions mentioned on the first level are endangered must be avoided. Furthermore, it is wise from a precautionary point of view to maintain as much ecosystem diversity as possible in order to keep the degree of vulnerability to the unforeseen or even unforeseeable consequences of human and non-human interventions as low as possible. Even though it is difficult to derive findings for human behaviour from observations of evolution, the empirically proven statement 'he who wagers everything on one card, always loses in the long run' seems to demonstrate a universally valid insight into the functioning of systemically organized interactions. For this reason, the conservation of the natural diversity of ecosystems and landscape forms is a categorical principle, whereas the depth of intervention allowed should be specified on the basis of compensatory principles and standards.

The same can be said for the third level, genetic and species conservation. Here too, initially the causal chain should be laid down: species conservation, landscape conservation, maintaining global functions. Wherever there is conclusive evidence of this chain, a categorical order of conservation should apply. These species could be termed *'primary keystone species'*. This includes those species that are essential not only for the specific landscape type in which they occur, but also for the global cycles above and beyond that specific landscape type owing to their special position in the ecosystem. Probably, it will not be possible to organize all species under this heading, but we could also think of groups of species, for example humus-forming bacteria. In second place there are the species that characterize certain ecosystems or landscapes. Here they are referred to as *'secondary keystone species'*. They, too, are under special protection, but are not necessarily subject to categorical reservation. Their functional value, however, is worthy of special attention. Below these two types of species there are the remaining species that perform ecosystemic functions to a greater or lesser extent. What this means for the worthiness of protection of these species, and the point at which the precise limit for permitted intervention should be drawn, is a question that can no longer be solved with categorical principles and standards but with the help of compensatory principles and standards. Generally, here too, as with the issue of ecosystem and landscape protection, the conservation of diversity is recommended as a strategy of 'reinsurance' against ignorance, global risks and unforeseeable surprises.

It remains to be said that, from a systemic point of view, a categorical ban has to apply to all human interventions where global closed loops are demonstrably at risk (WBGU guard rail principle model). Furthermore, it makes sense to recognize the conservation of landscape variety (also of ecosystemic diversity within landscapes) and of genetic and species diversity as basic principles, without thereby being able to make categorical judgements about individual landscape or species types as a result.

H 4.3
The use of compensatory principles and standards in biosphere conservation

In order to be able to answer the question about the valuation of partial infringements of *compensatory* principles or standards, which are referred to in the issue of conserving specific species or landscapes, we need rules for decision-making that facilitate the appreciation process. In the current debate about rules for using the environment and nature it is mainly teleological valuation methods that are proposed (Hubig, 1993; Ott, 1993). These methods are aimed at

1. estimating the possible consequences of various options for action at all dimensions relevant to potentially affected people,
2. identifying the infringement or fulfilment of these expected consequences in the light of the guiding standards and principles and
3. then weighting them according to an internal key so that they can be weighed up in a balanced way.

On the positive side of the equation there are the economic and cultural values created by use, for example in the form of income, subsistence or an aesthetically attractive landscape (parks, ornamental gardens, etc); on the negative side there are the destruction of current or future usage potentials, the loss of unknown natural resources that may be needed in the future and the violation of aesthetic, cultural or religious attributes associated with the environment and nature.

There are, therefore, related categories on both sides of the equation: current uses vs possible uses in the future, development potentials of current uses vs option values for future use, shaping the environment by use vs ruining the environment as a result of alternative use, etc. With the same or similar categories on the credit and debit sides of the balance sheet, the decision is easy when there is one option that performs better or worse than any other category. Although a so-called *dominant option* of this kind is rare in reality, there are certainly examples of dominant solutions – and of the opposite, ie subdominant solutions. Thus, for example, the overfelling of the forests of Kalimantan in Indonesia can be classed as a sub-dominant option since the shortterm benefit, even with extremely high discount rates, bears no relationship to the long-term losses of benefits associated with a barren area covered in *imperata* grass. The recultivation of a barren area of this kind is considerably more expensive than the income from the sale of the wood, including interest. As a result of the Kyoto Protocol, this situation is made even more acute, because the private-sector players can gain private profit from the devastation of the land by means of reafforestation if they class this as a climate project. However, a strategy of this kind (clearance followed by reafforestation) should be classed as negative in terms of the carbon balance (WBGU, 1998b). In addition to the lack of ecological reasons, there are also no cultural, aesthetic or religious reasons for the conversion of primary or secondary woodland into grassland. At best, we can talk about a custom of letting rainforests, as a 'biotope not worthy of conservation', be put to short-term use.

However, if we disregard the dominant or subdominant solutions, then the weighing of options that violate or fulfil compensatory standards and principles will depend on two preconditions: best possible knowledge of the consequences and a transparent, consistent appreciation process (Akademie der Wissenschaften, 1992).

H 4.4
Knowledge and values as the foundation for appreciation processes

Adequate knowledge of the consequences is needed in order to reveal the systemic connections between usage forms, ecosystem reactions to human interventions and socio-cultural condition factors (Wolters, 1995). With the Council's *syndrome concept,* a number of such systemic connections have been identified (eg Chapter G). The ways in which the individual elements of the system operate are identified by the various scientific disciplines and then integrated in an interdisciplinary network (WBGU, 1998a). The task of applied ecological research, for example, is to show how ecosystems are burdened by different usage concepts and practices and what are the specific consequences of certain interventions in nature and the natural environment. The economic approach provides a benefit-oriented valuation of natural and artificial resources within the context of production and consumption. Cultural and social sciences study the social and cultural feedback effects between use, social development and cultural selfperception and form the dynamic interaction between forms of use, socio-cultural lifestyles and forms of control. Interdisciplinary, problem-oriented and system-related research contributes to forming a basic stock of findings and insights about functional links in the relationship between humankind and the environment and also in developing constructive proposals as to how the basic question of an ethically justified use of the biosphere can be answered in agreement with the players concerned. All of these aspects are explained in detail in the specialist chapters of this report. Accordingly, in order to ensure sufficient biosphere conservation, scientific research, and especially transdisciplinary system research at the interface between natural sciences and social sciences, is essential (Chapter J).

However, knowledge alone does not suffice. In order to be able to act effectively and efficiently while observing ethical principles, it is necessary to shape the appreciation process, ie the process of weighing the various options for action, according to rational criteria (Gethmann, 1998). To do this, it is first of all necessary to identify the dimensions that should be used for valuation. The debate about the value dimensions to be used as a basis for valuation is one of the most widely discussed subjects within bioethics. Of the various branches of science, economics in particular has taken on this issue. For this reason, in the following the economic approach to the valuation of biosphere services is presented and discussed.

H 5 Economic valuation of biosphere services

H 5.1
Economic valuation as an expression of specific valuation ethics

Economics, too, has an ethical basis in the form of 'social subjectivism'. At heart, 'social subjectivism' comprises a utilitarian value theory, according to which only the preferences of individuals are used to determine values (Marggraf and Streb, 1997). The Council's starting hypothesis in dealing with the economic aspects of valuation issues is that ethical and economic valuation approaches are not contradictions in terms, but that the manifestation of specific valuation ethics can be seen in economics. Accordingly, we will look for economic criteria and arguments that can be applied as an integral part of the ethical valuation concept. Economics can derive criteria for the boundary between categorical and compensatory criteria and it can name criteria that can be used in a supporting capacity in a transparent, consistent appreciation process. With regard to this argument, the aim of the Council is to identify the advantages of the economic valuation approach and to promote greater consideration of economic aspects in biosphere conservation. However, it is not unilaterally in favour of the economic valuation approach and does not therefore resolve the constantly cited conflict between ethics and economics in favour of economics.

Building on these introductory remarks on the relationship between economics and ethics, first of all the methodological foundations and the need for explanation of economic valuation approaches will be shown (Section H 5.2). Then the basic procedure for an economic valuation of the biosphere will be presented (Section H 5.3). An important step here is the determination of value categories that can be assigned to the biosphere (Section H 5.4). The economic calculation cannot be transferred to the valuation of the biosphere without qualification. For this reason, a discussion of the limits of the economic valuation approach is necessary (Section H 5.5). The variety of existing value dimensions makes the choice of options for action more difficult. That is why the Council is trying – in a next step – to place the value categories in order from a global perspective (Section H 5.6). The section on the economic valuation of the biosphere closes with a brief summary (Section H 5.7).

H 5.2
Methodological foundations and explanatory potential of economic valuations

The methodological goal of economic valuations is based on the monetarization of individual preferences. For politicians, yet also for the people affected, the 'trick' of economic valuation methods consists in that they express in monetary terms the action alternatives desired by the public and implemented by politicians. This is how the quantitative foundations for political decisions are laid. Even if monetarization does not always succeed, it still remains the desirable goal. Economic valuations are often faced with strong criticism because they establish monetary values for the natural environment. However, an economic valuation can often consist of much more than the process of pure monetarization; thus, criticism of this approach should always take into account what the valuation method is supposed to explain.

Monetarization is the focus of criticism of the attempts to apply economic valuation methods to the environment – in this case to the valuation of biosphere services. Building on the perspective of moderate anthropocentrism, economics regards humankind as the central authority for the derivation of monetary values. In contrast, the physiocentric view ascribes to nature an intrinsic value that exists independently of individual preferences, and it consequently rejects the transfer of the economic model to the environment. In order to somewhat dilute this conflict between anthropocentrists and physiocentrists – and, in practical terms of environmental policy, the demands of physiocentrists and anthropocentrists are usually not so far apart (Section H 3) – the methodological foundations of economic valuation should be outlined first. Besides, in this text, it is especially important to explain in more detail which explanatory potential is seen as underlying economic valuation.

The preferences of individuals are the starting point of economic valuations. They are the reference points for the valuation approach based on neo-classical welfare economics. In addition to the focus on the individual, the desire for additional utility maximization is the second assumption underlying the economic valuation approach, ie individuals strive to implement those alternatives that provide them with the greatest benefits.

On the basis of these fundamental assumptions, the task of economic valuations is also seen in recording and valuing the benefits to be gained by various alternative political actions and in reproducing them in a comparable utility equivalent – usually in monetary terms. In an expanded form, this can be found in formalized cost-benefit analyses. They are conducted in the political sphere in order to increase the rationality of political decisions and contribute to objectivization (Cansier, 1996).

When assessing economic valuations it is essential not only to take a critical look at the methodological foundations but also to consider the explanatory potential of the economic valuation approach. In this way, economics by no means claims to assign a value to all things. Rather, an attempt is made to make the usually implicit valuations in a society transparent and thus relevant to decisions (Burtraw and Portney, 1991; Kosz, 1997).

This explanatory potential of economic valuations can also be applied to the valuation of the biosphere. Decisions on the protection of the biosphere are unavoidable. For example, the whole of biological diversity cannot be conserved in its current state. It will be essential to consider carefully the extent to which humankind wishes to conserve biological diversity. On the one hand, such decisions occur explicitly if, for example, the main concern is to decide which land areas and their species are to be designated as protected areas and, on the other hand, implicit considerations are made if a road is built through a semi-natural ecosystem for the purposes of the economic development of a region, for example. If corresponding ecological considerations have not been included in the plans for road-building, an implicit valuation and prioritization should be included in the decision for construction along the lines that the economic benefit should or should not be given higher priority than the loss of biological diversity that may be associated with the construction of the road.

The need to act and to take a decision cannot be avoided. Implicitly or explicitly, valuations are conducted constantly (Weikard, 1998; Goulder and Kennedy, 1997; Perrings et al, 1995). Because of this inevitability of decisions, especially when protecting the biosphere, the issue of valuation should be viewed pragmatically. Pointing out that nature has intrinsic values is of no help with most decision-making problems, which have to be taken in political reality (Pearce and Moran, 1998). The anthropocentric approach thus has higher operationality because it does not set intrinsic values of nature as absolute. Instead, the anthropocentric approach aims at weighing up different values of human societies (Heister, 1997). Another strength of anthropocentric justifications for the conservation of biological diversity lies in the fact that anthropocentric approaches can be derived directly from central (liberal-democratic) principles. With the ethics of moderate anthropocentrism advocated by the Council it is at the same time possible and intended to link ecological aspects to the individual cost-benefit rationale. Because of its integrating function, moderate anthropocentric nature ethics appears to be the only ethics that can acquire social and thus legal binding force. Only this approach builds almost entirely upon the rules that already exist in and justify a civilized society (Geisendorf et al, 1998).

Along these lines, the attempt by economics to render such decision-making situations more transparent by means of monetarization should be viewed as an approach that contributes toward demonstrating the economic relevance of biosphere services. In this connection, the exact calculation of the benefits granted by the biosphere is less important. The *demonstration function of economic valuations* is decisive (Fromm, 1997). For instance, valuation studies indicate the economic relevance of environmental problems (Costanza et al, 1997; Repetto, 1993) and thus greatly help to increase public awareness of environmental issues (Hampicke, 1991). The conversion, or more modestly, the attempt at conversion of biosphere services into monetary values also makes sense because the value is expressed in a 'currency' that can be understood and further processed in the political decision-making process (Daily, 1997a). The results of economic valuations can thus not only be used as arguments for anthropocentric conservation. Instead, they can also be helpful for physiocentric viewpoints, especially because monetary values are more convincing than an indication of vaguely perceived intrinsic values (Hampicke, 1991).

H 5.3
Overview of the procedure for economic valuation of the biosphere

The following procedure would be suitable for an economic valuation of the biosphere (Fromm, 1997):

1. *Identification of the benefits granted by the biosphere*, ie the economically relevant functions (on a quantitative scale). In terms of content, reference can be made here to the functions of the biosphere set out and discussed in the previous chapters. In terms of methodology, reference can be made to the concept of the total economic value, which is presented below as a heuristic instrument for determining the different benefits granted by the biosphere (Section H 5.4).
2. *Review of the applicability of the cost-benefit rationale to the biosphere*. Here, the criteria of the limited substitutability and of the irreversibility of damages are the ones that place limits on the application of the economic rationale. This point will be discussed in detail because of the importance of this step in the analysis (Section H 5.5).
3. *Monetarization of the benefits created.* There are various valuation methods that attempt, indirectly via an analysis of market data or directly via survey methods, to derive an economic value from individual preferences. The Council has already described these methods (WBGU, 1994) and explains them in more detail in a current special report (WBGU, 2000b). For this reason, these methods will not be dealt with in more detail here.
4. *Calculation of the present values of the monetarized benefits.* If monetarization is the goal, the time curve of the benefit streams or of the adverse effect should be taken into account, ie future utility or disutility factors should be discounted to the present value. However, at this point it is not intended to go into the complicated problems associated with the choice of the appropriate discount rate needed for weighing up the inter-generational costs and benefits. Although these problems are central to all valuation issues, in this report the valuation aspects specific to the biosphere shall be at the fore.

If a monetarization procedure is used as the basis for an economic valuation, it is immediately clear that an economic valuation does not have to, and should not, remain limited to monetarization. Instead, in an economic valuation many other qualitative aspects should be taken into account besides monetarization, for instance the identification and description of the benefits of natural assets, in this case specifically the benefits of the biosphere (Section H 5.4). An aspect of quality of this kind is also the second stage of analysis that indicates the limits of the economic rationale (Section H 5.5).

H 5.4
Value categories of biosphere services from an economic perspective

H 5.4.1
Individual values and 'total economic value'

The various individual 'values' that have been developed in economic valuation theory cover different dimensions of the problem (eg in terms of time, the short-term foreseeable use versus the long-term hoped-for use) and various sections of the biosphere. In a kind of imaginary experiment, one can assume a 'Total Economic Value' (TEV) across all sections and along the time axis. This 'Total Value' is intended to include all value aspects that determine the demand for environmental assets (Pearce and Turner, 1990). Its elements are listed in Fig. H 5.4-1. In summary, they are (Meyerhoff, 1997):

$$\begin{aligned} \text{TEV} &= [\text{use-dependent values}] + [\text{non-use-dependent values}] \\ &= [\text{direct values + indirect values + option values}] + \\ &\quad [\text{existence value + other non-use-dependent values}] \end{aligned}$$

In this context, the – mathematically unnecessary – brackets indicate a certain affinity of certain types of values; these will be explained now (with respect to the value categories, cf the remarks on the economic valuation of freshwater in the Council's 1997 report, WBGU, 1998a). In addition, a reference is always made between these value categories and the properties of the biosphere as 'assets'. That is to say, there is an examination of the extent to which the asset in question is a private or public asset. Public assets (collective assets) differ from private assets in that there is no rivalry with regard to consumption. Moreover, the exclusion principle cannot be applied to them. This distinction between the two types of asset – although in reality there are mostly mixed forms – is important both in the development of suitable approaches for the conservation and use of the biosphere as well as for the attempt to determine the economic value of biosphere services. The determination of individual preferences and the conversion into monetary values depends heavily on whether the preferences are expressed on markets (biosphere services with predominantly private asset character) or whether the preferences have to be determined in another way, ie with corresponding valuation methods (biosphere services with predominantly collective asset character).

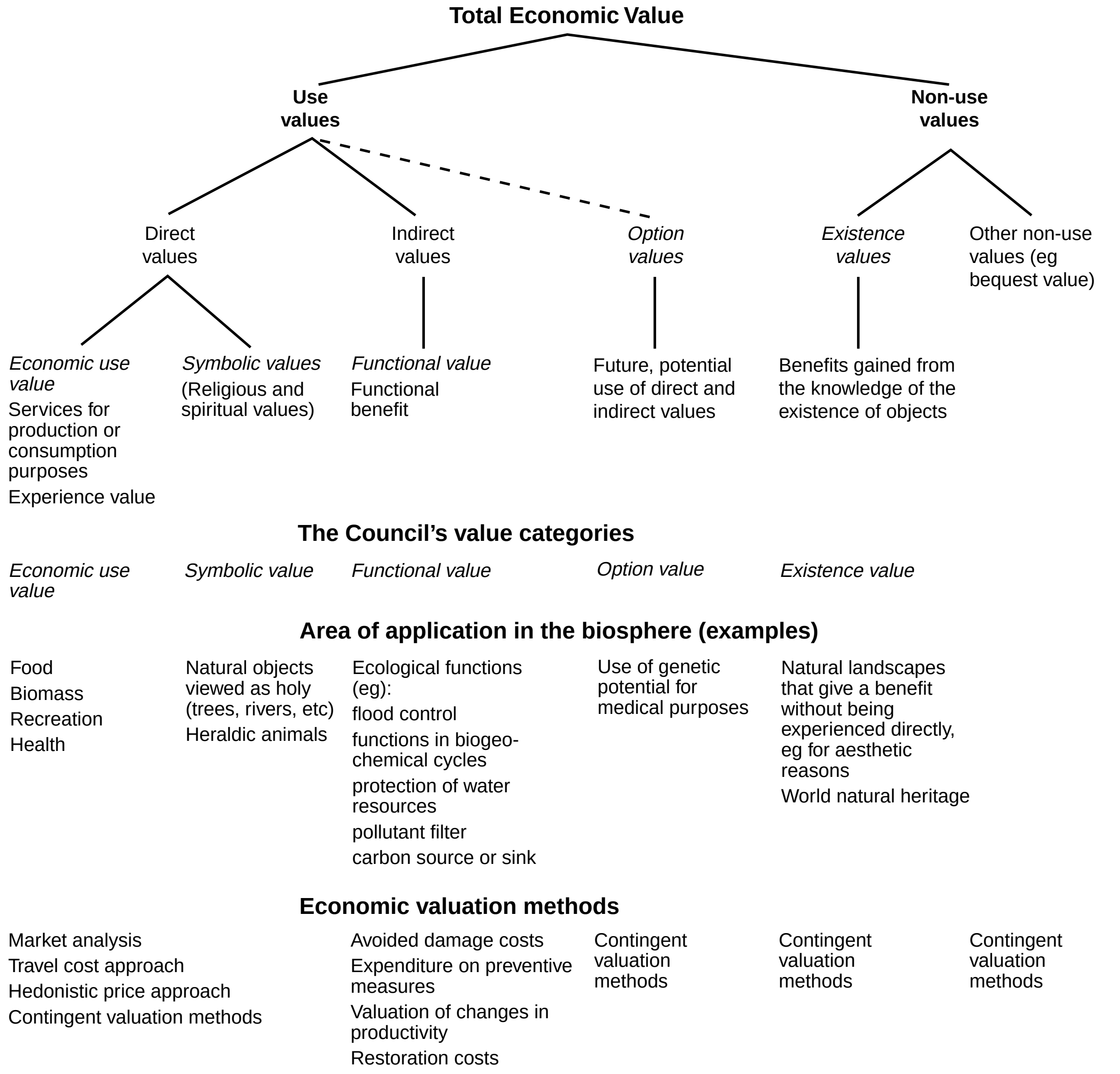


Figure H 5.4-1
Composition of the total economic value of biosphere services.
Source: WBGU on the basis of Pearce and Moran, 1998; Meyerhoff, 1997

In Fig. H 5.4-1 the breakdown into use-dependent and non-use-dependent values is at the fore. However, a breakdown of this kind only makes sense when the concept of use is defined narrowly. The term 'non-use-dependent values' is not supposed to suggest that no gain in benefits is associated with these values. Rather, a limited definition of use is applied that aims at a direct use of the biosphere linked to a personal proximity to the biosphere service. Thus, for example, the use of the symbolic value – if instrumental usefulness of the symbolic value is assumed – or of the economic benefit value, presupposes physical proximity to the biosphere, whereas with the existence value the mere knowledge of a section of the biosphere far from one's personal habitat is enough to create social utility without directly using biosphere services.

The *direct values* comprise an *economic instrumental value* and a *symbolic value*. The economic value can be seen in the fact that biosphere services can be used for production and consumption purposes. If nature is used for biosphere production services such as wood, grain, cotton, etc, this is a private asset. A frequently underestimated value of the biosphere is the *experience value* (in the sense of event or 'great experience'). The experience value is termed a consumption value because the individuals use the aesthetics of nature directly as a consumer good. This means that the experience value is just as much an economic value as the use of resources for the production of goods. In contrast to the dominant case of the private asset properties of economic use values, the collective asset character of the biosphere tends to dominate the experience value.

Symbolic values are assigned by individuals to certain elements of the biosphere. For example, this includes holy animal and plant species, possibly also parts of the non-living biosphere, such as holy rivers or mountains. On the whole, the symbolic value comprises the religious or spiritual values assigned to sections of the biosphere. A clear designation of the symbolic values as a public or a private asset is not possible at a fundamental level. A decision about the predominant asset components can only be made on a case by case basis.

The *indirect values* also include the varied ecological services that the biosphere performs for humankind (eg many functions in biogeochemical cycles, flood control, etc; Fig. H 5.4-1). The maintenance of this specific efficiency of ecosystems is usually an asset that should be safeguarded publicly, because no potential users can be excluded from the ecological services that people tend not to perceive constantly and consciously, but rather notice only when they are lost. As a consequence, there are also no private providers who take care of the maintenance of the ecological functions.

The *option value* of biological diversity can be seen in the intention of keeping open the future use of a resource. In this sense, the option value can be seen as a sort of insurance premium. Insofar as it refers to future uses, it is one of the economic values. In a broader definition, the option value can refer to all value categories, because it indicates the possibility of a future realization of a value category. If the option value refers to a non-use-dependent value, such as the existence value, the option value could also be assigned to the category of non-use-dependent values (Table H 5.6-1). In Fig. H 5.4-1 this fuzzy assignment is indicated by the broken line.

The *non-use-dependent values* are – as described above generally – of a different kind, as the comparison of experience and existence values shows. In contrast to the experience value, with the *existence value* no value is seen in the fact of using services directly. Instead, the awareness of the mere existence of natural assets causes satisfaction or a feeling of well-being. For example, many people give donations for the protection of tropical rainforests or the conservation of coral reefs without ever having used them in any way whatsoever, not even as a cradle of aesthetics or recreation. A separation from the symbolic value, which is included in the use values here, is not always clear and has to be decided on a case by case basis. The intrinsic value can be quite clearly differentiated from the existence value. The existence value is anthropocentrically defined and is derived from individual considerations of assigning a value to the mere existence of something, whereas the intrinsic value should be understood from a physiocentric point of view and cannot be traced back to individual preferences. Since no one can be excluded from this value and there are also no rival relationships, there is very rarely a purely public asset to be seen here.

The bequest value is derived from the desire to pass on elements of the biosphere to future generations because of their symbolic and identification values. As with the existence value there is a close link to the use-dependent symbolic value. For example, the bequest value is expressed in the fact that voluntary contributions are used for nature conservation areas. However, at the same time, this example clearly illustrates that it is very difficult to separate the bequest value from the other value categories. Thus, the expenditure of voluntary contributions for nature conservation areas can have very different causes. For example, it may be related to the experience value, the existence value, the symbolic value or – among educated individuals – the functional value. These difficulties in classifying the bequest value can also be seen in the literature, where it is viewed both as an inter-generational option value and as a special form of the existence value (Pommerehne, 1987). For this reason, the bequest value is listed in Fig. H 5.4-1 only for reasons of completeness and will not be explicitly included in the following as a value category placed to the fore by the Council.

Other values can also be listed (information values, values with respect to scientific research interests, amenity values, biophilic values, etc Ott, 1999). However, most of them can be assigned to the value categories listed.

H 5.4.2
Human perception of biosphere values

From Fig. H 5.4-1 and the remarks on the asset characters of the value categories it can be seen that there are great differences in the degree to which the value categories for an economic valuation can be measured. For example, the various services of the biosphere are perceived very differently by individuals. Whereas direct values are directly accessible for consumption or production purposes and are therefore known, the functional values in particular (indirect values) usually escape human perception. Awareness of the importance of these biosphere services usually only manifests itself when the service in question is no longer provided to the usual extent, eg as a consequence of human interventions.

This varying perception of biosphere services has two important consequences for an economic valuation:

1. The results of a market valuation and the economic value of biosphere services differ in most cases. In a market valuation, only the preferences revealed on the market are taken into account. Because of the collective asset character, the preferences for many biosphere services are not included in a market valuation. Nevertheless, the biosphere has an economic value, which, for example, can be seen in the fact that, if there is an impairment of biosphere services, there is damage to human health and to assets created by humankind that can cause high financial losses. Familiar examples here are flood damage or the reduced natural protection against avalanches as a result of human interventions in ecological systems. It is therefore the particular task of economic valuations to identify the difference between market valuation and the 'true' economic value.
2. In many cases, the limited individual perception or market valuation of biosphere services results in a massive underestimation of the importance of the biosphere to people. Insofar as individuals fail to recognize ecosystemic relationships or to assign the appropriate value to biosphere services, the limits of the economic rationale become clear. However, such limits do not fundamentally call the economic approach into question. However, they do make it clear that the result of an economic valuation cannot alone be the sole criterion for political decisions and still needs interpretation within the context of democratic decision-making processes.

H 5.4.3 The function of the concept of total economic value

The Council sees the concept of total economic value primarily as a heuristic instrument. The aim of the concept of total economic value in this context is not to derive one single arithmetical factor from the valuation procedure and to divide it proportionately among experience, existence, option, function, symbolic values, etc. These attempts would remain unsatisfactory, because there would be too much overlap in the contents of the value categories (Geisendorf et al, 1998). Furthermore, a quantitative value would feign a degree of accuracy that the concept of total economic value is incapable of. For this reason, the Council does not regard the purpose of this procedure to determine a total economic value solely as a challenge of quantification. Instead, this procedure is understood as a system of arguments in which elements of quality should, and must, be taken into account (Section H 5.5). In addition, the procedure to determine total economic value includes the call for completeness when considering value categories. In this context, total economic value also implies an enumeration of natural assets, thus emphasizing once again the heuristic character of the approach.

In this context, reference can be made to the respected, but also criticized, study by Costanza et al (1997). Here, an attempt was made to place values on globally relevant ecosystemic services. As a result of this study, an estimate of US$33,000 thousand million year^{-1} was determined, ie globally relevant ecological functions, such as regulating the carbon cycle, the water cycle or food production, have a total value that exceeds the value of all goods and services produced worldwide – in other words the gross global product – by a factor of 1.8. Even if the various methods of determining the monetary values of ecological services can be criticized, the study forced the authors to list as far as possible all the ecological services. In addition, the debate which followed publication showed that – regardless of the accuracy of the results, the relevance of ecological services is increasingly being considered. This, too, is an example of the above-mentioned demonstration function of economic valuations.

A further advantage of the concept of total economic value is its notional applicability to regions. Economic values for certain areas can be determined intuitively or as estimates, and types of land use can be derived from this (WBGU, 2000b).

H 5.5 Limits to the applicability of the economic rationale to the valuation of biosphere services

H 5.5.1 The substitution paradigm and the essentiality of biosphere services

The assumption of the substitutability of assets and production factors is characteristic of the economic method. The environment is also subjected to this substitution paradigm within the context of the neoclassical theory, which is the foundation of the economic valuation approach. It is assumed that biosphere services are mutually substitutable. By contrast, the consideration of the possibilities for substituting species clearly shows that the complete substitution of a species is not possible, because each species performs very specific functions in the ecological system context, with the result that we can only talk about substitutability with respect to genetically identical species, which logically means that these are no longer two different species, but an identical species (for more detail on the substitutive and complementary relations of species, cf Fromm, 1999). Thus, with regard to the applicability of the economic rationale, the question arises whether the biosphere service which is to be valued is an essential service, ie that certain biosphere services cannot be dispensed with (Beirat Umweltökonomische Gesamtrechnung, 1995; Fromm, 1997). In the literature, the term 'critical natural capital' is also used for essential functions of nature (Geisendorf et al, 1998).

With regard to the applicability of economic valuations, these considerations mean that it has to be decided which biosphere services are indispensable in a narrow sense. This task cannot be performed by recourse to the preferences of the citizens, because they do not usually have the required level of knowledge for identification and adequate value assignment. This means that an external valuation body independent of individual preferences is needed (Farnworth et al, 1981), which may also be able to correct the individual preferences meritorically (Common and Perrings, 1992). In this connection, reference is made also to the 'ecological gap' in the economic valuation of ecosystems (Pearce, 1976).

Thus, with respect to the valuation of many biosphere services, a certain amount of scepticism prevails as to whether individuals have the skills to assess and valuate ecological systems appropriately. The Council recognizes the significance of expert knowledge in the valuation of biosphere services. Many valuation issues cannot be solved without recourse to expert knowledge. This applies in particular to the valuation of those biosphere's ecosystem services that are beyond immediate perception and thus cannot create any individual willingness to pay. However, it has to be examined through which procedure the opinion of the experts enters the political decision-making process. It should not work the way that small groups of experts make decisions that may have noticeable economic consequences for the majority of the population without there being democratic control over this process (cf the various methods for recording and justifying standards for biosphere conservation in the Council's special report; WBGU, 2000b; as well as Section H 6).

Ideally, it should be ensured that individuals, at least the majority of them, would arrive at the same valuation as the experts, provided they have been fully informed of the consequences. Meritorial interventions of this kind should therefore always be examined critically. This necessary recourse to expert knowledge is, however, not a fundamental objection to economic valuations, but rather a problem of information that should be solved within the context of the processes of social decision-making (Section H 6).

H 5.5.2
The problem of irreversibilities

In addition to the non-substitutability or essentiality of biosphere services, the problem of irreversibility of adverse effects on the biosphere occupies a key position in the discussion of problems relating to economic valuations. In association with economic and ecological criteria for irreversibility, damages to the biosphere can be termed irreversible if they

- cannot be compensated by natural regeneration mechanisms and
- cannot be reversed or substituted by the use of anthropogenic-technological resources (WBGU, 1995a; Fromm, 1997), within planning periods relevant to humankind.

The core problem of irreversible environmental damage can be seen in the combination of (1) the irrecoverability of the benefit which can be realized with 'good' environmental quality and can be lost through environmental damage, and (2) the uncertainty about the extent of this loss of benefit. A presently unavoided irreversibility leads – in the case of positive future benefits – to inevitable losses in the welfare of future generations, expressed in increased damage and in the elimination of options for action (Fisher and Krutilla, 1974). For this reason, it is largely undisputed in the literature that the conventional cost-benefit rationale is unsuitable for the valuation of irreversibilities (Fromm, 1997).

With respect to irreversibilities, the 'safe minimum standard' has been proposed as an alternative decision-making rule (Ciriacy-Wantrup, 1968; Bishop, 1978). The fundamental idea is based on the consideration that, on the one hand, future generations should not have imposed on them any unreasonable cost in the form of irreversible damage. At the same time, however, measures should be taken to avoid the current generation having to bear high opportunity cost resulting from the avoidance of irreversible burdens on the biosphere. In this context, irreversibilities should be avoided if the opportunity cost of the current generation are not unacceptably high. Consequently, with a view to safe minimum standards, there is a call for binding guiding principles to be set for the application of the economic cost-benefit rationale. This guarantees a minimum level of protection provided that the social cost of the protection of the biosphere does not become unacceptably high (WBGU, 1994).

Within the context of safe minimum standards, using the example of species conservation, this would mean: How many potential benefits are lost to humankind if a safe minimum of protection for species is guaranteed? If it is assumed that every species has a positive value, the problems of systematic recording of the benefits are avoided by concentrating on the opportunity cost. At the same time, the burden of proof is placed on those who want to exploit natural resources or prefer alternative uses that destroy species (WBGU, 1994).

H 5.5.3
Conclusions about the applicability of the economic valuation approach

Both the problem of non-substitutability and also the risk of irreversibilities, linked to the uncertainty about future benefits, reveal the limits of the economic rationale based on individual preferences. As a consequence, a complete determination of the values of biosphere services by means of individual valuations should be assessed sceptically. Two conclusions can be drawn:

1. A determination of values of all biosphere services that is based on individual preferences is practically impossible. The only possibility to calculate a monetary value is to add to the overall economic value an 'appropriate' supplement that has been determined on the basis of individual valuations – directly via interviews or indirectly via market valuations. However, suitable scientific criteria for measuring such an 'appropriate' supplement are largely not in place, with the result that this supplement can only be derived qualitatively from expert knowledge. However, the important demonstration function of economic valuations remains in place. The exact level of the economic value determined does not play the decisive role then. Instead, an approximate idea about the extent of the problem can be created without the determined value as such having to be taken too seriously.
2. The inaccuracies that are unavoidable in the determination of an economic value for biosphere services on the basis of their character as a collective asset and the insufficient knowledge of ecosystemic interrelationships illustrate that economic valuations cannot be the sole basis for political decisions. Economic valuation methods are thus only one of many assisting factors that can be used to make decisions. Here, in particular, ecological and social criteria should be included in the weighing up process, unless they can be integrated in an economic valuation. The results of valuation studies, therefore, need further interpretation within the context of the democratic decision-making process, irrespective of whether monetarization occurred, as was implied in this section when the limits of the applicability of the economic rationale were discussed. Furthermore, it becomes obvious that valuation issues are always an economic-ethical problem (Hampicke, 1991), because the partial separation from the concept of an individual valuation requires an ethical justification just as much as the economic approach itself. The confrontation of economics and ethics in the form of a conflict does not lead any further, anyway. Instead, economics should be understood as an expression of certain valuation ethics.

H 5.6
An attempt to rank the value categories from a global perspective

The large number of value dimensions clearly illustrates that decisions for weighing them are needed. This need for weighing them can be visualized if the value categories are brought into a relation with the three types of landscape use (Section E 3.3.1). The land use types refer to three categories: Type 'E' means adequate protection despite intense use. Type 'N' means dominance of protection over use. Type 'M' means protection through sustainable use of resources. Whereas with landscape use type 'E' (conservation despite use) the economic benefit dominates, with landscape use type 'N' (conservation before use) mainly the symbolic value, the option value and the existence value are very high. The functional value is assigned special significance generally, because it plays the decisive role with regard to the maintenance of the dominant goal for each landscape use type, be it that it creates the ecological foundations for the maintenance of the economic benefit (type 'E'), or be it that the functional value determines the protection requirement of a landscape (type 'N'). With the landscape use types, therefore, the question arises as to which values are used in the decision on land use – and to what extent – because not all values can be maximized at the same time.

However, the more value dimensions that have to be considered in an appreciation process, the more complex the decisions become and the more likely there are to be distortions in the weighting, because most people tend to perceive certain value categories more consciously and to assess their value subjectively as higher than it actually is objectively. Moreover, the individual weight of the 'actually' especially relevant valuation factors becomes more marginal if more dimensions are included. For this reason, it is advisable to limit oneself to the key value dimensions. The discussion about the limits of the applicability of the economic rationale to the valuation of the biosphere, which was conducted above, provides two important criteria according to which the value categories can be ranked – also justified from an economic point of view. These are the criteria of non-substitutability (essentiality) and irreversibility.

Furthermore, a distinction should now be made between a weighting of the value categories from a global vis-à-vis a regional perspective. At the regional level, practically no generally valid statements can be made about a ranking of the value dimensions, given the variety of the different landscapes to be found in reality. Therefore, the ranking has to be specified in each individual case. To do this, the criteria outlined above should be applied. One rule to determine a ranking could, for example, be as follows: the greater the uncertainty about the damage, the higher the probability of irreversibility and the greater the probable monetary undervaluation, the greater should be the weight given to the value category concerned in assessing options for action.

The task of the Council is to describe and analyse global change and to derive recommendations for action by global environmental policy. That is why the Council considers it important to abstain from the relativizing statement that, ultimately, the specific application has to decide on the weighting of the value categories. Instead, the Council decided to specify a certain ranking of the various value categories from the perspective of such a global environmental advisory body. For the valuation of options for action that have an impact on the biosphere, the Council proposes the following ranking of the value dimensions that is shown in various points in Fig. H 5.4-1:

- *Functional value*: This refers to the influence of the intervention in question on the ability of the given ecosystem to function. As outlined above, functional values at a global level have a categorical character where they refer to global ecosystem cycles. There they cannot be compensated and thus they meet the criterion of essentiality. At a regional level, although they can be compensated in principle, this is only the case when there are serious reasons for such an intervention. Infringements of the functional value should be weighted most heavily, because, if function is not maintained, all other value dimensions will be negatively influenced, but the maintenance of function itself still exceeds these values. The outstanding significance of the biosphere's functional value becomes clear if one imagines the functions which the biosphere – mostly beyond human perception – provides. A simple thought experiment may illustrate that the above mentioned TEV of the biosphere's ecological services is almost infinite (Daily, 1997b). Imagine one wishes to spend a pleasant day on the moon and that it is necessary to think about the effort needed to create the same living conditions on the moon that enable human beings to live a pleasant life on Earth. Even if it is assumed that the technology needed to create a climate and an atmosphere suitable for humans were in place, one can immediately see the enormous financial effort required to create an artificial environment suitable for humans on the moon. If we were to try to make the moon habitable for humans with terrestrial flora and fauna, problems with knowledge and implementation that have not yet been solved would result (eg Which organisms are needed and how many?). This thought experiment also shows that the empirical determination of such a holistic economic value of biosphere services would hardly be beneficial to our knowledge, because the value is practically infinite due to the outstanding significance for human life on this planet.

  At the fore of an economic valuation of the biosphere there is thus a marginal valuation, ie the question is: what benefits are lost to humankind when biosphere services are slightly impaired by human activity, more formally expressed: when the scope of services is reduced by one unit (Costanza et al, 1997; Fromm, 1999).
- *Use value*: Unlike the functional value, no categorical character can be assigned to the use value. Rather this value is regarded as capable of being compensated. This means that the use value may be limited in order to realize other values, if the benefit exceeds the costs of such an alternative action. From a global point of view – for example with a view to safeguarding sufficient food supply for the world's population – the use value can be weighted as the highest in comparison with the following values.
- *Symbolic value*: This means an aesthetic, religious or otherwise culturally determined assignment of meaning to natural phenomena (or also artificial products). The symbolic value can be placed slightly behind the use value in this ranking. Some people are to an extreme degree willing to pay for the maintenance of landscapes or species of high symbolic value. Furthermore, people regard reductions in the symbolic value as a loss of the preconditions for a good life. Nevertheless, the Council weights the use value of the biosphere –

especially with a view to the promotion of sustainable development processes and the safeguarding of food for the world – slightly higher than the symbolic value.
- *Existence value*: The existence value can be exchanged for other values just like the symbolic value or the use value; it does not, therefore, make any claims to categorical validity.

In addition to these four 'real' value categories, the Council especially emphasizes the significance of the *option value*. This means the possibility of the future realization of a value. The option value is linked to all other value dimensions by means of the concept of probability. The option value cannot, therefore, be directly compared to the other value categories, but is alongside and linked to the other value (real value) in each case by means of the probability of it occurring (Table H 5.6-1). With explicit emphasis on the significance of the option value, the Council would like to counteract the tendency for these value dimensions not to be sufficiently considered in the choice of the options for action.

This breakdown into a hierarchy of value dimensions is supposed to be merely an initial aid in decision-making when possible options for action are evaluated and in drawing up binding action standards. Most deviations from this hierarchy can be expected where the uncertainty about the possible benefits of biosphere services is very high. For example, in many cases a certain use value (such as sales of wood from forms of logging) often is opposed by an extremely uncertain option value of a much greater extent (such as the destruction of a possible natural cancer drug) or a marginal infringement of an otherwise categorical functional value (influencing the world climate). In such cases, no clear decision-making rules can be taken from the hierarchy of value dimensions. Nor is this the prime intention: On the one hand, the above-mentioned criteria of non-substitutability and irreversibility, for example, do not make an impact on a valuation of options for action at the regional level. On the other hand, the objective of this ranking can particularly be seen in the fact that attention is drawn to the general significance of the various value categories. At the same time, this ranking does not claim that it applies in this form to every option to be evaluated. In cases where it is difficult to weigh the options, additional procedural criteria should be used, and these are dealt with in more detail below (Section H 6).

Table H 5.6-1
The Council's order scheme.
Source: WBGU

Real Value	Corresponding Option Value	Ethical Principle
Functional value F	$F * p_F$	Categorical principle
Use value N	$N * p_N$	Compensatory principle
Symbolic value S	$S * p_S$	Compensatory principle
Existence value E	$E * p_E$	Compensatory principle

H 5.7 Conclusion on economic valuation

The starting point for an (economic) valuation should initially always be individual preferences. A study on behalf of the German Federal Environmental Agency also comes to the conclusion that 'with respect to the conservation and development of biodiversity, the values and intentions of the latter [the members of society] are the guideline for the measures to be taken, unless they need correcting for higher-ranking moral reasons' (Geisendorf et al, 1998). The starting point is therefore the valuation of the biosphere based on individual preferences. Strategies for protection and the sustainable use of the biosphere should, therefore, start with individual evaluators and reinforce their valuation of the biosphere. Only when such strategies are insufficient is an external valuation that is not based on individual preferences also to be integrated in the valuation process. On the whole, the importance of economic valuations is considered to be very great. Furthermore, as a result of the heuristic character of the concept of the total economic value, it is clear that, in any consideration of the biosphere, the entire bandwidth of different demands – and thus values – has to be taken into account, regardless of the methodological difficulties that occur with an exact monetary valuation. The importance of economic approaches can be seen in the Biodiversity Convention, where the need and the requirement to record values more precisely and to quantify them is pointed out in many places.

H 6 The ethics of conducting negotiations

The explanations about the economic values and their application to the biosphere have shown very often that a justifiable, clear valuation of options for action is not possible. How should we proceed in such cases? According to what criteria can the options be weighed in such cases? Conflicts with regard to the weighing of options cannot usually be solved by ethical considerations alone (with the exception of dominant cases, sub-dominant cases or cases with absolutely equal infringements of values on every dimension). Ethics would exceed its abilities if it promised that it could derive concrete standards or weightings for the relevant valuation dimensions that would be binding for everyone solely from existing ethical knowledge. The process of weighing options always includes subjective valuations which, although they can be justified ethically, claim no universal validity vis-à-vis third parties or do not compel a clear prioritization for everyone.

How do we deal with competing ethical valuations? In this dilemma, ethics has concentrated on *procedural criteria* (Ott, 1996). These criteria are supposed to ensure that people who have to weigh up between the various value dimensions do so in a fair and competent way (Renn and Webler, 1998). Here, 'fair' means that everyone involved in the weighing of options has an equal opportunity to present their arguments and justifications and to criticize others; 'competent' means that the process of testing arguments is conducted according to logical and transparent criteria. Ethics offers testing procedures for making judgements and setting priorities according to rational-logical methods in conformance with accepted primary principles. Such a consistent valuation strategy can be implemented either by an individual evaluator himself or in negotiations with different groups of evaluators. Because conservation of the biosphere is largely an object of political negotiation and involves many players, in the following we will deal only with the process of conducting negotiations.

How can ethical considerations provide help for a rational and fair way of conducting negotiations? How can general commitments be agreed on in spite of the plurality of moral systems and preferences and in spite of the insurmountability of the problems in final justification? A few important standards for the conducting of negotiations are listed below (Renn and Webler, 1998):

1. It should be ensured that all the people involved in the negotiations are aware of, or can mobilize, up-to-date knowledge about the possible consequences of the various options for action (options for action also include generally binding restrictions on action along the lines of standards and agreements). In this process, by analogy with the classification of risks (WBGU, 2000a), attention must be paid to representing consequential impacts in terms of their extent, probability of occurrence and breadth of the remaining uncertainties. Only on the basis of a sound and honest overview of the expected consequences of an action can an ethically justifiable process of balancing the pros and cons be carried out.
2. It makes sense in negotiations pragmatically to define the essential primary principles. These principles are usually laid down in universally recognized human rights. The American bio-ethicists Beauchamp and Childress (1994) have set up their own guiding principles that they feel have proved themselves as primary principles in discourses. These principles, in turn, should be understood in the sense of a hierarchy (quoted after Revermann, 1998):
   - Principle of *no damage* (no damage to life, limb or property),
   - Principle of *autonomy* (consideration of human self-determination),
   - Principle of *doing good* (avoiding or remedying damage or improving a situation seen as unacceptable),
   - Principle of *justice* (at least formal equality when assigning rights and duties in similar cases).

   Drawn-out discussions about anthropocentric or physiocentric perspectives, however, are mostly counterproductive, because the implications of both points of view are less far apart than appears obvious from the fundamental positions. Also in the further explanation of primary principles, we advise the use of mild wording and that attention be paid to concrete distinctions and definition with regard to the standards for action.

3. By contrast, when incorporating secondary principles and standards, a detailed debate is necessary. Above all, the bandwidth of *normative statements* should be specified. This means restriction to those *standards and principles* that are relevant to the problem concerned. Various methods, such as the value tree analysis presented in the Council's special report, are suitable for this in principle (WBGU, 2000b; Renn, 1997). On the one hand, it is necessary to allow only those criteria that have an inner relationship with the subject matter; on the other hand, the requirement for fairness means that all values and standards advocated by the parties concerned should be considered as far as possible.
4. In order to be able to discuss normative criteria and principles in practical negotiations, it is necessary to point out certain rules for justification forms to the participants. Adherence to formal criteria such as coherence (lack of contradiction) and consistency (logic) are called for. There are also substantial criteria such as the golden rule of reciprocity ('Do as you would be done by') or the subsumption of a criterion to be examined under another upper criterion that has already been recognized as valid. In the reality of society, there is also compatibility with statutory provisions or international agreements, which ideally reflects the previous community agreements about collectively binding values and objectives based on consensus or majority decisions.
5. In the course of negotiations, different conflicts arise that have to be dealt with in different ways. The main conflicts occur on the *cognitive level* (what is correct?), the *interest level* (what is of benefit to me?), the *value level* (what is needed for a good life?) and the *normative level* (what can I reasonably expect of all those involved?).
6. Superordinate criteria are needed to resolve conflicts at these different levels; such criteria will have to be agreed in negotiations (similar arguments in Dryzek, 19990). With cognitive conflicts, these methodological rules can be the proof or, with conflicts of values, empirical yardsticks of a successful life. There are special problems with normative conflicts, because it will scarcely be possible here to resolve the issue of justification, as described in detail above, within the meaning of intersubjective commitments. Different assessment criteria can always be classified as justifiable or unjustifiable. Today, most ethicists assume that different types and schools of ethical justification can claim parallel validity. It therefore remains up to the groups involved to choose the type of ethically legitimate justification they wish to use (Ropohl, 1991; Renn, 1997). Nevertheless, the limits of particular justifications are trespassed wherever primary universally accepted principles are violated (such as human rights). Otherwise, standards should be classed as legitimate if they can be stringently justified within the framework of ethical reasoning and if they do not contradict universal standards that are seen as binding for everyone. In this process, conflicts can and will arise, eg that legitimate derivations of standards from the perspective of Group A contradict the equally legitimate derivations of Group B (Shrader-Frechette, 1988). In order to reach a joint selection of standards either a portfolio of standards that can claim parallel validity should be drawn up or compensation solutions will have to be created in which one party compensates the other for giving up its legitimate options for action in favour of a common option.
7. When choosing possible options for action or standards, options that infringe categorical principles, for example by endangering the systematic ability of the biosphere to function for human use in the future (guard rails), can be excluded from the outset. At the same time, all sub-dominant options have to be excluded. Frequently, sub-dominant solutions are so attractive because they promise quick monetary profits for one party, but over time they lead to lasting losses or global risks (Beck, 1996). In this case, intermediate financing or compensation by third parties should be considered.
8. With the relative weighting of the various valuation dimensions it makes sense to create a hierarchy of values in the way described above. In the process, it should become clear that symbolic valuations for the subjective well-being and the design of a 'good' life have just as much normative justification as material use values; at the same time, the safeguarding of basic economic functions is often a precondition for symbolic associations coming into effect. When valuating option values, it should be ascertained first of all whether there is any information on probabilities and use potentials. If there is, the level of discounting of current use vs future use should be determined. For many forms of ecological risks it may be justified to indicate discount rates of zero or almost zero. If there is no information about the probability or use potentials – and this is often the case – valuation can only be conducted according to functional aspects (existence of function equivalents) or

experts' estimates. At the same time, decentralized incentive systems and liability agreements can be used to give impetus to the provision of knowledge and constant adaptation processes. In addition, the existence value must be taken into account in the appreciation process after the other criteria have been included.

9. When weighing options for action, formal methods of balancing assessment can be used. Of these methods, the cost-benefit analysis and the multi-attribute or multi-criteria decision have proved their worth. The first method is largely based on the approach of 'revealed preferences', ie from people's preferences shown in the past expressed in prices, the second being based on the approach of 'expressed preferences', ie the explicit indication of relative weightings between the various cost and benefit dimensions (Fischhoff et al, 1982). But both methods are only aids in weighing up and cannot replace an ethical reflection of the advantages and disadvantages.
10. When specifying options for action and, above all, standards for action it is important to ensure that implementation conditions and review criteria are specified together with the standards. Standards are valid only to the extent that they can also be implemented.

Conclusions for biosphere conservation H 7

What contribution does ethics make towards clarifying the possibilities and limits of the use of the biosphere? The use of (cultivated) nature is an anthropological necessity. Human consciousness works reflexively and humans have developed a causal recognition capacity that enables them to record cause and effect anticipatively and to productively incorporate assessed consequences into their own actions. This knowledge is the motivating force behind the cultural evolution and the development of technologies, agriculture and urbanization. With power over an ever-increasing potential of design and intervention in nature and social affairs over the course of human history, the potential for abuse and exploitation has also grown. Whereas this potential was reflected in philosophical considerations and legal standards at a very early stage with regard to moral standards between people, the issue of human responsibility towards nature has become the subject of intensive consideration only in recent times. Ethical considerations are paramount in this respect. On the one hand, they offer concrete standards for human conduct on the basis of criteria that can be generalized, and on the other hand, they provide procedural advice on a rational and fair decision- and policy-making process.

A simple breakdown into categorical and compensatory rules and prohibitions can assist decision-makers for the justification of principles and standards on biosphere conservation. As soon as human activities exceed the guidelines of categorical principles there is an urgent need for action. But how can we detect whether such guidelines have been exceeded? And how can we ensure from the very outset that these inviolable standards and principles are not exceeded? Here are four central considerations in this respect:

First of all, in almost all of its recent reports the Council (WBGU, 1997, 1998a) has called for international functional units to perform a monitoring and early warning function (eg the proposal for a United Nations Risk Assessment Panel in the 1998 report; cf WBGU, 2000a). Such functional units should not be organized as new authorities, but rather as a network of scientists and professional observers who can quickly and reliably make a diagnosis of cases where the guide rails have been exceeded or are about to be exceeded. This function is also, and especially, needed in the field of biosphere use, because only by valuating global data and developments can infringements of categorical values be identified.

Secondly, international agreements that at least help to protect the categorical values are urgently needed. Since arguments in favour of the violation of values will hardly endure in the discussion with respect to categorical risks, there is a great prospect of an agreement there. This procedure is called the triage strategy in the literature (Rolston, 1994a). Agreements that promise effective protection and appear clearly justified ethically have priority.

Thirdly, the Council considers that the opportunities for implementation of the ethically required actions for the low-impact use of the biosphere are less well guaranteed by conventions or ordinances under administrative law (with the exception of categorical standards). Rather, it places its trust to a greater extent in the creation of decentralized incentive systems that, on the one hand, give impetus to the required provision of knowledge and, on the other hand, offer economic incentives for ethically required conduct. Since the protection and conservation of the biosphere represents a global asset and the beneficiaries and bearers of the costs are frequently not the same people, negotiations on an international and a sub-political level (multinational companies, NGOs, etc) are also needed

Fourthly, the Council considers an analytical breakdown into three strategies of biosphere conservation to be helpful for the implementation of categorical guidelines. It can be assumed that the breakdown into the three categories will not be made without conflicts. Here, a discursive method of decision-making could be used, the fundamental rules of which are outlined above. The Council has drawn up the following strategies:

- The first strategy is that of complete protection with severe restrictions on all use by humans (*Noah strategy*).

- The second strategy provides for a balanced relationship between conservation and use, where extensive resource use should go hand in hand with the conservation of the ecosystems concerned. A selective form of use is called for here (*curator strategy*).
- The third strategy is based on optimum use involving assurance of continuous reproduction. The guiding principle here would be an intensive and, at the same time, sustainable, ie with a view to the long term, use of natural resources (*demiurge strategy*).

The first strategy is recommended when categorical values are at stake or, when options are being weighed, clear protection interests have priority over use interests. Since, in such cases, the interests in resource use are frequently found in different population groups than the interests in protection, it is essential for compensation payments or at least compensation services to be made, by means of which the expected gain in benefit for the international community is shared with those who have had their rights restricted by the protection. For example, if a landscape that absolutely has to be conserved is to be kept largely free of economic use so that humanity as a whole can benefit from it in the long term, the local population, whose income scope is considerably limited as a result, has to be adequately compensated with an additional income or an additional benefit. Ideal in this case are self-supporting structures in the areas concerned in which a protection function is performed by means of economic incentives and decentralized control mechanisms. Compensation payments ensure that this strategy is not implemented at the expense of the mostly poor local population. At the same time, the willingness of the rich countries to renounce some of their own income in favour of a global benefit is also put to the test. This mechanism of compensation payments is also an effective means of ensuring that far-reaching use is prohibited only in those cases in which really categorical values are infringed or in which there are clear results from the weighing of benefits and risks.

The second strategy is always of benefit in cases where there are value conflicts when weighing up between economic benefits and a clear judgement is difficult. In this case, it makes sense to find creative solutions in the sense of conservation through use. Here too, economic incentives have to be created that ensure that the users do not exploit the maximum potential, but prefer extensive forms of land management to the benefit of long-term protection. Section E 3.3.3 'Conservation through use' outlines how this should be implemented in practice.

Like the first strategy, the third strategy is based on categorical values or clear appreciation judgements – but this time in the opposite direction. Over 6 thousand million people in the world have to be provided with enough food and other products and services. On that land where intensive farming is possible without serious impairment to the biosphere it is not only ethically tolerable, but practically obligatory, to use these potentials intensively. However, here it must be ensured that the natural preconditions that make intensive use possible in the first place will continue to be in place in the future. Intensive use of nature taking account of sustainable framework conditions is called for.

Following these three strategies should not be understood just on a global level. Even within a regional area (maybe a town) the three different strategies can be pursued in partial areas or in certain functional spaces. The analytical breakdown into three strategies should thus be applied expediently at local, regional and national level. The Council is convinced that, in dealing with the global dimensions of biosphere conservation, too, this simple breakdown into three fundamental strategies that can be derived logically from ethical considerations is an important tool both for diagnosing present problems and assessing appropriate policy options.

Global biosphere policy I

A guard rail strategy for biosphere conservation and management I 1

To help operationalize the debate on sustainability, the Council has developed the guard rail concept (WBGU, 1996, 1998a). In this chapter we apply this concept to the biosphere, deriving principles from the ideas outlined in Chapters C–H that can help safeguard the development of humankind and society as part of the biosphere.

Guard rails are specific, quantitative damage thresholds that, if exceeded now or at some point in the future, will bring such intolerable consequences that even major advantages of one-time use cannot offset the damage . These guard rails designate areas that must be avoided since otherwise the precept of sustainability will be violated (WBGU, 1998a). Thus, it does not define an 'optimum' target status or prescribe a set route or 'narrow flight path' for achieving that goal, rather within the guard rail broad scope for development is opened up within which processes of learning and searching can proceed unhindered. For that to be the case, however, it must at all costs be ensured that the guard rails are not exceeded and that we do not enter the area of non-sustainability.

This concept will be applied to the biosphere at the regional level (Section I 1.1), at which concrete human action takes place, and secondly at the global level (Section I 1.2–1.6), at which additional necessities become recognizable that are not visible from the regional perspective. Because of the major uncertainties and knowledge gaps that exist – and which have been mentioned repeatedly throughout this report – it is not always possible to give exact guard rails in the sense of precise, quantifiable limits as the Council was able to do in the context of global climate protection (WBGU, 1995b, 1998b). Therefore, 'biological imperatives' have been formulated that are intended to communicate principles by which the values of the biosphere for today's and coming generations may be preserved and used in a sustainable manner. These imperatives essentially reflect the categorization of values that was presented in Chapter H.

At regional level the guard rail strategy can be translated in concrete terms into the designation of protected areas (Type N, 'conservation before use'; Section E 3.3.2). Protected areas deliver important ecosystem services for the bioregion (eg erosion protection by high-slope forests or flood protection by floodplain meadows) and protect valuable species. For this reason they must be preserved from economic use. Furthermore, for the other two types of land use (Type M, 'conservation through use', and Type E, 'conservation despite use'; Section E 3.3.1) 'guidelines' are defined. These are, in contrast to general principles (imperatives) or numerically defined damage thresholds (guard rails), to be understood as concrete management rules which will ensure, for example, erosion protection or avoidance of eutrophication even if ecosystems are used intensively (Box I 1.1-1). Setting guard rails beyond which, for example, a given rate of erosion or application of nutrients is no longer sustainable, requires, among other factors, differentiated consideration of the various soil and climatic conditions and is an important research issue.

The guidelines for the use of renewable resources refer to both extensive and intensive land use (and accordingly the use of aquatic habitats) and are implemented on a regional basis. Unfortunately, for the foreseeable future, we cannot expect them to be applied everywhere: the observed trends tell a different story in both industrial societies and developing countries (Chapter C).

The definition of guard rails at the global level is necessary in order, when guidelines are not respected, to guarantee that the minimum requirements for our common survival in the biosphere are fulfilled. The concept of *global* guard rails or 'minimum safety standards', which the Council has already pursued in similar contexts, can in principle also be applied to the biosphere. The numerically precise definition of such limitations of human action – that necessarily always contain a normative component – is however particularly difficult on the global scale because of the large number of uncertainties involved.

However, we have given a numerical statement as a guard rail here because the threat to the biosphere and the loss of biological diversity constitutes a grave

Box I 1.1-1

Guidelines for the multi-functional use of renewable resources

Guideline: Preservation or restoration of the regulatory function of intensively used ecosystems
Multifunctional use of renewable resources reduces biogeochemical stresses on managed systems and their neighbouring systems by
- reducing the internal decoupling of biogeochemical cycles and energy flows,
- synchronising processes to breakdown, re-form and build up living and dead biomass,
- minimizing soil degradation (erosion, physical and chemical degradation),
- eliminating undesirable biochemical deficits,
- establishing balanced biogeochemical regimes,
- avoiding eutrophication and toxification from both non-point and point sources,
- monitoring system status and stress.

Guideline: Preservation or restoration of the habitat function of ecosystems
Multifunctional use of renewable resources conserves biological diversity at the species and biotope levels and thus increases the elasticity and resilience of ecosystems by
- diversifying use in both temporal and spatial terms,
- establishing mixed stocks and diverse crop rotation,
- preserving site diversity,
- creating non-used buffer areas and protected zones (temporary and regional),
- avoiding as far as possible the use of biocides,
- protecting endangered species,
- adapting use to match the productivity of stocks,
- clarifying dependencies and interactions among communities,
- monitoring and characterizing communities of organisms and their changes.

Guideline: Long-term preservation or restoration of the use function of ecosystems, giving consideration to economic and ecological parameters
Multifunctional use of renewable resources leads to forms of food, fodder and raw materials production in which energy flows and biogeochemical cycles are optimized. This is achieved by
- reducing material and energy losses (closed-loop materials and waste management),
- reactivating or promoting self-regulatory processes,
- optimizing plant and soil protection,
- minimizing resource consumption through optimization of use strategies,
- expanding the spectrum of species used,
- exercising caution in the use of non-site-appropriate, non-adapted or alien species.

Guideline: Preservation or restoration of the cultural and social functions of ecosystems
Use of renewable resources leads to social stabilization of indigenous societies and serves the interests of the population as a whole by
- safeguarding jobs and income,
- conserving rural cultivated landscapes and appropriate economic structures,
- conserving historically developed social structures,
- safeguarding leisure and recreational use,
- preserving cultural heritage.

risk in the context of global change. This risk has been categorized by the Council in previous reports as the 'Cassandra' risk type (Chapter B; for risk classification cf WBGU, 2000a). Due to the delayed effect that is associated with this risk type, warning voices are seldom heard because the damaging impacts they are warning against are not tangible or even conceivable in the present. As was detailed in the Council's risk report (WBGU, 2000a), voluntary commitments on the part of global players and international coordination are the key instruments with which to strengthen long-term responsibility vis-à-vis Cassandra risks. It is also in that sense that the global biological imperatives presented in Sections I 1.1–1.5 and the guard rail given as a conclusion in Section I 1.6 (to designate 10–20 per cent of the worldwide land area for nature conservation) are to be interpreted: they can constitute elements in a global strategy that should be taken up by existing international institutions and incorporated into their programmes of action.

I 1.1
First biological imperative: preserve the integrity of bioregions

Applied at the bioregional level (Section E 3.9) the guard rail concept means two things. First of all, it makes sense to place use restrictions on certain areas (Type N, Section E 3.3.1) the focus of which should be the preservation of regulatory functions or the provision of ecosystem services (eg renunciation of economic use of slope forests because of their importance in protecting against erosion). In addition, there are protected areas of supra-regional or even global significance that are part of a global guard rail (Section I 1.3). These are designated at national or global level, but must also be binding on the bioregion.

Secondly, however, in zones that are suited to extensive or intensive use in agriculture or farming (types M or E; Sections E 3.3.3 and E 3.3.4 respectively), guard rails might be crossed if, for example, the groundwater is endangered as a result of excessive fertilization or eutrophication is triggered in adjoining aquatic ecosystems, or unsuitable agricultural methods lead to intolerably high erosion rates. For such zones 'guidelines' may be developed that can be expressed in practice not in the renunciation of use of certain areas, but in rules for reasonable use with the intention of guaranteeing that the given use stays within the realm of sustainability (Box I 1.1-1; Section E 3.9).

I 1.2
Second biological imperative: safeguard existing biological resources

From the demand that the production of food and renewable resources ('food and fibre') may not be endangered (Section D 3.1), the following biological imperative may be derived on the basis of the concept of 'use value': Biological resources that are required for the (constantly necessary) adaptation and further development of crop plants and livestock animals may not be endangered.

This includes the acutely endangered enormous diversity of traditional, locally adapted varieties that are of considerable importance for plant breeding and food security. The Council is concerned because this valuable diversity of traditional varieties is increasingly disappearing (genetic erosion). Particular efforts are required here and these are elucidated in more detail in Sections D 3.1 and I 3. *Ex-situ* conservation (eg in gene banks) may not be the solution in all cases but, given the worldwide situation, it should increasingly be pursued (Section D 3.1; FAO, 1996c).

Furthermore, the *wild, related species* of the cultivars we use should be protected. The plant-based genetic resources in what are termed 'gene centres' should be given particular consideration (Hammer, 1998; Section D 3.1). These centres are zones in which valuable genetic resources occur in a particularly concentrated form. They cannot be protected as a whole because of their extensive geographic spread, and because they do not just house biotopes that contain valuable genetic resources for wild, related cultivated plants, but are also themselves a patchwork of diverse landscape types. Fore these diversity centres there is a particular responsibility to protect these resources that should be taken into consideration in the context of bioregional management (maintaining genetic resources *in situ* or *on farm*; Section D 3.1). The services that are provided in such bioregions and which ultimately benefit everyone will in the long term be extremely difficult to provide unless mechanisms for supra-regional and global financial compensation are established, since generally – seen from the perspective of the local population – this is the economically less interesting alternative in comparison with more intensive forms of land use (Section I 3.5).

Genetic transfer through the release of transgenic plants can be an endangering factor, eg if the alien genes have a competitive advantage outside the agro-ecosystem (Regal, 1994; Section D 3.2). Resistance to disease, tolerance of cold, drought or salt are examples of features that could cause a shift in the competition balance among wild populations if cross-breeding were to occur. And so the use of this technique must be investigated strictly in each individual case. The release of transgenic plants into gene centres in which the wild varieties of these cultivars occur is therefore associated with particular risks. It cannot be ruled out that the wild populations would be endangered by hybridization and competitive pressure and that genetic diversity would be lost as a result (WBGU, 2000a). For example, genetically modified maize should not be planted in the original area of distribution (Mexico) since out-breeding and possible changes in the competitive balance could endanger the genetic diversity of the wild species.

I 1.3
Third biological imperative: maintain biopotential for the future

The biosphere contains many as yet unknown substances and principles for humankind and this 'option value' must be safeguarded for future use. As was discussed in detail in Section D 3.3 not all sites are equally interesting in terms of harvesting natural substances. Particularly high chances of finding rich pickings in a small area with little investment is naturally to be found in those areas with high biological diversity of natural ecosystems (eg tropical forests, coral reefs). As a result of the variety of ecological niches and species adaptation to a highly complex habitat there are in such places a comparatively large number of interesting 'solutions' of a biochemical or structural nature. These hotspots of biological diversity are therefore particularly important.

If in areas of high biological diversity there is an indigenous population, then the traditional knowledge accumulated over many generations relating to the different species and their effects can be used to gain valuable insights for bioprospecting (eg methods of ethnobotany, Section D 3.3.6, and property rights, Section I 3.3.3)

Sites at which extreme environmental conditions have driven species in the course of their evolution to adapt in very differentiated ways are also interesting. Examples are sites with extreme abiotic conditions, eg hot springs, arid areas or deep sea with the particular pressures of that environment. In areas with a high degree of diversity, a range of extreme abiotic and biotic conditions and an unbroken tradition in the indigenous population, the option value of these natural resources is particularly high. In order to preserve the option value of hitherto unknown species and forms of use for future generations, areas of natural or semi-natural ecosystems must be conserved and certain human uses such as commercial extraction of biomass, hunting and fishing precluded. The regions must be differentiated in terms of the numbers of endangered species. It is too risky to provide just one protected area per species or ecosystem, so several representative areas need to be protected in order to ensure the long-term protection goal. And the protected areas need to be cross-linked into the landscape (Section E 3.3.2). As far as we know some ecosystems and species react extremely sensitively to human influence, which means that *a certain portion of the biosphere needs total protection against human influences.* Enforcing this sort of protection that is based on values that cannot be translated directly into monetary terms and that cannot be developed until some point in the future in the face of concrete, conflicting interests is a particular challenge.

The Council is aware that a scientifically grounded 'water-tight' derivation of a guard rail in the form of protected area targets is not possible at the present time. If, however, here the figure of 10–20 per cent of terrestrial area is given, then this is a broad estimate that is mainly founded on expert intuition (Section E 3.3.2). This figure will however vary greatly from region to region, depending on the natural status and features. Since such areas are generally also interesting for other reasons (eg protection of the existence value) there are synergies with the guard rail for the preservation of the global natural heritage (Section I 1.4). And this percentage already includes the preservation of populations and species for reasons of existence value (Section I 1.4) and option value.

I 1.4
Fourth biological imperative: preserve the global natural heritage

The preamble to the Convention on Biological Diversity affirms that biological diversity is a 'common concern of humankind'. Similar formulations in other agreements on the biosphere, Agenda 21 and the programmes of international institutions permit the conclusion that in the international community a global consensus in favour of preserving the natural heritage of creation has been established. According to this consensus it is unacceptable to allow large losses of worldwide biological diversity. The reasons for this are varied and they have been explained at various points in this report: they range from concrete 'survival arguments' (without the maintenance of agrobiodiversity the world's food is in danger, Sections D 3.4 and I 1.2) to more normative rationales (existential and symbolic value; preservation of a natural heritage site can be rationalized in a similar way as monuments are preserved as world cultural heritage sites; Chapter H). And, ultimately, this guard rail also has consequences in the form of claims to territory, ie nature conservation becoming in certain areas the primary form of 'land use' (Section E 3.3.2).

Landscapes and ecosystems

Here, first of all we should name the parts of the biosphere that according to the UNESCO convention and other territory-specific conventions make up the natural heritage of humankind and therefore enjoy special protection (Section I 3). Just as the loss of cultural treasures that have been acquired over the course of the cultural evolution of humankind is unacceptable for the global community, a global consensus has been established on the basis of the high existential and symbolic value also to preserve the natural treasures of biological evolution or geologically valuable formations. These include places such as Lake Baikal, Yellowstone National Park or the Serengeti. These 'jewels of the biosphere' are in many instances already under national and international protection (eg through the World Heritage Convention, Section I 3.3.1) but in many cases require additional support, particularly if the capacity of the respective country – often a developing country – is strained.

These 'jewels' that are already protected should in a global approach be supplemented by representative sections of all of the major ecosystems of the Earth. The demand that no ecosystem type may be allowed to disappear is much easier to implement than is that same demand applied to species, even though there have already been irrevocable losses in the area of ecosystems. To this end it will require a *network of protected areas that includes representative examples of all natural ecosystem types* (Section E 3.3.2). Topological aspects must be taken into particular consideration when selecting areas (habitat connectivity, corridors, stepping stone ecosystems).

From these thoughts recommendations for landscapes and ecosystems can be derived:
- They must incorporate areas already under protection.
- Following a gap analysis in the current representative nature of the protected area system they would have to include the missing areas. This analysis is time-consuming and cannot be carried out by the Council at this point. This approach could be calculated on the basis of the various

ecosystem types by way of an example: this is where nature conservation research is called on (Chapter J).

- The question should be posed whether there are limits to the mix of ecosystem types in a given landscape, both regionally and globally. Can the landscape complex be shifted in an arbitrary manner without serious consequences, as for example is currently happening with the loss of wetlands or high-slope forests? Can a minimum requirement of surface area be posited for the various ecosystem types across the globe in the various regions (corals, mangroves, forests, wetlands, high moorlands, etc)? Here, too, urgent research questions arise (Chapter J).

The existing protected areas account for 8.2 per cent of the global land area if the weakest IUCN protective categories are included. By counting Categories I-V only, the figure is 5.3 per cent (McNeely and Miller, 1984; Section E 3.3.2). In light of the shortcomings of the worldwide system of protected areas (unrepresentativeness, non-implementation, redundancies) a considerably higher land area will be necessary. The figure of between 10 and 20 per cent of the global terrestrial area mentioned above which also results as a rough reference value from other calculation approaches (Section I 1.3), therefore appears appropriate in the Council's view.

Species

Of course, natural heritage does not just consist of certain ecosystems or landscapes, but also includes the species that live in them. Consistent application and adherence to the guard rail for ecosystem conservation and to the bioregional management rules will ensure therefore that species are also protected. This is not something that is to be taken as guaranteed, therefore species conservation measures make sense if particularly valuable species would otherwise have no chance of survival. 'Particularly valuable' means that when applying the value categories outlined in Chapter H an extraordinarily high evaluation results that justifies its importance. As a rule it will be a mixture of several categories that scored high. That might be, for example, high scores on existential and symbolic value (symbolic species: tiger, panda, whale; Box E 3.3-3), or species with a high functional value such as a central role in globally significant ecosystems (keystone species; Section D 2).

Species diversity is in no way spread evenly across the Earth, rather the various global diversity maps show hotspots of biological diversity (Fig. D 1.2-1). And in terms of preserving the global natural heritage these areas in which a high species diversity is located in a small area are particularly interesting or in which a large number of endemic or particularly diverse (genetically distinct) species are found. In selecting protected areas particular attention should be paid to these hotspots of species biodiversity. And for setting priorities, in addition to the data on the 'biological importance' of areas, additional data on the current level of threat or current protected status should be evaluated, as was done by Stattersfield et al (1998) applying a global approach to the example of bird species. The intersection of hotspot maps from different sources and quality to produce world maps on biological diversity, the significance of biodiversity and the threats to biodiversity is currently a dynamical field of research that requires prioritization (Williams, 1998; Barthlott et al, 1999; Chapter J) and which will be very important for deriving a quantitative guard rail for global natural heritage in the future. Since the current status of research is not sufficient to derive a scientifically reasoned derivative of that type of quantitative guard rail, we have outlined a few thoughts here as to how one might arrive at an initial appraisal.

Since many species lay claim to minimum areas a first very rough quantification might be possible on the grounds of required area if one focuses on the 'particularly valuable' keystone species, symbolic species or umbrella species (Box E 3.3-3). Guard rails for species conservation might be quantifiable on the basis of the extinction probability of large mammals and birds *in situ* (using population-genetic mathematic models) because just maintaining viable populations of the large mammals in the wild for at least several centuries involves large land areas.

In order to guarantee protection against extinction a minimum population size must be maintained. The concept of Minimal Viable Population (MVP) results from the following estimated figures:

1. 50–100 individuals at least are necessary to avoid extinction through demographic fluctuation.
2. Around 500 individuals are the minimum number to prevent depressions as a result of in-breeding.
3. 5,000–10,000 individuals are the minimum number to guarantee evolutionary changes and adaptations to natural variability.

These figures that apply to mammals are probably too low for long-lived plant species (eg for oaks with a lifespan of 400 years at least 400,000 individuals are necessary). As a result of dropping below these levels in the 20th century mammals have become extinct in all US national parks (with the exception of one) with the species loss falling in linear progression to the increasing size of the parks (Newmark, 1987). Belovsky (1987) estimates that the reservation size for large mammals (>50kg) has to be 100,000–1,000,000km^2 if they are to be preserved from extinction over evolutionary time periods (10,000–100,000 years).

Quantification on this basis is therefore possible in principle, but so far has only been done for individual species, never globally. Of course, the required areas for individual species are not simply added to one another since protected areas may provide home to several such species (Shafer, 1990). They cannot (and do not necessarily have to) be satisfied completely in totallly protected reservations (Type N): integration with the ambient cultivated landscape is essential (Section E 3.9). Furthermore, several populations of one species at different localities should have this minimum size. It should be noted that these figures are based on theoretical reflections and would have to be re-examined for each case using a Population Viability Analysis (PVA). So far only a few such analyses have been performed and documented (eg for the spotted owl and the grizzly bear in the United States): this opens up a broad and extremely relevant field for nature conservation research.

There is another approach for calculating estimates which rests on the requirement for ecosystem regulatory functions at species level. From Section D 2 it is clear that sustainable provision of ecosystem goods and services is linked to a minimum of species diversity. The costs for maintaining ecological services rises exponentially to the fall in the number of species. Based on experience gained from ecological experiments, at least 10–100 plant species (an average of perhaps 30 plant species) are necessary in each ecosystem type in order to maintain in the long term these services with a justifiable input of energy and labour. If one considers the various altitude types, climate zones and soil compositions, then this requisite minimum increases because many species are specialized to one or just a few climate or soil types and would have to be replaced by other species if the edaphic conditions were changed. An admittedly unreliable and oversimplified estimated calculation that assumes 30 plant species worldwide, 50 soil types, 10 altitude classes and 10 climate types would result after simple multiplication in 150,000 plant species. This calculation is of course a very rough estimate since most plant species are not fixated exclusively on one of the various types. The number is still surprising since it is in the same order of magnitude as the estimated *total number* of vascular plants on the Earth (approx 320,000 species; Heywood, 1997).

On the basis of this and other considerations the estimate to allow nature conservation priority on 10–20 per cent of the terrestrial area worldwide does not seem exaggerated.

I 1.5 Fifth biological imperative: preserve the regulatory functions of the biosphere

Biogeochemical cycles of the Earth System

The major biogeochemical cycles of the Earth System are currently being influenced by humankind on a massive scale (Section F 3). Biosphere-climate linkages are already being affected and human-induced climatic changes are having an impact on the biosphere and vice versa. Therefore, the objectives of the Framework Convention on Climate Change are also relevant in the context of the biosphere. According to Article 2 of this Convention ecosystems should not be overstrained in their ability to adapt to climate change, and food production and sustainable economic development may not be jeopardized (maintaining the functional value of the biosphere, Chapter H). Thus, for example, the not implausible scenario of a runaway greenhouse effect must be avoided since it would bring with it unacceptable costs for humankind and society (Section F 4). That ultimately means that *climate protection is also an essential prerequisite for conservation of the biosphere*.

Therefore the global guard rail that the Council has already developed for climate protection (WBGU, 1995b, 1998b) may be transferred and applied to the biosphere. To this guard rail one could add estimates of potential migration rates of biomes or ecosystem types as a reaction to climate change. An important additional criterion for coastal ecosystems (corals, mangroves, mudflats) is the rise in sea level (and the timing of these risks) as a result of climate change.

Hotspots of criticality

In Section F 5 the importance of the biosphere for the global Earth System was estimated with the help of a criticality indicator that highlights the hotspots in a geographically explicit manner and comprises the following base indicators:

1. Solar energy intake or productivity of the biosphere;
2. Importance of the role of the biosphere for the global hydrological cycle and the associated regulatory function for the Earth System;
3. Regional seasonal albedo distribution of the biosphere in the sense of a stabilizing negative feedback;
4. Appraisal of the resilience or robustness of the biosphere vis-à-vis a change in environmental conditions using the example of temperature and precipitation changes.

At the global level regions can be identified using the approach outlined in Section F 5 upon which particular attention should be placed to maintain certain natural biomes or ecosystems, since the biosphere in these areas does not just fulfil an important function within system Earth, but also responds sensitively to changes in environmental conditions. These hotspots must be maintained because of their ecosystem functions for the Earth System. Identified as important, and at the same time fragile, biogeographic regions for example in Section F 5.3 are certain areas in the Northwestern United States, the Southwestern part of Canada, the Atlantic coastal part of Amazonia with Guyana, Surinam and parts of Brazil, critical areas on the northern edge of the steppes of Kazakhstan, regions along the Sahel zone and zones transitioning into rainforest in West and Central Africa. Fig. F 5.3-2 shows these and other hotspots of criticality that merit protection.

From these ideas, minimum requirements for area-related ecosystem conservation may be derived: in these sensitive regions with globally important biosphere functions land use may not be allowed to lead to changes in natural vegetation across large areas since this would impair the functioning of those areas in terms of the global regulatory mechanism.

I 1.6
Conclusion: an explicit guard rail for biosphere conservation

It is certainly not possible with the current knowledge available to derive a precise and scientifically founded guard rail for biosphere conservation in the form of a proportion of the total area that should be protected. The estimates do, however – whatever their methodological shortcomings – offer at least reference points which the Council has used for general orientation. The various approaches to maintain the components and aspects of the biosphere from the various appraisals of their function and their value all come to a similar scale of area required: on 10–20 per cent of the worldwide terrestrial biosphere 'nature conservation use' should be the priority form of land use. Of course, distinctions need to be made according to biomes, countries, etc since there will be regions where a figure of 80 per cent or even 90 per cent of priority conservation area is not exaggerated; and in other regions 2–5 per cent may actually be sufficient.

This figure should be understood more as a *stimulus towards systematic reflection* than as a quantitative prescriptive figure for actual biosphere policy. It is a call to the international community to turn its attention as a whole and in earnest to the central issue of the biosphere. In many countries this will be easy, in others more difficult. More thought needs to go into mechanisms for international agreement and burden-sharing (Chapter I).

The selection of these areas is a difficult task for which scientific criteria and claims are insufficient, and which must be enforced in the societal process (Section E 3.9). There is now a large body of literature on selection criteria and procedures as well as on prioritization (eg Miller et al, 1995; Johnson, 1995; Dinerstein et al, 1995; Stattersfield et al, 1998).

In these areas other uses such as sustainable forestry, soft tourism, scientific expeditions, habitat for indigenous communities, etc are not precluded, as long as no large amounts of biomass are extracted and the activities do not fundamentally change the character and features of the landscape under protection (eg by biogeochemical inputs; Section E 3.3.2). Given the impact of humankind and society on each and every ecosystem today, adaptive management is to be recommended, that means flexibility and an ability to learn in the case of protection targets and measures as nature conservation areas are developed (Section E 3.3.2.5).

But the biological imperatives cannot simply be fulfilled by designating protected areas. The following points should also be noted:

- *Topography*: The situation of protected areas in relation to one another and their linkage is very important (migration corridors, escape zones in case of climate change, stepping stone ecosystems on the routes of migratory birds, etc)
- *Regional concepts*: priority nature conservation areas must in the respective regional context be supplemented with zones of extensive use within the framework of a concept for differentiated land use (eg buffer zones; Section E 3.3.2). Bioregional management offers some approaches in this regard for integrated consideration of the various demands placed upon landscapes (Section E 3.9).
- *Guidelines for land use*: Even in the zone in which intensive management is envisaged, certain rules should be kept, eg for soil and water protection. Species conservation will, for example, also be reflected in hunting rules and trade restrictions (Section D 3.1). These guidelines are given in Box I 1.1-1.

From these ideas important research recommendations can be derived (Chapter J) since it will without a doubt be one of the primary tasks for applied biosphere research to track down more precisely the central target parameters of global change rather than working with the to some degree inadequate tools of expert estimates.

I 2 Elements of a global biosphere policy

I 2.1
Tasks and issues

The call for a global policy of sustainable use and conservation of the biosphere rests, in accordance with the Council's reasoning, up to this point on two foundations:

1. For this type of policy, moral and ethical principles are asserted which attribute an intrinsic value to the biosphere and thus concede it an existential right of its own (Chapter H).
2. We point out that the loss of biological diversity and the reduction of biosphere services constitute a serious restriction of the future viable path of development for society and therefore, in particular with a view to future generations, also the risk of long-term loss of societal prosperity (Chapters C–F).

Preventing such welfare losses requires first of all that global and spatial conservation goals are established, on the basis of which differentiated protective measures and sustainable forms of use may be developed. It must be the aim of these endeavours to prevent humankind from triggering the eradication of species. To that extent it is necessary to establish a pragmatic and gradual biosphere policy that combines government and international control with a decentralized system of incentives to create a comprehensive strategy of sustainability for the biosphere.

Various specific challenges present themselves in connection with designing this sort of global biosphere policy– by contrast to many areas of action in the area of environmental and resource conservation policy:

- Biological diversity, in its three components – ecosystems, species and genetic variability – is an unusually *complex* asset and object of protection.
- There is a considerable *problem of uncertainty and knowledge* with regard to target models and the measures and implementation routes to be taken.
- There are particular difficulties in developing a *quantified appraisal* of biological diversity.
- A global biosphere policy calls for the adequate consideration of *temporal, spatial, geographic and social allocation conflicts* and for the optimum spatial level of action to be established.
- Global biosphere policy is inconceivable without the fundamental *willingness to participate and cooperate* on the part of the various private and public players at local, national and international level.

I 2.1.1
Overcoming the knowledge deficit

A central hindrance to the establishment of conservation strategies for biological diversity are the serious knowledge deficits that still exist and which relate to biological and biogeochemical contexts, in particular the causes, scale and consequences of a loss of biodiversity and the impact of human actions (Becker-Soest, 1998a, b; Chapters D–F and J). Above all, there are limits to answer the fundamental question of how much nature humankind needs in the long term to survive. In that respect, the derivation of clearly definable global and regional guard rails (bioregional level) is highly problematic (Sections E 3.9 and I 1). So biosphere policy must still operate without knowledge of the precise mechanisms of the biosphere dynamic, and political action must take place in a context of gross uncertainty. For this reason, the Council talks about 'biological imperatives' instead of quantifiable guard rails.

These five identified imperatives (Section I 1) should in the view of the Council, however, be given particular consideration and therefore form the subject of a global biosphere policy. These policy fields are not sufficient to be able to provide a comprehensive explanation of the importance of biodiversity (Chapter H), but they do point to areas on which global biosphere policy might focus:

- Preserving the integrity of bioregions.
- Safeguarding existing biological resources.
- Maintaining biopotential for the future.
- Preserving the global natural heritage.

- Preserving the regulatory functions of the biosphere.

The major knowledge deficits lead to a situation where simply calling for renunciation of activities that are detrimental to nature has little chance of success at a national, let alone at an international level (Hampicke, 1991). It is especially true that cost-benefit considerations are extremely difficult in this policy field because of the high level of uncertainty and the evaluatory problems. At the same time it is also true that there is still no operational interpretation of the precautionary principle that would be accepted internationally.

The position taken by the Council of moderate anthropocentrism does however advocate the preservation of essentially any species unless to preserve a particular species would be associated with considerable disadvantages for society (Chapter H). This is a fundamental stance on the part of the Council that may be relinquished only at extremely high conservation costs.

The question of where and how the conservation task thus outlined might be fulfilled is not clearly answered with that statement. There is as yet no full-coverage overview of the natural potential of the biosphere and individual measures take hold differently depending on the region. The conservation of certain components of the biosphere is associated in both spatial and temporal terms with divergent costs and prosperity effects. Indeed, the conditions for success of a protective policy also differ depending on the place, situation and time. The land use planning form of environmental protection for example requires there to be good planning agencies in place that can enforce what they plan which in turn depends on the distribution of property rights to natural resources and certain starting conditions in terms of settlement structure. A global biosphere policy is therefore characterized by regional specialities that make it more difficult to design a uniform strategy in the sense of one homogeneous framework of action or a globally applicable instrument. This means that a global biosphere policy is not simply subject to the information deficits described, but also to deficits in terms of capacity for governance. As a consequence, when organizing the process of searching for scientific links and interactions or for differentiated modes of implementation, institutional diversity is strongly advisable.

I 2.1.2
Problems of spatial and temporal distribution

In addition to the knowledge deficits there are aggravating conflicts that one can essentially term 'distribution conflicts', although in many instances it is rather a case of a spatial or temporal violation of the equivalency principle. Essentially these conflicts are over the spatial and temporal distribution of benefits and the adaptation or opportunity costs of practising or omitting a policy of biodiversity conservation. If these benefits and costs coincide either temporally or spatially then it can be assumed that the beneficiaries are willing on the basis of a vested interest to bear the costs and thus pursue a goal-oriented biosphere policy. The further these advantages and 'disadvantages' however diverge in spatial or temporal terms, the more likely it is that biospheric conservation will not take place.

In spatial terms this conflict often coincides with the classic North-South conflict since

- the countries of the 'northern' hemisphere reap the benefits and those of the 'South' bear the costs of certain development processes and policies;
- given divergent stages of development, the interests of these country groups must necessarily diverge (Shiva, 1995; Suplie, 1996; Biermann, 1998).

Countries with a high level of development have a growing interest, not just on economic grounds (incl protectionist intentions), in preserving the genetic pool generally to be found in the developing countries. But they also tend to rate nature conservation more highly – whether for reasons of a high development status that promotes environmental sensitivity, a specific education policy or a higher 'level of knowledge'. Developing countries by contrast fear ecological imperialism on the part of the industrialized countries which they assume would like to obligate them to waive use of their natural development potential without remuneration (non-use for instance of biodiversity-rich tropical forests) and in that way bar their passage towards any prospects of development.

Important conclusions may be drawn from this. It must be made clear to the 'cost bearers' that biosphere conservation is also a welfare gain for them. At the same time, ways must be found to connect the benefits of using biological resources with the costs of protecting them, so that the beneficiaries of regional biosphere conservation bear a fair share of the costs. Above all, the impression must be avoided that biosphere conservation is always associated with waiving use of certain scope for development. This may sometimes in actual fact be the case, but in the majority of cases there is the opportunity to guarantee conservation by means of adapted use. This is one of the crucial reasons why the Council accords great importance to the motivation approach and, in that context, underlines the sort of measures that highlight the economic advantages of biosphere conservation, that also favours a cooperative action approach (Section I 3.3). Furthermore, realizing the spatial equivalency principle is a decisive step on the way to achieve biosphere conservation. Negotiations and compensatory mechanisms are necessary to that end at the common level of both beneficiaries and cost bearers. Action does not therefore always have to take place at the global level, national or regional associations can also offer interesting starting points.

It is more difficult to overcome the temporal conflicts of distribution. They result from a development-based underestimation of future use in preserving biodiversity, ie as a result of the short-term orientation of nations and economic players. Nations that are fighting for survival and possess high eco-capital stocks but few real capital reserves as a rule will follow short-term interests leading to the disproportionate use of their eco-capital and thus necessarily to an under-emphasis of the sustainability principle. As the Council has already underlined (WBGU, 1994, 1995a) this is why in the case of many developing countries economic development and development of the sense of long-term responsibility go hand in hand. Long-term responsibility means, in this case, a mental willingness among private and public decision-makers when weighing up opportunities and options to give adequate space to their own future and that of subsequent generations (Wink, 1998).

At the individual level similar problems can emerge. Nature conservation or the use of renewable resources based on the principle of sustainability often hinge of the essentially relinquishing current use. This implies, for example, that given the long time it takes for a tree to grow the fruits of that sort of sustainable use may only be harvested by later generations, leaving the present-day owners to incur opportunity costs (costs incurred by loss of the opportunity for alternative use). The solution to this problem may come from voluntary self-commitment (intrinsic motivation) on the part of the owner or from the control route (bans and rules), a route that generally however requires a high degree of monitoring input (adherence to documented self-commitment or the rules). It is also conceivable, however, for the owner to have his current day renunciation honoured by the beneficiary acquiring 'tradable permits' to use the resources, and the proceeds from trading these permits benefit the owner. This specific form of motivation for owners of important natural resources through economic incentives would also open up scope for club or sponsorship solutions.

I 2.1.3
Coordination problems

The third problem relates to coordination. Given the spatial and temporal divergence of beneficiaries and cost-bearers and the autonomy and interest diversity of the states or private and public decision-makers involved, a global biodiversity policy calls for negotiation. There is a need to negotiate the designation of areas meriting conservation under global consideration, the awarding of access and usage rights for this eco-capital and possible compensatory payments for the countries that have to bear the opportunity costs of a policy of preservation (Becker-Soest, 1998a, b). There is no assured solution to this coordination problem and even where agreements have been arrived at there are still serious implementation and monitoring problems.

Conservation of certain environmental assets constitutes a public asset since the global society, or at least many nations, cannot be excluded from the advantages of preventing species loss. The costs of that sort of conservation policy are incurred mostly at national or regional level, but the advantages are felt at transregional or transnational or even intertemporally. This leads to a situation where 'free-riding' pays off and the level of conservation given is lower than is economically advisable. One can interpret this problem as a classic prisoner's dilemma game in which the inclination not to pursue a conservation policy proves to be the dominant strategy, a decision which may prove to be fatal from a collective perspective. To that extent the task with which we are essentially faced consists in inducing cooperative behaviour and looking for mechanisms that lead to voluntary cooperation. Since there is no superior sanctioning force to 'punish' non-cooperative behaviour, the motivational approach is particularly important here.

Given the complexity of the protective task, biosphere conservation cannot – or at least only with great difficulty – be enforced *against* the interests of those impacted, such as governments, but also private entities that bear the costs of biosphere policy. This is then a problem of the monitoring required to oversee most measures. Analyses on the approx 120 international environmental agreements currently in existence show that effective regulations have been realized primarily wherever a relative degree of homogeneity of interests prevailed (Haas et al, 1993; Knill, 1998). But, particularly in biosphere policy, we must assume that not just a very heterogeneous political objective, but as a rule also a large heterogeneity of interests exist that make it particularly difficult to pursue a command-and-control approach. On the basis of legitimation and enforcement requirements, a combination of government and private rules is at least needed in order to ensure that the various players are prepared to collaborate. In addition to liability approaches under civil law, trade regulation or for instance the institutional regimes for trade in patents for genetic structures, there must also be 'motivation' of the players. This insight has moved the Council to emphasize both the motivational approach (Section I 2.4) and the learning and educational approach (Section I 2.5).

In accordance with the above, therefore, four approaches present themselves in the context of giving concrete form to biosphere policy and implementing such a policy, each of which should be seen as relating to each other and not in isolation:

- A *command-and-control approach* that takes effect where agreements are shared by all players and where implementation is easily handled and monitored (Section I 2.2).
- An approach to develop *planning and implementational governance capacities*, in which in addition to the global level the governance capacities of nations and regional associations is the central focus (Section I 2.3).
- A *motivational approach* that allows for cooperative action, strengthens non-governmental activities and achieves a readiness among private players to collaborate (Section I 2.4).
- A *learning and educational approach* that intrinsically motivates players to adhere to the behavioural rules associated with the measures from an inner conviction rather than any sense of compulsion (Section I 2.5).

I 2.1.4
Points of departure for a global biosphere policy

The main points of departure for a global biosphere policy may be described on the basis of the problems outlined above.

Overcoming the nature of the biosphere as a collective asset

First of all, it should be stated that in the light of the economic and ethical argumentation that is endorsed by the Council in the context of biosphere policy and for reasons of the knowledge deficits listed and the character of nature as a collective asset (one can use the asset without paying for it) we can assume that pure market solutions will not be sufficient to achieve appropriate conservation and sustainable use of the biosphere. One may assume that an individual willingness to pay for the conservation of the biosphere exists that must also be used. But, given the characteristic of the biosphere as a collective asset, this willingness will only be manifest to a limited extent. Including ethical values (eg existence value) also leads to a situation where value elements come into play in the context of conservation concerns that cannot be reconciled with ideas on how to mobilize a willingness to pay. This is linked to the thesis that the 'inherent' value of nature cannot be adequately expressed in monetary units (Hampicke, 1991). Thus it is also extremely difficult to offset the benefit of nature preservation against conservation costs. Determining the minimum level of conservation ultimately remains a political decision.

But that also means that political decisions in the area of biosphere policy necessarily run counter to the interests of individual nations, regions or individuals and therefore must be perceived as 'foreign' or imposed (acceptance problem). Therefore, one can expect more frequent conflicts of interest. Regulations or bans (control approach) and the development of international governance capacities are in theory possible methods of implementation but require the power of enforcement and monitoring. Neither is guaranteed, even in highly developed democracies and leads to enforcement deficits and evasive action (eg black markets in endangered species). Control and the building and further development of governance capacities are in the Council's view important instruments of implementation, but unless they are joined by the motivation of the players through cooperation, communication of insights and economic incentives, the prospect of the line of argumentation being successful is bleak.

Arousing economic interest in biological diversity

In general, research into procedures to preserve biological diversity does not begin unless long-term sources of returns are thereby being opened up. Therefore, an economic interest in biological resources has first to be aroused. This generally requires first the allocation of property rights and the right to market the resource for profit. Thus, scientific findings in forest research in the industrial nations are advanced significantly by the forestry industry itself. From this realization the Council devotes particular attention to the topic 'Conservation through economic use': biosphere policy that runs counter to economic interests holds very little prospect of being enforced. An expanding population, an active policy to overcome poverty and an appropriate strategy of use will be more efficient in achieving the goal of biosphere conservation than any 'reserve' strategy (keeping spaces free of human use), adherence to which cannot in any case be guaranteed in many developing countries.

Overcoming the North-South conflict and regulative decisions

Ascertaining the desirable minimum level of conservation is a political decision that requires agreement among autonomous states at international level. How difficult it is to achieve this can be seen from the international negotiations that have already taken place in this field up to now. Preventing blockades by certain states or players is one of the largest problems in global biosphere policy. To that extent it is therefore important for institutional rules or arrangements to be found that serve to overcome the interest and distribution conflicts that exist. If one enquires as to the specific interests pertinent to the North-South conflict the following situation often results for certain countries with high biological diversity: subsistence farming exists alongside large landowners who generally enjoy political backing and often have a short-term oriented interest in the profitable use or transformation of semi-natural areas. This is in part a result of an unstable political environment and inflationary processes. These circumstances invite the short-term exhaustion of profit potentials. Furthermore, as a rule a nationalist prestige mentality kicks in that is inclined to balk against international dictates or what are called the 'interests of multinational companies' which are subject to greater public scrutiny than the large domestic companies. This often leads to what is from an environmental point of view problematic homogenization of the policy interests with the interests of domestic, often government-owned large industry or the preferences of large landowners. In combination with political corruption, graft and nepotism there is then an overexploitation of biological resources that are often not covered by existing environmental law. Educational deficits make it more difficult at the same time for public monitoring, central information is even sometimes suppressed. At international negotiations therefore as a rule there is a hardening of positions of interest and partial coalition forming among countries with similar interests. But also countries on the demand side of biodiversity have specific interests that do not always serve the conservation of biological diversity. Not just that they call for access to biological resources to enhance their companies' competitiveness, but the accusation of what is termed 'eco-dumping' also offers a welcome opportunity to assert protectionist objectives, particularly in the area of agriculture. This exacerbates the international conflicts of interest since agricultural exports of developing countries are blocked.

The Convention on the International Trade in Endangered Species of Endangered Fauna and Flora (CITES), given this structure of interests, proves not to be sufficiently effective (Section D 3.1). The Biodiversity Convention, by contrast, aims to strengthen private initiative by promoting international trade with availability and usage rights for biological resources. Policy failure in the designation of protected areas, the allocation of property and usage rights serving to stabilize power, the insufficient implementation of existing environmental provisions, lack of monitoring and the one-sided orientation of the goals to specific interest groups do not allow what are essentially positive incentives within the CBD to come to the fore (Becker-Soest, 1998b).

Under these conditions therefore all efforts must be made to improve the educational and training structures in the countries of origin (and these are generally developing countries) and to build up a research landscape of their own in these places that will focus on that country's own biological resources. Above all, it must be profitable for the countries of origin of biological diversity to expand their knowledge about threats to and evaluation of biological diversity and to realize these in economic terms. This requires that exclusive property rights to biological resources and semi-natural areas to be transferred at the individual or at least local level with provision for purchase and resale. This must be supported by the international adjustment and adoption of liability, patent and contractual rules (Becker-Soest, 1998a, b).

Mobilizing willingness to pay and voluntary commitment on the part of important players

One possibility of strengthening the economic importance of maintaining biological diversity consists in arousing in the industrialized nations interest on the part of conservation-conscious 'buyers' and bring influence to bear on the supply countries via the purchasing chain, that has become so powerful. If it were possible to cause these trading entities through voluntary commitments to increase the monitoring of conditions of use of biological resources in the supply countries, economic adjustment would be triggered that could serve the interests of conservation and sustainable use. This however requires that the products to be labelled appropriately (labelling strategies) with information not only about the benefits of use, but emphasis on features that inform about production methods. In this way, the willingness to pay of the end customer in combination with an information policy pursued by the industry or rather its suppliers serves as an important economic implementation level for the conservation of biological diversity in developing countries.

Harnessing global networking trends

In the light of the divergent starting positions, international agreements on concrete protective measures in favour of biodiversity can only be achieved in lengthy rounds of negotiations. Against that background the incorporation of national conservation strategies into worldwide marketing campaigns, for example by multinational food, tourism or pharmaceutical companies, offers the opportunity of illustrating the direct economic significance of biological resources and increases the incentives to join in the cause (Suchanek, 1998; Klemmer and Wink, 1998). The pressure of competition and the prospect of competitive advantages also trigger incentives to develop new methods to implement conservation and use concepts for biodiversity and thus overcome conflicts between social safeguards, economic success and biodiversity conservation.

Enforcement of environmental agreements internationally continues to be a problem that has not been resolved to a satisfactory degree. It hinges to a high degree on national incentives for environmental protection. Particularly in the area of worldwide biodiversity, these incentives are lower in developing countries since the advantages generally concentrate on the Western user countries, whereas the burdens are borne on the ground. In the context of a functioning labelling strategy it is in the interests of the producers to prove that the standards are being respected (Gerecke, 1998). Multinational companies in particular see themselves in this regard compelled by media pressure to disclose the risks and consequences of their production procedures for environmental and social standards. The producers' vested interests therefore take the place of government control/monitoring. Fraud is therefore easier to uncover.

The call for worldwide harmonization of ecological standards generally ignores the differing spatial dimension of environmental burdens. 'Eco-dumping', as it is called, has not taken place if the burden is limited exclusively to the regulating country since, in those cases, the autonomous decision taken between level of use and level of conservation in that country must be accepted. No one can presume to be 'imposing' anything on the citizens of that place (Karl and Ranné, 1997; Bender, 1998). Even given the worldwide environmental changes the interests in conserving biological diversity varies from country to country. The introduction of homogeneous standards runs the risk of developing one-size-fits-all solutions that do not leave those concerned the opportunity to give expression to their own preferences. In that context, competition of differing standards allows for a graduation of the various levels of conservation that result as a reaction to market-forming process – and thus the expressed will of the customer (citizen). Of course, this hinges on the form of use truly reflecting the preferences of the population and not just those of a small upper class.

In the following sections the instruments and strategies will be described that play an important part in the integrated biosphere policy outlined here. Section I 2.2 describes the legal control approach as expressed in international agreements. Section I 2.3 is dedicated to cooperative solutions to which governments and private players can aspire. The motivational approaches, particularly in combination with economic incentives, are the focus of Section I 2.4, and then in Section I 2.5 the opportunities for environmental education and information are presented and analysed.

I 2.2
Approaches under international law

I 2.2.1
Instruments of regulation under national law

National environmental law has various regulatory instruments for achieving desired environmentally friendly behaviour: product bans (applying to production and use), technical standards, direct and indirect taxation and levies, tradeable permits (eg in the United States), subsidies, etc. Another acknowledged distinction divides direct and indirect regulation, supplemented through informal administrative action, in particular self-commitment agreements (Schuppert, 1998). Direct behaviour control is characterized by the fact that it prescribes a particular type of behaviour to the target population and enforces adherence where necessary with the use of sanctions. Indirect behavioural steering by contrast attempts to bring influence to bear on the motivation of the target population via intended selective profit and loss effects. Behaviour that runs counter to the concern motivating the regulation may be undesirable, but is still classified as legal. Informal administrative action in the form of normative agreements is found above all in the self-commitment agreements with industry. This is where industry declares – in a legally non-binding fashion – that it is prepared to act in a particular way, and with the administration or legislature waives any formal action (government-directed cooperation); Kloepfer, 1998).

I 2.2.2
Direct behavioural regulation as a control instrument in international law

I 2.2.2.1
The absence of enforcement agencies under international environmental law

The typical characteristic of direct behavioural control, guaranteed enforcement by a sovereign body vis-à-vis the addressee, leaves very little room for use of this instrument at international level. At most there is the United Nations Security Council that can under certain circumstances (to preserve international peace and security, Art. 1 United Nations Charter in combination with Art. 39 and Chapter VII of the United Nations Charter) make decisions that are binding under international law and deploy mechanisms of enforcement as required. The German Advisory Council on Global Change has already taken up a position on the question of whether the competence title accorded the United Nations Security Council up to this point is sufficient to be able to include the United Nations Security Council in overcoming ecological crises (WBGU, 2000a). It has been suggested that the competence base of these measures should be extended to apply to environment-related security issues (Bilderbeek, 1992). However, in this discussion one should realize that the structure of the Security Council, through the right of veto, gives the five permanent members a preferential, ultimately unsanctionable status. In the German Advisory Council's view it is doubtful whether an international environmental regime should be established on that basis.

I 2.2.2.2
The absence of central decision-making bodies under international environmental law

Another question is whether, and to what extent, new centralized decision-making bodies should be created under international environmental protection. In the Hague Declaration of 11 March 1989 there are the first indications in that direction (Beyerlin and Marauhn, 1997), and in the run-up to the Rio Summit there were actual calls for the creation of an environmental legislative body, an environmental security council and an environmental court under the auspices of the United Nations (Bilderbeek, 1992). These ideas have not been realized. Still, contracting parties shy away from entrusting decision-making powers to an institution that, although they themselves have created, would subsequently be independent and thus they would be letting the future workings of the treaty out of their hands (Beyerlin and Marauhn, 1997). Essentially, under environmental law, in addition to the conclusion of a treaty the consent of all states is required for any change or expansion of that treaty. An exception to this 'sovereignty-friendly approach' is the Montreal Protocol, the norms of which can be amended with a two-thirds majority when consensus is not achievable and the amendment is legally binding *on all parties* (Art. 2 para 9 c-d; Palmer, 1992; Beyerlin and Marauhn, 1997). Therefore, an obligation under international law can to that extent be imposed on a contracting party *against its will*. Although in Art. 29 para 3 of the CBD there is also a simplified contractual amendment procedure, any amendment in that instance that is not agreed unanimously requires ratification by the contracting states in order to become effective under international law.

I 2.2.2.3
Direct behavioural control as an implementation standard in treaties under international law

National control instruments are also important in terms of agreements at international level. Because only very few provisions in environmental agreements under international law are *self-executing norms,* ie directly applicable (once they have become part of the country's legal ordinances), it is the task of national instruments to implement international agreements effectively into national law. Often, it is clear directly from the international agreements which instruments are relevant for national implementation: often the regulatory goals can only be realized through direct behavioural control norms.

There are however by way of exception also agreements that contain environmental bans on government action under international law but where the addressee of the norm remains the state (eg treaties to limit nuclear weapons testing). Often, countries are subject to prescriptive measures regarding certain types of environmental action that typically are only assumed by state agencies. This would include, for example, the obligation to cooperate on environmental questions, the obligation of states to exchange information in accordance with Art. 19 IV of the CBD or the obligation to establish conservation zones on their national territory.

As a rule, however, norms under international law ultimately relate to the environmentally relevant actions of non-governmental entities, whether it be private companies or households. The state has to approve these activities by way of prevention or monitor them repressively. Arrangements in the form of a complete ban are intended to ensure for instance that marine pollution through radioactive waste (Art. 25 of the Convention on the High Seas) or environmental damage through drilling in the continental shelf (Art. 5 VII of the Convention on the Continental Shelf) do not occur. In the same way states are not just obliged to establish nature conservation zones, but also to ensure that certain actions are restricted or banned within those territories. One of the oldest instruments of international environmental law are the national fishing quotas that obligate states to exploit certain resources only in certain quantities. When limiting international trade in protected species under CITES states have to ensure that the trade into and out of their territory is stopped by means of enforcement measures, that include punishments or penalties.

I 2.2.2.4
Mechanisms to guarantee treaty compliance

To what extent obligations under international law can truly be implemented is in the hands of the signatory states. The attempt to motivate these states to actually fulfil the obligation they have made takes place at two levels. At the first level there is an attempt through various monitoring measures to ascertain the degree of implementation that has occurred and at the next level to reduce the shortcomings in implementation by measures of sanction or support.

Monitoring

There are agreements under environmental law in which states are obliged at regular intervals to provide a report to the responsible secretariat on the progress of implementation. Here, therefore, it is truly in the hands of each state to point out difficulties emerging and deficits.

In the case of inspection, the Secretariat may be justified in monitoring the implementation process and if necessary in conducting unscheduled checks. This type of measure has so far been largely impossible to enforce in the context of environmental agreements since they do allow inspectors to perform checks within the national sovereignty of a state.

Compliance

If states have ratified an agreement under international law, they are under an obligation to transpose the international provisions effectively into national law. General international law has various options for responding to breach of treaty. Measures of retortion and retaliation are recognized under customary international law. These headings include measures that one state would adopt vis-à-vis another state in order to force the other state to rectify a certain situation. A deadline is often given in this context. Whereas retortion is a measure that is allowed under international law (breaking off diplomatic relations), retaliation is the venging of one injustice by means of another in order to move the state to reverse a wrong under international law for which it is responsible. More and more often multilateral agreements however contain more specialized – and therefore, primary – regulatory mechanisms in order to guarantee that states remain faithful to a given treaty. Particularly in international commercial law sanctions are an important instrument for achieving contractual fidelity; they are applied less frequently in environmental law (eg the threat of trade sanctions against China and Italy on the grounds of violation of CITES provisions). In the context of environmental law it is more common for 'soft' sanctions to be applied that essentially represent the withdrawal of certain accorded privileges (Wolfrum, 1999). Hence, in the World Heritage Convention (WHC) and the Montreal Protocol certain states are accorded a special status that allows them access to monies from an associated fund. In the case of a violation against certain provisions, these privileges can be withdrawn.

Another way of guaranteeing adherence to internationally agreed environmental standards is through a liability regime. Environmental damage outside one's own national territory that is caused by a lack of compliance with a treaty must be borne by the polluting state. There are two limitations to that sort of system, however: global ecological damage is very difficult to quantify and rarely can it be attributed to a specific state. In light of the inherent limitations of a liability regime, it is difficult to deploy this instrument beyond the scope of certain well defined and precisely attributable cases.

Limits to sanctions

Whether sanctions are the appropriate response to treaty infringements and failure to implement a treaty really hinges on the causes of non-compliance. A lack of fidelity to the treaty can as a rule be traced back to one of the following factors (Bothe, 1996): lack of will, lack of care or lack of capacity. Deficits in implementation may also be based on the fact that the state felt it necessary to sign the treaty for foreign policy purposes but had never had the intention of providing effective implementation, other than through token measures. Furthermore, a state might erroneously assume from carelessness that an international obligation is already covered by existing laws. And finally, a state may create laws that respond to the spirit of the agreement but may not be in a position to enforce those laws.

Sanctions as a mechanism for guaranteeing treaty compliance are at most appropriate in the first two cases, but cease to be appropriate if the will to implement is present, but the means of implementing are limited as a result of a lack of technical know-how or economic reasons. The modern environmental agreements therefore are increasingly drawing on indirect control by raising public awareness, motivation and support. Examples of these types of measures include technical support, training programmes and financial assistance.

I 2.3
Approaches for positive regulations

I 2.3.1
Negative versus positive international regulations

Research on international regimes makes the distinction between *negative* and *positive* international regulations (Scharpf, 1996; Zürn 1997, 1998b). Negative regulations serve to create new behavioural links between states across borders in the social and economic spheres in order to counteract protectionist policy initiatives, ie joint rules are established that limit or completely suppress certain national policy actions.

By contrast, in the context of positive regulations, states design and formulate together the content and programmes of policy, for instance for the protection of the environment. As opposed to reliance on the desired impact of the market in the case of negative regulations, the issue here is one of implementing collective goals that are not achievable purely by means of market forces. In developing positive regulations for the conservation of the global biosphere international players such as governments, NGOs and multinational companies all agree on certain policy content according to which they would restrict certain environmentally damaging actions in such a way as to be able to achieve the target of conservation, sustainable use and benefit-sharing for the preservation of the global biosphere.

In more recent studies on international environmental policy that underline positive regulations covering the issues concerned, three international environmental regimes are repeatedly cited as positive and effective examples (Zürn, 1997, 1998a, b): the acid rain regime that combats cross-border air pollution; the ozone protection regime that was created to protect the ozone layer; the oil tanker regime that is intended to reduce intentional oil pollution of the seas. Research into international environmental protection cooperation has shown that four prerequisites were required for lasting and effective positive regulations to emerge. These conditions may serve as a pattern for achieving positive regulations for the conservation of the global biosphere.

I 2.3.2
Prerequisites for positive regulations and incentives

Haas et al (1993) developed in more detail a concept for successful international environmental protection as a result of several case studies (protection of the ozone layer, acid rain regime, protection of North Sea and Baltic Sea, oil pollution of the oceans and international fishing). International cooperation for the conservation of the global biosphere can live up to the challenges of positive regulations if it demonstrates the institutional features of what is termed C-4 design (Levy et al, 1993; Zürn, 1997, 1998a). An environment conducive to cooperation is created, violations are handled flexibly, weaker government are supported in capacity building in order to be able to achieve the goals set and in the case of stragglers, interest in international environmental protection should be aroused and the positions of states that support such regulations reinforced.

Environment conducive to cooperation (contractual environment)

When the players' aim is to achieve international cooperation on environmental protection, existing international regimes can improve the environment since for example forums for negotiations and points of linkage to certain regulations present themselves. For instance, negotiations on international nature conservation and topics relating to that are conducted under the auspices of UNEP. The model of sustainable development introduced at UNCED is being transferred in its wake to the problem of preserving biological diversity and thus leading to the concept of conservation through use or conservation despite use.

Norms and regulations agreed in common by the players create expectations of behaviour that motivate positive regulations and stabilize existing ones. Through monitoring and verification services, information on compliance with regulations can be provided to reinforce behavioural expectations. Institutions also provide forums in which information may be exchanged and communications processes upheld, thus allowing transaction costs to be lowered. In situations in which a dilemma would be expected from a game theory perspective in the configuration of national interests, a contractual institutional environment is of considerable importance.

If states violate regulations, there is a problem in terms of compliance with the behavioural expectations. In such cases reliable information and reduced transaction costs are particularly relevant for communication. If the institutional environment were missing there would be an escalation. But if the environment is transparent as a result of being truly anchored in an institutional setting a communicative process can emerge in which the participants agree on the content of, and adherence to, norms and regulations. For example, there is a controversial discussion on the ecosystem approach that is being negotiated as a new implementation strategy for the comprehensive protective claim to species diversity, ecosystem diversity and genetic variability. It is taking place in the existing environment of the Biodiversity Convention (Section I 3).

International agreements and their institutional environment that cover certain aspects of the conservation of the global biosphere exist for various issue areas and in various forms (Sections D 3.2 and I 3).

Flexible compliance management

Since sanctions, the formal identification of violations and court decisions are more the exception than the rule under international law, 'soft' reactions such as reporting procedures and negotiations are much more relevant. International law suffers from the lack of enforcement bodies and is essentially dependent on 'soft' mechanisms.

If players in international environmental problems show significant interest in joint problem solving it is not essential to monitor for violations of the regulations for that cooperation to go ahead. Initially, the players agree on new political measures out of their own interest in order to achieve goals that appear to be worthy and desirable to all, such as the regimes to protect the North Sea and the Baltic Sea demonstrate. Their interest in violating the regulations is low in those circumstances and hence 'soft' forms of verification are sufficient. Examples of soft measures might be the national reports that Parties to the Biodiversity Convention have to present at the Conference of the Parties. In addition, there and in other newer environmental treaties under international law a variety of dispute-settlement mechanisms are generally provided, eg negotiations, mediation or arbitration procedures. Court-like, binding dispute mechanisms are rarely used by states (Beyerlin and Marauhn, 1997). For this reason it makes sense to involve elements within the agreements which raise the interest of each partner in implementing the agreement.

When nevertheless regulations are violated, a flexible handling of violations may be considered that makes other forms of achieving compliance and adaptive behaviour more sensible. For instance, a format of understanding-oriented discourse (Box I 2.3-1) in which communicative action (WBGU, 1998a) is the focus is very promising. The potential for violation should be restricted from the outset by giving space and opportunity on a regular basis for discussion and agreement on both general and specific problems of compliance (Zürn, 1997). The COP under the auspices of the Biodiversity Convention could provide just that sort of forum for an understanding-oriented discourse. Another strategy to achieve compliance is to deploy positive incentives in the form of additional development cooperation or monies from international funds.

The Council therefore recommends overall that violations be handled in a flexible manner, with the participating players being given space and opportunity in an understanding-oriented discourse to communicate with one another on problems in compliance and behavioural adjustments. Regular conferences are appropriate for this purpose. The flexible management of compliance should be supported by appropriate monitoring.

National capacity building

In order to be in a position to solve global environmental problems, in many countries – particularly in developing countries and the new Eastern European democracies – cognitive, administrative, institutional and financial capacities must first be improved because the available resources and capacities are not sufficient. Although the capacities in OECD states are in general very solid, that does not mean automatically that the specific conditions for the relatively new policy area of preserving and protecting biological diversity are already covered (OECD, 1998).

International institutions can often draw on intergovernmental or inter-organizational networks or have their own mechanisms by which technology and management transfers may be realized. Training programmes, provision of policy-relevant information and research support can help the governments of developing countries and the new Eastern European democracies to create and implement stronger programmes for the conservation of the biosphere. Often, it is national experts from the OECD states working under the auspices of the international institutions who man that sort of programme. In many cases these programmes help to improve the capacities of countries in order for them to be able to implement even more effective measures ('help towards self-help'). In order to achieve fair burden-sharing

Box I 2.3-1

Rules for achieving understanding in discussions

Understanding-oriented conditions for discourse are based on the theory of communicative rationality (Habermas, 1971, 1981, 1992; WBGU, 1998a). Communicative action is action that aims to convince others by argument. A discourse in which a symmetrical exchange of information takes place fulfils the requirements of communicative action if all participants have the same rights and obligations and – voluntarily or under verifiable rules – refrain from strategic behaviour patterns.

The ideal of the discourse is based on the assumption that with the help of communication an agreement between opposing interests and value conflicts of the various parties can be achieved, without a party being excluded or their interests or value being left unconsidered. The point of such a discourse is to evaluate the options for collective decision-making according to their desirability.

On the basis of the theory of communicative action and the practical experience with negotiations and participatory procedures, procedural rules can be derived that can prove helpful in understanding-oriented discourses for the protection of the global biosphere (Habermas, 1981; Bacow and Wheeler, 1984; Barber, 1984; Kemp, 1985; Amy, 1987; Burns and Überhorst, 1988; Haller, 1990; Fiorino, 1990; Fietkau, 1991; Renn, 1991; Karger and Wiedemann, 1994a; Oppermann and Renn, 1995).

- A clear *mandate* for the parties to the discourse is required so that it is clear to all participants what task has been entrusted to them as delegates and what scope for action they possess. Any decision is always bound into a context that is predetermined by previous decisions. It is therefore important prior to commencing the discourse to clarify in detail to what extent previous decisions can still be revised and what scope for action there is within the mandate for convincing by a better argument. All persons participating must know the limits of the mandate precisely, and also actively agree to those limits, if they wish to participate in the discourse.
- Preparation and implementation of a discourse call for lengthy *time periods*, therefore international negotiations on the protection of the biosphere should take place without undue time pressure. At the same time, however, the community of nations and national political systems often push for quick decisions. Often the implementation of such quick decisions is then delayed for much longer time periods as a result of protest and resistance from the impacted population than would have been the case with a slower decision-making process incorporating a discourse (Kasperson, 1986).
- In order to be able to pursue an *understanding-oriented approach* within a discourse and not to lapse back into strategic behavioural patterns, it is necessary to discuss the rules of communicative discussion from the outset with all participants and to adopt these by consensus. This empowers those leading the negotiations to ensure compliance with rules that have been accepted by all.
- The result of the discourse must demonstrate openness by the fact that none of the parties should try to 'sell' their pre-formulated decision to the other parties. No one is demanding that parties have to be ready to change their opinion or attitude on certain questions on the basis of communication (although the readiness to do so is certainly helpful), but all parties must declare their readiness to relinquish their preferred option in favour of another option if this comes out as better than all other options in the context of statements and balancing of interests and values among all participating parties. Every party must therefore always be willing to relinquish its own preference for a particular option.
- All parties participating in the discourse have the *same rights and responsibilities*, which is implicit in the tenet of fairness. Outside the discourse, of course, there are hierarchical relationships and differing responsibilities, competences and power relationships. The discourse cannot dissolve these predetermined structures. Its own power, ie the binding power of the results arrived at, will have to adjust to the legal and political reality. The discourse itself however is tied to the internal rule of strict equality. No party, however powerful in the political reality, can claim privileges or special rights in the discourse.
- Discourses are dependent on the *relevant knowledge* that is available at the time of the deliberations with regard to the consequences and secondary consequences of the options under discussion being available to all participants. Organizational preparation must be made to incorporate and integrate necessary expert knowledge into the process of the discourse.
- All parties must bring to the process a readiness to learn. The participants should be prepared to learn from the lines of argument and evidence brought by other parties and, as required, rethink their position. That does not mean that individual parties must just give up their individual preferences, interests or values, but just that they should be ready to correct the linkages between options and values they have made in the light of new findings. This also applies to mutual recognition of knowledge. It is only when all parties acknowledge the argumentative approach of the other parties and seek to understand that a fruitful dialogue will be possible (Haller, 1990).
- All parties participating in a discourse should agree from the outset to refrain from passing moral judgement on positions. This relinquishment of all moralizing does not mean that arguments may not be classified according to moral categories or that ethical arguments must be banned from the discourse. On the contrary, without an ethical evaluation of options, an important component of the evaluation would be missing. It is indeed a feature of an understanding-oriented discourse to establish generally binding criteria for the purpose of positing moral norms. These norms may not however be attached to persons or institutions, but rather behaviours. What should be avoided is passing moral judgement on parties or their positions during the discourse.
- In the context of discourses it is important that delegates provide *feedback to their reference groups regarding the results achieved* in each stage of the negotiations. If one waits until the final result then approval from the various groups is rarely achieved because the other group members have not been party to the process of consensus building and can therefore no longer understand the solution that has been achieved step by step. An explicit feedback of all partial results makes it possible for groups to give their vote for and against each step and to call for renegotiation or new aspects. This feedback helps the delegates to establish the consensus on a broader basis. In the same way, it is necessary for the public not participating in the discourse to inform themselves about the process and the various results achieved. The credibility of the result of such a process is largely tied to the transparency of the process itself.

under international environmental protection cooperation, regulations are required according to which the obligations on participating countries are proportional to their capacities, in other words the performance capacity of the political systems and economies is taken into account.

Since international environmental institutions often have small secretariats and few capacities, they have to develop and build up networks with other international institutions and related programmes, for instance, with the World Bank, UNDP and various regional development banks. That sort of inter-organizational coalition and network can be a considerable help in promoting the performance of weaker states. And, for instance, the Global Environment Facility (GEF) functions as a financing mechanism for the Biodiversity Convention with UNDP, UNEP and the World Bank as 'parent organizations'.

Arousing interest (concern building)

In many cases of international environmental protection the players are certainly motivated to solve environmental problems. They are often, however, not in a position to do this alone since there are cross-border environmental problems and risks that can only be solved together with other players, this is particularly true of global biosphere conservation. If however other players do not share the concern then it cannot necessarily be expected that international institutions will be able to introduce effective regulations. Institutions and states are not then powerless, however. There are several ways in which the interest of states can be raised or promoted.

In order to encourage these states to collaborate on effective international conservation and sustainable use of the global biosphere, their concerns and interests must not be ignored, rather they must be included on the international agenda. This can be facilitated by open agenda-setting procedures in international institutions so that states are in a position to bring their problems up for discussion on the international agenda and thus lend more weight to the issues.

Even if stragglers show only limited interest in solving the global biosphere conservation issue, linking a number of problems together can enhance that interest. If the environmental problem is linked to other concerns or interests then the stragglers usually rethink their disinclination. This type of approach promises results if linked to incentives such as financial assistance, technology transfer or trade restrictions. A promising approach in this regard is the Biodiversity Convention: economic incentives are planned, ie industrialized countries intend to step up their technology and finance transfers to developing countries. In exchange, the biodiversity-rich developing countries agree to increased nature conservation and species conservation measures (Section I 3). The Biodiversity Convention thus links the goal of use of biological diversity with benefit-sharing, so that developing countries otherwise less interested in cooperation receive something in return for making sustainable use of their biological diversity.

Institutions can increase international public pressure by driving competition among governments to be stronger advocates for the environment, because obligations to positive regulations contribute to creating an international reputation and image gains. Institutions play a key role in that regard. International institutions are almost always reserved in their criticism of governments, NGOs are not subject to such constraints. So they play an important and active role by criticizing governments, national policies and multinational companies. The information they use for such purposes is often gleaned from attending formal international meetings.

Research into environmental regimes has shown that the interest in international environmental policy among less motivated states and straggling countries can be aroused and strengthened. An international network of international institutions, government, NGOs, mass media and multinational companies can exert public pressure over the players, but also raise interest and understanding for positive regulations. In this context, triggering societal learning processes within states, governments and multinational companies is a crucial factor within a global biosphere policy. These learning processes touch inner-societal interest configurations and national regulations that influence one another and so ultimately an adaptation of behaviour to comply with the positive regulations does occur.

I 2.3.3
Conclusions for the conservation and use of the biosphere

Conservation of the global biosphere is a comprehensive and complex task that can only be sufficiently and effectively solved if the above-mentioned conditions of positive regulations are fulfilled, or at least envisaged as a goal, and the guard rails for the preservation of the biosphere are respected. In summary one can state that (Levy et al, 1993) a contractual environment, flexible handling of compliance, building national capacities, learning processes and growing interest parallel to ongoing activities all influence one another in a reciprocal and synergistic relationship. Positive regulations relating to the global biosphere conservation that are intended to work long-term and effectively require comprehensive strategies that take into account these reciprocal impacts and work in a dynamic process at various levels (international, national and societal). Positive regulations that are anchored in that way then generate creative solutions for global environmental protection and provide a long-term basis if the substantive form of the regulations takes into account the guard rails for the preservation of the biosphere (Section I 1). To this end three basic forms of areas should be considered particularly effective in which positive regulations of the conservation of the biosphere should be effective. These three forms result from translation of the guard rail concept into designation of the 'N', 'M' and 'E' areas (Sections E 3.3.1 and I 1). The MAB programme of UNESCO adopts a similar approach (Section I 3.3.2).

Areas with absolute priority of conservation over use

Certain areas with unique biological diversity or high scientific or aesthetic value are considered 'world natural heritage' sites (conservation type 'N', cf Section E 3.3.1). In these areas the conservation of the biosphere is given absolute and unlimited priority over the use of nature. As early as 1972 under the auspices of UNESCO an agreement under international law called the Convention for the Protection of the World Cultural and Natural Heritage was concluded (WBGU, 1998a). This agreement obliges its members states to place certain areas defined as 'world natural heritage' under particular protection (Section I 3.3.1). In the context of this agreement under international law the parties can seek the support of the international community if they cannot implement sufficiently the requisite protective measures. To this end the World Heritage Fund was set up to provide support to developing countries.

UNESCO therefore offers a suitable institutional and contractual environment with more and more countries declaring their readiness voluntarily to take upon themselves self-limitations in order to designate areas that they could use commercially and thus damage as world natural heritage sites and so give priority to the conservation of the biosphere. They receive the motivation to take this step first of all from the fact that the institutional and contractual framework UNESCO provides with regard to the conservation of the world natural heritage sites creates unanimous behavioural expectations among the participants. In addition to the transfer of financing, scientific and technological advice and assistance can help set up national programmes to implement the world natural heritage convention. Since these funds are often too weakly endowed because they are based on member contributions, increased inclusion of interorganizational networks and linkage with other financing mechanisms such as the GEF would make sense. The contribution commitments from states to the Fund should guarantee fair burden-sharing, ie the member states should be obligated in proportion to their economic capacities. With economic incentives, and financial or technological support through the Fund, hitherto disinclined states can be motivated. One fact is obvious, the greater the economic incentive, the greater is the readiness to preserve world natural heritage sites. The recommendations of the Council regarding financing of preservation measures in Section I 3.3.1 (world heritage), I 3.5.3.2 (GEF) and I 3.5.2 (biosphere fund) should be seen in that context.

Areas governed by the maxim 'conservation through sustainable use'

By contrast to the world natural heritage sites, where the conservation of the biosphere enjoys absolute priority, here we are talking about areas in which the biosphere is to be protected but at the same time may also be used, only if the use is extensive-sustainable (conservation type 'M', Section E 3.3.1). The aim in these territories is to preserve the diversity of the biosphere for future generations. After UNCED a model emerged for sustainable development that was translated into the term 'conservation and sustainable use of biological diversity' in the Biodiversity Convention.

The endeavours to link use of biological diversity with benefit-sharing measures are to be seen as a positive development since in this way the interest of the developing countries, often rich in biodiversity, will be aroused. The motivation of these states to commit to sustainable use of the biosphere and to act in an environmentally friendly manner increases if financial and technology transfer brings with it economic advantages. These countries are then in a position to develop their own economic capacities and thus contribute to enhancing their economic productivity. This positive approach within the Biodiversity Convention to raise interest in the conservation and sustainable use of biological diversity by benefit-sharing with the developing countries should be transferred to other problems of biosphere conservation.

Intensive use areas with as high a level of conservation as possible

Compared to the two areas defined above, these are areas that are already being used intensively today and thus have already been transformed to a significant degree (conservation type 'E', Section E 3.3.1). Despite intensive use, here too, the model of sustainable use should be the point of orientation. The options for improvement relate above all to international cooperation in the context of the UNCED follow-up process, the GEF, UNEP and UNDP (Section I 3).

A contractual environment did emerge in the context of the Agenda 21 process. Behavioural adjustments on the part of players were achieved in the sense that among the OECD states more and more countries have drawn up a national plan for sustainable development. Implementation often leaves a lot to be desired, however. The contractual environment therefore needs to be improved. In order to be able to verify such national sustainability plans a monitoring system is appropriate that manages violations flexibly and also comprises forums in which understanding-oriented discourses on problems in producing and implementing national sustainability plans can be conducted. The transfer of finance and technology is a tried and tested means of arousing interest in sustainable development and at the same time increasing national capacities.

I 2.4
Motivational approaches

A global biosphere policy can build on a comprehensive control or cooperation approach. In both cases, selective economic incentives (such as remunerating of renunciation via tradable permits or subsidies) can and should be applied. Both strategies do justice to the biosphere cause

- if for example the commercial use of animals and plants is regulated, for instance via trade restrictions or the specification of usage provisions for renewable resources, or
- if the habitats of animals or plants are being protected by preserving them from biogeochemical loading that would endanger them and/or by restricting human use fully or in part.

The first route primarily uses legal control, the second draws on planning procedures – often in combination with subsidies for usage renunciation. In that regard, the loss of nation-state control potentials in the context of an ever more globalized economy calls for the development of supra-national regulatory competences (Scharpf, 1997; Petschow, 1998). Global issues may call for global governance (Commission on Global Governance, 1994; Kirchgässner, 1998). These may in accordance with the fiscal principle of equivalence or the principle of subsidiarity also be associations of nations or regions (perhaps in the context of bioregional management, Section E 3.9).

The motivational approach builds on the idea that there may well be an individual willingness to pay for many concerns within biosphere policy and that this readiness can be mobilized. This approach is not a policy of selective economic incentives – whether via government financing funds, awarding subsidies, guarantees, etc. Rather what is meant is the creation of motivational requirements for the establishment of diverse and 'spontaneous' solution concepts on a government and private basis. What is sought is institutional diversity that is not the expression of conscious state intervention for the pursuit of an internationally coordinated model, but rather the result of individual, local or regional protective ideas. This has various consequences.

Globalization and biological diversity

This calls, for example, for a re-evaluation of the globalization process. The expansion of world trade and production networks is time and again, almost as if it were the latest fashion, seen as the trigger for increasing threats to global biological diversity and the call goes out for political action to correct globalizing markets. Need for action is seen above all in the further development of the GATT/WTO regime with regard to adapting to international environmental protection agreements and harmonization of national environmental standards (Section D 3.1). Competition and globalization are often in this context seen as the primary threat to the conservation of biological diversity. Many authors are of the opinion that without international harmonization of ecological standards, ie without control, a race-to-the-bottom will begin with the danger that the threat to the biosphere will go unchecked (Oates and Schwab, 1988; Revesz, 1994; Markusen et al, 1995).

This is a one-sided view. It must be juxtaposed for example by economic research results that see the globalization process not just as an ecological risk but as an opportunity of achieving effective and acceptable environmental protection measures through the competition of national institutional systems (Streit, 1995; Karl, 1998; Becker-Soest, 1998b). Thus, actually a race-to-the-top is also conceivable that under certain conditions could contribute to the conservation and sustainable use of the biosphere. The Council therefore considers it necessary to approach the question of the impact of the globalization process on the biosphere in a differentiated manner and to warn against generalized judgments. In particular, in the context of global biosphere policy, the Council underlines the idea of institutional diversity and system competition. This opens up new opportunities for the conservation of the biosphere.

Supplemental benefit of adhering to standards and conditions

The fundamental idea behind system competition on the basis of the motivational approach is that adhering to protective conditions or certain, not necessarily political, standards proves in the context of preserving biological diversity not just to be a cost factor for producers but may also be seen as supplemental benefit. This supplemental benefit can be marketed for a profit and is able to grow environmental-innovative processes. These standards compete as product or site features with other products or sites with differing standards. Competition therefore is not just between products, but also between standards.

These do not at all have to be set by the government, but may by analogy to many ISO norms be formed 'spontaneously'. Consumers or those searching for sites decide at the point of purchase to also accept standards (Wegner, 1998, on the potential of labelling strategies in the context of environmental protection also IWÖ and IFOK, 1998; Karl and Orwat, 1998). Producers who are not subject to such standards, place themselves in danger of having to be sanctioned by global competition and accept economic disadvantages. If there is the additional risk of having to adjust to legal standards anyway in the long term, the incentive increases to market these measures in advance of that time as voluntary, bring new standards into play at the global level as elements of competition and thus trigger an ecological dynamic within free markets (Knill, 1998). It is not therefore primarily about following a command-and-control strategy to prevent poor countries from drawing rich and environmentally sensitive countries down to their level but the reverse, bringing mechanisms into play that cause all countries to adjust to more demanding standards (Vogel, 1997).

To the extent to which a private willingness to pay for the conservation and sustainable use of the biosphere can be built up and mobilized, standards and norms, expressed in economic terms, serve to reduce transaction costs. By reducing the transaction risk and increasing the confidence in product and procedural quality, voluntary standards improve the comparability of products in environmental terms and thus enhance quality competition. Currently, for example, in the European context in this respect two standards are significant: ISO 14000f and the EU Eco-Management and Audit Scheme (EMAS – EU Regulation No. 1836/93) (Petschow, 1998). Both provide key information on the removal of information asymmetries and uncertainties between sellers and buyers and can therefore be the basis for product and site-related environmental policy. They facilitate benchmarking in relation to sites and products that allows customers and the public in general to assess the environmental protection being practised in the case of a given product or site.

Certification (eco-labelling)

A good example in this regard is the Forest Stewardship Council (FSC) founded in 1993 by representatives of the timber industry, environmental associations – for instance the World Wide Fund for Nature (WWF) was one of the initiators – and indigenous communities that, since 1996, has been present in the market with a seal that has been used to mark worldwide approx 13 million hectares of forest already (Box E 3.3-8). This certification is based on ten principles of sustainable forestry. These are 'spontaneously' defined quality features that aim to draw on a certain willingness to pay for environmental protection. Now that FSC timber has conquered the German market because companies such as Otto-Versand (mail-order) or OBI Baumärkte (DIY stores) are concentrating on such products, the seal has turned into a trade mark that is interesting from a biosphere conservation perspective. It does not have to remain the only standard. For instance, the *Arbeitsgemeinschaft deutscher Waldbesitzerverbände* (AGDW) [Association of German Forest Owners' Federations] is already thinking of establishing a system of certification of its own in the context of a pan-European initiative for sustainable forestry, in other words institutional diversity is emerging from the competition in which in the long term better certification systems will come out on top. Similar experiences are already available for the textile/garment and leather/shoe product groups and can be extended to cover other products and sites.

For the eco-label instrument to be able to develop its positive effects in the sense of a greening of purchasing behaviour, and of the patterns of production and nature usage, credibility must be ensured. And here research can, and indeed must, help by developing – also in competition – criteria that can be adopted by the major trade organizations. It is clear that the retail trade above all must accept environmental standards and eco-labelling so that it reflects back on the producers. This feedback is often more effective than asserting protective ideas via government dictate or ban. This often leads to more and more instances of voluntary commitment that can be tested for acceptance by consumers. The motivational approach relies on spontaneous reactions and by mobilizing the willingness to pay and the commercial interconnections among countries this approach helps preserve the biosphere.

Private funds

There are other instruments in the context of this approach. For instance, private sponsors can establish funds that support biosphere conservation. In the case of certain renewable resources the temporal discrepancy between cost and benefit is an important cause of domination by short-term interests (Section I 2.1). Funds could in this situation purchase tradable permits with which the owners of resources are obligated to renounce extraction of stocks or at least couple extraction with certain regulations. The idea here is not government funds weighed down by bureaucracy and financing rules. Private funds mobilize a specific kind of willingness-to-pay and ensure full institutional diversity so that the protective concern can be addressed in a flexible manner.

The positive impact this sort of private fund can have is demonstrated by the foundation system in the United States. Philanthropic foundations, such as Carnegie, Rockefeller or Stanford, were from their very inception intended to relieve the educational burden on the state and establish a kind of 'private society' with a mission for the common good with private backing for school education, libraries or science and research (Hüttl and Semmerl, 1998). In this context a considerable degree of institutional diversity emerged with interesting competitive elements in a field of activity that is highly complex. Similar forces could be allowed to develop for the sake of biosphere policy. For this kind of private initiative to develop and expand the foundation law in Germany would have to be changed and contribution of monies to such foundations made attractive.

Swifter assertion of protective standards

International agreements on concrete measures to protect the biosphere can only be reached in lengthy negotiating rounds given the differing starting points with which they contend. By contrast incorporating national preservation strategies into worldwide marketing campaigns, eg by multinational food, tourism or pharmaceutical companies, increases the option of making clear the direct economic importance of biological resources and thus the incentives to join the cause (Suchanek, 1998; Klemmer and Wink, 1998). The pressure of competition, or rather the prospect of competitive advantages, also triggers incentives to develop new ways of implementing conservation and usage concepts for biological diversity and in this way the lines of conflict between social safety nets, commercial success and preserving biological diversity may be overcome.

Worldwide protection of competition

For private markets to function consumers must be given the opportunity to select and direct the flow of goods. When individual states give breaks or privileges to producers it prevents adherence to the standard of preserving the biosphere from becoming a relevant criterion in the purchasing decision. One-sided limitations on supply or government-induced price hikes distort the consumers' information. Such national privileges are often asserted by strong interest groups with the argument of securing jobs. Worldwide however they lead to a reduction in incentives for investment in the conservation of the biosphere and in the long-term to structural deterioration of the competitiveness of national sites. This kind of protection is what the GATT/WTO system is meant to prevent in the context of international trade. In practice, these efforts come up against a host of barriers. Even within the European Union trade regulations are used as a vehicle for protecting assert able interests (Winkler, 1998). Alternatively, therefore, the concept of system competition relies on private sector regulation of trade flows, in other words regulation via the market and competitive processes. In order to provide consumers with all the relevant information about products, however, there is a particular need to communicate information about the environmental impact in recipient countries. Information and labelling obligations can do a certain amount. Essentially, however, to prevent protectionist measures, a different understanding of the opportunities offered by international economic interconnectedness is required. Foreign direct investment by German companies is an opportunity to open up new markets and in this way secure domestic jobs, create jobs in the investment target countries and thus make clear to the local population the value of their biological resources. Direct investment in the countries of origin of biological diversity therefore promotes the interests that are oriented to preserving the biosphere. By contrast, intervention in competition by protectionist measures endangers not only the conservation of the biosphere but in addition to that also the long-term competitiveness of domestic jobs.

Consumer information

Even if the consumer has often proved him/herself to be more independent and reasonable than well intentioned control measures would lead one to believe, excessive diversity of different information (eg labelling) would actually confuse rather than assist a conscious decision in favour of the conservation of biodiversity. New labels also run the risk of not making it into the range of important suppliers, eg the major retail chains, unless they can count at least one larger multinational company in its circle of cooperating partners. Therefore, informational instruments have an important role to play. The Council sees above all support for the development of independent consumer reports – similar to *Stiftung Warentest* in Germany – and market launches of new labels as areas where policy needs to act. This could prove more effective than exclusive trust in political negotiations.

International agreements will in the light of the global importance of biological diversity continue to play a crucial role in the conservation and sustainable use of biological resources. But the Council calls also for the world not to regard global competitive processes as a danger to the preservation of the biosphere. Especially in an age where national power of enforcement is being devalued, private self-regulating regimes are becoming important. The Council will therefore in a subsequent report take a more detailed position on ways in which such self-regulating mechanisms can be used to promote sustainability in the context of market-economy systems.

I 2.5 Environmental education and environmental learning

I 2.5.1 Introduction

The conservation and sustainable use of the biosphere and its resources is a difficult task for environmental policy and makes it necessary to deploy all available policy instruments intelligently. These instruments include environmental education that is oriented to bringing about long-term changes in attitudes and behaviour. Deployed at all levels of formal and non-formal education, environmental education must provide socialization contexts and learning strategies in order to reflect in a new way the relationship of humankind to its natural resource bases and develop new patterns of action. It must not just focus on the acquisition of knowledge relevant to the environment, but also incorporate all relevant perception, experience and behavioural modalities relevant to the people-environment relationship.

Beyond this narrow framework of school-based and non-school-based primary education, training and further training, however, it is also about achieving new, sustainable lifestyles for all groups in society in their various professional contexts and life situations and thus it is all about (life-long) 'learning'. These processes, which since the 1980s have been termed 'environmental learning', take place in an 'experimenting society' (Fietkau, 1984) in which through information, communication and participation, but also targeted intervention, new forms of living and consuming can be tried out that ultimately guarantee a sustainable and future-viable society of which the sound use of the biosphere is an important element. A concrete approach to environmental learning at town/municipal level will be presented using the example of promoting the decision to buy organic products (I 2.5.5). This goal of sustainable development has gained ever greater weight since the Rio Conference in 1992. The Commission on Sustainable Development (CSD) also points out the need for a comprehensive programme of sustainable environmental education. They emphasize the importance of awareness-raising in a non-school context and the promotion of sustainable lifestyles. Since sustainable development is however far more extensive than 'just' environmentally friendly development, since it must incorporate economic and socio-cultural development too, strictly speaking the terms 'environmental education' and 'environmental learning' have become too narrow and should be replaced by 'education' or 'learning for sustainable development'. If the Council continues to use the old terms in this section it is not just because they are more familiar to most readers but also because for the issue of protecting the biosphere many learning processes on ecological contexts are still necessary in order even to be able to link these to the economic and socio-cultural conditions of social development.

Over the last few years experts have been engaged in a lively discussion on the status and re-direction of environmental education within the education system (eg de Haan et al, 1997; Trommer and Noack, 1997; Beyer, 1998), also in response to stimulus from the German Council of Environmental Advisors (SRU, eg 1994) and WBGU (eg 1994, 1996). The Council welcomes the fact that the current version of the orientation framework of the Bund-Länder Commission already adopted (BLK, 1998) on 'Education for sustainable development' creates the necessary framework for the implementation of educational practices that must now be fulfilled by all of the constituent states (Länder) of Germany. In these guidelines, however, a certain neglect of the social dimension of sustainability in particular cannot be overlooked. Issues such as international development policy must not be allowed to be left unconsidered in the educational system and the necessary interlocking of environmental and development issues must be reflected in any educational practice that follows the model of sustainable development.

In the evaluation study commissioned by the Federal Ministry for Education and Research (BMBF) on 'Environmental education as innovation – assessments and recommendations relating to model experiments and research projects' (de Haan et al, 1997), however, implementation weaknesses were evident that still call for consistent endeavours on the part of all players in the educational system. In particular it may be noted that tuition on the environment and nature has over the course of time increased in scale (number of school hours) and is not just restricted to the 'natural' or 'exact' sciences, but has also become established in a number of social science subjects. Nevertheless, the comprehensive aspects of biological diversity and its functions as discussed in this report hardly play any role in the subject matter taught (Bolscho et al, 1994; Mayer, 1995; de Haan et al, 1997; Lob, 1997).

I 2.5.2
Environmental education and biosphere conservation

In all conventions related to the environment and climate thus far attention has been drawn to the need for education and training in order to achieve the objectives of the conventions. In the Convention on Biological Diversity (CBD) this reference is rather meagrely expressed in Article 13. However, at the 4th Conference of the Parties to the CBD an extensive workshop on this topic took place; some countries, such as Canada, for example, submitted initial proposals and case studies on the topic 'Learning about biodiversity' (1998).

This (as yet) secondary importance of perception, evaluation and learning processes within society is reflected in opinion polls. The worldwide loss of biological diversity is given little regard in the public eye compared with other environmental issues such as 'climate change' or 'the hole in the ozone layer'. It has hardly been taken up by the media at all and therefore has not really penetrated into most people's awareness, even though the issues have been discussed intensely among experts for some years. Even a topic that is addressed in the media frequently such as destruction of tropical rainforests which with the associated destruction of habitats is one of the core causes for the loss of biological diversity, is categorized as a climate change problem in the public mind.

The issue of biological diversity has various difficulties that may act as barriers to achieving appropriate levels of public attention.

If a species of plant or animal becomes extinct in some ecosystem, no one feels directly threatened by it. At first glance, unlike with climate change, there is no threat to one's own health or life. The link to everyday life and survival is not directly clear to most people and given other problems such as transport problems, energy consumption, demand for ecological products, etc in which the public has an important role to play, the importance of this issue becomes even less clear.

The diverse interactions between components of the biosphere, hydrosphere, pedosphere, etc that can lead to the threat or loss of biological diversity are complex and cannot be understood at first glance. Above all, given this complexity, it is not obvious what implications the loss of biological diversity can have for humankind (Sections D 1 and 2). Furthermore, the topic relates to a host of very different ecosystems worldwide that even without the particular situation of 'extinction' would not be familiar to most people.

The loss of species is a worldwide phenomenon, but its impact is not felt everywhere. In some cases we are talking about species of whose existence the public is first made aware when the announcement is issued that they have become extinct (Sections E 2.2–2.4.). Many species that are at home in far flung ecosystems have never existed as far as the public is concerned. But even the extinction of domestic species remains hidden to many since the process progresses insidiously with people for example getting used to the fact that they are encountering fewer and fewer marsh marigolds. Apart from this effect of habituation, at least in Western Europe, only a small section of the population really has regular encounters with nature nowadays and thus the opportunity to even notice that certain species of animals and plants are disappearing. The vast majority of the public lives in urban habitats where the plant and animal diversity is generally not threatened with extinction (Section E 3.8)

As a result of the complex and multilayered nature of this topic and, at least at first glance, the lack of a link to everyday life, it is not easy to communicate the importance and the context of the loss of biological diversity. What makes it even more difficult is the fact that this issue cannot be dealt with adequately without consideration of ethical questions since no normative protective demands have as yet been derived from the description of ecosystem functions (Chapter H).

The topic 'loss of biological diversity' and the conservation of the biosphere could run the risk of not being taken seriously, of just being more pessimistic cries from the 'environmental hysterics'. It therefore appears imperative to demonstrate the way this topic is linked to other ecological issues and not necessarily highlight the discovery or solution of a completely new, unexpected danger. Notwithstanding all of the urgently necessary preventive measures and adjustments for other problems that have been in discussion for a longer time (climate change, the consequences of emissions and large material flows, etc) the linkage to the preservation and loss of biological diversity must be shown and integrated into the development of sustainable lifestyles.

Environmental education is a central instrument of environmental policy and must react to the difficulties outlined above and, as soon as possible, find ways of incorporating this issue into its educational curricula and programmes.

I 2.5.3
The tasks of environmental education and environmental learning

Producers and consumers that consume raw materials, landscape and goods determine the destruction or conservation of biological diversity. This occurs through the use of more or less energy-intensive or environmentally damaging technologies, more or less sizeable material flows in the production of goods, daily consumption decisions, mobility patterns and acceptance of political measures by consumers and producers. Environmental education and environmental learning must support the conservation of the biosphere, as underlined at the outset, both by making it a direct issue in the curricula of the entire educational system and by general sustainable development in society.

Placing the topic on the curricula of the educational system does not just aim to increase knowledge, but is oriented to all psychological processes that strengthen appreciation for nature and behavioral intentions to preserve the biosphere. Learning processes affect the entire person, not just the rational being: 'They incorporate all the senses, desires, yearnings, feelings and motivations' (Csikszentmihalyi, 1987, quoted after Environment Canada, 1998).

Knowledge about biological conditions that can lead to the destruction of species is necessary but, as is constantly being proved, it is not a sufficient condition for achieving nature conservation. This is true above all of abstract knowledge so often communicated in a classroom situation. It makes more sense to impart knowledge that is related to concrete issues and beyond that knowledge about action that relates to certain goals that can actually be applied. It is also crucial for the desired behaviour patterns to be viable and also attractive for the persons concerned. Furthermore, it must be ensured that people actually want to protect the natural assets, species and habitats, landscapes, etc in question, that is, that they have developed the relevant attitudes and motivations. For this to happen it is generally necessary for people to focus on the nature that they can see and experience in relation to their everyday life; that means that they can 'appropiate' nature (Kruse, 1999 and Section E 3.5). Each group or individual itself must perform this process of appropriation and must be able to draw on direct and indirect experiences. Just because their grandparents love nature does not mean that the grandchildren necessarily do the same. The latter must appropiate nature as a part of their own specific lives.

Measures for environmental education can promote this process of appropriation, which aims at the appreciation of nature, the readiness to engage in conservation – with corresponding behaviour patterns – and sustainable use. Measures must be taken and reinforced which accord the topic of 'biological diversity' or 'humankind and the biosphere' a permanent place in the context of the education system. But even that is not enough.

Education and learning must in a broader sense support the acquisition and maintenance of sustainable lifestyles, that help reduce material flows for material and energy consumption, keep the consumption of landscape as low as possible, and shape human mobility in an acceptable way (BUND and Misereor, 1997; UBA, 1997b; Enquete Commission, 1998). The discussion on the development of sustainable models has become livelier in the social and natural sciences in the last few years, and concepts and concrete blueprints for their realization in society are essentially available (eg Jischa, 1993; Müller, 1995; Kastenholz et al, 1996; Brand et al, 1997), but hardly ever implemented. A number of barriers stand in the way of realization. For broad-scale popularization in the public mind the term 'sustainability' presents certain difficulties: it is abstract, vague and unusual (Kuckartz, 1998). This is not necessarily true of the specific concepts for which the term stands. Educational efforts alone are not sufficient to overcome these difficulties, particularly since implementation of sustainability models must take place at various levels under the influence of corresponding control bodies (such as statutory regulations). Furthermore, the readiness among consumers or producers to change is still very low. Educational efforts and measures for environmental learning risk falling on deaf ears or throwing away what potential for change there might be in their target audience if they are not backed by concerted efforts in all policy areas and the coordinated deployment of instruments on course for a recognizable and communicable goal: the conservation of the biosphere as an important component of sustainable development.

I 2.5.4
Substantive criteria for shaping biosphere conservation education

'Teach them and they will forget, demonstrate them and they will understand, involve them and they will remember' (Geller, 1989). According to this slogan, addressing the topic of biological diversity should in addition to knowledge components also be geared to people's experience and motivation so that problem and action-oriented learning can take place on the basis of experience. Furthermore, ethical aspects and a specific link to everyday life must be incorporated.

Knowledge components

Imparting knowledge about the topic of biological diversity is not the sole, and certainly not the all-sufficient, task of environmental education. But it is nevertheless necessary particularly since educational practice has shown that there are still major shortcomings in this regard. These relate first of all to morphology that is now rarely taught in biology (Mayer, 1994; Flury-Keubler and Gutscher, 1996), and secondly to the communication of ecosystem functioning with the explicit inclusion of biodiversity. Imparting knowledge about the importance and function of biological diversity should take account of the insights given us by psychology of learning:

- It should link to experiences of the learner. What that means must be examined anew for each target group. The concerns of the target group must be analysed and considered in an open and sensitive manner. For trainees in fisheries different concepts will be developed than for pupils in a secondary school. Matching learning content and learning methods in this way is an important prerequisite for the success of educational measures. For this reason sufficient resources need to be provided in order to plan and update learning strategies and to constantly adapt them to changed practice since the characteristics of target groups change. This is clear from the example of a group of school pupils – hardly uniform (Jugendwerk der Deutschen Shell [German Shell Youth Organization], 1997). Here, one cannot simply assume, as classic pedagogy would perhaps urge one to do, that a subject's direct environment constitutes an attractive place of learning or even a relevant link to everyday life (de Haan, 1998). The challenge for the teachers is to create contents specific to subgroups that is not just presented according to their own style of thought and life.
- It should allow the learner sufficient creative space for his/her own experiences, ideas and priorities. In this sense, infrastructural parameters (timetables, teaching forms) should be able to be handled more flexibly and demonstrate openness to participatory approaches.
- The content should be presented from as many different perspectives as possible (interdisciplinary treatment) so that the factual interlinkage of problems can also be represented cognitively and can thus lead to a deeper understanding of the facts.
- Other topics and objectives that the learner finds attractive should be used. For example, the internet seems to be a particularly attractive learning platform for young people, this should be used intensively for familiarization with the topic of biological diversity. Use of the internet also allows for international and intercultural exchange as is currently being realized for example under the GLOBE project (Seybold, 1999).
- The ability to think systemically and in a complex way must be promoted by means of suitable methods (games, computer simulations).

Experiential components

Empirical studies provide indications that sensory experiences with nature (landscape, plants and animals) play a role in promoting a person's readiness to conserve nature (Klee and Berck, 1993; Eigner and Schmuck, 1998). People who like to spend their leisure time within nature (walking, bird watching, camping) demonstrate more environmentally friendly actions than people who have less frequent contact with nature (Nord et al, 1998). Children and young people with intensive experiences of nature consider on average environmental threats to be more serious, show greater dismay and higher responsibility for environmental situations and a greater readiness to behave in an environmentally friendly manner than children and young people with a less intensive experience of nature (Mayer and Bögeholz, 1995, Bögeholz, 1999). Experience of nature can be made in different ways and different contexts (Table I 2.5-1). Particularly the 'ecological' and 'instrumental' types demonstrate a high level of motivation and strong intention to act in an environmentally friendly manner for the promotion of which existing educational institutions (pre-schools and schools) provide a host of opportunities. It should also not be overlooked that experiencing and familiarizing oneself with nature also fulfils important social functions. It is not the nature experience alone that is decisive, but also the fact that it can be shared with a reference group (Szagun et al, 1994).

These differing experiences of nature that go hand in hand with intensive experience of nature should be promoted in the context of environmental education measures, and also evaluated.

Value components

The way ecosystems function does not allow one to derive normative statements (Chapter H). Therefore, the discussion of values and ethical aspects in connection with the educational objectives of 'strengthening the readiness to participate politically and acquire competence in the evaluation and risk assessment of products, projects, programmes, develop-

Table I 2.5-1
Dimensions of relations to nature.
Source: Mayer and Bögeholz, 1995

Individual orientation	Cultural context	Area under consideration	
		Organisms	Activities
Enquiring	Science	Characteristic species, systematic groups	Natural scientific studies and hobbies
Ecological	Nature conservation	Endangered and protected species	Ecological commitment, nature conservation activities
Instrumental	Economy	Crops and livestock, wild fruits, mushrooms	Gardening, hunting, fishing, harvesting
Aesthetic	Aesthetics	Houseplants, ornamental plants, natural aesthetic objects	Walking, nature photography, drawing nature, gardening
Social	Animal partnership	Pets, sporting animals	Keeping and breeding pets, animal protection activities, sports with animals

ments, etc' (BLK, 1998) is essential for any appropriate treatment of the subject. Learners must not just gain insight into their own value positions in relation to nature and biological diversity and be able to rationalize these, but also learn to understand the diversity of existing and often contrary interests and values. They should learn to adopt the perspective of other people and negotiate tenable decisions in cases of conflict (conservation versus use).

The concept of life-long learning and target-group specific content

The way people deal with nature is something that they learn and practise from earliest days (WBGU, 1994, 1996). A large number of educational institutions and formative reference groups participate in the process of life-long socialization and learning. These include pre-schools, schools, vocational training and profession, other networks and groups (NGOs), the family, friends and neighbours. The treatment of the topic 'conservation of the biosphere', if it is going to be successful, must be done in a target-group specific and adaptive manner to suit each stage of education. That means that the content must take into consideration the level of knowledge and the background of experience of the respective recipients and link in to everyday contexts. People take in new information actively, interpret it and compare it with knowledge or convictions they possessed before. Palmer (1995, quoted after Environment Canada, 1998) found in her studies that children already had clear ideas when they entered school about far flung environments and also possessed concepts of biodiversity, and that this knowledge influenced the interpretation of new information and experiences.

The evaluation of model experiments in Germany has in many instances demonstrated the importance of integrating educational content into the worlds in which specific target groups live (de Haan et al, 1997). In general, it is less of a case of conceptual deficits with regard to adequate environmental education than shortcomings in the transfer of those concepts into educational practice. Here, enhanced further training for teachers and the dismantling of structural barriers must be employed, but beyond that also greater incentives for effective educational practice.

Particular target groups

In many conventions, but particularly in Agenda 21, reference is made to the importance of specific target groups for the realization of sustainability goals. For the conservation of the biosphere certain relevant groups may be enumerated:

- Particular educational products should be envisaged for women since they have a central role in terms of the organization of household and family and so as a rule have a major influence on consumption decisions (purchase of food, clothes, etc) but are also responsible for shaping the conditions of socialization and for raising children. They therefore have a great decision-making power in relation to sustainable consumption, and in their educational role they also exert influence on the development of new attitudes and lifestyles. The outstanding role of women in the development of sustainable patterns of production and consumption has been discussed frequently (WBGU, 1998a) and should be reflected in education-related measures under development cooperation.

- Special informational programmes should be developed and expanded for tourists who often without knowing it are supporting the trade in endangered species.
- For consumers who by virtue of their demand are responsible for the extinction of certain species – with due consideration for culture-specific consumption patterns – programmes must be developed to create incentives for renunciation or extensive restrictions of certain food habits. Also expanding existing legal sanction options, eg within the CITES regime, must be examined. An example for demand patterns with damaging consequences is the consumption of fish caught alive (by use of potassium cyanide) which is considered a status symbol in wealthy Chinese families in Hong Kong and other Asian countries (Section E 2.4). Also, the fact that certain parts of animals are desirable in some traditional Asian medicine (tiger bone, the horn of the black rhinoceros) has contributed to the dramatic decline in these populations (D 3.1).
- Local NGOs have an important role to play in changing behaviour patterns that are damaging to the biosphere and their efforts are in need of support. They often contact groups and act in 'learning contexts' that are not reached by formal educational programmes. In addition to financial support, it is usually not content that is required, but rather offerings relating to learning techniques, communication strategies, project planning methods, methods for self-organized learning and participation.
- At the hotspots of biological diversity it is urgently necessary for appropriate educational activities to be strengthened and expanded. Above all, promotion of participatory conservation projects should be planned with particular consideration of the potential of NGOs.

Biosphere reserves as particular learning contexts with different target groups

UNESCO's biosphere reserves are particularly suited to educational and learning processes since conservation and the use of particularly valuable ecosystems must be integrated together with the local population. The three zones of biosphere reserves (core, buffer and transition zones) call for different concepts of use and conservation that have to be realized by different players (biosphere reserve management, land owners, farmers and foresters, hunting reserve owners, inhabitants, tourists, conservation organizations, etc). Here, it is necessary to articulate and negotiate economic, ecological and social interests and claims. The 356 biosphere reserves in 90 countries (as at January 1999) which according to the UNESCO definition should also serve an educational purpose provide an excellent opportunity to link educational and learning programmes and for an exchange of experiences to take place.

Training the trainers

A fundamental prerequisite for target-group specific education for the conservation of biological diversity is the careful training of educational personnel. The appropriate concepts must form an integral part of the professional training of teachers. Teachers that are already practising their profession must take advantage of relevant further training. In that context it should be examined where effective support can be given for such educational measures in countries with high biological diversity.

I 2.5.5
Measures for 'learning' sustainable lifestyles

Alongside environmental educational measures that promote a knowledge, experience and value-oriented encounter with the biosphere and biological diversity, it is also necessary to take targeted measures to promote environmentally friendly actions that can be effective in the concrete every day lives of individuals and groups. Landscape consumption and pollution of natural environments are driving forces for biodiversity loss. In the countries of South America and Asia the felling of large areas of forests, in tropical coastal regions the landscape consumption via the destruction and conversion of natural coastal ecosystems (eg mangroves, corals), in Europe landscape consumption in the form of agriculture are important causes for the impairment of biological diversity (BfN, 1997a). The patterns of action associated with such processes and the driving forces on which they are based are complex and vary from region to region. This complexity is reflected in the Council's syndrome concept, here particularly in the Overexploitation Syndrome, the Aral Sea Syndrome and the Dust Bowl Syndrome (Chapter G). A large number of measures must be developed, deployed and evaluated to solve the problems (Section I 3 and Chapter K).

By way of example we will look more closely at the potential for change in the consumption decisions of individuals (use of foods), and take the case of Europe where landscape consumption and pollutant inputs are relevant in the day-to-day activities of consumers in the consumption of foodstuffs from 'conventional' farming. One could similarly look at the reduction of paper consumption. In the social sciences a number of measures have been developed by means of which changes in the actions of groups and societies can be 'triggered' (Homburg and Matthies, l998; Mosler and Gutscher, 1998). These measures are 'change techniques' and cover a broad spectrum that goes beyond the simple communication of information.

Communication of information and acquisition of knowledge are necessary measures, but are in no way sufficient to change complex patterns of behaviour. The techniques described in more detail below for explicitly changing behaviour can be applied at different levels in collaboration with various players. They can be conducted in large national 'programmes', in smaller programmes for example at the level of the town or municipality or as programmes for special institutions such as schools, hospitals, etc. The German Federal Government should be an initiator of this type of programmes and as required also provide funding. Furthermore, it must be ensured that the necessary parameters are created at federal and state level to allow the envisaged changes in action patterns. The programmes should be planned and implemented by local players who aim to collaborate with research institutions in order to ensure scientific follow up and evaluation. The first step is to decide what area of activity is to be changed (buying decisions, mobility decisions, energy consumption, etc) and what influences on those actions are considered relevant. By way of example, in this section we shall explore buying decisions in relation to food. The following describes various principles that are significant in planning and carrying out this type of measures.

Changing environmentally relevant actions

Using the example of the consumption of food from organic cultivation, we shall present the steps and measures that must be taken in order to promote this more sustainable form of land use. Since there are hardly any empirical data available specifically for this area of consumer behaviour, the results from other, well researched areas (recycling and avoidance of waste, energy saving, traffic avoidance) will be transferred (Schahn and Giesinger, 1993; Geller, 1995; Schultz et al, 1995). Two principles in particular should be respected (Kotler and Roberto, 1991):

1. A package of different measures must always be applied; isolated activities are not sufficient to change stable patterns of behaviour.
2. The measures must, wherever possible, be designed in a target-group specific way since this is the only way one can expect to achieve efficient effects. Matching measures to the target group can be ensured in particular by using participatory options (Geller, 1989; Matthies and Krömker, 1999). Precise proposals of how to achieve target group specificity are made, for example, in the context of participatory social marketing (Prose, 1997).

In the following, the factors will be enumerated that have an impact on the consumption of the products of 'organic' (as opposed to 'conventional') farming. After that, measures will be listed that lead to a change in the respective influencing factors and thus ultimately to a change in behaviour. The attribution of particular measures to certain influencing factors is not definitive, since they may relate to several influencing factors.

Options for action

Consumption of organic products can only be increased if they are easily available to consumers. It is not sufficient for example for one or two specialist 'organic shops' to be located in a given community that can only be reached with increased input of time and organization. These products would need to be available for purchase at every normal supermarket. The diversity and quality of the products on offer must also be ensured, since one cannot assume – as is clearly sometimes the case in marketing resource-friendly products – that the consumers are prepared to accept lower quality, less choice and higher prices (Schneider, 1998).

Measures to improve the options for action are:

- *Change the situation*. Enhancement of the range available in normal supermarkets or the association of different producers to ensure sufficient supply capacities and a uniform product presentation are examples.
- *Information and labelling*. Clear labelling of products (eg green ecolabel) must be created and any confusion of the consumer as a result of a plethora of perhaps contradictory information must be avoided. Clear indications within shops through signage and corresponding shop design is also relevant.

Attitudes, values, norms

Influence on consumer decisions comes from positive or negative attitudes towards a product. Positive attitudes to environmental protection promote the readiness to take corresponding action. The attitude that biodiversity conservation is worth pursuing can lead to consumers being prepared to assume greater efforts and costs in order to be able to act accordingly (Bamberg and Kühnel, 1998). If no positive attitudes are present actions that call for greater effort will be even more unlikely. Values and attitudes lead also to persons seeking out further information and corresponding options for action. Membership in a certain reference group plays a key role in the emergence of values and norms (Fuhrer and Wölfing, 1997) since these are normative and reinforcing. The attention of consumers may often be drawn to new options for action by written information and publicity, but crucial in actually forcing the decision to act in a particular way are often conversations with neighbours, friends, club associates or relatives. Their function as multipliers must therefore be taken into consideration (Prose, 1997). Possible measures to promote positive attitudes towards the preservation of the biosphere are:

- *Persuasion*. Persons that are credible and in trust (neighbours, friends, family, etc) act as multipliers, communicate the issue wherever possible personally and try to convince their contact person.
- *Model behaviour*. In (mass)media, on advertising posters, in brochures, etc the desired actions are lived out and demonstrated by model persons. Models can be fictional or real persons and also, for certain groups, comic figures.
- *Goals*. Persons or institutions (supermarkets, schools, canteens, etc) are asked to volunteer for a particular goal (eg 30 per cent of required food covered by organic products) that they hope to achieve. The goal must be neither too high nor too low to prevent the volunteers from giving up to soon because it is too much for them or they reach the goal too quickly. It is important to monitor the achievement of the goal.
- *Self-commitment*. This method can be linked closely with the goal-setting method. Persons or institutions commit voluntarily to achieving a certain goal and generally feel bound by the promise. It is most effective when the commitment is made publicly. Here, too, monitoring of actual progress is crucial.

Perception of products

The attractiveness of organic products depends heavily on the everyday knowledge and convictions of potential consumers regarding the characteristics of these products. Relevant features whose perception and positive evaluation should be promoted by means of relevant public representation (promotion): taste, health compatibility, durability, appearance, accessibility, price, selection or positive or negative connotations that are associated with the origin of the products.

Measures to promote positive perception of the products are:

- *Publicity*. The relevant positive characteristics of the products are disseminated by mass communication (eg posters, ads), selective communication (radio and television features) or personal communication (eg passing on leaflets, conversations with neighbours, other multipliers).
- *Sales presentation*. An attractive design of the presentation area in the shops (light, roomy, clean, backgrounds, clear and well ordered, etc) underlines the attractiveness of the products.
- The strategies under *model behaviour, targeted information and persuasion* are also relevant.

Knowledge about products

The perception of organic products is closely linked to knowledge about them and about conventionally produced foods. And it is only when a person knows something about the ecological background to food production, its causes, consequences and side effects that they are in a position to make conscious consumer decisions. Knowledge about where to obtain organic products is also an important precondition. Furthermore, it is crucial for consumers to know how to recognize the products. Measures to increase knowledge about organic products are:

- *Communicating knowledge*. Use of all available communication channels (mass communication, selective and personal communication) to present the relevant contexts and evaluations in a way that is generally understood and has a local angle. The relevance to a person's own opportunities for action must be clearly recognizable. Here, too, target-group specific differences should be respected.
- *Visits*. Interested persons should have the opportunity to get to know the relevant producers and their production methods. In addition to 'open days', the production background can also be presented for example by presenting videos at the points of sale. The linkage to the landscape and nature of the region should be made clear.

Incentives to act

The incentive for the consumption of organic products must be clearly visible in comparison to traditional products. Incentives are closely linked to how the goods are perceived. Setting incentives via pricing can be achieved through targeted government support for organic farming as is for example currently the case in the EU-compatible Austrian programme to promote farming that is environmentally sound, extensive and conserves natural habitats (ÖPUL). Incentives to act can also be created via non-material values such as taking responsibility for intact nature, more healthy and tasty eating habits, a contribution to maintaining regional jobs, etc. Here, the knowledge of which product features could serve as incentives to which target groups is a key prerequisite. Possible measures to increase the incentive to consume organic products:

- *Rewards*. The consumers of organic products are 'compensated' for their decision with material or non-material gifts. This could for example be other products that invite the consumer to practise environmentally friendly behaviour (bread bins, drinking bottles, etc), other organic foodstuffs or invitations to visit organic farms. These measures are not suitable for continuous use (too costly) and so are not suitable for building up an intrinsic motivation to act in the desired fashion, but they can provide valuable service in initiating new courses of action.

- *Lotteries*. Here, too, the issue is one of 'remuneration or compensation' for a consumer's decision with the difference that there is only a certain degree of probability that they will receive the compensation.
- *Competitions*. Different organizations (supermarkets, city districts, sections of road, municipalities, schools, etc) can be motivated to compete with one another on the proportion of organic products they consume. What is important is that the consumption is still linked to the ideal values (eg city X is doing more for sustainability of the region that city Y) that assume the function of giving the group a certain identity.

PERCEIVING THE CONSEQUENCES OF ACTIONS

The consequences that follow an action will influence whether that action is repeated or not. What is crucial is which of the many possible consequences are actually perceivable and which go unnoticed. The conservation of biological diversity is generally speaking difficult to see for the layman, particularly in an urban environment. What are easier to see are direct factors relating to a person's own day-to-day life such as high food costs or a quality increase. The positive consequences of consumer decisions must be visible for the consumer if the behaviour is to become attractive. The consequences of an action that are recognized in turn have an impact on the knowledge about an action, the incentive to act, product perception and also the attitude to a given product. Measures to communicate the consequences of actions:

- *Feedback*. Feedback can relate to various consequences of increased consumption of organic products. One might consider for example information about the amount of pesticide or transportation kilometres saved, resettlement of certain plant and animal species, the number of farms switching to that form of production or the size of total sales of 'organic products' per supermarket or town/community. The feedback could be in various forms, eg advertising posters, newspaper information, leaflets, local news, personal letters. In particular, feedback can be combined with competitions.

I 2.5.6
Recommendations for research and action

Education and learning are important instruments for the conservation and environmentally friendly use of the biosphere. Deployment of these two things should take place in coordination and interaction with other instruments and methods to develop and promote sustainable economic and lifestyle patterns that ensure the preservation of the biosphere. Education and learning for the biosphere must not be allowed to be limited to school-based learning: 'Biodiversity education is not just for children and the school; it takes place in our homes, in our workplaces, in our community, in our holidays and also in our schools' (Environment Canada, 1998). Education and learning must not be limited to communicating knowledge and information campaigns. Rather it is necessary to establish a broad concept of education and learning as is envisaged in this chapter and to implement this in practice.

Even if the topics of biodiversity, the position of humankind within the biosphere, damaging or potentially beneficial impacts on the preservation of the biosphere have rarely been picked up under the educational perspective, there is sufficient knowledge available to be able to translate it into educational and learning programmes; other knowledge can be made fruitful by analogy with other areas of nature and climate protection. Many questions still have to be addressed, however, in further systematic research and be processed in a problem-solving way for education and learning. These include for example

– increased investigation of everyday ideas, concepts and attitudes to biodiversity, the role of the biosphere for human life, the relationship of nature and culture as a basis for target-group specific learning and educational activities,
– the promotion of culture-specific and cross-cultural research on the perceptions, concepts, attitudes, values with regard to biological diversity, the conservation and use of biological diversity (eg also on indigenous knowledge and persuasive systems) in order to recognize the culture-specific divergence of perspectives and the target-group specific diversity of interests and their political relevance (at Conferences of the Parties, round tables, etc).

Simultaneously, by way of example, a number of recommendations for action may be formulated that could make the environmental instrument of education more effective now than has hitherto been the case:

- Compilation and evaluation of international research results on 'biodiversity learning', of school curricula and also model non-school-based projects.

- Investigation of environmental programmes and approaches to community environmental learning to see whether they can be transferred or adapted to other geographical contexts and target groups.
- Investigation of the compatibility of legal, technical and economic parameters within which 'environmental learning' should be initiated and stabilized in order to avoid contradictory learning incentives.
- Systematic analysis of educational activities in biosphere reserves and their connection with other biosphere-related management activities for the conservation and use of biological diversity. Promotion of networking of educational activities in biosphere reserves nationally, Europe-wide and internationally in the context of the use and/or expansion of existing information (eg BRIM = Biosphere Reserve Integrated Monitoring) and cooperation systems at UNESCO. Clarification of possible support for such networking initiatives from national or UNESCO funds.

I 3 The Convention on Biological Diversity: implementation, interlinkage and financing

The complex network of organizations, conventions, plans and programmes for the conservation and sustainable use of biological diversity shows that biosphere policy has now become an important field for activities of international relations. Against the background of the model of sustainable development a change from classic concepts of species and nature conservation with a sectoral or regional focus towards more complex agreements on the people-biosphere relationship has taken place. In addition to the direct effects, such as overuse or clear-cutting, increasingly, socio-economic factors are playing a role in the use of biological resources.

The Convention on Biological Diversity (CBD) signed in Rio de Janeiro in 1992 during the United Nations Conference on Environment and Development (UNCED) is an expression of this new, more comprehensive approach and an important interim result in a difficult process of negotiation that since UNCED has become ever more complex.

I 3.1 Substantive and institutional basis for the Convention on Biological Diversity (CBD)

The CBD is today the central and decisive set of international regulations for the biosphere (WBGU, 1996). Existing biosphere-related conventions, programmes (Section I 3.3.3) and institutions have reoriented since the CBD entered into force and have adjusted their work to focus on the new concepts and goals established in the CBD.

The CBD has now been ratified by 178 countries. The United States is the only industrialized country not to have ratified it: this step continues to founder on the blockade policy within the US Senate that can be traced back to resistance from the biotech industry.

The parties to the CBD commit to *conserve* biological diversity, to the *sustainable use of its components* and to the *fair and equitable sharing of the benefits* arising out of the utilization of genetic resources (Art. 1 CBD). This triad of objectives demonstrates graphically the convention's broad approach: At the forefront initially was coverage of institutional deficits in global nature conservation that had been criticized on several occasions by the World Conservation Union (IUCN). Deliberations in the run up to UNCED were also dominated by the model of sustainable development that called for the integration of the conservation and use of biological diversity.

What is more, the need for fair burden sharing became clear. Conservation measures in the biodiversity-rich, but structurally weak countries had to be facilitated and compensated by expanded finance and technology transfer. This financing is essentially handled through GEF. What are termed 'incremental costs' for measures to implement the convention can be made available by GEF. In the first few years there was a clear discrepancy between the funds accorded to biodiversity and actual funds disbursed. The application of the financing rules of GEF seemed to be more difficult for biodiversity policy than for example for climate policy. Ascertaining the incremental costs incurred in preserving worldwide biological diversity in the form of certain measures taken in individual countries continues to be a challenge for environmental economists and decision-makers.

The CBD regulates the availability and use of biological diversity. It underlines the national sovereignty of the parties to the convention over their biological diversity and leaves it up to them how they regulate access to these resources. In place of the older principle of biological diversity as the common heritage of humankind emerges the new principle of common concern for the use of biological diversity. The CBD does not contain fixed rules for agreements between 'suppliers' and 'users' of biological diversity. The contracting partners are supposed however to develop procedures for achieving prior informed consent and designing their agreements on mutually agreed terms. In their regular meetings, the parties concretize the framework for rules of access and the concept of benefit-sharing and endeavour to incorporate relevant interest groups (Section I 3.2.9).

For the implementation of the principles and triad of objectives set out in the preamble, the CBD commits contracting parties to a number of measures (WBGU, 1996). Articles 5–21 relate to substantive questions and call in particular for

- the development of national strategies for the conservation and sustainable use of biological diversity and the revision of existing plans and programmes with regard to their impact on biological diversity (Section I 3.2.1.2),
- assessment, research and monitoring of biological diversity (Sections I 3.2.6 and I 3.2.7),
- the reinforcement of *in-situ* measures (eg through the development of a system of protected areas) and complementing that with support for *ex-situ* measures (eg in botanical and zoological gardens and gene banks; Sections I 3.3.1 and I 3.3.2.2),
- the improvement of institutional parameters, application of (eg economic) incentives for the conservation and sustainable use of biological diversity and the reduction of negative incentives (Section I 3.5),
- national capacity building, strengthening and expanding scientific-technical cooperation, educational and training programmes and the exchange of information (Sections I 3.2.2 and I 3.2.3).

The institutional framework for cooperation of the parties in the implementation of the Convention is established in Articles 23–42. The Conference of the Parties (COP) is the decision-making body and after an initial phase of annual conferences it is now convened every two years. The Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) prepares the decisions of the COP and accepts commissions for work. The Convention Secretariat in Montreal coordinates the cooperation of the parties and organizes the exchange of information on the establishment and expansion of a communications system, the Clearing House Mechanism (Section I 3.2.2).

Since the CBD entered into force in December 1993 four COPs and four meetings of the SBSTTA as well as numerous sessions of informal working groups have taken place (WBGU, 1996, 1998a). The first COP in Nassau (1994) addressed organizational and substantive planning for the convention's work, established the appropriate bodies and adopted a medium-term programme of work. The topics of the subsequent COPs in Jakarta (1995), Buenos Aires (1996) and Bratislava (1998) focused on establishing priorities. If one takes stock of the negotiating process up to this point one will see a wealth of decisions and recommendations on a broad range of topics. Programmes of work for various ecosystems and use systems were adopted and working groups or expert bodies established to advise on special cross-sectoral topics (eg biosafety, access to genetic resources). The dialogue of the parties within the binding framework of the CBD, if sometimes criticized as too vague, has proven indispensable. To develop a comprehensive biosphere policy, both the will of each party to cooperate and the dynamic further development of the CBD system itself are crucial. Thus the interlinkage of the work being done under the CBD with that under other conventions and in other processes serving world environmental policy is becoming ever more important. Furthermore, deficits in scientific policy advice and implementation (Section I 2.1) would seem to advocate further development of the existing bodies of the CBD or supplementing the same.

I 3.2
Focuses of implementation

In May 2000 the COP-5 will take place in Nairobi. High hopes are attached to that meeting. One topic due to be hotly discussed is biosafety (Section D 3.2). The original plan to adopt a Biosafety Protocol on the cross-border traffic of genetically modified organisms in Nairobi will take much longer given the failed final talks in Cartagena in February 1999 and will tie up negotiating capacity. Much more than a status report on this topic should not be expected at the COP-5. Given its importance this topic is dealt with separately in Section D 3.2.

Progress of the CBD in the area of ecosystems can be seen, however. The COPs in Jakarta, Buenos Aires and Bratislava developed programmes of work for marine and coastal biodiversity, forest biodiversity, agrobiodiversity and biodiversity in inland waters, and the stage of implementation reached in each is to be discussed. For future conferences it is planned to develop programmes of work for arid areas, grasslands and savannahs and the Mediterranean region.

As cross-sectoral topics there will be discussion amongst other things about the ecosystem approach, alien species (Sections E 3.6 and I 3.2.7), the development of indicators and promotion of taxonomy. Ongoing discussions regarding measures to implement the CBD continue – specifically tourism, incentive mechanisms, information exchange, education and training and impact assessments.

The COP-5 will continue to build on the results of the working group on the implementation of Article 8(j) on the role of indigenous and local communities (probably in Spain, January 2000) and on the expert meeting on access to genetic resources and benefit-sharing (Costa Rica, October 1999).

I 3.2.1
Innovative structures

One fundamental and overarching topic in the preparation phase of the COP-5 has been a revision of the way the CBD works. The existing bodies allow for continuous cooperation among the parties, but so far they do not provide for the incorporation of independent scientific experts and can only provide insufficient guarantees in the crucial monitoring of progress.

An informal meeting of experts (London, January 1998) discussed the possibility of improving the structure and working methods of the CBD and forwarded recommendations to the COP-4 that took place in May 1998 in Bratislava.

These recommendations related in particular to an improvement in the scientific advice and monitoring of implementation, the incorporation of non-governmental players and cooperation with other conventions and programmes.

The fact that a special working meeting was convened in June 1999 (ISOC) shows what importance the community of parties accords this topic. The establishment of a new Subsidiary Body on Implementation (SBI), a proposal for which many parties from the Group of 77 and China had called, however, made it more difficult to achieve agreement. The Council recommends that the German federal government support the further development of the CBD institutional system and in that context in particular take up the recommendations and arguments discussed in the following Sections I 3.2.1.1 and I 3.2.1.2.

I 3.2.1.1
Establishment of an IPBD to provide scientific advice

Experience from a variety of negotiating processes in international environmental and sustainability policy make it clear that there is a need for well founded and independent scientific advice. The IPCC (Intergovernmental Panel on Climate Change) fulfils this role for climate policy (WBGU, 1997, 1998a). There is no comparable institution to provide for advice and follow-through on international biodiversity policy. The vagueness of the scientific foundations, terms and concepts with which work is being conducted in the negotiations is increasingly becoming an obstacle to the development and implementation of decisions by the contracting countries. One example for this situation is the discussion on the definition and design of the ecosystem approach (Section I 3.2.3) that is one of the fundamental concepts of the CBD. The scientific deficit may be seen at two levels.

First of all, the knowledge available on the state and loss of biological diversity and the consequences of this trend is still insufficient and patchy. The gaps must be identified systematically and worked on. At the same time sound scientific follow-through of topics that have already been processed politically is also important.

Furthermore, there is the failure to translate the results of scientific research into politically relevant options for action and the integration of scientific, socio-economic and legal expertise.

A first attempt to do justice to these shortcomings was undertaken with the Global Biodiversity Assessment (GBA; WBGU, 1996). This GEF-financed report was published by UNEP in 1995 and submitted to the COP-2 in Jakarta (Heywood and Watson, 1995). As the original title indicates, it was initially an exercise in taking stock that constitutes a very good scientific basis for international biodiversity policy. The report was produced with the broad, international participation of scientists and involved peer review procedures very similar to the work of the IPCC. A continuation and supplement to the GBA in the form of a continual evaluation and advisory procedure was not envisaged and it remained at a one-off endeavour– with many unresolved questions of practical policy against the background of the established dramatic and irreversible loss of biological diversity.

Providing scientific-technical advice in biodiversity policy has up to now been the job of two permanent bodies: SBSTTA and the Scientific and Technical Advisory Panel (STAP) of the GEF. These bodies, however, fulfil firmly delineated tasks within the political process. STAP is first and foremost responsible for evaluating GEF project applications and evaluations and does not provide policy advice beyond that task. It is the function of SBSTTA in the CBD system to suggest and evaluate scientific expertise in response to specific requests from the COP. The results of these expert assessments must then be packaged into motions for decision by the COP. SBSTTA, as a subsidiary body subject to instructions from the COP, is closely bound to the programme of work of the CBD, must work on the instructions from the COP and is not free to select the topics it investigates. In the force field of political interests the independent scientific work that would be necessary cannot be realized. Often at SBSTTA meetings instead of independent scientists it is government representatives who are present and who conduct discussions at the political level of the COP: SBSTTA is increasingly becoming a 'mini COP'. It remains to be seen whether the envisaged establishment of an Ad Hoc

Technical Expert Panels within SBSTTA could in part offset the politicization of SBSTTA by allowing a focused, scientific discourse on selected CBD topics.

Other than SBSTTA and STAP therefore, there is a lack of an independent body of experts or network to provide scientific policy advice on biodiversity that – in addition to priority topics it would select for itself – could take up current questions and problems from the political process, work on targeted recommendations and submit these to the community of parties and other interested players. The body would not focus exclusively on the biological-ecological perspective. Integration of socio-economic and legal expertise in the analyses and action recommendations would be essential. The scientific body should regularly revise the current scientific status as was successfully done in the GBA and extrapolate that further, but place more weight on practical questions of application and implementation.

First of all, it should be investigated to what extent closer cooperation with existing scientific bodies and regional networks could counteract the deficits in scientific advice. In the view of the Council, however, it is to be expected that establishment of a *scientific expert body for biological diversity*, eg in the form of an Intergovernmental Panel on Biological Diversity (IPBD) will be necessary. In this panel, internationally recognized scientists could be brought together who would provide continuous and independent work and scientific policy advice.

It will only be possible to establish an IPBD with the administrative and financial support of the international community and its institutions (in particular UNEP and CBD), this would however be offset by the advantages of lower transaction costs and the productivity of an IPBD working in a coordinated and targeted manner, and therefore justified.

A helpful example of this sort of body is the IPCC that was established back in 1988 – prior to agreement of the Framework Convention on Climate Change – directly by the United Nations General Assembly; it works under UNDP and WMO and is not tied to the decisions of the COP. Nonetheless the governments have the opportunity to participate in the IPCC process by nominating members for the IPCC and through their collaboration in UNEP and WMO.

Similarly to the GBA and IPCC, the IPBD would build on the broad, international participation of scientists and a differentiated multi-stage peer review procedure. Cooperation with the CBD process would be the aim, but there would be no subordination to the COP. The relationship of IPBD to SBSTTA could be shaped analogously to the successful cooperation between SBSTA, the scientific body of the Framework Convention on Climate Change, and the IPCC. The contributions of the IPBD could give the discussion on biodiversity a greater degree of objectivity. Science would also benefit from the establishment of an IPBD through improved coordination and networking, and the experts would be increasingly sensitized to the political dimension and parameters of the debate.

The Council recommends that, if the IPBD is set up, it should build upon the experiences of the Global Biodiversity Assessment and the IPCC in order to avoid construction weaknesses right from the outset.

I 3.2.1.2
Monitoring progress, implementation and reporting

In addition to an improved system of scientific advice, investigation of CBD implementation should also be improved. Many parties – in particular representatives of the G 77 – called for the establishment of a Subsidiary Body on Implementation (SBI) in the course of the negotiations at the COP-4. The industrialized countries rejected this, however, on the grounds of the anticipated extra financial and administrative costs. Furthermore, in the course of the discussion the industrialized countries questioned in the discussion the benefit of an implementation body that would in addition to the COP and the SBSTTA meet for regular rounds of discussions. It is undisputed that the implementation of the programmes of work and measures that have now been adopted will in future require greater attentiveness from the community of parties. This will be guaranteed to begin with by more clearly structured agendas for the conferences. Broad support was given to the proposal for a 'strategic plan' that, alongside a long-term programme of work, would provide for a certain standardization of smaller discussion bodies within the CBD system, a continuously updated list of scientists and continual coordination with other relevant conventions and institutions. The secretariat will concretize this proposal further and then submit it to the COP-5. Furthermore, various options for more effective monitoring of implementation were presented, eg the establishment of a permanent working group for the COP that would deal exclusively with implementation questions.

The regular reports from the parties can make an important, albeit insufficient, contribution to the strategic implementation of the CBD. Art. 6 of the CBD call on the parties to develop national strategies for the conservation and sustainable use of biological diversity. Existing plans and programmes with an impact on biological diversity must be adapted to the specifications of the convention. The COP-2 in 1995 agreed framework guidelines for establishing national reports that were submitted to the COP-4 in 1998 for the first time. Whereas the first national reports essentially took stock of the state of biological diversity and the general implementation of the convention in the contracting countries, subsequent reports were intended to contribute to the strategic, gradual implementation of each of the issues. The Secretariat of the Convention will draw up a synthesis report that will be developed further and the details of implementation results added. The COP-5 has to decide how the reporting from parties is to be done in future. A particular concern in that context is to facilitate by means of the reports a certain amount of international comparability on the status of implementation and to recognize weak points early on. This will only be possible in the long term with the introduction of a sort of 'accounting' system that allows for the status of biological diversity to be checked against a set of agreed indicators.

One should also not underestimate the international effect of the obligation to report on the domestic process of coordination and agreement. In many countries interdisciplinary committees were convened in preparation for the national reports that, in addition to decision-makers, also included expert social groups and the private sector in the debate.

The Council recommends supporting elaboration of a 'strategic plan' for the further implementation of the CBD, investigating the opportunities for improved coordination within the community of parties in coordination with other conventions and processes under global environmental and sustainability policy and promoting initiatives to that end in the negotiations.

On a national level, also, the conditions for biodiversity policy should be improved. The Council continues to consider it appropriate to elaborate a national strategy for Germany (WBGU, 1996) that would build on the German national report from 1998 and beyond that would aim to develop sectoral biodiversity strategies. This concerns, above all, the incorporation of biodiversity aspects into agriculture, forestry, fishery, research and the further development of biodiversity policy in the areas of biotechnology, economic and finance policy and development cooperation. The different interlocking convention processes should also be considered, as they require constant coordination. The close cooperation of the lead agencies in each case at federal level is an important prerequisite.

The BMZ faced up to this challenge and in 1997 developed its sectoral concept for 'Preserving biodiversity through nature conservation'. Other sectoral strategies should be produced, for example, under agricultural and forestry policy, research and education policy and economic and finance policy should be produced.

The cross-sectoral character of the Convention and the diverse tasks that implementation brings with it demand close and continual coordination among agencies, but also between the federal, state and municipal levels. The Council therefore recommends that the German federal government convene an interministerial working group on biodiversity policy in which all agencies participating in the development of a sustainable biodiversity policy would be represented.

I 3.2.2
Exchange of information and capacity building

For the exchange of information among the parties a Clearing House Mechanism was set up that, first and foremost, is intended to make the work of the parties and the results of their implementation measures widely accessible. This happens primarily via a web-based information service and regular regional conferences. The most urgent task here is to preserve decentrality and to keep the technical effort involved for the parties as low as possible. Other functions fulfilled by the Clearing House Mechanism are to network the various scientific institutions for the purpose of addressing the various topics under CBD and coordination with other biodiversity-relevant conventions. The continuity of German support is essential for the further development of the Clearing House Mechanism and should also be guaranteed in future. One might investigate possible inter-linkage of the international conventions and programmes – for biodiversity and other fields of action – by means of a joint clearing house, which could for instance be located under UNEP.

Almost all decisions taken by the COP for the purpose of implementing the CBD recall the need to promote national capacities by means of appropriate technology transfer. Without the support of the countries with strong financial and technology resources, the biodiversity-rich and structurally weak countries are not in a position to use their endangered biological diversity in a sustainable manner. In addition to greater consideration for biodiversity in programmes of economic and technical cooperation in general, under the CBD it is important to build up suitable structures for the transfer and dissemination of knowledge and technology. Research cooperation with special training programmes, eg in the field of taxonomy or the sustainable use of endangered ecosystems, are particularly important in this context in order to be able to achieve a fundamental understanding in the population for the importance of biological diversity and thus an interest in their long-term preservation. Support should be given to the development in the biodiversity rich countries of research institutions of their own and to the mobilization of corresponding corporate investment.

The Council recommends that the German federal government take a close look when it develops a national strategy at the opportunities for enhanced technology transfer for the conservation and sustainable use of biological diversity. This is only possible in close cooperation with the BMZ (Federal Ministry for Economic Cooperation and Development).

I 3.2.3 Programmes of work in line with the 'triad of objectives'

At the forefront of the gradual development of topic-specific programmes of work under the CBD for the various ecosystems (so far, marine and coastal ecosystems, forests, agrobiodiversity and inland waters) is an integrated consideration for the conservation and sustainable use of biological diversity. In this way, the hitherto prevailing spatial restriction to natural or semi-natural ecosystems or protected areas was lifted. This reorientation leads to biodiversity issues gaining a greater relevance to a larger area and being given greater consideration in land use planning as a whole. At the COP-3 it was decided to place savannahs, arid areas, grasslands and mountain ecosystems on the agenda of forthcoming COPs.

I 3.2.4 Ecosystem approach

The ecosystem approach is a concept fundamental to the implementation of the CBD and to which, for example, reference is made in many of the programmes of work and decisions of the COP. Furthermore, this integrative concept is also important for bioregional management (Section E 3.9). Currently, however, it is being used in the CBD without a clear definition or indeed an unanimous view on its content. Since the ecosystem approach entered the CBD without prior validation by means of independent scientific debate or deliberation by the SBSTTA, and in many instances has perturbed some players, it seems that an improved scientific grounding for this approach is more necessary than ever. This process has already begun with relevant expert workshops within the CBD framework (most recently in Trondheim, September 1999). The Council recommends giving priority to the advancement of the substantiation of this concept.

I 3.2.5 Indicators and monitoring

Within the framework of the convention the elaboration of a coherent system of indicators for monitoring the global status of biological diversity has advanced very little. There are still major uncertainties regarding methodology and scientific bases that should be addressed in targeted research (Section J 2.1). It would also make sense to bring together various existing projects on indicator development for biodiversity at international level (CSD, IUCN, IFF, CCD, OECD, etc). It would be desirable for the iterative development and binding introduction of an internationally compatible core set of biodiversity indicators to assess, at the various levels of aggregation, pressures, status/trends and responses to intervention. It is important for this to be linked to the development of sustainability indicators as is currently being advanced for instance by the OECD and CSD. In order to speed up this process, consideration should be given to convening an international expert dialogue whose work could be continued by a future IPBD.

I 3.2.6 Taxonomy

From scientific circles time and again warnings have been issued about the lack of capacity building in the field of taxonomy. Taxonomy is even often referred to as a 'dying science'. This is particularly true of developing countries, but even in industrialized countries the recording of biological diversity has often been seriously neglected in terms of both personnel and funding. In light of this situation, the Council recommends increased research support for taxonomy (Section J 3.1.1).

The Global Taxonomy Initiative (GTI) attempts to counteract the crisis in taxonomy by developing an international support programme (Eberhard, 1999). Recently, there has been discussion about whether the GTI ought to be institutionalized as a framework project. At the 4th meeting of the SBSTTA of the CBD the overwhelming majority of the delegates supported the promotion of the GTI within the CBD process. It was disputed however, whether it should be tied to UNEP. An upgrading of taxonomy would however bring with it a change in GEF policy since the latter would have to draw up clear and specific guidelines in the context of new or existing GEF projects. The GTI would also have to be linked to existing information networks, in particular the Clearing House Mechanism.

I 3.2.7
Alien species

The phenomenon of the spread of alien species has been addressed many times by the Council (WBGU, 2000a; Section E 3.6). Particular attention has been drawn in that context to the need for an analysis of ecological risk from the planned introduction of alien species. The Council also recommended the introduction of international regulations pertaining to the release of organisms not only for the purposes of biological control, but also for food production.

For agriculture and forestry there are already clear parameters. A comprehensive risk analysis for all potential 'newcomers' is not possible, but for instance most innovations today in the classic area of pest control in which the introduction of new alien species plays a role call for a risk analysis to be carried out (WBGU, 2000a). Furthermore, the FAO has developed a code of conduct for the import and release of exotic organisms that serves as a guideline for governments, exporters and importers and should contribute towards risk minimization (WBGU, 2000a). In the Council's view it is necessary to harmonize existing regulations governing the introduction of alien species and to expand them to include the areas of application mentioned above (Section E 3.6). The deficits in preventive risk analysis should be reduced using models and scenarios. Central to this in the Council's view should be the precautionary principle, or specifically, the avoidance of introducing alien species. In detail, the Council recommends:

- *Harmonization of relevant terms and provisions*: In order to ensure that the terms used in national legislation in connection with the introduction of alien species are consistent, it is necessary to establish clear definitions and content of terminology. Furthermore, the provisions in connection with the introduction of alien species and genetically modified species should be harmonized, since numerous issues are similar in the two cases.
- *Institutional responsibilities and scope for checking regulations on intentional release*: There is already in many countries an obligation to obtain approval for the introduction of alien organisms; deficits prevail in many countries with regard to the extent to which existing regulations and possible sanctions can be checked for violations. The precautionary principle should be the basis on which the release of alien species is carried out. Therefore, prior to any intentional release, environmental impact assessments must be carried out. These must also apply to releases in the context of agriculture and forestry. As a matter of principle, those responsible for the introduction of alien species should be liable for potential follow-on damage. The responsibilities of international institutions and national agencies for prevention and management in cases of emergency must be clarified.
- *Prevention of unintended introduction*: Unintended introduction should be prevented by border and seed controls, logistical measures such as shorter waiting times in container traffic, but also awareness-raising in the population and important target groups (tourists, hunters, fishermen, aquarists, foresters, farmers, garden owners, etc). Already today, various approaches relating to the analysis of introductions in various areas for similarities and differences can be employed for the purpose of early warning and prevention. These approaches should be developed further in the direction of an early warning system.

I 3.2.8
Terminator technology

'Terminator technologies' are new developments in plant breeding using bioengineering procedures in which the ability of plant genetic resources to germinate is restricted or prevented altogether. The seed of these new varieties when sold is not affected, but the harvested plant is incapable of reproduction. The use of the harvested material for replanting is thus rendered impossible and so the seed has to be bought anew each time. The first patented Technology Protection System from the company Delta & Pine Lands is an application of this technology. Other applications produce limitations to the natural resistance of plants (eg Novartis' patent on 'systematic acquired resistance genes'). The fears that cultivation of these new varieties could lead to an impairment of biological diversity have so far not been sufficiently grounded in scientific studies. However, these technologies became an issue of contention during the COP-4 as a risk to nature and society that is difficult to quantify. The dependence on the use of terminator technologies and the increasing control of plant production by influential seed companies raises at the very least socio-economic problems. The Council recommends research on the ecological and socio-economic impact of terminator technologies in order to allow for a scientifically based treatment of the topic.

I 3.2.9
Access to genetic resources

The extraction of components of biological diversity and their use should be compensated in accordance with the Biodiversity Convention by the fair and equitable sharing of the benefits that accrue from that use (Section D 3.3; WBGU, 1996). On the basis of sovereign rights of availability the countries of origin have the power to regulate access to their genetic resources. With regard to designing agreements between users and suppliers of genetic resources the convention contains very general parameters such as prior consent from the country of origin (Prior Informed Consent, PIC) and consideration for the ideas of both sides (Mutually Agreed Terms, MAT). Therefore, the aim of this new arrangement was not to achieve access provisions issued by one side for the use of genetic resources, but rather parameters that promote the exchange of genetic resources (Henne, 1998). The question of implementation of CBD provisions with regard to access to genetic resources and benefit-sharing has played a particularly important role at the COPs. The increasing interest in the use of biological diversity while resources continue to become ever scarcer is a challenge for both supply countries and user countries alike. The supply countries have an interest in controlling access to their genetic resources by means of appropriate regulations and in participating in the profits derived from that use. The regulations and laws may not however be designed in such as way as to fundamentally restrict the use of biological diversity and thus the interest from foreign demand. For the user countries there is the problem of ensuring the users, particularly private companies, are adhering to the various access provisions.

Experiences with national and regional access regulations issued so far show that there is a need for an internationally agreed standard to serve as an orientation framework for suppliers and users for shaping access to genetic resources in line with the spirit of the convention. In addition to the possibility of developing protocols under the CBD, international framework guidelines and codes of conduct may be agreed. These guidelines are not binding in character, but they are also not associated with a complex procedures that come with negotiating and adopting protocols and are therefore more flexible and perhaps more efficient. In October 1999 an expert body will meet to establish more concrete options for international regulations and submit these to the COP-5 for discussion and decision.

The Council recommends that the German federal government helps to swiftly advance the process of developing international standards for access to genetic resources and benefit-sharing within the framework of the CBD. There is a considerable need for research with regard to suitable structures for cooperative projects on the use of genetic resources (Section J 1.3). In developing that type of structure, information from work on the ground and in exchange with relevant companies should be evaluated. Greater use should be made here of the experience that is available through cooperation with the countries of origin of genetic resources in the context of the GTZ's sectoral project. The role of technical cooperation for the building of technology and research capacities and training programmes should be reinforced. Cooperation with the partner institutions in the countries supplying genetic resources should in the Council's view aim for transparency in the decision-making and participatory process, sustainable use and benefit-sharing. Initiatives already launched that involve in the political debate relevant companies and institutions active in natural substance research should be continued and intensified. A network of cooperation models for the promotion of sustainable bioprospecting should be developed in cooperation with the competent executing agencies (eg GTZ, BfN, ZADI). Individual instances of cooperation in supplier countries show that a sensitivity to the political dimension of the topic and a readiness to cooperate in developing standards and implementing such standards do exist.

I 3.2.10
Indigenous peoples and traditional knowledge: intellectual property rights

The role of indigenous and local communities and the importance of traditional knowledge is a cross-sectoral topic of the CBD. At the COP-4 of the CBD (1998) it was agreed to convene a working group for the implementation of the corresponding Article 8(j), due to meet for the first time in January 2000. Indigenous and local communities are often directly dependent on biological diversity as a result of their traditional ways of life and therefore often directly affected by the loss of that diversity (Section E 3.5). In many regions of the Earth indigenous and local populations have been expelled from their home regions by the establishment of large-scale conservation areas. Art. 8(j) of the CBD calls on the parties to respect and preserve the traditional knowledge, innovations and practices of the indigenous communities. The application of this traditional knowledge should be promoted and the benefits accruing from that use shared in an equitable fashion. As indicated by Art. 8 and hotly discussed at the COPs, discussions about land rights and intellectual property rights are making their way onto the agenda (Henne, 1998). Having said that, the discussion is limited to references to the responsible forums. The question of acknowledgement of *sui generis* systems for the protection of the traditional knowledge and practices of indigenous and local communities is being discussed with increasing intensity. Here there is a close relationship to other forums, to the World Intellectual Property Organization (WIPO) and above all to the WTO with respect to the TRIPs revision.

The Council recommends that the German federal government take on the task of implementing Art. 8(j) by directing its development cooperation (promotion of GTZ sectoral project) in that direction and by means of constructive tackling of the questions of alternative protective systems for traditional knowledge in the discussion on international standards for the access to genetic resources and benefit-sharing. Beyond that it should be ascertained which interdisciplinary research institutions are addressing the issue of indigenous and local communities and these could provide constructive accompaniment to the implementation issues. Consideration should also be given – perhaps in the context of an international research project – to establishing a system or 'world map' that would illustrate the importance of indigenous and local population groups for the policy of the conservation and sustainable use of biological diversity.

I 3.3 The role of the Biodiversity Convention within the institutional network

The CBD stands at the heart of the institutional network working to ensure the conservation and sustainable use of the biosphere (Fig. I 3.3-1). The broad approach of the CBD makes close cooperation with existing conventions and programmes essential. In that context it is important to guarantee a coherent biosphere policy in which the various approaches within the agreement supplement one another and tasks are assigned in a flexible manner. The G8 environmental ministers expressed the fundamental intention in the communiqué of their meeting in March 1999 'to step up our efforts to build a coherent global and environmentally responsive framework of multilateral agreements and institutions' (BMU, 1999).

The Council shares this view. In the case of agreements with a direct link to the biosphere suitable structures can be built – starting from the harmonization of reporting duties and ranging all the way to developing interlocking programmes of work, and there are many opportunities for coordination. However, it is important beyond that scope to consider the more major interactions, eg the relations between the biosphere and pedosphere, hydrosphere and atmosphere, and the policy strategies in each case.

Conflicts have already emerged between the goals of the different conventions, one example is the problem of carbon sources and sinks which the Council has addressed in a separate report (WBGU, 1998b; Section I 3.4.3). In light of the large number of negotiations running in parallel, detailed coordination among forums is becoming ever more important since the long-term compatibility of conventions and programmes must be guaranteed. The Council recommends therefore the establishment of a permanent agenda item for these questions on the agenda of the relevant international organizations (CSD, UNEP, UNDP, UNESCO, FAO, WTO, etc) and conventions (CBD, FCCC, CCD, UNCLOS).

Alongside the global conventions and programmes for the conservation and sustainable use of biodiversity in the following sections we shall consider the institutions involved in the UNCED follow-up process and the Convention on the Law of the Sea in their respective relationship to the CBD, and highlight potential synergetic effects and conflicts.

I 3.3.1 Conservation

The UNESCO World Heritage Convention

The aim of the UNESCO World Heritage Convention agreed in 1972 (157 member states) is the worldwide protection of cultural and natural heritage of extraordinary value for humankind. Currently, there are 582 sites or areas in 114 countries, 445 of which are in the cultural heritage category and 117 in the natural heritage category, and 20 that are listed in both categories (UNESCO, 1999). Suggestions for inclusion of areas are submitted by the member states and checked into by a special World Heritage Committee. The IUCN is the advisory body on the natural heritage sites. The fact that the World Heritage Convention focuses on both natural and cultural heritage is increasingly important for biodiversity policy. The connection between nature conservation and cultural conservation is as important for the conservation and sustainable use of cultural landscapes as it is for the preservation of a natural heritage site (Section E 3.5; Rössler, 1995).

There are certain selection criteria for natural heritage sites that are of particular interest for biosphere conservation. These include above all extraordinary and representative examples of ecological or biological processes, natural phenomena or sites of great

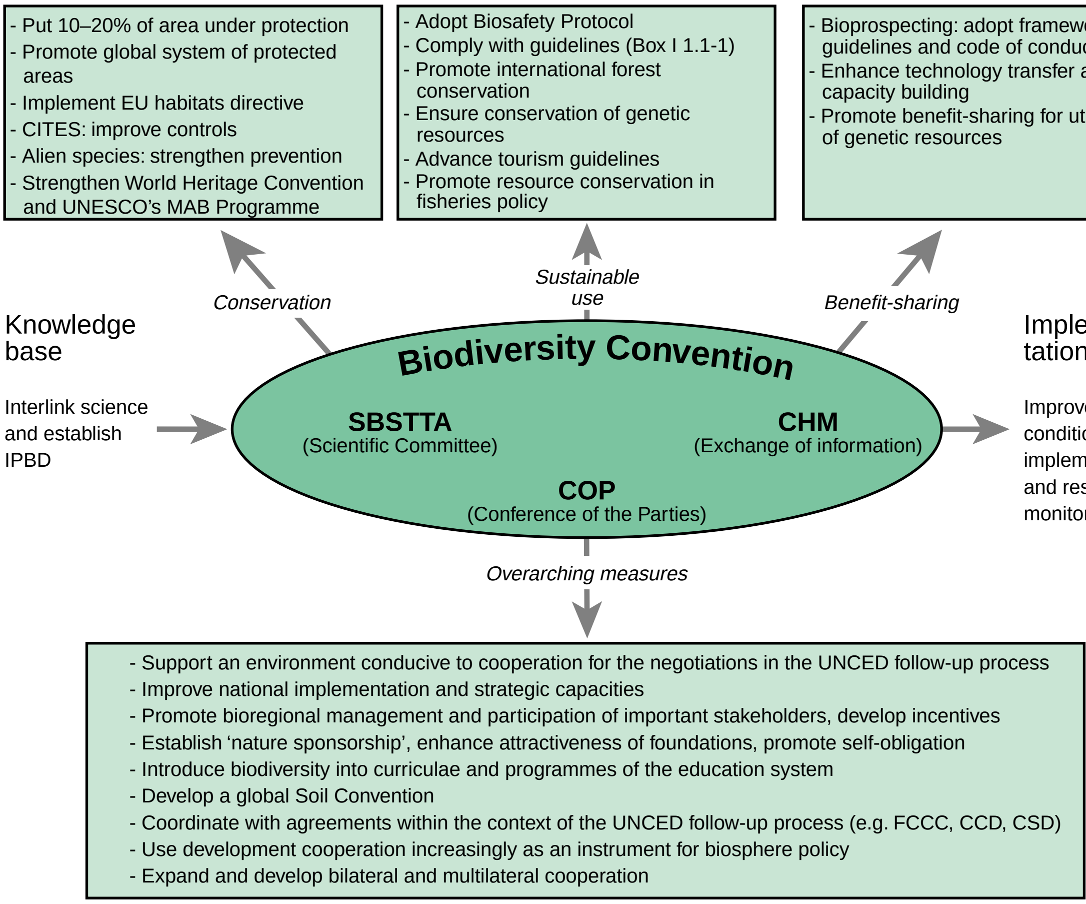


Figure I 3.3-1
Council recommendations for global biosphere policy in the context of the CBD network.
Source: WBGU

natural beauty and habitats of outstanding importance for the *in-situ* conservation of biological diversity or for the conservation of endangered species with 'universal value'. The status of areas (conservation, management and integrity) is also an important criterion. The regular reporting on the status and threat to natural heritage sites is among the duties of the contracting states. If neglected, the status of world heritage site may be withdrawn. Furthermore, a worldwide list of endangered territories is kept. If an area is in acute danger, targeted measures can be introduced, eg campaigns to mobilize the public. There are a number of examples in which this approach has successfully preserved important areas from destruction or degradation.

The convention's World Heritage Fund is fed from mandatory contributions and additional voluntary contributions. The mandatory contributions from states account for 1 per cent of their payments to the general UNESCO budget. Currently, the Fund has around US $3 million. In light of this extremely limited financial endowment priority is given to the highly endangered sites. Replenishment of the fund would be necessary to be able to fulfil more effectively the many and diverse tasks (selection of sites and areas, training and equipping managers, producing status reports, environmental education projects and assistance in emergencies).

The World Heritage Convention is an important element in a global conservation strategy and thus significant in terms of implementation of the Biodiversity Convention. Efforts should be made to deploy to a greater extent GEF funds for projects to protect natural heritage sites and to link the concerns of the World Heritage Convention with the implementation measures of the Biodiversity Convention.

In Germany the Convention is perceived above all as an instrument for protecting cultural heritage, which is reflected in the fact that lead responsibility lies with the Ministries of Culture. It should be investigated whether the instrument could not be used increasingly, particularly in Germany, to see the natural and cultural heritage in combination since they are inextricably linked. In that sense the World Heritage Convention could also be used as a building block in the national strategy to implement the Biodiversity Convention.

Trade in endangered animal and plant species (CITES)

Section D 3.4 dealt in detail with the way in which the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) works and the difficulties in implementing that convention. The conservation of endangered species sought under CITES concurs in principle with the objectives of the CBD. The linkage of conservation and sustainable use as pursued by the CBD and, for example, the consideration of the concerns of indigenous and local communities are aspects also being increasingly addressed by CITES. In this regard there could be an exchange of experience as well as joint development of instruments and principles with regard to the specific demands and circumstances of each.

Conservation of migratory species (CMS)

The aim of the Convention on Migratory Species (CMS) is the development of effective nature conservation strategies for countries that are located in the regions along the migratory routes of migratory species. In 1979 these 'Range States' signed the agreement that entered into force in 1983; the convention's secretariat is based in Bonn.

The protective goal of the CMS is pursued at two levels. Endangered species are listed in the first Appendix (Art. 3). A species is considered endangered if it 'is in danger of extinction throughout all or a significant portion of its range' (Art. 1 para 1e). The 76 animals listed in Appendix I are placed under total protection and may not under any circumstances be extracted from nature. Furthermore, the parties are obligated to preserve their habitat and to remove hindrances from the migratory routes. Appendix II lists species that have a poor conservation status and for the protection of which international cooperation is recommended (Art. 4 para 4). An information system on migratory animal species is being developed.

Wetlands of particular importance (Ramsar Convention)

The Convention on Wetlands of International Importance Especially as Waterfowl Habitat was signed in 1971 in Ramsar, Iran, and entered into force in 1975. The aim of this international cooperation was initially to protect the endangered habitat of waterfowl and wading birds. Since then the Convention has been expanded to cover wetlands in general as valuable ecosystems. The definition in Art. 1 includes a variety of different ecosystems, eg mangrove swamps, mountain streams, mudflats, tropical rivers and coral reefs. The protective system under Ramsar is based upon a listing of valuable wetland areas. Each party to the convention commits to naming at least one wetland area within its territory. The list so far comprises 965 wetland areas in 113 states and a total area of over 670,000 hectares.

The CBD's programme of work for biodiversity in inland waters provides for the Ramsar Convention as an 'executing agency'. The cooperation between the CBD and Ramsar can be seen as an example for the future interlinkage and harmonization of all conventions with relevance to biodiversity.

Conclusions

On the basis of certain legal terms that have been left imprecise and the broad protective canon of Art. 8, the CBD comprises the protective areas of all global protective conventions that entered into force before it (particularly Arts. 8(a), 8(d), 8(l) of the CBD). The rights and duties of a party arising from existing agreements under international law are unaffected (Art. 22 of the CBD).

The preamble of the CBD declares improved coordination with existing conventions and programmes to be a goal, as well as efforts to complement the measures taken under these various regimes. Cooperation with organizational units of different agreements as provided for in Art. 23 IV h and 24 I d of the CBD should be stepped up. Special agreements establish the basis for cooperation between the CBD secretariat and the secretariats of Ramsar, CITES and CMS. The short-term goal of this cooperation could initially be to harmonize the reporting duties. The Council therefore recommends advocacy at the forthcoming discussions regarding the future national reports of CBD to achieve optimum coordination with the reports and implementation of other conventions. It is also important to have a close exchange between the convention secretariats and the bodies of the CSD.

One example for the transfer of implementation programmes from the CBD to specialized conventions is the decision by the CBD to designate the Ramsar Convention as the executing organization for the ecosystem topic 'biodiversity of inland waters'.

The specialized conventions all compile lists of varying degrees of exhaustiveness on the respective protected assets (endangered species, valuable territories). Under the CBD the idea of producing lists of valuable and endangered components of biological diversity was rejected by the contracting states effected (especially the developing countries) who feared that by designating certain biodiversity hotspots there would be restriction and concentration of project funding on the selected regions. The Council advocates identifying worldwide hotspots of biological diversity since this does not just facilitate transparency and orientation but above all provides an important basis on which to perform criticality analyses (Section I 1.4). Therefore particular attention should be given not just to the hotspots of species diversity, but also for instance to the areas of origin of important genetic resources (Section D 3.4.3) and the biosphere functions of ecosystems (Section F 5.3.2).

It is particularly important to coordinate the respective subsidiary bodies of the conventions for scientific and technical advice. In the Council's view there is a need for coordination with regard to project coordination and financing by the GEF. When drawing up the guidelines for the GEF the CBD should also pay attention to the realization of goals and provisions of other relevant conventions. This is particularly possible when planning joint implementation projects.

Furthermore, there are opportunities for joint measures of information dissemination and capacity building. Openings are already visible through the linkage between the Clearing House Mechanism and the information networks of the other conventions. The further design of the clearing-house mechanism should focus on this cooperation and a greater informational exchange. Secondly, the Clearing House Mechanism must develop beyond the status of an information system in order to be able to record the complexity and dynamism of biological diversity across sectoral and thematic lines. This would include for example the evaluation of national reports as central sources of information, the possibility of intersecting geographically explicit information to produce trend and criticality estimates, monitoring and the development of indicators or the development of user-friendly search engines. On the part of the German federal government the Clearing House Mechanism is backed by a research and development project commissioned by the BMU (Federal Ministry for the Environment).

I 3.3.2
Sustainable use

UNESCO 'Man and the Biosphere' programme

The Man and the Biosphere programme (MAB) established in 1970 by UNESCO cannot easily be categorized according to the scheme used in this section: both the conservation of biological diversity and the sustainable use of biological diversity are among the goals of this programme (Nauber, 1995; on the organizational structure of MAB cf WBGU, 1996, 1997). The programme's most important instrument is the biosphere reserves that are proposed and cared for by the member states. These are model areas in which concepts are to be developed and tested together with the people who live and work in those areas by way of examples for the integration of the conservation and sustainable use of the biosphere (Erdmann and Spandau, 1997). Biosphere reserves are tailored to the landscape level, which is particularly important for nature conservation and most neglected. In light of this focus on the bioregional context more detail on the concept of biosphere reserves was given in Section E 3.9 (Box E 3.9-1). Environmental education, research (eg long-term ecosystem research, interdisciplinary research programmes) and environmental observation are important components in this concept. Two examples of biosphere reserves are presented in Boxes E 3.9-2 and E 3.9-4.

The programme derives its particular significance from the combination of the individual areas to a worldwide network (356 biosphere reserves, participation of over 100 countries) in which the results and experiences can be exchanged and for example transferred. In 1995, the statutes for the network and a new strategy were developed (Seville Strategy; UNESCO 1996b). These documents give a clear framework for the programme and for individual biosphere reserves, eg periodic evaluations and reporting duties are envisaged. There is still, however, no mechanism for the denial of status as a result of neglect or failure to respect the regulations. In the Seville Strategy the states have given a number of goals and recommendations that with their modern, integrative approach do not simply give a clear instruction for the design and follow-up of biosphere reserves, but also form a bridge to the Biodiversity Convention. The MAB programme offers very good preconditions that will be an important component in the implementation of the Biodiversity Convention at regional level (Bridgewater and Cresswell, 1998).

It is the view of the Council that these openings should be used to a greater extent in future and also for corresponding national strategies. These include above all the application of the Seville strategy and the further development of the network. The trend towards larger biosphere reserves linked to one another and their environment more effectively and increasingly also transnational biosphere reserves should be welcomed and promoted further (one example is the Franco-German cooperation in the biosphere reserve 'Vosges du Nord/Pfälzerwald'). The MAB programme could be used better as an instrument for international cooperation on biosphere conservation. Since there is no discreet financing mechanism for this purpose, the countries should be encouraged to make increasing use of the GEF. There should not be any competition between the IUCN's worldwide network of protected areas (Section E 3.3.2) and the network of biosphere reserves because the two concepts complement one another (Phillips, 1998). The cooperation between the IUCN Commission for Protected Areas (WCPA) and the MAB programme should therefore be intensified.

Biosphere reserves could play a particular role as experimental fields for integrated biosphere-oriented research and monitoring. This should not be focused simply on ecological research: biosphere reserves should also be used more for pilot projects on economic and social science research questions (eg methodological development for inventorying and valuing ecosystem services, long-term studies on social living conditions for humans and long-term safeguarding of natural life-support systems; Section J 3.2.3).

Global system for the conservation and sustainable use of plant genetic resources

Resolution 3 of the Final Act of the CBD negotiations in Nairobi (1992) calls for clarification of the pending issues relating to *ex-situ* stocks that had been developed prior to entry into force of the CBD, as well as farmers' rights, and adjustment of these to meet the requirements of the CBD. The FAO began in response in 1993 to revise the International Undertaking on Plant Genetic Resources (IUPGR). The IUPGR was agreed in 1983 under the lead of the FAO as a non-binding declaration of intent and deals with plant genetic material as a 'common heritage of mankind' that should be freely available for all users. The aim of the agreement is to ensure that plant genetic resources of economic and social interest (especially for agriculture) are researched and preserved and are available for breeding and scientific purposes. The Commission on Genetic Resources for Food and Agriculture (CGRFA) has carried out a revision of the IUPGR over several negotiating rounds.

The Council welcomes the decision in favour of a legally binding agreement by the IUPGR and recommends support for the negotiations and their conclusion in the period set aside for that purpose early in 2000. This would allow for the COP-5 of the CBD to address the agreement in the same year. The conditions for acceptance of the revised IUPGR as a protocol to the CBD should be examined in good time.

Safe use of biotechnology

The efforts towards safe use of biotechnology are expressed in the CBD in several provisions: Art. 8(g) calls for the parties to create a national risk prevention system in the area of biotechnology, Art. 19 para 4 obliges them to exchange information on possible adverse impacts in the use of genetically modified organisms and pursuant to Art. 19 para 3 the need for a protocol on safety of biotechnology (Biosafety Protocol) should be examined. As is expounded in other sections of this report, the negotiations for that protocol have foundered for the time being (Section D 3.2). There is therefore as yet no binding international agreement under international law on the safe handling of biotechnology. However, there are guidelines initiated by various international organizations that regulate aspects of the field of biotechnology on a *voluntary* basis: first of all there is the Codex Alimentarius (FAO and WHO) from 1962, the voluntary code of conduct of the United Nations Industrial Development Organization (UNIDO) regulating the release of organisms into the environment (UNIDO, UNEP, WHO and FAO) from 1991 and the code of conduct on biotechnology developed by the Commission on Plant Genetic Resources for Food and Agriculture (CPGR). In 1993 the Commission stopped its work however on Section 3 of this biosafety code of conduct since questions of biosafety were to fall more under the auspices of the CBD. Now that the negotiations on a Biosafety Protocol have failed for the time being there is a gap in that respect in the regulations.

Since all of the codes of conduct outlined above are non-binding declarations of intent they cannot easily be instrumentalized as aids for the implementation or even design of an agreement binding under international law. If the COP gives them express mention then they will be recognized to a greater extent. The Council emphasizes that without the Biosafety Protocol safe handling of genetic engineering remains patchy and causes uncertainties. The recommendations of the Council on biosafety can be found in Section D 3.2.2.4.

I 3.3.3
Benefit-sharing

Intellectual property rights

In various international agreements, above all the 1994 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs), the member states have established the standard agreed in that context to be the minimum protection in the design of their national legislation on protection of intellectual property. The dispute surrounding the role of intellectual property for the conservation and sustainable use of biological diversity has led to the obligation being included in the text of the CBD of ensuring that such rights – notwithstanding the law of the given state and international law – are supportive of the objectives of the agreement and do not run counter to those objectives (Art. 16 para 5).

These two points offer an opportunity to explore synergies, but also contain the risk of counter-productive effects. In the implementation of the various provisions at the national level it must be ensured that the protection of intellectual property serves as a prerequisite for creating incentives for the development of new technologies that preserve biological diversity and put it to sustainable use. Ensuring the economic value of genetic resources and traditional knowledge through protection rights would also be an incentive for developing countries to preserve these resources and with them biological diversity. To that extent benefit-sharing with developing countries and indigenous communities could take place via protective rights.

A particular problem in recognizing the traditional knowledge of indigenous peoples is the lack of transferability of protective rights in place up to now. International recognition in the form of a patent generally fails for two reasons: first of all it is difficult to prove that knowledge used for generations is *new,* in other words that no one else has possession of it. The nature of exchange as cultivated over centuries within a community and between communities promoted collective knowledge. Furthermore, it is doubtful whether for example the discovery of the effect of a particular plant contains an inventive action or whether it is simply a discovery that is not coverable by protection (Simpson, 1997).

It is therefore questionable whether patterns of use with very low novelty or inventive aspects could be an adequate protective instrument for traditional knowledge. The weak point in the protection of patterns of use is in addition to the short duration (7–10 years), the lack of recognition at international level (not included in the TRIPs agreement) and within many national legislations (only very few countries, incl Brazil, China, Germany, Japan and Malaysia, recognize this right at national level; Gollin, 1993).

The trade secret might be the best way to protect the traditional knowledge of indigenous peoples. If the knowledge is not in the hands of individual medicine men or shamans, but exists as group knowledge, there can be practical problems in keeping it a secret. Furthermore, it is the obligation of those seeking protection to prove that it has introduced the necessary steps to preserve secrecy. Ecuador, for example, is trying to overcome these difficulties in a pilot project begun in 1997 under the title 'The Transformation of Traditional Knowledge into Trade Secrets'. It is the goal of the project to catalogue traditional knowledge under the guarantee that this will be treated with confidentiality and thus create a monopoly for this information. Knowledge that fulfils the requirements for a trade secret can also be traded in that capacity. The returns are divided between the government and those communities that allowed their knowledge to be registered. The communities commit to using the returns for public projects (Simpson, 1997).

In summary one can state that there are currently no legal instruments at international level that adequately recognize the right of indigenous peoples to their traditional knowledge. In particular, the traditional knowledge of indigenous peoples cannot be placed in the categories of intellectual property.

It would correspond to the CBD goals to create an international protective regime that does not just comprise significant intellectual property rights for an industrial nation, but also the interests of indigenous peoples and developing countries worthy of protection. That sort of option is a possibility at the forthcoming renegotiation of Art. 27 para 3(b) of the TRIPS agreement, according to which at the present time plant varieties can already be made subject to an effective *sui generis* system. Such *sui generis* protective systems – in contrast to general patenting protection – are particularly suited to the economic methods of indigenous and local communities, and should therefore be supported.

In a broader context such overlapping and other conflicts between trade and environment are dealt with by the Committee for Environment and Trade, a body of the WTO. This configuration tends to indicate at least the suspicion that trade aspects enjoy a disproportionately high importance in that body. From the point of view of the Council it would be advisable to express the equal substantive ranking of environment and trade at institutional level.

Convention on the Law of the Sea

As a result of the growing technological possibilities of using genetic and biochemical resources from living marine organisms, the biological diversity of the seas in recent times has increasingly moved into the international spotlight. Certain sea areas appear to be particularly valuable in this regard, for instance coral reefs or the ecosystems around the openings of hot springs on the sea bed. Organisms and bacteria are found in these places that live under unusual heat and pressure conditions and therefore open up new prospects for application (Section D 3.3). The potential of marine biodiversity as a source for new products (medicines, adhesives, dyes) and as a supplier of 'pollutant binders' or enzymes for industrial and bioengineering applications has triggered a number of bioprospecting measures. Many industrialized countries have formed consortia that collect marine organisms and research potential areas of application for marine resources. Large multinational companies and smaller biotech companies have begun collecting and researching.

The legal parameters contained in the CBD pertaining to access to genetic resources and the balanced distribution of the advantages arising from that access are influenced in the area of the marine environment (that is, also marine resources) by the provisions of the Law of the Sea. Therefore they only apply in areas of national jurisdiction in the marine environment if they concur with the 'rights and obligations of states under the law of the sea' (Art. 4a, 22 (2) CBD).

In the territorial seas (12 nautical mile zone) the United Nations Convention on the Law of the Sea (UNCLOS; WBGU, 1996) grants coastal states exclusive right to regulate scientific marine research. And according to the provisions of the CBD, research can only be pursued with the express consent of the coastal state and shall be operated under conditions determined by that state (Art. 245 UNCLOS), which allows the incorporation of adequate benefit-sharing from the use of marine genetic resources.

Also, in the exclusive economic zone (200 nautical mile zone) the Convention on the Law of the Sea accords the coastal states the powers of jurisdiction with regard to scientific research (WBGU, 1996). In determining the nature of the research, however, the rights and duties of other states should also be taken into consideration (Art. 56 UNCLOS). For instance, 'under normal circumstances' coastal states are to agree to scientific marine research by another party to the convention. And this consent may only be refused in cases that are explicitly regulated (Art. 246 UNCLOS). Implementation of the access and benefit-sharing regulations of the CBD must in the context of the exclusive economic zone be oriented to the relevant provisions in the Convention on the Law of the Sea. For instance, at least six months prior to the intended start of research work, detailed information on the research project must be submitted to the coastal state.

Outside national sovereign territory the question of access rights is moot since pursuant to Art. 256 and 257 of UNCLOS all states – regardless of their geographic location – have the right to pursue marine research in that area (the sea bed and its subsoil are beyond the borders of national sovereignty) and in the water column beyond the borders of the exclusive economic zone. International cooperation in the sense of just distribution of financial and other advantages is provided by the Convention on the Law of the Sea only for research and the exploitation of mineral resources from the sea bed (in particular Art. 137, 140 and 143) and furthermore is relativized by implementing the Agreement of 1994. There are no such provisions for the use of the marine genetic resources of the high seas (Wold, 1998; Verhoosel, 1998). Given the large potential profits and the idea of international cooperation for fair and equitable international economic order expressed in both the Convention on the Law of the Sea and the Convention on Biological Diversity that take into consideration above all the special interests and needs of the developing countries the question arises of whether a regime for genetic resources of the high seas should not be considered, similar to the one in place for mineral resources. Pursuant to Art. 118 of UNCLOS and also Art. 5 of the CBD the states are definitely obliged to cooperate with one another and commence negotiations in preserving and managing living resources outside their area of national sovereignty.

I 3.3.4
Implementing CBD commitments within the EU: the example of the Habitats Directive

As well as its member states the European Union also became a party of the CBD and therefore committed itself to its implementation. Determining whether in the implementation of the commitments entered into under the CBD the EU must become active in the form of directives or regulations or whether it leaves it up to the nation states within the EU to concretize the framework obligations arising from the CBD directly in national law, is a decision for the EU and its member states; the EU and the member states cannot however exercise rights on the basis of the convention simultaneously (Art. 34 para 2 of the CBD).

The allocation of competence between the EU and its member states is organized according to the 'principle of limited individual authorization', in other words the Community may only act if that competence has been given to it by treaty. In the sphere of environmental protection this has taken place above all by means of Art. 175 of the EU's Treaty of Rome (Art. 130s TEC). The EU has concurrent competence in relation to the member states in this sphere (Middeke, 1994). Therefore, as long as no Community environmental provisions have been adopted, the member states may issue their own regulations. Despite the competence awarded by Art. 175 TEC, the EU is not able to take action in all areas of environmental protection. The Community must take note of the principle of subsidiarity (Art. 5 TEC) that establishes a limit to the EU's exercising competence. According to this principle, the Community may only become active in the area of environmental protection in cases where responsibilities compete, if and to the extent to which the goals of the measures in question cannot be achieved at the member state level.

Shortly after the CBD entered into force, EU Directive 92/43 on the Conservation of Natural Habitats and of Wild Flora and Fauna (Habitats Directive) was adopted. To the extent to which the sphere regulated by this Directive and the Directive on the Conservation of Wild Birds (Birds Directive 79/409/EEC) adopted in 1979 comprises the commitments of the CBD, the member states may no longer independently become active beyond implementation of the Directive. And so by the same token that means that for those spheres that are not covered by the Directive, each member state must become active in order to fulfil its obligation under international law. There is therefore a need to delineate the substantive scope of the Directive. The main goal of the Habitats Directive is to promote the conservation of biological diversity. The legally binding goal of the Directive (Art. 2 para 1) is limited in the German version to '*species diversity' [Artenvielfalt],* which would suggest a translation error, since the English and French versions talk about *biodiversity* and *biodiversité* respectively at that point.

This goal is to be achieved through provisions to conserve natural habitats and regulations on direct species conservation (bans on culling, fishing and disturbance, as well as trade bans). The core element of the Directive is to establish a coherent, European ecological network of Special Areas of Conservation (SACs) called NATURA 2000 (Art. 3 para 1 of the Habitats Directive). Furthermore, transnational, contiguous land conservation is to be created that would counteract the hitherto insular nature of protected areas and therefore also allow for the genetic exchange of wild species that is necessary to the conservation of biological diversity (Section E 3.3.2).

The protective mechanisms of the Habitats Directive only take place in areas designated in that context. Conservation of biological diversity outside the areas to be created therefore remains the responsibility of member states (Freiburg, 1998). Ecosystems whose diversity also falls under the conservation efforts of the Convention are of central importance in the CBD (Art. 2 para 14 of the CBD; Section D 2). The definition of the ecosystem by contrast is not mentioned at all in the Habitats Directive. The central term in that context is the natural habitat, which is defined by geographical, biotic and abiotic features as a completely natural or semi-natural terrestrial or aquatic area. In the habitats listed in the annex to the Directive one finds areas with definitions as varying in precision as fruit, hay or salt meadows, high and low heathland, rivers, ponds or mudflats. The definition of habitat pertains to the perspective of the species or individual organism, that of ecosystems underlines the functional interdependence between biotic and abiotic nature. These two terms certainly overlap, that is not disputed (Freiburg, 1998). What remains questionable however is whether the protective mechanisms created under the Habitats Directive for habitats also provide sufficient conservation for the diversity of ecosystems. If this is not be the case it remains the task of the states and governments to put in place further regulations by which to fulfil their commitments under the CBD.

Protected areas are often only inadequately delineable within certain national borders (Section E 3.3.2). Therefore certain of the CBD goals can only be implemented at the transnational level. With the EU therefore there is an opportunity for implementing the CBD since it can organize the creation of a networked system of landscape conservation across national boundaries. The EU as a regional organization with far-reaching powers in the environmental sphere can exercise a model role here. It should therefore be considered whether one could not form regional frameworks in other regions that could assume transnational organizational functions in the context of environmental protection. It would appear, however, difficult to realize such an idea. Even at EU level the success of the Habitats Directive is completely dependent on the will of member states to cooperate. No area can be placed under protection by the EU against the will of the respective member state.

More detailed discussion of the rather unsatisfactory status of implementation of the Habitats Directive and the envisaged EU-wide NATURA 2000 network in Germany can be found in Section E 3.3.2.6.

I 3.4
Agreements and arrangements under the UNCED follow-up process

I 3.4.1
AGENDA 21 and the Commission on Sustainable Development

Under the auspices of the Commission on Sustainable Development (CSD) the agreed guidelines and programmes of AGENDA 21 are being pursued and dealt with chapter by chapter, including Chapter 15 where measures for the conservation and sustainable use of biological diversity are addressed. At the 8th

CSD session in 2000, the topic will again be taken up under the focus on integrated land use planning. So far the CSD has issued only very general statements on the topic of biological diversity.

A concrete result pertaining to the CBD was achieved at the recent 7th CSD session in 1999. As a result of the EU's commitment, a call was included in the final declaration for inclusion of tourism guidelines in the CBD. Although the topic 'sustainable tourism' only played a marginal role at the United Nations Conference on Environmental and Development in 1992 and this aspect is therefore only mentioned in passing in AGENDA 21, the CSD was commissioned by a special session of the United Nations General Assembly in 1998 to submit a measures-oriented international programme of work on the topic of sustainable tourism to minimize the negative impact of tourism and promote its positive contribution to sustainable development (Section E 3.7). There are however different views regarding whether sustainable tourism should be address separately just in relation to biological diversity or sustainable tourism as a whole. The Council believes this question should be clarified for the future.

I 3.4.2 Desertification Convention

Decisions taken in the context of the United Nations Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification Particularly in Africa (Desertification Convention – CCD) cannot be seen independently of agreements under other global environmental conventions, since arid areas are particularly prone to environmental change (for a discussion of a global soil convention, cf Box E 3.3-7). At the same time, the biological diversity in arid areas is considered particularly valuable and worthy of protection in light of its adaptation to extreme conditions. Whereas most terrestrial ecosystems demonstrate a high buffer capacity for climate change, this is not true of arid or semi-arid zones. In those areas even minimal climatic changes can amplify the existing high natural variability in such a way that irreversible soil degradation is triggered, and that is always a herald of the destruction of biological diversity (WBGU, 1995a). Arid and semi-arid regions could therefore be some of the first regions to see sustained change in their ecosystem dynamic as a result of global environmental changes (West, 1994). In the same way desertification may also have repercussions on the local and global climate (IPCC, 1996b) and therefore on the vegetation cover. In addition, any permanent degradation of vegetation cover leads to the loss of biological diversity and the release of the greenhouse gas CO_2. Soil degradation can therefore reinforce the increase in 'sources' or the decline in 'sinks' for greenhouse gases. It is clear from this example that agreements in the context of the CCD can no longer be seen in isolation of the arrangements under the two other Rio Conventions. This growing need for coordination between parallel convention processes has become clearer at each of the COPs over the last few years (Pilardeaux, 1997, 1998). A coordinated approach to global environmental conventions is also becoming increasingly important in order to avoid duplication, overlap or even contradictory measures. A first step in this direction is the programme of work on biological diversity in arid regions that was agreed at the 4th SBSTTA session (1999) of the CBD and will be submitted for adoption at the forthcoming COP. This programme of work is based on the ecosystem approach, is oriented to the Convention's triad of objectives and is intended to be demand-oriented and flexible. The goal is to identify synergies, gaps and overlaps in the topic of biological diversity in arid areas in the current programmes of the CBD. In order to avoid duplication, the programme of work is to be developed in collaboration with the CCD and other relevant institutions. One basis for this work is the Memorandum of Understanding between the CBD and CCD secretariats. The issue of biodiversity in arid areas will probably be a focus of an upcoming SBSTTA session. It is also planned to convene an *ad-hoc* expert group on that topic under the auspices of SBSTTA.

Wherever its participation allows, the German federal government should bring its influence to bear at the COPs to ensure that increasingly issues of overlap with other environmental conventions are discussed in the subsidiary scientific bodies of the COPs of the individual Rio Conventions, such as the Committee on Science and Technology (CST) of the CCD.

I 3.4.3 Framework Convention on Climate Change

The terrestrial biosphere plays a crucial role in stabilizing the concentration of greenhouse gases, particularly the concentration of CO_2. It is only if the storage and sink effect is maintained and the biosphere continues in future to absorb as much if not more carbon dioxide than it has thus far that stability will be achieved (Section F 3; IPCC, 1996a). Legally binding, quantifiable reduction commitments from the industrialized states were not adopted until the advent of the Kyoto Protocol to the Framework Convention on Climate Change (FCCC) that has still not entered into force. It provides for a certain amount of offsetting of biological sinks and sources (afforestation, reforestation and deforestation since 1990) against the obligations of the industrialized countries to reduce their emissions (Art. 3 para 3; WBGU, 1998b). Furthermore, Art. 6 of the Kyoto Protocol allows projects that increase the absorption through sinks in other Annex I states to also be offset. And finally, the Clean Development Mechanism (CDM) defined in Art. 12 allows for the certification of emissions reductions that are achieved in projects in developing countries. It is still pending whether sink projects may also be offset or just projects to reduce emissions (WBGU, 1998b).

Regulating the offsetting of sinks in accordance with the Kyoto Protocol raises a number of issues on the definition of offsettable activities or the measurable carbon stocks. One recommendation for a decision at the 1st COP of the protocol on definitions relating to the activities pursuant to Art. 3 para 3 of the Kyoto Protocol (afforestation, reforestation, deforestation) and the offsetting of additional activities pursuant to Art. 3 para 4 of the Kyoto protocol will only be made at the COP of the convention once the IPCC has completed its special report (not before 2000) and the issue has been addressed by the scientific body of the convention (SBSTA). A decision on the precise form of the CDM, including criteria for the selection of projects and the modalities for certification are to be decided after the Buenos Aires Action Plan (COP-4) by the year 2000. There was no coordination between the CBD and the FCCC before adoption of the Kyoto Protocol. And no other negotiating processes such as the IFF were taken into consideration. It is to be hoped that this coordination will be established in future.

The Council has addressed the topic of offsetting biological sinks against the commitments of the industrial states according to the Kyoto Protocol in detail in a special report (WBGU, 1998b). The type of offsetting of activities in the area 'land use change and forestry' as provided in Kyoto Protocol does not take into account the complex dynamics of the terrestrial biosphere and may lead to negative incentives both for climate protection and the conservation of biodiversity. For instance, the transformation of primary forests that are characterized by high carbon content but also high biological diversity, into secondary forests or timber plantations might indirectly be promoted if the offsettable activities are so defined. This would bring about a loss of biodiversity (WBGU, 1998b). If afforestation projects are included in Art. 12 (CDM) this could create an additional incentive to clear primary forests in order to be able to offset the subsequent planting of plantations (WBGU, 1998b; Schulze et al, 1999).

Sink projects in developing countries could however also include forest conservation projects. The protection of an area of forest from logging or degradation would be an offsettable project in line with the CDM if emissions were prevented which otherwise – without the project in question – would have entered the atmosphere. However, if forest conservation projects are offset in the absence of a commitment to produce a complete carbon inventory for the developing country this might lead merely to the spatial shift of emissions: forest destruction will take place somewhere else, outside the project boundaries. This sort of shift is actually very likely, as long as the CDM projects do not address the underlying causes of forest destruction. It is also questionable whether the necessary long-term assurance of forest conservation can be guaranteed. The investors should really be made liable indefinitely for the protected forests. If a forest that was protected under a CDM project is logged towards the end of the project period the carbon dioxide amount thus emitted should be a negative offset against the investor state. However, it is more than doubtful whether that sort of liability mechanism is really realizable particularly in developing countries. Furthermore, both the investing country and the host country have an interest in oversubscribing the emissions reduction thus achieved. This offers in combination with the considerable uncertainty of verifying the sink effect a dangerous incentive for the abuse of offsetting forest conservation projects within the CDM. Offsetting afforestation projects under CDM should be prevented as long as there is no offsetting of emissions in developing countries (WBGU, 1998b). Forest protection projects should only be offset once a complete national carbon inventory has been submitted. And it should also be investigated whether the existing GEF mechanism cannot fund to an increasing degree projects to protect natural stocks and sinks, particularly in primary forests and wetlands (WBGU, 1998b). Since the GEF constitutes the financing instrument for both the FCCC and the CBD, synergetic effects can be used and at the same time the risks associated with offsetting CDM projects avoided.

I 3.4.4
Intergovernmental Forum on Forests

The United Nations Intergovernmental Forum on Forests (IFF) as the successor body to the Intergovernmental Panel on Forests (IPF) held its 3rd session in May 1999. And it is clear that the negotiations continue to proceed extremely sluggishly as a result of serious differences of opinion.

The question what institutional form the outcome of the IFF deliberations will take, that is expected to be forthcoming in 2000, remains unanswered. A binding forest conservation agreement under international law could assume the form of an independent FAO convention or become effective as a protocol in the context of the CBD. Clarification of the institutional questions had up to that point proved to be extremely problematic and so for that reason was postponed until after the substantive discussions, in order not to hold up the negotiations.

The Council has spoken out in favour of a Forest Protocol under the auspices of the CBD in the past (WBGU, 1995b) and still considers this solution to be the most promising with regard to the goal of a global policy of sustainability. In a forest convention that is to be renegotiated and anchored to the FAO, the main emphasis would likely be on use. Equal rights for conservation and sustainable use of biological diversity as already enshrined in the CBD would have to be renegotiated and established. However, given the lack of international consensus on a CBD protocol a separate forest convention would be preferable to a merely non-binding continuation of the discussion in an intergovernmental body.

I 3.5 Incentive instruments, funds and international cooperation

I 3.5.1 Incentive instruments

In Art. 11 of the CBD a call is issued to all parties to recognize the importance of incentive instruments and increasingly to deploy social and economic incentive measures for the conservation and sustainable use of the individual elements of the biosphere. Drawing on that call, the OECD deployed a working group that focused on the economic aspects of biodiversity (Working Group on Economic Aspects of Biodiversity). In December 1998 the draft of a manual was published that discusses the options relating to incentive instruments in biodiversity policy; it is based on 22 case studies. The aim of the handbook is to provide policy with guidelines – coordinated with the ecological, social and economic framework conditions – to be able to make increasing use of incentive instruments for the sustainable use of biological diversity (OECD, 1998).

In contrast to command-and-control regulations, economic incentive instruments do not prescribe certain actions, as do for example the statutory provisions on the installation of certain filter equipment under the German Emissions and Ambient Pollution Control Act (*Bundesimmissionsschutzgesetz*). Rather the cost-benefit ratios associated with certain alternative actions are changed. Emissions certificates, such as used successfully in the United States in the context of clean air policy, mean that emissions reductions pay off financially since certificates acquired at an earlier date can be sold. Emissions taxes increase the cost of emissions. The decision of whether to continue with emissions or to buy filters to reduce tax payments ultimately remains the decision of the individual decision-maker. By means of that type of economic approach the information advantage that exists at the decentralized level is exploited, particularly to assess alternative actions. Instead of prescribing uniform action by law, with the economic approach it is up to the economic players themselves to decide in accordance with their own cost-benefit analysis what action to take.

The CBD calls on parties to make greater use in biosphere policy of instruments that draw on the advantages of economic rationale. A fundamental message from the OECD handbook is therefore that appropriately defined property rights and economic incentives should be utilized, wherever possible, to provide incentives for sustainable use, and that recourse should only be taken to regulations, access restrictions and sustainable use subsidies where this is absolutely essential (OECD, 1998).

In light of the large number of players that are involved in protecting and using biodiversity and the complex links between the anthroposphere and biosphere, the OECD handbook is based on a broad understanding of incentive instruments. In addition to economic incentive instruments in the narrow sense (ie property rights, taxes and other levies, certificates) the following measures are also counted under incentive instruments:

- strengthening scientific and technical capacities,
- including all relevant players in the decision-making process on the conservation and use of the biosphere,
- ensuring that all available information on biological resources and their impairment is provided to decision-makers,
- strengthening or creating suitable institutions in order to be able to make the requisite political decisions,
- implementing and enforcing incentive measures in the stricter sense,
- monitoring biological resources.

All of these measures are requirements for support for the sustainable use or conservation of biological resources to be forthcoming. Therefore, they constitute the requisite framework conditions for successful deployment of the above-mentioned incentive instruments in the narrow sense and form an important foundation on which a consistent and successful policy mix may be based (OECD, 1998).

It is very difficult to elaborate any one single policy instrument in such a way that it alone is in a position to deploy to all the relevant players just the right incentives for the conservation and sustainable use of biological resources. In its handbook therefore the OECD recommends using a broad spectrum of incentive instruments in order to do justice to the differing problem pressures within the field of biosphere conservation and the varying interests of the participating players. Since many incentive instruments overlap in their mechanism of effects, this also caters to the case where an instrument is not able to provide the requisite incentives.

The statement that only a combination of incentive instruments does justice to the goal of the CBD of promoting sustainable use of biological resources is to be seen in direct combination with the broader understanding of the OECD with regard to the definition of incentive measures. The use of combined incentive instruments requires suitable scientific, technical and policy capacities and institutions. Here, the importance of capacity building for successful implementation of incentive instruments is clear (OECD, 1998).

The Council emphasizes that as a rule the combination of different incentive instruments is necessary. At the heart of this approach is the allocation of property rights. However, in order for conservation and use goals to be achieved in the long-term, accompanying incentive instruments such as taxes and subsidies or also regulative measures such as restricted access should be included. Above all the concept of biosphere reserves that is oriented explicitly towards the conservation and sustainable use of biological resources requires a combination of a number of instruments of an economic, legal and planning nature (Section E 3.9).

I 3.5.2
Environmental funds

Implementation of a policy to preserve biological resources requires additional funds since the financial support agreed at UNCED has not yet been available at the anticipated level, but the pressure of problems is continually increasing. Regulations relating to conservation and management must be implemented and monitored and users of biological resources compensated for restrictions. Art. 20 and following of the CBD call therefore for increased financial commitment from the signatory states, in particular the economically stronger countries, and the reinforcement of existing financial institutions.

Explicit reference is made to the GEF (Art. 29). However, that gives the impression that international environment funds are endowed exclusively from public budgets. Contrasting with that impression, in the following discussion the assumption is of a broader understanding of the use of funds.

The reality on the ground however is one of opposition to the call for additional funds for the conservation of the biosphere in many respects. Public funds in favour of international environment and development projects are decreasing against the background of budget shortfalls and economic structural crises. At the same time up to 1997 foreign private investment, especially in Southeast Asia, Latin America and Central and Eastern Europe, rose dramatically. There was discussion of activating this private investment willingness in favour of the worldwide conservation of the biosphere. At international level these have been dissussed in light of experience in the preceding years with the increasing number of new environmental funds with regard to greater incorporation of the instruments of international financial markets in the funding of environmental strategies. Foreign private investments, eg in the area of bioprospecting and the development of labelling systems for products derived from forms of cultivation that preserve the biosphere, can in addition to private – philanthropic – foundations and sponsors become important sources of funding for national environmental and development projects (McNeely and Weatherly, 1996; Acharya, 1995). A report issued by UNDP at the end of 1997 listed 46 funds already in existence and 11 about to be introduced in developing countries (Bayon and Deere, 1998) funded from both government sources and private donations. If the Asian financial crisis comes to an end soon and foreign investment increases once more, the discussion about strengthening private commitment in the development and management of international funds should be explored more thoroughly.

Environmental funds address a vast field that ranges from support for specific individual projects, eg national parks in Uganda and Jamaica, through to the implementation of national and international environmental strategies, eg the Indonesian Biodiversity Strategy. Correspondingly, there are also many ways in which the fund capital can be used, whether as direct subsidy or funding the launch of financially self-sufficient environmental projects. In connection with ongoing funding the various aspects of an endowment may be used; the interest accrued on the nominal capital (foundation solution), ongoing revenues (from contributions or fees) and the disbursement of the fund's capital at a particular time, including interest. The fund capital (as in the case of GEF) can come from internationally agreed donations from member countries, direct bilateral development assistance, the use of debt-for-nature swaps (Section I 3.5.3.2), private foundations or the proceeds from specific usage fees.

By contrast to general government (multilateral) financing, funds offer the opportunity of deploying money in a targeted way and are therefore recognizable to the public and may be monitored for specific purposes (McNeely and Weatherly, 1996; OECD 1998). Successful deployment of this financing instrument requires clear administration, monitoring of fund use on the basis of the fund's goals and assurance of continual impetus for international environmental protection. Existing environmental funds have drawn on a range of organizational solutions where in particular the inclusion of the private sector is being pursued with varying degrees of intensity. For instance, NGOs and private foundations are involved in fund raising and management. Incorporation of private companies, eg pharmaceutical companies in the area of bioprospecting, in the development of environmental funds is limited at the present stage to just a few environmental funds. By strengthening this incorporation however in the medium term two important potentials emerge for funding international environmental policy:

1. Relief for public budgets;
2. Strengthening and more efficient organization in the use of funds since, particularly in the case of multilateral – publicly financed – funds there are often high administrative costs and a lack of transparency in the rules governing the allocation of funds (Bayon and Deere, 1998).

Therefore institutional incentives and infrastructures for intensified private commitment should increasingly be created. Enhanced commitment for private environmental funds or financial innovations beyond that scope is appropriate in cases in which the protective goals can be asserted through the creation of clear property rights and the development of private markets. Investments can then be planned on the basis of the anticipated revenues (eg income from natural parks, tourism or bioprospecting) with activation of a latent willingness to pay assuming particular importance (Section I 2). In the area of preserving particularly valuable ecosystems and global regulatory functions, however, it is perhaps more appropriate to conceive of private funding from sponsors as playing a supplemental role. To ensure a financial basis for preserving resources that have a high option value (food production, renewable resources, bioprospecting) in addition option rights against later economic use might also be issued via international financial markets. Having said that the financing effect is essentially limited to a onetime issuing of usage rights, with positive impetus for the enforcement of conservation concerns hinging on price trends on the financial markets (Lerch, 1996; Becker-Soest, 1998b). Experience so far with the use of environmental funds indicates that the following aspects in particular determine need for political action.

Transparency and operationalization of financing criteria

For capital donors, but also for possible beneficiaries, it is crucial for the goals that are envisaged by the environmental fund to actually be achievable. Clear criteria and control mechanisms are required in this case. An example of a criterion that is relatively difficult to implement would be the provision of the GEF that funding is only available for incremental costs incurred in the protection of the global environmental assets.

Decentrality and diversity of the environmental fund

The special nature of local parameters and the need to implement management rules and conservation goals make it advisable also when organizing and setting targets for the environmental fund to adopt a differentiated approach worldwide. The Council therefore welcomes the diversity of the environmental funds emerging with regional focuses, eg in Latin American and Asia. A prerequisite for the successful development of decentralized environmental funds, particularly with the introduction of additional private funding elements, is however the development of an appropriate infrastructure. This includes, in addition to the use of decentralized incentive instruments, the promotion of local financing structures in rural regions (Yazon and Benjamin, 1997), in order to facilitate the attractiveness of these areas for foreign investment but also access for the local population to funding and decisions on the implementation of management rules.

Networking of decentralized environmental funds

Regardless of the large number and differing nature of the various environmental funds, in order to realize global conservation goals an international concerted effort is required. Support for opposing or parallel projects reduces the effectiveness of financing instruments deployed. Furthermore, against the background for instance of labelling strategies and image campaigns employed by private funds, the participation of private players demands a high degree of transparency in all activities. This is where existing international organizations in cooperation with the national government could fulfil important information functions regarding best practices in the area of funding and possibilities for private participation, in order also to ease their transition into the international financial markets (Chichilnisky, 1997).

INCORPORATING WORLDWIDE COMPENSATORY GOALS

The discussion on funding for international environmental and development projects is often eclipsed by the North-South conflict. Given the worldwide importance of biological resources in economically weak countries, any worldwide conservation strategy will require financial support from the OECD countries. Options for linking these redistribution concerns to the efficient use of financial resources are however overwhelmingly to be found in the shape of decentralized incentive instruments in combination with strengthening the access of the local populations in many developing countries. To that extent a call for increased financial commitment from the economically strong countries must precede any strengthening of decentralized incentive instruments or the dismantling of existing misplaced incentives, eg in the area of international agricultural policy, and obstructions to local population groups.

Overall therefore funding for international policy for the conservation of the biosphere is really only in second place a call to the OECD countries to increase their financial commitment from the public purse. As experience with environmental funds has shown, there is above all a need to act in developing institutional structures and advancing information and incentive systems. The Council therefore advocates the differentiated deployment of environmental funds with a special focus on private financing instruments in the context of preserving food, raw materials production and prospecting, as well as implementation of management strategies. If it is also possible to dismantle the many misguided incentives that threaten the biosphere through subsidies, then implementing an international policy to protect the biosphere does not necessarily have to be associated with financial burdens on the public coffers.

I 3.5.3 Development cooperation

I 3.5.3.1 Biosphere conservation activities

Development cooperation is an important instrument for biosphere conservation. Two sectoral concepts from the German Federal Ministry for Economic Cooperation and Development (BMZ) provide the basic lines of German development policy in the context of international nature conservation. In 1992 the framework project 'Promoting the implementation of international tropical forest-relevant programmes' was launched, in 1997 this was joined by the sectoral concept 'Preserving biodiversity through nature conservation'. In both concepts the search for compensatory mechanisms to offset usage waivers play an important role. The fundamental idea is that through the creation of income sources in and around protected areas and the controlled use of protected areas compensatory opportunities may be created to replace traditional forms of income (Section E 3.3).

In addition to sectoral concepts the BMZ also has fixed-term sectoral projects that are initiated as pilot projects. In 1993 a sectoral project 'Implementing the CBD' (BIODIV) was established that was to support developing countries in the national implementation of the Convention and also therefore individual measures of pilot nature. Support for national biodiversity strategies also falls under this project. The project is carried out on behalf of the BMZ by the German Society on Development Cooperation (GTZ).

The Tropical Ecology Support Programme (TÖB) established in the follow-up to UNCED is a transregional service project executed by the GTZ that serves to provide demand-oriented project support in the areas of tropical forests and tropical ecology. The aim of the TÖB is to increase the ecological sustainability of development cooperation projects. To this end a project-accompanying research and advisory service has been built up that assists development cooperation projects in environmentally relevant questions. The results achieved flow directly into the project planning and implementation process. The TÖB publishes its findings and makes them available to other sectors and organizations involved in development cooperation.

The goal of the sectoral project on tropical forest conservation is to document the work of NGOs in the area of national nature conservation and contribute to achieving acceptance for their work. A database containing the participating NGOs was compiled which is also intended to support development cooperation measures. Furthermore, support is given to national and international NGOs that are active in the area of tropical forest conservation (30 projects).

The German contribution to the international agricultural research network CGIAR (Consultative Group on International Agricultural Research) is backed by the sectoral project 'Promoting international agricultural research' that strengthens national agricultural research through a number of projects. The strategic reorientation of CGIAR towards the protection of natural resources and the environment and the conservation of genetic diversity, which took place in 1995, was a milestone in that context. Moreover, there are a number of projects on biosphere conservation under bilateral cooperation.

Beyond that Germany provides experts to work throughout the world in the framework of development cooperation on the conservation of the biosphere. Furthermore, there is the Kreditanstalt für Wiederaufbau (KfW) which provides support to the investments of Germany's partner countries, and has dedicated 30 per cent of its total commitments to backing developing countries in the area of environmental and resource conservation (1998: US$400 million). Germany is also active in the conservation of the biosphere in the multilateral context. Between 1994 and 1997 Germany's contribution to the GEF was around US$200 million, which accounts for 12 per cent of the total budget. After Japan and the United States, Germany is the third largest contributor.

Overall the Council endorses the concepts developed by the BMZ in the area of development policy conservation work and recommends that this route be pursued further. The sectoral concept 'Preserving biodiversity through conservation' is particularly important since it defines nature conservation work as a cross-sectoral task. Initial efforts to increase the spatial scope of nature conservation are already under way.

I 3.5.3.2 Financing instruments

Despite the commitment that can be seen in the area of the conservation and sustainable use of the biosphere, it must be noted that if the current demographic trends in the developing countries persist for the foreseeable future the last remaining semi-natural areas will also be in danger. Particularly in Latin America, Africa and Asia, the concept of sustainable use of natural resources will encounter limitations. A strategy for the sustainable use of these resources will only be in a position to satisfy the growing usage interests if it can be upgraded as required, in other words if it can produce more for the people. Therefore, protected areas too will have to become more economically viable, in order to convince decision-makers on the ground that they should be preserved (Krug, 1997). This will be impossible without external help. Furthermore, the loss of biological diversity is advancing at such a great pace that in many instances the focus will have to be on selecting the most important areas to be saved.

Global Environment Facility – GEF

Internationally, the GEF is already an important financing instrument for the conservation and sustainable use of biodiversity, but in recent times the complaints about how difficult it is to prove incremental costs have been multiplying. Many biodiversity conservation projects have a local focus and have difficulty proving their global relevance. This problem does not exist in the context of climate protection. The GEF which was established in 1991 in response to a Franco-German initiative only covers incremental costs that developing countries incur for *global* environmental protection and not the costs for those measures that a given country would have initiated anyway under its national policies. The funding of projects through the GEF is always a supplement to the efforts of a country or bilateral and multilateral development cooperation. Around 40 per cent of GEF funds go to projects that serve the conservation and sustainable use of biological diversity. 4.1 per cent of these funds serve to preserve biodiversity in arid and semi-arid areas, 6.5 per cent in coastal zones, 15.5 per cent in forest ecosystems, 2.4 per cent in mountain ecosystems, 2.2 per cent in other support activities and 8 per cent of GEF funds for biodiversity conservation are deployed for short-term measures. For the period 1998 to 2002 GEF has a total of US$2.75 thousand million at its disposal.

An additional financing instrument could emerge from the Clean Development Mechanism (CDM) agreed under the Kyoto Protocol, although the countries of Africa fear that they will be hardly considered at all in that context. Also in the context of international cooperation support has been given for a long time now by development cooperation institutions and private donors to national conservation funds to safeguard investments in the area of nature conservation. However, this instrument has to be used carefully since there is the danger that all that happens is that national budgets are relieved of a burden they would otherwise shoulder. For this reason German development cooperation has been hesitant to use that particular instrument.

Debt-for-nature swaps

The Council sees debt-for-nature swaps as a promising instrument under development cooperation. By swapping debts for conservation measures the intention is for developing countries to be in a position to reduce their debt burden and at the same time make investments in resource conservation. This instrument constitutes a meaningful financing option for nature conservation projects if the conditions are accepted and controls allowed. Worldwide between 1987 and 1994 around US$178 million was waived under debt swap facilities and made available for projects to conserve biodiversity (Bayon and Deere, 1998). Since 1993 this instrument has received US$100 million in support from Germany annually and currently over US$350 million of that is in the implementation phase. Up until recently debt swaps were limited to bilateral and private creditors; multilateral creditors had not been involved in debt swaps.

This stance shifted somewhat as a result of the IMF and World Bank initiative launched in 1996 for Highly Indebted Poor Countries (HIPC). This strategy is based on the approach that debt relief on the part of the international donor community is linked to implementation of economic policy rejuvenation and reform measures by the debtor country. On that basis a considerable lowering of the debt burden for seven countries has been achieved, which so far have received commitments of over US$3 thousand million in debt relief. The G8 Summit in Cologne in 1999 gave a clear signal of continued support for the poorest developing countries. The German federal government's Cologne Debt Initiative that was adopted on that occasion aims above all to deepen and expedite the HIPC initiative. By the year 2000 all eligible countries will be given clarity on the scale and timing of the debt relief they can expect to receive. The debt burden of the poorest countries of the world is to be relieved by up to US$70 thousand million. It is expected that 36 developing countries will benefit. On the basis of this multilaterally agreed approach a binding and complete debt waiver was also agreed in the Paris Club for those countries that qualify for assistance under the HIPC initiative. The debitor countries are to be able to use the funds thus released for projects that promote sustainable development. In the Paris Club that was founded in 1956 the creditor governments negotiate with their debtors on the public, bilateral debts of countries of the South. The larger OECD countries as major creditors are generally involved in all rescheduling negotiations. Criticism of this debt initiative (from churches amongst others) is directed at what they see as the inadequate scale of the debt relief measures. The Council welcomes the debt initiative because the countries in question will amongst other things be given greater scope to conserve the environment, and considers further steps in this direction to be appropriate. In order to improve and strengthen biosphere conservation, however, a greater financial commitment from official development cooperation is required. In this context, the Council has repeatedly pointed out that an increase in funding for Germany's development cooperation appears urgently required and that a target of 1 per cent of Gross National Product would be a worthy goal and appropriate to the urgency of the problem (WBGU, 1994, 1998a).

Research strategy for the biosphere J

Perhaps the most important aspect in relation to the topic of the biosphere is the extraordinary lack of knowledge. Only a small fraction of the world's species has been described so far, and we do not even know the total number of species worldwide. Just to attempt to record and describe the whole spectrum of species on the Earth would be the job of the century. If one were also to research the role that each species plays in the ecosystem or the possible benefit that could be derived from each species, then research would be faced with an almost insoluble problem. Scientific explanation of the ecological function of just one species is extremely elaborate and difficult: the task of doing this fully for the known, let alone the unknown, species is titanic. In that light, the question of setting priorities in biosphere research is of crucial importance.

Since this report – like the Biodiversity Convention itself – does not consider biological diversity in an exclusively biological context, but also incorporates socio-economic interactions, a research strategy to address the issues cannot be restricted only to research in the biosciences in the narrow sense – such as taxonomy, systematics or ecosystem research. Integration with the sustainable use of biological diversity (agricultural, forestry, fisheries) must also be ensured. This requires an interdisciplinary approach that also incorporates for example economics, ethics, psychology and sociology: for instance, methods for economic valuation, awareness-raising and benefit-sharing in the access to genetic resources.

The more comprehensive the mission, and the broader the circle of disciplines involved, the greater the danger is of simply pursuing 'multidisciplinary' research that merely juxtaposes the results of different disciplines without integrating them into the actual research approach. The elements of proposed biodiversity programmes are often formulated in such a general way that almost every biological-ecological project would be at home there: the mode of approach is more encyclopaedic than strategic.

Accordingly, biodiversity research has so far had little influence on political decision-making (Catizzone et al, 1998). The urgency of the biodiversity crisis and science's responsibility to society, coupled with the scarce resources available for research, thus make a strategic approach all the more imperative.

The starting point for a problem-oriented strategy should be the question of what services or products are being endangered which the biosphere provides for humankind and society, or what acute problems exist in the interaction between society and the biosphere (di Castri, 1996). One core issue in that respect is how many natural ecosystems and how much biological diversity are necessary at the various levels (local, regional, global) to secure these ecosystem goods and services for the long term (PCAST, 1998).

In fact, a whole bundle of these key questions may be posed: What does the biosphere provide for humankind? What elements are particularly valuable to humankind? Which of these are indispensable? Can they be explicitly defined in geographical terms? Is it known what state they are in and to what threats they are exposed? How can limited resource capacities be used as efficiently as possible for the protection of these particularly important elements? How can international cooperation be guaranteed in favour of this approach? How can duplicate work be avoided without giving up the necessary research competition? Is the methodological and theory base adequate to provide satisfactory answers to these questions? These sample questions could easily be expanded to form a long list.

In this chapter the Council provides a strategic framework for biosphere research that can serve as a basis for a European and internationally networked research programme. Part of this framework can already be filled out with concrete substantive research recommendations, but the Council does not claim to have been exhaustive.

The following three aspects form the key parameters of a strategy for biosphere research: (1) priority must be given to research into the cognitive foundations of the guard rail strategy on the biosphere (Section J 1); (2) in addition, there must be research into methods and instruments (Section J 2); (3) given the deficit in knowledge and theory, broad-based pure research is required comprising both biological-ecological and socio-economic elements (Section J 3). The Council has already outlined certain elements for that kind of strategy in its research report (WBGU, 1997); these are addressed anew and supplemented here. The proposals put forward in Section J 3.1 on biological-ecological basic research can very easily be reconciled with the core programme elements of the global research programme on biological diversity 'Diversitas' (Diversitas, 1998).

J 1 Research on the five biological imperatives

In Section I 1 the Council developed a guard rail strategy for the conservation and sustainable use of the biosphere; it also serves as a useful point from which to set research priorities. In order to translate the guard rail strategy into a research strategy, we have subdivided the following according to the five biological imperatives (Section I 1). In this chapter reference is made both to research questions raised in this report and to a number of current publications on the topic (Solbrig, 1994; Holz and Kaule, 1995; GTZ, 1997; RMNO and NRLO, 1997; Ziegler et al, 1997; Barthlott and Gutmann, 1998; Catizzone et al, 1998; Linsenmair, 1998; Meyer et al, 1998; PCAST, 1998; Specht, 1998; Diversitas, 1998).

J 1.1 Preserving the integrity of bioregions

The landscape is the 'habitat of humankind'. At the regional level humankind can experience and understand nature, biodiversity, ecosystems and biogeochemical cycles (Section E 3.9). Above all, it is at that level that concrete problems in the conflictual field of land use versus nature conservation are expressed even if they depend essentially on national or global framework conditions. It is essentially crucial to the integration of natural sciences, social and sociological research at that level: bioregional research should be interdisciplinary. That is why it is becoming increasingly important to promote biosphere research at this scale.

The Council has emphasized the equal status of different demands of a given landscape: conservation before use, conservation through use and conservation despite use (Section E 3.3). In each of the three areas – which constitute more of a continuum than strictly distinguishable types – the use and conservation of biological diversity must be reconciled even if in a gradated and differentiated form. A host of research questions result from the development of a differentiated system of land use.

PROTECTED AREAS: 'CONSERVATION BEFORE USE'

- At the level of the bioregion, the definition and evaluation of the ecosystem services of semi-natural ecosystems (Box D 2.5-1; Section E 3.9) and criteria for the proper selection of protected areas and their topological context are all important research questions. In cultivated landscapes, nature conservation often faces particular challenges from structural change in land use which should be countered through problem-oriented research (eg open land biotopes in Central Europe; BMBF, 1998). The research questions on the global significance of protected areas are discussed in Section J 1.4.
- Land use decisions that are made for a given location in the landscape often have an impact on other areas. An understanding of the influence of and threats to the services protected areas provide as 'islands' amid surrounding cultivated landscape and their socio-economic framework conditions and driving force is a prerequisite for successful nature conservation. In order to be able to understand these connections, research is necessary in the area of the larger *landscape patterns and processes*. An important research topic is also the development of methods for recording regionally significant ecosystem services and their importance for the surrounding intensive use areas.
- Recognizing the *limits of sustainable use* in natural ecosystems (eg local recreation and tourism, collecting and bioprospecting, hunting, fishing, timber harvesting) and the selection of suitable nature conservation instruments for regional implementation are key topics. Increasing value must be attached to research on the role of local communities for the conservation of biological diversity (the relationship between cultural protection and nature conservation; Section E 3.5), on the status of nature conservation in the population and on suitable communication of its goals.
- There is an increasing demand for scientifically founded concepts on the *restoration or re-naturation* of already degraded areas (both terrestrial and marine) (Box D 2.4-1). Research on the

importance of fragments of remaining natural vegetation, on corridors and stepping-stone ecosystems is particularly important. Comparative studies over long periods of time that comprise socio-economic components are to be recommended.

Extensive land use: 'conservation through use'

- The concept of 'conservation through use' means a *balancing act* between the economic capacity and the preservation of important ecosystem structures or services. Accordingly, research will have to provide answers to the following questions, among others: What forms of extensive use are economically viable? How can ecological services and the conservation of biological diversity in the cultivated landscape be evaluated in monetary terms (Section J 3.2.3)? How can the conflicts between the use and conservation of biological diversity best be solved?
- This landscape type offers a particular opportunity to integrate the conservation of the (wild and domesticated) diversity of *plant genetic resources* into agricultural use (Section J 1.2). There are still considerable knowledge gaps in the corresponding methods, their application and evaluation.
- The *case studies* up to this point must be evaluated in order to achieve a better adaptation of the regional situation in each case. The interaction of economic incentives, motivation of the local population, the needed institutional framework and the adherence to ecological objectives in the 'conservation through use' strategy require a more thorough and systematic evaluation.

Intensive use: 'conservation despite use'

- In the case of *intensive land use*, biological diversity also strongly influences the incidence and control of damaging organisms, pathogens and pollinators. With regard to sustainable and environmentally friendly land use, particular attention should be dedicated to this aspect and research should be stepped up in this area.
- The Council sees a need for research on the *relationships* between biological diversity (structure and function) and the services of intensive-use ecosystems (Section J 3.1.3). The issues that present themselves here relate to the specific combination of species that are required to maintain the self-regulatory functions of the system, and also to ascertaining the critical masses of biological diversity, in order to maintain services in intensively used agro-ecosystems. There is also a need for further research on the functional linkage of intra-systemic and inter-systemic biodiversity. This would include clarifying to what extent a site-appropriate relationship between structural diversity and agrobiodiversity supports services or has a stabilizing effect, and what landscape changes or changes in use lead to detrimental effects. To this end, research on biological and genetic diversity should be linked.

Overarching questions

The challenge at regional level consists of integrating the various landscape types in the region in order to achieve stable, multifunctional land-use systems and/or strategies for the sustainable use of natural systems that are adapted to the biogeographical and socio-economic conditions in a given region (Section E 3.9).

- External inputs into agriculture are sometimes in a substitutive relation to ecosystem services. Working on the premise that the conservation of agrobiodiversity can best be guaranteed through the sustainable use of agrobiodiversity, an urgent need for research arises in *ascertaining the potential and actual contribution of agrobiodiversity* to productivity, stability and sustainability of agro-ecosystems (Section D 3.4). The targeted contribution or deployment of biological diversity as a 'means of production' needs to be investigated.
- *Recording biological diversity*, the resources and services of ecosystems and agrobiodiversity, and evaluating their status or trends using indicators all face major methodological problems (Section J 2.1). Solving those challenges will provide an important foundation for the development of regional sustainability indices and spatial models at the various scales. Analysis of the threat to important ecosystem services posed by human activity, estimation of the consequences and developing criticality thresholds would all benefit enormously from that sort of spatial model. One core issue in this context is how our ability to anticipate the response of complex ecosystems to disruptions might be improved (Section J 3.1.3).
- The different conditions prevalent in various forms of society – above all *socio-economic and agro-political framework conditions* – for successful, regional management with and by the local population merit closer consideration. Cross-disciplinary research in the natural and social sciences relating to regional management structures with the participation of local players is required to this end. Bioregional management and the various instruments associated with that approach should be accorded greater attention by research. In particular, research should be conducted regarding the impact of legal, economic and agro-

political framework conditions on the connection between land use and agrobiodiversity.
- The three *landscape types* have been categorized only very broadly in this report. In order to facilitate the formulation of concrete recommendations for action for specific regions it is recommended that criteria be developed by means of which a system for classifying landscape types differentiated by region might be established.
- There is a great need for knowledge about regional *carrying capacity limits for tourism*, in particular in relation to the designation of zones of specific use intensity. It should therefore be investigated whether tourism capacity limits can be ascertained for various natural landscapes or protected areas using critical 'disturbance rates' for animals, plants or ecosystems.
- There are already a number of successful programmes in Germany on *tropical forest research and tropical ecology* that enjoy good cooperation with developing countries (BMBF 'SHIFT' programme; Tropical Ecology Support Programme of the GTZ; Section I 3.5.3.1). These experiences should also be used in other areas. For instance, joint projects bringing together German scientists and scientists from developing countries to work on agricultural research should receive greater support, since they offer crucial contributions to global food security, poverty reduction and environmental and resource conservation (ATSAF, 1996). Research 'on the ground' assumes an important multiplier function. The drop in financial support for international agricultural research should be counteracted by German involvement (WBGU, 1998a). In particular, we recommend that the BMZ makes more funds available than in the past in support of research on diverse aspects of biodiversity for food, fodder and raw materials production in developing countries. These activities should be coordinated with those of the BMBF and the BML. In order to incorporate the research potential of the universities to a greater extent, the DFG should also be involved in drafting such programmes.

J 1.2
Safeguarding existing biological resources

FOUNDATIONS AND EVALUATION

- The '*strategic genetic reserves*' of humankind must not be endangered (Section I 1.2). This includes above all the traditional varieties of crops and livestock and the wild species related to them. Therefore, as a general rule, research into genetic resources should be directed at maintaining and enhancing the diversity of varieties and the spectrum of cultivars (Section D 3.4; Meyer et al, 1998).
- Increased *recording of and research into cultivated and wild species 'on farm'* is an urgent necessity (FAO, 1997a). This should also include the crop plants that do not belong to the 'Top 30' (Section D 3.4.2). Cultivated plants such as manioc, potatoes, millet, amaranth or trees used in agroforestry that are important food staples regionally and whose potential is a long way from being exhausted are in urgent need of further development by means of plant breeding and eco-physiological research.
- *Identification of valuable wild species* or populations with desirable characteristics (eg resistances) for ensuring the genetic diversity of the cultivated species should take priority. Furthermore, the potential uses of plants, particularly with respect to the development of environmentally friendly products, and expanding the spectrum of cultivars being cultivated as suppliers of renewable raw materials, must be researched.
- The models for *forecasting sustainable fishing yields* must be improved (Section E 3.4). At the present time fishing quotas can only be fixed for the current year since the recruitment of young fish fluctuates greatly from year to year. However, through interdisciplinary and internally coordinated studies in fishing biology and planktology, physical oceanography and meteorology, greater understanding could be achieved on controlling recruitment, which would then have to be reflected in longer term prediction models.

STATUS AND TRENDS

- Work on *distribution maps of the wild related species* for cultivated plants and animals *in situ*, taking inventories and compiling digital catalogues of species in protected areas and inventories of old varieties and local varieties should be advanced (Section D 3.4).
- Systematic *investigation and evaluation of plant genetic resources ex situ* and population genetic studies on the state of these resources is an area that is still largely being neglected (Section D 3.4). Therefore, the Council welcomes the envisaged improvement in the documentation and information systems on plant genetic resources in Germany and feels that this should be expedited (Begemann et al, 1999). Research should focus on elements of a possible early warning system for genetic resources.
- The existing or planned national and international *databases on alien species* have different content congruent with the differing goals pursued in each

case (Section E 3.6). Coordination, standardization and simplification of these databases would help avoid overlaps and make this set of instruments far more effective.

Threat

- One reason for the failure to find consensus in the negotiations on the Biosafety Protocol (Section D 3.2) is the insufficient realization of the *risk potential of 'green genetic engineering'*. In this area, therefore, there is a crucial need for risk research (safety and support research and long-term monitoring) that should take account not just of ecological, but also socio-economic and cultural impacts. Since 'green genetic engineering' is an area with major economic expectations, it must especially be ensured that the research is guaranteed to be independent of vested interests (WBGU, 2000a).
- Also, other direct and indirect *potential dangers* to the genetic resources of cultivated species should be investigated and inventories produced on endangered genetic resources in the area of origin.

Management

- Development of combined *protective strategies for genetic resources* is conditional on there being comparative research on the advantages and disadvantages of the various instruments (*ex-situ, in-situ* and *on-farm* conservation). The focus, however, should increasingly be on *in-situ* conservation; particularly in the case of *on-farm* projects, there is a need for research to make up ground on the conservation of genetic diversity under various ecological conditions. Research should also give greater consideration to the options for biosphere reserves and protected areas to improve the substantive interlinkage of traditional nature conservation and *in-situ* conservation. The priorities are: (1) research on the size of population necessary to avoid negative effects from genetic drift; (2) development of reasonably priced and manageable methods of reproduction; (3) development of efficient transfer mechanisms to finance conservation and benefit-sharing in the use of agro-genetic resources.
- Fishing for living marine resources must be designed in a way that has a lower impact on stocks and the environment by means of highly *selective catching methods* (Section E 3.4). Current fishing practices lead to animals being caught that are not desired (by-catch) and which for the most part have to be thrown back but do not survive. Technical improvement of catch methods (particularly through net and dredger design) could reduce the amount of by-catch.
- The scientific foundations for *intensifying aquaculture* with due account for sustainability are as yet inadequate (Section E 3.4). Important topics for research and development work are the generation and breeding of stocking material, optimization of breeding plants (efficiency enhancement for food use, reduction of the risk of illness among rearing material) and minimization of negative impacts on the environment (marine eutrophication and pollution, ecosystem conversion, land appropriation in competition with other uses, groundwater salination).
- Many important scientific foundations on which concrete and general guidelines could be established for the *management of alien species* are still missing (Section E 3.6). For improving forecasts on the possible spread of alien species and the consequences of that spread, knowledge about the distribution history and autecology of the introduced species and knowledge of the biotic structures within the ecosystem being invaded are essential. Evaluation of introductions documented over longer periods of time and records of the typical characteristics of successfully established, alien species can provide valuable pointers.

J 1.3 Maintaining biopotential for the future

Foundations and evaluation

- The *research and cataloguing of biopotential* should focus on as yet undeveloped habitats. Marine habitats especially offer particular opportunities here because they not only have hardly been studied, but also demonstrate a large number of organisms with a high degree of chemical complexity. Also sites with extreme biotic or abiotic conditions should be given special consideration, since here evolution has found solutions that could be of interest for industrial use (hot springs, deep seas, 'black smokers', etc).
- The co-evolution of interacting organisms (eg predators, herbivores, symbionts, parasites) often leads to biochemical structures that are particularly interesting to bioprospectors. The systematic *research of functional relationships between organisms* presents a particular opportunity for discovering new substances. Research into these secondary metabolites that have been optimized in the course of evolution for their particular biochemical function and thus may be of great benefit (Section D 3.3) is currently being neglected. In this context, the potential among the large number of as yet unknown species is of considerable importance.

- High expectations are now being attached to bioprospecting. The current scientific basis, however, is not sufficient to be able to assess whether *expectations with regard to the commercial importance* of biological resources and the opportunities for the conservation of biological diversity are justified. There are currently not even remotely reliable estimates regarding quantity or potential usable content of biodiversity (Section J 3.1.1), nor is it possible to estimate the possible future importance to the natural substances market. In the light of the current swift and irreversible loss of biological diversity these knowledge gaps are disastrous.
- Furthermore, there is a need to *differentiate according to the respective production processes*, since bioprospecting targets various components: biomass, biomolecules, genetic information or technical principles for bionics. This distinction is given little consideration in research at the present time, which leads to misunderstandings in the political debate (Section D 3.3).
- The debate surrounding *opportunities and impacts of the use of biological diversity* on nature and benefit-sharing is heavily polarized. There is currently no scientific basis for bringing some objectivity into this discussion or for creating a long-term balance of interests that gives consideration to both the demand and supply side of biological diversity and the preservation of biopotential. Market and industrial studies and an evaluation of representative projects to find the future focal points of bioprospecting should be undertaken and the foreseeable demands on the biosphere ascertained.

STATUS, TRENDS AND THREAT

Since biopotential is above all located in natural ecosystems, research on status, trends and threat faces similar tasks to those encountered in the context of preserving the global natural heritage (Section J 1.4). The corresponding general recommendations are dealt with there.

- However, in the light of the *particular importance of biopotential*, it does require some specification. This is particularly true of the threat to biological diversity as a result of bioprospecting. The rise in prices as a result of increased demand for special natural substances can, for instance, lead to non-sustainable collection. A study on the trade in medicinal plants in Germany gives some insight into the importance of natural substance production based on biomass (Lange, 1996). Medicinal plants are in demand over a long period of time and therefore are in danger of overuse. It is necessary here above all to conduct research into effective methods of *in-situ* and *on-farm* conservation.

MANAGEMENT

- The opportunities of bioprospecting both for economic development and the conservation of biological diversity are influenced by the *legal provisions governing access to biological resources* in the countries of origin and user countries (Section D 3.3). However, against the background of excessive expectations the provisions developed so far in the countries of origin have had more the effect of deterring investors and without having created legal certainty. Furthermore, the important question of the appropriate participation in the profits in the country of origin generally remains unanswered. There is therefore a need for considerable research into how suitable, transparent and enforceable access provisions might be crafted.
- Currently there is an expansion of *research into microorganisms* in the search for potential active agents. The socio-economic and regulative consequences of shifting bioprospecting to these organisms that are not limited to the hotspots of biodiversity in the tropical developing countries have not yet been studied.
- The *concept of benefit-sharing* as a system of incentives for the conservation and sustainable use of biological diversity is outlined only vaguely in the Biodiversity Convention and needs to be given more concrete form. The various approaches and composition of the elements of benefit-sharing (participation in monetary profits, technology transfer, capacity-building) must be investigated separately in each case given the very different parameters. If, for example, indigenous and local communities are expected to be impacted by bioprospecting projects, or if use of their traditional knowledge is part of the project, appropriate benefit-sharing with comprehensive participation must be agreed. There are no fit-all solutions; even the much cited example of INBio in Costa Rica cannot necessarily be directly transferred to other countries of origin. Research should first and foremost focus on those regions very rich in biodiversity for which there are as yet no suitable concepts, but in which companies are showing considerable interest (eg Africa).
- In the economic area industrial innovations and new product developments are safeguarded by the *protection of intellectual property* (eg through patents) that in the international sphere has been reinforced by GATT/WTO agreements. However, the collective rights of indigenous and local communities are not sufficiently acknowledged at international level. Alternative concepts of conservation, including those transferable to collective knowledge systems, remain largely unresearched.

- What are termed '*terminator technologies*' are new developments of plant breeds using bioengineering in which the ability of plant genetic resources to germinate is limited or suppressed altogether. Dependence on the use of terminator technologies and the increasing control of plant production by influential seed companies raise at the very least socio-economic problems. In the Council's view research on the ecological and socio-economic impact of terminator technologies is to be recommended in order to facilitate a scientifically based discussion of the topic.

J 1.4 Preserving the global natural heritage

An improvement in the scientific basis for nature conservation measures is urgently required and is also called for in the Preamble to the Convention on Biological Diversity. To that end efforts towards research relevant to nature conservation and environmental observation must be redoubled and better interlinked at European and international levels (Wissenschaftsrat, 1994; WBGU, 1997). Research and tuition still has to make up a considerable amount of ground given the importance of nature conservation (Section E 3.3.2). Section J 1.1 comments on research issues relating to the landscape type 'conservation before use' in the bioregional context.

Foundations and evaluation

- The *ecosystem approach* is a fundamental concept for the implementation of the CBD, to which reference is made in many of the programmes of work and decisions of the COP. It is however currently being used without there being a clear definition of its substance. Therefore, a scientific basis needs to be established for this approach. Corresponding expert workshops (most recently in Trondheim, September 1999) have already begun this process. The Council recommends pursuing the substantive design of this concept as a matter of priority.
- A systematic analysis of which species, ecosystems and landscapes are essential from a global perspective – with consideration for all value categories – is not possible at the present time. Therefore, methodological development and application of an '*integrated assessment' of the biosphere* to include the global level must be pursued further in order to create a scientific basis for that type of criticality analysis. An example of the current unsatisfactory situation is the absence of a uniform system of classification for the ecosystems of the world.
- It is agreed that there is a need for a worldwide, effective and representative *system of protected areas*, but actually setting area conservation goals is currently more of an art than a science. The definition and evaluation of the ecosystem services provided by protected areas are important research topics for developing criteria for the selection of protected areas and their topological interconnection. At the outset of efforts to preserve species there should be an evaluation that takes into account both ecological and social criteria. There is still a considerable need for research in this area. The conscious application and weighting of the different value categories can provide a basis for this (Chapter H).
- The link between new scientific findings in ecology and the concrete management of protected areas on the ground should be improved. The aim should be to improve cooperation and the *exchange of knowledge and technology* between scientists and practitioners of nature conservation; for example, to communicate the paradigm shift that has taken place in modern ecology to the practical level and vice versa to present the current issues facing practitioners to the scientists.

Status and trends

- *Criticality analysis* through the intersection of hotspot maps of varying origin and quality to produce worldwide maps of biological diversity, its importance, threat and protected status for priority setting all currently constitute a dynamic research field which is extremely important for deriving a guard rail for global natural heritage. The current state of research is inadequate, however, and is not sufficient to enable a scientific and well founded derivation of a quantitative guard rail. Research initiatives such as the IBOY project (International Biodiversity Observation Year) from Diversitas can help provide valuable data for this purpose and should be supported.
- The loss of biological diversity as a core trend in the biosphere is still not being sufficiently studied and indeed is under-fed with data. For instance, there is no reliable *estimate of global extinction rates* of species and the anthropogenic impact. Research on this topic is crucially important to being able to evaluate the status of the biosphere. One example of international research efforts in this area is the new Committee on Recently Extinct Organisms (CREO) that is attempting to monitor and evaluate the extinction of species in various taxonomic groups through the development of new methodologies (CREO, 1999).

Threat

- The direct causes of the loss of biological diversity in the various ecosystems are now actually well known. However, there is a deficit in the area of the indirect driving forces that are often interlinked with societal processes (Chapter C). The *effect of socio-economic parameters* on processes such as land-use changes, fragmentation of species range or the introduction of alien species is not sufficiently known for management methods to be designed or forecast. The methods, such as qualitative modelling, need to be improved.
- Study of the impact of existing *economic incentives* (eg subsidies) on the way natural capital is treated and especially on protected areas should be improved in order to establish a basis on which market forces may be redirected to ensure the preservation and cultivation of ecosystem services.
- As a result of the dramatic loss of species diversity and key ecosystems that have served in the course of the Earth's history as the 'creative centres' of evolution, the *resource base of natural evolution* and with it the speed and direction of evolution could suffer (Myers, 1996a). Evolutionary biology should react to this challenge. Research work is needed in order to adapt nature conservation strategies in such a way as to ensure that the most important evolutionary processes are included.

Management

- Particularly in the case of *marine and coastal ecosystems* the scientific basis is lacking for the selection, planning and management of protected areas. Integrated, multidisciplinary research and monitoring is necessary in order to ensure that the existing and newly designated marine protected areas fulfil their purpose.
- *Corridors and stepping stone ecosystems* between semi-natural ecosystems or protected areas assume additional importance in the light of human-induced climate change and the fragmentation of natural ecosystems. The effectiveness of networking varies from case to case and the benefits of corridors and the preconditions for their successful functioning has not been sufficiently investigated. In Europe the implementation of the 'Habitats' Directive and the network system Natura 2000 can provide a framework for such research.
- In the solution of current problems in connection with the acceptance of and conflicts in protected areas, behavioural and social science linkages need to be recognized and taken into account. Applied social science *research on participatory and discursive approaches* in nature conservation should be promoted; the bioregional context above all provides an appropriate framework for this purpose. These are also important topics for the training of nature conservation experts.
- *Evaluation of the effectiveness* of protective and management efforts has been neglected up to now. There is a lack of detailed studies on the effects of nature and conservation areas, resource conservation areas and biosphere reserves.
- Recognizing *sustainability limits for use* in protected areas (eg local recreation and tourism, collection and bioprospecting, hunting, fishing, wood harvesting) is an important prerequisite for good management, particularly in the densely populated central European landscape.
- There is a great need for research with regard to the *minimum area of ecosystems* required to maintain ecosystem services. The basis and models from population biology are also missing with regard to the question of the minimum size protected populations must be in order to be viable in the long term. The MVP concept (minimum viable population) should be pursued and developed further.
- The research on *export quotas for the trade in endangered species* should in particular be oriented to basic biological data for the species under consideration (stock, population dynamic, reproductive patterns, etc), the extent of the threat (trade, habitat destruction, environmental pollution, etc) and the development of management plans (conservation and controlled use, reinvestment of profits, optimum combination of export quota regulations, etc). Specifically, the impact of the limited resumption of trade in untreated ivory should be scientifically documented and analysed. The options for limited economic use of such species that are not directly in danger of extinction (eg CITES, Appendix II) should be researched. The profit accruing from that use should directly benefit the conservation of species stocks and support local communities working for conservation. To contain and prevent the illegal trade in endangered species there needs to be research into innovative control mechanisms (certification systems, use of genetic testing).

J 1.5
Preserving the regulatory functions of the biosphere

Basis and evaluation

- Further development of *integrated Earth System modelling* as the most important instrument for understanding the global functioning of the biosphere should be promoted. A wide range of dynamically linked model approaches and a hierarchy of models should be cultivated and developed further, both nationally and at European level.

- *Landscape diversity* seems necessary for the efficient functioning of ecosystem complexes, also with respect to global regulatory capacity. It should be investigated how great landscape diversity has to be in order to fulfil the biogeochemical functions and what significance the fragmentation of the ecosystem has for the regulative function of the global biosphere.
- The hypothesis of *functional similarity of primary producers* (on the basis of redundancies and compensations inherent to the system) with regard to global biogeochemical cycles for carbon, nutrients and water must be verified.
- The *economic appraisal of global regulative functions* of the biosphere is an interesting and important challenge for researchers (Section J 3.2.3).

Status and trends

Monitoring and early warning systems for the terrestrial and marine biosphere should be developed in particular for criticality hotspots (such as: Northern Ocean, Section F 5).

Threat

The functions of certain biogeographical regions for the Earth System (global biogeochemical cycles and energy flows) should be evaluated with regard to their individual importance, effect and resilience. The following points in particular should be borne in mind:

- The construction of global maps on the *criticality of geographical regions* in relation to biogeochemical cycles is particularly important research that should be pursued further as a matter of urgency (Section F 5.4.1).
- Increased research into *critical thresholds* is necessary in order to be better able to define guard rails for climate change and for intervention in biogeochemical cycles.
- The possible *limits to fragmentation* of natural ecosystems should be studied. This includes study of the changed impact of fragmented ecosystems on different local processes (hydrological cycle, erosion, etc) and the changed resilience limits that result.

Management

Research needs to be conducted into the fundamental opportunities and limitations of targeted human interventions on global biogeochemical cycles and energy flows as elements of the planetary metabolism. The conceptual model of conscious 'global biogeoengineering' is only reflected so far in certain hypothetical experiments on the modification or stabilization of carbon sinks and sources and real attempts at iron fertilization of the sea, but a deeper understanding of this 'Earth System management' is essential – even if only to be better able to analyse the consequences of unintended human intervention in the Earth System.

- In this context, *structural studies* on the interaction of a number of homeostatic regulative mechanisms with various characteristics and scales (both in time and space) are particularly important.
- Also significant is the *analysis of individual regulative processes* with regard to their dynamic structures and resilience limits. For instance, there is still little understanding of the role the biosphere plays in the (global) hydrological cycle, its influence on the structure and distribution of clouds and thus also on the Earth's climate.

J 2 Methods and instruments

J 2.1
Indicators

The development of *indicators of biological diversity* (above all indicator systems to quickly record the biological diversity of an area, but also to describe the role and mechanisms of biodiversity for ecosystem processes) must be accorded central importance within research support. Indicators play a major role in all attempts to record and evaluate the status and trend of biological diversity at various levels (gene, species, ecosystem) and scales (biotope, bioregion, biome, globe). Such systems are therefore an essential prerequisite for monitoring biological diversity and for criticality analyses.

An important goal is the iterative development of a universally applicable core set of biodiversity indicators that can record pressures, status/trends and responses to intervention at various levels of aggregation. A particular focus should be placed on the ecosystem and landscape levels since it is there that the knowledge gaps are greatest.

Alternative concepts for describing global species diversity (eg rapid assessment programmes, remote sensing) should also be pursued in this context. Research must compare the various international approaches (eg CBD, CSD, OECD, SCOPE, BioNET) and assess their suitability for integration into indicator systems for sustainable development.

J 2.2
Biodiversity information technology

Many practical questions of biodiversity management (planning approaches, prioritization in the selection of species and protected areas) can be answered in a much more expedient manner through the *deployment of information technology* (eg GIS, databases) (Hawksworth et al, 1997). The data available decentrally, eg in the collections and museums, government administrations and NGOs, are not currently accessible. An important field of research is therefore the integration of and access to data on biological diversity (PCAST, 1998). The Council welcomes the new initiative from the BMBF on this point (BIOLOG; BMBF, 1999); it should be closely coordinated with the activities of the German clearing-house mechanism. The biogeographical, systematic and taxonomic initiatives all rely on the development of methods in biodiversity information technology (eg Global Taxonomy Initiative, Section I 3.2.6; Systematic Agenda 2000; Species 2000; Section J 3.1.1). The Council also welcomes the OECD initiative for a new information network (Global Biodiversity Information Facility – GBIF), which will link decentralized databases and allow open access via the Internet (OECD, 1999), in which context especially the developing countries will require support in becoming technically equipped.

J 2.3
Monitoring and remote sensing

Marine monitoring

The *continuous observation* of relevant abiotic and biological parameters in the sea is significant for various reasons (increasing intensity of use, environmental pressure, climate change). Satellite-based procedures have been providing data with global coverage for around two decades now, but must continually be calibrated against *in-situ* data in order to be able to provide long-term reliable data. Therefore existing surface-based long-term series should be continued and supplemented. Access to the data thus recorded is currently not satisfactory and should be made easier. The trend observed in many developing countries of closing observation stations should be stopped and reversed. This is an important task for technical development cooperation. The role of voluntary observation ships should be supported with new instrumentation. The existing international organizations and programmes (eg WMO, ICES, GOOS, CLIVAR-GOALS) could be responsible for implementing and coordinating this type of monitoring programme.

Remote sensing

Earth observation will play an important role in biosphere research. Particularly the availability of appropriate global datasets from satellite-based remote sensing gains particular significance for the development of monitoring programmes (eg for recording ecosystem types and land use) and indicators. An important research question is what components of biological diversity are actually recognizable from satellites. For that reason, efforts in this area (eg in the context of ESA Earth observation programme) should be continued.

J 3 Basic biosphere research

J 3.1
Biological-ecological basic research

J 3.1.1
Describing and inventorying biological diversity (taxonomy, systematics)

The inventorying, taxonomic description and classification of global species diversity are far from being completed, particularly in tropical areas and in the marine context (eg mangroves, corals, deep seas; Section I 3.2.6). There will continue to be considerable need for research for a long time to come (cf core programmes element 3 of Diversitas). Stork (1997) notes that the chances of an insect species being discovered are much slimmer than its chances of becoming extinct.

Even in Germany the ability to identify animal and plant species is restricted to an ever dwindling group of specialists. Taxonomic knowledge, however, is required in order to record the diversity of species in a given region and to chart their geographic distribution. For many species that have hardly been used and wild growing food plants such studies are an essential prerequisite for further investigation of potential uses and conservation. The Council therefore recommends that urgent support be given to research and training in the area of taxonomy and systematics. In this context, the aim should be increased cooperation between taxonomists and ecologists. Also projects to secure knowledge of regional biological diversity that are generally sponsored by local nature conservation associations, should be given increased support in order to counteract the impending loss of regional expertise.

That also includes greater participation on Germany's part in international initiatives on taxonomy and species inventorying (eg Systematics Agenda 2000, 1997; Species 2000 Program, 1999; Global Taxonomy Initiative, Section I 3.2.6), as for example is already happening with the development of a Global Register of Migratory Species (GROMS) in support of the Convention on Migratory Species (CMS; Section I 3.3.1). Important tasks result for research at natural history museums. In particular the following points should be considered, some of which were taken up by the research programme 'Biodiversity and Global Change' (BIOLOG) of the German Federal Ministry for Education and Research (BMBF, 1999):

- In many countries, particularly in developing countries, it is necessary to reinforce *scientific capacities* in the area of taxonomy in order to support effective cataloguing of its resources. In addition, it is necessary to develop user-friendly identification methods in order to expand the number of people with knowledge of species.
- At the present time there is a distinct bias in the context of recording biological diversity in favour of vertebrae and vascular plants and to the disadvantage of invertebrates, fungi and microorganisms. In order to facilitate an undistorted recognition of the hotspots of biological diversity, inventory exercises should be conducted for as many bioregions as possible covering all taxa (All Taxa Biodiversity Inventories, ATBIs).
- *Molecular biological methods to describe genetic diversity* are indispensable for modern taxonomy. These methods must be developed further and simplified for routine application. The use of advanced data processing methods is a compelling prerequisite for guaranteeing international access to appropriate collections and databases (Section J 2.2).
- The *identification of relationships*, in particular at the level of genera and families, is very important for prioritizing species conservation programmes.
- Understanding of *habitat demands of species in marginal sites* should be improved as a matter of urgency in order to be able to evaluate and predict spatial and temporal changes in biodiversity as a result of global change. Together with information on the total range of the given species, this relationship is an important basis for evaluating biogeographical conservation.

J 3.1.2
Population biology and population genetics

Alongside research in the area of taxonomy and systematics, a second focus should be placed on population biology. Processes that lead to the evolution, genesis, maintenance and endangering of species begin in individuals or populations (cf core programme element 2 of Diversitas, 1998).

Therefore, deeper knowledge of population biology and genetics is a basic prerequisite for understanding the spatial and temporal dynamics of ecosystems and their species composition. The different populations of one species can also demonstrate specific local adaptations to certain environmental conditions which can be of great economic importance for the development of resistances in crops. The Council sees an urgent need for research in the following areas:

- The *genetic variability within and between populations* of endangered species – but also of wild related species of crops – merits more study. Thus, the potential consequences of genetic erosion for the survival of species with small populations can be made clearer. The impact of demographic, environment-related and genetic chance occurrences, as well as natural disasters on the population dynamic is highly relevant in this context.
- The *sources-sinks dynamic and genetic transfer* within and between populations should be studied more closely with the approach of meta population biology in the context of long-term projects. That way a basis for the management of endangered species would be established in the light of increasing habitat fragmentation. In this context, the MVP concept (Minimum Viable Population) should be carried forward and tested on various experimental model systems.

J 3.1.3
Functional ecology

The third focus of biological basic research the Council recommends is support for functionally oriented ecology and ecosystem research (cf core programme element 1 of Diversitas). It is the precondition amongst other things for responding to the following core question: 'Are there ecosystem thresholds of diversity, above or below which abrupt changes in the structure and functioning of ecosystems result and in particular: are there minimum limits below which the system collapses?'

Our understanding of the diverse interactions and connections within ecosystems is extremely rudimentary, but is the precondition for both evaluating human interventions in the biosphere and for the development of sustainable use systems. For the implementation of many of the research recommendations enumerated here, the fundamentals of taxonomy and population biology are in turn required; interdisciplinary approaches are therefore what will lead to success.

- The biodiversity of an ecosystem is strongly determined by *site factors*. A tighter approach to the effects of the various site factors should be recorded and combined to form an overall complex.
- The *reciprocal relations* between diversity, structure and function of ecosystems call for intensive research initiatives. Grassland, climatic chamber and laboratory experiments are not sufficient for that purpose. Experiments relating to the connection between biodiversity and ecosystem processes must also urgently be conducted in other terrestrial, limnic and marine ecosystems and on several levels (not just at species level). In parallel, findings from experiments with model ecosystems in the field should also be verified. In this context the connections between biological diversity and soil processes, herbivore activity and pollination are of particular importance.
- Ecosystems seem in many cases to demonstrate a higher diversity than is necessary for their functioning under stable environmental conditions. If this assumption is correct, then even extensive interventions by mankind might prove insignificant – however only if stable environmental conditions can be guaranteed. This *hypothesis* is in urgent need of clarification. The impact of extreme climatic events (in simulated scenarios of global climate change) and other anthropogenic disturbances on the relationship between species diversity and ecosystem processes and the stability or resilience of ecosystems (Box D 2.4-2) must therefore also be studied. In this way the ability to indicate early on the potential consequences of human interventions in the biosphere could be enhanced and corresponding countermeasures could be developed and taken.
- In this connection not just the question of the influence of species diversity *per se*, but also the *influence of the respective species composition on ecosystem processes* need to be pursued. How are two systems that have the same number of species but a different composition of species types (eg beech forest versus spruce forest) functionally different?
- The possibilities of identifying what are termed *keystone species* (Section D 2.4) in ecosystems and using them as indicators for the structure and

function of systems must be opened up by means of theoretical and empirical studies. Closely linked to that is the decoding of characteristics that empower a species to dominate (eg mass development of damaging organisms, invasive species; Section E 3.6). This knowledge is essential amongst other things for the further development of sustainable land use strategies and for nature conservation.
- Great efforts are required to research *consumers and decomposers* that have hitherto been neglected by taxonomy and ecological research, for their diversity and their impact on ecosystem processes. The functional links between microbial diversity and the higher plants or animals (eg mycorrhiza, pathogens, parasites) should be a focus of that effort. Furthermore, the influence of climate change, land use change and biogeochemical deposition on the composition and stability of microbial communities should be investigated.
- Clarifying biotic regulation of *conversion processes in soils* is the basis for a site-appropriate, sustainable and environmentally friendly soil management. In order to avoid lasting and irreversible damage, therefore, it is necessary systematically to record the resilience of organism communities in the soils and integrate these into comprehensive evaluatory concepts. Drawing on the Council's soil report (WBGU, 1995a) an expanded Critical Load Concept is proposed. This would require basic research dedicated to the interlinkage of biodiversity in soils and ecosystem functions, clarifying transition scales and developing methodological approaches to the measurement of the functional diversity of the various taxa. Existing indicator systems (eg World Bank or OECD) should be extended and supplemented to be able to produce quantitative descriptions of the biotic status of soils. Without that sort of system, human interventions cannot ultimately be evaluated. Approaches adopted so far are inadequate for deployment at system level.

J 3.2 Socio-economic basic research

J 3.2.1 Ethics

Cross-cultural research

Cross-cultural research can provide important contributions to the identification and understanding of different forms of behavioural ethics vis-à-vis nature (Sections E 3.1 and E 3.5). The following issues are worthy of particular consideration:
- Cultural and religious norms relating to the valorization of the biosphere.
- Relationship of normative behavioural orientation and actual behaviour.
- Identification of universal or quasi-universal principles relating to the use of natural resources.
- Identification of reconstructable normative rationales in different cultures.
- Analysis of cultural pluralism and multiculturalism in relation to the perceived validity of norms in relation to biosphere use.

Identification of consensual values

In order to establish a better foundation on which to evaluate political measures for protecting the biosphere, particular importance should be attached to identifying values about which there is a consensus (Chapter H). The following are the priority topics in this respect:
- Systematic collection and analytical evaluation of value systems in society, both those actually lived and the normatively posited, (for instance, using a value tree analysis).
- Evaluation of existing discussion and negotiation procedures under the aspect of validity and ability to convince on ethical grounds.
- Elaboration of pilot studies to test new forms of ethical discussion.

Conducting negotiations on biosphere conservation

Particularly in the area of biosphere conservation, national and international negotiations can benefit from an analysis of procedural demands on an ethical and scientifically satisfactory form of conducting negotiations (Section I 2.3). Social sciences research should above all make efforts on the following points:
- Analysis of political negotiating protocols under the aspect of the relevance of ethical arguments and their impact on participants in the negotiations.
- Evaluation of case studies of successful and less successful discussions and negotiations in which ethical arguments had a role to play.
- Implementation of support studies on ongoing negotiations by observers trained in the social sciences.
- Planning of pilot studies on the constructive steering of ethically discursive negotiating processes oriented to the requirements of procedurally satisfactory negotiations.

Secondary norms

Derivation of secondary norms and behavioural orientation on the basis of primary norms accepted by all sides (or principles), the results of empirical behavioural sciences and ethically motivated discourse is a field of research with particular significance for the solution of conflicts between conservation and use of the biosphere. Priorities in that context include:

- The derivation of categorical and compensatory norms on the basis of primarily acknowledged and agreed principles and norms.
- Recording actual normative behaviour of humankind and the subjective justification for that behaviour.
- Summarizing analysis of the insights from discourses on norms and values.
- Pilot studies on the constructive synthesis of behavioural orientations that are normatively derived, developed discursively and factually ethical in one or several 'mega discourses'.

J 3.2.2
Perception and individual evaluation

The development of approaches for assessing and valuing biodiversity (in economic, ethical, cultural, etc terms) should be accorded high priority in order to be able to characterize and highlight the impacts of human intervention into the biosphere.

- *Cross-cultural research* on the perception, evaluation and culturally driven interpretive patterns of natural assets (animal and plant species, specific ecosystems and landscapes) should be conducted to a greater extent. This can lead directly to the identification of conflict potentials with negative impacts on biodiversity.
- An *analysis of the complex factors that condition action* for conserving ecologically important species can make an essential contribution to increasing the efficiency and acceptance of species and nature conservation programmes. Therefore, for instance, the role of symbolic species, system knowledge or personal concern should be researched. Furthermore, the question of how biodiversity and the threats it faces can be communicated to the public should be explored.
- The historic and social *variability of the people-nature relationship* as influencing factors for the evaluation and treatment of biological diversity should be researched more fully. The various players and their importance first of all for everyday lifestyles and economic practices and secondly in terms of political action are factors that need to be considered in global processes (eg Biodiversity Convention).

J 3.2.3
Economic valuation

- *Monetarization of biosphere values*. Economic valuation procedures are an important aid for policy in making the necessary evaluatory decisions in the light of the costs and benefits involved. Currently, however, there is a considerable research deficit in ascertaining the monetary standard for individual biosphere value categories. Reference is made especially in this context to ecological functional values, social, cultural and aesthetic values as well as symbolic values that cannot generally be given a market value but should be considered to a greater extent in political decisions.
- *Methodology for economic valuation*. In particular, in the area of valuing biosphere services, further methodological thought is required with regard to the use of economic valuation approaches. For example, in ascertaining willingness to pay, the methodology needs to take into account the fact that willingness to pay may well vary greatly between high-income and low-income countries. Also, the problems with regard to an appropriate valuation of complementary biosphere services and the emergence of irreversibility point to the need to expand the methodological foundation of the economic valuation approach that currently has a dominant focus on *Homo economicus*.

Recommendations for action for a sustainable biosphere policy

K

The foundations of a strategy for action

Scope for action for a global biosphere policy

The Council's strategy for a global 'biosphere policy' reaches beyond traditional biodiversity policy in the light of its links to climate and soil conservation. It is first and foremost oriented to those developments in the biosphere that should be avoided at all costs (Section I 1). To this end, biological imperatives, guard rails and guidelines are defined above. Given the large number of uncertainties and knowledge gaps it is still not possible to give exact guard rails for the biosphere in the sense of precise, quantifiable limits. This is why biological imperatives were first developed that are intended to communicate principles with which the values of the biosphere may be preserved and used sustainably for today's and future generations. These imperatives are to

1. preserve the integrity of bioregions,
2. safeguard existing biological resources,
3. maintain biopotential for the future,
4. preserve the global natural heritage,
5. preserve the regulatory functions of the biosphere.

These biological imperatives are the result of the studies on guard rails for the conservation and management of ecosystems and landscapes in Section E 3.9 (Imperative 1), the situation of genetic diversity and species diversity in Chapter D (Imperatives 2, 3 and 4), ecosystem and landscape diversity in Chapter E (Imperatives 1 and 4) and global biogeochemical cycles in Chapter F (Imperative 5).

Guard rails are by contrast specific, numerically defined damage thresholds that, if exceeded now or in the future, will have intolerable consequences. The application of the guard rail concept to the biosphere occurs at both regional (Section I 1.1) and global levels (Sections I 1.2–I 1.6). On the global scale, additional interactions can be recognized that are not visible from the regional perspective. Attaching a numerically precise definition of that kind of limit to human action is, however, particularly difficult on a global scale in connection with the biosphere because of the many uncertainties that persist. However, one numerical statement in the form of one guard rail is given because the danger to the biosphere constitutes a serious risk associated with global transformation. But the scientific derivation of a guard rail in the form of a precise area for protection is not yet satisfactory. If a value is given, then it is a rough estimate. Despite this limitation the Council recommends designating globally an area for nature conservation of 10–20 per cent (of the land area) (Sections E 3.3.2 and I 1.4). Of course, as a result of regional differentiation, this proportion will vary greatly from place to place.

At regional level the guard rail strategy may specifically be translated into the designation of protected areas ('conservation before use') in which ecosystem services that are important for the bioregion are provided and which, for that reason, must remain closed to economic use (Sections E 3.9 and I 1.1). Furthermore, guidelines are drawn up (Box I 1.1-1) for the other two types of land use ('conservation through use' and 'conservation despite use'). Guidelines are management rules for concrete action such as, for example, preservation and restoration of various regulative functions (habitat, use, cultural and social functions). Designating a guard rail, ie concrete numerical limits beyond which for example an erosion rate or an application of nutrients is no longer considered sustainable, is a research task and no sufficiently concrete policy formulation can take place here. Since for most areas of the biosphere no guard rails can as yet be defined, the Council bases its recommendations on all three of these strategic elements: biological imperatives, guard rails and guidelines. Together they define the scope for action of the global biosphere policy outlined here.

Biosphere policy as a process with a high degree of institutional and player diversity

Biosphere policy is not seen here as exclusively the task of governments and government institutions, but rather as a result of a many layered process that is also shaped by local networks, international organizations, associations and in particular multinational companies, in addition to national decision-makers. This diversity of institutions and players is also one of

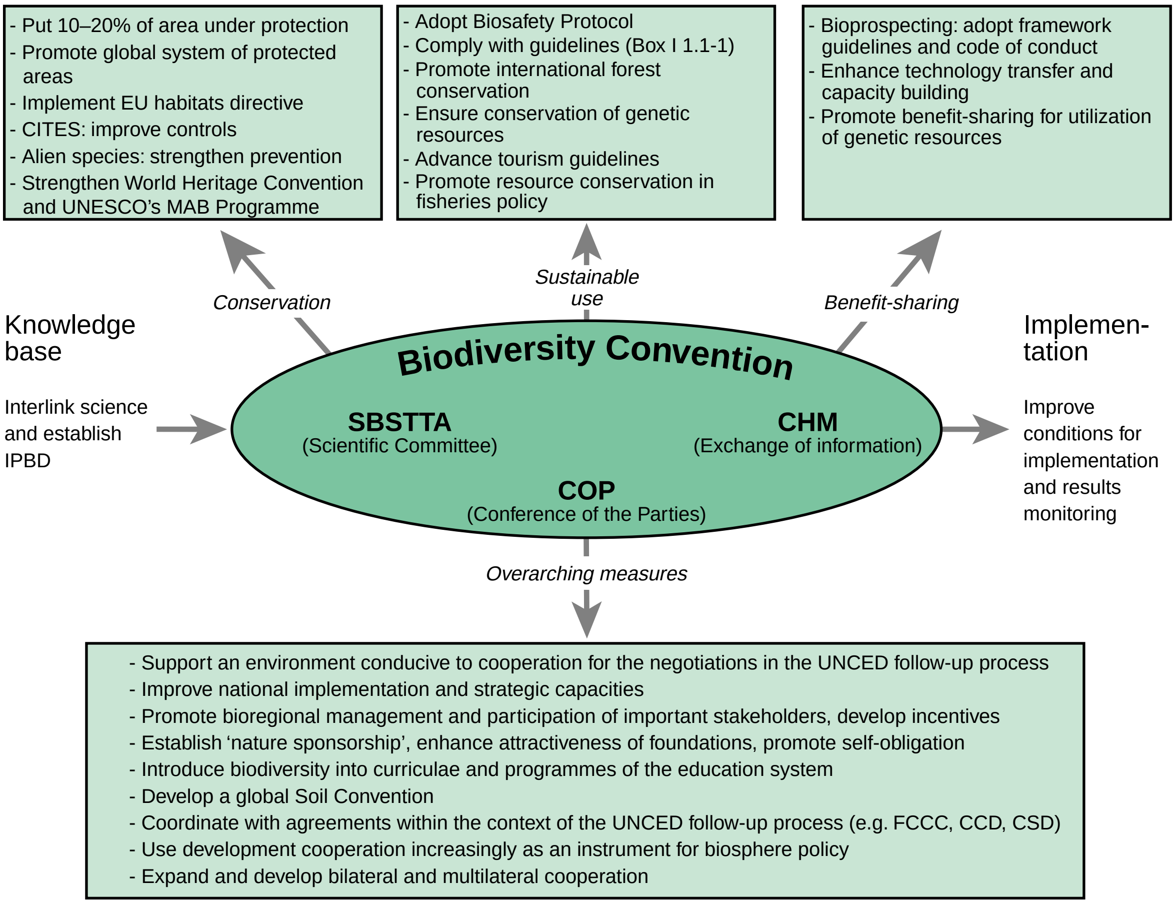


Figure K-1
Council recommendations for global biosphere policy in the context of the CBD network.
Source: WBGU, 2000a

the basic messages of the Convention on Biological Diversity (CBD).

Fig. K-1 shows how the recommendations of the Council could be implemented under the CBD. This illustrates to which elements of the Convention the recommendations refer. Alongside the three objectives of the CBD – *conservation, sustainable use* and *benefit-sharing* – overarching measures are also addressed. The outstanding importance of knowledge generation and of implementation is highlighted.

Despite the diversity of institutions and players, the addressee of these recommendations is always the German federal government in its role as co-shaper of the international political process. Since the development of a strategy for a global biosphere policy is still characterized by a large number of uncertainties, in particular as a result of large knowledge deficits, a lack of political measures and insufficient monitoring of results, there can be no claim to an exhaustive presentation here.

K 2.1
Local communities, NGOs, environmental and user associations

K 2.1.1
Environmental education and environmental learning

Given the inadequate understanding in society at large regarding the importance of, and the threat to the biosphere, the scientific deficits identified by the Council may not be allowed to delay the development of biosphere-specific educational and learning concepts. On the contrary, these cognitive deficits should actually serve as an incentive to advocate and work towards introduction of the topic into the entire educational system. Environmental education and environmental learning comprise here the communication of concepts of biological diversity – still largely unknown in the public – as well as the motivation and readiness to work for the conservation of the biosphere and its use, always linked with the criterion of sustainability. The complexity of the biosphere holds a particular challenge for environmental educational and learning concepts, but at the same time offers numerous possibilities for linking the programmes and curricula of different establishments. The Council's recommendation is essentially to increasingly introduce the topic of the biosphere into the curricula of schools, universities and programmes and to support local learning processes.

K 2.1.2
Securing the participation of important local players

In the context of the management of biological resources in the region, it is important to identify those interest groups that can in the long term prevent or promote the long-term use of biological resources. In particular, the extensive knowledge and motivation of local players should be used. These include above all those persons who are active as volunteers in nature conservation and those who have acquired a broad base of local knowledge through their professional activities. Often motivational and informational work can be provided to encourage institutions, individuals and groups to get involved, whose action (or inaction) plays a key role in the use of biological resources. The range of participation can go from simple improvement of cooperation right through to mediation of conflicts between efforts towards conservation and use. In any case, it has proven valuable not to leave the communication of interests to chance or indeed to the groups with the strongest assertive power. Rather, through targeted moderation one can ensure that crucial interest groups are given a chance to speak and that decisions are taken that truly lead to improved integration of conservation and use.

K 2.1.3
Safeguarding the intellectual property rights of indigenous communities

Article 8(j) of the Convention on Biological Diversity (CBD) calls for the traditional knowledge, innovations and practices of indigenous communities to be respected and preserved. Support should be given to the application of this traditional knowledge, and benefit from that application should be distributed fairly. As indicated in Art. 8 and a controversial subject of discussion at the Conferences of the Parties, deliberations surrounding land rights and intellectual property rights are also appearing on the agenda. However, the discussion is limited to references to responsible forums. The question of recognizing *sui generis systems* for protecting the knowledge of indigenous and local communities is being discussed with increasing intensity. Here, there is a close link to other forums, the World Intellectual Property Organization (WIPO) and above all the World Trade Organization (WTO) with regard to the revision of the Agreement on Trade Related Intellectual Property Rights (TRIPS). The Council recommends supporting implementation of Art. 8(j) by orienting the efforts under the auspices of development cooperation accordingly (support for the sectoral project of the Gesellschaft für Technische Zusammenarbeit, GTZ) and addressing questions relating to alternative protection systems for traditional knowledge in the deliberations over international standards for access to genetic resources and benefit-sharing.

K 2.2
Governments and government institutions

K 2.2.1
Improving national implementation and strategic capabilities

The cross-sectoral character of the CBD calls for an integrational strategy of implementation in the contracting countries. The objectives of the Convention should for instance be incorporated into traditional approaches to protect nature and species and these should be expanded in the case of the biosphere with the addition of sustainable use concepts. The Council considers development of a national strategy for Germany (WBGU, 1996), building on Germany's national report from 1998, still to be appropriate and beyond that it aims to develop sectoral biodiversity strategies. This would especially mean incorporating the policy areas of agriculture, forestry, fisheries, research and the further development of biodiversity policy in the areas of biotechnology, economic policy, fiscal policy and development cooperation. The Federal Ministry for Economic Cooperation and Development (BMZ) has already risen to this challenge; in 1997 it developed a sectoral concept titled 'Preserving biological diversity through nature conservation'. The cross-sectoral character of the Convention calls for continual coordination between the ministries as well as between the federal, regional and municipal levels. The Council therefore recommends establishing an 'Interministerial Working Group on Biodiversity policy', in which all agencies and departments involved in the development of a sustainable policy on biodiversity would be represented.

K 2.2.2
Advancing the process of giving substantive form to the ecosystem approach

The ecosystem approach is an integrational concept for the implementation of the CBD, to which for example many programmes of work and decisions from the COPs refer. This approach is also an important basis for bioregional management (Section E 3.9). It is currently being used in the CBD, but without there being a commonly shared sense of its substance. Since the ecosystem approach was incorporated into the Convention without first receiving the all-clear from the scientific committee of the CBD (SBSTTA) and, in many instances, has proven to be a cause of irritation among various players, a scientific grounding to the approach is more necessary than ever. As a matter of priority the Council recommends moving forward with the process of giving substance to this concept and for use to be made of the corresponding competence science has to offer in that regard.

K 2.2.3
Promoting options for biosphere-friendly consumption

All measures that raise awareness and education will remain ineffective unless framework conditions are also created that allow for biosphere-compatible patterns of production and consumption within society. This is, for example, possible through economic and social incentives, or the targeted promotion of model projects. Programmes targeted to specific players and areas of action in which a mixture of incentives, action and information-oriented measures is deployed – backed up by science – should be initiated and carried through with the corresponding locally relevant players (eg consumer and environmental associations, companies) (Section I 2.5).

K 2.2.4
Integrating bioregional management strategies into existing planning instruments

The Council recommends promotion of a system of differentiated intensities of use, with the aim of integrating the various demands on the biosphere into one concept of sustainability-oriented use. The three land use categories, 'conservation before use', 'conservation through use' and 'conservation despite use', offer a sensible breakdown (Section E 3.3.1). In terms of application, it should be investigated to what extent the bioregional approach is already sufficiently anchored in the German planning system, and whether it can be coupled with implementation-oriented regional management without building up a second parallel system alongside the existing planning system (Section E 3.9).

Bioregional management offers a fruitful approach for considering the various demands on the landscape in an integrated manner (Section E 3.9). Pressures on nature in favour of the economy and pressures on the economy in favour of nature conservation should be subject to a similar requirement to furnish proof of their necessity. This strategy is also suitable for development cooperation, since it makes available a pragmatic mix of instruments that can allow implementation of a guard rail concept at regional level. Greater decentralization and shifting of decisions to the regional level is recommended as a precondition for protective efforts, particularly in countries with centralized structures. The goal of integrating both the conservation and use of biological diversity can more easily be achieved through bioregional management than the 'top-down', prescribed management of biological resources.

It should therefore be investigated in what ways the concept of bioregional management may be integrated within the framework of development cooperation in projects promoting rural regional development. Particular attention should be paid to long-term projects with the option of capacity building, cooperative planning methods and flexibility, in the sense of adaptive management. Following the model of international city twinning arrangements, it should be investigated whether a programme to promote international regional partnerships between countries with high and low biological diversity (thus, between industrialized and developing countries) could not be initiated. The various financial compensatory and incentive mechanisms should be evaluated at national and international level with regard to whether they are suited to promoting bioregional approaches.

K 2.2.5
Protected areas: reserving 10–20 per cent of the area for nature conservation

Protected areas are an important pillar in any strategy for the conservation of biological diversity (Section E 3.3.2). The Council therefore considers a worldwide, effective system of protected areas representative of the range of biomes, bioregions or ecosystems and areas with a great wealth of species or endemism to be indispensable. This system can generally be termed a 'guard rail' (Section I 1.4). The Council recommends as a rough indicative guide 10–20 per cent of the world's land area for this system of protected areas, selected according to substantive criteria.

Biological diversity cannot, however, be preserved merely in isolated protected areas: only ecological, social and economically integrated approaches offer any prospect of success. Protected areas must be seen in connection with the surrounding landscape; that means linkage of areas to one another and to the surrounding landscape use (Section E 3.9). In the environs of existing protected areas, support should be given to developing buffer zones with suitable management concepts ('conservation through use'), as already happens in biosphere reserves. The concept of bioregional management offers interesting approaches (Section K 2.2.2).

The status of implementation of the Habitats Directive and the EU-wide NATURA 2000 network envisaged in that directive must be considered very unsatisfactory in Germany. The Council once more recommends most emphatically that swift implementation be moved forward with due political resolve.

Social and societal aspects should increasingly be recognized and considered as part of the solution to the current problems in connection with acceptance and conflicts in protected areas. Participatory and discursive approaches through improved presentation and communication of nature conservation are important in order to achieve that all essential public acceptance. These approaches are also an important topic for training nature conservation experts.

Access to information on nature conservation is unsatisfactory in Germany. Improved organization, standardization and easier access to data in public institutions would allow nature conservation work to take place in a much more efficient manner. Support for an informational interlinkage of government and non-governmental nature conservation institutions would be useful for the exchange of experience. An important task for the German Clearing House Mechanism could also lie here.

K 2.2.6
Implementing the model of 'multifunctional land use'

Human intervention in the biosphere in terms of land use constitutes one of the biggest threats to biological diversity on the Earth. The dynamic with which the use-driven loss of biological diversity is progressing leaves the impression that the 'race against time' can no longer be won. From the point of view of the Council it therefore appears urgent for policy to make it a priority to address the problem of use-driven loss of biodiversity and support such activities at international level that might contribute to a solution of the problem.

In order to achieve highly productive land use at the same time, a *multifunctional model* should be formulated that does not need to be predominantly production-oriented – as was customary in the past – but must incorporate *all* functions of the ecosystem in question. To that end, management must be directed at long-term usability, the diversity of abiotic and biotic factors at the site must be considered and also the pressure placed on neighbouring ecosystems by land use in that given area. The model alone is however not sufficient, practicable instruments (eg indicator systems) will be required for implementation and evaluation.

The Council recommends transferring the principles of multifunctional land use as fully as possible to agricultural and forestry practice, because the worldwide introduction of that sort of strategy of land use promises to be all the more successful the earlier these practices are also realized in industrialized countries and the earlier their ecological and economic benefits become visible there. One urgent requirement is for pricing to contain the costs of soil protection, environmental protection and the conservation of biological diversity. The certification of corresponding use strategies and the labelling of their products is an important opportunity for promoting multifunctional land use.

There is not a great deal of time left if the present risk-laden and, in its impact, essentially unknown development trajectory is to be halted. There is an urgent need for swift and effective action.

K 2.2.7
Counteracting the temporal and spatial separation of biogeochemical processes

The knowledge about the effects of human intervention in biogeochemical conversion processes in ecosystems is essentially available, but so far it has not been sufficiently evaluated or translated into action at local or global level. For problems of biogeochemical build-up and depletion, avoidance or compensatory strategies must be developed and employed that aim to link together biogeochemical cycles in both spatial and temporal terms. Economic practices that are based on the overexploitation of national or managed ecosystems must be avoided at every spatial level. Management directed towards sustainable use should be identified by the ecolabels or promoted through other measures in order to offset the higher costs incurred by these strategies. It should also be publicized much more that sustainable land use comes with a price tag.

A possible strategy for avoiding biogeochemically driven changes in biological diversity is bioregional management (Section E 3.9), by means of which spatial disparities can be reduced and regional cycles strengthened. In order to preserve the necessary scope for action for the sustainable use of natural resources, there is a need for systematic recording and evaluation of the numerous interactions of production, consumption, trade and environment at different spatial levels. Internationally, the United Nations Environment Programme (UNEP) could assume the requisite coordination. On the whole this topic area should be addressed to a greater extent.

K 2.2.8
Introduction of alien species: precautionary control

In order for the terms employed in connection with the introduction of alien species to be used uniformly in national legislation (in Germany in the *Bundesnaturschutzgesetz* [Federal Nature Conservation Act] Art. 20 d II) it is necessary to ascertain and define clearly the meaning of these terms, which could be done by the Conference of the Parties (in cooperation for example with FAO, IMO or WHO) (Section E 3.6). Furthermore, the provisions in connection with the introduction of alien natural species and genetically modified species should be harmonized, since the problems are of a similar nature.

In many countries the intended introduction of alien organisms is subject to the obligation to obtain approval, but deficits often prevail with regard to the verification of existing regulations and possible sanctions for violations. In dealing with the problem, the precautionary principle should always be the basis. Planned introductions must also be accompanied by environmental impact assessments. These provisions should not just apply to releases into agriculture and forestry, but should be generally applicable.

As a matter of principle the originator must also be held liable for unintentional introduction of alien species and the responsible authorities for prevention, emergency management and early warning must be determined. Unintentional introductions could for example be prevented by border and seed controls (arranged by the IPPC), logistical measures such as shorter waiting times in container traffic, but also and above all through awareness-raising in the population and amongst the major players. In the context of the CBD the possibility of drawing up common standards for dealing with alien species should be examined.

The most important means of transmission for the worldwide transfer of marine species is the ballast water on ships. Annually, 10 thousand million tonnes of ballast water are transported worldwide with 3,000–4,000 species finding a new home in that way every day (Box E 3.6-1). Since organisms from coastal waters die in the high seas and plankton from the high seas cannot survive in coastal waters, the International Maritime Organization recommends complete ballast exchanges to be carried out at sea. The Council welcomes this proposal and recommends swift implementation since this measure, if applied worldwide, could considerably reduce the unintentional release of alien species in aquatic ecosystems.

K 2.2.9
Improving comparability through indicators

Under the CBD not a great deal of progress has been made on drawing up a coherent system of indicators for monitoring the global status of biological diversity. There are still great uncertainties in the methodology and scientific basis; these should be addressed through targeted research (Section J 2.1). It would make sense to combine the existing projects on indicator development for biodiversity at international level (CSD, IUCN, OECD, IFF, CCD, etc). It would be desirable to achieve iterative development and the binding introduction of an internationally compatible catalogue of biodiversity indicators, which can record pressures, status/trends and responses to intervention at various levels of aggregation. It would be important in that context to establish close linkage with the development of sustainability indicators, as is currently being advanced in the context of the Organization for Economic Cooperation and Development (OECD) and the Commission on Sustainable Development (CSD). In order to speed up this process, it should be investigated whether a dialogue among international experts could be set up.

K 2.2.10
Reconciling interests in the use of genetic resources

In accordance with the CBD the extraction of genetic resources and use of the same should be compensated by the fair and equitable sharing of the benefits derived from that extraction and use (Section D 3.3; WBGU, 1996). On the basis of sovereign rights of use the countries of origin have the power to regulate access to their genetic resources. Regarding the design of agreements between users and suppliers, the CBD contains general parameters relating to obtaining the prior consent of the country of origin (Prior Informed Consent, PIC) and incorporating the ideas of both sides (Mutually Agreed Terms, MAT). Experience with national and regional rules of access have so far shown that there is a need for an internationally agreed standard to serve as a framework of orientation for supplier and user countries in order to shape access to genetic resources in line with the CBD. The Council recommends swiftly moving forward in the process of developing international standards for access to genetic resources and benefit-sharing in the context of the CBD. Greater use should be made of the experience in cooperation with countries of origin gained in GTZ sectoral projects. The role of technical cooperation for capacity-building measures should especially be reinforced, as also should the development of technology and research capacities and training programmes. Cooperation with the partner institutions in the supplier countries of genetic resources should, in the Council's view, be aimed at achieving transparency in the decision-making and participatory processes, sustainable use and benefit-sharing. All initiatives already under way to involve natural-substance companies and research institutions in the political debate should be continued and stepped up. Furthermore, a network of model cooperation arrangements for the promotion of sustainable bioprospecting should be developed – in cooperation with the responsible ministries – and with the executing agencies (eg GTZ, *Bundesamt für Naturschutz* [Federal Agency for Nature Conservation], ZADI, *Zentralstelle für Agrardokumentation and -information* [Central Office for Agricultural Documentation and Information].

K 2.2.11
Enhancing the attractiveness of the foundation system

The opportunities that foundations offer for the conservation and sustainable use of the biosphere are not being used sufficiently. Therefore, the legal basis in Germany for the foundation system should be made more attractive in tax terms. Promotion of nature and environmental protection fulfils the preconditions for a 'certain non-profit purpose' within the meaning of Section 10 b I clause 1 of the Income Tax Law, but does not fulfil the required profile in clause 2, since only environmental protection with certain cultural purposes is covered there (eg care of monuments). This does not tie in with the constitutional obligation on the state to protect the natural foundations of human life (Art. 20a Basic Law). It should be examined whether environmental protection cannot be upgraded in the light of these aspects. In order to enhance the attractiveness of the foundation system for the purpose of biosphere conservation, various social value categories could be introduced under an amendment of the foundation law and various release clauses added. This would seem appropriate given the special ranking that environmental protection is given under constitutional and international law (Art. 20a Basic Law). This would also encourage a certain degree of privilege being accorded to environmental foundations.

K 2.3 National and multinational companies

K 2.3.1 Promoting bioprospecting projects

Private players in natural substance research and industry should use the opportunities that the agreement of international framework directives provides in terms of access and sustainable use of genetic resources, and take an active role in international negotiating processes. Framework directives can stabilize the very divergent expectations in the countries of origin and buyer countries and prevent a greater polarization of interest groups.

The provisions on access issued in countries of origin thus generally serve to ensure transparency in prospecting projects and the associated decision-making process, hoping to promote access, not prevent it. One precondition for long-term constructive cooperation is the adequate participation of countries of origin in the results of research and development. This demand can for instance be met at the planning stage of the project through an exchange of information and cooperation with partner institutions in the countries of origin. Development of suitable structures for the first phases of bioprospecting on the ground, inventorying of biological diversity, studies on interaction *in situ*, ascertaining traditional applications and first test procedures *ex situ*, would be an important contribution to the promotion of national capacities in countries of origin and thus the long-term safe-guarding of resources (Section J 1.3). Large companies can set up their own cooperation projects and develop participation in partner institutions in a project into company policy. For smaller and medium-sized natural substance companies, the development of an institution to facilitate such cooperation and develop investment strategies would make sense. The Council would like to suggest working with the associations to investigate the possibility of developing an internationally transferable system of labelling for pharmaceuticals from sustainable production, eg in the form of voluntary commitments. This could provide an important contribution towards sustainable bioprospecting.

K 2.3.2 Supporting the trend towards voluntary commitments

Private activities are an important condition for success in global biosphere policy. A good example of this is the Forest Stewardship Council (FSC), founded by representatives of the timber industry, environmental associations and indigenous communities to promote sustainable forestry. It has had a market presence since 1996, with its seal having been used to label approx 12 million hectares of forest worldwide already. Since the FSC timber has conquered the German market, the seal has become an attractive brand under the aspect of biosphere conservation (Section I 2.4 and Box E 3.3-8). It does not have to remain the only standard however. For example, the *Arbeitsgemeinschaft deutscher Waldbesitzerverbände* [Association of German Forest Owners' Federations] (AGDW) is already thinking about establishing its own system of certification for sustainable forestry under a pan-European initiative. Furthermore, in 1998 at the Conference of Ministers in Lisbon the 'Pan-European Guidelines for Sustainable Forest Management of European Forests' were adopted. They form the basis of the German Forestry Council's suggestion for a pan-European certification initiative. Various European organizations from the forest and timber industry are taking part. In the interests of the intended promotion of sustainable forest management, the Council considers that it is necessary to reach an agreement to help move the certification approach on to a breakthrough, as this is in essence the right approach.

K 2.4 International institutions

K 2.4.1 Improving positive regulations

International cooperation on the protection of the biosphere is strengthened in particular if four institutional features of positive regulations can be respected or improved (Section I 2.3). The Council recommends:

1. Strengthening environments conducive to cooperation for international regimes to protect the biosphere so that norms, rules and principles for the conservation and sustainable use of the biosphere may be adopted and enforced, and transparency, information exchange and communication processes are anchored institutionally.

2. Flexible handling of violations. The players should be given greater scope and opportunity at the existing COPs, committees or newly convened meetings to engage in understanding-oriented discourse in order to be able to communicate regarding the difficulties they are encountering in adapting behaviour and implementing the rules and principles. Flexibility does not mean arbitrariness in implementation. Therefore flexible handling needs to be backed up by appropriate monitoring and a system of verification.
3. Developing and strengthening requisite capacities in the developing countries, in the new Eastern European democracies and in the CIS states. Intergovernmental and inter-organizational networks and related programmes should be used in this context, for instance the World Bank, the United Nations Development Programme (UNDP) or the various regional development banks. In this way the requisite technology, knowledge and management transfer can be achieved more easily. This transfer should amongst other things include training programmes, provision of policy-relevant information, research support and scientific and technological advice.
4. In the case of poor and straggling states, the interest and motivation of players for protection needs to be raised, in particular through open procedures regarding international agendas and at conferences. This interest can also be enhanced through financial or technological assistance. Furthermore, NGOs should be backed so that they can provide effective publicity, exert public pressure and formulate criticism of less motivated governments.

Improvement of these institutional features of international regulations should run parallel because they are mutually reinforcing. Failing to attend to any one of these elements could jeopardize the overall impact of the positive regulations.

K 2.4.2
Setting up an Intergovernmental Panel on Biodiversity

In the area of biosphere policy there is a lack of well grounded and independent scientific advice (Section I 3.2.1.1). The gaps in our insights into the status and loss of biological diversity and the consequences of that situation must be worked through systematically. What is more, it is important for well founded scientific support to be provided for current political issues – by integrating scientific, socio-economic and legal experts – and to develop policy-relevant action options for the community of parties and all interested players.

First of all it should be examined to what extent closer cooperation amongst existing scientific bodies and regional networks could counteract the deficits in scientific advice. In the Council's view, one should expect that it will prove necessary to establish a body of scientific experts, for example, in the form of an Intergovernmental Panel on Biological Diversity – IPBD. In this committee internationally recognized scientists could be brought together to work on a continual and independent basis and also to provide policy advice. The comparable body in the area of climate change is the IPCC which was set up in 1988 by the United Nations General Assembly; the IPCC works under the auspices of UNEP and WMO and also provides scientific policy advise for the community of parties of the Framework Convention on Climate Change.

The contributions from the IPBD could lend greater objectivity to the biodiversity discussion. Science too would benefit from the establishment of an IPBD as a result of improved coordination and interlinkage. The Council recommends building on the experiences of the Global Biodiversity Assessment and the IPCC in order to avoid any potential construction weaknesses from the very outset.

K 2.4.3
Advancing the negotiations on a biosafety protocol

Now that the negotiations on a binding agreement under international law to regulate the use of living modified organisms (Biosafety Protocol) have foundered for the time being, there is currently a regulatory gap. Directives have been initiated by various international organizations to regulate aspects of biotechnology on a *voluntary basis*. These non-binding declarations of intent are, however, very difficult to instrumentalize as aids for the implementation and design of a binding agreement under international law. The Council wishes to underline the fact that without a protocol on biosafety safe handling of genetic engineering remains patchy.

K 2.4.4
Safeguarding the conservation of genetic resources

Agrobiodiversity is of immense importance for the food security of future generations, for the sustainability and stability of agro-ecosystems of the Earth and as the parent material for innovation in breeding and biotechnology. Therefore, its conservation and sustainable use must be the primary goal of all relevant policy areas (Sections D 3.4 and I 1.2). In that context it must be noted that irreversibility is a characteristic feature of the loss of biological diversity: opportunities in biosphere policy, once missed, are not going to come round again. Therefore, early warning systems of the sort that the Commission for Genetic Resources for Food and Agriculture (CGRFA) wishes to introduce are particularly important.

Active use of agrobiodiversity should stand as the first option for conservation and should be implemented by as diverse an agrarian production system as possible. The services of the agrarian systems of the Earth, as well as the threat to that diversity, must become a central focus of both practical and academic training courses.

Worldwide preservation of a considerable portion of *ex-situ* collections is in danger. In this situation, the foremost task is to secure and provide financial support for existing collections. In particular, regular regeneration measures must be carried out. The collections should be combined into a global network for the sake of efficiency and cooperation. The existing collections must be supplemented according to the precautionary principle, with a particular eye to the necessary redundancy of stocks. It is a matter of priority to complete the collections in the centres of diversity of the respective species. Drawing up a red list for endangered cultivar species as a basis for undertaking corresponding conservation measures and financing the same should be the aim. The conservation of endangered domestic animal species and races must also be a focus of the efforts surrounding agrobiodiversity. Since in many cases *in-situ* or *on-farm* conservation is the only option, measures must be supported to prevent a total loss of certain components of agrobiodiversity. It is above all necessary *not to disrupt* locally organized *in-situ* or *on-farm* conservation and use of agrobiodiversity. In the past restrictive regulations relating to seed traffic, or agricultural advice focusing heavily on 'modernization', often wrought a great deal of damage.

In the area of utilization of agrobiodiversity, the funding of secondary evaluation of genetic resources (resistances, specific quality features) and characterization of currently used agrobiodiversity is a priority. In order to introduce valuable genes from genetic resources into elite material and to expand their genetic base, an extensive public-funded pre-breeding programme (where possible with linkage to gene banks) is necessary, alongside fundamental evaluatory work.

K 2.4.5
Strengthening the global system for the conservation and sustainable use of plant genetic resources

The final act of the CBD negotiations in Nairobi (1992) called for clarification of open issues relating to *ex-situ* stocks and 'farmers' rights', and for adaptation of the same to meet the requirements of the CBD. In response the United Nations Food and Agriculture Organization (FAO) began revising the International Undertaking on Plant Genetic Resources for Food and Agriculture (IUPGR) in 1993. The IUPGR was adopted in 1983 under the lead of the FAO as a non-binding declaration of intent and deals with plant genetic material as the 'common heritage of humankind' that should be freely available to all users. The aim of the agreement is to ensure that plant genetic resources of economic and social interest (in particular for agriculture) are researched, preserved and available for both breeding and scientific purposes. The FAO's Commission for Genetic Resources revised the IUPGR over several rounds of negotiations. The Council welcomes the decision in favour of a legally binding agreement on the International Undertaking and recommends support being given to the negotiations and their conclusion within the period set aside for that purpose, the early part of 2000. This would allow the 5th COP of the CBD to address the agreement. The prerequisites for adoption of the revised International Undertaking as a Protocol to the CBD should be examined in good time.

K 2.4.6
Advancing guidelines for sustainable tourism and biosphere conservation

The initiative for a supplemental arrangement to anchor tourism guidelines within the CBD is, in the Council's view, a step in the right direction since a 'Tourism Protocol' does not currently seem enforceable internationally (Section E 3.7). The guideline approach, more flexible as a result of its non-binding nature, is more suited to activating the requisite incentive systems for sustainable tourism than a protocol would be, since there is more scope and room for dynamic adaptation to current developments for the players. Having said that, this process is too focused on biological diversity since the Framework Convention on Climate Change (foreseeable increase in air traffic) and the Desertification Convention (concentration of tourism in arid and semiarid areas) are both affected. It does not seem practicable to thrash out guidelines or protocols for all of the 'Rio Conventions'. Therefore, the Council recommends examining whether the process launched under the auspices of the CBD could constitute an element in a future overarching international regulation on sustainable tourism.

K 2.4.7
Trade in endangered species: improving controls and providing compensation

In the case of the species classified according to the Convention on the International Trade in Endangered Species of Wild Fauna and Flora (CITES) for limited use (Appendix II), it should be ensured that the profits derived from that use directly benefit the preservation of species stocks, realization of preventive measures and support for local subsistence communities. The existing strategies for the appropriate combination of conservation and use aspects should be examined for weak points and supplemented accordingly (Section D 3.4). Establishing admissible export quotas should also be preceded by a scientific evaluation of species stocks, habitat quality, etc. There is also a continued need to develop individual management plans focused on the range states and their respective stocks for the sustainable use of national biological diversity and benefit-sharing. The controls and monitoring system for compliance with CITES provisions must also be improved. To that end the certification and corresponding recognition methods (eg genetic testing) that facilitate distinction between legally and illegally obtained specimens or products of an endangered species must be advanced. In the case of species excluded from use or trade in accordance with CITES (Appendix I) the strict trade regulations as foreseen in the convention can cut off important revenue sources in certain range states, particularly developing countries. The German federal government should therefore at the same time advocate compensatory measures for these countries disadvantaged by the regulations. One might think, for example, of compensatory payments or an appropriate debt waiver.

K 2.4.8
Making progress on a legally binding instrument for forest conservation

For a long time now the international community has been endeavouring to achieve a global regulation for forest management. A binding document failed at UNCED in 1992. The result was a non-binding 'Statement of Principles for a Global Consensus on the Management, Conservation and Sustainable Development of all Types of Forests' (WBGU, 1996). The debate surrounding an international instrument is as topical as ever. On the one hand, the topic of forests can be dealt with in a special convention of its own that would have to be agreed. On the other hand, there is the possibility of adopting a forest protocol under the auspices of the CBD. The Council has spoken out in favour of a forest protocol under the auspices of the CBD in the past and still considers this solution to be the most promising (WBGU, 1995b). In a new forest convention located within the FAO and to be negotiated anew the equal status of conservation and sustainable use that is already enshrined in the CBD would first have to be achieved. Given the lack of current international enforceability of a protocol to the CBD, however, an independent forest convention might in any case be preferable to a merely non-binding continuation of the discourse in an intergovernmental body (Section I 4).

K 2.4.9
Strengthening UNESCO's Man and the Biosphere programme

UNESCO's Man and the Biosphere programme (MAB) established in 1970 is particularly important because it combines individual areas into a worldwide network (356 biosphere reserves, participation of over 100 states) in which experiences and results are exchanged and, for instance, transferred to comparable regions. In 1995 the statutes were drawn up for the network and a new strategy (Seville Strategy). These documents provide a clear framework for the programme and for individual biosphere reserves, eg periodic reporting and evaluation is envisaged. In the Seville Strategy the states are given a number of objectives and recommendations, which provide not just clear instructions for the design and management of biosphere reserves with their modern, integrational approach, but also form a bridge to the Biodiversity Convention. It is the Council's view that these possibilities should be used to a greater extent in the future, also in connection with corresponding national strategies. This would include above all application of the Seville Strategy and the further development of the network of biosphere reserves. The trend towards larger biosphere reserves better linked with their environs and increasingly transnational is something to be welcomed and should be promoted further. Better use could be made of the MAB programme as an instrument for international cooperation on biosphere conservation. Since there is no financing mechanism specifically for that purpose, the states should be encouraged to make increasing use of the GEF. The worldwide network of protected areas from the World Conservation Union (IUCN) and the network of biosphere reserves complement one another. Cooperation between the Commission for Protected Areas of the IUCN and the MAB programme should therefore be intensified.

K 2.4.10
Promoting the World Heritage Convention as an element of a global conservation strategy

The goal of the 1972 UNESCO World Heritage Convention is the worldwide conservation of cultural and natural heritage of outstanding value to humanity. The World Heritage Convention is an important element in a global conservation strategy and therefore also important for the implementation of the CBD. Replenishment of the World Heritage Fund is necessary if it is to be able better to fulfil the numerous tasks with which it is charged. Efforts should also be made increasingly to deploy GEF funds for projects to protect natural heritage areas and to link concerns under the World Heritage Convention with the implementation measures of the CBD. In Germany, the World Heritage Convention is perceived above all as an instrument for the conservation of cultural heritage, which is reflected in the fact that lead responsibility lies with the Ministries of Culture. It should be investigated whether the instrument could also increasingly be used to see and protect natural and cultural heritage as indivisible from one another. In that sense the World Heritage Convention should be applied as a building block in the national strategy for the implementation of the CBD.

K 2.4.11
Developing a global soil convention

In the past the Council has on several occasions pointed out that the destruction of soils is hardly being recognized at all by the public (WBGU, 2000a). Soil degradation is however a global problem. Furthermore, soils are a crucial element in the dynamics of the Earth System and are therefore a pivotal element of biosphere conservation (WBGU, 1995a). International policy has to this day failed to do justice to this importance (Box E 3.3.-7). Whereas global conventions have been negotiated on the protection of the climate and biological diversity, the Desertification Convention (CCD) addresses only one portion of soil degradation worldwide. The CCD is global in terms of its membership possibilities, but its jurisdiction is limited to arid areas. Therefore, the Council in its 1994 annual report recommended developing the Desertification Convention further into a global soil protection convention. This can take place by expanding the CCD, drawing up a protocol to the existing convention or negotiating a new convention. The Council's proposal (WBGU, 1995a) was taken up by the Tutzing Initiative for a Soil Convention (TISC) that submitted a first draft on this subject in 1998. The Council welcomes this new discussion on the creation of a global soil convention and recommends that soil-related issues be addressed to a greater extent in the UNCED follow-up process and in particular in the context of the forthcoming Conference of the Parties. By ascertaining what the potential fields of conflict and objections of the international community might be, the plan is to evaluate what obstacles there are to the implementation of this project and what strategies for creation of a convention for global soil protection would have to be developed.

K 2.4.12
Promoting resource conservation in fisheries policy

Since the continuing overcapacity is the main cause of overfishing (Section E 3.4), the Council recommends supporting measures to reduce fishing fleets under the auspices of the FAO's International Action Plan on the management of fishing capacities at relevant conferences (eg FAO Meeting of Ministers on Fishery, FAO Fisheries Committee, meetings of the EU Fisheries Council) and the entry into force in the context of the United Nations Agreement on Straddling and Highly Migratory Fish Stocks (UNFA). The Council considers dismantling subsidies to be a suitable method in this context.

The management analyses submitted each year for over 100 fished stocks of the North Atlantic by way of scientific coordination of the International Council for Exploration of the Sea should be given greater attention when setting annual overall catch quotas (by the EU Fisheries Council and the other riparian states). In the case of stocks that are in danger from overfishing we advocate in this context the use of internationally recognized fisheries protection zones and moratoria until the stocks in question have recovered. Moratoria should only be lifted on the basis of stock analyses by the International Council for Marine Research. In the area of aquaculture, support should be given to the switch to environmentally friendly, long-lived and adapted forms. It would be helpful in this context to develop and enforce international criteria and labelling of environmentally friendly aquaculture. The principles enumerated in the FAO Code of Conduct and the directives for implementation of the same provide a basis, which could be built upon.

K 2.4.13
Improving coordination between global environmental agreements

In order to avoid duplication, overlaps or contradictory developments, coordination of individual processes under global environmental and sustainability policy is necessary. For instance, there was no timely coordination between the Biodiversity, Desertification and Climate Change Conventions prior to adoption of the Kyoto Protocol, that deals with offsetting biological sinks and sources against greenhouse gas reduction commitments for the purposes of climate protection (Section I 3.4.3). The possibilities envisaged in that protocol of offsetting afforestation, deforestation and reforestation against fulfilment of the obligation to reduce carbon dioxide emissions are not reconcilable with the objectives of climate, soil and biosphere conservation (WBGU, 1998b). The ongoing deliberations of the Intergovernmental Forum on Forests (IFF) were also not taken into account. Alongside a general improvement in the exchange of information and increased coordination between the individual negotiating processes, the Council recommends a harmonization of reporting systems within existing environmental conventions and joint development of indicators. In particular, the scientific committees of the COPs should increasingly address issues of overlap with other environmental conventions.

K 2.4.14
Strengthening development cooperation as an instrument of biosphere conservation

In the context of its development cooperation, Germany makes an important contribution to global biosphere conservation for instance by establishing national parks in developing countries, drawing up environmental action plans or supporting nature conservation-oriented rural development. Within the framework of the sectoral project 'Implementing the CBD' launched in 1993 and a number of other projects with similar objectives (eg the Tropical Ecology Support Programme and numerous projects under bilateral cooperation) the BMZ is directly engaged in implementing the goals of the CBD (Section I 3.5.3). The Council welcomes this commitment and recommends that the federal government continue to make intensive use of this instrument. Support should be given especially to projects that place the valorization of nature and thus the strategy of 'conservation through use' increasingly at the service of integrated support for economic development and conservation of the biosphere (Section E 3.3.3).

The work of the GTZ in the area of bioprospecting and the development of international standards for access to genetic resources and benefit-sharing (Section I 3.2.9) and protective systems for indigenous knowledge (Section I 3.2.10) should also be continued since they support important goals within the CBD. Furthermore, it should be examined in what way the concept of bioregional management might be combined with the existing approaches of rural regional development (Section E 3.9). Finally, the exchange of information and capacity-building through the transfer of technology are important pillars of international biosphere policy. Therefore, support should be given to the development of research institutions of their own in biodiversity-rich countries and the readiness of companies to invest in such initiatives should be mobilized accordingly. The Council recommends giving close attention to the possibilities for expanding technology transfer in the interests of the conservation and sustainable use of biological diversity when drawing up national biodiversity strategies.

K 3 Funding and international cooperation

K 3.1
Increasing deployment of combined incentive systems

Article 10 of the CBD calls on the parties to deploy social and economic incentive measures increasingly for the conservation and sustainable use of the biosphere. The Council supports the information advantages that go along with the incentive system at a decentralized level in order to achieve ecological goals in as efficient a manner as possible. In the light of the complexity of issues faced both with regard to ecological interconnections and the large number of players involved, a broad spectrum of incentive instruments should be introduced and deployed in combination with one another. This combined deployment of incentive instruments calls for suitable scientific, technical and political capacities.

K 3.2
Strengthening bilateral and multilateral cooperation

Germany is highly committed to international biosphere conservation and, after Japan and the United States, is the third largest contributor to the GEF. Also, in the case of the debt-for-nature swaps, the Federal Republic of Germany is one of the leaders worldwide providing annual support of around US$100 million. Debt-for-nature swaps are intended to allow developing countries to reduce their debt burden and, at the same time, make investments in the conservation of biological resources. This instrument is a meaningful option for funding nature conservation projects if the conditions attached to it are accepted and controls are possible. The Council explicitly welcomes the German federal government's initiative for debt waivers for the highly indebted poor developing countries (Cologne Debt Initiative) because it provides the impacted countries with greater scope for action in favour of nature conservation (Section I 3.5.3.2). However, given the declining development funds from the OECD countries over many years, at the same time as the problems are exerting a greater pressure than ever, higher financial commitment from the international community is unavoidable. The Council notes with concern that the international community is further away from the 0.7 per cent target than ever. Therefore, the increase in German development cooperation funding already advocated in earlier reports to a target level of 1 per cent of gross national product is not just compatible with the UNCED resolutions thus worthy to be pursued and proportionate to the urgency of the problems, but also to be understood as an appeal from the Council for urgent action to take place in this area.

K 3.3
Developing 'nature sponsorship' as an instrument of biosphere policy

By analysing the three pillars of biological diversity (genes/species, ecosystems, global systems) the Council has outlined in the present report biological imperatives for a guard rail strategy for the biosphere, in compliance with which it defines the minimum requirement for 'good' environmental policy. From this approach a geographically explicit catalogue of keystone species, ecosystems and landscapes that should be preserved could be derived. One could speak of the 'green heart' of our planet that must continue beating.

As outlined above, public monies should be deployed in a considerable degree for the achievement of this goal with the most effective instruments in economic terms being selected. It would be illusory, however, to expect that funding would come from tax revenues of individual states alone. Therefore, the Council suggests providing political support for the efforts initiated already by various NGOs (eg WWF) to create a privately operated 'Biosphere Fund' – in particular, with regard to integration of this idea to become a worldwide concept.

This Fund would be established with the aim of protecting available areas of strategic importance for the biological diversity of the Earth that are not yet under government care (eg purchase of areas or project support) and safeguarding their functions within the global ecosystem (Section I 1.4). This could, for example, be done by founding a suitable private stock company whose shareholders would purchase rights of codetermination and profit-sharing rights with regard to future use (for instance, in the context of sustainable tourism). It is to be expected that the high level of individual willingness to pay for environmental conservation would make this form of 'nature sponsorship' an important instrument in global biosphere policy. From the point of view of public decision-makers, one might think of how these funds could be supported in a subsidiary manner – eg by granting tax relief for stock subscribers in recognition of the non-profit cause. Such ideas from the Council might seem utopian at the present time, but the power of individual opinion-building in the context of shaping a sustainable environment may possibly be more effective in the emerging global knowledge society than any official regime.

K 3.4
A worldwide system of protected areas can be funded

Funding for biodiversity conservation measures constitutes a major challenge: there is a considerable funding gap, particularly in relation to compensatory payments to developing countries (Section E 3.3.2). New studies show that a worldwide system of protected areas, comprising approx 15 per cent of the worldwide land area (Section K 2.2.5), would cost an additional total of approx US$21.5 thousand million annually. It is not impossible for the international community to make this sum available. Appropriate shaping of economic incentives and reduction of subsidies could yield these funds. Initial estimates of worldwide subsidies with a damaging effect on biological diversity total between US$950 and 1,450 thousand million per year. Reduction and partial redirection of agricultural subsidies by honouring ecological services would provide major opportunities for the conservation of biological diversity.

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Glossary

M

Adaptive management is flexible, adaptable management of natural or artificial ecosystems (➥ ecosystem approach). Incomplete knowledge about biological systems and their constant change is recognized as a fundamental reality. Aims or strategies are not set 'once and for all'; a non-dogmatic, experimental approach is used whose results are evaluated and used in feedback to improve management. Adaptive management is characterized by a general disinclination towards irreversible interventions and a general preference for high biological and cultural diversity.

AGENDA 21 is the legally non-binding programme of action for ➥ sustainable development that was adopted in 1992 at the United Nations Conference on Environment and Development. AGENDA 21 encompasses 40 chapters, each recommending individual measures on sectoral (such as Chapter 15 on Conservation of Biodiversity) or cross-cutting (such as 'Financial Resources', 'Children & Youth' or 'International Institutions') issues.

Agrobiodiversity is the ➥ biological diversity of all organisms in agro-ecosystems and the diversity of these systems themselves. The composition of agrobiodiversity has been brought about by some 10,000 years of agriculture and would not exist without it. A worldwide trend towards agrobiodiversity loss persists unabated.

Albedo is the proportion of solar radiation, usually expressed as a percentage, that is reflected from the Earth's surface (soil, water, ice and vegetation) or from clouds.

Alien species (or 'invasive species', 'alien species') are species that since the start of the modern era have been introduced either by human activities – intentionally or accidentally – in previously unpopulated areas or have migrated there independently (Section E 3.6). The modern era saw the start of a previously unseen worldwide exchange of fauna and flora elements that led to the transfer of organisms in regions well beyond the limits of their natural ranges. Seen from a world perspective, the introduction of alien species is the greatest threat to biological diversity – after the loss of habitats as a consequence of changes in land use.

Biodiversity ➥ biological diversity.

Biodiversity Convention (or Convention on Biological Diversity – CBD) is the central international regulatory instrument pertaining to the biosphere (Section I 3). It was signed in 1992 at the UN Conference on Environment and Development, entered into force in 1993 and has since been ratified by 178 states. The parties to the CBD undertake (1) to conserve ➥ biological diversity, (2) to use its components sustainably and (3) to share the benefits arising from the utilization of genetic resources fairly and equitably. This means that the CBD is not a pure nature conservation agreement; it also governs the availability and use of biological diversity. Existing conventions, programmes and institutions relevant to the biosphere have taken a new direction since the CBD entered into force and have adapted their work to the new objectives and concepts of the CBD.

Biodiversity hotspots are regions of the Earth that are rich in ➥ biological diversity and endemic species and whose natural habitats are at risk. They account for only around 2 per cent of the land surface, but contain over 50 per cent of the diversity. Many of these hotspots are in tropical developing countries.

Biological diversity (or biodiversity) means the diversity of life forms in all their varieties and interrelations. It includes the entire range of variations within and variability between systems and organisms at the three levels set out below, as well as the structural and functional relationships between these levels, including human interventions:

1. *Ecological diversity* – diversity of biomes, landscapes and ecosystems through to ecological niches
2. *Organismic diversity* – diversity among taxonomic groups such as phyla, families, genera through to ➥ species diversity
3. *Genetic diversity* – diversity of populations ranging from individuals to genes and nucleotide sequences

Biological imperatives are principles that assist in conserving and sustainably using the ➥ values of the biosphere for present and future generations. They are necessary because, in the case of the biosphere, definable damage limits (➥ guard rails) cannot always be set.

Biome is the largest biogeographical unit, a large-area biotic community with similar life forms and climatic conditions; however, it may embrace a large number of integrated ecosystem types. Biomes are usually named after the predominant type of vegetation, eg tropical rainforest, savannah or tundra.

Bioprospecting (or 'prospecting for biological diversity') is the search for biological material (collection, identification and analysis) for the purpose of processing these for potential industrial use (Section D 3.3). Because of the higher degree of success, this is mainly conducted in countries with high levels of ➥ biological diversity.

Bioregion is a geographically definable area that is characterized by its typical ecosystems as well as its culture and history and comprises several ecosystem and ➥ landscape use types (eg water catchment areas, forests, arable land, settlements). The bioregion is a suitable framework for the management of biological resources (➥ bioregional management) because it facilitates an integrative perspective on the ecosystems in a region with their interlinkages and biogeochemical fluxes, and safeguards close feedback between measures and their impacts. As a result of the clarity of the bioregion and the close link between the local population and policies, conflicts of interest can be better solved on the ground.

Bioregional management strives, through use of a range of instruments and involvement of relevant groups and institutions, to develop and implement a gradated conservation and usage concept for the biological resources of a bioregion (Section E 3.9.2). A zoning concept, the networking and involvement of relevant players, the consideration of sustainability rules for intensively-used land, ➥ adaptive management and capacity building are key elements of this approach.

Biosafety (or 'safety of biotechnology') refers to strategies for managing the risks posed by biotechnology, especially the transmission, handling and use of genetically modified organisms (Section D 3.2). The release into the wild of transgenic plants and their uncontrolled spread, and any negative secondary effects in natural ecosystems and in foods are examples of such risks. These risks are characterized by high levels of uncertainty with regard to the probability of their occurrence and the extent of damage as well as with regard to the certainty of assessment of these two parameters. Negotiations on an international agreement on this issue are currently on-going (Biosafety Protocol to the ➥ Biodiversity Convention).

Biosphere is the area of the Earth occupied by life, from the inhabited layer of the Earth's crust (including the seas and oceans) right up to the lower layer of the atmosphere. The biosphere forms a global ecosystem almost exclusively driven by solar energy, made up of organisms and that part of non-living material that interacts with the organisms. It is characterized by complex, worldwide biogeochemical cycles. People (and their economic activities) as living creatures are also components of the biosphere. The biosphere is closely functionally interlinked with the atmosphere, pedosphere and hydrosphere.

Biosphere values (or 'values of biological diversity') are the various value categories that are fundamental for a ➥ valuation of biosphere services, for example (Section H 5.4). The Council makes a broad distinction between five value categories:

1. *Functional value*, ie the varied ➥ ecosystem services that the biosphere performs for humans (eg biogeochemical cycles, flood control, soil protection);
2. *Economic use value*, ie the ecosystem services for production or consumption purposes (eg food, wood, recreation, the experience of nature);
3. *Symbolic value*, ie an aesthetic, religious or other culturally inspired assignment of meaning to natural phenomena (eg holy trees, heraldic animals);
4. *Existence value*, ie the benefit arising from the sheer knowledge of the existence or conservation of biological diversity without it being used personally;
5. *Option value*, ie the possibility of a future realization of a value of the four other categories (eg possible benefit of a ➥ genetic resource for medicine in the future).

Core problems of global change are, in the ➥ syndrome concept, the central phenomena of global change. They appear there either as particularly significant ➥ trends of global change, such as human-induced climate change, or they comprise several interrelated trends. One such 'megatrend' is the core problem of 'soil degradation', which comprises several trends such as erosion, salinization, contamination, etc.

Criticality index is a composite indicator that can measure the vulnerability of a region or the population that lives there to crises – here environmental or development crises in particular.

Debt swaps refer to the 'exchange' of debt titles (usually in developing countries) for certain actions, such as a certain environmental policy (debt-for-nature swaps) or a certain food security policy (debt-for-food-security swaps). The form that these transactions take depends on the type of debts. In the case of debts to foreign banks, for example, the debt-for-nature swaps open up opportunities to simultaneously score successes against the debt crisis and for environmental protection.

Disposition in the ➥ syndrome concept refers to the susceptibility of a region to a certain syndrome. The 'disposition area' refers to the geographical distribution of the disposition; it is determined by natural and anthropogenic framework conditions that change only in the long term.

Ecosystem means a causal web of biotic communities and their abiotic environment as a recognizable, spatially separate entity. The basic ecological components are the producers (usually green plants, but also microorganisms), consumers (animals and microorganisms that feed on organic matter) and decomposers (microorganisms and animals that decompose organic matter). They are connected to each other by means of food chains and webs, through which the energy absorbed by the producers is transferred. Another key feature of ecosystems is the conversion of nutrients and other substances in biogeochemical cycles.

Ecosystem approach is a fundamental concept for the implementation of the Convention on Biological

Diversity and ➥ bioregional management; it is referred to frequently. Nevertheless, there is currently neither a generally recognized definition nor agreement on what it entails. A provisional description is as follows: in the ecosystem approach, the use of biological resources, or the influencing of them, should be based on the application of appropriate scientific findings and methods that broadly relate to the ecosystem level. Here, special attention should be paid to the consideration of complex systemic effects, non-linear dynamics, time lags, threshold values, discontinuities and similar typical ecosystem properties. In this process humankind is understood as an integral component of ecosystems. ➥ Adaptive management is an important strategy of the ecosystem approach.

Ecosystem service describes the link between ecosystems and human use (Box D 2.5-1). As a result of valuation, originally value-free ecological structures, functions or processes turn into products and services. The human race depends on a large number of ecological products and services that cannot be replaced by technology. These are not just marketable products from agriculture, forestry and fisheries; they also include control services (eg climate, water cycle, biogeochemical cycles, soil formation and conservation) and ecosystem services for the quality of human life (local recreation, the experience of nature, ecosystems as sources of culture, etc).

Ecotourism is a form of nature tourism that aims at minimizing negative impacts on the environment and socio-cultural changes, contributes to financing protected areas and protection schemes and creates sources of income for the local population (Section E 3.7).

Evapotranspiration is the total evaporation of water from the soil and from vegetation.

Exposure in the ➥ syndrome concept refers to natural or anthropogenic events or rapid processes, such as natural disasters or sudden fluctuations in exchange rates that, in a region prone to crises in which there is ➥ disposition, can trigger a syndrome.

Ex-situ conservation is the conservation of components of ➥ biological diversity outside their natural habitat, for example in gene banks or botanical and zoological gardens.

Genetic diversity refers to the diversity of genetic information within populations, species or ➥ ecosystems. It forms a level of ➥ biological diversity. For example, high genetic diversity safeguards the potential of a species to successfully adapt to environmental changes, because selection – whether natural or artificial, as by breeding – can only take place if there is genetic diversity. For this reason it is of inestimable value for plant breeding and is also a prerequisite for natural evolution. Genetic diversity among plants and animals used by humankind is currently falling rapidly (genetic erosion).

Genetic resource means such genetic material (ie biological material with functioning genetic information) that is of current or potential benefit to humankind.

Global governance is a term which, while used increasingly in politics and political science, has no definitive and agreed definition; sometimes the term is used normatively, sometimes analytically. Often global governance is used to describe the notion that the great increase in international institutions in recent decades has not only brought about a quantitative change, but has also led to a new quality that transcends the traditional understanding of policy between states. Global governance is by no means a form of global government.

Global network of interrelations means, in the ➥ syndrome concept, a qualitative network embracing all ➥ trends of global change, as well as their interactions. The global network of interrelations provides a highly aggregated description of the global change system in terms of specific phenomena.

Guard rails demarcate, in the ➥ syndrome concept, the domain of free action for the people-environment system from those domains which represent undesirable or even catastrophic developments and which therefore must be avoided. Pathways for sustainable development run within the corridor defined by these guard rails. In this report the proposed guard rail is for 10–20 per cent of worldwide land area to be given nature conservation status.

Guidelines are management rules for land use that are intended primarily to ensure sustainability on intensively used land (➥ landscape use type 'economic use').

In-situ conservation is the conservation (or restoration) of ➥ biological diversity in natural ➥ ecosystems. Viable populations of species are conserved in their natural habitats or – in the case of domesticated species or varieties – in the habitat in which they have acquired their special characteristics.

International regimes are regulatory systems comprising implicit or explicit principles, standards, rules and decision-making processes within which the expectations of players – usually countries – converge in a specific area of international relations.

Landscape use types are idealized use types for landscapes and their ecosystems. The Council makes a distinction between three different types (Section E 3.3.1):

1. Landscape use type 'N' ('Nature conservation' type, 'conservation before use' principle). This is a landscape that is significant from a biological-ecological point of view that, for example, is charac-

terized by its high biological diversity with many endemic, rare or endangered species (➥ biodiversity hotspot). In this case, priority is given to the interests of conservation; exploitative economic use has to take a back seat.

2. Landscape use type 'E' ('Economic use' type, 'conservation despite use' principle). This type of landscape is characterized by especially good economic utility (eg high agricultural yield with favourable soils). In this type the economic use interests dominate. By adhering to ➥ guidelines, the sustainability of the use on the land has to be ensured.
3. Landscape use type 'M' ('Mean protection requirement' type, 'conservation through use' principle). A median position between the two types 'N' and 'E' described above is characteristic of this landscape use type. Both the protection requirement and the economic use interest are in a median area. Landscapes of this type are suitable for pursuing both conservation and use objectives in an integrated approach.

Multifunctional land use is a guiding principle that is not predominantly oriented to production nor restricted to individual components or organisms, but that embraces equally all ➥ ecosystem services and functions (Section E 3.3.4.10). The highly productive, industrial land use should be designed in a way that is sustainable, environmentally sound and socially acceptable with the help of ➥ guidelines. In the process, the pollution of neighbouring terrestrial and aquatic systems and of the groundwater and the atmosphere emanating from the intensively used ecosystems has to be taken into account. Multifunctional land use can be regarded as the implementation of the ➥ ecosystem approach in highly-productive intensive agriculture and forestry.

Net Primary Production (NPP) is a measure of plant growth (increase in biomass) and is calculated from the quantity of carbon that green plants absorb by means of photosynthesis, minus respiration. Among other things, NPP is an indicator of the reaction of vegetation to climate change and the rise in atmospheric carbon dioxide concentrations.

On-farm conservation is a strategy for the ➥ *in-situ* conservation of ➥ agrobiodiversity by means of the targeted promotion of traditional agriculture that is characterized by high diversity in cultivation. This is not just a matter of merely conserving the *status quo*; the continuation of traditionally anthropogenic and natural selection processes is supported, which is not possible in ➥ *ex-situ* conservation.

Species diversity is part of ➥ biological diversity. It is usually expressed as number of species per unit area. Total species diversity has increased greatly in the course of the Earth's history. As a result of 5 major extinctions it has been temporarily drastically reduced, but in the early Holocene (around 10,000 years ago) it reached its maximum. Currently, there is the threat of a 6th wave of extinction, this time human-induced. The number of species living on the Earth today can only be estimated roughly; one of the estimates is around 14 million species, with a range of variation from 4 to 110 million species (Table D 1.2-1).

Sustainable development is mostly understood as a concept of environmental and development policy that was formulated by the Brundtland Report and further developed at the UN Conference on Environment and Development in Rio de Janeiro in 1992. In the process, democratic decision-making and implementation processes should promote development that is ecologically, economically and socially sustainable, and should consider the needs of future generations. With its ➥ syndrome concept the Council offers an approach to the operationalization of this complex concept.

Syndrome concept is a scientific concept for the interdisciplinary characterization and analysis of global change developed by the Council. Key elements of the syndrome concept, in addition to the ➥ syndromes, are the ➥ global network of interrelations, comprising ➥ trends and their interactions and the ➥ guard rails.

Syndromes of global change refer to functional patterns of critical relationships between humankind and the environment that manifest themselves spatially. These are characteristic, globally relevant constellations of natural and anthropogenic ➥ trends of global change as well as the interactions between them. In analogy to medicine, every syndrome is a 'global symptom'; it represents an anthropogenic cause-effect complex with specific environmental stresses and thus forms a discrete pattern of environmental degradation. Syndromes reach beyond individual sectors such as industry, biosphere or population, as well as across individual environmental media such as the soil, water or air. Syndromes always have a direct or indirect spatial reference to natural resources. A syndrome can usually be identified in several regions of the world with differing degrees of intensity. Several syndromes may occur simultaneously in one region.

Taxonomy is the science of identification, description, nomenclature and classification of living or extinct organisms in a hierarchical system.

Trends of global change are in the ➥ syndrome concept phenomena in society and nature that are relevant to global change and characterize it. These are changeable or processual factors that can be determined qualitatively, such as the trends of 'population growth', 'intensified greenhouse effect', 'growing environmental awareness' or 'medical progress'.

Valuation of biosphere services is the attempt to assign a ➥ value to biosphere services. Economic valuation approaches use monetarization to derive a monetary utility equivalent for biosphere services in order to contribute to objectification and comparability. This does not diminish the significance of ethical evaluation concepts, especially in cases where the economic approach meets the limits of its applicability because of the non-substitutability and irreversibility of many biosphere services.

Variety is the lowest category of crop that is characterized by different features and can be propagated without changing. Thus, plant breeders have developed thousands of potato varieties, for example, with different properties that, nevertheless, all belong to the same species: *Solanum tuberosum*. Varieties can be legally protected (eg by the German Varieties Protection Act), meaning that the breeder of a variety also has the marketing rights.

The German Advisory Council on Global Change

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Joint Decree on the Establishment of the German Advisory Council on Global Change (April 8, 1992)

Article 1

In order to periodically assess global environmental change and its consequences and to help all institutions responsible for environmental policy as well as the public to form an opinion on these issues, an Advisory Council on 'Global Environmental Change' reporting to the Federal Government shall be established.

Article 2

(1)

The Council shall submit a report to the Federal Government by the first of June each year, giving an updated description of the state of global environmental change and its consequences, specifying quality, size and range of possible changes and giving an analysis of the latest research findings. In addition, the report should contain indications on how to avoid or correct maldevelopments. The report shall be published by the Council.

(2)

While preparing the reports, the Council shall provide the Federal Government with the opportunity to state its position on central issues.

(3)

The Federal Government may ask the Council to prepare special reports and opinions on specified topics.

Article 3

(1)

The Council shall consist of up to twelve members with special knowledge and experience regarding the tasks assigned to the Council.

(2)

The members of the Council shall be jointly appointed for a period of four years by the two ministries in charge, the Federal Ministry for Research and Technology and the Federal Ministry for the Environment, Nature Conservation and Reactor Safety, in agreement with the departments concerned. Reappointment is possible.

(3)

Members may declare their resignation from the Council in writing at any time.

(4)

If a member resigns before the end of his or her term of office, a new member shall be appointed for the retired member's term of office.

Article 4

(1)

The Council is bound only to the brief defined by this Decree and is otherwise independent to determine its own activities.

(2)

Members of the Council may not be members either of the Government or a legislative body of the Federal Republic or of a Land or of the public service of the Federal Republic, of a Land or of any other juristic person under public law unless he or she is a university professor or a staff member of a scientific institute. Furthermore, they may not be representatives of an economic association or an employer's or employee's organization, or be permanently attached to these through the performance of services and business acquisition. They must not have held any such position during the year preceding their appointment as member of the Council.

Article 5

(1)

The Council shall elect a Chairperson and a Vice-Chairperson from its midst for a term of four years by secret ballot.

(2)

The Council shall set up its own rules of procedure. These must be approved by the two ministries in charge.

(3)

If there is a differing minority with regard to individual topics of the report then this minority opinion can be expressed in the report.

Article 6

In the execution of its work the Council shall be supported by a Secretariat which shall initially be located at the Alfred Wegener Institut (AWI) in Bremerhaven.

Article 7

Members of the Council as well as the staff of the Secretariat are bound to secrecy with regard to meeting and conference papers considered confidential by the Council. This obligation to secrecy is also valid with regard to information given to the Council and considered confidential.

Article 8

(1)

Members of the Council shall receive all-inclusive compensation as well as reimbursement of their travel expenses. The amount of compensation shall be fixed by the two ministries in charge in agreement with the Federal Ministry of Finance.

(2)

The costs of the Council and its Secretariat shall be shared equally by the two ministries in charge.

Dr Heinz Riesenhuber
Federal Minister for Research and Technology
Prof Klaus Töpfer
Federal Minister for Environment, Nature Conservation and Reactor Safety
May 1992

— Appendix to the Council Mandate —

Tasks to be Performed by the Advisory Council Pursuant to Article 2, para 1

The tasks of the Council include:

(1)

Summarising and continuous reporting on current and acute problems in the field of global environmental change and its consequences, eg with regard to climate change, ozone depletion, tropical forests and fragile terrestrial ecosystems, aquatic ecosystems and the cryosphere, biological diversity and the socioeconomic consequences of global environmental change. Natural and anthropogenic causes (industrialisation, agriculture, overpopulation, urbanisation, etc) should be considered, and special attention should be given to possible feedback effects (in order to avoid undesired reactions to measures taken).

(2)

Observation and evaluation of national and international research activities in the field of global environmental change (with special reference to monitoring programmes, the use and management of data, etc).

(3)

Identification of deficiencies in research and coordination.

(4)

Recommendations regarding the avoidance and correction of maldevelopments.

In its reporting the Council should also consider ethical aspects of global environmental change.

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