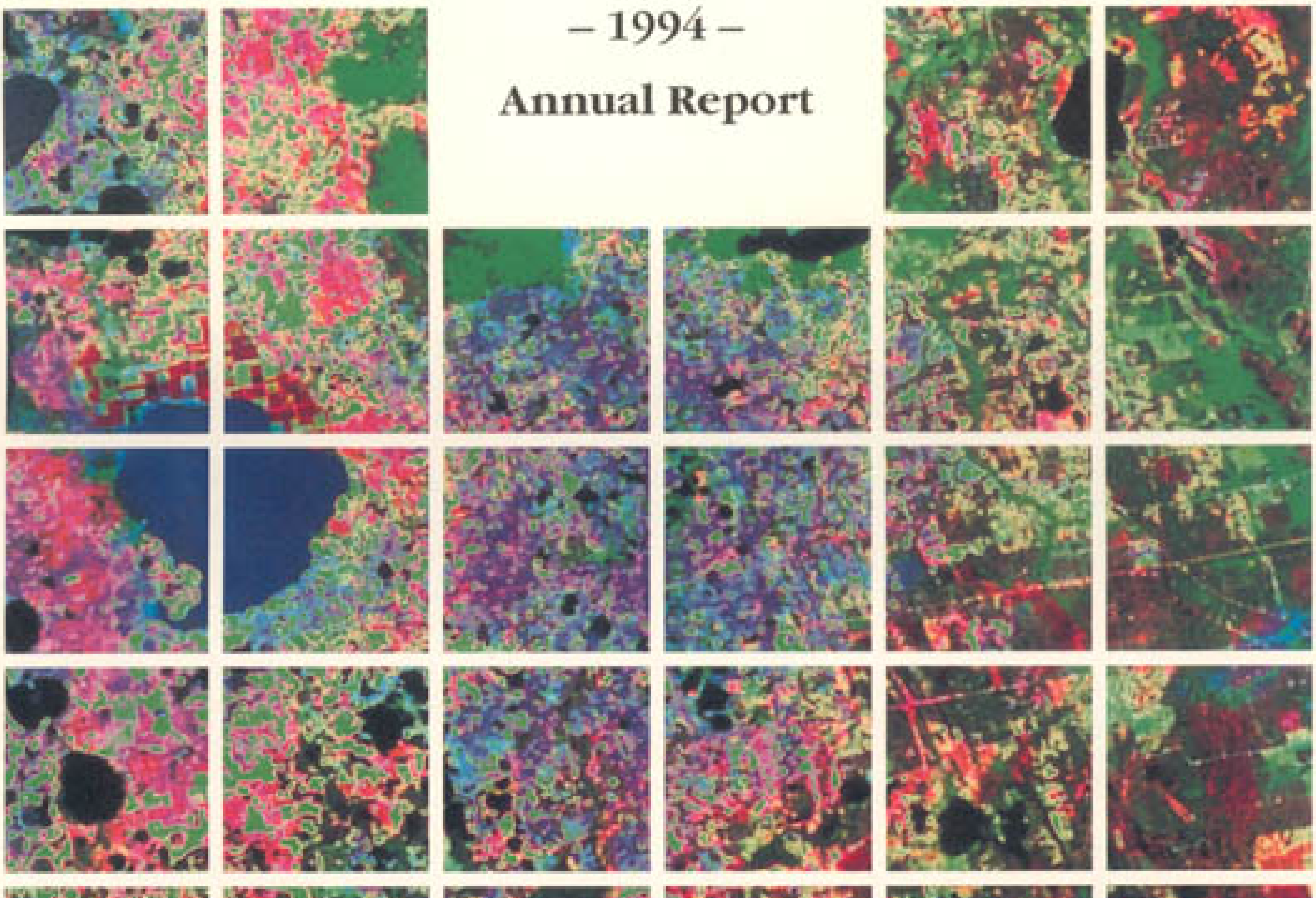
German Advisory Council on Global Change

World in Transition: The Threat to Soils

– 1994 –

Annual Report



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The German Advisory Council on Global Change

Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen

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German Advisory Council on
Global Change

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A Summary

World in Transition: The Threat to Soils

1 Structure of the Report

The 1994 Annual Report of the German Advisory Council on Global Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, WBGU) is divided into two sections. The first section *(standard section)* presents and comments on new developments in various fields of Global Change. In addition to findings from natural science, special reference is made to international conventions that already exist or which are currently being negotiated.

The second section of the Report *(focus section)* deals with the global threat to soils. The importance of soils for the ecosphere and the anthroposphere is demonstrated using global soil-related environmental trends and their interactions. Soils form an essential basis for humanity, but have received too little attention to date. In differing respects, human activities lead in many parts of the world to various levels of soil degradation, from declining fertility to irreversible destruction. Many local processes cumulate to form a global environmental trend that must be counteracted with political action as a matter of urgency.

In the run-up to an international "Convention to Combat Desertification" (the "Desertification Convention"), the Council would like to draw attention through this Report to the growing worldwide threat to soils. The fact that the slow destruction of soils is a process barely perceptible to human senses has meant in turn that this topic is dealt with in the environmental debate as a somewhat marginal issue. Therefore, the threat to soils must be accorded much greater significance on the environmental agenda -improved legal frameworks must be created, both nationally and internationally, for soils as an environmental asset.

2 Current developments (standard section)

♦ The carbon cycle and ozone depletion

Of the annual worldwide carbon emissions caused by the burning of fossil fuels and the combustion of biomass, amounting to around 6.8 gigatonnes, the ultimate fate of 1.4 gigatonnes still needs to be determined. It would appear that terrestrial, not marine sinks account for the discrepancy – for example, timber growth, increased humus formation and higher levels of biomass production. The so-called CO_2 fertilising effect plays a subordinate role in this respect. *Stabilisation* of CO_2 emissions at the 1990 level, as agreed in the "Framework Convention on Climate Change" as a first step to be taken by the industrial nations, would still signify a growing CO_2 *concentration* to more than double that of the pre-industrial age, even after the year 2100. That could lead to a worldwide temperature increase to levels which have not existed during the past 200,000 years.

The low rates of increase of CO_2 emissions during the period from 1991 to 1993 (but no longer for the first quarter of 1994) have not yet been fully clarified; reduced emissions in the transition countries of Eastern Europe cannot be the sole reason. Another factor explaining the lower rate of increase is the cooling process caused by the stratospheric aerosol layer formed after the Pinatubo eruption. Although ozone concentrations recovered in the winter of 1993/1994 from the "Pinatubo effect", the trend towards an ozone depletion rate of 3% per decade on the global mean appears to continue unabated.

♦ The "Global Environmental Facility"

In March 1994, industrial and developing countries reached agreement on the restructuring of the *Global Environmental Facility* (GEF), and a renewed increase in its budget to around US$ 2 billion for the 1994 to 1997 period. The largest contributors are now the USA, which provides US$ 430 million, followed by Japan (US$ 410 million) and Germany (US$ 240 million).

The fact that the future of the GEF was assured in this way, despite the difficult economic situation and tight constraints being faced in many countries, is certainly a positive step forward. In view of the enormous efforts that are required in the various spheres of Global Change, the Council holds, however, that further additional funding is imperative. This applies especially if protocols to the agreed Conventions on "Climate", "Biological Diversity" and "Desertification" are to be specified and adopted, and new Conventions on "Forests" and "Soils" are to be striven for. People's participation and cooperation with non-governmental organisations should be assigned higher priority for the GEF. This relates both to project planning and implementation, as well as to the development of national strategies for Sustainable Development in the individual countries.

♦ An instrument for the "Framework Convention on Climate Change": *Joint implementation*

The signatories of the "Framework Convention on Climate Change" have not yet agreed on binding targets for CO_2 or other emissions. However, the first conference of the parties (COP), which will take place between 28th March and 7th April 1995 in Berlin, is expected to arrive at such a concrete target definition. In that event, the need to select and design instruments for implementing emission reductions will become acute. The concept of Joint Implementation envisages that a signatory state can achieve its reduction not *only* through reductions within its own territory, but *also* through the funding of mitigation and preventive measures in other countries; the emission reductions achieved in other countries could then be "credited" accordingly against the national emission target.

The Council suggests that the application of this instrument should be promoted as far as possible; even so, it cannot and should not become the primary instrument in a global strategy for reducing greenhouse gases. If skilfully applied, the instrument offers substantial scope for reducing both economic costs and environmental damage. To achieve application of the instrument across as broad a range as possible, the Council recommends that a supranational institution (e.g. the Secretariat of the "Climate Convention") be entrusted with the task of supporting and verifying Joint Implementation projects. Germany should foster the application of the instrument through participation in bilateral pilot projects, whereby the relevant coordination could be assigned to the Federal Environmental Ministry.

♦ A contribution to the "Convention on Biological Diversity": CITES

Implementation of the "Convention on Biological Diversity", which came into effect on 29th December 1993, must also be pursued more intensively. Since its coming into effect in 1975, the *"Convention on International Trade in Endangered Species of Wild Fauna and Flora"* (CITES), formulated in connection with the first United Nations Conference on the Human Environment in Stockholm in 1972, has proved to be the most important international treaty so far on the control and regulation of international trade in endangered species of wild fauna and flora.

When the CITES convention was drawn up, the general assumption was that both exporting and importing nations have a vested interest in protecting species of fauna and flora as a future resource. Accordingly, the Convention provides the signatory states with a broad scope regarding the interpretation and implementation of the provisions it contains. A fundamental weakness of the CITES Convention, however, is the lack of clear definitions and classification guidelines with respect to the level of protection to be granted to endangered species.

In Germany, so far, global protection of endangered species has been neither a central field for action nor an important research area. This is all the more surprising given the fact that the Federal Republic was the first country in the European Community to join CITES and passed strict species protection regulations when implementing the objectives of the Convention as national law. The Council's recommendation to the Federal Government is that this "pioneer role" be put into practice and activated on a global scale. An important step towards conserving biological diversity at the national level, and an internationally important signal, would be the enacting of the draft for a new "Nature Conservation Act" that has currently been shelved.

♦ The concept of the "Convention to Combat Desertification"

More than 25% of the world's surface and over 900 million people are more or less seriously affected by desertification. At UNCED, this topic was once again made a central issue of political debate; chapter 12 of AGENDA 21 outlines the issues to be addressed concerning desertification. At the same time, it was agreed to establish, before the end of 1994, an international Convention with specific and legally binding obligations for combating desertification.

The particular measures proposed as part of the "Desertification Convention" are highly promising at first glance. These measures envisage integrated approaches to combating desertification and to extending successful projects through coordination and cooperation of the various funding institutions. In essence, the attempt is being made to learn from the mistakes of the past. People's participation is an important basis for locally relevant and environmentally sound project management. The Council recommends proactive and rapid implementation of the Convention, whereby existing programmes and projects organised through bilateral and multilateral cooperation (in particular the work of "GTZ" – the German Organisation for Technical Cooperation) could be integrated under the umbrella of the Convention.

3 German research on Global Change

In the view of the Council, research in Germany on Global Change continues to display deficits in terms of content as well as of organisation. Research lacks the *interdisciplinarity* needed to address complex problems in an adequate manner, as well as the *international links* needed to respond appropriately to the global nature of environmental changes and their effects in other parts of the world. Furthermore, there is a lack of *competence* in demonstrating ways to *solve the problems* posed by Global Change.

Whereas the diagnosis of physical changes in the environment is primarily a task for single disciplines within the natural sciences, analysing cause-and-effect chains of Global Change is an especially important field for the social sciences. Working out directives for action aimed at reversing these changes demands close cooperation between natural scientists, social scientists and engineers. In the opinion of the Council, there is no escaping the fact that willingness to participate in *multi-disciplinary dialogue* and to pursue an *interdisciplinary perspective* has declined at the universities. Both aspects do not fit into the career patterns typical for many faculties and areas of research, and fail to be rewarded to the extent due. These problems can only be solved through flexible, topic-oriented and project-oriented structures and research associations interacting across institutional boundaries.

With respect to the international dimension of research, the Council considers German climate research, in conjunction with marine and polar research, to be firmly established within global and European research programmes. For other research fields – especially that of soil degradation – the situation in Germany is less favourable. If research is to fulfil the obligations imposed on it through the implementation of the various global conventions (especially those on "Biological Diversity" and "Desertification"), the situation has to be improved substantially. Research on the environmental problems of developing countries must be strengthened institutionally and with additional personnel, and given a regional and topical focus.

The institutional base in Germany continues to lack the problem-solving competence required to tackle Global Change. There is an abundance of activities aimed at diagnosing Global Change, but also a lack of inter-disciplinary expertise in the formulation of objectives and the development of suitable instruments. In the opinion of the Council, the scientific community's function as political advisor should be extended in future to embrace the development and evaluation of the goals, instruments and institutional frameworks for the legally binding global conventions, as well as the protocols to be adopted.

The Council recommends that research centres with appropriate problem-solving competence be established as a matter of priority and developed to become starting points for flexible, topic-oriented and project-oriented research associations.

4 The threat to soils (focus section)

The key focus of the 1994 Annual Report is soils – one of the natural bases for human life and social development. The Earth has few areas remaining that have not yet been put to use; virtually all fertile areas are already under cultivation. Increasing yields through fertilisation and the use of biocides is subjected to environmental limits, but greater benefits can be drawn from many soils on a sustainable basis using new breeds and environmentally sound soil management. Human beings have always cultivated soils, but have also damaged or destroyed them through overgrazing, intensive farming and deforestation, through excess depletion of raw materials, through settlements, waste tipping, traffic and wars.

Causes of human-induced soil degradation in millions of hectares

Continent/ Region	Deforestation	Over-exploitation	Overgrazing	Agricultural activities	Industrial activities
Africa	67	63	243	121	+
Asia	298	46	197	204	1
South America	100	12	68	64	–
Central America	14	11	9	28	+
North America	4	–	29	63	+
Europe	84	1	50	64	21
Oceania	12	–	83	8	+
World	579	133	679	552	22

Source: Oldeman, 1992 + = low significance – = no significance

Soil degradation as an important component of Global Change was not adequately dealt with in AGENDA 21 and during the 1992 UNCED Conference in Rio de Janeiro, because neither the industrial nor the developing nations (due to the close links with population growth) had ever attached the requisite priority to this issue. However, the consequences of land resource use, especially as a result of rapid population growth, will *clearly precede* the terrestrial effects of climate change over the next two to three decades. The problems generated by land use will become even more apparent if weather conditions fluctuate to a greater extent due to the in-creasing effects of climate change, and if ecozones undergo large-scale displacements.

♦ Analysing the stresses on soils

In the past and the present, human beings have always intervened in terrestrial ecosystems and their soils as "exploiters" of natural resources, often ignoring any principle of sustainability. Examples include the clearing of woodland for cropping and the excessive exploitation of forests, overgrazing of grassland, the use of inappropriate cropping methods, exploitation of vegetation for domestic use and the growth of industry or urban agglomerations. Worldwide, almost 2,000 million hectares of land show at least minor signs of degradation, corresponding to approx. 15% of the ice-free land surface. Around 300 million hectares of land surface are already seriously degraded.

If soil degradation is to be reduced and its causes eradicated, it is essential that the loads at *each respective location* be identified, their effects within the ecosystems determined and these assessed in relation to the stress-bearing capacity of the respective soils. If soil degradation is to be combated, explaining causes with the help of the natural sciences and perhaps removing symptoms does not suffice; instead, the economic driving forces be-hind such degradation, and their sociocultural background, must be analysed and integrated into local, regional and global strategies for mitigation and prevention.

Soil degradation is the result of *excess loads* on the respective ecosystem. An *evaluation* allowing the quan-tification of anthropogenic changes and their *assessment* with respect to the conservation of natural soil func-tions and the sustainable use of land, must therefore take as its starting point the measurement of these excess loads.

The Council bases its analysis on the concepts of “critical loads”, “critical operations” and “critical losses”, i.e. the flows of energy, material or information beyond the boundaries of the respective system, thereby causing critical states in soils. The concept applied is an extension of the *critical loads* concept that was developed in connection with the problems of air pollutants and their deposition in forests.

An important task for research in the future will be to determine the stress-bearing capacity of soils for different types of environmental stress. However, from the global perspective neither information on stresses nor on the stress-bearing capacity of soils will be sufficient to arrive at reliable conclusions; the collection and processing of the data required must be tackled through global cooperation.

♦ The interactions of the ecosphere and the anthroposphere with soils

Soils interact in manifold and complex ways with the ecosphere and the anthroposphere. A detailed description of these interactions is given as part of the key focus on soils, with particular attention being paid to the links between natural science and social science aspects.

Atmosphere and soils

Anthropogenic changes in the composition of the troposphere have caused depositions of locally, regionally and to some extent globally altered fluxes of trace substances in soils and waters via the atmosphere. The most important anthropogenic greenhouse gases show strong sources in regions with intensive land-use activities; they cumulate to account for approx. 15% of the total anthropogenic greenhouse effect. Soils and their ecosystems are therefore threatened as a sink for airborne pollutants, and at the same time are a source for greenhouse gases. Several European states have agreed upon measures for reducing the emissions of nitrogen oxides (NO_x) and sulphur dioxide (SO_2) and have implemented these with measurable success. However, the Council considers that further measures for reducing emissions are urgently needed. Fossil fuels must be conserved through more efficient technologies and through renewable energy. Reduction of nitrogen oxide emissions must be achieved, primarily in the transport sector.

Hydrosphere and soils

The link between the pedosphere and the hydrosphere is of major importance: soils and waters are the central habitats of all organisms. Humans exert direct or indirect influence on the interactions between soils and waters, manifested structurally as destruction, compaction and sealing, and materially in the deposition of substances in waters and soils. Managing these environmental assets has not yet been regulated through any international soil or water convention. Since the late 1980s, there have been steps towards establishing a soil protection concept that takes account of the close links between soils and waters. The Council recommends that this be put into practice as rapidly as possible – regardless of resistance by particular interest groups. AGENDA 21 includes a separate chapter on water (Chapter 18), and most of the other chapters in the action plan refer to water issues. The Council will deal with the global threat to water in many parts of the world in its 1996 Report.

Biosphere and soils

The components of the biosphere selected for describing the interactions with soils in this Report are biodiversity and forest ecosystems. The clearing of forests for timber or to obtain grazing land, and the exploi-tation of raw materials generally have an adverse effect on the quality and quantity of soils, and indirectly on biological diversity. Agriculture, which itself causes environmental changes and which itself is affected by changes in biodiversity, was and continues to be of particular importance for the conservation of biodiversity. Agrarian ecosystems are often used in a short-sighted way to achieve the highest possible yields in the shortest possible time, without paying any heed to soil productivity. The concept of *"differentiated soil and land use"* emphasises the priority of intensive agricultural use only on high-grade, fertile soils. The concept of *"integrated cultivation"* can contribute to a reduction of stress. In the light of current EU policy on the fallowing of agricultural land, the Council considers it especially important that links be established between the protection of fauna and flora, on the one hand, and assuring the sustainability of nature, on the other. The destruction of forests that has been occurring since the middle of this century, and the soil degradation this has triggered off are no longer limited to specific regions, but extend through the tropical forests of South America, Africa, Asia, the mountain forests of the Himalayas, and, last but not least, the boreal forests. A "Forest Convention" with measures binding on the signatories was not agreed upon at the UNCED Conference in Rio de Janeiro. This is regrettable, not only from the environmental but also from the economic perspective, since only with an international agreement will it be possible to implement the most cost-effective way to combat the global forest problem. The Council wants to repeat and underline its recommendation in the 1993 Report that a "*Convention for the Protection of the Tropical Forests"* be striven for, and that a special finance mechanism be instituted for this purpose.

Population growth and soils

Population growth exerts enormous pressure on soils, and the soil degradation it provokes is in turn a reason for additional migration and urbanisation processes, which then lead to additional stress on soils elsewhere. The higher the rate of global population growth, the higher the demands on the soil functions. There is already a growing disparity between growth-related demand and the availability of land. Many states are no longer capable of feeding their own populations with domestic agricultural products. In many of these countries, there are but few or inadequate means for securing the food imports needed through non-agricultural production and international trade. The consequences are the threat of inadequate food supplies and famine, acceleration of soil degradation and international migration, with the concomitant immigration pressure this exerts on the industrial nations. The Council wants to draw attention to the recommendations it made in the 1993 Annual Report, where it was proposed that German development aid be increased to 1% of GNP.

Economy and soils

As the central component of the anthroposphere, the economy is the primary source of demand for soil functions and also the prime factor responsible for soil degradation. It can be assumed in this context that problems will grow at an over-proportionate rate. Given the speed of population growth and the level of soil degradation already apparent, one can expect an increasing scarcity of soils available for meeting competing demands. Land, however, lends itself particularly well to the clear definition of rights and duties associated with the use of land, given its spatial demarcations. Seen this way, the accusation that the damage and destruction of soils is due to market failure does not hold true; many forms of soil degradation are due to political failure. Therefore, the allocation of rights and duties associated with the use of land, and local guarantees of these rights, remain key recommendations of any policy for sustainable land use.

Institutions and soils

Whenever reference is made to institutional frameworks relating to soils, more than just national or international facilities are at issue. What is meant are all the settings that regulate or influence the intra-state and/or inter-state cooperation of economic subjects and political decision-makers in the utilisation of soil functions. For the international level, they generally take the form of legal frameworks and conventions. The Council recommends that the German Federal Government take action to strengthen the FAO and UNEP activities aimed at protecting land and soils;

effective soil protection must be understood as a precautionary measure for avoiding further conflicts. Improving the informational basis on the distribution, properties and stress-bearing capacity of soils is of major importance in this regard. A global monitoring and information network should be established, which can then serve as the basis for global planning and action.

Psychosocial sphere and soils

Soils are a habitat for people, animals and plants, and in many respects can be seen as the basis for individual and collective action. Since virtually every human activity involves soils, every person is in some way or other a *"land actor"*. From the individual's point of view, soil performs fundamental functions. It is the indispensable source of nutrition, the fundamental basis determining where people live, work or spend their leisure time, and the basis for meeting human needs regarding control over space, property and possessions. For this reason, political approaches must proceed on the basis of a more broadly defined concept of soil (what soil *is*), and must expand the definition of soil functions accordingly (purposes *served* by soil). Soil, in its multi-layered meaning, plays the role of an *"archive"*, from which valencies and actions of individuals, groups or even entire cultures can be reconstructed (the *cultural* function of soil). This cultural function is supplemented by the social function, which is rooted in territorial behaviour. A quantitative assessment of how human behaviour contributes to soil degradation, as was carried out for the greenhouse effect, appears barely feasible; however, this does not mean that one can release citizens from their (co-)responsibility for that collectively and globally important asset – soil.

♦ The soil-centred Global Network of Interrelations and the main syndromes of soil degradation

In its 1993 Annual Report, the Council introduced a special method for organising the interdisciplinary presentation of the main interactions within Global Change over the long term: significant trends are woven together to form a "Global Network of Interrelations" intended to show the mutual dependencies of worldwide developments. The Council therefore presents, in its 1994 Annual Report, a "soil-centred Global Network of Interrelations" as the result of an in-depth analysis of the worldwide developments affecting soils. The resulting description of soil-related trends (especially in the hydrosphere, the economy and population) is clearly more differentiated; land-use change is shown to be one of the main driving forces of Global Change.

However, the analysis must go one step further. The subject-oriented presentation of the Global Network of Interrelations for example combines several worldwide influences on soil degradation into a single trend, even though this trend has to be differentiated with respect to causes, character and effects. For this reason, the concept of *syndrome* is introduced as a new cross-sectional phenomenon. The notion of "syndrome" is apt in this context, particularly in relation to the key focus of this year's Report. The loss of and the deterioration of soil functions is expressed in terms of certain "clinical profiles" which are composed of *symptoms* such as wind erosion, water erosion, physical or chemical degradation. If soils are understood as the "skin" of Planet Earth, then the analyses of these syndromes are in a certain sense "geodermatological diagnoses".

In this diagnosis, "syndrome" is understood as the actual "clinical profile", its causes and effects. The Council defined what it considers to be the twelve most important anthropogenic "soil diseases". The names chosen for these syndromes are deliberately symbolic, each one being taken from a selected crisis region or a striking phenomenon accompanying the syndrome. However, the label always stands for a particular syndrome that occurs or can occur in different regions of the world. The twelve syndromes are:

1. Changes in the traditional use of land: the *"Huang He Syndrome"*
2. Soil degradation through mechanised farming: the *"Dust Bowl Syndrome"*
3. Overexploitation of marginal land: the *"Sahel Syndrome"*
4. Conversion and/or overexploitation of forests and other ecosystems: the *"Sarawak Syndrome"*
5. Mismanagement of large-scale agricultural projects: the *"Aral Sea Syndrome"*
6. Long-range transport of nutrients and pollutants: the *"Acid Rain Syndrome"*
7. Local soil contamination, accumulation of waste and inherited pollution: the *"Bitterfeld Syndrome"*
8. Uncontrolled urbanisation: the *"São Paulo Syndrome"*

9. Overdevelopment and overexpansion of infrastructure: the *"Los Angeles Syndrome"*
10. Mining and prospecting: the *"Katanga Syndrome"*
11. Soil and land degradation through tourism: the *"Alps Syndrome"*
12. Soil and land degradation as a result of war and military action: the *"Scorched Earth Syndrome"*

This cause-related classification of the phenomenon "soil degradation" into global or regional components cannot, of course, be completely discrete: certain syndromes may occur in conjunction with others in certain locations; the overlapping involved in such cases deserves special attention.

On the basis of the syndrome analysis, in any case, specific countermeasures can be identified and recom-mendations for actions be formulated. As the description of these steps in the Report shows, special importance has to be attached to the promotion of "soil awareness": the soils problem receives little, much too little atten-tion by the majority of the population, but also among decision-makers and those directly involved with soil (e.g. farmers). For that reason there is an urgent need for soils to be made a topic of environmental information and environmental education at all levels.

♦ Two regional case studies of soil degradation

In order to show the manifold interactions of soils with the socioeconomic sphere, the Council applies the syndrome approach to two regional case studies: the *"Sahel"* zone and the *"Leipzig-Halle-Bitterfeld"* region in eastern Germany.

The Sahel zone

The problems of soil degradation and desertification in the Sahel can be attributed to changes in nature as well as to socioeconomic causes. With reference to the three most important forms of land use – *nomadism, subsistence farming* and *cash crop farming* – it is shown how the traditional, ecologically adapted forms of land use can no longer be practised today in their original form, not only on account of high population growth but also because the traditional social regulation mechanisms are either wholly or substantially absent, and the economic and political framework has changed.

1. The *nomadic groups* in the Sahel are increasingly restricted in the mobility and flexibility that once provided them with a secure basis for ecological adaptation. Growing competition from other forms of land use, political measures and unclear or disadvantageous land-use rights led to their sedentarisation; they were pushed into more marginalised locations much less suitable for grazing livestock. The sensitive soils and ecosystems in the region are degraded as a result, mainly due to overgrazing.
2. *Subsistence farmers* are similarly affected by displacement to marginal land that is unsuitable for sustainable farming. The loss of long fallow periods as traditionally practised, greater mechanisation without parallel soil protection measures, such as erosion protection, and forms of irrigation which are not adapted to local conditions all have negative effects on the soils.
3. Finally, *"cash crop farming"* (cotton, groundnuts) on fertile soils is not pursued in a sustainable fashion. These monocultures are farmed with the help of machines and pesticides, both of which can cause great problems.

The social changes in the Sahel zone were caused and further exacerbated by a set of internal and external conditions. Of importance for domestic policy is the general neglect of rural concerns and the orientation to agrarian export production through large-scale capital-intensive projects in the agricultural sector. External factors can be identified both in the global economic conditions (agricultural subsidies and/or export policies of the industrial nations, international debt) and in the practice of international development organisations, which in the past were not geared to the principle of sustainability, and which through their orientation to production technology gave too little consideration to the existing development potential. In addition, they failed to develop an integrated strategy for solving the problems that actually exist. If the complex problems faced by the Sahel are to be solved, greater attention must be given to the socioeconomic causes, above all to the rationale for action on the part of the local people, and to extending their field of possible actions through organisational and financial decentralisation.

The "Leipzig-Halle-Bitterfeld" region

The soils in the *"Leipzig-Halle-Bitterfeld"* region are contaminated, in some cases alarmingly, by depositions of airborne pollutants, above all, however, through the deliberate depositing of inorganic and organic substances. A prime cause of this contamination was the concentration of chemical industries, mining and energy production, all of which used outdated production methods. Since the turn of the century, there have been five brown coal mining fields, and large-scale chemical plants developed in Bitterfeld (paints and dyes), Leuna (methanol, nitrogen) and Buna (synthetic rubber). For the economically and also environmentally sound development of this and similar regions, soil remediation and the removal of contaminated soil are a matter of urgency, whereby the remediation of the entire region requires considerable support from the state or from outside the region.

In the agrarian areas of the "Leipzig-Halle-Bitterfeld" region, a restructuring process should be initiated that conserves or re-establishes the various functions of soils. This can best be done by developing an agricultural sector that is appropriate to local needs and which preserves the environment.

♦ Recommendations for action

The Council considers soil and land degradation to be the sole or common impairment of four main soil functions, namely habitat function, regulation function, production function and cultural function. The world food problem ranks first among the recommendations for action. The central issue here is: How can the food supply be assured worldwide without endangering the sustainability of nature in general and of soils in particular?

A series of measures have been proposed with which, one believed, the problem could be quickly solved. These include, for example: not using marginal lands for agricultural purposes, cutting back on meat consumption in industrial countries, reducing losses caused by stockpiling and by transport to the final consumer, dispensing with ploughs, banning of biocides, transition to crop diversification and agroforestry. A commonly held view is that action and property rights should be clearly defined and allocated. None of these measures, however, can solve the world food problem by itself, because they all require either a major change in values or are not feasible due to excessively high population pressure. *Increasing yields per surface unit* is therefore essential to assure an adequate food supply for humankind in the long term.

In this Report, the Council formulates a guideline that seeks a path between the notions of complete autarchy, on the one hand, and unrestricted free trade in agricultural products, on the other: *Agricultural production should be adapted to the carrying capacity of soils; it should be carried out worldwide primarily at locations where it can be done on a sustainable basis with relatively low environmental stress, cost-effectively and with high yields.*

It follows from this guideline that:

1. Fertile soils and their productivity should be secured for the long term.
2. Production on less fertile soils should be increased in a sustainable manner; where this is not possible, because substantial degradation occurs, land use must be reduced.

Even if world food supplies are seen as the most important theme in connection with the soil problem, protection of the *habitat function for wild fauna and flora* must also be ensured. Whereas in the case of food there is a fundamental interest in human welfare, rendering help to self-help a central principle, protecting the habitat function for fauna and flora must be achieved collectively, i.e. through political insight and agreement. However, it must be realised that not every habitat is equally worthy of protection, and that international efforts must be concentrated on the most important of these habitats, purely on account of the financial restrictions that exist. Ensuring the habitat function of certain soils can ultimately be achieved only through legally binding rules and bans, i.e. through limitations on use or through alternative land use.

Population growth is one of main trends within Global Change. A high population density, and the necessary increase in the production function of soils that this entails, threatens at the same time the habitat, regulation and cultural functions of soils. Even if the German Federal Government does not put a major emphasis on the problem of population growth, out of consideration for the political sensitivity of many countries, the Council nevertheless points out the seriousness of current developments: The foreseeable food supply problems are not the result of the general degradation of land and soil alone, but ensue above all from the fact that population growth is particularly high in precisely those parts of the world where agriculture will not be capable, or only to a limited degree, of feeding the growing population in the coming decades.

However, because it is foreseeable that food production will not suffice to feed a world population that continues to grow at the current rate, those countries with low or stagnating population growth are also called upon to take political action:

- The problems that are associated with soil degradation will increase in magnitude and pose an ever-greater challenge to international environmental policymakers; Germany, too, will find itself under increasing pressure to respond to this challenge.
- As long as there is no income basis besides agriculture in a given country, with the help of which food imports can be paid for, there will be a threat of local and regional malnutrition that will either require greater volumes of financial transfers to these countries or else will lead to migration (*"environmental refugees"*), which may then have adverse effects on the domestic affairs of possible target countries, Germany included.

Support for active population policy can therefore prove to be a cost-effective measure in the future, both in countries threatened by malnutrition and soil degradation as well as in countries to which possible migrational flows will be directed.

Given the many facets of the soil problem, the Council recommends that scientists and politicians in Germany should deal with these globally pressing problems more intensively. Because the syndromes are quite many, and the therapies which could be applied vary considerably, for which reason the need for international coordination on issues relating to soils is great, a soil protection policy was not put on the political agenda in many countries until after the other environmental media had been tackled. Internationally, steps taken have not advanced beyond mere declarations.

The Council emphasises that, in view of the seriousness of the soil problems outlined in this Report, a new efficient institutional framework should now be established. For this reason the German Federal Government should decide in principle whether a differentiated "Soil Declaration" suffices *or* whether a global "Soil Con-vention" has to be striven for. After all, the "Desertification Convention" will cover some of the problems, and a "Forest Convention", which the Council advocated in its 1993 Annual Report, would also address one of the most critical soil syndromes.

Climate change, which only becomes apparent over a long period of time, is now the object of relatively intensive international efforts. The effects of global soil degradation, in contrast, are already visible today and will increase in magnitude within the immediate future. *The German Federal Government should therefore strive to ensure that global soil protection obtains a similar attention on the international agenda as has been achieved for climate policy.*

B Introduction

The dynamics of unintended Global Change continues at an unprecedented rate, changes in atmospheric composition, population growth, loss of biodiversity, degradation of soils. The international community has recognised at least to some degree how dramatic these changes have become, despite the problems at national level which still dominate concerns and so obscure global issues. As a result the community is now attempting to reverse these trends by implementing conventions binding on all nations, or by concluding agreements at the global level aimed at creating the preconditions for such a reversal.

For the first time ever, the increasing concentration of a long-lived group of substances in the atmosphere has been successfully controlled by an almost global action: the tougher restrictions of the “Montreal Protocol”, amended in 1992 at the fourth Conference of the Parties contain the provisions for implementing the Vienna Convention for the Protection of the Ozone Layer. They prescribe that the production of chlorofluorocarbons (CFCs) be terminated worldwide by the end of 1997. If these regulations are complied with, there is a chance that the “ozone hole” will have shrunk again within the next decades.

The first Conference of the Parties to the “Convention on Climate Change” will take place in March/April 1995 in Berlin, and is hoped to achieve initial commitments on the part of the industrial countries on the reduction of CO_2 emissions. That would be a first step towards mitigating the anthropogenic greenhouse effect and the global climatic changes caused by it.

The “Convention on Biological Diversity” which entered into force on 23rd December 1993 defines measures to preserve the habitats of wild flora and fauna in order to reduce the rapid loss of species and the threat to the stability of ecosystems this causes. Because a “Convention on the Protection of the Forests” has not yet been enacted, achieving this objective is out of reach.

Following the description of the complex inter-relationships between the anthroposphere and the ecosphere in the 1993 Annual Report, the Council concentrates in this Report on a further main trend, the *degradation of soils*. This means, firstly, that the necessary attention is being given to a problem that is little acknowledged but rapidly intensifying. Secondly, the recommendations for action made to the Federal Government in this context provide a basis for worldwide protection of soils in the form of a “Soil Declaration” or a “Soil Convention”. Thirdly, the Report seeks to encourage an attitude which attaches similar values to soils, the fragile “skin” of our planet and the basis for our nourishment, as was once the case in earlier cultural epochs.

In a first section (standard section), recent developments in climate research are presented and specific aspects considered important by the Council discussed in relation to the operative and planned Conventions. The topics selected are: the bilateral or multi-lateral implementation of measures for reducing CO_2 emissions (Joint Implementation); the restructuring and enlargement of the Global Environmental Facility (GEF); the problems of species protection as shown by the example of the Washington “Convention on International Trade in Endangered Species of Wild Fauna and Flora” (CITES), and the more recent “Convention to Combat Desertification”. Recommendations for German Global Change research round off the first part.

C Standard section: Selected aspects of Global Change

1 Current developments

1.1 Carbon cycle

The carbon cycle is of cardinal importance for all life and for the Earth's climate. Because of its many organic compounds (e.g. protein molecules), but also because of inorganic compounds (e.g. carbon dioxide), the element carbon displays the most complex of all element cycles. Because humans exert a strong influence on this cycle through industrial and food production, as well as other forms of land use, and change the climate in the process, knowledge of the carbon cycle is essential before counter-measures can be instituted. The most striking example for such disruption is the increase in the mean carbon dioxide level in the atmosphere from 280 to 358 ppmv (parts per million volume) since the onset of industrialisation. This increase is the main factor contributing to anthropogenic global climatic change.

The forecasts for the carbon cycle presented in the 1990 status report of the *Intergovernmental Panel on Climate Change* (IPCC, 1990), which is organised by the UN organisations WMO and UNEP, have meanwhile been confirmed, but there are also new developments.

The current state of knowledge about anthropogenic disturbances of the carbon cycle can be summarised as follows: of the mean annual emissions during the 1980s from the utilisation of fossil fuels, amounting to 5.5 ± 0.5 Gt (gigatonnes) C (carbon), and the destruction of vegetation, amounting to 1.3 ± 1.3 Gt – which taken together produce a mean of 6.8 Gt, 3.4 ± 0.2 Gt of C remain in the atmosphere in the form of CO_2, i.e. the other half has left the atmosphere again. Only 2.0 ± 0.6 Gt were absorbed by the ocean, so there must be another, terrestrial sink for anthropogenic carbon with an uptake capacity of 1.4 ± 1.6 Gt of carbon. Where this sink is, and what form it takes, cannot be derived from measurements taken to date of the distribution of carbon isotope ratios in the oceans and atmosphere. It could be accounted for by timber growth in (boreal) forests, afforestation, or increased humus formation; the so-called CO_2 fertilising effect probably accounts for only a minor proportion of the “missing” carbon.

Different models of the carbon cycle have all shown that a stabilisation of CO_2 emissions at the 1990 level would still produce a growing CO_2 level in the year 2100, to more than double the pre-industrial level. If the concentration of CO_2 is to be stabilised (the ultimate objective of the “Convention on Climate Change”) below a level of 750 ppmv, which is about 2.5 times the starting value in the year 1750, a reduction of global CO_2 emissions to below today's level must be achieved in the course of the next century. An unknown terrestrial sink causes uncertainties in this model calculation of up to 30% of the maximum CO_2 concentration.

Whereas in the period between 1988 and 1990 the concentration of CO_2 in the atmosphere rose dispro-portionately fast compared to emission levels, the increase over the period 1991-1993 was the lowest since direct measurements were first commenced in 1958. The most important reasons for these fluctuations in the rate of increase are not quite clear yet. One factor was certainly the reduced level of emissions in the former Warsaw Pact countries now undergoing the transition to the market economy, but this cannot be the only one. Cooling by the stratospheric aerosol layer as a consequence of the Pinatubo eruption may be another significant reason.

The second most important greenhouse gas, methane (CH_4), recently showed lowered increase rates (1992: 0.1% in the northern hemisphere; 0.45% in the southern hemisphere; average 1983-1991: 0.7% p.a.), as a result of which the interhemispheric difference of the CH_4 concentrations is diminished. Because methane has a residence time of about 10 years it only needs to have a sink about 10-20% stronger, or reduced sources, in order to reach stable concentrations. This finding is less surprising than the reduction of the rate of increase of CO_2. Possible factors explaining the reduced increase rate of CH_4 are: fewer leaks during natural gas production and distribution; higher decomposition rate due to increase UV-B radiation in the troposphere as a result of stratospheric ozone depletion; less production in marshlands due to global cooling following the eruption of the Pinatubo volcano, and less coal mining.

1.2 Stratospheric ozone depletion

The 1993 Annual Report of the WBGU (1994) drew attention to the fact that the total ozone in the stratosphere is declining in bursts following strong volcanic eruptions and the greatly increased aerosol levels these produce. This was clearly noticeable following the eruptions of El Chicon (1982) and Pinatubo (1991) *(Fig. 1)*. The cause for this is now thought to be the heterogeneous chemistry of aerosol droplets (Hofmann et al., 1994). Data available for the period up to spring 1994 confirm a continuing strong reduction in total stratospheric ozone in 1993 (two years after the eruption of Pinatubo). However, a certain “recovery from the volcano effect” during the 1993/94 winter was noticed in January/February 1994.

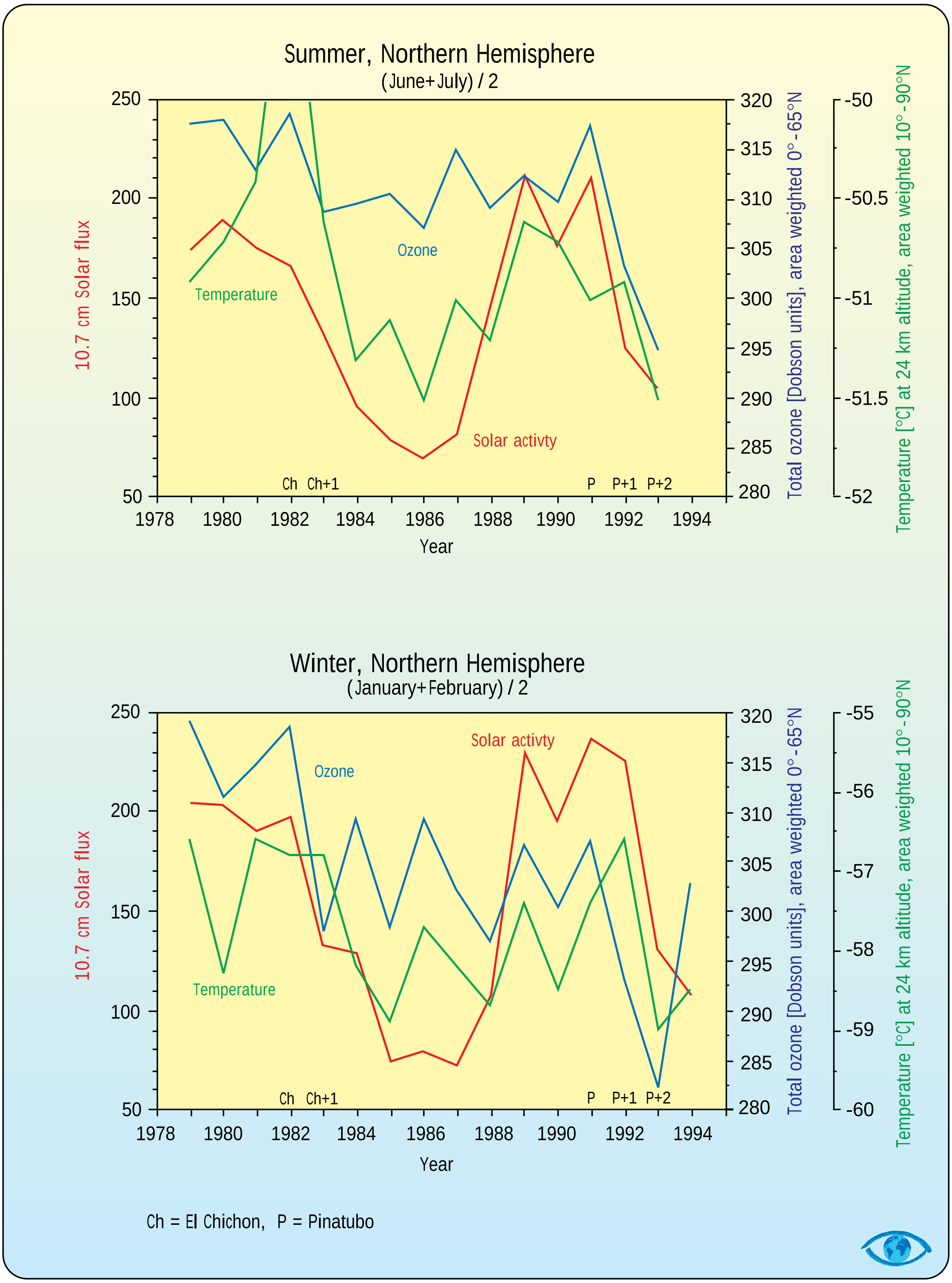
This recovery, which has been observed since autumn 1993, correlates with the reduction of aerosols two years after the eruption of Pinatubo. However, it must be assumed that the aerosol concentration will remain at a high level, so that a total decline of the volcano effect on stratospheric ozone cannot be expected yet. Superimposed on this effect remains the anthropogenic ozone decline of approx. 3% per decade on a global mean (WBGU, 1994). This value is arrived at by combining a stronger trend for the Antarctic, a medium-scale trend for the Arctic winter and a small trend for the tropics.

HCFCs have now been developed as substitutes for CFCs. The former generally have a shorter lifetime and thus a lower ozone depletion potential than CFCs. From the ozone chemistry perspective, they therefore qualify as good substitutes (Ravishankara et al., 1994). Because HCFCs are very powerful greenhouse gases, however, they remain suspect from the climate research perspective.

Concentrations of trace gases which destroy stratospheric ozone are increasing due to greater anthropogenic sources. These include methane and nitrous oxide (WBGU, 1994), but also methyl bromide CH_3Br, which is produced when grassland is burned (Khalil et al., 1993; Manö and Andreae, 1994). Because fires of this kind have increased as a result of population growth since 1850 by approx. 100%, an anthropogenic increase in methyl bromide can also be identified.

A trend analysis for UV-B radiation is possible to only a limited extent on account of the time series being too short. However, measurements of UV-B radiation at more and more sites confirm the increase in radiation that could be anticipated during phases of low stratospheric ozone concentration.

Figure 1: Ozone concentrations in summer and winter in the northern hemisphere



1.3 Further development of the Global Environmental Facility

In March 1994, industrial and developing countries agreed on the restructuring of the Global Environmental Facility (GEF) and an increase in its funds to around US$ 2 billion for the new term. Following a pilot phase (1991-1994), the second phase (1994-1997), the so-called GEF II, has now commenced.

1.3.1 Origins and tasks of the GEF

The basic idea

The GEF is a global environmental fund originally established in 1990 by 17 industrial countries and 7 developing countries, and operated in cooperation between World Bank, UNDP and UNEP. Its central task was initially the provision of funds for environmentally relevant projects in developing countries with a "globally relevant" benefit. The initial membership of 24 increased continually to a total of 70 states in October 1993, representing approx. 86% of the world's population (GEF, 1994a; World Bank et al., 1992a; World Bank et al., 1992b).

The background to these new financing arrangements can be seen in the special nature of global environmental problems. According to the largely consensual estimation of industrial and developing countries, it is the highly developed countries that bear the main responsibility for Global Change (threat to the ozone layer, greenhouse effect, marine pollution). Nor is there any dispute that the most globally relevant environmental problems can only be combated in a meaningful way through the common endeavour of all states, both industrialised and developing ("global environmental partnership"). In some cases – such as measures to preserve biodiversity – appropriate protective measures must be implemented in the developing countries especially.

Establishment and organisation

The GEF was called into being in November 1991, mainly at the initiative of the French and German governments. It was originally conceived of as a three-year *pilot programme*, for which a total volume of US$ 1.13 billion was made available (as at 30.9.1993).

The GEF is administered through the three international organisations nominated for this purpose (the "implementation organisations"), each of which has precisely defined responsibilities, thus helping to avoid the creation of a new bureaucracy:

- UNDP is involved with finding projects, bears responsibility for projects involving technical cooperation and support for institutions, and implements smaller grant-aided programmes for non-governmental organisations.
- The Scientific and Technical Advisory Panel (STAP), set up at the initiative of UNEP, develops the criteria for providing funds and is responsible for scientific and technical advice.
- The *World Bank* implements measures relating to financial cooperation and administers the trustee fund (see below). The administration of the GEF has been established within the World Bank, whereby stress is laid on its independence vis-à-vis the implementation organisations and the conventions; the GEF Secretariat is accountable only to the GEF Council.

Fields of involvement

During the pilot phase, a total of US$ 750 million was spent in four main areas *(Table 1)*:

1. Reducing greenhouse gas emissions, including measures for reducing energy consumption.
2. Preservation of biodiversity.
3. Protection of international waters.
4. Protection of the ozone layer (recipients here were above all those countries which do not receive support from the "Montreal Protocol" funds).

Measures for combating soil degradation, desertification and deforestation are similarly supported, although only to the extent that they relate to the four areas mentioned above (Wells, 1994; UNDP, 1993; UNDP et al., 1993; GEF, 1992).

Table 1: GEF expenditure during the pilot phase according to field of involvement

Field of involvement	Expenditure	
	planned	actual
Climate protection	40 – 50%	40%
Preservation of biodiversity	30 – 40%	42%
Protection of international waters	10 – 20%	17%
Protection of the ozone layer	remainder	1%

Source: GEF, 1994a

1.3.2 From pilot programme to the finance mechanism for funding the Conventions

Interim funding by the GEF

In AGENDA 21, the GEF was given special consideration as an interim funding mechanism for the “agreed incremental costs” of the poorer countries when implementing the two conventions signed in Rio de Janeiro (UNCED, 1992). The Parties to the two Conventions must make a final decision on whether or not to accept the GEF as a funding instrument. Precisely on account of this new range of tasks assigned to the GEF by UNCED, it was necessary to restructure the organisation and its decision-making structures (1994b).

There are parallels between the GEF and the funds set up by the “Montreal Protocol” with respect to their basic tasks and responsibilities, in that the latter is also a mechanism for administering the financial obligations which ensue for the industrial countries vis-à-vis the developing countries under various conventions. This fund was established in 1990 by the second Conference of the Parties to the Montreal Protocol. The total volume of the fund was approx. US$ 695 million, with Germany being the third largest contributor after the USA and Japan. This financing serves specifically to cover the additional costs that the developing countries may have through measures taken to implement the CFC substitution targets. In 1996, the Conference of the Parties to the Montreal Protocol must decide, on the basis of an evaluation study to be carried out in 1995, on the continued existence of this convention-specific fund.

Mobilisation of new funding

At the GEF meeting in March 1994, representatives from 87 countries agreed to restructure the GEF and to provide a total of about US$ 2 billion for the second phase. The biggest future contributor in absolute terms will be the USA (US$ 430 million), followed by Japan (US$ 410 million) and Germany (US$ 240 million). These contributions will be provided in accordance with the distribution formula for the 10th replenishment of the International Development Agency of the World Bank (IDA 10) (GEF, 1994b; BMZ, 1994). The *Global Environmental Trust Fund* is now fully assimilated in the newly-created GEF Trust Fund.

Reforming structure and decision-making

The negotiations on GEF II were decisively influenced by the search for an organisational solution which would harmonise demands on the part of recipient countries for balanced and equitable representation regarding investment projects with the demands of contributing countries for influence on the selection and financing of projects (UNEP et al., 1993b). The compromise that was reached involves four major components:

1. Establishing an *Executive Council* comprising representatives from 32 Member States, whereby 16 seats are reserved for developing countries (including China), 14 for industrial countries and two for countries from the previous Soviet Union and Eastern Europe (transition countries).
2. Two Co-Presidents will conduct the meetings which are scheduled to take place at least twice a year. These two persons will function as representatives of the GEF especially concerning Conventions. One position is occupied by

the Chief Executive Officer of the GEF Secretariat, while the other (the *Elected Chairperson*) is elected by the Members of the GEF Council. The post of elected chairperson is filled alternately from one meeting to the next by someone from a developing or an industrial country, with the transition countries assigned to the latter group.

3. The resolutions passed by the Executive Council should be based on consensus wherever possible. If this cannot be achieved, a so-called double, weighted majority – consisting of 60% of the Members represented in the Council and 60% of the contributing countries – is required. This effectively provides both the con-tributing and the recipient countries with a right of veto.
4. The General Assembly of the GEF, attended by all Members, shall be convened every three years.

Table 2: Contributions to the GEF Trust Fund in US$ millions[a)]

Contributing countries	Contribution	Contributing countries	Contribution
Group I[b)]		Group II[b)]	
Australia	29	Brazil	6
Austria	20	Egypt	6
Canada	87	India	8
Denmark	35	Ireland	2
Finland	22	Ivory Coast	6
France	143	Mexico	6
Germany	240	Pakistan	6
Great Britain	135	Turkey	6
Italy	115		
Japan	415		
Netherlands	71	Group III[b)]	
New Zealand	6	China	6
Norway	31		
Portugal	6		
Spain	17	Others[c)]	9
Sweden	58	Non-assigned[d)]	6
Switzerland	45		
USA	430	Total in US$	2,023

Source: GEF, 1994b

a) Calculated by converting the special drawing rights in US$ on the basis of the daily exchange rate over the period 1.2.1993 to 31.10.1993.
b) Group I consists of non-recipient contributing countries which participate at the replenishment meetings. Group II comprises recipient contributing countries which participate at the replenishment meetings. Other contributing countries are included in Group III.
c) Includes the higher value of contributions due to accelerated payment that is not accounted for in the above figures, as well as new and additional contributions to the GET which are expected to be available for GEF-II.
d) It is anticipated that other contributing countries will make payments amounting to approx. 3% of the US$ 2 billion fund (US$ 1,427.52 million in special drawing rights).

1.3.3 Evaluation of GEF II

Despite the stagnation afflicting the world economy and the tight budgetary constraints in many countries, the continued existence of the GEF was placed on a firm footing and additional funds were mobilised (El-Ashry, 1994). However, in view of the enormous efforts that are required in the various spheres of Global Change (see the 1993 Annual Report), it is imperative that further additional funds are provided in the future. This applies especially if Protocols to existing Conventions (on “Climate”, “Biological Diversity” and “Desertification”) are to be adopted and new conventions on forests and soils are to be striven for.

Care must also be taken to ensure that funds are not distributed among too many projects because of compro-mises sought between the donor countries and the large number of recipient countries, or are strongly ori-ented towards regional balance. An unresolved issue is the extent to which the transition countries can be inte-grated. According to the Montreal Protocol, they do not classify as developing countries, and the incremental costs would presumably be very high indeed. Another threat which must be countered is that, in order to finance their GEF obligations, the contributing countries may re-channel development aid that they had already scheduled, rather than providing additional finance.

Following the reform of the decision-making mechanism, the GEF now takes account of the interests of contributing and recipient countries to a greater extent than before. The lack of balance in the pilot phase has thus been largely removed. In future, the population affected and non-governmental organisations (NGOs) are to be more integrated both in project planning and implementation as well as in the development of national strategies for Sustainable Development of the individual countries. One major task that remains is to promote an understanding that national measures are needed for global reasons, which means that the global benefits and/or costs of national measures have to become topics which politics in each country is able to address.

1.4 An instrument for the "Framework Convention on Climate Change": Joint Implementation

The following section concentrates on one special aspect of the "Framework Convention on Climate Change" and on the first Conference of the Parties that will be held between 28th March and 7th April 1995 in Berlin: the concept of Joint Implementation. The reason for this narrowing of focus is that the first Conference may agree on a more concrete definition of objectives than in the current version of the Framework Convention. While the Convention does not prescribe any particular instruments, Joint Implementation is explicitly named as one possibility.

1.4.1 *Joint Implementation* in the "Framework Convention on Climate Change"

Of particular relevance for the use of instruments for combating climatic change is Article 3, paragraph 3 of the Convention, which calls on the Parties to implement the respective measures in a cost-effective manner. The emission reductions aimed for should be achieved at lowest possible cost. This clause is especially important in connection with the environmental and economic framework for the reduction of greenhouse gases. The actual location of emission reductions has no significance as far as the climatic effects of greenhouse gases are concerned, but if the costs of that reduction are to be minimised, the variable marginal costs of emission reduction must be taken into account. Energy consumption per unit of GDP produced shows a particularly high level of variation *(Table 3)*.

Increasing energy efficiency and reducing CO_2 emissions is mainly to be achieved by using modern technology. However, the greater the energy efficiency that is achieved by such technology, the more the associated costs are to increase. Assuming that increasing emission reduction will be accompanied by disproportionately rising costs, then the industrial countries are already in the steeper parts of the marginal avoidance cost curve, whereas other countries still are in the flatter part. This means that from the economic perspective the locational factor where emission reductions are achieved is quite important.

This is the background to the inclusion of Joint Implementation in the Convention. It is not explicitly defined in the Convention, but a number of Articles indicate what is meant by the term (Art. 4, sub-para. 2a, 2c; Article 3, para. 3). Joint Implementation is generally interpreted to mean that a Party can fulfil its emission reduction obligations not only through emission reductions in its own territory, but also by financing reduction measures in other countries. To what extent the emission reductions achieved in other countries can then be "credited" against domestic emission targets is intensely debated, however.

The signatories of the "Framework Convention on Climate Change" have not yet agreed on binding targets for CO_2 emission reductions. Article 4, sub-para. 2b formulates for the states listed in Annex 1 (OECD and transition countries) the commitment to undertake measures "... with the aim of returning individually or jointly to their 1990 levels these anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol". The Convention itself contains neither a *binding* global reduction target nor any *country-specific* emission targets. However, some countries or groups of countries have unilaterally committed themselves to achieve emission reductions. The German government, for example, has announced a 25-30% reduction in CO_2 emissions (base year 1987) by the year 2005, and the EU a stabilisation of emissions at the 1990 level by the year 2000. In addition to the EU Member States, other countries have announced planning targets or commitments on themselves (IEA, 1993): Australia, Austria, Canada, Finland, Iceland, Japan, New Zealand, Norway, Sweden, Switzerland and the USA. Even if these were mere declarations of intent without any binding obligations under international law, it can nevertheless be expected that these countries will take action to reduce CO_2 emissions. To that extent, Joint Implementation should be seen only as an instrument for coordinating the achievement of *unilateral* targets (Barrett, 1993a).

Article 4, subparagraph 2d of the Convention requires that the Conference of the Parties specifies the criteria for Joint

Table 3: Energy consumption per unit of GNP in selected countries

Country	Megajoule per US$ GNP
USA	15
Great Britain	11
Germany	8[a]
Japan	5
Poland	79
China	76
Hungary	46
Mauritania	79
Mexico	30
India	26
Bangladesh	12
Mali	3

Source: WRI, 1992
[a] Not including the new *Bundesländer* in eastern Germany.

Implementation at its first session in 1995. The "Intergovernmental Negotiating Committee for a Framework Convention on Climate Change" (INC/FCCC) has to work out proposals regarding the instruments. The Council suggests that various aspects of Joint Implementation should receive special attention during the discussion:

- the problem of search and transaction costs,
- the integration of developing and transition countries,
- the importance of the instrument for international and national climate strategies and
- the development of the instrument into a general system of tradeable permits.

1.4.2 Preconditions for Joint Implementation

The possibility of financing emission reduction projects outside national borders appears to be a meaningful approach if this can be carried out more cost-effectively. In view of the different national marginal abatement costs already mentioned, Joint Implementation can result in a definite reduction of emission reduction costs. Alternatively, additional emission reductions can be achieved at given costs (EU, 1994).

Joint Implementation can also develop positive effects through the transfer of modern technology to developing countries. If one considers the enormous increases in emissions that can be expected as a result of India and China catching up in their development, then rapid renewal of inefficient power plants obtains major importance, particularly since no emission targets are envisaged for these countries. The following explanation of some difficulties that will be faced when applying this instrument should be seen against the background of these potential benefits.

1.4.2.1 Search and transaction costs

Search and transaction costs

In practice, the cost reductions which could be realised may fall short of what is theoretically possible, because substantial search and transaction costs can prevent or delay Joint Implementation projects.

In order to carry out Joint Implementation projects, a favourable emission reduction opportunity must be sought, i.e. projects with as low a level of incremental costs per unit of abatement as possible (Barrett, 1993b). If Joint Implementation projects are negotiated bilaterally, then the transparency of this “market” as a whole, taking all sectors into account, will probably be low. If the *search costs* exceed the cost savings to be achieved, then the search for a project will probably come to a premature halt. The process is made even more difficult by the fact that projects involving participating countries must match each other with respect to the volume of finance of specific projects provided. Agreement between potential partners on a specific project is further obstructed by a specific feature of investment in reducing CO_2 emissions – in contrast to other air pollutants such as SO_x or NO_x, emissions of which can be reduced by “end-of-pipe” technologies, this is only possible with CO_2 through the conversion of old or the construction of new energy systems (Maier-Rigaud, 1994). Investments in reducing CO_2 emissions therefore affect energy production, energy consumption and hence also the energy policy of a country. Divergent energy policy approaches on the part of participating states, e.g. regarding the deployment of certain technologies or energy sources, can therefore block Joint Implementation projects.

Once the contracting parties have agreed on implementing a project, additional *transaction costs* are incurred when negotiating the actual terms of contract; the latter must define who is to bear the costs, what emission volumes are to be credited, and how long the project is to last. The question of cost allocation can impede negotiations on Joint Implementation projects. The construction of a power plant can serve as an example here. Under Joint Implementation, the investing country would have to bear the “incremental costs”. These result from the difference in the costs of the Joint Implementation power plant and the average-sized power plant that would typically be built otherwise in that country. The investing country would therefore have to pay the (presumably) higher costs for establishing the more modern type of power plant as well as the possibly higher operating costs for the duration of the project. These costs would then have to be set-off against the possible benefits that accrue to the partner. This can be reduced energy consumption, or the improvement of local air quality. Such a cost-benefit analysis, however, is somewhat theoretical since a country’s average or “model” power plant can only be identified with difficulty. The same applies to potential positive effects on the environment. In practice, therefore, allocation of costs will have to be negotiated between the contracting parties (Jones, 1994).

This is how the “Framework Convention on Climate Change” should perhaps be interpreted. Article 4, para. 3, for example, states that the developed countries shall provide financial resources needed by the developing countries “to meet the agreed full incremental costs of implementing measures that are covered by paragraph 1 of this Article and that are agreed between a developing country Party and the international entity or entities referred to in Article 11, in accordance with that Article”. The term incremental costs as used here is made more specific in Article 12, para. 12, where it is stated that the developing countries “may, on a voluntary basis, propose projects for financing, ... along with, if possible, an estimate of all incremental costs, of the reductions of emissions and increments of removals of greenhouse gases, as well as an estimate of the consequent benefits.” The Convention therefore con-tains a clear reference to the mechanism for passing on the incremental costs. A certain degree of standardisation, which would be highly desirable in the event of Joint Implementation being politically upgraded under a strategic framework for greenhouse gas reductions, still needs to be developed. Until then, agreement on the full costs of a specific measure will continue to be a matter that the contracting Parties will have to negotiate (Article 4, para. 3).

Another important component of such an agreement will have to be the definition of the “emission credits” granted to the investing country. The abatement achieved through Joint Implementation can be determined by comparing the emissions of the Joint Implementation project with those of a “baseline” project (a potential criterion could be the average energy efficiency). The high demands imposed on such an accounting system become evident if one imagines that – in analogy to cost accounting principles – the emission reductions have to be determined over the entire lifetime of the project. Special attention must be given to the fact that, subsequent to the transfer of operations to the foreign operator, the latter may find it difficult to maintain the standards over time, because necessary reinvestments are not made or because energy sources with higher carbon content are used instead. The emission reductions originally calculated on the basis of a “model plant” cannot then be applied without qualification to the entire life time of the project (Maier-Rigaud, 1994).

As with the estimation of incremental costs, problems also arise regarding the definition of the baseline situation. The questions which need to be asked are: What is an average power plant in the respective country? Would a modern plant be built with and without Joint Implementation? Will a sink, e.g. an area of tropical forest, genuinely be protected, or will a new forest area be cleared that would have been left unscathed were it not for the Joint Implementation project? The question of emission credits is largely unresolved, especially with regard to measures for the protection of sinks as expressly intended by the “Framework Convention on Climate Change” (Loske and Oberthür, 1994), and it is becoming increasingly apparent that such credits can only be defined through negotiation in each specific case (Barrett, 1993a).

Projects with low abatement cost-benefit ratio are not suited as potential Joint Implementation projects, since the time-consuming and costly search for partners, combined with the high transaction costs engendered by complex negotiations on contractual conditions, would probably cancel out any such benefit. As far as the remaining projects are concerned, a constant search must be mounted for ways to reduce these implementation costs.

Monitoring emission reductions

Monitoring the actual emission reductions, a difficult task even at the national level, must be given special attention on account of the potential harmony of interests between the two contracting parties. Both sides will probably be interested in documenting as high an emission reduction level as possible to the international community. The investing country (and/or company) reduces its abatement costs because it can dispense with more expensive domestic reductions equivalent to the documented emission reductions abroad. The investing country or firm could reward the contractual partner accordingly for this service – it would then be advantageous for both partners to exaggerate the level of actual abatement (Bohm, 1993).

Even if one does not assume that the opportunities for making incorrect statements are actually exploited in reality, some kind of supervision or monitoring needs to be set up in order to exclude this possibility. A solution to this problem has to be found at the latest when, after agreement on country-specific emission targets, the emission reductions achieved through Joint Implementation projects may be off-set against these targets. The international community will only be able to agree on this mechanism for crediting emission reductions achieved in other countries against national emission targets when there are guarantees that the planned emission reductions have actually been made. (It may be necessary, for example, to have repeated measurements of each Joint Implementation project by an independent body).

Institutional arrangements

The success of Joint Implementation as an instrument will largely depend on the institutional arrangements. These will have to give adequate consideration to the problems of search and transaction costs, and of monitoring its application. Furthermore, national sovereignty must be impinged upon as little as possible if Joint Implementation is to become politically established. Against this background, the question arises as to the extent to which competence should be transferred to a supranational institution (Hanisch et al., 1993). Several models are conceivable:

1. Bilateral negotiation and information system: the parties involved submit a report to the other Parties to the Convention on the emission reductions achieved.
2. Involvement of a supranational institution: this would promote the establishment of a Joint Implementation market.
3. The supranational institution also checks and verifies the emission reductions achieved through Joint Implementation projects.
4. “International Credit Bank”: this would arrange for fund transfers by states willing to invest in Joint Implementation projects, issuing emission credits in return.

In a simple *bilateral* negotiation and information system, the parties would be left to monitor emission re-ductions themselves. However, extensive exploitation of the cost reduction potential demands as large a number of participants as possible; the more projects that are carried out, the higher the cost savings.

The Council therefore believes that an alternative should be striven for, namely to commission an existing or a newly-created *supranational institution* with the task of promoting a Joint Implementation market. Depending on the financial resources made available, the Secretariat of the Convention could discharge this function. This institution could compile and publish lists describing the location, costs and emission reductions of possible Joint Implementation projects; at the same time, common standards for evaluating such projects could be developed. In addition, the number of potential projects can be increased if the institution brings together several host countries to finance a large-scale project that would otherwise involve too great a financial burden for any individual country. Conversely, different projects could be bundled in "portfolios", with shares in these portfolios made available to potential investors.

Such an institution could thus contribute towards a major increase in transparency and the reduction of transaction costs, and provide a boost to the Joint Implementation market. At the same time, the national sovereignty of the states involved would remain untouched, in that each country would be free to decide on whether or not to participate in this market.

As soon as region- and country-specific emission targets are laid down and become binding in international law, and emission reductions abroad can be credited against agreed national targets, solutions must be found to a series of problems: in addition to detailed regulations governing the admission of projects, the distribution of costs and the emission credits awarded to investors, the problem of monitoring must also be solved. *Auditing* Joint Implementation projects (in terms of criteria to be defined through a consensus of the Parties) and *monitoring emission reductions* are tasks that could similarly be assumed by the supranational institution (EU, 1994). However, responsibility might then come into conflict with national sovereignty, a situation which would have to be adjusted for with specified consultation rules.

Box 1

Joint Implementation:
Promoting the bilateral system as an interim solution

Until such a supranational institution has been established, a simple bilateral negotiation system could be promoted as a preliminary model. Such reciprocal deals have already been concluded at government level. Norway, for example, supports the financing of a coal to gas boiler conversion, an energy saving housing complex in Poland, and a particularly efficient lighting project in Mexico. The Federal Government should actively support the further development of Joint Implementation by agreeing on similar pilot projects. Prime examples for such cooperation could be the modernisation of power plants which use fossil fuels. Through the practical application of the offset system, standardised project criteria and contractual conditions terms could be developed, which in turn can function as a model for future initiatives by private enterprises. The instrument can ultimately achieve broader application only through the involvement of private firms.

The Council advocates that the German employer's associations, and especially the industrial associations, collate relevant project proposals in order to reduce search costs, and that they forward these to the Federal Ministry for the Environment, which could then become a kind of national Clearing House. Banks and banking associations could also be integrated into such a procedure, which would facilitate the conclusion of projects between interested parties.

If, after a trial period, Joint Implementation is successfully and widely applied in the private sector, this state or semi-state support will cease to function as a trigger, since one could expect the establishment of private Clearing Houses – within a Joint Implementation market. In California, for instance, the *Global Warming* Alternatives (GWA) enterprise has been set up, offering governments, companies and individuals the opportunity to compensate for their CO_2 emissions. GWA is planning to offer shares in various reciprocal projects at home and abroad. In order to minimise the investment risk, the separate projects are to be bundled in a portfolio in which interested emitters can acquire shares. No comparable development has been observed in Germany to date. State-funded pilot projects probably perform an important impetus in this regard. However, it should be said that at present there are no economic incentives for enterprises, neither in the USA nor in Germany, to make such reciprocal investments attractive in a large manner.

The advantages of a *supranational credit bank* for implementing the concept relate primarily to the fact that the investment risk for the investors could be lowered through the collation of projects in portfolios. The extent to which this proposal can be implemented is reduced, however, by the (restricted) scope for decision-making on the part of those willing to invest. They can no longer choose their partners freely, but invest in a rather anonymous portfolio instead.

1.4.2.2 Integration of developing and transition countries

The potential benefits of the Joint Implementation concept can only be realised if the developing and transition countries are willing to participate. Generally, Joint Implementation projects are open to all Parties to the Convention (Article 4, para. 2). Even though the sovereignty of developing and transition countries is not called into question in any sense by Joint Implementation projects, they have tended to be rather critical towards the idea (Düngen and Schmitt, 1993; Oberthür, 1993; Krägenow, 1994). Whether or not this is just a tactical manoeuvre to improve their bargaining position, or whether such rejection is based on particular features of the concept, remains an open question. If the latter is the case, this would have to be taken into consideration when the concept is further refined. Some aspects of Joint Implementation which appear prob-lematic from the viewpoint of developing and transition countries are outlined in the following.

Opportunity to achieve cost-effective reductions

In the debate on Joint Implementation it is generally assumed that emission reductions should be credited to the country that bears the incremental costs of the investment – as a rule the industrial country (Jones, 1994). This could mean that developing and transition countries would lose an incentive to cooperate due to the fact that their low marginal abatement costs would be “used up”, so to speak, by other countries. Their marginal costs increase the higher the level of reduction. In the short-term this does not represent a problem, but should the “Framework Convention on Climate Change” be made more stringent at some stage in the future, this will involve the imposition of emission reduction targets on both developing and transition countries that can only be achieved at higher marginal abatement costs. This problem could be solved, however, if these countries receive an assurance today that a base year (e.g. 1990) will be taken when formulating any future country-specific emission quotas.

Financing *Joint Implementation projects*

Another obstacle preventing the integration of developing and transition countries into the concept could be the mechanism for allocating costs according to the incremental costs, as outlined above. The incremental costs are calculated as follows (Barrett, 1993a):

  Costs of the Joint Implementation project
– costs of a baseline project
± benefits (and costs) accruing to the developing or transition country from the Joint Implementation project
= incremental costs to be paid by the industrial country to the developing or transition country.

In certain circumstances, such a strict calculation of the incremental costs could mean that developing or transition countries obtain no financial benefit from the deal. Whether or not other benefits of the Joint Implementation solution (such as the transfer of technology and know-how) will persuade such countries remains to be seen. In any case, there is every possibility that developing and transition countries will only be motivated to cooperate if the payments they receive from the industrial countries far exceed the incremental costs.

1.4.2.3 Transition to a system of tradeable permits

Despite the problems outlined above, Joint Implementation is one of the few economic instruments of environmental policy that has a good chance of being realised on the international level, not least because it is anchored in the Climate Convention. Putting the instrument into practice would enable experience to be gathered and facilitate the introduction of other economic instruments, in particular a system of *tradeable permits.*

Joint Implementation could indeed progress without difficulty towards such an international system (Jones 1994; Hanisch 1991). Despite the similarity of these two instruments, there are some conceptual differences between them. With a global tradeable emission permit system, trading can commence as soon as the contracting states have reached agreement on country-specific emission targets. The definition of average “model plants”, as has to be done for the Joint Implementation concept, is not necessary. Moreover, the manner in which emission reductions are actually achieved in the individual countries is of no relevance for the operation of the tradeable permit system. Joint Implementation differs in this respect: every case of Joint Implementation relates to a specific project or projects, baseline projects must be defined and calculations of costs and emission reductions must be carried out (Bohm 1993). While the behaviour of emitters under a global emission permits system is steered through the market price for emission permits, Joint Implementation is an instrument that applies only to specific plants or installations. Therefore, if the Joint Implementation concept is to develop into a system of quotas and permits, this will, however, require a different set of institutional arrangements.

1.4.2.4 Joint Implementation as an element of an integrated climate policy

Joint Implementation is thus only one component and not the main instrument in a strategy for greenhouse gas reductions, it will be only one element in a bundle of measures, both on the global and national levels. This is a consequence of the fact that, even within an ideal institutional framework, the application of the instrument at *global level* remains limited. Particularly, there is no scope for integrating small enterprises and private households into the concept, while in the industrial area its applicability will be limited to large-scale projects on account of the high search and transaction costs.

Given this background, there is a need to qualify the objections levelled at the Joint Implementation concept, namely that the industrial countries could buy themselves out of their reduction duties and neglect to reduce emissions on their own territory, and that the pressure exerted by cost factors to develop new CO_2 reduction technologies would be lower. This argument, however, over-estimates the quantitative importance of Joint Implementation within the global context (Schmitt and Düngen 1992; Torvanger 1993). The industrial countries will only be able to meet a small part of their emission reduction duties through Joint Implementation projects (Loske and Oberthür 1994). The main part will have to be implemented within the industrial countries.

At the *national level*, Joint Implementation is not intended as a substitute for other climate protection measures. National efforts on the part of industrial countries to meet the Convention targets therefore must not be neglected. Rather, the industrial countries are virtually forced to implement binding and effective national measures, i.e. command-and-controll or economic instruments aimed at reducing greenhouse gas emissions. Joint Implementation is therefore only a complementary instrument for effecting certain emission reductions.

A national CO_2 levy or “carbon tax” would be one example for an incentive encouraging the private sector to reduce emissions. Under such a system, firms would have to pay a certain amount for each emission. Under such a scheme, emissions would be reduced until the marginal abatement costs per unit of emission are equal to the tax per unit. However, to provide the private sector with an incentive to participate in Joint Implementation projects, domestic emitters would have to be granted credits for their CO_2 emission reductions achieved abroad within the rating system for the domestic CO_2 levy or tax. Economic incentives encouraging domestic emitters to participate in Joint Implementation projects increase the greater the difference between foreign and domestic marginal abatement costs, and the higher the domestic rate of CO_2 levy or tax. The benefit obtained through lower marginal abatement costs abroad therefore obtains increasing significance as the CO_2 tax rate increases (Maier-Rigaud, 1994). This shows clearly that any international agreement on the Joint Implementation concept also requires a national climate protection strategy. How the integration of private companies is to be achieved at the national level is a matter for the individual Parties to determine.

1.4.3 Recommendations for action

The Council would like to draw attention to the recommendations made in the 1993 Annual Report: an emission permits system should be made an essential part of the global climate protection strategy. Reaching agreement on the initial distribution of emission permits is still the crucial obstacle to such a system at present. Joint Implementation seems more practicable, can become a pioneer for a tradeable permit system, and is more capable of producing international consensus in the short run. Even though Joint Implementation cannot be the principal instrument in a global climate strategy, it offers considerable scope for cost reductions and can develop positive effects through the transfer of adequate technology. In order to achieve its application on as broad a scale as possible, the Council recommends that a supranational institution (e.g. the Secretariat of the Climate Change Convention) be assigned the task of promoting and verifying Joint Implementation projects. Germany should foster the application of the instrument through participation in pilot projects.

As far as the question of crediting of emission reductions against overall reduction duties, the Council advocates the following strategy:

– On the one hand, crediting should only be partial, because Joint Implementation would then lead indirectly to more stringent climate protection targets.
– On the other hand, one should not dispense with all crediting against duties, because this would diminish the incentive to introduce the system and develop it further.

In any case, global, regional and national reduction targets must be specified. National efforts should not be reduced, and for this reason the commitments should be made at a sufficiently high level given the opportunities provided by Joint Implementation. Furthermore, efforts must be made to ensure that participation in Joint Implementation projects does not lead to a reduction in the financial commitments resulting from the Convention (or, indeed, in the volume of development aid). Overall, the discussion on Joint Implementation should be seen as an opportunity to seriously examine all the instrumental options for stabilising the climate.

1.5 A contribution to the "Convention on Biological Diversity": CITES

1.5.1 Short description of the problems

When it came into effect in 1975, the *"Convention on International Trade in Endangered Species of Wild Fauna and Flora"*, formulated in 1972 at the UN Conference on the Human Environment in Stockholm, was the first global environmental policy regime to tackle *one* of the prime causes for the decline in biological diversity. It is not restricted to the protection and preservation of particular species, but applies to all species that are endangered through international trade.

CITES, which has 121 member states, is the most effective treaty for the protection of wild fauna and flora, alongside the "Convention on Biological Diversity" that was signed by 165 nations at the 1992 Earth Summit in Rio de Janeiro (Bendormir-Kahlo, 1989). To what extent the tasks assumed by CITES will overlap those of the Convention, or in what fields these two fundamental treaties will complement each other, needs to be clarified and will be the subject of future negotiations.

The great interest shown by states in joining CITES has various reasons. When it was drawn up, the general assumption was that both exporting and importing nations have a vested interest in protecting species of fauna and flora as a future resource (Lyster, 1985). Accordingly, the Convention provides the signatory states with a broad scope regarding the interpretation and implementation of the provisions it contains. On the other hand, any state willing to join can do so without having to comply with any particular preconditions regarding existing standards for the protection of endangered species or nature in general. Nor does membership of CITES oblige the signatory states to implement any parallel measures. Implementing the provisions contained in CITES at the inner-state level therefore depends primarily on the importance attached to the Convention by the respective state, which itself determines the intensity of controls as well as the type and scope of sanctions it wishes to impose (Bendormir-Kahlo, 1985).

Given the fact that the decline of biodiversity is not determined by monocausal factors – i.e. is not only a result of international trade – CITES is not an all-embracing treaty for the protection of endangered species. Other important factors, such as the shrinkage, fragmentation and destruction of natural habitats of wild fauna and flora and increasing environmental pollution are not given explicit consideration as possible factors endangering species.

In its present form and function, CITES can only be partially effective. It can only be one of several steps taken to

Box 2

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

In response to the endangerment of wild fauna and flora by international trade, efforts have been made since the mid-1960s to formulate an international treaty for monitoring and regulating this trade. When the states participating at the first UN Conference on the Environment in 1972 in Stockholm had called for such a treaty the final version of the *"Convention on International Trade in Endangered Species of Wild Fauna and Flora"* (abbreviated CITES) was signed by 21 states on 3rd March 1973. The Convention formally came into force on 1st July 1975; in April 1994, 121 states were Parties to the Convention.

The central element of the Convention is a catalogue consisting of three separate annexes, listing the species of fauna and flora according to the degree to which they are endangered. Annex 1 contains species that are acutely threatened with extinction. The provisions in CITES prescribe that commercial trade in these species be fully prohibited until wild stocks have been regenerated. With some exceptions, any commercial trading of these species is prohibited. The only trade permitted is in species bred in captivity, provided that the breeding facility was approved by the CITES secretariat. Annex II lists species where the decline in stocks signifies a potential threat. International trade in these species is regulated by a system of export and import controls; they may be bought and sold as wild or as bred in captivity only with a valid CITES certificate. Annex III contains those species that have been declared to be endangered on their own territory. Trade in these species is only permitted on presentation of an export licence or certificate of origin.

CITES has two executive bodies, the Conference of the Parties, which meets every two years, and a Permanent Secretariat. The CITES secretariat, administered by the "World Conservation Union" (IUCN) and the "World Wide Fund for Nature" (WWF) on behalf of the Executive Director of UNEP, is responsible for preparing and organising the conferences, and is a point of contact for the Member States in the periods between the conferences. The secretariat only reacts if CITES regulations are violated. Otherwise, it filters the information and data it receives, forwards these to the relevant national institutions and integrates them into its annual reports on the implementation of the Convention.

During the "Conference of the Parties" decisions are taken regarding which species are to be included in one of the three Annexes, or which species need to be reclassified. Resolutions require a two-thirds majority. Monito-ring and regulating international trade is done on the basis of import and export controls and subsequent statistical evaluation. The CITES documents used in this process must comply with certain requirements concerning form and content, and are needed for all international transactions involving endangered species.

preserve biological diversity, since it cannot deploy any measures for actively preventing the endangerment of species through uncontrolled or excessive exploitation. This has led in many cases to a situation where CITES was unable to intervene until the last possible moment, when a species was already facing extinction. In practice, it has proved exceedingly difficult to implement the internationally agreed CITES regulations at the national and the local level. Serious violations of the regulations, flourishing illegal trade with endangered species and obvious implementation problems throw light on the design faults and possible weaknesses in the Convention, which are described in more detail in the following, along with possible solutions.

1.5.2 Causes and solutions

1.5.2.1 Design faults and weaknesses

A fundamental weakness of the CITES Convention is the lack of clear definitions and classification guidelines with respect to the level of protection to be granted to endangered species. There is no concrete definition regarding when and under what conditions a particular species is threatened with extinction, when a species is at risk and when risk becomes a threat. Article 2 of the Convention states that Annex I shall contain those species "... which are impaired or could be impaired by trade" (text of the 1973 Convention, Art. 2 (1)). The Article in question continues by stating that Annex II shall contain all species, "... which, while not necessarily being under threat of extinction at this time, could become so" (Art. 2 (2)), and Annex III is supposed to list all species "... which are subject to special regulations in their [the Parties] sovereign territory" (Art. 2 (3)).

International trade in species listed in Annexes II and III is permitted in principle, but is supposed to be monitored by a system of export and import controls. In the so-called "Bern criteria" formulated at the first Conference of the Parties in Bern, which serve the Parties to this day as a basis for including or classifying endangered species in the respective Annexes, it is only stated that the inclusion of a species in the Annexes depends on an assessment of the "biological status" and the "commercial status" by the contracting states.

The actual classification of species is based on resolutions passed by a two-thirds majority during the conferences held every two years. If political and economic interests dominate, this two-thirds majority requirement can be a major obstacle to the inclusion or classification of species. Because the decision is not taken by an independent committee of experts, this means that the only species enjoying the protection of the Convention are those that the Member States view as worthy of protection. This rule therefore contains the risk that the decisions taken are primarily politically and economically motivated, with species protection aspects being assigned mere secondary status.

In addition, the rough classification into species that can be traded internationally and those in which all forms of international trade are prohibited, does not do justice to the complexity of the problem and the different degrees of endangerment. Because inclusion in Annex I signifies a total ban on trade, and is only considered when developments have reached an extremely threatening stage, inclusion is often made too late. On the other hand, many of the species that used to be listed in Annex II have been included in Annex I since the Convention came into force. One of the reasons for this is that Annex II is a general pool for species displaying the most varying degrees of endangerment and does not comprise any sub-categories. The range extends from species with such low populations that no trade is actually tolerable (but which lack the requisite majority of Member States to be included in Annex I), to others in which trade could be conducted without further complications. A meaningful approach would be to base categorisation in the Annexes on the *"IUCN Red Data List of Threatened Animals"*, a response which has been rejected by the majority of the Member States so far, however. Moreover, even these criteria containing specific guidelines for classifying species into one of five categories, namely, extinct or presumed extinct, threatened, highly at risk, at risk, potentially at risk of endangerment, are somewhat outdated and are currently being revised.

1.5.2.2 "Bern" vs "Kyoto" criteria

During the 8th CITES Conference in Kyoto, a modification of the previous classification criteria was applied for by the states in Southern Africa (Botswana, Malawi, Namibia, South Africa, Zambia and Zimbabwe) and accepted. According to CITES Resolution number 8.20, the "Bern Criteria" are to be replaced, at the forthcoming 10th Conference which will take place in autumn 1994 in the USA, by the "Kyoto Criteria". Assuming that "... commercial trade can benefit the conservation of species and ecosystems" (CITES, 1994), it is planned to facilitate the regrouping of a species from Annex I to Annex II for the purpose of sustainable use of the species. Generally valid biological threshold values for endangered species are intended to serve as decision-making criteria (CITES, 1994), so that only such species are listed in Annex I which have a wild population of less than 250 in reproductive age. (In the most recent draft, the threshold value concept has been diluted still further to become a guideline criterion).

Even though it appears to make sense to classify species according to key biological data such as size of population, each particular species (and sub-species) in fact needs to be subjected to as precise an evaluation as possible regarding the minimum population necessary to ensure the survival of the species. If this is not done, the reclassification implied by the present draft of the "Kyoto Criteria" would probably accelerate the extinction of species already known to be threatened in their existence (e.g. chimpanzees, gorillas, blue whales, snow leopards) (Mills, 1992).

1.5.2.3 "Sustainable use" as a species protection concept

"Sustainable use" has been discussed since the appearance of the "World Conservation Strategy" as one possibility for preserving endangered species, and indeed explicitly as a species conservation concept. The idea is that a population of wild species should be used "... at a rate within its capacity for renewal and in a manner compatible with conservation of the diversity and long-term viability of the resource and its supporting ecosystems" (IUCN/SSC, 1992).

The Council advocates that this concept be subjected to careful examination. In some parts of the world, under the auspices of the "Species Survival Commission" of the "World Conservation Union" (IUCN/SSC), various pilot projects for sustainable use of wild and sometimes endangered species have been started (cf. *Box 3*). Initial assessment of these projects will be available in 1995 (personal message from C. Prescott-Allen, Co-Chair, IUCN, SSC).

Box 3

Protecting the green iguana in Costa Rica

The green iguana *(Iguana iguana)*, an indigenous Central American species, is severely threatened; the population has declined so drastically that it has been included in the Annex to the CITES Convention. One of the main reasons for this decline is the rate of deforestation in that region, since forests are the natural habitat of the iguana. This is compounded by the fact that the local population has shown little interest in preserving a species of animal that is neither popular nor particularly attractive.

The *Iguana Verde Project* in Costa Rica is pioneering new methods of species protection: instead of aiming for total protection, efforts are being made to enable the survival of the iguana through sustainable use. Rather than attempt to preserve the existing population as best possible (e.g. by prohibiting and combating illegal hunting), the project aims to increase the population by artificial breeding methods. Since 1988, a farm near the west coast of Costa Rica has been breeding iguanas and releasing them to the wild after a period of months. Back in the wild, they can be "harvested" again when fully grown.

By breeding and releasing iguanas in this way, a number of objectives can be pursued simultaneously:

- **Species protection**
  Iguanas are to be reintroduced to the wild and their population increased. By breeding them on the farm, their chances of survival are increased from approx. 5% in nature, where the young in particular are exposed to numerous predators, to approx. 95%. Without such supportive measures, survival of the iguana in Costa Rica could not be safeguarded.

- **Habitat protection**
  The iguana's natural habitat is the forest, on which they depend for protection from the sun and for food. The Iguana Verde Project therefore plants new forests on degraded grazing and farming land, above all with indigenous species of trees, and returns the iguanas to nature there. The intention is to turn these reafforested areas into biosphere reserves at some point in the future.

- **Sustainable use**
  The project permits the local population to sustainably use the iguana. The meat and leather of the animal are used, and hunting it is a popular leisure activity. A new source of food and income is thus created for the benefit of the population, which now has a personal interest in protecting the iguana. Sustainable use causes neither degradation of vegetation or soils, as would be the case with cattle rearing, nor does the care and rearing of the iguanas require intensive labour. As poikilotherms, iguanas have a favourable energy balance on account of their low base metabolic rate. In addition to supplying the local population, thought is also being given to selling iguana meat in the cities, or, in the long term, exporting it. One important aspect of this project is the participation of the local population in breeding, releasing and harvesting the animals. Environmental education in the field of "iguana management", and at the same time in soil and vegetation protection, is a major element of the Iguana Verde project.

Within the framework of an integrated concept, iguana hunting could lead in future, in association with the harvesting of timber, fuel and fruit, to sustainable use of the tropical rainforest in Costa Rica. Of decisive importance, however, is that an interest in preserving the iguana and the rainforest be instilled in the population, and that they be integrated into these tasks.

1.5.2.4 Quota regulations

Stricter export quota regulations should be applied for the species listed in Annex II of the Convention (Conf. Res. 3.15 (1981), Conf. Res. 4.13 (1983) and Conf. Res. 5.21 (1985)). This would imply that annual export quotas for these species be laid down in the respective countries of origin, which would then permit a certain degree of control to be exercised over the volume of international trade. If these quotas were then redefined every year or two years, this would enable the latest data on population trends within the various species to be taken into consideration.

Export quotas alone do not suffice, however, as the example of the export quota regulations for the African elephant have shown. In 1985, the 5th CITES Conference adopted a "Management Quota System for the African Elephant" (Conf. Res. 5.12 (1985). The system failed to have any effect, however, because the export countries lacked adequate monitoring and control mechanisms (Swanson and Barbier, 1992).

Successful application of export quota regulations requires effective national controls on extractions and exports as well as the curbing of illegal trading (where this is a problem for the species in question), through stricter controls in the importing countries where necessary. (Quota regulations have been introduced at EU level for particular species defined by a scientific working group). Export quotas should not be defined in an arbitrary fashion, but on the basis of scientific knowledge and key biological data on population dynamics and reproductive behaviour of the individual species, as well as on the degree of threat from habitat destruction, external influences and damage to the environment. It therefore seems meaningful to supplement an international export quota regulation agreed through CITES with a management plan for using and preserving the national populations of species.

1.5.2.5 Implementation problems

There are major shortcomings in the implementation of the CITES Convention, both in the control of legal international trade in Annex II species, and especially with regard to the curbing and prosecuting of illegal transactions with threatened or endangered species. Identifying the roughly 8,000 species of fauna and 40,000 species of flora listed in the Annexes is too much to expect of customs officials in both exporting and importing countries. Besides the problems involved in identifying the species themselves, it is above all through illegal trade that the Convention is undermined. Estimates by the World Wide Fund for Nature (WWF) put the monetary value of illegal trade at US$ 2-3 billion annually (WWF, 1993).

1.5.2.6 Positive list

One of the basic options for reforming the CITES Convention would be to introduce a so-called positive list, rather than the current practice of issuing lists of prohibited species. Such a positive list would list only those species which are proven to be unproblematic and in which international trade is therefore admitted. This would at least alleviate or even solve the many problems involved in identifying species, and give protected species a chance to regenerate. Assuming that far fewer species would be listed in such a positive list than in the CITES Annexes used to date, such a step would also release funds that so far have been spent on monitoring and supervising international trade for the preservation of species in their natural habitats.

1.5.2.7 CITES: A forum for North-South cooperation?

The large majority of the 121 states which have signed the CITES Convention are developing countries; only 23 of them are industrial countries (CITES, 1994). CITES is financed from contributions by the respective Member States. However, the size of contribution plays no role in the decision-making process: the Conferences are governed by the principle of “one country, one vote”.

Although one could expect that CITES could be another forum of North-South conflict, on account of its membership structure and the way it is funded, this is only partially the case. Actors with highly divergent interests are represented in this Convention, but only in a few cases has this led to block formation along the North-South axis. Rather, there is an open conflict between those who wish to preserve species in the strict, conservationist sense, and those who strive for intensive exploitation of species within the framework provided by the CITES regime.

This conflict over content and the debate on the fundamental issue of biodiversity conservation instruments obtained a clear profile at the 8th Conference, which dealt with the continued ban on ivory trading. Even though the motion to include the African elephant in Annex I of the Convention was brought by a developing country, Tanzania, southern African states refused their support and instead established a cartel for the commercial exploitation of ivory (Barbier, 1992).

Successful implementation of the CITES regulations is also made difficult by the fact that too little consideration is given to the specific problems faced by Member States from the Third World, the main owners of biological diversity. Seeing wild species as part of “humanity's heritage” – as often is supposed in the North – also implies a global responsibility for protecting these species. But the CITES arrangements still place the main burden on the developing countries themselves. Many of them are unable to meet the challenge this represents; in many cases they possess neither the institutional nor the technical capacities to implement the CITES regulations effectively. With a few exceptions, developing countries do not attach much priority to environmental issues in general, and biodiversity conservation in particular, on account of the pressing social and economic problems. International transfers (the funds solution) could create monetary incentives for preserving biological diversity, thus enabling the industrial countries to contribute to the preservation of global biodiversity. Implementing such a solution, however, gives rise to serious questions regarding national sovereignty, to which consensual answers need to be found.

1.5.3 Assessment

The CITES approach, which aims at protecting endangered species through regulations imposed on international trade, has proved in some cases to be a successful, in others an ineffective instrument. A positive example, in terms of basic concept at least, is the protection of the African elephant. At the 7th CITES Conference held in Lausanne in 1989, this “prestige species” was transferred from Annex II to Annex I (Conf. Res. 7.9). The time which has since elapsed may be too short to make any conclusive assessment regarding the success of the international trade moratorium which then followed, particularly since elephants are among the species which reproduce at a relatively slow rate. Nevertheless, illegal hunting of elephants has declined sharply. This decline is coupled to falling prices on the world market for ivory and a lower demand in the large consumer countries such as China, Hong Kong, Japan and the USA. For less popular and less attractive species, however, such as insects, reptiles or bats, inclusion in Annex I to the CITES Convention was not enough to ward off extinction or the threat of it. There is clear evidence that the international measures instituted by CITES are inadequate, but have to be supported by further action at the national level. In general, practicable species- and country-specific concepts need to be developed on the basis of the *precautionary principle* laid down in the CITES Convention. This principle would suggest that use or trade is permitted only if investigations show that such use or trade does not jeopardise the survival of the species in question.

Preserving biodiversity also depends on legislative and institutional arrangements established at international and national level so that appropriate measures can be implemented for each species. Trade bans, as the example of the African elephant shows, can be an instrument for regenerating decimated populations in the short to medium term. In the long term, however, they will not prevent the extinction of a species if the other factors threatening it are not taken into consideration as well. Controlled, or limited "ecotourism", for example, could be a meaningful use of species in which trade is banned, while at the same time providing a source of foreign currency earnings for the countries involved. As the example of the trade in parrots demonstrates, export quotas which create financial incentives for species conservation (see *Box 4*) are a possible solution that could be applied to other species. Commercial use of endangered species should therefore be subject to the imperative of "sustainable use", coupled to effective protection of the species' habitats against pollution and destruction – i.e. against excessive interference with the ecosystems by human beings.

Box 4

The international parrot trade: The example of Argentina and Surinam

Parrots are particularly vulnerable to international trade. Worldwide, they are the species of vertebrates that is most traded, which has led to all species of parrots being listed in one of the three CITES Annexes. In addition to the demand for these birds on domestic and export markets, parrots are particularly endangered through direct stresses on and destruction of their habitats, e.g. through the clearing of primary forest; in many cases, both factors are found (Beissinger and Bucher, 1992).

In the following, two different cases for the regulation of parrot trade are compared: on the one hand, Argentina with its relatively lax national legislation and relatively uncontrolled export, and, on the other, Surinam, which has had comparatively strict export quotas.

Argentina

Argentina is one of the few South American countries that legally exports wild parrots; it is the world's largest exporter of parrots, with an estimated retail value of approx. US$ 800 m (Thomsen and Bräutigam, 1991). Argentina also acts as a transit country for parrot exports from Paraguay, Bolivia and Brazil. Despite the bans imposed by these countries on the export of parrots, consignments of very rare specimens are diverted more or less regularly via Argentina, where they are provided with CITES certificates and effectively "legalised" on re-export (EP, 1991). IUCN/SSC (1992) has released figures according to which as many as 30% of the Blue-fronted Amazon parrots exported from Argentina originated from Paraguay.

Blue-fronted Amazon parrots are found in an area 3,000 km long, extending from the northeast of Brazil to Paraguay and northern Argentina in the south. Because they are found above all in flat regions, mainly in flocks of up to one thousand birds, and use fixed routes when searching for food, they are easy to catch (Lantermann and Lantermann, 1986). Catching is now concentrated in northeast Argentina, since only a few specimens are left in the southern part of the country.

A *Significant Trade Study* carried out by the *World Conservation Monitoring Centre* (WCMC) for the CITES Secretariat identified the destruction of natural habitats, the advance of human settlements and international trade as the three crucial factors leading to the decline of Blue-fronted Amazon parrots stocks.

What is problematic, however, is not only the high numbers of directly exported birds, but also the fact that certain methods for catching these birds contribute indirectly to the destruction of habitats. The catchers, mostly small farmers and landless campesinos, cut openings in the red and white Quebracho trees to get to the unfeathered nestlings. If these openings are not resealed with resin – a rare occurrence – then nesting space is lost for future brooding of the Blue-fronted Amazon parrot, which has specialised in this type of tree. If the nesting cavities are difficult to reach, because they are very high up, for example, then the trees are often felled in order to get to the young birds (EIA, 1992). In both case, about 95% of the Quebracho trees are either damaged or completely destroyed (Bucher, 1991). This is ecologically fatal, since the Quebracho tree needs about 150 years to reach maturity and provide a suitable brooding place for Blue-fronted Amazon parrots.

An export quota for Blue-fronted Amazon parrots was imposed by the Argentinian authorities responsible for implementing the CITES Convention in 1990. However, this quota was not based on scientific studies, but on the estimated average export figures for previous years, namely 23,000 a year in 1990 and 1991. Because the United States submitted a proposal at the 8th CITES Conference to include the Blue-fronted Amazon in Annex I, a so-called "zero export quota" for Argentina was laid down until such time as reliable information on the actual stocks of this species are available.

Surinam

Unlike Argentina, Surinam has one of the lowest deforestation rates in the world, despite its relatively large areas of tropical rainforest; deforestation in the interior is under 0.1%. Indigenous fauna – 674 bird, 130 reptile and 200 mammal species have been identified so far – are monitored and protected by the *Nature Protection Division of the Surinam Forest Service* (LBB). This body is also the authority responsible for implementing CITES. Surinam is considered the only country in the world that has successfully developed and implemented a strategy for the sustainable use of its parrot species; this is the case for at least 21 of the indigenous parrot species (Thomsen and Bräutigam, 1991).

The Surinam government has developed, together with the LBB and through cooperation with traders, an export quota system that produces foreign currency revenue while at the same time combating illegal trade. New quotas are determined each year on the basis of field research data. All parrot exports must be authorised by the *Association of Animal Exporters*, and only those traders who are members of the Association may export animals. A minimum amount of foreign currency earnings to be achieved through sales is defined by the LBB for each species of parrot. Exporters must pay the selling price to the central bank in foreign currency prior to export and are later credited with the amount in domestic currency. This ensures that the currency revenues remain in the country, rather than being transferred abroad (Thomsen and Bräutigam, 1991).

These features of the Surinam system show the direction in which trade in wild fauna could develop. However, one must also consider that it is easier for Surinam, with its relatively low export volume, to monitor trade and to prevent illegal trading than it is for states like Argentina or Brazil. The Surinam example also shows how important it is for an effective management system that export quotas are not set arbitrarily, but on the basis of reliable data, and that adequate institutional and personnel capacities must be available for monitoring catches, accommodating the relevant species and exporting them.

1.5.4 Recommendations for action

The global protection of endangered species has been neither a central field for action nor an important research field in Germany. This is all the more surprising given the fact that the Federal Republic was the first country in the European Community to join CITES and to pass strict species protection regulations when implementing the objectives of the Convention as national law. Germany has therefore set a high standard with respect to species protection legislation, both within Europe and in the world as a whole. This "pioneering role", as least as far as legislation is concerned, must be translated into practice, however, and activated on a global scale. In view of the rapid decline of biological diversity in the order to 20 to 75 species per day (WBGU, 1994), this seems more urgent than ever before. An important step towards conserving biological diversity at national level, and an internationally important signal, would be the enacting of the draft for a new Nature Conservation Act that has currently been shelved.

In March/April 1995, Berlin will be hosting the first Conference of the Parties to the “Framework Convention on Climate Change”, which came into force on 21st March 1994. This conference will also have a bearing on the necessity of practical implementation of the “Convention on Biological Diversity”, which came into effect on 29th December 1993 – and promises to produce positive synergy effects. What is needed is that all the parties to the Convention implement it as national law through appropriate measures as soon as possible, and that they achieve in the near future an internationally acceptable consensus with regard to those clauses and regulations in the Convention which are still disputed. Here, too, Germany could and should establish a clear precedent.

In summary, it continues to be of great importance that trade in endangered species be monitored, and that CITES be actively used as a major instrument for preserving biodiversity and for the practical implementation of the Convention, despite all the weaknesses in its basic concept. CITES needs to be structurally improved, for example in form of resolutions or supplements to the Convention. It is also necessary to raise the amount of funding – this could partly be done with GEF resources. The “Convention on Biological Diversity” must be implemented quickly, because species protection through CITES (despite any forthcoming reforms) does not commence until a species has been classified as “threatened with extinction”. *Full protection of species and biological diversity must, in the opinion of the Council, be pursued with precautionary measures and with a range of different instruments.*

1.6 The concept of the “Convention to Combat Desertification”

1.6.1 Historical origins

More than 25% of the world's surface and over 900 million people are more or less seriously affected by desertification (see Box 21 for definition of desertification). Desertification is therefore a pressing global environmental problem. The phenomenon became a matter of worldwide concern in the early 1970s, when a catastrophic drought in West Africa killed some 250,000 people. The *United Nations Conference on Desertification* (UNCOD) subsequently convened in Nairobi in 1977 marks the beginning of the international political debate on combating desertification. An ambitious Plan of Action was agreed upon at UNCOD with the goal of bringing the problem under control by the year 2000 (Grainger, 1990; Toulmin, 1992).

Until the end of the 1970s, programmes centred on reforestation in the form of shelterbelts around growing settlement areas, initially on a large-scale and later, to an increasing degree, through village-based schemes. In the 1980s, water harvesting methods supplemented such projects. Despite the substantial successes achieved by some individual projects, the target defined in 1977 is far from being attained today, six years before expiry of the “deadline” 2000. The reasons for this are numerous, ranging from a steady population growth in the affected regions through uncoordinated action on the part of contributing countries to unfavourable global economic conditions (Ibrahim, 1992). At the 1992 UN Conference for Environment and Development in Rio de Janeiro (UNCED), the subject was once again made a central issue of political debate. Chapter 12 of AGENDA 21 describes a series of programme areas considered important for combating desertification (UNCED, 1992). At the same time, it was agreed to prepare an “International Convention to Combat Desertification in Countries Experiencing Serious Drought and/or Desertification, Particularly in Africa”, referred to in the following as the “Desertification Convention”, which shall contain concrete, legally binding obligations for member states.

Following that decision in Rio de Janeiro, an *International Negotiating Committee for the Elaboration of an International Convention to Combat Desertification* (INCD) was formed, with a secretariat responsible for organisational issues and for providing scientific support during the negotiation process. The INCD is financed with UN funds and a trust fund. A special fund was also set up for those developing countries needing financial support to participate at the Committee’s meetings.

In addition to official representatives of the individual states, a total of 223 non-governmental organisations were admitted as observers to the “Desertification Convention” negotiations. Since its establishment, the INCD has convened four Preparatory Conferences, namely from 21st May – 3rd June 1993 in Nairobi, 13th – 24th September 1993 in Geneva, 17th – 28th January 1994 in New York and from 21st – 31st March 1994 in Geneva again. Negotiations between the states, which number more than 100, were successfully completed on 25th June 1994 in Paris. The “Convention to Combat Desertification” is to be signed at a Conference of Ministers to which France has invited the community of nations to Paris in November 1994.

1.6.2 Areas of consensus

One major reason for the general failure of UNCOD’s ambitious 1977 Plan of Action is the lack of coordination on the part of both assisting and supported countries. Projects were mainly bilateral, with hardly any exchange of experience, for example on successes and failures in implementing specific schemes (Toulmin, 1992). The INCD conferences which have been held so far have determined that *cooperation and coordination* of schemes and projects, on-site wherever possible, shall be one of the primary elements in the new “Desertification Convention”. Joint control of financial resources allocated to the projects selected for implementation and effective administration of existing funds are part of this objective. Furthermore, agreement was reached that the measures recommended by the “Desertification Convention” should follow a bottom-up approach. Local participation should play a significant role, and here particularly the involvement of women. The strategic keyword in the draft convention is *capacity building* (INCD, 1994).

To take the specific conditions in each region into consideration, *regional annexes* were agreed upon for the Convention. Consensus was also reached on special treatment for the African continent, which was initially a controversial issue. Besides the African regional programme, however, there will also be such regional annexes for other regions in the world with special desertification problems. Africa is assigned a special position in that the priority of its desertification problem is expressly mentioned in Article 7 and a corresponding programme *(Regional Implementation Annex)* came into force in June 1994 on conclusion of the INCD negotiations. In future, research into desertification is to be promoted and access to data improved, with the transfer of adaptive technologies also defined as a priority.

1.6.3 Areas of conflict

While considerable progress was made and extensive agreement reached in the “Desertification Convention” on many detail issues, there are still many areas of dispute, above all regarding a series of fundamental issues in which the divergent positions of the industrial and developing countries are clearly apparent. One central point of dispute concerns the *global dimension* of desertification problems. Most industrial countries take the view that desertification is first and foremost a regional problem with regional causes, while developing countries affected by desertification see it as a worldwide phenomenon with global causes. These different positions are important for the respective negotiation tactics, in that those responsible – and hence the financial obligations – are primarily either the individual states affected by desertification, or the international community as a whole.

Other controversial positions are directly related to this. The industrial countries have consistently rejected at the INCD meetings any *interconnection between worldwide climate change and desertification.* The developing countries could negotiate from a position of much greater strength if this interconnection were to be acknowledged, since climate change is mainly caused by the industrial countries. Furthermore, the latter would also have to admit to having a vested interest in combating desertification, rather than appearing purely as aid-givers as they have done to date.

The question of how to *finance the programmes to be implemented* is therefore a controversial one. According to UNEP estimates, between US$ 10 and 25 billion will be required over the next 20 years to combat desertification effectively. This contrasts with the less than US$ 1 billion that is currently available each year, and reflects the line of argument taken by most industrial countries that the problem is best solved on a regional basis, for example through improved land use and stronger control of population growth. They derive a direct obligation on the part of those countries affected by desertification. However, most of the latter are LLDCs (least less developed countries). This fact alone means that they need financial and technical support from the industrial countries in order to combat desertification.

There is also some uncertainty regarding the *financial mechanisms* to be created. The developing countries demand a new fund for combating desertification, a demand that the industrial countries have so far rejected since they are anxious about losing control over the allocation of funds. A new “window”, or replenishment of the GEF (combating desertification as a fifth task) has been rejected by the industrial countries, because this would mean they acknowledge the global dimension of the problem.

The question of *institutional arrangements* also needs to be clarified. The industrial countries would like to see desertification integrated into existing (UN) organisations. Developing countries, on the other hand, and especially the African states, fear that the rigid structures and power relations in existing institutions are too inflexible to cope with the new and pressing tasks that combating desertification involves.

1.6.4 Recommendations for action

The particular measures planned as part of the “Desertification Convention” are highly promising at first glance. These measures envisage integrated approaches to combating desertification and the extension of successful projects carried out so far to include coordination and cooperation efforts (GTZ, 1992b). It has been realised that participation by the population and its self-help organisations in planning and implementation is a critical factor on which the success of land use schemes depends. In essence, the attempt is being made to learn from the mistakes of the past.

However, there are a number of other problems that will be faced when implementing the “Desertification Convention”. The financial issue is one of these. The Council would like to restate the recommendations made in its 1993 Annual Report, which included increasing development aid to 1% of Gross National Product.

The Council also recommends proactive and rapid implementation of the “Desertification Convention”, whereby existing programmes and projects organised through bilateral and multilateral cooperation could be integrated under the umbrella of the Convention, thus optimising success through improved coordination. This would make it possible to (re)activate the scientific, technical and legal-institutional expertise available in Germany relating to the desertification problem, and to deploy that expertise more widely on an international scale.

The problem of desertification affects large areas of the world. However, there is no disputing the fact that Africa is the continent most seriously affected. The Council wishes to point out that Europeans have a special obligation towards Africa, one that ensues from historical relationships and the geographical proximity of the two continents. The Council also refers to the migrational pressure that can be prevented by implementing the “Desertification Convention” and which would affect Europe first and foremost. This fact alone makes it clear that the industrial countries should have a major interest in actively and forcefully supporting the Convention.

2 The structure of German research on Global Change

In its 1993 Annual Report, the WBGU drew up a catalogue of research deficits in the field of Global Change. The Council expects that the topics mentioned there, to the extent that this has not already taken place, be integrated into the research strategies of the relevant ministries and made the object of new research projects. They should also be included, however, in the programmes of existing institutes and research associations. One example of how this can be achieved is the R&D strategy entitled “Helping to safeguard the future”, set up by the BMFT in March 1994, in which important elements of the WBGU recommendations are already integrated. The approaches contained in the strategy for overcoming the weaknesses listed below point in the same direction and should lead to this path being adopted by other ministries as well. The special research recommendations on Sustainable Development made in Section D 4 are congruent with the more general subjects listed in the 1993 Annual Report.

Besides the deficits regarding content, the Council also stated in 1993 that the organisation of German research on matters relating to Global Change is not commensurate with the challenges that exist. It continues to lack both the *interdisciplinarity* needed to tackle complex problems in an adequate manner, as well as the *international links* needed to respond appropriately to the global nature of environmental changes and their effects. Furthermore, there is a lack of *competence* in demonstrating ways to *solve the problems* posed by Global Change. The following sections deal with these structural deficits in German Global Change research.

2.1 Interdisciplinarity

Whereas the diagnosis of physical changes in the environment is primarily a task for various disciplines within the natural sciences, working out directives for action aimed at reversing or ameliorating these changes and for analysing their causes and effects demands close cooperation between natural scientists, engineers and social scientists. For instance, none of the central issues concerning locally appropriate, sustainable and environmentally sound use of land can be dealt with successfully without such interdisciplinary cooperation.

The German Science Council (Wissenschaftsrat) made a number of statements on environmental research in Germany in a position paper released in May 1993. It demands greater integration of various disciplines with the fields of cultural studies, social sciences and behavioural sciences, supplementary to the involvement with environmental problems on the part of the natural and engineering sciences, economics and on problems of Global Change. This applies both for the individual researcher, who must include concepts and findings from other disciplines into his investigations, as well as for cooperation between scientists from different fields.

Because they can unite all potentially relevant disciplines “under one roof” the universities are predestined, although not exclusively, as the main location for such interdisciplinary research approaches. However, in the opinion of the Council, there is no escaping the fact that the willingness to participate in *multi-disciplinary dialogue* and to pursue an *interdisciplinary perspective* has declined at the universities. Both aspects do not fit into the career patterns typical for many areas of research and faculties, and fail to be rewarded.

In the Council’s view the problems of Global Change continue to receive too little attention in academic education. The demand that degree studies be of limited duration and tightly organised with respect to content (as opposed to the current situation where students are free to study what they like for as long as they wish) means that little space will remain for such attention. Nevertheless, these topics should be touched upon in basic courses and dealt with in greater detail on the graduate level. Graduate colleges (“Graduiertenkollegs”) could provide a major stimulus for the interaction of research and teaching with respect to the problems of Global Change. In order to promote interdisciplinary research, more research centres, foundation professorships and special research units should be set up at universities. They should have a special focus on Global Change, be of specified duration, and have flexible staffing arrangements. These would permit the bundling of separate activities carried out by separate departments and to focus on jointly selected themes related to Global Change, so that larger projects can be tackled and problem-solving competence generated.

Interdisciplinary research in the natural and engineering sciences is mostly carried out at larger institutions or in research associations formed with universities (e.g. the ecosystem research centres). The main bodies in Germany performing research on Global Change have so far been extra-university institutions, the major research centres and Blue List institutes, the Max Planck Institutes and the research institutes of the Fraunhofer Gesellschaft, as well as the institutes operated by the relevant ministries at federal and *Land* level. However, as far as the problems of Global Change are concerned, these institutes have in common a lack of social scientific expertise; their activities are mostly limited to the analysis of problems from the natural scientific and engineering perspectives, with the result that they often fail to arrive at integrated and comprehensive problem-solving approaches.

For the above reasons, the bodies funding those natural scientific and engineering institutes concerned with Global Change problems should institute organisational measures to enable them, through reorganisation and concentration of potential, to carry out appropriate research projects in close cooperation with the universities, and to integrate social scientific expertise more fully. Achieving this will require not only state funds and incentives, especially from the BMFT and the DFG (German Research Council), but also that universities, faculties and institutes reorganise their research work away from their excessive focus on only one particular discipline. The challenge facing Global Change research can only be met if structures are flexible, oriented towards specific themes and projects, and if research associations exist which link different institutes.

2.2 International links

The international dimension of German research on Global Change was already touched briefly in the 1993 Report. In addition to the points made there, the Council considers the following arguments to be especially important. German climate research, in conjunction with marine and polar research, is firmly established within global and European research programmes, exercising a considerable influence in this sphere. For other research fields, especially that of soil degradation, the situation is less favourable, and is in urgent need of improvement if German research is to take its place among the leading research nations – especially if it is to fulfil its tasks as regards the implementation of the various global conventions (especially the “Convention on Biological Diversity”, 1993; the “Framework Convention on Climate Change”, 1993, and the “Convention to Combat Desertification”, 1994).

To achieve this, German research should be encouraged to exercise greater influence on the planning and shaping of international programmes, e.g. within the *International Geosphere-Biosphere Programme* (IGBP), and to push for the networking of research at the European and international level. Furthermore, it is essential that research institutes and their programmes relate more strongly to international programmes; reference is made especially to such programmes as the *Human Dimensions of Global Change Programme* (HDP), the *Man and the Biosphere Programme* (MAB) and the *World Climate Research Programme* (WCRP). Greater activities towards international programmes can provide an innovative impulse for German research on Global Change and thus contribute more effectively to solving global environmental problems.

With regard to the analysis of Global Change and the relevant solutions, a major focus should be laid on research in developing countries, in the tropics and subtropics. These regions form important elements of the global systems, particularly with respect to population growth, climate, biodiversity as well as soil and water problems. Global models of environmental changes and their natural and socioeconomic causes and effects have little relevance if they are not based on information from the tropics and subtropics. Despite substantial efforts and certain scientific achievements, research institutions in these countries often are not in a position to supply such information in the required quantity and quality, and hence to make a full contribution to the international research programmes on Global Change. At the same time, many countries in the tropics and subtropics are affected by the consequences of Global Change. In particular, therefore, they need scientifically based approaches for combating and preventing environmental damage and for instituting concepts of Sustainable Development. Germany has placed itself under major obligations in this connection within the framework of AGENDA 21. It participates in a number of major development projects, but to only a minor extent in the research necessary for their success. The SHIFT programme ("Studies of Human Impact on Forests and Floodplains in the Tropics") established by the BMFT is a promising start, and one which should be extended in content, geographical application and organisation.

The Council also states that, with few exceptions, German research on the environmental problems faced by developing countries and on the interrelations between environment and development is still not sufficiently developed, and should therefore be strengthened both institutionally and with personnel resources, and be given a regional and topical focus. This requires a corresponding support framework on the part of the Federal Government, one which envisages greater cooperation between the various ministries and authorities. An independent scientific commission could prepare the structural measures to be deployed and provide expert opinion regarding the research programmes to be developed. Particularly the research components in the development projects organised and funded by the BMZ (Federal Ministry for Economic Cooperation and Development) should be expanded, and more closely coordinated with the BMFT [Federal Ministry for Research and Technology], the BML (Federal Ministry for Food, Agriculture and Forestry) and the BMU [Federal Ministry for Environment, Nature Conservation and Reactor Safety]. In order to activate the research potential at universities, the DFG must become involved in the conceptual development of such programmes. In-situ research has an important multiplier function. Cooperation with scientific institutions in developing countries on questions of Global Change should therefore be extended further, on the basis of partnership and with specific reference to research and further training. This will require appropriate funding for the exchange of scientific personnel, including sufficiently funded scholarship programmes.

2.3 Problem-solving competence

The institutional base in Germany continues to lack the problem-solving competence required to address Global Change. There is an abundance of activities aimed at diagnosing Global Change, but also a lack of scientific expertise in the formulation of objectives and the development of suitable instruments. Solutions to the problems of Global Change must address complex interrelationships, which in turn necessitates the linking of natural scientific and socioeconomic approaches. The research directed to this end should thus be interdisciplinary and inter-institutional.

In the opinion of the Council, the scientific community's function as political advisor should be extended in future to embrace the development and evaluation of the goals, instruments and institutional frameworks for the new global conventions and treaties, as well as the protocols to be adopted. The concept employed when establishing the Potsdam Institute for Climate Impact Research represents an initial approach to the generation of problem-solving competence on the basis of ecological and economic interaction models. This institute was designed to make an important contribution to removing the structural deficits within German Global Change research described above. However, the fact that the institute is currently failing to get off the ground is an indication of the dissatisfactory situation in German research funding.

The Council recommends that similar such centres, with the potential to become strong and efficient research centres, be established as a matter of priority and developed to become starting points for flexible, topic-oriented and project-oriented research associations between natural science and social science working groups. Careful consideration should be given to the question whether a new institute for global environment policy research should be established in Germany.

D Focus section: The threat to soils

1 General issues

1.1 Introduction

1.1.1 People and soils

The old prayer for “healthy air, fertile land and peace on Earth” was a perfect illustration of humanity’s basic needs. Fertile soil, as one of the essential foundations for human life and social development, is the central focus of this Report.

Soils are complex physical, chemical and biological systems which are subjected to constant change through the influence of weathering, soil organisms and vegetation, but above all through the economic activity of human beings. Temperature and precipitation as principal climatic factors interact with the properties of soils (the regulatory function of soils) and together determine vegetation and hence the carrying capacity of soils for agriculture and forestry (utilisation function) and the variety of the biosphere (habitat function).

Arable land makes up a relatively small proportion of the total land surface of the Earth; virtually all areas with fertile soils or land that can at least be used for low-density livestock farming are already exploited by people. The old dream of the desert that becomes a “blossoming garden” can only be fulfilled in isolated cases, at costs so high that they are ecologically questionable. Increasing yields through fertilisation and pesticides are subjected to environmental limits, but greater benefits can be drawn from many soils on a sustainable basis using new breeds and environmentally sound soil management.

The development of human cultures has always been determined to a major degree by Man’s relationship to land. Ever since hunters and gatherers became livestock breeders and farmers, human societies have progressively “gained mastery over the Earth” by appropriating the soil and its resources. Most soils are cultural products; human beings have always cultivated soils, but have also damaged or destroyed them through overgrazing, intensive farming and deforestation, through depletion of mineral resources, through settlements, waste tipping, transport and wars. During the course of the last 150 years, these negative developments reached global dimensions through the development of extensive parts of North America, Northern and Central Asia, and the clearing of forests and savannas in the tropical and subtropical belts.

The expansion of farming and livestock farming was often accompanied by a loosening of social bonds between people and the land. As soon as one plot of land used in the past was exhausted or no longer provided sufficient food, people simply “took” the next. Within only a few decades, large areas of land were subjected to radical changes. The consequences were grave for agriculture and indirectly also for the world’s economy and the migration of people. The destruction of soils, and the loss of vegetation this produces, has a wider-reaching impact on water resources and climate on a regional and global scale.

In modern industrial society, this relationship to land has deteriorated still further – we are no longer as “rooted” in the soil as were our farming ancestors, even if considerable social status is attached to owning one’s own house and garden. We hide the soil under concrete and lawns and value it above all as building and industrial land. The “Bitterfeld Syndrome” (Section D 1.3.3.7 below) is one of many examples for this disturbed relationship to soil possessed by an industrial society that no longer heeds the interaction between soil and the elements of life – air and water. Protecting soils in agrarian and recreational landscapes, also to ensure a reliable water supply, is increasingly becoming a central element of environmental protection and environmental research. The experience and knowledge gained in this context must be integrated within international programmes, especially with regard to Eastern Europe and the developing countries of the South.

Soil degradation, as an important component of Global Change, was not adequately dealt with in AGENDA 21 or during the 1992 UNCED Conference in Rio de Janeiro, because neither the industrial countries nor the developing countries, who gladly exclude the topic because of the close linkages between soil degradation and population growth, had ever attached the requisite priority to this issue. The problems associated with soil degradation occur most of all in the poorest regions in the world, where they will also have their worst effects unless radical and effective action is taken soon. Further increases in population in these regions will dramatically increase the pressures on limited soil resources. This is compounded by the fact that any expansion of agriculture is to the detriment of other ecosystems, preservation of which is a matter of urgency and already part of a binding international convention: the “Convention on Biological Diversity” that came into effect on 29th December 1993.

Over the next two to three decades, the effects of soil degradation will *clearly precede* the effects of climate change. Soil problems will become more and more apparent if weather conditions fluctuate to a greater extent due to the increasing effects of climatic change, and if ecozones undergo large-scale shifts.

Soil degradation no longer occurs purely at the edges of deserts and where primary forest has been cleared, but in all parts of the world. Serious risks to soil resources are also being generated in the mid to long term in the industrial countries with often more favourable local natural conditions. The situation in these countries is characterised by high turnovers of material and energy, combined with the emissions and immissions that ensue. The consequences of intensive industrial activity and technicised agriculture and forestry, as well as constant growth in traffic levels, represent a threat to soils in the form of overexploitation, compaction, surface sealing, acidification and contamination.

The problems associated with increasing soil degradation were dealt with in the past by various national and international committees. However, these failed to give sufficient consideration to the fact that soil degradation involves a complex set of closely interlinked problems which can only be explained with multi- and interdisciplinary analyses, and only be solved or alleviated transnationally. However, the same causes have different effects in different ecozones of the world (e.g. boreal and temperate zones, tropical and subtropical drylands, tropical wetlands), and the same phenomena (e.g. erosion) can have different causes, with the result that regionally specific solutions need to be worked out.

The impact of soil degradation and its typical variants is influenced not only by initial and boundary conditions of a physical, chemical and biotic nature, but to a major extent by special socioeconomic and cultural features of the respective region, as well as through the specific values held by local people. Soils are also threatened by increasing urbanisation, and the decoupling of element cycles this engenders. At the end of this millenium, the Earth will be inhabited by more than 6 billion people, of whom about half will live in towns and cities. This development is leading to the risk of human beings literally having the “ground cut from under their feet”, i.e. losing contact with nature and its laws. Educating people about existing problems and increasing the level of acceptance for what may be costly measures are therefore essential steps.

Too little attention has been given to the fact that events or developments in distant regions do not occur in isolation from each other, but are often interrelated. Increasing economic links and development cooperation, but also local climate changes with global effects, influence the various regions mutually, although to differing degrees.

In its 1993 Annual Report, the Council laid the foundation for an integrated analysis of global problems by showing how the separate compartments of the ecosphere and anthroposphere are networked. The main section of this year’s Report analyses the causes of environmental damage to soils and outlines solutions for safeguarding and improving land use. It is the expressed aim of this main section not only to analyse the scientific side of the complex, but also to integrate more strongly the “critical variables” in the anthroposphere, i.e. the social scientific side, into the analysis.

In order to make the interconnections between these factors clearly visible, two regions with different starting positions and development potentials are analysed: the “Sahel region” and the “Leipzig-Halle-Bitterfeld” urban agglomeration. Both regions demonstrate in their own typical fashion the key functions of soils as carriers for agricultural and industrial production, as habitat for manifold biota, as regulator in the hydrological cycle and as a source and sink of minerals, trace elements and pollutants, as well as the essential basis for human culture. An analysis of the Sahel zone is topically relevant for the implementation of the “Desertification Convention”; the Leipzig-Halle-Bitterfeld agglomeration is a prime example for the regulatory function of soils in relation to the regional balance of elements.

1.1.2 Soils and soil degradation

Soils are structural and functional elements of terrestrial ecosystems, formed in a historical process of development through the interaction of geological, climatic and biotic factors at the respective site. Geological factors include the type of parent material and its mineral composition, the relief of the area, its exposition and the groundwater regime. Climatic factors include the level of solar radiation, precipitation, humidity, air temperature and wind speeds, and the characteristics of the hydrological regime (the hydrological cycle) that result from these factors. Finally, among the biotic factors are the species of flora, fauna and microorganisms which exist in the specific area. People, and their interventions in the biotic and abiotic components of ecosystems, thereby changing the natural dynamics and development of those ecosystems, must also be included in the latter group.

This short description gives an idea of the enormous number of possible combinations between these factors, and that these also apply to the soils that result. Another important point is that soils have formed over a long period of time and are constantly developing and changing. Soils do not have uniform properties, therefore, but instead form a mosaic of different types reflecting the possible combinations of factors and processes which constitute them. Depending on local conditions, these pieces of “mosaic” can cover areas ranging from only a few square metres to larger units measuring square kilometres. The variety of soils is a major factor determining the diversity of terrestrial ecosystems and their biota, and exerts a powerful influence on regional landscapes. However, this very variety of soils makes it difficult to deal with their degradation as a global environmental problem.

Box 5

World soil map

In order to classify the variety of soils, various classification systems have been developed in different countries over the last 100 years. Very different criteria have been used in obtaining these systems, however. What they all have in common is that they define *soil type* as the smallest spatial unit with a uniform structure, within predefined limits, which is then expressed in a vertical arrangement of soil properties (horizons). Depending on needs or available information, these soil types are combined in different soil associations of varying aggregation. The higher the degree of aggregation, the less detailed the information can, of course, be.

In any one region, similar but also very different soil types will exist alongside each other in “soil landscapes”. It is important to know in this connection that the different soils in a landscape are often coupled with each other through mass transfer processes. Soil maps generally show only the main or dominant type in a particular area and the proportion of the most important secondary soils, but little or nothing about the properties and distribution patterns of soil associations.

Until now, the basis for all global soil analyses has been the FAO-UNESCO World Soil Map, which comprises a total of 19 sheets (scale 1:5000000). These maps were prepared between 1961 and 1978 at the recommendation of the International Society of Soil Science (ISSS). This was the first time that a set of maps had been produced with a common legend for the whole world, and later used for a series of global surveys (desertification, soil degradation, carrying capacity of soils, releases of trace gases, etc.).

The classification scheme used in the World Soil Map involves two categories: *major soils* and *groups of major soils*. In all, 106 major soils in 26 groups are identified. *Table 4* shows the surface areas (in millions of hectares) of the soil groups, their share of land surface and their agricultural potential (Buring, 1979). *Fig. 2* charts the spatial distribution of these soil groups (Bouwman et al., 1993). Here, xerosols and yermosols are classed as desert soils, the solonchaks and solonetz as saline soils, and the shallow soils (lithosols, rankers and rendzinas) grouped together as leptosols. All major soils in which permafrost occurs are in this latter group (see Driessen and Dudal, 1991 for a detailed description of the major soils).

A resolution of 1°, as is the case in *Fig. 2*, cannot reveal the high spatial variability of soil types that actually exists. However, the legends used in the 19 sheets of the original maps contain the most important soil associations and the soil properties important for any land use (e.g. particle size, stoniness, relief, salinisation). The data for the separate continents used for preparing the maps also vary significantly, so that the reliability of the information provided by the various sheets fluctuates considerably. By constant development of the maps and the inclusion of new information, it became necessary to rework the legends (FAO, 1990b; FAO et al., 1994). These improvements, however, do not entirely remove the lack of information in this field. Only with enormous international efforts would it be possible to obtain the information on the entire land surface of the Earth needed for the preservation and sustainable use of soils.

If soils are to retain their structures and functions over longer periods of time or be used sustainably, then consideration must be given to the spatial and temporal variability of the factors affecting them, i.e. the respective location factors and their dynamics, as well as the soil properties themselves. The basis on which the requisite decisions are taken should be a global survey detailing the physical, chemical and biotic properties of soils. It should be stated clearly in this context that the global information currently available is not complete, or exists only in very low spatial and temporal resolutions; only one global survey exists so far, but in a scale of 1: 5,000,000. The Council referred to this state of affairs in its 1993 Report and demanded the improvement and expansion of *systems and networks for monitoring the Earth*, as well as the *information systems* these require.

1.1.2.1 Soil functions

Soils are the point of interaction between the two basic biotic processes of terrestrial ecosystems: *production*, i.e. the generation of biomass by green plants (primary production) from CO_2, water and salts with the help of solar energy, and *decomposition*, i.e. the subsequent breakdown of this biomass through the uptake of O_2 by consumers and decomposers, and the release of nutrients, trace elements and CO_2.

For plants, animals, microorganisms and people, as well as for energy, water and material budgets, the following four basic functions of soils can be derived *(Box 6)*.

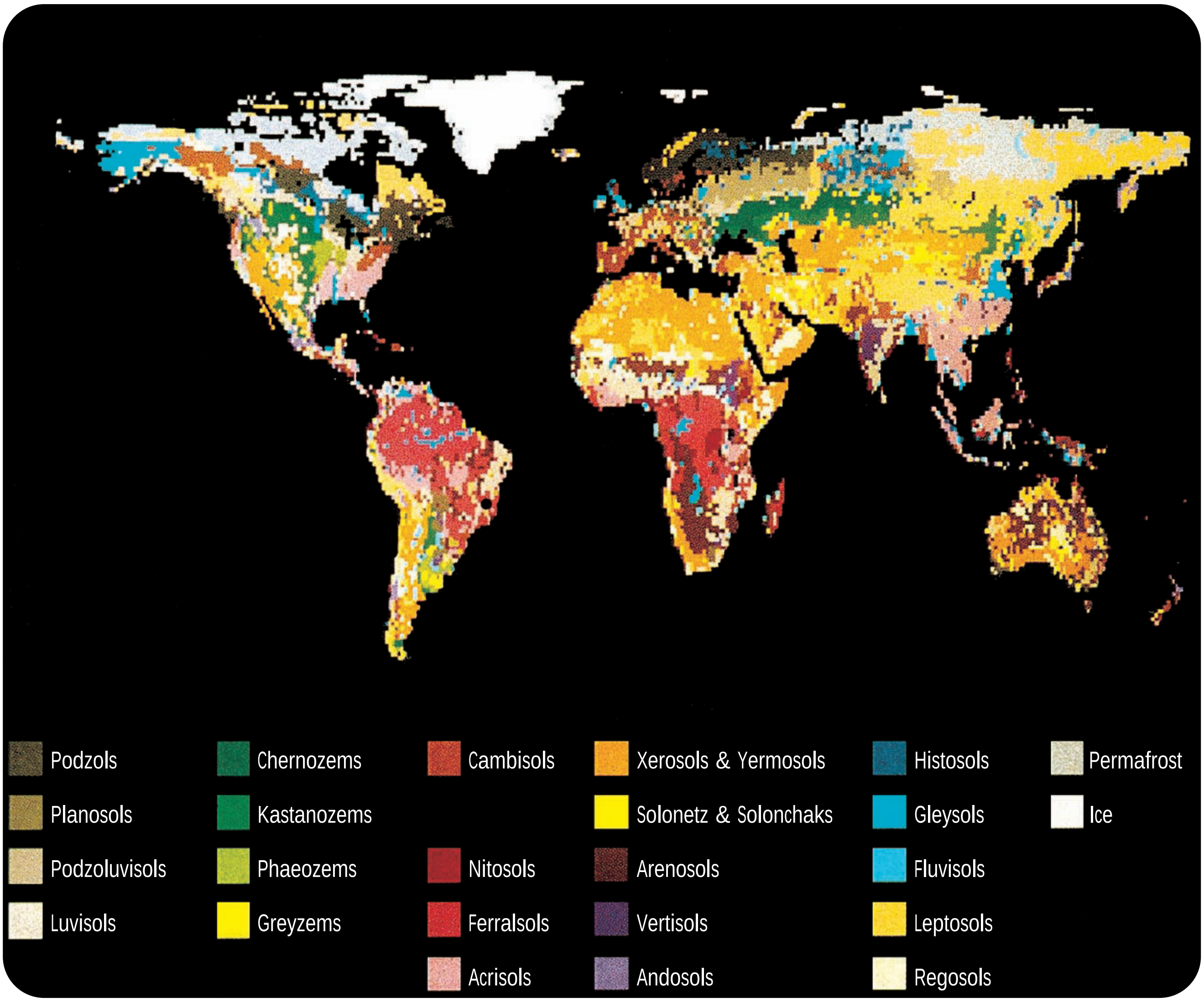
Habitat function

Soils are the habitat and the basis for life for a wide variety of plants, fungi, animals and microorganisms which live in and on soils, and whose metabolism is the basis for the regulation function and the production function of soils. Soil organisms are responsible for the synthesis, conversion and decomposition of organic substances in soils. Soil organisms influence the stability of ecosystems in that they decompose toxic substances, produce growth substances and generate a dynamic equilibrium between processes of synthesis and decomposition. Soil organisms also make an important contribution to biodiversity. Soils provide the rooting volume for plants, and serve as a supplier of water, oxygen and nutrients. Soils are therefore the basis for the primary production of terrestrial systems and at the same time for *all* higher heterotrophic organisms in the food web – consumers and decomposers – and thus for people as well. However, soil is also a habitat for people, for whom land is “territory” that they inhabit and utilise.

Regulation function

The regulation function includes the accumulation of energy and substances, as well as their transformation and transportation. Via various processes, soils regulate the exchange of substances between hydrosphere and atmosphere as well as neighbouring ecosystems. The regulation function comprises all abiotic and biotic internal processes in the

Figure 2: World soil map with soil types



Source: FAO, 1990a

Box 6

Classification of soil functions

HABITAT FUNCTION

REGULATION FUNCTION

UTILISATION FUNCTION

- Production function
- Carrier function
- Information function

CULTURAL FUNCTION

Table 4: Major soils of the world

	Total		Potential farming land	
Major soils	Area	Share	Area	Share
	million ha	%	million ha	%
Acrisols, Nitosols (Red tropical soils rich in clay, sometimes acidic)	1,050	8.0	300	9
Andosols (Soils formed from volcanic ash)	101	0.8	80	2
Cambisols (Brown earth and less well-developed soils)	925	7.0	500	15
Chernozems, Greyzems, Phaeozems (Black or bleached grassland soils, grey forest soils)	408	3.1	200	6
Ferralsols (Highly weathered soils in humid tropical regions)	1,068	8.1	450	14
Fluvisols (Young alluvial and coastal soils)	316	2.4	250	8
Gleysols (Hydromorphic soils)	623	4.7	250	8
Histosols (Organic soils or peat soils)	240	1.8	10	0
Lithosols, Rendzinas, Rankers (Shallow, stony soils formed from different types of rock)	2,264	17.2	0	0
Luvisols (Soils rich in alkalis, with clay accumulations)	922	7.0	650	20
Planosols (Bleached soils with hydromorphic properties due to waterlogging)	120	0.9	20	1
Podzols (Soils low in nutrients, with bleached upper horizons and accumulation of iron and humus in the underlying horizon)	478	3.6	130	4
Podzoluvisols (Luvisols in an advanced stage of development)	264	2.0	100	3
Regosols, Arenosols (Little-developed sandy soils)	1,330	10.1	30	1
Solonchaks, Solonetz (Saline and alkaline soils)	268	2.0	50	2
Vertisols (Black clay soils containing cracks)	311	2.4	150	5
Xerosols, Kastanozems (Semi-arid soils, weakly developed grassland soils)	896	6.8	100	3
Yermosols (Arid soils with very low humus content)	1,176	8.9	0	0
Other units	435	3.2	0	0
Total area	13,195		3,270	

Source: Buring, 1979

soil which are triggered by external influences. These subfunctions include the buffer capacity for acids, the filtering of substances from rainwater, infiltration water and groundwater, the storage capacity for water, nutrients and harmful substances, the recycling of nutrients, the detoxification of harmful substances, the destruction of pathogens, etc.

Utilisation function

The term utilisation function refers to those functions of soils that people deploy in a "gainful" way to satisfy their needs. Different properties of soils are exploited for specific purposes. A distinction is therefore made between the following subfunctions: the production function, the carrier function and the information function.

Production function
With very few exceptions, such as fishing, people are "consumers" of soils in their role as consumers of vegetable and animal foods. Since farming began, the deliberate utilisation of soils for agricultural and forestry production (of foodstuffs, animal feed and regrowing raw materials) has become increasingly important for human society. However, humankind has increasingly become an "exploiter" of soils instead. A further production function in addition to agriculture is the exploitation of natural stores. The raw materials acquired, such as coal, oil, gas, peat, gravel, sand, rocks and minerals are the "motor" driving many activities, particularly in the secondary sector of the economy, and are gaining in importance in the mechanised and chemicals-based agriculture and forestry (raw materials function). Extracting these raw materials usually involves destruction of soils, however.

Carrier function
The carrier function embraces a number of different subfunctions, namely use for settlements, transport, supply and disposal, for industrial and commercial production and for the disposal of waste, also called the disposal function.

Information function
These comprise the uses to which soils are put by people as an indicator for their fertility, mechanical stress-bearing capacity, usefulness for vehicles etc. The "genetic pool" provided by soils is the link to the production function, in that the information contained in soils tells us not only about the condition of soils (e.g. their fertility), but also its uses for bioengineering. Finally, the preservational properties of soils mean that they are an "archive" for natural and cultural history (see "cultural function" below).

Cultural function

As a specific part of humans' respective habitat, land and soil are the essential basis for human history and culture. This function is largely ignored or forgotten today, but because of its importance it is described in *Box 7*; reference is also made to Section D 1.3.1.7.

Global aspects of soil functions

The functions of soils, and the role they play within *Global People-Environment Interactions* were outlined in the Council's 1993 Report (WBGU, 1994). The following aspects were viewed as especially important from the global perspective:

Habitat function
– Soils contribute to biodiversity.
– Soils represent a genetic pool.

Regulation function
– Soils influence the exchange of radiation and sensible heat.
– Soils regulate the hydrological cycle of the continents.
– Soils are stores and transformers of nutrients.
– Soils are sources and sinks for carbon dioxide (CO_2) and methane (CH_4).
– Soils are sources of nitrous oxide (NO_2).
– Soils are buffers, filters, transformers and stores for pollutants.
– Soils are sources for contamination of neighbouring environmental compartments.

Box 7

The cultural function of soils

Soils and land are the natural basis for all human history and culture, a fact that is all too often ignored or forgotten. This is shown by the very root of the word culture – colere –: to cultivate the land (the soil) and to care for it. Local conditions determine whether plants and animals occur in a specific region or how they adapt to the location; human beings are integrated within this adaptation process.

The quality of soils, i.e. their suitability for cultivation and sustainable use, exerts a determining influence on the forms of economy and settlement, as well as on the social structures and the legal basis of human societies. Furthermore, soils are not only surfaces on which humans live; the annual rhythm of sowing and harvesting also shapes the religious and cultural behaviour of people.

The quality of soils determines whether farming or livestock breeding can be carried out in a particular region, and their yield capacities determine the type of utilisation and density of settlement. Both have an influence on the forms of settlement which develop. The limits on the extent to which food can be transported mean that the productivity of landscapes determines the existence and size of towns and cities, which then have social and cultural feedback effects on the land.

In many parts of the world, the quality of soils determines whether the rural population lives in prosperity or poverty, as well as, through the distribution of land tenure, the structure of society. Property claims and rights to use land influence jurisdiction. Territorial claims (space to live) have been and continue to be the root cause of wars. Religious bonds to soil as a “well of fertility” or as the “realm of the ancestors” influence in certain parts of the world how soils are handled, but also the extent to which the population is rooted in its homeland.

This outline is intended to show that soils play a crucial role as a cultural asset for humankind. Only when this fact is taken into consideration can the changes in land use that are needed be achieved. This is also the necessary emotional basis for people to treasure soils more around the world (see also Section D 1.3.1.7.1 below). Protecting soils should become a primary cultural task for all human society.

Utilisation function
– Soils form the basis for food production.

An assessment of these global aspects of soil functions shows clearly that anthropogenic *soil degradation*, i.e. the lasting or irreversible disturbance of soil structure and soil functions, represents one of the most serious environmental problems of our time. This led the Council to make this problem the cardinal focus of this year’s Report, whereby the main emphasis is placed on the production, habitat and regulation functions of soils, since this is where the global dimension is most apparent. If action is to be taken to reduce soil degradation, decisions at regional and local level must be made which take account of other functions as well. The Council includes this aspect in the following analyses and recommendations.

1.1.2.2 Soils as fragile systems

Because soils are structural and functional elements of terrestrial ecosystems, they exchange substances and energy with the environment across their own boundaries (thermodynamically open systems). Genetic information is also transmitted. They are therefore open to all forms of *external interventions and/or stresses*. These can include, for example, shifts in the radiation budget (UV-B), changes in the precipitation or temperature regime (climate change), changes in atmospheric composition (e.g. of ozone, CO_2, SO_2, NO_x), changes in land use (e.g. clearing of forest for cultivation, ploughing of grassland, irrigation and drainage, amelioration, intensified use, covering with buildings), accumulation of pollutants or nutrients, but also the intentional and unintentional introduction of exotic, i.e. non-indigenous organisms.

Soils were generated by a historical development process. The periods required for that process are of the order of thousands of years, a different scale than the time-span of human cultural history and far removed from the horizon of experience possessed by any one generation. The gradual adaptation of biota to the prevailing environmental conditions over long periods of time led to the optimisation of those systems, evidenced as approximation to a state of dynamic equilibrium. Dynamic equilibria in open systems are characterised by the fact that energy and matter inputs are always equal to total outputs. This results in no changes occurring in the level of stocks. Fluctuations of boundary conditions can lead to temporary internal changes of structures or functions without posing a lasting threat to the system, i.e. they are within the system's internal capacity to compensate and regenerate. Biota can adapt to slow changes in abiotic factors (climate change, loss of nutrients, acidification) or biotic factors (mutation, influx of alien species), whereby soils may undergo definite changes (developments) over geological periods (millennia).

Over the long term, soils can be completely destroyed by intensive erosion, thus exposing new rock material that can then be weathered to form new soil. However, stresses on a system become problematic if they are so rapid or powerful that they exceed the endogenous capacity of the system to compensate and regenerate (critical and supercritical stresses). Such stresses include human-induced changes in land use and regional climate, since lasting or irreversible changes to soils can occur in the medium term (decades to centuries), changes that are termed soil degradation.

If people interfere with soils so much that degradation occurs, their behaviour changes from that of a "consumer" to that of an exploiter who thus destroys his own basis for life over a shorter or longer period. This affects not only the soil itself – neighbouring systems also suffer as a consequence of the loss of soil functions, and must be protected, e.g. to preserve biodiversity or water resources, or for reasons associated with climate.

1.1.2.3 Soil degradation

Definition

Anthropogenic soil degradations are permanent or irreversible changes in the structures and functions of soils or their loss, changes which are caused by physical and chemical or biotic stresses induced by human beings which exceed the stress-bearing capacity of the respective systems.

Changes are *permanent* if they cannot be equalised within human time-spans (decades to centuries) by natural regeneration mechanisms in the soil, but can be reversed in an environmentally sound and economic manner through the wise use of energy and raw materials. Examples include compaction of upper horizons and the reversal of this condition through tillage, nutrient deficiency and its removal through fertilisation, changes in pH values and increases through liming or decreasing alkalinity through the addition of gypsum or sulphate, or the flushing of salts through irrigation.

Table 5: Extent of human-induced soil degradation for the main types of soil degradation, in millions of hectares

Types of degradation	Light	Moderate	Strong/extreme	Total
Water erosion	343	527	224	1,094
Wind erosion	269	254	26	549
Chemical degradation	93	103	43	239
– Loss of nutrients	(52)	(63)	(20)	(135)
– Salinisation	(35)	(20)	(21)	(76)
– Contamination	(4)	(17)	(1)	(22)
– Acidification	(2)	(3)	(1)	(6)
Physical degradation	44	27	12	83
Total	749	911	305	1,965

Source: Oldeman, 1992

Changes are *irreversible* if they cannot be equalised within human time-spans (decades to centuries) by natural regeneration mechanisms in the soil, but at most with excessive, i.e. ecologically unwise, external deployment of energy and raw materials. Examples include wind and water erosion, contamination with pollutants over wide areas, soil destruction as a result of mining activities, compaction to deeper levels and large-scale sealing through road building and settlements.

Soil degradations are therefore restrictions in the functions of soils. Such an analysis is always based on a use-related criterion as defined by humans. From the ecological perspective, there is no “good” or “evil”, just a reaction of systems to changing external conditions. The reactions can partly be quantified and assessed, and can therefore serve as the basis for evaluation.

An assessment of when changes in soils are no longer within the range that can be compensated for by internal regulatory mechanisms is not possible in all cases, however. As a precautionary measure for preventing possible damage, a multi-stage evaluation system should therefore be applied which can draw attention to the threat that exists before soils reach critical conditions (this approach is also pursued in the draft Soil Protection Act in Germany).

Global dimensions of soil degradation

As “consumers” and “exploiters” of natural resources, people have interfered with terrestrial ecosystems in the past and the present. The principles of sustainability and protection of the environment were often ignored in the process. Clearing and overexploitation of forests, overgrazing of grasslands by oversized herds, incorrect farmland management, exploitation of vegetation for domestic purposes and the growth of industry or urban agglomerations are prime examples. The “unanticipated” consequences of these interventions are now proving to be more or less severe soil degradation in the whole world. Even though this was already seen decades ago as a serious and widespread problem, the geographic extent and the intensity and causes were only partly known.

Not until 1990 was a world map of the status of human-induced soil degradation finally produced by UNEP and ISRIC, in close cooperation with soil scientists and environment experts (Oldeman et al., 1991). With the help of this map, which is at a scale of 1 : 10 M, it is possible to carry out a regional and global assessment of the extent and intensity of soil degradation. Because enormous efforts are required in order to measure soil degradation directly, and due to the fact that the data for large parts of the world are of exceptionally low quality, the data shown below are estimated figures arrived at by a group of experts.

Table 6: Factors of human-induced soil degradation, in million ha

Continent/Region	Deforestation	Overexploitation	Overgrazing	Agricultural activities	Industrial activities
Africa	67	63	243	121	+
Asia	298	46	197	204	1
South America	100	12	68	64	–
Central America	14	11	9	28	+
North America	4	–	29	63	+
Europe	84	1	50	64	21
Oceania	12	–	83	8	+
World	579	133	679	552	22

Source: Oldeman, 1992 + = low significance – = no significance

These data must therefore be evaluated with all due caution, because they contain uncertainties in both directions and do not embrace all types of degradation. The survey results are briefly summarised below.

Four different kinds of human-induced soil degradation can be distinguished. In the case of water and wind erosion, soil is washed or blown away, and degradation takes the form of a loss of soil material. Physical and chemical degradations occur when soil mass is retained, but where internal negative changes of a physical or chemical nature are induced. Another type of soil degradation that must be taken into consideration is biotic degradation. Knowledge of such processes still shows many deficits, however, which is why there is no information for the global level.

Table 7: Types and causes of soil degradation, in million ha

Types of degradation	Causes				
	Natural vegetation Deforestation	Natural vegetation Overexploitation	Overgrazing	Agricultural activities	Industrial activities
Water erosion	471	38	320	266	–
Wind erosion	44	85	332	87	–
Chemical degradation	62	10	14	133	22
Physical degradation	1	+	14	66	–
World	578	133	680	552	22

Source: Oldeman, 1992 + = low significance – = no significance

The fact that soil degradation is not a marginal dimension of anthropogenic environmental change is clearly shown by the findings obtained by the global survey, whatever criticisms may be levelled at it (Oldeman et al., 1991). Of all soils in the Earth's ice-free land surface, which measures approx. 130 million km^2, almost 20 million km^2, or about 15%, already show *definite signs of human-induced degradation*. This is the result of a large-scale survey carried out for the UNEP by the International Soil Reference and Information Centre (ISRIC). *Water erosion* accounts for 56% of this total, followed by *wind erosion* (28%), *chemical degradation* (12%) and *physical degradation* (4%). These figures do not include degradation of forest soils and latent damage that accumulates over longer periods of time, or changes in the communities of soil organisms.

Table 8: Global and continental distribution of farming, grazing and forest land, and the respective proportion of their soils which are degraded, in million ha

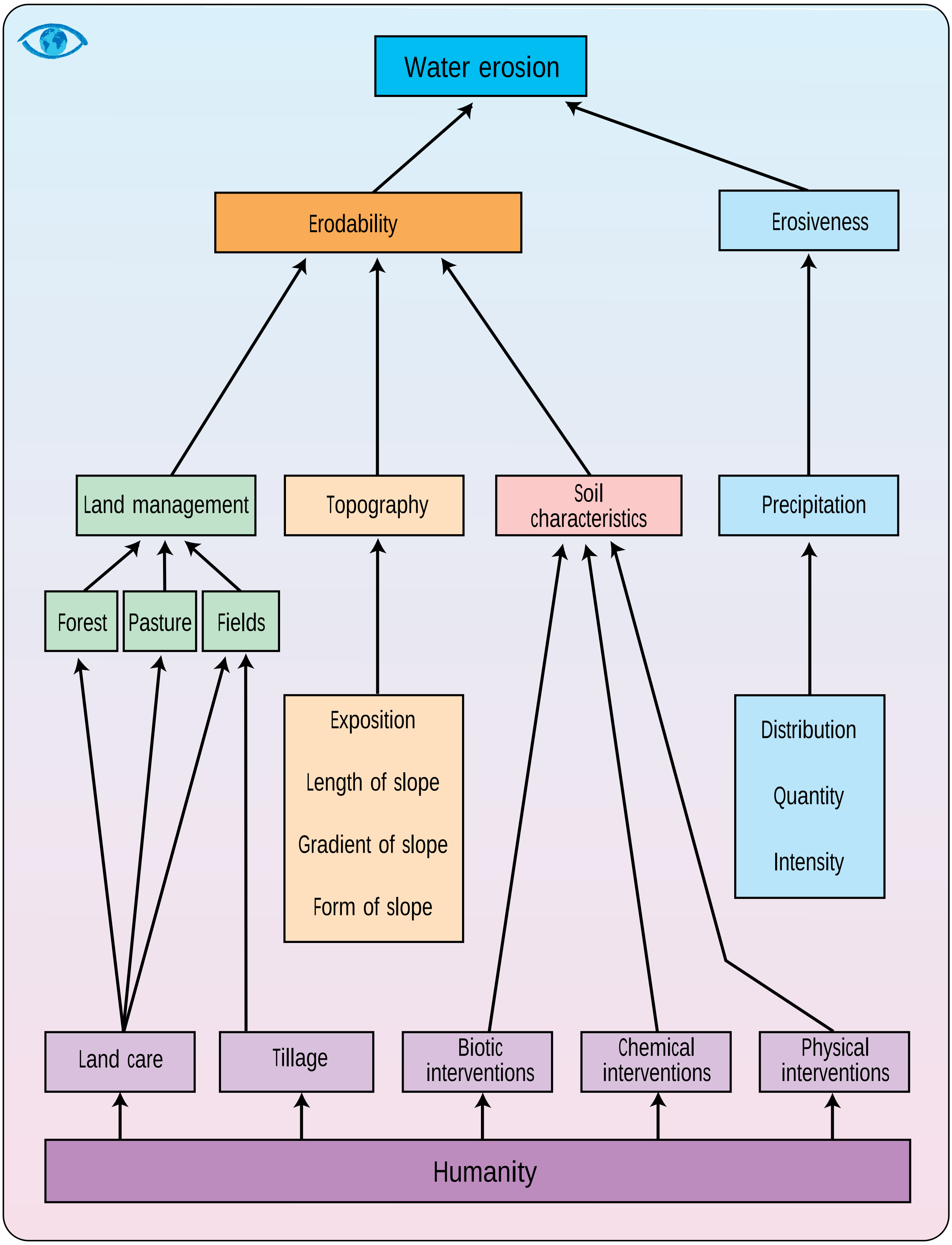
	Farmland			Grasslands			Forest and savanna		
	Total	Degraded	%	Total	Degraded	%	Total	Degraded	%
Africa	187	121	65	793	243	31	683	130	19
Asia	536	206	38	978	197	20	1,273	344	27
South America	142	64	45	478	68	14	896	112	13
Central America	38	28	74	94	10	11	66	25	38
North America	236	63	26	274	29	11	621	4	1
Europe	287	72	25	156	54	35	353	92	26
Oceania	49	8	16	439	84	19	156	12	8
World	1,475	562	38	3,212	685	21	4,048	719	18

Source: FAO, 1990

Water erosion

Soil erosion caused by the impact of raindrops and surface runoff can lead to different effects. Destruction of soil structure furthers clogging and crusting, and impairs plant growth. Removal of fertile topsoil leads to nutrient loss and the associated decline in production. In extreme cases, the rhizosphere is reduced to

Figure 3: Water erosion is determined by two location-dependent variables: erosiveness of precipitation and erodability of soils. While humanity has not significantly altered erosiveness, it has an enormous impact on erodability, with predominantly negative consequences for soils. With good knowledge of the location conditions, however, utilisation strategies can be developed that extensively avoid this form of erosion.



such an extent that cultivated plants can no longer be grown. Sloping, structurally labile soils are susceptible to rill and gully formation. This removes valuable soil material and renders the land useless for agricultural purposes. A distinction is generally made between four different types of water erosion:

- clogging of topsoil
- loss of topsoil material and nutrients
- deformation of terrain by rills or gullies
- coverage of soils on lower slopes and in valleys.

The second type is predominant in terms of surface area, but control and reclamation is more difficult in the case of the third type. The total land area impaired by human-induced water erosion is approx. 1.1 billion ha, 56% of which is in humid regions of the world, and 44% in the tropical and subtropical regions.

Fig. 3 shows in diagrammatic form the interacting forces that influence water erosion. In addition to weathering and topographical factors, human beings also intervene in these processes in many different ways. They can therefore accelerate erosion processes, but can also arrest erosion by taking appropriate action. The diagram also shows quite clearly that erosion depends on the respective locational factors as well. Thus, suitable measures to counteract erosion processes can only be taken after careful analysis.

Wind erosion

Removal of soil material by the wind is a widespread phenomenon in arid and semi-arid regions featuring thin or sparse vegetation cover. It typically occurs with more coarse-textured soils. Wind erosion is aggravated by the reduction of vegetation cover, overgrazing or by tillage. Approx. 0.5 billion hectares of land surface are affected by wind erosion, with 94% being located in dryland regions.

Three types of wind erosion are generally distinguished:

- loss of topsoil as a uniform process
- terrain deformation through deflation hollows and dunes
- coverage of land surface by eroded, windborne particles.

What these three types of wind erosion have in common is that the material lost is deposited again elsewhere. These side-effects, such as the silting up of river courses and harbours, the filling of storage lakes, the blocking of transport routes and the encroachment of sand sheets on settlements, can often be quantified better than the erosion itself, which affects entire areas of land. Several billion US$ must be spent each year on removing these side-effects – money that would be better invested in preventing erosion in the first place.

Chemical degradation

The total area of the globe affected by chemical degradation of soils is of the order of 240 million ha. A distinction is made between four different types of chemical degradation:

Nutrient loss and/or loss of organic substance
Nutrient loss always occurs where natural systems are disturbed (changes in land use, humus depletion) or when agriculture and forestry fail to replace the nutrients which are leached. The effects are particularly marked in soils that are poor in nutrients.

Salinisation/Alkalisation
Salinisation is a phenomenon that often occurs in conjunction with irrigation. Human-induced causes include incorrect irrigation practices, leading to rising levels of saline groundwater, increased evaporation and the penetration of sea water in coastal regions. Because salinisation frequently involves the accumulation of sodium ions, the blocking of exchange sites and the formation of soda (sodium carbonate) leads to alkalisation of soils.

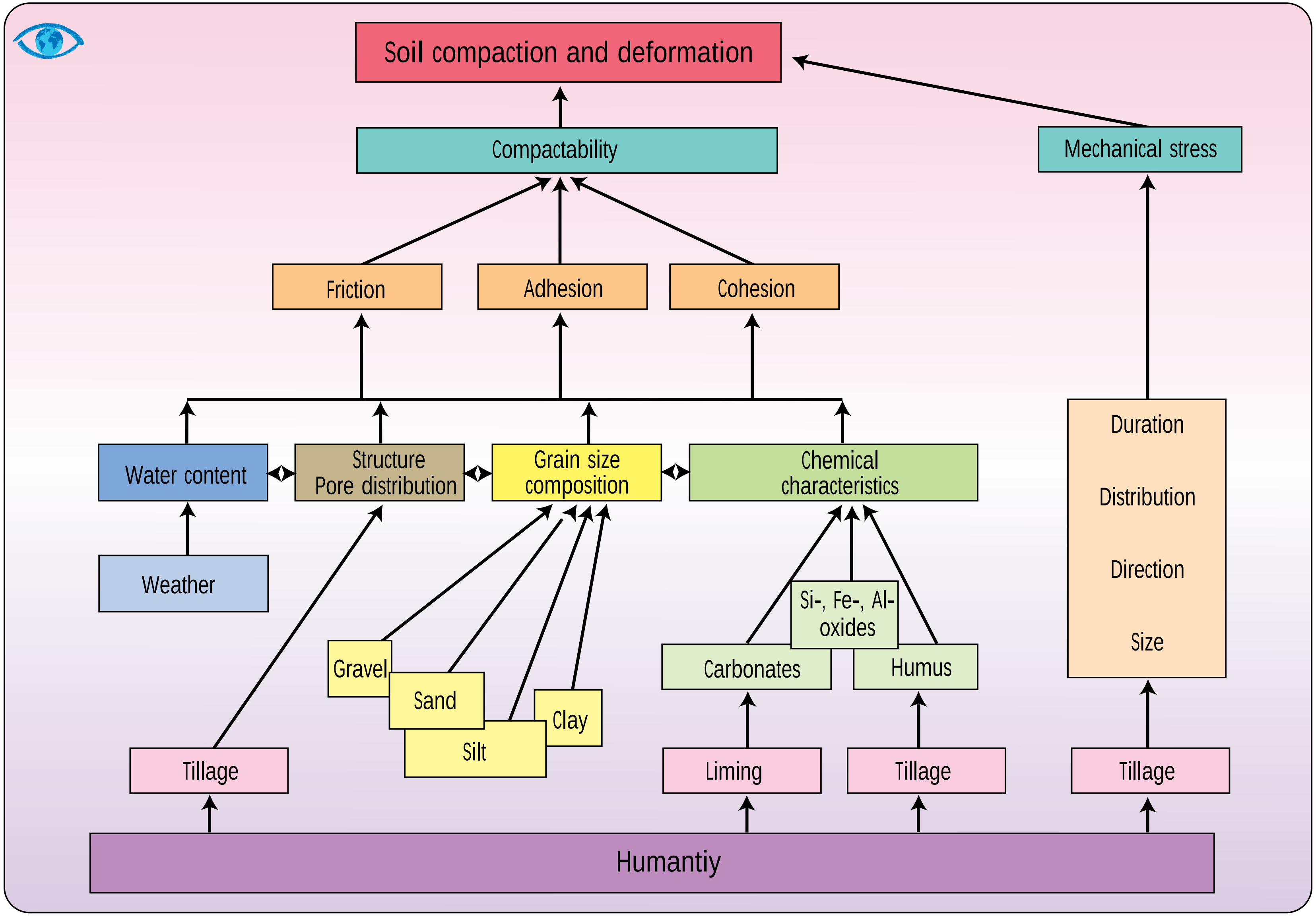


Figure 4: Soil compaction depends on the compactability of soils and the stress involved in each case. Both factors can be influenced in a number of ways. Defects that lead to soil degradation appear when heavy machines have the wrong tyres or are used to work the soil at the wrong time. This "wrong time" is essentially characterised by a high water content that greatly increases compactability.

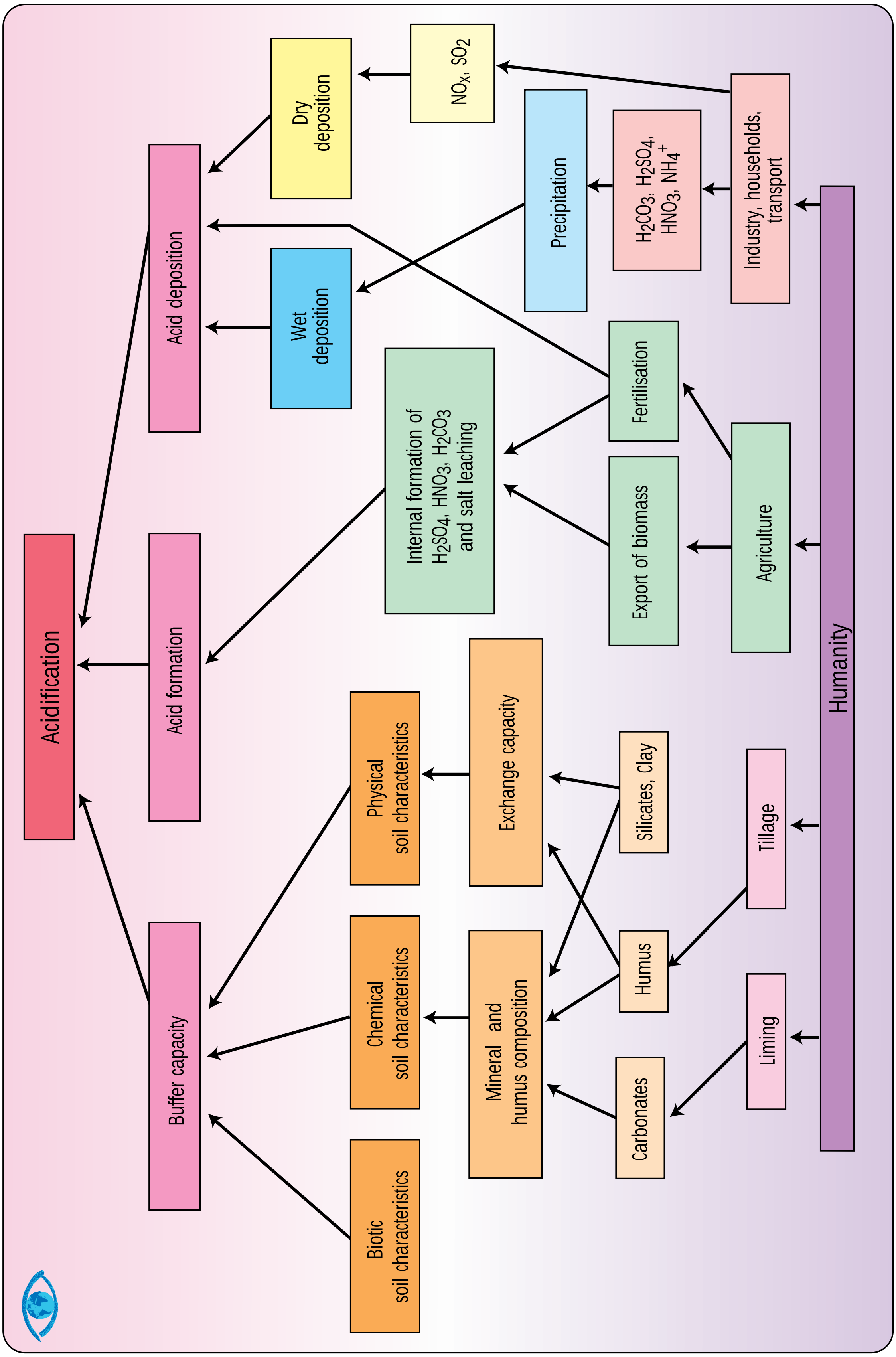


Figure 5: Soil acidification depends on three factors: acid deposition, internal formation of acid in the soil and the buffer capacity. Whenever the rates of acid formation and deposition are higher than the buffer capacity, the result is a lowering of the pH value, sometimes below 4.5. Clay minerals and other soil silicates are dissolved rapidly while aluminium ions and later iron ions are set free. Such low pH values are harmful for most cultivated plants.

Contamination/Poisoning
Contamination and poisoning have many causes, such as industrial and agricultural accumulation of organic and inorganic pollutants, landfills, misuse of pesticides, over-fertilisation, acid deposition, emissions from motor vehicles, etc. This type of soil degradation occurs to a greater extent in industrial countries as well as in urban and industrial agglomerations elsewhere in the world.

Acidification
Acidification also has different causes. These include acid depositions from the atmosphere, as well as acidification caused by the use of fertiliser or the export of biomass. On a regional scale, oxidation of reduced sulphur compounds has a critical impact in coastal areas. The same applies to tailings from mining which contain sulphides.

The impact of acidification depends on the buffer capacity of soils. It can be seen from *Fig. 4* that recommendations for counteractive measures cannot be given unless precise knowledge of local conditions is available.

Nutrient losses account for more than half of all chemical degradation. In some regions with high levels of industrialisation and intensive agriculture, eutrophication must also be seen as degradation, especially in relation to biological diversity and the stresses imposed on neighbouring systems.

Physical degradation

Soil degradation caused by physical factors currently accounts for approx. 83 million hectares globally. This type of degradation can be manifested as compaction, coverage, surface sealing and subsidence.

Compaction and deformation of soil structure is always caused by agricultural and forestry machines whenever machinery is too heavy or too heavily loaded, and/or where the stability of the soil is low on account of excessive water and clay content. Because mechanical loads have a three-dimensional effect extending deep into the soil, soils often suffer irreversible damage over the long term. Surface crusting arises when the removal of vegetation cover or protective humus layers leads to microerosion through raindrop impact. High humus content and a good supply of carbonate reduce such effects *(Fig. 5)*. Physical degradation can also be caused by river and lake flooding, or by the depletion of organic soils.

One effect that is increasingly important is the surface sealing of land by traffic and settlement areas. In many cases, highly fertile soils are affected, thus amplifying the negative impact. How land use is distributed in Germany is shown in *Fig. 6*. Of the total surface, 11% is used by roads and buildings, whereby roads cover “only” 2%, and railway lines, airports and canals 3%.

In terms of pure covering, these values (and similar values in other countries) seem low, but surface sealing is not the only effect. Others include reduced groundwater recharge due to increased runoff, serious contamination by pollutants and more intensive warming of the air layers close to the ground.

This description should suffice to show that the distribution of different types, degrees and causes of soil degradation across the various continents of the world follow different patterns. This means that the global problem of soil degradation requires a regional or even local analysis on which to base the requisite counteractive measures. Degradation of soils is particularly serious in those regions that are among the poorest in the world. This means that effective countermeasures can only be applied when soil degradation is recognised as an international problem and its reduction understood as a common task,

If soil degradation is to be combated worldwide in an effective manner, not only must a regional survey of soil degradation be carried out – the complex causes leading to particular types of soil degradation, or, more precisely, to *degradation syndromes* (see Section D 1.3.3) must also be identified. The advantage of such a procedure is that the problems are not viewed monocausally but in their natural and anthropogenic interactions. Only from such a perspective can useful approaches for solving the problems be developed.

Box 8

Intensity and causes of global soil degradation

The most comprehensive survey so far on global soil degradation was carried out as part of the UNEP-ISRIC study in 1991. In that study, four different stages in the intensity of degradation (degree of degradation) were identified:

1. *light:* the terrain has somewhat reduced agricultural suitability. Restoration to full productivity is possible via modifications to the management system.
2. *moderate:* The terrain has greatly reduced agricultural productivity, but is still suitable for use in local farming systems. Major improvements are required to restore full productivity.
3. *strong:* The terrain has lost its production capacity and can no longer be used for agricultural purposes. Major inputs of investments and energy would be required for terrain restoration.
4. *extreme:* the soils cannot be cultivated and can no longer be remediated. They have been turned into wasteland through human action.

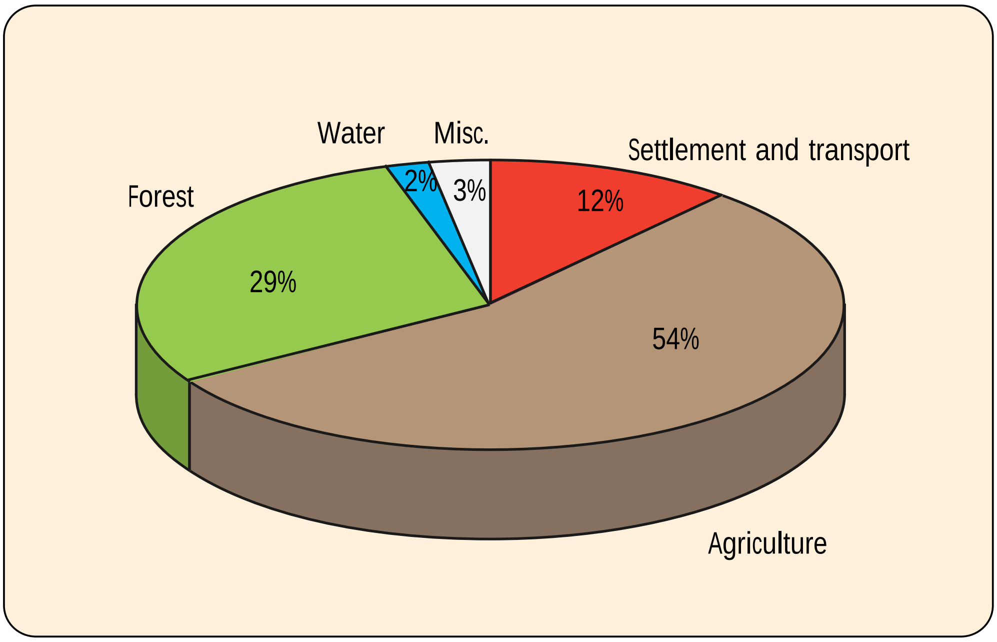
About 1,995 million hectares of land worldwide show evidence of soil degradation. This is equivalent to approx. 15% of the ice-free land surface of 130 million km^2. Of that amount, more than 295 million hectares of land surface are *strongly* degraded. Restoring these soils to full productivity is still possible, but investments of time and money would have to be very high. Approx. 113 million hectares are strongly degraded by deforestation of primary forest, and 75 million hectares by overgrazing. Bad management of cultivated land has destroyed about 83 million hectares, with the result that such soils can no longer be reclaimed at farm level. Approx. 40% of these strongly degraded soils are in Africa, 36% in Asia, i.e. the continents with the highest rates of population growth are also those worst affected by soil degradation. About 10 million hectares are extremely degraded or eroded, and are therefore unreclaimable.

About 910 million hectares of land display *moderate soil degradation*. Although still being used as farmland, the productivity of these soils is declining rapidly. If they are not restored soon, damage will be irreversible in the near future. More than a third of this terrain is found in Asia, about 20% in Africa, and approx. 12% in South America. The major causes are deforestation, mismanagement and overgrazing.

A light degree of soil degradation leading to reduced productivity can be identified for about 750 million hectares. This land could be restored to full productivity if correctly managed. Asia, Africa and South America again account for most soils showing light degradation.

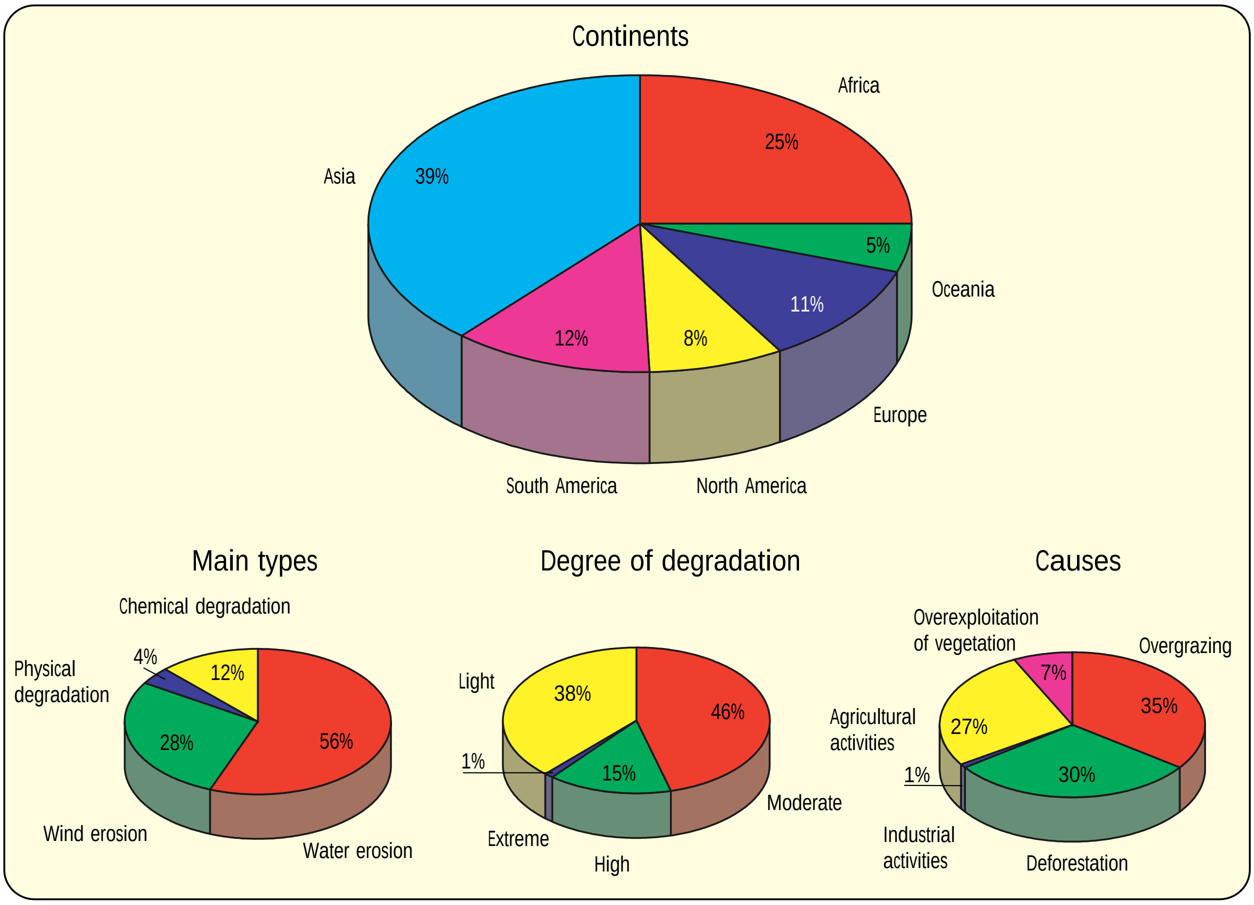
Fig. 7 shows that about 15% of land worldwide shows signs of anthropogenic degradation. However, not only the causes, but also the effects are global. Soil degradation has a negative impact on food production and, in many parts of the world, biodiversity; clearing of forests also means disturbance of the habitat function. By altering energy turnovers and the biogeochemical cycles of carbon and nitrogen, soil degradation also has an effect on the climate, i.e. the regulation function of soils is upset.

Figure 6: Land use in the Federal Republic of Germany



Source: Bundesministerium für Raumordnung, Bauwesen und Städtebau, 1994

Figure 7: World soil degradation. Nearly 2000 million ha of soil are degraded through human activities, equivalent to 15% of the land area of the Earth.



Source: Oldeman, 1992

1.2 Global analysis of the stress-bearing and carrying capacity of soils

1.2.1 Ecological limits to stress-bearing capacity

If soil degradation is to be reduced and its causes eradicated, it is essential that the loads at each *respective location* be identified, their effects within the ecosystem determined and that these be assessed in relation to the stress-bearing capacity of the respective soils. However, it does not suffice for the avoidance of degradation to ascertain the causes and to remove the symptoms – more important is the integration of the economic driving forces into the local, regional and global strategies for mitigation and prevention. This approach was already described in the 1993 Annual Report.

Soil degradation is the result of excessive loads on the respective ecosystem. A *framework for evaluation* allowing the quantification of anthropogenic changes in soils and their assessment with respect to the conservation of soil structures and functions, and the sustainable usefulness of soil, must therefore take as its starting point the quantification of these excess loads.

The Report bases its analysis on the concepts of “critical loads”, “critical operations” and “critical losses”, i.e. the flows of energy, material and information beyond the boundaries of the respective system which induce critical states in soils. States of soil structure or soil functions are designated as critical when the system is exposed to excessive loads which lead to various forms of soil degradation. The concept applied is an extension of the *critical loads* concept that was developed in connection with the problems of air pollutants and their deposition in forests, and with the environmental and preventive research of the AGF (Beese, 1992). Until now, the concept has been restricted to substances and applied mainly to acidification and nitrogen eutrophication.

The advantage of the concept, shown schematically in *Fig. 8*, is that it also takes losses into account which can be uncritical for the *source system*, but which must be considered critical for *neighbouring systems*. One example is the release of N_2O from farming land, which has no major effect on the nitrogen balance of local soil due to the low rates of loss, but which can exceed the stress-bearing limits of the atmosphere.

The concept also takes account of the fact that links also exist with other systems via energy and element flows, links which often extend beyond the area in question and which therefore have to be taken into consideration as well. Examples would be urban agglomerations as sinks, or distant regions serving as sources of raw materials. Budgeting net fluxes is only possible if these sources and sinks are integrated into the analysis.

Box 9

Critical loads for ecosystems

Ecosystems have been mapped in Europe for some years now, the aim being to identify ecotoxicological impact thresholds in the form of *critical loads* (Nilsson, 1986; Nilsson and Grennfelt, 1988). Below the critical load level, delivery of one or more contaminants does not yet cause harmful effects to the ecosystem – according to present knowledge at least. Efforts are also being made to determine critical concentrations (*critical levels*) in a similar way. As a basis for political decision-making, discussion is centred on defining levels above and below the critical levels which integrate safety margins and/or tolerable levels of harmful effects (*target loads concept*).

Such approaches are aimed at pollutant containment strategies assigning priority to the deposited masses per unit of time and surface area, in contrast to other approaches based on immissions. This involves the identification of particular regions or ecosystems as being especially threatened. Applying this approach requires a detailed geographical mapping of cause-effect chains. This spatial resolution of available data on loads or exposition often fails to correspond to the spatial variability of ecosystems, however. The grid used by suitable current models for transport and deposition is 150 km · 150 km (Lövblad et al., 1992; EMEP, 1993). For the time being, it is only possible to define limits for areas which are composed of different ecosystems.

In defining these limits, account must be taken of the resilience of the environmental media soil, vegetation and surface water (Minns et al., 1988; CCE, 1991 and 1993; UBA, 1993). These describe various factors for soil and their exposure to acid deposition, e.g. soil structure, soil composition, and the budgets for water, nitrogen and carbon. However, a dynamic equilibrium has generally been assumed, i.e. the dynamics of slow, relaxing processes in the soil have rarely been given sufficient attention. Surveys have been carried out for some countries and for Europe as a whole with respect to the pollutants acid and nitrogen, and impact thresholds estimated (Nilsson, 1986; CCE, 1991 and 1993; Heij and Schneider, 1991). Limits for acid loads were compared with emission reduction scenarios with respect to their ecological and economic impacts (Alcamo et al., 1987). Threshold values between 0 and 0.075 g H m^{-2} $year^{-1}$ were defined for Scandinavia (Nilsson, 1986) and 0.05 – 0.28 for the USA (Johnson et al., 1985). Nitrogen loads of 0.3 – 2 g Nm^{-2} $year^{-1}$ are critical for natural ecosystems with different levels of productivity.

The *critical loads* concept has proved to be a flexible and practicable instrument. In their 1994 Report, the Council of Experts for Environmental Issues (SRU) recommended that this concept be applied on a wider basis and developed further.

The following categories need to be defined in greater detail in order to apply the concept to soils:

Critical loads

Examples are depositions of acids, heavy metals, organic compounds, salts or nutrients (N). Critical loads of acids are based on the buffer rate of soils within an ecotoxicologically harmless range. The buffer rate below pH 4.2 is usually very high due to the extent to which clay minerals are dissolved, but at such levels of acidity cation acids (Al^{3+}, Fe^{3+}) are released which are toxic for plants and soil organisms.

The degradation rate of pesticides is a critical parameter which has to be predicted. This depends on the actual structure of the pesticides themselves, and on the soil and climate conditions at the respective location. A location-specific system for assessing the risk of groundwater or cultivated plants being contaminated has been developed for 106 different substances (Blume, 1992; Blume and Ahlsdorf, 1993). The location-specific risk of contamination by 47 organic substances (especially dioxins and furans: Litz and Blume, 1989) and by heavy metals was also assessed in a similar manner.

Critical loads of salts, such as those sometimes caused by irrigation, depend on the degree to which cultivated plants can tolerate saline conditions. Addition and removal of water must be controlled in such a way that threshold values or threshold ranges of salt content or concentration are not exceeded when evaporation levels are high.

Whereas in the first case an internal soil process (function), namely buffering, is used to define the critical load, in the second case it is a parameter of state, a volume or concentration. Investigations must therefore be carried out for each specific case to determine which indicator is best suited for assessment.

Critical loads of nitrogen or pesticides can be determined not only in terms of internal soil conditions, but also on the basis of the losses produced. Quality standards for drinking water can be exceeded when over-saturation of ecosystems with nitrogen leads to excessive nitrate concentrations. The same applies to pesticides. In both cases, input must be checked or prevented until losses are no longer critical. Soil is not degraded in these cases, but its regulation function is subjected to excessive loads, which in turn has a negative impact on neighbouring systems. Further examples can be cited for other elements and substances.

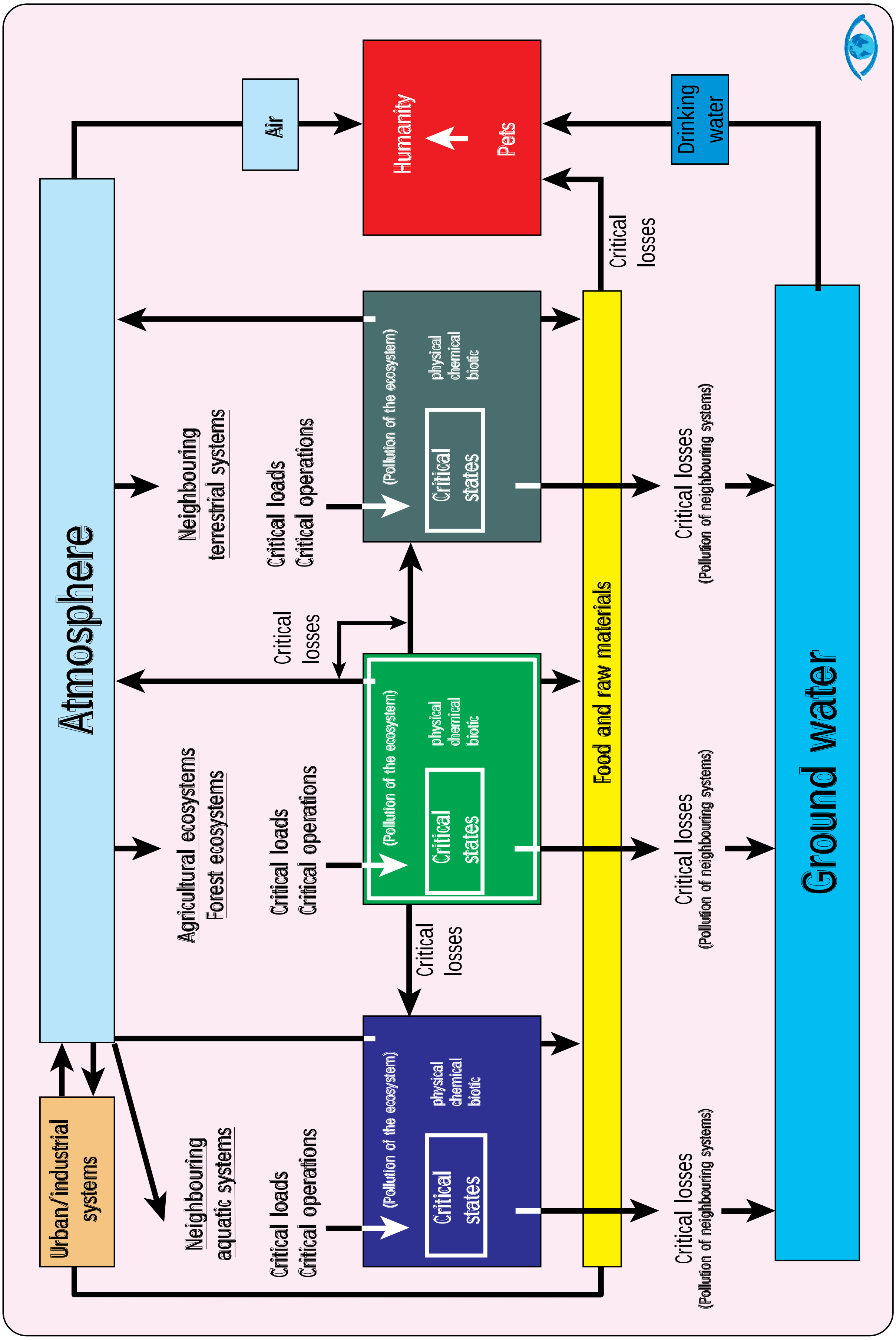


Figure 8: Assessment diagram

Critical operations

These are physical interventions, such as fragmentation of soil units, compaction and surface sealing, tillage, as well as biotic operations such as plant cultivation and livestock farming, all of which lead to critical alterations in the structure and function of soils.

Examples for physical operations include compaction and deformation. It is necessary here to define the internal critical states for the soils as mentioned above, and these must be strictly complied with. The water infiltration capacity can be changed so radically that heavy rains produce overland flow and hence erosion. If critical losses (loss of soil through erosion) are then exceeded, this can be used as an indirect and approximate parameter of evaluation.

Examples of biotic operations are grazing and overgrazing. Oversized herds can destroy the vegetation and induce critical states in the soil, e.g. compaction of topsoil through trampling, causing higher surface runoff, water and wind erosion and higher incidence of landslides. The operation here (grazing) must be designed in such as way that the soil is not subjected to excessive stress, i.e. the size of the herd must not exceed the carrying capacity of the soil with respect to grazing stock. The latter is measured in terms of soil productivity and the fodder requirements of the animals.

Critical operations can be determined for mechanical stresses such as soil compaction and soil deformation by comparing the actual mechanical stress-bearing capacity of the soil with the maximum mechanical loads that occur, e.g. from tractors, combine harvesters or bulldozers. To do this, it is necessary to determine the mean contact surface pressure of the machines and to calculate the “pre-stress value” (= the soil’s own stability). As long as the pressure exerted by the machines is well below this pre-stress value, the mechanical response of the soil will be elastic, i.e. it will buffer the load, whereas excess loads will lead to a plastic and hence irreversible change in the soil structure. Examples for the destruction of soil structure are the reduced capacity of roots to penetrate the soil, or the loss of an assured supply of oxygen.

Critical states

Critical states occur in soil when the physical and chemical state of the soil is permanently changed as a result of chemical, mechanical or biotic stresses, or when plant, animal and microorganism biota (biotic states) are changed to such an extent that the productivity, stability and biological diversity of the soil are impaired.

Critical states in soils can be defined structurally or functionally. Structural parameters include shear resistance, bulk density, pore distribution and pore shape, humus content, the composition and mass of organism biocoeneses, or the content and concentrations of nutrients and contaminants. Structural parameters are weathering rates, mineralisation of nitrogen, decomposition, water and gas transport, pressure compensation or the growth of plants and soil organisms.

In general, the *derivation of critical internal states of soils is still at an early stage of development*. Various “lists” of contaminant concentrations are available as standard limits, but these mainly relate to possible impacts on humans via the food chain. However, no binding values exist at present for evaluating soil functions. The situation is even worse in the biotic sphere, where so-called indicator plants and indicator plant communities for certain soil parameters have only been defined for a small number of locations. There are no reliable criteria which can be applied to biota of fauna and microorganisms. This means that critical operations, loads and losses are still ill-defined.

There is an urgent need to develop a comprehensive indicator system for evaluating soil states which is not confined to substances alone. This system should be integrated into the extended concept of critical loads presented here. If this indicator system is to be applied effectively and with specific reference to individual locations, it is necessary to abandon the existing tendency to measure total concentrations only. Indicators must be developed for different biosystems (from single cells to ecotopes), and can consist of single parameters, aggregates of parameters or systemic parameters. Depending on the issue at stake – for soils, this is primarily the sustainable and environmentally sound use of land, the preservation of specific soil functions, or the stresses imposed on neighbouring systems – the relevant indicator or combination of indicators must be used as the basis for assessment. It is patently obvious that such a project cannot be realised quickly. However, it would appear that the problem can be solved in the medium term if the above strategy is pursued.

It must also be made clear that the theoretical boundary at which the respective stress becomes critical for a system's stress-bearing capacity can only be stated for precisely defined uses, since it is impossible to derive a general limit given the number of interacting variables. A step-by-step procedure based on precautionary, inspection and risk values is therefore essential if the critical value is to be obtained. Such an approach is already integrated into the draft Soil Protection Act in Germany. Given the basic uncertainty when defining critical states, safety factors based on the precautionary principle should always be taken into account.

Critical losses

Critical losses are losses of substances or organisms that can become critical for soils or which represent the critical loads for neighbouring systems. The stresses produced must be evaluated separately for each "recipient" (humans, animals, groundwater, atmosphere, neighbouring terrestrial and aquatic systems). They can be limiting values for certain uses, without the soils themselves becoming degraded, e.g. contamination of groundwater (drinking water) by nitrate or pesticides. Critical losses which affect the soil itself include erosion and nutrient loss.

Whereas critical stresses caused by loads and operations have been defined for soils to only a marginal extent, there are already some practical examples which relate to critical losses. Because people are directly affected through drinking water and food, some international standards have been defined (WHO). This leads to a situation where loads and operations relating to soils are defined as critical primarily because people are affected by the losses concerned. But there are also other cases. For example, the critical level for the loss of soil through erosion or removal can be measured in terms of the new soil formation rate (rate of weathering), but the release of trace gases which have an impact on climate, in contrast, is measured in terms of the type, intensity and distribution of nitrogen fertilisers.

The concept of *critical loads* presented here can be applied to terrestrial ecosystems in many different ways. *In the view of the Council, it should be developed further in the medium term and integrated into national and international soil protection legislation.* The major advantage of the concept is that it is dynamic, i.e. it includes the time variable in the definition of critical limits, and location as an indicator for the variety of interactions. The concept is therefore potentially capable of integrating biological diversity and the principle of sustainability.

Contamination of soils

Acid depositions, the application of organic and inorganic fertilisers, and the deposition or input of toxic substances all represent chemical stresses on soils. Salinisation is another form of chemical stress, and frequently occurs in connection with irrigation. The common terms associated with these processes are *nutrient-humus loss, acidification, contamination or poisoning, salinisation or alkalisation, and eutrophication.*

Chemical pollution shows considerable local variation, and is often linked to specific emitters and land-use practices. In addition to local chemical pollution, however, substances can also be released which have an extensive, transboundary distribution. In the case of acid depositions, for example, it is not only the geographical distribution of emitters which plays a major role, but also differences in location. Topographical features and the structure of vegetation at the site of immission also exert a critical influence on the mode and rate of substances deposited.

The fact that pollutants in plant stocks (filter effect) have been overlooked has led, among other things, to loads to forests being underestimated, and must be seen as one of the causes for the importance of deposition for the stability of forest ecosystems not being realised for a long time (Ulrich, 1989). Knowledge about material loads has improved substantially over the last 15 years, but dry depositions still represent a source of uncertainty when statements about material loads at specific locations and in specific regions have to be made.

The stress-bearing capacity of a site depends, in addition to the deposition rates and the physical and chemical properties of a substance, on how the substance in question is transported and transformed within the soils. The processes which operate are shown in *Fig. 8.* These, and the soil properties which influence them, together determine the bioavailability of the deposited substance. Bioavailability, in turn, decides whether the substance is taken up by organisms and whether toxic effects are produced. The interaction of these processes also influences the rates at which

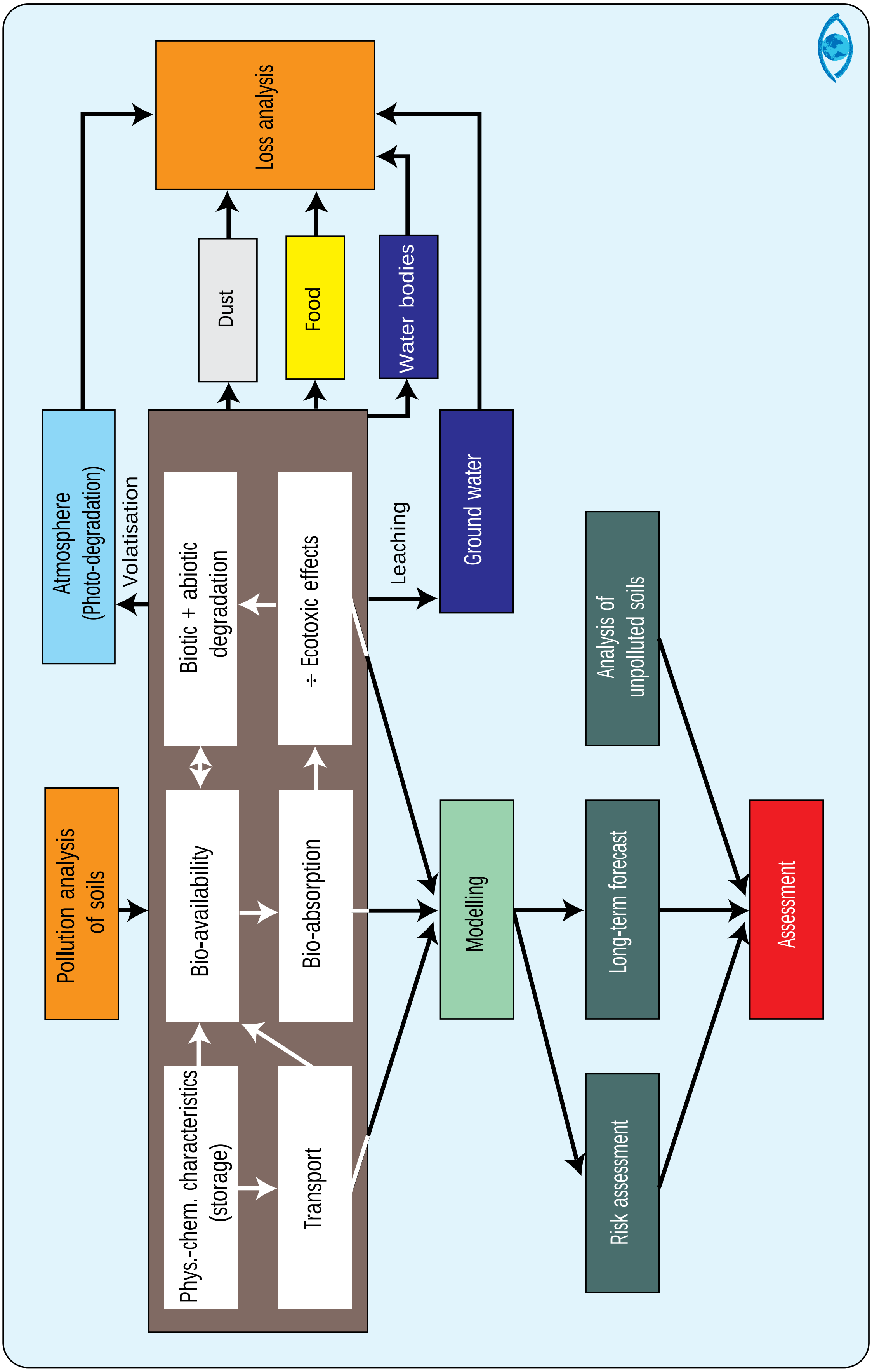


Figure 9: Assessment concept for chemicals in soils

substances are transported to and act as loads on neighbouring systems. This means that the alleviation of load on one system or compartment can be bound up with loads to a neighbouring system that may be even more fragile.

To arrive at criteria for loads which can be applied to large areas (e.g. regional landscapes), aggregated structures and functions must be analysed and evaluated: plant and animal communities, or suitable indicators for these, such as indicator organisms, biomasses, diversity indices, physiological states or degree of coverage. Important examples of aggregated processes in soils are turnovers of organic substances (litter, dung, humus) and the concomitant release of carbon, nitrogen, sulphur and phosphorus compounds. Because these processes can be viewed as “output” of the respective biocoenosis, the determination of turnover rates would appear to be a suitable means for ascertaining the critical states of organism communities in soils.

The overall balance of substances delivered to or leaving ecosystems can also be an indicator of loads, showing whether a system displays growth or is in a degradation phase instead. It can also be calculated when critical states are reached through accumulation or when deficiencies occur in the system through losses. The approach taken by input/output analysis, which is based on balancing material flows, is an important tool for recording and forecasting loads to and the stress-bearing capacity of soils (Brunner et al., 1994). This approach is presently the one which can best be corroborated and which can be applied to larger areas.

The problems of aggregated information and the mixture of qualitative and quantitative data result from the increasing impreciseness, the lack of falsifiability and increasing subjectivity of evaluation the greater the degree of aggregation involved. While it is sometimes necessary to take decisions on the basis of inadequate data, since only in rare cases is it possible to wait until all the interrelationships have been explained, one should be aware at all times of the greater probability of error that this implies.

One risk is that decisions can become a matter where the person concerned uses his or her own discretion because available knowledge is either uncertain or inadequate, with the result of that decision being influenced by arguments that may have little to do with the point at issue. This should not detract from the fact that the acknowledged facts regarding a series of forthcoming environmental decisions are sufficiently clear, even without further improvements to the data available, to eradicate the worst conditions and to achieve significant improvements. For many toxic substances that are released to the environment, evaluation is less developed, for the reasons mentioned above, and must be improved as a matter of urgency.

An important research area in the future will be to define the stress-bearing capacity of soils more precisely for different types of environmental stress.

However, from the global perspective, neither information on stresses nor on the stress-bearing capacity of soils are sufficient to arrive at reliable conclusions (Sigliani and Anderberg, 1994). Collecting and processing the information required is a global task and can only be achieved on a global scale. To do so, however, it is necessary first of all to set up the capacity for data acquisition “on-site” (including the provision of training to suitable people). The equipment for data acquisition and data processing must be provided, since in many parts of the world they are not available, and the requisite software designed for the respective conditions has yet to be developed. On this basis, soil degradation abatement strategies can then be developed which take account of local and regional characteristics and which ensure the long-term conservation or usefulness of soils.

If development policies were directed at global problems, they could make an important contribution towards collecting and disseminating the required data on the stress-bearing capacity of soils and for research into location-specific utilisation strategies. Such knowledge is not sufficient for implementation, however, unless the economic and sociocultural conditions are also created parallel to such knowledge. Joint efforts should be made in the fields of research policy and development policy to find new directions and approaches in this respect.

1.2.2 Economic evaluation of soil degradation

Through the services and uses they provide, soils are resources which make a decisive contribution to ensuring the survival of human societies; soils are therefore assets of global importance from an economic point of view.

The services and uses associated with soil functions are values which demand global efforts aimed at their long-term conservation, improvement and, where necessary, restoration – whereby economic aspects must also be taken into consideration. Impairment of soil functions reduces the usefulness and the productivity of soils. In addition to the economic losses thus caused, account must also be taken of the compensation and remediation costs, insofar as such measures are feasible in the first place.

Close economic links exist between the individual functions, e.g. between the habitat and production functions. The regulation function is also economically important when soil processes, e.g. the formation of groundwater or of greenhouse gases, or the silting of surface waters, are important for people or society.

A distinction must also be made between the costs incurred directly as a result of impaired soil function and those that are brought about by the effects of soil changes or damaged soil functions on people or on other environmental media. These interrelations also explain the dependence of soil on Global Change, e.g. through the greenhouse effect.

Soil degradation is usually caused by local factors that only lead to global consequences when they occur on a wider scale. However, there are also examples of soil degradation being caused by factors in very distant regions through global commercial links (see Section D 2.1.2.2.5). When producing an economic evaluation of soil degradation, particular attention must be given to the fact that soils are, for all practical purposes, not expandable, and are available to only a limited extent. Consideration must also be given to the fact that the uses of soils are restricted by their respective properties. This factor has an important bearing on the value of soils as a protected interest in relation to other environmental assets, and on any comparison of the respective costs of reversible and irreversible damage or impairment.

Soils as an environmental medium within an environmental accounting system

No ready-made concepts are available for positioning soils within an environmental accounting system. A definition of the total economic value of soils is also lacking. The extent to which the

– *current use value* of soils (as an expression of utility for the private sector or national economy),
– *option value* (as a preference, i.e. willingness to pay, for the protection of soils. e.g. as a habitat for soil organisms),
– *existence value* (as a preference for the preservation of soils and the landscape, e.g. as an archive of natural and cultural history)

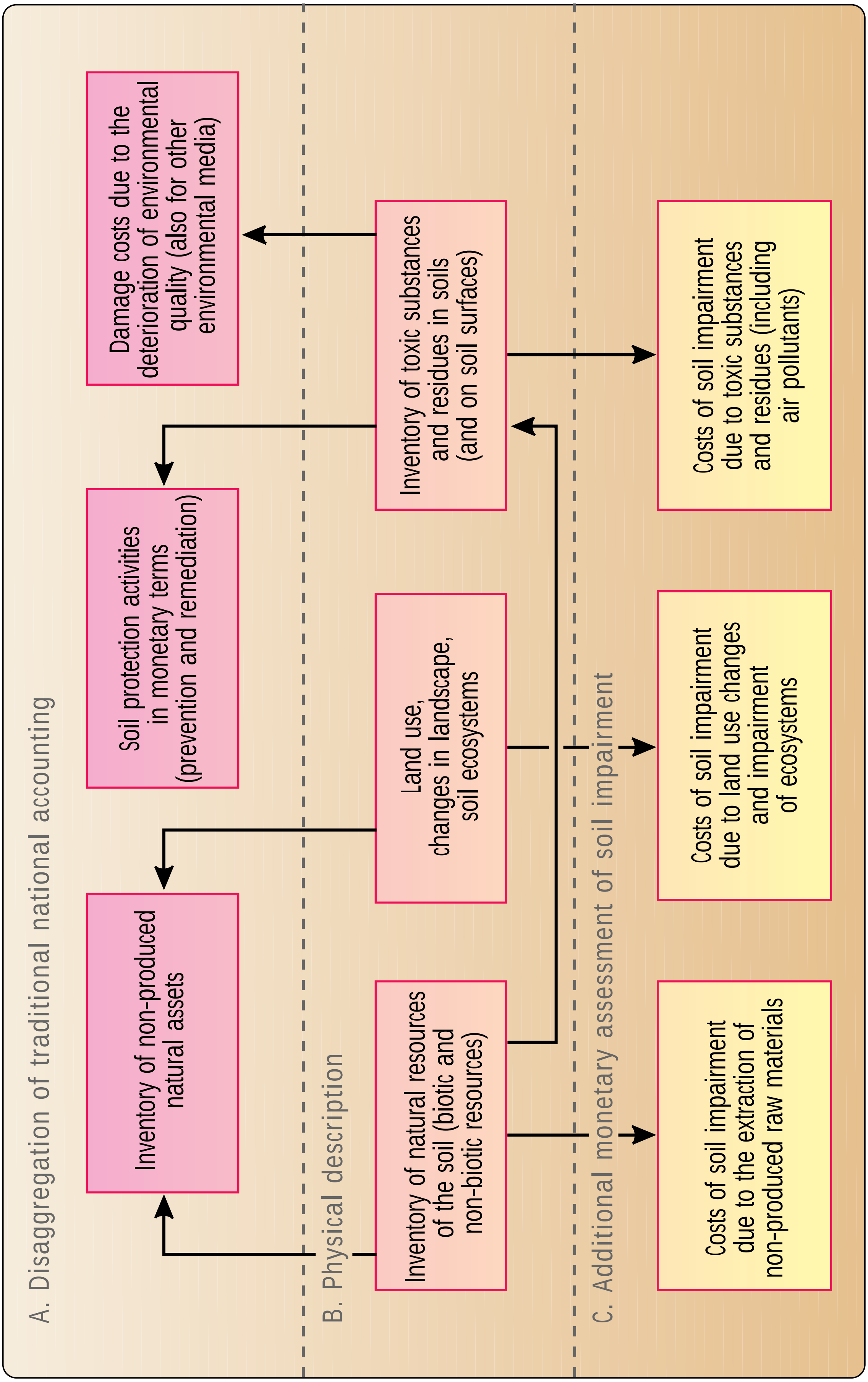
results or should result in an *overall economic value* should be examined within the framework of a research project that also includes developing and newly industrialised countries.

The German Federal Statistical Office is currently developing an environmental accounting system with scientific support from the advisory council for “Environmental-Economic Accounting” at the Federal Ministry for Environment, Nature Conservation and Nuclear Safety. A link to soils as an environmental medium can be shown *(Fig. 10)* by using “modules” from this accounting system.

Such accounting systems are an important instrument for reinforcing awareness of increasing soil degradation and the related losses in utility and welfare, and for encouraging the relevant prevention strategies. Such concepts still need further refinement, however. In particular, they need data in order to produce a monetary assessment of the individual resources, data which is not yet available in adequate quantity and quality.

As a statement of flows and stocks, the services listed in *Table 9* are to be allocated to the inventory potential of the soil, the utilisation of which leads to changes through natural processes and human activities. Hübler (1991) studied the relation between the impairment of soil functions and the resulting costs of soil pollution in Germany for different types of impact. Taking into account the methodological approaches used there regarding the cost structure of different kinds of harmful environmental impact on the soil, it is possible to allocate the cost factors to the individual soil functions, defined according to direct and indirect impairment of the soil *(Table 9)*. The impairment of the habitat,

Figure 10: Components of the integrated macroeconomic "environmental accounting" system as applied to soils



Source: modified from Statistisches Bundesamt, 1991 production and regulation functions brought about by Global Change could also be included here. Cost factors which are necessary for measures to combat the negative effects of Global Change, such as reduction of CH_4 and N_2O emissions, should be taken into account as well. The required expenditures for soil protection must also be counted as avoidance costs; for example, worldwide erosion protection is estimated to cost US$ 17.5 billion for 1992 and US$ 30 billion for the year 2000 (WWI, 1992).

Table 9: Factors of stress on soils caused by Global Change

Primary impairment	Cost factors	Function		
		H	U	R
Impairment of the habitat function	Disturbance of the balance between production and decomposition of organic matter			x
	Measures to minimise impacts of climate and land use change (with respect to accumulation and release of substances)			x
Impairment of the utilisation function	Production losses due to climatic impacts (CO_2, UV-B radiation, temperature, precipitation)			x
	Fertilisation and pest control to increase yields and sustain production			
	Protection of fragile soils	x		x
	Protection of other ecosystems	x		x
	Provision of additional production areas			
	Research and application / distribution of findings			
	Residues in water, other ecosystems and food			x
	Procurement of additional food			
	Loss of natural soil cover	x		x
Impairment of the regulation function	Irrigation and water supplies (in the case of surface sealing, compaction and humus deficiency)		x	
	Preservation of soil as a filter, buffer and transformer for providing clean drinking water	x	x	
	Poor vegetative soil cover (prevents assimilation of CO_2)	x	x	
	Conservation of soils as carbon reservoir	x	x	
	Compensation for N_2O release from fertile and intensively fertilised agricultural areas (water and heat budgets)			
	Reduction of CH_4 emissions from natural and artificial wetlands (particularly from rice cultivation)			
	Release of pollutants from soils with declining storage capacity			

Source: WBGU, 1994

H = Habitat function U = Utilisation function R = Regulation function

Elaborating such an accounting system will require much greater coordination at both the national and international level. The focus here could be on ascertaining the costs for measures to stop the loss of soils (especially cultivated soil) through degradation and for measures against the progressive decline in yields obtained from utilised soils in the newly-industrialised and developing countries. It would make sense to provide these countries with support determining these costs.

Box 10

Economic evaluation of soil degradation

Up to now, the extent and the impact of soil degradation have been analysed primarily from the natural scientific perspective. The findings obtained are often of limited use in political decision-making, however. If they can be translated into monetary terms, at least in part, their essential content becomes more obvious and they become easier to implement. This applies in principle to all forms of soil degradation, whereby specific lines of approach are required to evaluate each in economic terms.

Degradation through erosion

The evaluation of so-called *on-site* damage has been limited in the main to impairment of the *production function* of soil through the removal of soil material or the loss of nutrients. Evaluating this type of damage can be based on the loss of productivity (cost of damage approach), in other words the declining yield of the soil, or the damage can be calculated using the avoidance cost approach. Available evaluation studies can be criticised with regard to details, but economic analysis essentially provides solid results with respect to the production function. One excellent example is the calculations for Costa Rica carried out by the World Resources Institute (WRI, 1991).

Major problems are raised by the evaluation of the *ecological regulation function of soils*, however, damage which can affect areas far beyond the actual surface used:

– An example is the loss of water storage capacity of soils, but also the release of CH_4 and N_2O, which are known to have a global impact. Even if an economic evaluation of these types of damage has been problematic to date, they must not be ignored, since this leads to an underestimation of the value of soils. There is a great need for research in this area.
– Similar arguments exist with respect to damage caused by the leaching of nutrients and deposition of sediments. These extend from eutrophication of other ecosystems and the silting of bodies of water (which can adversely affect shipping and hydro-electric energy production) to damage to coastal ecosystems (where negative effects on fishing and tourism are possible). Here, evaluation can be based on the cost of damage or repairs. Such *off-site* damage must be taken into account if the total economic value of soils or land use is to be determined.
– Practicable evaluation procedures exist for many of these types of damage, although they have to be adapted to the specific conditions in each individual case before they can be applied in practice. In general, however, these methods need further refinement.

In contrast, it is still a matter of speculation how processes which precede erosion should be evaluated economically – e.g. clearing of primary forest in order to enable utilisation for forestry or agricultural production. The mass transfer processes which may then occur can be evaluated well, at least in relationto the production function. However, the question as to how the transition from primary forest to utilised land should be evaluated is still unresolved. Evaluations of biodiversity reductions (WBGU, 1994) form a complex with the evaluation of subsequent production and/or degradation, and should lead to an overall evaluation.

The importance of the evaluation of erosion damage for environmental policy can be seen from the potential fields of application:

(1) At the micro- and project-related level, the success of soil protection measures is often expressed in terms of the number of trees planted, how many kilometres of terraces have been built on slopes, etc. Of crucial importance for assessing soil protection measures, however, are not the conservation measures themselves, but their actual output – the increase or preservation of grain and fuelwood production, or the retention of specific environmental regulation functions. If these factors have been determined, then the attempt can be made to carry out an economic evaluation, whereby the benefits identified for a particular protective measure must be seen in relation to the costs involved.

(2) At the macro- and/or national level, state interventions into the price system have been identified as one of the causes of soil degradation; in many cases, subsidies are given to forms of land use which favour soil degradation. Determining the total economic value of different land-use forms (sustainable use of tropical forests versus extensive livestock grazing) could show the political decision-makers the direction in which

economic incentives should aim. The evaluation of different land-use forms is very difficult, however.

Chemical degradation

Whereas soil erosion is a problem worldwide, chemical degradation of soils is mostly concentrated in industrial regions or regions with intensive agriculture. At the same time, these regions also expend substantial resources on soil protection (indirectly, in many cases, through policies for improving the quality of air and the purity of water). Defined limits for stresses on soils are mostly based on scientific findings and technical standards; until now, they have not been adapted to the respective conditions at specific locations. As a consequence, the macroeconomic costs of soil conservation are rarely compared explicitly with the relevant benefits (damage avoided).

The determination of economic targets within the context of an overall cost-benefit analysis can be an important aid for the political sphere. However, there is a general lack of any economic, immissions-oriented definition of stress limits for soils that refers to specific uses of soils (e.g. agriculture and forestry, industrial land). There are substantial research deficits in this area. The increasing mechanical stresses on soils through cultivation and ploughing, and by the amelioration of dense soil reclaimed through the recultivation of open-cast brown coal mines and flushing dumps demands cost-intensive machinery and considerable time expense. In addition to these fixed costs, it is also important that an economic evaluation be made of previous restrictions in function (e.g. as filter and buffer, or as a rootzone habitat), as well as the long-term consequential damage induced by the amelioration measures themselves. The very different ways in which different soil types react depends on the composition of the soil and the type of stress (static or dynamic), which also leads to variations in evaluation according to the scale of survey maps used. There is a lack here as well of fundamental knowledge and experience with relevant evaluation criteria. Research needs are therefore apparent in this field, too.

In all, continued soil degradation should be subjected to economic analysis and evaluation at both the national and global level in order to assign this problem its rightful place when scarce environmental funds are being allocated.

1.2.3 Land use, carrying capacity, food security

In the previous sections, reference was made to comprehensive evaluation systems which enable anthropogenic stresses on the habitat, regulation and utilisation functions of soils to be assessed. The aim of such assessment is to reduce soil degradation worldwide and to ensure sustainable, environmentally sound and locally appropriate forms of land use.

An important factor which must be determined in this connection is the capacity of specific locations to produce products of value to humans, on the basis of which the *carrying capacity for the population* can then be ascertained. The concept of carrying capacity comes from the field of ecology and refers to the population of a given species that can survive indefinitely per unit area of habitat. If this size is exceeded, the natural basis supporting the species is adversely affected and is ultimately destroyed, resulting in a population crash or migration. Carrying capacity, thus defined, is therefore a critical parameter.

The capacity to produce food under prevailing local conditions is limited. The limiting factors are quality of soil, climatic conditions and the available or applied land management strategies.

As shown above, loads, operations or losses can cause soil degradation, which in turn can result in reduced productivity of soils and hence a reduction of carrying capacity. Each unit of land surface can then feed fewer people. Conversely, soil amelioration (through fertilisation, irrigation, drainage or other methods) can also compensate for soil deficiencies, thus increasing yields and carrying capacity; cultivation measures (cropping techniques, breeding) can also increase yields. All methods for increasing yields are only feasible within the production potential of the respective location and are heavily influenced by socioeconomic factors which enable or prevent the deployment of supportive measures (Puetz et al., 1992).

The carrying capacity for the population is therefore the number of human beings per unit of land who can be supplied indefinitely with sufficient food and renewable raw materials under prevailing climatic conditions and conditions of use without causing soil degradation and excessive stresses on neighbouring systems. Production should be carried out using a minimum of external energy and raw materials to ensure that the land can be cultivated indefinitely.

Using the concept of carrying capacity, it is possible to estimate the critical population densities for each region which, if exceeded, will lead in the long term to degradation of the soil, declining production, famine, and subsequent migration or population decline (see Section D 1.3.1.4).

Calculating the carrying capacity should be based as far as possible on a wider approach that takes not only basic needs such as food, clothing, fuel and housing into account, but also integrates the social and cultural requirements of human societies. Even under the most meagre living conditions, people still need goods which do not serve to guarantee the minimum level of subsistence, but which also involve the exploitation of soil functions when being produced and used. The carrying capacity of soils is influenced to a critical extent by the way in which natural resources are managed. In industrial countries, carrying capacity is very high due to enormous inputs of external energy and raw materials – a model that cannot be applied on a global scale. Waste and waste disposal methods, as well as trace gases, are playing an increasing role as factors limiting the carrying capacity of soils. These limits relate not only to stresses on soils themselves, but also to stresses imposed on neighbouring systems.

The knowledge that neither the environment, nor users and consumers may be subjected to additional burdens through land use, is relatively new, and not generally accepted. These limitations of land use have been taken too little account of in the past, but should now be taken into consideration at an early stage in developing countries as well, in order the mistakes made by industrial countries not to repeat.

The development of improved technologies and the growing capacity to solve problems that arise also have an influence on the carrying capacity of soils. Additional factors are the social, cultural and economic behaviour of human beings. If the latter factors are not taken account of, any determination of the future carrying capacity of soils will remain inaccurate.

Despite the reservations expressed above, the concept of carrying capacity and its relation to minimum food supply can provide the basis for drawing attention to existing and anticipated discrepancies between carrying capacity and population density in those regions of the world which have rapidly expanding populations. Building on such an approach, precautionary *relief strategies* can be developed in order to avoid malnutrition and famine, and help prevent the migrations or military conflicts which then ensue.

The carrying capacity of natural terrestrial ecosystems is very low for human societies, since very little of the biomass produced can be used directly. Killing animals which live on the biomass produced increases carrying capacity only marginally, since the conversion of plant biomass to animal biomass involves substantial energy loss.

The vast majority of the Earth’s population is therefore dependent on the managed exploitation of terrestrial ecosystems. This occurs on approx. 11% of the Earth’s land surface in the form of farming (of varying intensity) and through livestock grazing on a large proportion of the vegetated land that comprises 25% of the Earth’s non-ice covered land surface. Forests, which still cover about 30% of the Earth’s land surface, are also being exploited to an increasing extent, whereby an ever-greater proportion is being lost through clearing. It goes beyond saying that any form of land use by humans is at the expense of natural systems, which undergo structural and functional changes in the process. The latter point does not mean that there are always negative changes in soil chemistry or biological diversity. Agriculture in Central Europe prior to industrialisation led to greater biodiversity, but at the same time is an example for progressive soil degradation.

Compared with the *net primary production* (NPP) of natural ecosystems, which have optimised their biomass production over very long periods of time, and whose plant communities are well adapted to the respective local conditions, agricultural cultures generally have a lower NPP. In developing countries especially, the NPP of cultivated plants is often a mere 10 to 20% of the natural local productivity. This indicates that the efficiency of plant production through human agency has not advanced very far yet in relation to the NPP of natural ecosystems (FAO, 1993a).

The NPP of natural ecosystems is not distributed evenly over the Earth's land surface, however, but features two zones of high productivity – the tropical and the temperate zones. *Fig. 11* shows the global distribution of NPP (Esser, 1993). In addition to temperature and the level and distribution of precipitation, NPP depends heavily on soil fertility. Carbon is closely bound to the organic substance in soils (humus), and can be seen as an indicator for the organic basis of soil fertility. The fertility of tropical soils is mainly due to organic substance, whereas in temperate zones both mineral and organic components are highly important. This has consequences for the productivity of agricultural cultures, since the organic substance in soils reacts more quickly and intensively to human operations than the mineral substance. The severe decline in NPP due to cultivation of the land (farming and livestock grazing) by humans has the following causes:

- cultivation of monocultures or highly simplified crop rotation leads to decoupling processes in the balance of elements and thus to nutrient deficiency and acidification.
- This process is exacerbated by the export and only partial return of biomass.
- Tillage leads to humus depletion and hence to the depletion of nutrient reservoirs and soil stabilisers.
- The problem of parasites is greater in the case of monocultures.
- Intensive grazing reduces the diversity and the density of plant populations.
- Cultivated plants generally adapt less well to the respective local conditions than indigenous plant species.
- Adapted cultivated plants are being increasingly replaced by higher-yield plant breeds which are less well adapted.
- Soil degradation is worsened by a temporary absence of plant cover or by gaps in plant cover, thus reducing the productivity of soils.
- Burning of plant waste leads to loss of nutrients and to a decline in the biological activity of soils.

Box 11

Criterion of carrying capacity: Sustainable, environmentally sound and locally appropriate land use

The objective of sustainable, environmentally sound and locally appropriate land use is to combine the preservation or regeneration of the natural abiotic and biotic basis of landscapes with economic land use. Only in this way can stable rural societies survive or develop while at the same time preserving their cultural heritage.

To achieve this objective, a number of environmental principles must be complied with:

- the principle of waste recycling
- the principle of symbiosis
- the principle of biological diversity
- the principle of elasticity and resilience
- the principle of dynamic equilibrium.

On the basis of these principles, four theses defining this form of land use can be formulated:

Thesis 1:
Sustainable, environmentally sound and locally appropriate land use leads to a reduction of loads on neighbouring systems through

- reduction of decoupling processes in utilised ecosystems or enterprises
- synchronisation of the synthesis, conversion and decomposition of living and dead biomass
- minimisation of soil degradation.

Guiding principle: Conservation or restoration of the regulation function of soils.

Thesis 2:
Sustainable, environmentally sound and locally appropriate land use leads to preservation of biodiversity (flora, fauna and microbial organisms) and, concomitantly, to improved elasticity and resilience through
– diversity of cultures, and their spatial and temporal organisation
– integration of farming, livestock farming and forestry
– integration of compensation zones (biotope diversity)
– establishment of protective zones
– environmentally appropriate tillage methods
– reduced deployment of agrochemicals
– preservation of soil structure (habitat).

Guiding principle: Conservation or restoration of the habitat function of soils.

Thesis 3:
Sustainable, environmentally sound and locally appropriate land use leads to more efficient use of resources required for production, through
– reduced losses of substances and energy (economy as a circular resource flow system)
– reactivation or promotion of self-regulation processes
– elimination or balancing of substance deficiencies (amelioration, fertilisation)
– soil conservation measures.

Guiding principle: Long-term conservation (sustainability principle) or restoration of the production function of soils.

Thesis 4:
Sustainable, environmentally sound and locally appropriate land use leads to efficient land use and stable rural societies through
– sustainable production of high-quality foods
– assurance of a reasonable income for the rural population
– conservation of rural landscapes
– guarding the cultural heritage.

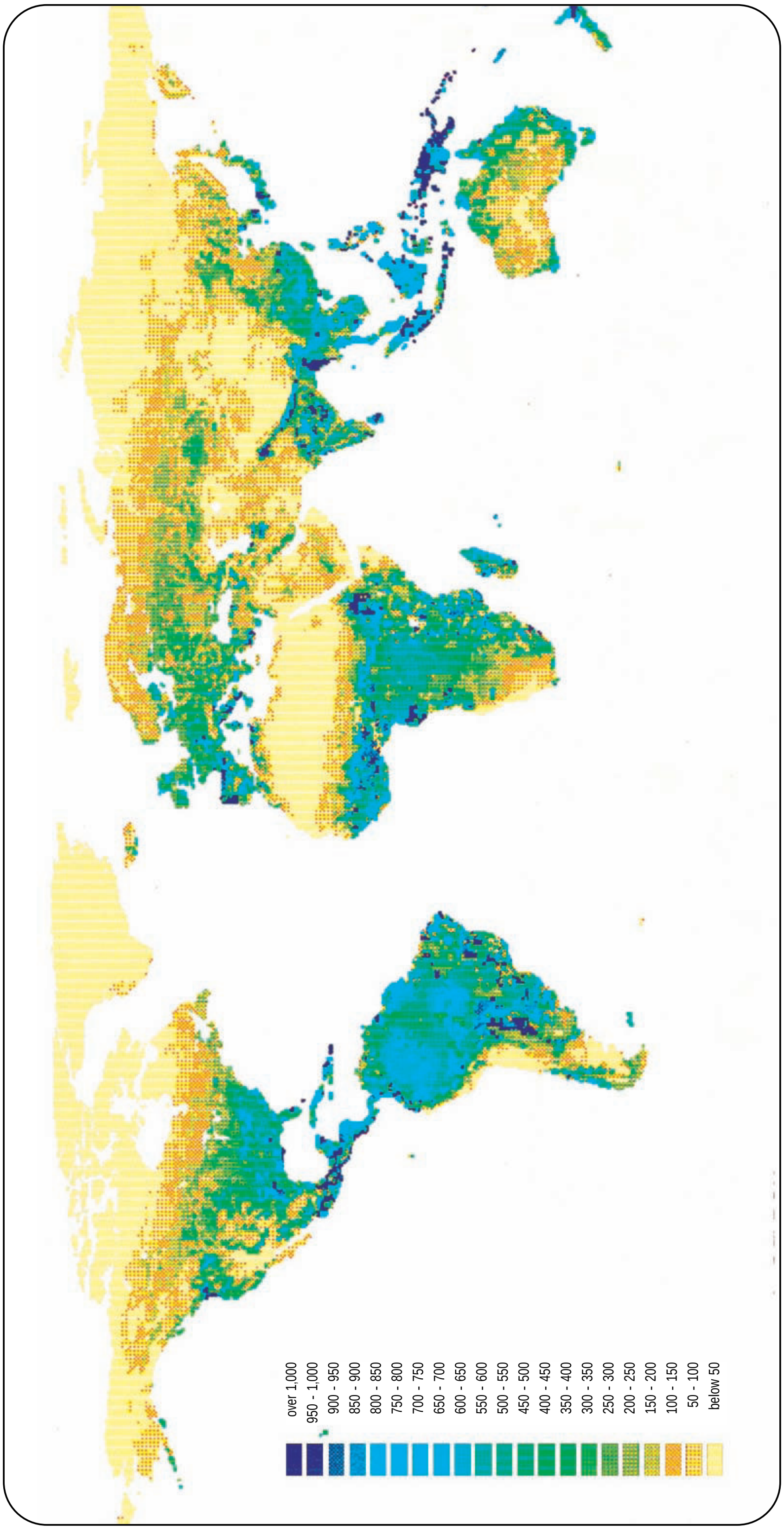
Guiding principle: Conservation or restoration of the cultural function of soils.

Fig. 12 shows the NPP of cultivated plants in proportion to the potential natural NPP (Esser, 1993). The map indicates clearly that the NPP of agricultural cultures is far behind the productivity of natural vegetation in large areas of the world. It also shows that farming only reaches or exceeds a level of biomass production of the same order as the potential natural NPP where high volumes of fertilisers and pesticides are deployed. Examples for such farming methods can be found above all in Western Europe. However, the high yields which are obtained there are only profitable under the economic conditions which prevail there, and often involve considerable environmental damage and high levels of energy consumption, so that this form of land use cannot be viewed as a model for other parts of the world.

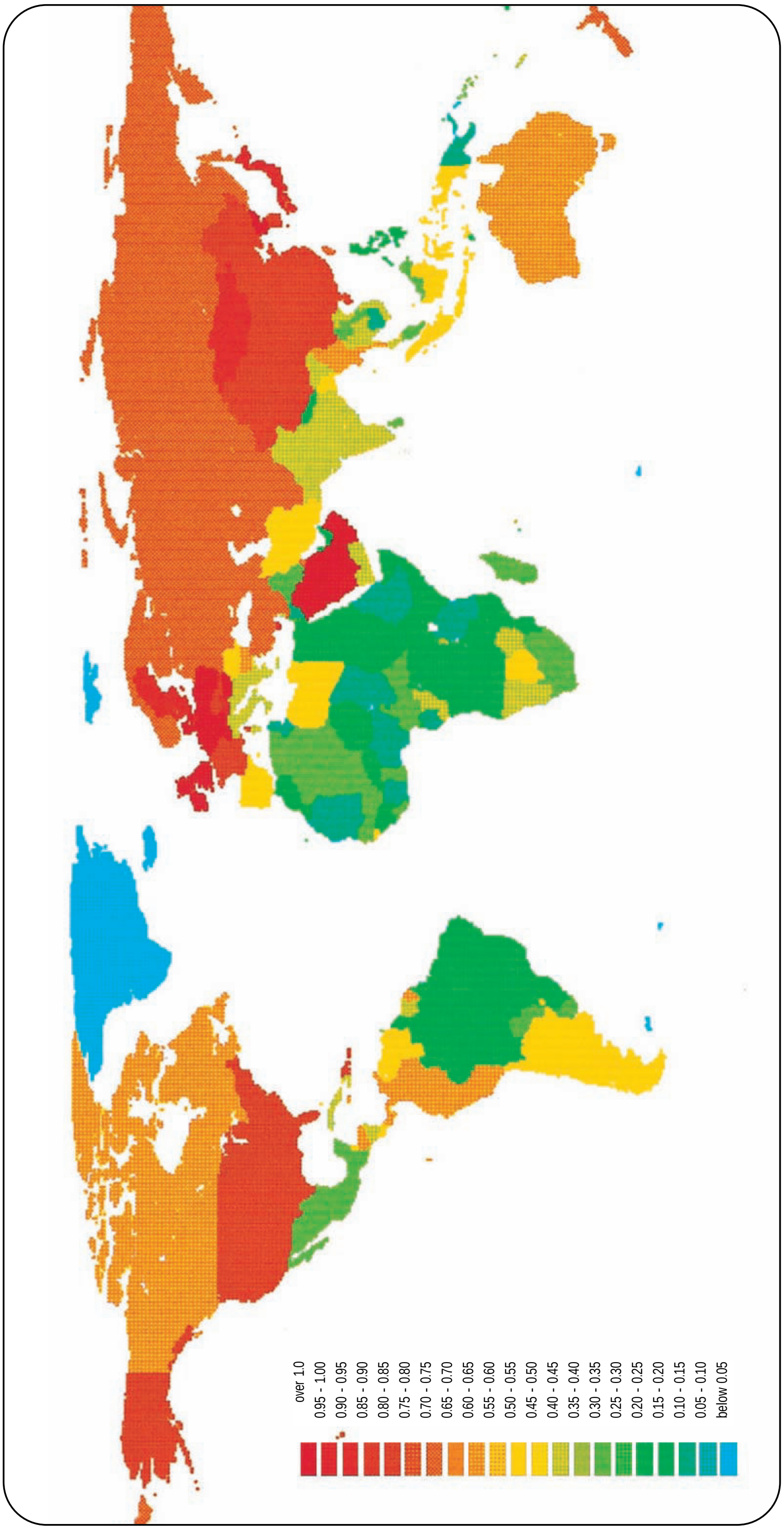
Fig. 12 also shows quite clearly that many regions have a major potential for yield increases if they succeed in applying *forms of land use which are better adjusted to local conditions*. Increasing the relative agricultural productivity to a mean of 50% of NPP would substantially improve the global food situation (see also FAO, 1989).

The above points indicate that there is considerable potential worldwide for increased yields, without larger increases in the area of cultivated land at the expense of other ecosystems being necessary. The demand must be raised, in the interest of the environment, that increasing requirements for food and raw materials be covered by *more intensive use of existing cultivated land in accordance with local conditions.* Only in this way is it possible to prevent further destruction of natural ecosystems, and the negative impact this is known to have on biodiversity and the planet’s carbon and nitrogen budgets. The guiding principles outlined in *Box 11* could function as standards governing intensified use (see von Urff, 1992).

Figure 11: Global distribution of Net Primary Production (NPP) in 1980, in g of carbon m^{-2} $year^{-1}$



Source: Esser, 1993



Source: Esser, 1993

Figure 12: Relative agricultural productivity, shown as the relative proportion of net primary production of cultivated plants in relation to the potential natural net primary production

The distribution of NPP also indicates that, in developing countries especially, the fertility and therefore carrying capacity of soils is particularly low, due to the very old soils to be found there, and that it is based on organic soil material. This means that interventions in these very fragile system are often very problematic. A direct comparison with interventions in temperate zones is therefore inappropriate. In particular, the clearing of temperate forests in the past has little in common with the destruction of the tropical rainforests, and must not be used as an argument justifying the large-scale deforestation of the latter.

On the other hand, the myth that tropical soils are essentially unsuitable for intensive and sustainable land use (FAO, 1993a) must also be refuted. It is indeed possible, on the basis of precise analyses of local conditions and consideration of location-specific factors, to practise sustainable and environmentally sound land management on large areas. About 57% of soils in the tropics are not typical "tropical soils", such as oxisols and ultisols; about 24% of tropical soils are classed as fertile. The figure for the temperate zones is only marginally higher, at around 27%.

Global surveys of potentially cultivable soils must therefore be carried out and improved as a matter of priority. Only on such a basis can sustainable, environmentally sound and locally appropriate land use with higher yield potentials be developed.

If one looks at the development of agrarian production over recent years and relates this to the world's population (*Fig. 13*), it can be seen that while production has doubled in the last 30 years, per capita food supply has only increased by approx. 20%. Following a rapid rise in the first 25 years, per capita production is now stagnating, and will decline over coming years. There are major differences in food supply at the regional level, however. *Fig. 14* shows that the development in different regions has varied greatly. Regions with stagnating or declining per capita production contrast with those where there has been a definite increase (e.g. east Asia).

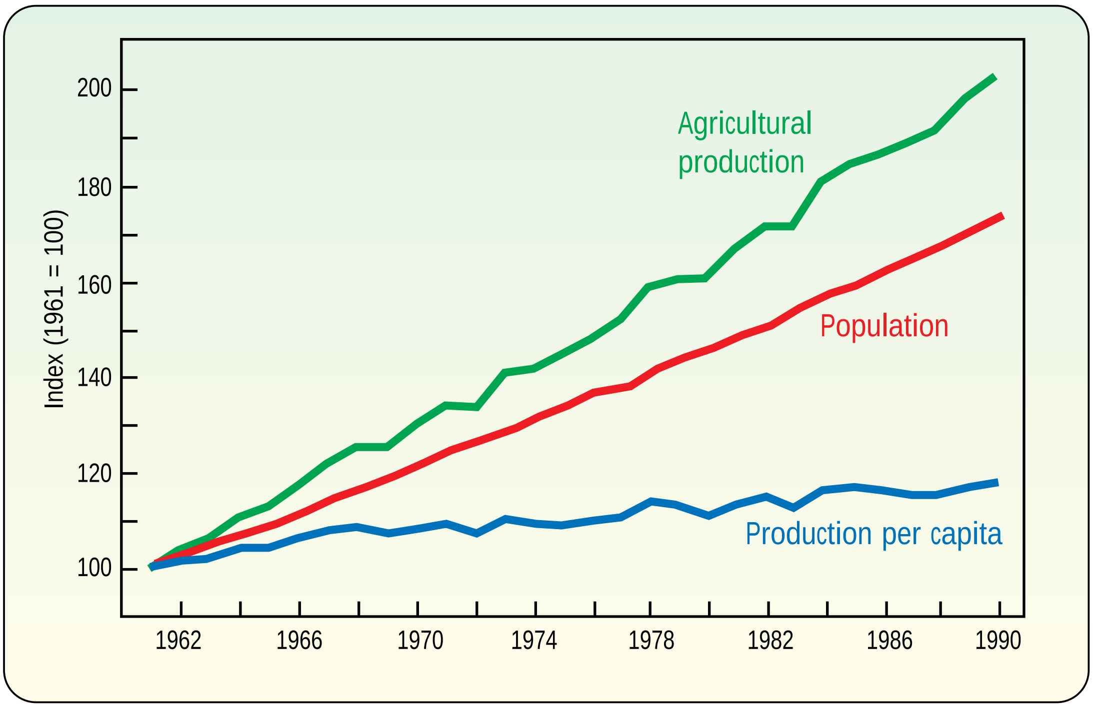
If poverty is to be combated effectively, then abatement of population growth must be supplemented by measures for soil conservation and for increasing productivity (Commander, 1989). It is apparent in this context that models developed in the industrial countries can only be transferred to a limited extent, and should not be imitated on a global scale due to the high input of energy and raw materials involved. Instead, locally appropriate land-use strategies must be developed which are sustainable and environmentally sound. *Box 11* contains a summary of criteria to be applied to such land-use systems.

The Council deliberately chose the rather lengthy term *"sustainable, environmentally sound and locally appropriate land use"* because it contains all the elements of land use it considers important. Future forms of land use must take into account the diversity of biotic and abiotic factors at the respective location, must be oriented towards sustainability, and may not impose excessive stresses on neighbouring systems, i.e. they must be environmentally sound. Other terms such as "ecological land use" or "ecological farming" have not been used because they are either non-identical with the approach being recommended here, or because they are defined in different ways in different countries.

The introduction of such strategies on a global scale can be all the more promising, the sooner these practices are also implemented in the industrial countries, and the sooner their ecological and economical benefits are demonstrated there. The Council therefore recommends that the Federal Government endeavour to implement the principles of "sustainable, environmentally sound and locally appropriate land use" within agriculture and forestry throughout the country. It should also take steps to ensure that environmental accounting systems at national and enterprise level are changed so that balance sheets include assets such as biological diversity, the quality of groundwater and surface water and soil fertility. Furthermore, intensive efforts should be made to introduce and implement a comprehensive Soil Protection Act.

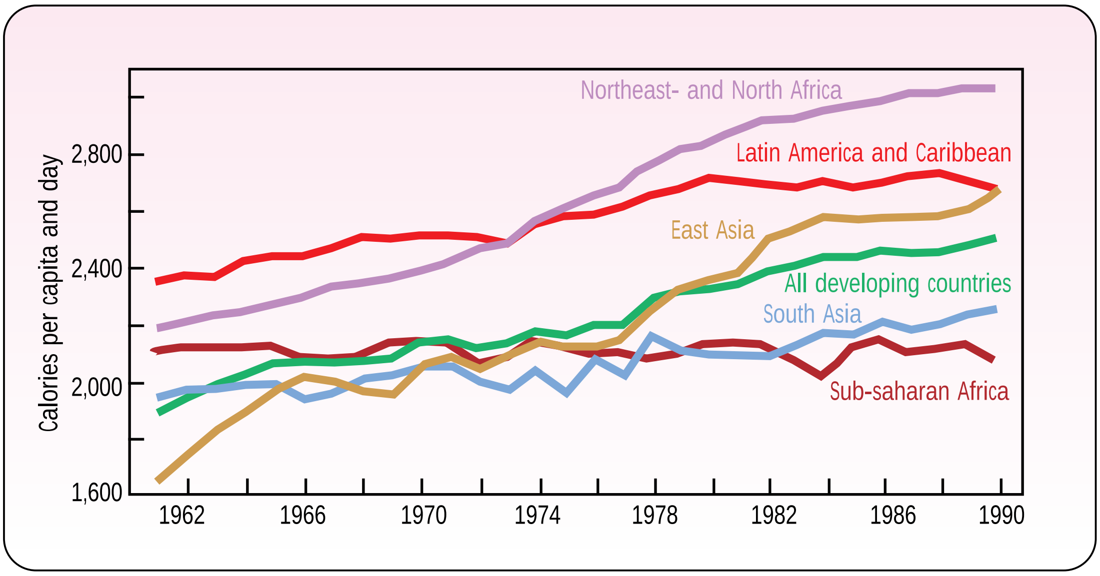
The strategies which need to be developed are characterised by high and locally appropriate input of labour. In large areas of the world, the required increase in yields can only be achieved through a combination of integrated crop farming, livestock farming and timber production using appropriate agricultural techniques, suitable livestock and plants, and the appropriate use of agrochemicals. If the latter production factors were dispensed with altogether, this would result in low-yield production and/or additional expansion of cultivated land to the detriment of natural forests and grasslands. Sustainable, environmentally sound and locally appropriate land use should not be overlaid with dogma, but instead should be pragmatic and results-oriented.

Figure 13: Worldwide agricultural production, population and production per capita



Source: FAO, 1993a

Figure 14: Food supply in the developing countries



Source: FAO, 1993a

Another important aspect for any analysis, however, is that sustainable, environmentally sound and locally appropriate land use, and the ameliorations and protective measures this involves, be supported by investments where pay-back is calculated on a long-term basis. This means that one can only expect such systems to be applied on a larger scale if interest rates are low, wages within tolerable limits and prices capable of covering costs. A look at the current situation reveals that these preconditions do not yet exist in many countries of the world.

An urgent requirement for the global introduction of sustainable, environmentally sound and locally appropriate land use are prices which cover the costs for soil conservation and environmental protection. We are far away from this requirement at present.

In an analysis carried out by the FAO, UNFPA and IIASA, the carrying capacity of soils in developing countries was investigated (1983). The criterion applied was the maximum calorie-protein production for three different input levels, which was then related to food requirements and the development of population levels. This is no doubt a rather simplified approach, but the findings point to some “neuralgic” zones in the world where serious conflicts can arise. From the global perspective, it is necessary that rapid and effective action be taken to alleviate and combat the situation in such areas, because the combination of poverty and migration could otherwise develop into a catastrophe of hitherto unseen proportions (see Section D 1.3.1.4 for further discussion of this topic).

The most important conclusions for the various scenarios can be summarised as follows (Higgins et al., 1983):

– Soils in the developing countries (excluding east Asia) can basically produce sufficient food to feed 1.5 times the population in the year 2000. This is even possible at a low level of intensity. For an intermediate level of intensity, the figure could be 4 times instead. The precondition for this, however, would be an open world trading system and freedom of migration – a rather extreme requirement.
– If one assumes the other extreme, namely that no exchange of excess production and labour occurs (autarchy), then 38% of the land surface would have exceeded its carrying capacity as early as 1975. These regions already had a population of 1.17 billion at that time (1975), despite a carrying capacity of only 0.6 billion.
– Making the somewhat more realistic assumption that there is a certain limited exchange of surplus production and labour, 54 out of 117 countries investigated would not be able to safeguard their food production at a low level. By the year 2000, this figure would rise to 64.
– 28 of these “critical” countries would have to increase their land use to at least the potentially available limit and an intermediate level of intensity. They would also have to cultivate all cultivable soils if they want to produce their own food requirements themselves. 17 of these countries would even have to achieve high intensification of land use, while 19 other countries would still not be able to provide an adequate food supply to their population, despite reaching this level of production.
– The most critical region in the world according to this study is Southwest Asia, but by the year 2000 more than half of all African countries as well will be no longer able to feed their own population if land use is at a low level of intensity.
– If measures necessary for the conservation of soils are not taken, the anticipated development would be even more dramatic.

The summary of findings presented above can only serve as an initial estimation of the interrelated problems of soil degradation and global food supply, since the input figures used are still rough and the spatial resolution insufficient. However, the problem has clear contours and can also be localised quite clearly. This applies in particular to the physical potential of the various regions, although there is still no reliable assessment of the social, economic and institutional factors that steer development, or the national and international links between these factors. Only when these have been taken into consideration is it possible to draw a clearer picture of the situation as it actually exists. It is therefore necessary to refine the concept of carrying capacity so that it embraces the limitations which exist due to impairment of the utilisation, habitat, regulation and cultural functions of soils. Approaches which point in this direction have been presented in this Report.

Global soil conservation

The problem of soil degradation also illustrates the dilemma of global soil protection. Most damage to soils occurs at local level and is frequently caused by local factors. Regional and global causes have been little researched, however, and their impacts can only be described in rough outline. Because the cumulative impact of local effects also has global consequences as described above, however, these effects must also be subjected to international regulations. In developing countries especially, many people face threats to their very survival as a result of continuing soil degradation, but these problems cannot be solved locally due to economic, social and cultural factors (Commander, 1989). Global soil conservation must therefore be seen as a precautionary principle for preventing conflict.

Acknowledgement of this fact was the basis for the "World Soil Charter" adopted at the 21st FAO Conference in 1981 (FAO, 1982a). The principles laid down in that charter in the form of 13 theses (WBGU, 1994) continue to have topical relevance. They call on governments, international organisations and land users to use soils sustainably and to preserve them as a resource for future generations. However, little has been done so far to implement these principles internationally, even though the necessity of soil conservation has been emphasised in UNESCO, UNEP and UNDP programmes (WBGU, 1994). Furthermore, there are a number of other international and transregional organisations, including the European Council, which have taken up the problems of soil conservation. Regulations and laws for protecting soils also exist at the national level in various countries. Even so, all these resolutions and declarations of intent have not led to the problem of worldwide soil degradation being tackled substantially.

The Council recommends that the Federal Government examine whether a United Nations Framework Convention on Land Use and Soil Conservation ("Soil Convention") would be a way to overcome these serious deficiencies. Draft definitions of the objectives which such a convention would have to pursue are formulated in *Box 12.*

Box 12

United Nations Framework Convention on Land Use and Soil Conservation ("Soil Convention")

Draft definitions of objectives

Draft 1:

Objectives

The objectives of this Convention … are:

- reduction of soil degradation, especially soil degradation caused by physical and chemical factors, and the preservation of soil fertility,
- conservation of the soil functions, especially the habitat function, the regulation function, the utilisation function and the cultural function,
- fair and equitable sharing of the benefits arising from the economic exploitation of soils, especially through
  - regulated access to land and soils,
  - appropriate transfer of relevant technologies for sustainable, environmentally sound and locally appropriate land use
  - and appropriate funding of soil conservation measures.

(Text adapted from Article 1 of the "Convention on Biological Diversity")

Draft 2:

Objective

The objective of this Convention and any related legal instruments …, is … to reduce soil degradation to a level which prevents dangerous anthropogenic disturbances of the soil functions (habitat, regulation, utilisation and cultural function).

Such a level should be achieved within a time frame sufficient to

- allow *ecosystems* to adapt naturally to changes in soils,
- ensure that *food production* is not threatened and
- enable *economic development* to proceed in a sustainable manner.

(Text adapted from Article 2 of the "Convention on Climate Change")

1.3 Causes and effects of soil degradation

1.3.1 Ecosphere and anthroposphere - Their interactions with soils

1.3.1.1 Atmosphere and soils

Anthropogenic influences on the composition of the troposphere have caused local, regional and indeed Global Changes in trace element loads to soil and bodies of water. These trace elements can damage ecosystems, e.g. when they increase nutrient levels or have direct toxic effects on organisms. Ammonium (NH_4^+), nitrate (NO_3^-) and sulphate (SO_4^{2-}), especially, are transported via atmospheric pathways and deposited in ecosystems as fertiliser. Phosphates, on the other hand, are transported primarily via the hydrosphere. These substances are mainly released through the burning of fossil fuels and by agricultural activities.

Some heavy metals mobilised largely by human agency and many synthetic organic chemicals have toxic effects on ecosystems – often with synergistic effects. Organic substances containing chlorine (such as hexachlorocyclohexane and polychlorinated biphenyls, for example) are introduced into the environment primarily as agrochemicals or in connection with other non-contained systems. Both organic and inorganic substances can accumulate in ecosystems, with the risk of being suddenly mobilised as a result of altered physical and chemical conditions, leading to serious impacts on both soils and waters ("chemical time bombs") (IIASA, 1991; RIVM, 1992). As a result of regional and sometimes global transportation, metals and organic substances which are difficult to degrade can build up in food chains, even in areas far removed from the emissions themselves.

The sources of the most important anthropogenic greenhouse gases are predominantly in regions subjected to land exploitation by humans. These sources account for about 15% of the total anthropogenic greenhouse effect. If the agricultural sector employed methods geared first and foremost to the actual nutrient requirements of plants and animals (optimum use of fertilisers), this could significantly reduce the emissions of methane (CH_4) and nitrous oxide (N_2O) in particular. The increase in nitrous oxide levels is especially threatening because some major sources have yet to be identified. Warming of soil would provide a positive feedback upon the greenhouse effect, as warmed soils emit higher levels of methane and carbon dioxide. When permafrost soils thaw, they also become a very powerful source of methane.

1.3.1.1.1 Effects of an anthropogenically changed atmosphere on soils

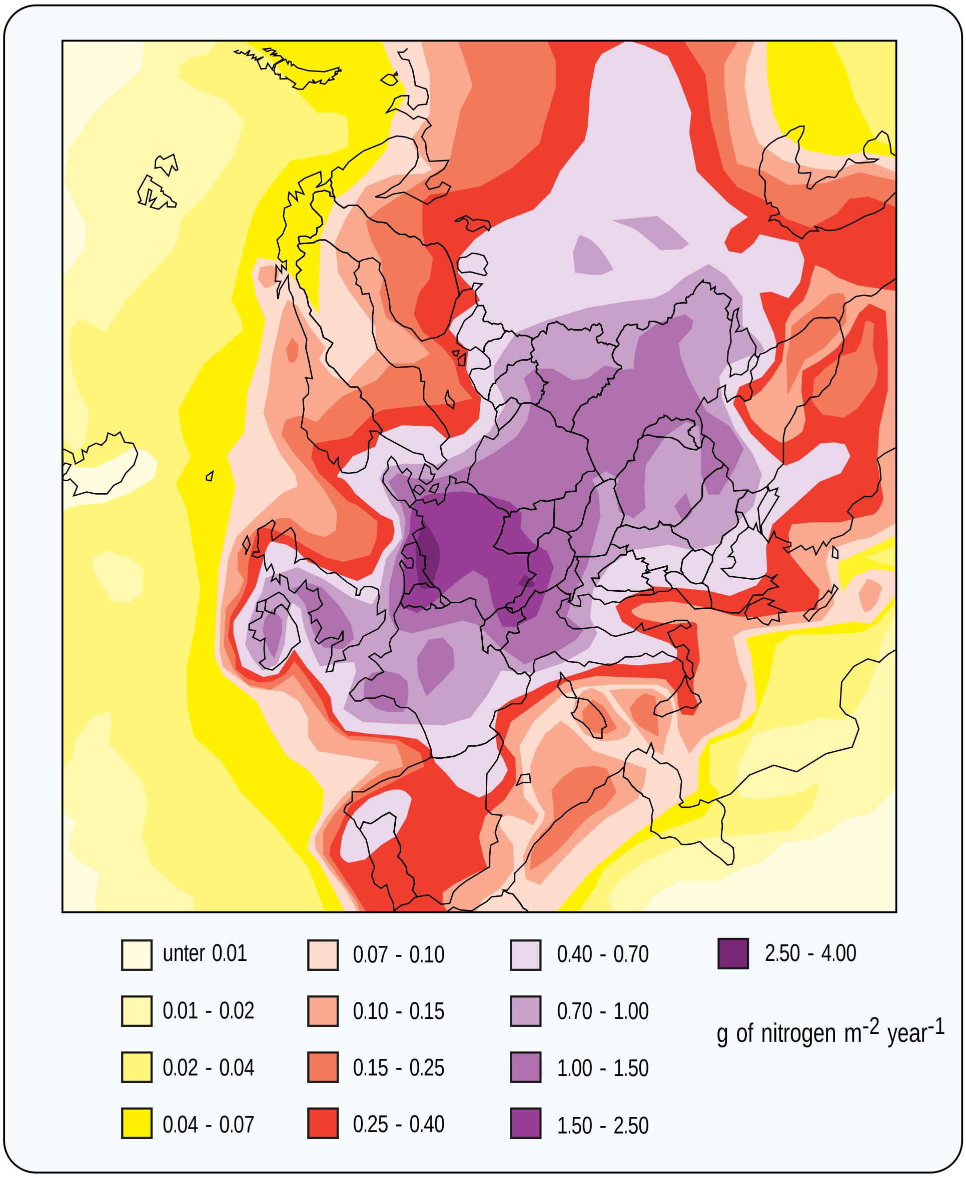
Deposition of substances which cause eutrophication and acidification

As a result of the increasing use of fossil fuels and the spread of intensive agriculture, emissions of gaseous ammonia (NH_3), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) have increased. In the atmosphere, these trace gases are transformed into ammonium (NH_4^+), nitrate (NO_3^-) and sulphate (SO_4^{2-}), respectively. These ions have an acidifying effect on the soil, even if they are transported in neutralised form. Global emission values for these substances as well as those for Europe are summarised in *Table 10*.

Because of the physical distribution of the sources of these harmful gaseous substances and their short atmospheric lifetimes (a few days), the spatial distribution of both the gases and the products into which they are transformed in the air is very heterogeneous. Typical ammonia values of 0.2 – 0.3 g NH_3 m^{-3} are found in rural areas of the USA, for example, whereas similar areas in Holland show values of 5 – 10 g NH_3 m^{-3} (Lovett and Likens, 1992; Vermetten and Hofschreuder, 1992). Depositions in soils vary greatly, both physically and as a function of time. No supraregional surveys have been carried out which detail the total delivery of trace materials by both wet and dry deposition. Estimates are available for single regions, however, based on the location of emission sources and the dispersal patterns of emissions.

For some years now, under the UN-ECE (*UN Economic Commission for Europe*) (*Box 13*) Convention on Long-range Transboundary Air Pollution, loads of nitrogen and sulphur compounds have been modelled for Europe and compared with data obtained from a network of measurement points. Most measurements are congruent to within a factor of two (Iversen, 1993; Sandes, 1993). *Figure 15* shows the loads of the trace substance ammonium. Such maps fail to reflect local variability in deposition levels, however, since they are based on mean values over larger areas. This local variability is strongly dependent on surface roughness (for example, a forest of conifers in comparison to a deciduous forest or unforested land). Measurements for total deposition at selected locations or estimates based on measurements are shown in *Table 11* for some European countries.

Figure 15: Depositions of ammonium in Europe for 1991. Model results, depositions averaged over 150 km· 150 km grids



Source: EMEP, 1993

Ammonium and nitrate depositions and the eutrophication of soils

The mobility of nitrogen oxides and especially ammonia by means of atmospheric transport has been significantly increased as a result of human activities. This effect has been found on a global scale and is particularly evident in industrial regions. In agriculture, which is responsible for most emissions of ammonia, intensive farming methods such as large-scale livestock farming and the use of mineral fertilisers are major contributors. As a result, ecosystems are supplied with far higher levels of nutrients than required. In Europe, with the exception of a few peripheral regions (southern Italy and parts of Greece), critical levels for the transport of nitrogen are considered to have been exceeded,

Table 10: Emissions of NH_3, NO_x und SO_2: a) globally, b) in selected European countries

a) Global emissions

	NH_3 (10^3 t N $year^{-1}$)	NO_x (10^3 t N $year^{-1}$)	SO_2 (10^3 t S $year^{-1}$)
Natural sources	3,800	17,000	43,000(1)
Fossil fuels	2,400	19,600	97,000 – 105,000
Agriculture, including biomass burning	42,000 – 48,000	12,200	1,500 – 7,500
Total	54,000	49,000	150,000

(1) including precursors of SO_2

b) European countries. So far, 10 of the 28 states in Europe have been surveyed (Status: March 1994)

	NH_3 (%)	NO_x (%)	SO_2 (%)
Natural sources	1	0	0
Agriculture	97	0	0
Power stations and district heating	0	21	54
Heating, industry	0	13	27
Heating, domestic	0	4	9
Production processes	1	3	4
Fossil fuels, production and distribution	0	1	0
Solvents	0	0	0
Road traffic	0	46	4
Other transport	0	10	2
Waste, treatment and disposal	1	2	0
Total	100	100	100

Sources: Logan, 1983; Warneck, 1988; "CORINAIR" database, 1990; Crutzen and Andreae, 1990; Isermann, 1994

Table 11: Depositions of NH_4, NO_3 and SO_4 (total deposition = wet and dry deposition)

Location	Period	Biotope	NH_4^+ (g N m^{-2} $year^{-1}$)	NO_3^- (g N m^{-2} $year^{-1}$)	SO_4^{2-} (g S m^{-2} $year^{-1}$)	Source
Solling	1980	Deciduous forest	2.8	2.3	7.3	(Höfken et al., 1983)
Solling	1980	Coniferous forest	3.6	6.8	20	(Höfken et al., 1983)
Taunus, Vogelsberg	1983 – 85			0.4 – 0.6	1.2 – 1.4	(Grosch, 1986)
Eggegebirge	1986	Coniferous forest	1.2	1.1	3.3	(Prinz et al., 1989)
Eggegebirge	1986	Unforested land	1.0	0.9	1.8	(Prinz et al., 1989)
Holland	1989		~ 1.4 – 8.4	~ 0.4 – 2.5	~ 0.6 – 3.8	(Erisman, 1993)
France	1989 – 93	open land	0.4 – 0.7	0.3 – 1.0	1.5 – 2.1	(ONF, 1993)
France	1987 – 91	forest	0.2 – 2.0	0.2 – 2.3	1.0 – 5.8	(ONF, 1993)
Great Britain	1986 – 88		< 1 – 7	0.4 – 1.6	1 – 6	(RGAR, 1990)
Finland	1991		0.15 – 0.4	0.04 – 0.09	0.1 – 0.3	(Leinonen and Juntto, 1992)

Selected surveys based on data from measuring stations during the past decade; the periods of observation are not identical due to the insufficient amount of data available.

Box 13

International agreements on clean air and immission control in Europe

– The *UN Economic Commission for Europe Convention on Long-range Transboundary Air Pollution, Geneva 1979: Protocols on limiting and stabilising SO_2 emissions (Helsinki, 1985), NO_x (Sofia, 1988) and volatile organic compounds, VOCs (Geneva, 1991, not yet in force).* Agreement was reached in the first generation of international protocols that large combustion plants be equipped with the best available emission reduction technologies. Most of the ECE nations also agreed to reduce transboundary SO_2 emissions by 30% (relative to 1980) by 1993, and to stabilise NO_x emissions at the 1987 level. The VOC protocol requires most ECE countries to reduce their VOC emissions by 30% of their 1988 levels by the year 2000, while the NOx protocol requires that no further increase in NO_x emissions occur. 12 ECE countries, including Germany, France and Italy, have committed themselves to a 30% reduction in their NO_x emissions by 1998 (base years between 1980 and 1986).

  Negotiations are currently being held on the second generation of protocols, which employ the concept of "critical loads". The signatories to the nitrogen protocol (ECE, 1988) committed themselves to implement this concept in practice. No such agreement has been reached in the sulphur protocol, however. Germany is currently chairing the ECE Special Working Party on the mapping of critical deposition rates and concentrations. Agreements covering the emission of persistent organic products (POPs) and heavy metals are currently in preparation. Persistent organic products include chlorine compounds, e.g. some pesticides and polychlorinated dibenzodioxins and dibenzofurans (PCDDs, PCDFs), and polynuclear aromatic hydrocarbons . These substances are very slow to decompose, as a result of which they are dispersed supraregionally and accumulate in the environment.

– *Commitments of EU Member States:* The *EC Large Combustion Plant Directive* requires most of the EU states to reduce their NO_x emissions in stages by 1993 and 1998 – for some Member States, including Germany and France, the reduction target is 40% (of 1980 levels by 1998).

– *The Convention for the Protection of the Ozone Layer (Vienna, 1985), the "Montreal Protocol" governing implementation of that Convention (1987), and the tougher regulations agreed upon in London (1990) and Copenhagen (1992) (see the 1993 Annual Report of the WBGU):* The implementation of this Convention has already led to definite decreases in the growth rate in the atmosphere of CFCs F11 and F12, as well as halons (Butler et al., 1992).

– *International Conventions for the Prevention of Marine Pollution in the North Sea (Paris Convention for the Prevention of Marine Pollution from Land-based Sources, PARCOM), the Baltic Sea (Baltic Marine Environment Protection Commission – Helsinki Commission, HELCOM) and the Mediterranean (UNEP Regional Seas Programme, 1976):* These cover atmospheric inputs of heavy metals, in addition to direct inputs, as well as recommended threshold limits for reducing inputs. Agreement was reached on a 50% reduction in sources of specific heavy metals and POPs by 1995.

– *Technical standards for emitters within the EU:* Directives governing the technical standards of particular emitters contain technical notes on *best available technologies*. So far, these have applied to large combustion plants and urban waste incinerators; regulations governing the incineration of hazardous waste and other important plant types are being drawn up. These do not specify emission reduction targets, but Member States are obliged to report on emitters of the gases SO_2, NH_3 and NO_x for compilation in the EU emissions inventory ("CORINAIR" database, 1990).

and for Central Europe the values have been exceeded by several fold (Nilsson and Grennfelt, 1988; CCE, 1991) (*Box 9*). The nutrient balance in these regions has therefore been severely disrupted, and these regions suffer from eutrophication.

Deposition of sulphate and soil acidification

On a global scale, the mobilisation of sulphur has about tripled as a result of anthropogenic activity (*see Table 11*). As a result, sulphate has become one of the most important acidification agents for most regions of the Earth. Acid concentrations in precipitation are generally on the increase in industrial regions (Likens et al., 1979; Kallend et al., 1983; Rodhe, 1988; Bhatti et al., 1992). On the other hand, sulphate deposition has been reduced in large areas of Europe and North America over the last decade following emission reduction measures. A parallel reduction in neutralising cations, however, has allowed only a minimal reduction in the acid content of rain (Hedin et al., 1994). Acid deposition levels are already critical in large areas of the Earth, meaning that the stress-bearing capacity of soils has been exceeded (*Figure 16*). Acidic precipitation is a particular threat to forest ecosystems in Central Europe which have intermediate or low base cation status.

Institutions

For the UN-ECE states, mechanisms for reducing emissions of nitrogen oxides and sulphur oxides have been agreed upon (*Box 13*) and have also been implemented with measurable success. Since the 1970s, SO_2 emissions in Europe have been decreasing. As far as NO_x emissions are concerned, it would appear that a trend for the better set in as of 1989, as a consequence of reduction measures applying to power plant and automobile technology in Germany and Europe. The reductions achieved were minimal in absolute terms, however (Umweltbundesamt, 1992; Bundesregierung, 1992; EMEP, 1993). Increases in emissions from the transportation sector have largely compensated for reductions effected in other areas, leading to a low net decrease. Forecasts of future energy requirements suggest that global emission levels will probably increase (WRI, 1992).

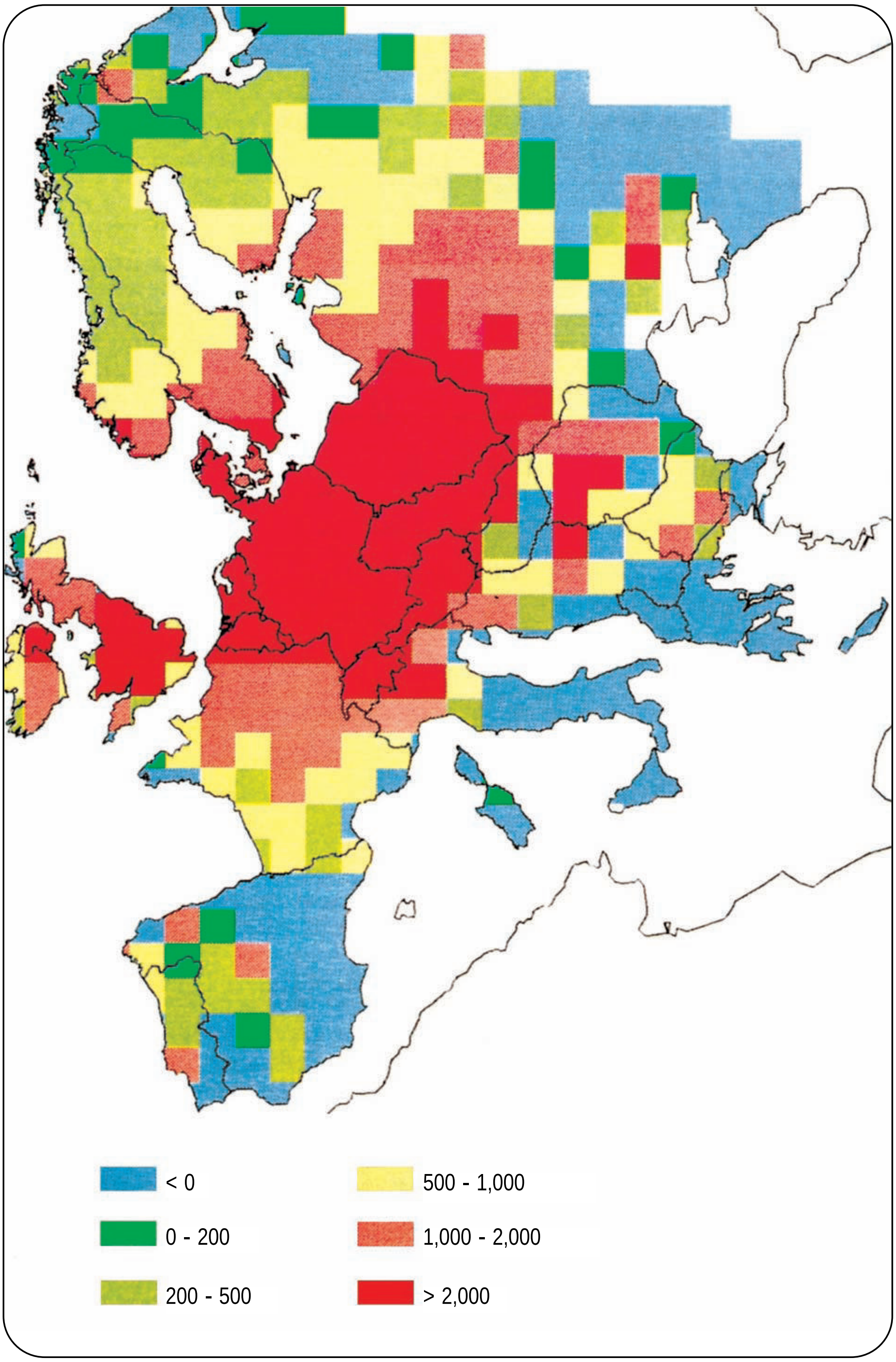
Further measures to reduce emissions are urgently necessary. According to one scenario, halving the area affected by acidification by the year 2010 can be achieved only through drastic means (such as a 30% reduction in the use of fossil fuels, or the deployment throughout Europe of best available emission reduction technologies) (RIVM, 1992). Use of fossil fuels should be reduced as far as possible through increased utilisation of renewable energy sources. Reductions in nitrogen oxide emissions must be achieved primarily through cuts in the transport sector (traffic volume, changes in the “modal split” between different modes of transport, reduction in the amount of fuel consumed by vehicle fleets, catalytic converter technology). Reference is made in this connection to the Report by Enquete Commission of the German Bundestag (Enquete Commission, 1994).

Emission reductions can be achieved in the agricultural sector through more appropriate use of fertilisers and in livestock farming (Isermann, 1994; Baccini and Brunner, 1991). The use of technically fixed nitrogen could be minimised, and the release of NH_3 could be reduced if livestock farming were geared more to the carrying capacity of soils (extended “critical loads” concept, see Chapter D 1.2.1), and if organically bound nitrogen were recycled more effectively through the integration of plant and animal production with local waste water and municipal waste disposal systems. Local standards prescribing the maximum amounts of fertiliser which can be applied would be necessary, but sufficient knowledge is now available for defining sustainable levels (Nilsson and Grennfelt, 1988; Dietz, 1992; CCE, 1993). In developed countries, a shift from overproduction to production based on need would further reduce environmental stress, especially in meat production, and hence mitigate nitrogen problems induced by net importation of protein-rich feedstuffs.

Deposition of heavy metals

A whole range of heavy metals have toxic effects on soil ecosystems, with negative impacts on soil microbiology and the biodiversity of soil flora. Because of these effects and the bioavailability of these elements, certain metals have been classed as particularly critical: antimony, arsenic, lead, cadmium, chromium, copper, nickel, mercury, silver, thallium, bismuth and zinc (Wood, 1974). These elements are widely dispersed in the ecosphere and accumulate in organic material – with serious effects on the humus horizon of soils as well as on soil organisms. Heavy metals can be mobilised suddenly when the physico-chemical properties of soil change (e.g. acidification). The uptake capacity of European and Japanese soils may well be reached in the near future (Nriagu and Pacyna, 1988). Insufficient knowledge about their toxic effects on ecosystems and the upper stress-bearing capacity of different sites means that the extent of the actual threat to soils (and terrestrial ecosystems in general) cannot be determined with any precision;

Figure 16: Exceedances of the critical pollution values of ecosystems using acid loads in forest soils and surface waters for 1991, 95% percentile, as an example. The map for forest soils is based on a flow equilibrium assumption and 5 sensitivity categories (0.02 g of free acid per m^2 and year as the critical pollution value for the most sensitive category)



Source: CCE, 1991

because of accumulation and the non-reversible dispersion involved, it must be assumed that existing stresses are grave indeed (Ayres and Simonis, 1994).

Heavy metals are mobilised above all in the following sectors: metal mining and processing industries and the combustion of fossil fuels, where heavy metals can occur as impurities, for example in hard coal (arsenic, cadmium, mercury); power stations and industrial plants (arsenic, lead, mercury); waste incineration plants (mercury) and road traffic (lead) (UBA, 1992). They are deposited in soils mainly via the atmosphere (wet and dry deposition) (Nriagu and Pacyna, 1988), but are also emitted from natural sources (especially manganese, iron, zinc, and others). The production of some inorganic pesticides containing heavy metals has been banned, particularly those associated with specific diseases (Minamata or Itai-Itai disease). However, pesticides containing copper, arsenic and mercury are still in use. The proportion of natural sources in biogeochemical cycles is generally on the decline, since anthropogenic mobilisation continues to increase. Some important heavy metals (nickel, copper, zinc, cadmium and lead) have been released in greater quantities over the last two or three decades than in the entire historical period prior to that. However, a reversal of this trend has now been achieved (for lead, cadmium and zinc at least) following emission reduction measures in the industrial countries, although this is off-set by major increases in heavy metal emissions in the less developed countries (Nriagu, 1992).

Higher immissions and sometimes extremely high immissions occur in urban agglomerations, especially in the vicinity of corresponding emissions. No international surveys of inputs are available, although there are national and regional estimates for some heavy metals (Ayres and Simonis, 1994). The estimated delivery of metals to soils, assuming even distribution over the inhabited surface of the Earth, is between 0.1 mg m^{-2} $year^{-1}$ (Cd) and 5 – 6 mg m^{-2} $year^{-1}$ (Cr, Cu, Pb) (Nriagu and Pacyna, 1988).

Table 12: Total depositions of Cd, Pb and Hg in different countries

Country	Period	Pb	Cd	Hg	Source
		(mg m^{-2} $year^{-1}$)	(mg m^{-2} $year^{-1}$)	(mg m^{-2} $year^{-1}$)	
Germany	1980 – 85	5 – 45	0.3 – 1.2		(Höfken et al., 1983; Grosch, 1986)
Hungary	1986	10	0.7		(Meszaros et al., 1987)
Finland, Sweden, Norway	1991	0.35 – 1.7	0.01 – 0.08	0.003 – 0.035	(Iverfeldt, 1991; Jensen, 1991; Leinonen and Juntto, 1992)

Table 13: Levels of various heavy metals in soils, precipitations and air

Element	Soils		Precipitations(3)		Air(2, 4)
	Hessen(1)	North India(2)	rural	urban	
	(mg kg^{-1})	(mg kg^{-1})	(g l^{-1})	(g l^{-1})	(ng m^{-3})
Vanadium			0.70	2.0	< 5
Chromium	27		0.38	1.2	
Nickel	33		0.50	1.5	1 – 3
Copper	11		0.45	2.8	1 – 500
Zinc	54		0.80	3.5	6 – 350
Arsenic	approx. 10	1.8 – 2.3	0.24	0.90	1 – 3
Cadmium	0.2	0.02 – 0.2	0.05	0.35	0.06 – 0.1
Mercury	0.1	0.03	0.07	3 – 10	
Lead	22	0.2 – 1.7	1.40	6.0	5 – 3.200

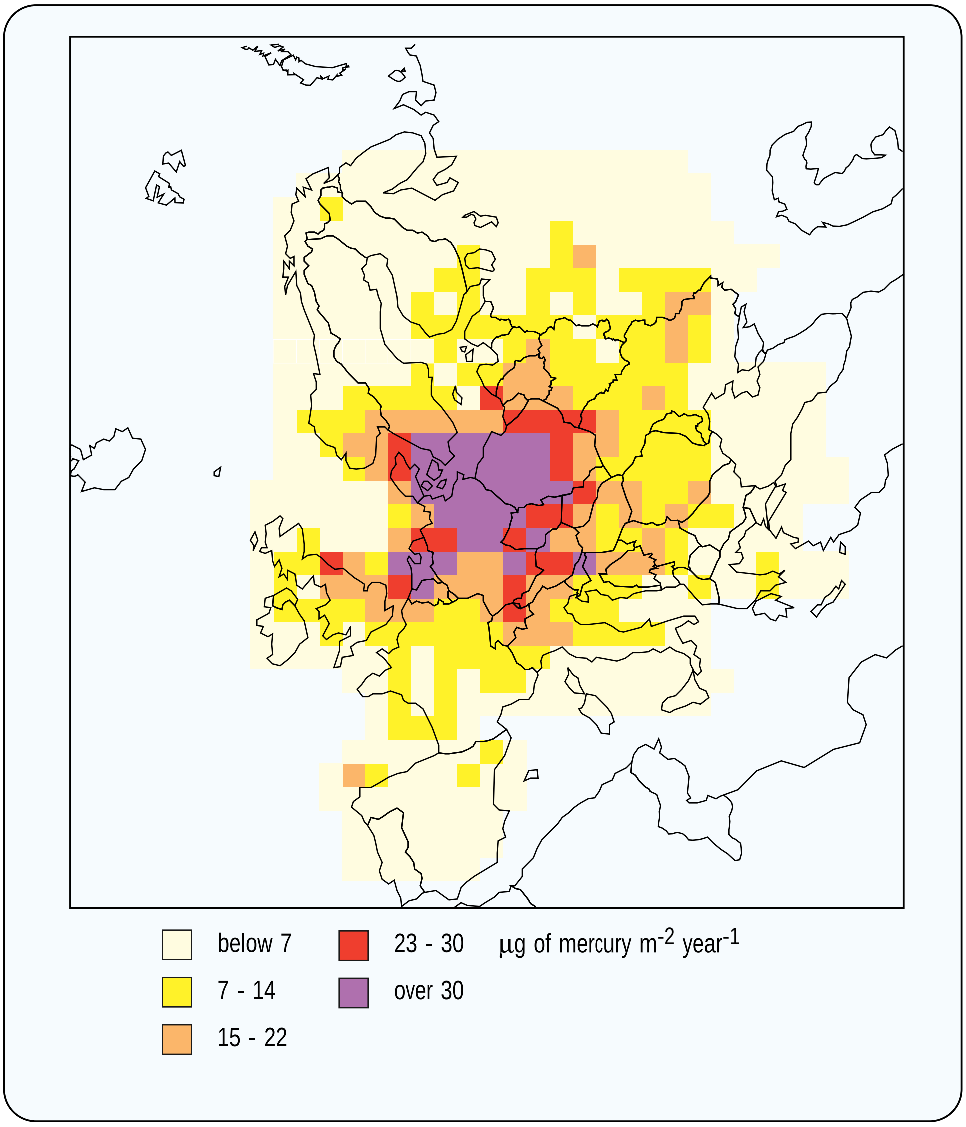
Sources: (1) UBA, 1984; (2) Krishna Murti, 1987; (3) Nriagu, 1992; (4) Wong, 1987; Lindberg, 1987

Table 12 and *Fig. 17* show the depositions of arsenic, lead, cadmium and mercury in European soils, based on selected studies and model calculations. The model calculations are based on emission data and meteorological calculations of dispersal. By comparing these with immission data, it has been shown that the emission sources of cadmium and zinc in Europe have only been partially identified (Petersen and Krüger, 1993).

Anthropogenic depositions of heavy metals in soils supplement natural concentrations, which can vary extremely even at local level due to different geological substrata. By way of example, *Table 13* shows values obtained for soils in the German state of Hesse and in northern India.

The metal accumulations shown in *Table 13* are frequently present in urban areas (where industry tends to be concentrated). Measurements made in so-called clean air areas show, however, that the entire Earth has been affected via long-range transportation of cadmium and lead, for example, and that heavy metal loads in air, water and soil are increasing (Stigliani and Anderberg, 1994). Heavy metal concentrations in the rainwater of urban areas exceed the recommended values for drinking water. In the urban agglomerations of less developed countries, rainwater is also used as drinking water (for more information on the impact of heavy metals on soils see “Chemical processes of soil degradation”).

Figure 17: Depositions of mercury in Europe for 1988. Model results



Source: Petersen, 1992

Lead

Global emissions of lead have increased by a factor of about 20 compared to the previous century (about 20,000 tonnes year^{-1} in the 1850 – 1900 period compared to about 430,000 tonnes per year in the 1970s and about 340,000 t per year in the 1980s). The transport sector currently accounts for about 72% of the total, while natural sources contribute only about 3.5% (Nriagu, 1992). Higher deposition levels are therefore found in areas close to sources, however, due to the low wash-out rates of lead containing particles also in clean air zones. Lead deposition is declining as a consequence of measures to reduce automobile emissions. However, this trend cannot be recognised yet in Eastern Europe, where urban agglomerations have lead immissions several times greater than those in Western Europe (RIVM, 1992). The concentration of lead in Greenland ice has increased by a factor of 200. The use of lead-free fuels has recently led to a decline in deposition flows – in the USA and in Greenland as early as 1970 (Rosman et al., 1993; Verry and Vermette, 1992).

Average concentrations in the soil (upper layer) are considered to be about 10 – 40 µg g^{-1}. Because of its particular affinity for organic substances (formation of complex compounds with humic substances), accumulation of lead in soils is particularly high (Schnitzer, 1978). Measurements made in coniferous forests indicate a very high level of lead accumulation in forest soils amounting to approx. 50% of deposited lead (Meszaros and Friedland, 1987; Friedland, 1920).

Cadmium

Global emissions of cadmium also increased by a factor of 20, from approx. 400 tonnes per year in the period 1850 – 1900 to about 7,400 tonnes per year in the 1970s, declining somewhat to approx. 5,900 tonnes per year in the 1980s. Metal mining and process account for about 55% of the total, while natural sources are responsible for only about 24% (Nriagu, 1992).

Average concentrations in the soil (upper layer) are considered to be about 0.01 – 0.5 µg g^{-1}. Measurements made in coniferous forests indicate that approx. 20 % of the deposited cadmium accumulates in forest soils (Meszaros et al., 1970). It is currently estimated that substantial accumulations are to be found in approx. 40% of all cultivated soils in Europe (RIVM, 1992).

Mercury

Mobilisation of mercury (Hg) occurs through both natural and anthrogenic mechanisms in roughly equal portions, each contributing 2,000 – 3,000 tonnes per year. Power plants and waste incineration are the major sources of anthropogenic emissions, with biological and volcanic sources being the main natural sources (Lindberg, 1987; Nriagu, 1992).

Mercury is transported primarily through the air in the form of gaseous substances (elemental Hg, mercury halides and organic compounds). Thus plants absorb mercury at least partially directly through stomata (Lindberg, 1987). Because of an atmospheric residence time of typically 0.5 – 2 years, mercury compounds can also be identified in atmospheric samples from clean air areas as well as in organisms found in these areas (for example, marine birds and mammals).

Concentrations of 0.02 – 0.07 µg g^{1} Hg can be found in uncontaminated soils (Lindberg, 1987). In European soils at least, and occasionally even in soils far removed from emission sources, concentrations several times this order can also be found (UBA, 1984; Johansson et al., 1991). It has been estimated that in Swedish soils the current depositions of mercury are several times greater than the critical loads (Bergbäck et al., 1989). Mercury has a very toxic effect on soil microorganisms. Fungi and bacteria frequently transform elemental mercury into methyl mercury, which also acts as a biocide due to its negative impact on photosynthesis and enzyme activity.

Contamination with radionucleides

As a result of the reactor accident at Chernobyl on 26th April, 1986, large amounts of radioactive materials were released in the form of fission products and rare gases, about 2 x 10^{18} Bq of each. Millions of humans were exposed to these as a result of long-range dispersal, deposition and subsequent accumulation of radioactive isotopes in the food chain, especially ^{131}I, ^{134}Cs and ^{137}Cs. The half-life of the radioactive isotopes ^{131}I, ^{134}Cs and ^{137}Cs are about 8 days, 2 years and 30 years respectively. About 5 x 10^{15} Bq of the long-lived isotope ^{137}Cs were released. Because a radiation dose of more than 0.35 Sv was anticipated, 135,000 people were evacuated from a contaminated area encompassing 3,500 km^2.

The total radiological load comprises direct external radiation from the radioactive cloud, materials deposited on the soil surface, as well as internal exposure resulting from inhalation of contaminated air and ingestion of contaminated food. A total of more than 20,000 km^2 of cultivated land and approx. 50,000 km^2 of forest were contaminated. Utilisation of both agricultural land and forests was subjected to restrictions of varying degrees, and about 3,000 km^2 of land surface is no longer usable at all (Kröger and Chakraborty, 1989).

About 97% of the total dose of 930,000 Gy emitted in Chernobyl was distributed over Europe and the western part of the Soviet Union, and 3% over other areas of the northern hemisphere (Simon and Wilson, 1987; Anspaugh et al., 1988). The distribution of radiation onto the surface of the soil was very inhomogeneous due to the emission process itself and the weather conditions along the path of transportation. A level of contamination of more than 550 kBq m^{-2} was measured in 1989 on about 10,000 km^2 of land in the Ukraine and above all in the neighbouring areas of White Russia (IAEA, 1991). In Germany a range of values mostly within the range of 1 – 10 kBq ^{137}Cs m^{-2} was measured, with a mean value of 6 kBq ^{137}Cs m^{-2}. For the 10 km zone directly around the accident site, resettlement or agricultural use is not planned for the foreseeable future; for the 10 – 30 km zone, some resettlement may be possible depending upon the success of the decontamination program.

1.3.1.1.2 Effects of extending and intensifying agriculture on the atmosphere

In addition to the many direct and indirect impacts on local climate and the atmosphere, the material emissions of intensive mechanised agriculture based agrochemicals are also of ecological significance.

Carbon dioxide

Changes in land use result in increasing release of carbon dioxide. For new findings regarding the CO_2 balance see Section C 1.1.

Methane

The increase in the tropospheric concentration of methane has been following a course roughly parallel to world population growth for a long time now (for development since 1992 see Section C 1.1). Anthropogenic sources predominate over natural ones (*Table 14*).

Large amounts of methane are released during anaerobic processes in agriculture. Rice farming makes the largest contribution (roughly 22% of global CH_4 emissions), with high emissions occurring in particular after nitrogen fertilisation. Livestock farming continues to make a significant contribution to the release of methane (approximately 13% of the total), varying in proportion to the number of animals raised, but also according to fodder composition. Land-use sinks for tropospheric methane do not compensate for emissions elsewhere. Rather, the application of nitrogenous fertilisers, for example, leads to a reduced CH_4 uptake capacity of soils (IPCC, 1992).

Table 14: Methane sources. Data in Tg C per year

	Mean	Range
Total sources	460	210 – 750
Anthropogenic sources	270	160 – 400
of those:		
livestock farming	60	50 – 80
rice farming	100	55 – 130
combustion of biomass	30	15 – 60

Sources: Enquete Commission, 1991; Cicerone and Oremland, 1988

Nitrous oxide

It has not been possible to locate many sources of N_2O, so a great deal of uncertainty still surrounds the data available. Accounting for approx. 35% of the emissions, agriculture is one of the main emitters of the greenhouse gas N_2O, which currently contributes approx. 6% to the additional (anthropogenic) greenhouse effect. The increase in atmospheric concentration of this trace gas (0.2 – 0.3% per year) is probably a reflection of the greater use of nitrogen fertilisers (responsible for roughly 13% of N_2O emissions). Approx. 3% of fertiliser nitrogen reaches the atmosphere as N_2O after chemical transformation by microorganisms. One of the main causes for this is fertilisation in excess of actual plant requirements (Isermann, 1994) (see also the Dust Bowl Syndrome, Section D 1.4.2). On average, more than 220 kg of nitrogen are used in agriculture in Germany per year and hectare. Additional nitrogen input stems from the improper use of liquid manure. These factors contribute greatly to acidification of soils and overfertilisation of forests.

The influence of changes in land use on the N_2O balance in the tropics and subtropics, particularly the clearing of woodland for cultivation, is still unclear. However, fire clearing of forestland and other forms of biomass burning resulting mainly from agricultural activities contribute approx. 7% to the total emissions in these regions. Because of the lack of knowledge about the sources of N_2O, there is still a substantial need for research to develop more intelligent emission reduction measures, including immediate action.

1.3.1.2 Hydrosphere and soils

The relations between pedosphere and hydrosphere are of central importance for the entire biosphere: soils and water bodies function as habitats and the basis for life, and their interactions influence the hydrological cycle and the exchange of elements in the biosphere.

Soils are habitats that have formed on the Earth's surface through the interaction of numerous environmental factors, containing air, water and living organisms and consisting of mineral and organic substances. Soils have a varying water storage capacity and therefore have an influence on the water resources of a region. The function of soils in the anthroposphere, particularly as a location for production facilities and infrastructure, has great significance for bodies of water and the stresses imposed on these. Stresses on the hydrosphere are typically regarded as indirect effects resulting from flows of (harmful) substances.

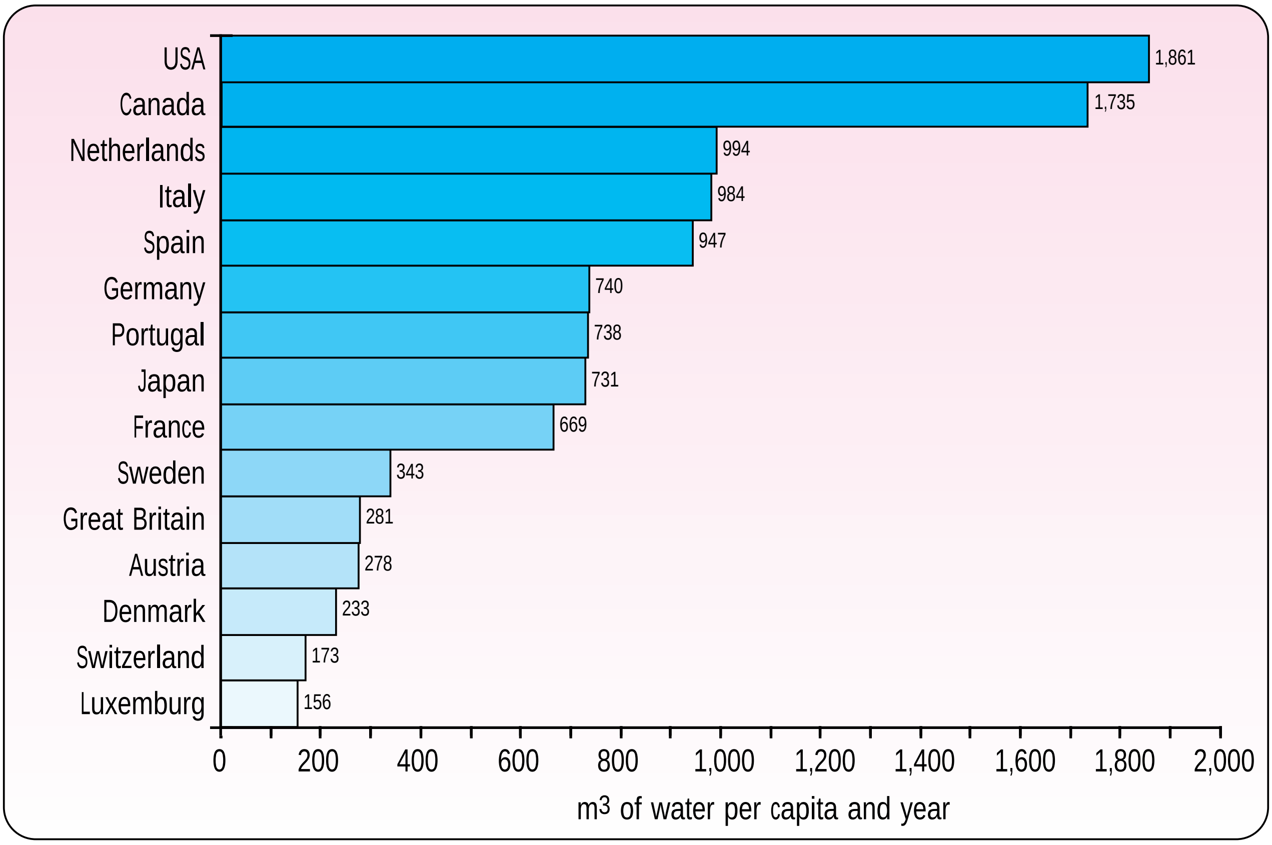
The extent to which different legal systems affect the level of soil pollution is described in greater detail in Section D 1.2.2 (see also Berkes, 1989; Ostrom, 1990; Conford, 1992). The section that follows deals primarily with stresses caused by substances; see Section D 1.3.1.7 with regard to cultural influences.

Since soils are the location where hydrosphere and pedosphere interpenetrate, it is necessary to distinguish between the influences that water exerts on soils and those that soils exert on water. Both types involve material exchange processes between liquid, gaseous and solid phases in the soil, but also the exchange of energy. Thus, changes in the hydrological cycle are both a cause and a consequence of soil degradation. Hydrospheric processes have a great number of effects on the pedosphere, especially through water erosion and the accumulation, distribution and leaching of substances, but also through precipitation and evaporation. At the biocoenosis level, water is a transport medium performing an important function with respect to plant and animal nutrition, which in turn influences material and energy flows.

1.3.1.2.1 Anthropogenic and natural processes

Directly or indirectly, human beings exert an influence on the above-mentioned interactions, resulting structurally in compaction and surface sealing, and materially in the deposition of substances in water bodies and soils (Bick et al., 1984; Büttner and Simonis, 1993; Suchantke, 1993). The main anthropogenic effect on bodies of water and thus indirectly on soils consists of the removal, utilisation and return of water from or to bodies of water (including groundwater). Regionally and nationally, however, there are major differences, culturally and economically determined, in the type and extent of the water quantities utilised, as shown in *Fig. 18*.

Figure 18: Annual water consumption in m^3 per inhabitant, selected countries



Source: WRI, 1992

Compaction

Compaction is the reduction of the total volume of the soil through compression or settlement, leading to changes in bulk density, pore volume and pore size distribution. As a result, the potential infiltration rate of the water drops, causing surface runoff and the risk of erosion to increase.

Soil compaction occurs when agriculture and forestry become increasingly mechanised, through the use of heavy machinery, for example. Among other effects, compaction reduces root penetration capacity and the number of soil-loosening organisms, and hence the capacity of soils to regenerate. For the hydrosphere, compaction of soils means reduced infiltration and thus a lower rate of new groundwater formation and, secondly, the accelerated runoff into bodies of water increases the risk of flooding.

Compaction of soils in agriculture and forestry can be countered through technical and organisational measures, such as the use of special tyres, choosing the optimal time for driving over soils, through methods like *reduced-till farming* (minimum ploughing), lighter equipment, use of draught animals as well as through plant-growing measures (crop rotation).

Surface sealing

There are a great variety of forms of surface sealing. In Germany roughly 90 hectares of soils are currently sealed every day for roads, parking lots and factory buildings; approx. 12.5% of the total surface is sealed, although in urban agglomerations the figure can be as high as 70%. Water-bound cover layers are still relatively permeable; bituminous cover layers, pavement and slab coverings and concrete, on the other hand, lead to a higher degree of surface sealing (Tesdorpf, 1984).

Surface sealing of soils (see also Section D 1.1.2.3) has a number of effects on the hydrosphere:

- Surface runoff increases and the buffer function of soils for precipitation is reduced; flooding and inundation may be the consequence.
- Evapotranspiration decreases; this leads to the formation of urban “heat islands”.
- Substances deposited on sealed surfaces (roads, car parks, etc.) are no longer filtered by soils and may not be decomposed, but are discharged via the public sewer system; this way they either flow directly into the receiving bodies of water or pollute the pedosphere as landfill waste following sewage treatment.
- Under sealed surfaces new groundwater is formed at a reduced rate, with a groundwater drawdown developing under towns in extreme cases.
- Surface sealing significantly reduces the infiltration of water and the exchange of gases, and hence the biological decomposition of harmful substances.
- Soils in the immediate vicinity may be subjected to excessive stress through the runoff of contaminated water.

Lattice slabs, a compromise between surface sealing and structural strength, are now deployed as a technical measure against the sealing of soils; they increase the volume of infiltrating water and lower the amount of surface runoff that needs to be channelled, but quality problems continue to exist or indeed intensify due to unpurified infiltration. The consequences of this can be abated by applying other technical measures, but in most cases cannot be entirely eliminated. Such measures include: the construction of retention basins as a substitute for the storage and buffer function of soils, although they, in turn, lead to additional surface sealing; artificial recharge of groundwater, which involves additional energy input, and dams and dikes on river courses as protection against floods.

To avoid additional sealing of soils and/or reverse existing sealing, the dynamics of the hydrological cycle must be given greater consideration in urban and regional planning (the German Federal Ministry for Research and Technology has launched an interdisciplinary network project in this context within the framework of urban ecology research). Large-scale desealing measures could be taken. Renaturalisation of river courses and the creation or restoration of natural flood areas are urgently required, as recent floods along the Rhine, Mosel and Rhone have shown. As a basic principle, operations with a negative impact on new groundwater formation should be minimised. Decentralised rainwater infiltration systems are being established by various pilot projects (here again the Federal Ministry for Research and Technology is funding a network project).

Nutrient deficiency and acidification

Acidification occurs as a natural process in most of the soils found in humid climates; biomass decomposition, root respiration, nitrification and humification all contribute to this process. Substantial depositions of industrial emissions (SO_2, NO_x) and emissions from intensive livestock farming (NH_4^+), however, significantly accelerate the natural acidification rate. During the last few decades the chemical properties of European forest soils have been considerably altered, acid concentrations having increased by a factor of 3 – 10 (Nilsson and Grennfelt, 1988). Acidification is becoming a problem in areas where deposition on soils with a low buffering capacity increases. Today, large areas in North America, Europe as well as parts of northern and southern China are affected by this phenomenon (Schwartz, 1989; CCE, 1991; Zhao and Seip, 1991).

Progressive soil acidification leads to loss of nutrients, mobilisation of potentially toxic metal ions (aluminium and heavy metal ions) and phenolic compounds as well as increased weathering of mineral components (silicates).

As pH decreases, heavy metal mobility rises and the filter function of soils declines. If pH falls below a value of approx. 4, heavy metals (Zn, Mn, Ni, Co) are leached to a much greater degree. In Central Europe, pH values and heavy metal concentrations in leachate and groundwater under rock of low buffering capacity already reach figures which no longer conform to the EU Directive on drinking water.

Liming has recently been carried out at many sites as a technical measure against soil acidification (particularly in forest soils). This is a measure aimed at neutralising further depositions as well as already accumulated acidic compounds, i.e. at regenerating the soil. However, a consequence of liming may be increased humus degradation and therefore the leaching of nitrogen. Liming measures must be adjusted according to local conditions. Effective, long-term measures, however, must be directed primarily at the respective causes, i.e. emissions from agriculture, industry, transport and private households.

Alkalisation and salinisation

Soils in arid and semi-arid regions with little or no eluviation are frequently subject to alkalisation. This is mainly due to the fact that sodium compounds delivered via precipitation remain in the soil as basic sodium carbonate (Na_2CO_3). Sodium carbonate then accumulates because the potential rate of evapotranspiration exceeds the precipitation rate.

Salinisation of soils occurs in different regions to various degrees. A distinction can be made according to the manner in which water-soluble salts accumulate: in the case of *precipitation salinisation*, which frequently occurs in arid climates, salts are delivered to soils via precipitation or dust; *groundwater salinisation* takes place in arid climates via the evaporation of rising capillary water in soils influenced by groundwater, as is found very frequently in coastal areas (mangroves, marshes). In arid climates, irrigation can also cause *artificial salinisation* of soils.

As saturation of soils with sodium ions increases, pore volume and plasticity decline. During dry periods, a hard crust is formed, water uptake is drastically reduced, pore water reacts alkalically and agricultural utilisation becomes virtually impossible. Increased salt content impairs or reduces plant growth because it increases the osmotic potential of groundwater and thus hinders water uptake. Large areas in India, Pakistan, Iraq, Egypt and in the U.S. have become completely unproductive as a result of incorrect irrigation (see also “Aral Sea Syndrome”, Section D 1.3.3.5). In humid climates, temporary salinisation of soils occurs when land is irrigated with sodium-rich waste water, and through the use of salt on icy roads.

Technical measures to regenerate salinised soils include lowering the groundwater level, soil drainage combined with loosening of subsoil or deep-ploughing of low-permeability soils, as well as supplying increased quantities of water in order to leach salts from soils (jeopardizing the groundwater). At the same time all of these measures, however, also threaten the respective ecosystems. Salinisation is negligible when subsurface irrigation methods are used in association with foil coverings that prevent or reduce evaporation. Controlled irrigation techniques, such as trickle irrigation, also help to reduce alkalisation.

Erosion and sediment loads in water bodies

Erosion is the removal of soil material by wind and water; it is a physical process that interacts closely with the local biocoenoses (*Box 8*). This natural process of erosion is frequently accelerated by human activities. Clearing of the original vegetation and subsequent agricultural utilisation may result in water erosion, even when there is little slope. Wind erosion may take on significant proportions, particularly in dry climates, and in some cases has anthropogenic causes, especially because of non-adapted agriculture lacking wind protection vegetation (hedges) and ground cover (“Huang He Syndrome” and “Dust Bowl Syndrome”, Section D 1.3.3.1 and 1.3.3.2).

Expansion of water bodies for shipping purposes is another factor that leads to changes in soils. These include the deepening of river beds by increased erosion resulting from the straightening of river courses, the lowering of the water table in coastal lowlands and meadows (which may also benefit soil formation) and the eluviation of soil components due to greater runoff.

Erosion of soils and the related increase in sediment input may lead to water pollution and the eutrophication of bodies of water, while greater surface runoff may result from soils losing their water storage capacity. The consequences of the sedimentation of eroded material include silting of lakes and the lower courses of rivers, in addition to flooding, which in turn may trigger off many different problems affecting the anthroposphere.

These processes create a link between soils and oceans, the other part of the hydrosphere, which only come into direct contact with each other in the relatively narrow coastal areas. Particulate and dissolved soil material is taken up by rainwater or by the wind and transported to the sea, either as surface runoff “channelled” by rivers, or diffusely through the air. The effects in the sea appear especially in coastal areas, where considerable damage may occur to ecosystems of vital importance to humanity (food resources, recreational value). Three important interactions can be determined:

– A high degree of sediment deposition may lead to destruction of mud flats, coral reefs and mangrove forests (time horizon in the order of centuries).
– Nutrient deposition (particularly from intensive agriculture) leads to eutrophication and to changes in marine biodiversity and in the long term to degradation of the marine habitat due to oxygen deficiency (examples: Baltic Sea, Black Sea).
– Organic and inorganic pollutants may accumulate in the food chain, thus causing permanent damage to biocoenoses, and possibly resulting in the poisoning of human beings as consumers (more on this below).

These major problems can lead to permanent impairment of the population’s health, food supply and economic activity. Forms of land management that are adapted to the respective climate and soils, i.e. sustainable, environmentally sound and locally appropriate land use, can offer protection against soil erosion and the related harmful effects on water resources, plants, animals and landscape (see Section D 1.1.2.2). Though only to a modest degree, different methods of ecological agriculture and forestry are being successfully applied in Europe (Vogtmann, 1985; Greenpeace, 1992). Virtually natural forms of hydraulic engineering also reduce the risk of erosion; the preservation and restoration of meanders, and restrictions on shipping tonnage as well as on measures to enhance the navigability of rivers are steps whose importance is increasingly emerging in public awareness and political debate (Cosgrove and Petts, 1990).

Contamination of water bodies by fertilisers

In intensive agriculture, substantial quantities of nutrients are removed when crops are harvested and have to be replaced by means of mineral fertilisers. Of the main nutrients, i.e. nitrogen, phosphorous and potassium (N, P, K) and numerous other trace elements, the various soluble compounds of nitrogen (ammonium NH_4^+, nitrate NO_3^-, nitrite NO_2^-) are currently the most problematic. Biological denitrification occurs in soil zones with low oxygen content. The natural nitrogen cycle, however, is disrupted by excessive inputs from agriculture in the form of mineral fertilisers and liquid manure. Depending on factors such as leachate volume, nitrate concentration in the soil, the type of soil and land use, nitrogen is leached into the groundwater, thus via various transformation products posing a potential threat to humanity in the drinking water (Seymour and Giradet, 1985).

Losses of the nitrogen as NH_4^+ and NO_3 are compensated for in natural nutrient cycles through biological fixation of atmospheric nitrogen and nitrogen deposited through precipitation. In many areas, however, the supply of nitrogen far exceeds natural requirements, especially as a result of high nitrogen deposition. This oversupply induces changes at the plant and ecosystem level (physiological changes in plants, altered species composition). Due to the accumulation of nitrogen compounds in the ground and possible losses through soil water, however, it may take a long time before such changes manifest themselves. The extent of environmental damage due to nitrogen deposition is still not completely visible today. Negative effects are expected for most European ecosystems where deposition exceeds 1 – 2 g of N m^{-2} $year^{-1}$ (Ulrich, 1989; Nilsson and Grennfelt, 1988).

In addition to the above, eutrophication of soils has a feedback impact on the greenhouse effect (Steudler et al., 1989): increased quantities of CO_2, CH_4 and N_2O are emitted and the CH_4 sink in the soils is diminished through the deposition of NH_4^+ (see Section D 1.3.1.1).

The problem of fertiliser deposition into bodies of water can be abated by creating water conservation areas, through time and volume restrictions (liquid manure regulations), through fallowing and greening requirements. However, the causes, such as excessive use of fertilisers, the influence of the chemical industry in agricultural consulting (sales-oriented agricultural consulting) and the excessive number of livestock per unit area, must all be tackled in order to pave the way for sustainable, environmentally sound and locally appropriate land use. Introduction of a nitrogen tax has been demanded by the Council of Environmental Advisors (SRU, 1987) as well as the German Federal Office of the Environment (UBA, 1994).

Contamination of water by plant protection agents

Plant protection agents used to combat pests, regulate growth or inhibit germination are industrially produced organic compounds that are not found in nature. Varying quantities of the agents applied enter soils directly or indirectly, where they accumulate, decompose, are altered or transported. Pesticides in particular can enter the hydrosphere via different routes (wind erosion, surface runoff or leaching). Low-humus and sandy soils are especially prone to leaching. Pesticides and their degradation products not only endanger aquatic and terrestrial ecosystems, but also pose a growing threat to humankind via the groundwater-drinking water pathway.

Methods for subsequent removal of these substances from drinking water have only been developed to a partial extent and standardised analytical methods are often lacking. In any case, this type of after-treatment is extremely expensive and makes little ecological sense. In contrast, adapted methods of sustainable, environmentally sound and locally appropriate land management (integrated plant protection, ecological farming, biological pest control: *Box 11*) can significantly reduce or completely prevent the pollution of soils and bodies of water with pesticides and other substances (Vogtmann, 1985; Sattler and Wistinghausen, 1989).

Contamination of water through industrial usage

Many of the current and former sites of production facilities and industrial enterprises are polluted with a broad spectrum of inorganic and organic substances and their degradation products (*hazardous waste sites*). Contamination of soils and bodies of water is caused by direct deposition or indirectly through landfilling with (sewage) sludge and waste, or through the deposition of harmful substances via airial transport. Additional contamination of surface, infiltration and ground water may occur as a result of leaching of contaminants from the affected soils (SRU, 1991; WM, 1992; WWI, 1994).

To combat the direct threat to groundwater, various technical methods have been developed for protective purposes (e.g. lining of hazardous waste sites, wells as hydraulic barriers) or for decontamination (e.g. microbiological cleaning, soil washing, water and soil-air purification). In future, priority must be given to the avoidance of contamination that may threaten water supplies. In addition to technical measures to ensure that ecotoxic substances are kept out of soils, substitution of these substances and the respective processes is necessary if the material flows of industrial society (the industrial metabolism) are to be designed and shaped to make them tolerable for soils (see Ayres and Simonis, 1994 on the subject of “industrial metabolism”).

1.3.1.2.2 Systems interactions

The anthropogenic processes mentioned above do not usually occur in isolation, but instead have systemic links of both spatial and temporal nature (Blume, 1992; Ripl, 1993). Three examples will suffice to illustrate those links:

Urbanisation and expansion of infrastructure

Increasing urbanisation and the expansion of material infrastructures in recent decades has led to an escalation of soil compaction through intensive construction work, surface sealing through new roads and buildings, soil acidification due to emissions from industry, transport and private households as well as soil contamination due to commercial usage (Tesdorpf, 1984; WWI, 1994). These processes have significant impacts on the hydrosphere. Although they have the longest tradition in the northern hemisphere, the most rapid changes are currently taking place in the metropolises of the southern hemisphere (see also “São Paulo Syndrome”).

If it is not possible to rapidly implement problem-solving strategies that are already perceptible in the North, such as “ecological urban restructuring”, “adapted technologies”, “closing of water cycles” and to make them practicable for appropriate application in the South, the related problems will undoubtedly grow rapidly (Oodit and Simonis, 1992).

Intensification of land use

The greatest anthropogenic changes in soils in terms of surface area, and water pollution associated with these changes, are caused by agriculture and forestry. Detailed studies, some of which take a global perspective, are available on these effects (including: SRU, 1991; Agrarbündnis, 1993; WWI, 1994; WM, 1992; FAO, 1993b; Nisbet, 1994).

Forest management has several impacts on soil and water, the most important of which are loss of habitat, erosion, acidification, nitrate leaching, decline of the regulation function performed by virtually natural forests with respect to the water budget.

The clear felling method of obtaining timber practised in many tropical, but also boreal forests (e.g. Canada) has far-reaching consequences for material and water resources. This method should be banned worldwide and replaced by recognised ecological forms of forest management.

Agricultural use of land in semi-arid regions is often only possible in conjunction with irrigation schemes. However, this often leads to gradual salinisation and concomitant losses in productivity. In some cases, the water required for irrigation is pumped from deep wells; this is usually fossil water of high salinity, which then increases soil salinisation and overexploitation of groundwater reserves (Lowi, 1993; WM, 1992). Modern, economical methods for irrigation and water harvesting should be applied on a broader basis and further developed.

Overgrazing

Intensive livestock fattening, as is carried out in Central and Western Europe particularly, disrupts the nitrogen cycle through feed imports and leads to considerable deposition of harmful substances in soils and bodies of water. In semi-arid regions where livestock farming predominates, extraction of groundwater using boreholes leads to an increased livestock density that frequently exceeds the carrying capacity of the soil. This results in a decline in protective vegetation cover, which then causes a reduction in the rate of new groundwater formation and increased erosion through surface runoff. The latter may also result from livestock farming on marginal soils and in marginal-yield areas in arid regions (see Section D 2.1), and subsequently lead to desertification (Herkendell and Koch, 1991; see *Box 21*).

1.3.1.2.3 International regulations

No international legal systems for water and soils has been established to date. In 1966, the *International Law Association* (ILA) laid down the “Helsinki regulations on the use of water from international rivers”, but these have not become binding in international law. In 1991, the *International Law Commission* (ILC) submitted a draft agreement on non-shipping use of international water courses which did not go into effect. The same fate was shared by the Convention of the “Maritime Law Conference” of 1982, which has not received the necessary ratification as yet. The “Basel Convention” does not directly deal with this topic, though the consequences of non-compliance with it may very well affect the network of interrelations between surface waters and soils. (The Law of the Seas Convention which came into effect late 1994, will be intensively dealt with in the 1995 Report).

However, there are also a number of bilateral and multilateral agreements governing the use of water and/or the prevention of pollution in international waters (*see Table 15*). Several international organisations (e.g. ECE, FAO, WHO) deal with relevant issues in this field, whereby globally occurring water problems are usually treated, at least indirectly.

In 1972 the first UN Environment Conference in Stockholm recommended three principles for water-related international cooperation under Point 51 of the *Stockholm Action Plan*:

1. early mutual notification regarding planned measures having transnational effects;
2. best possible use of water and avoidance of water pollution;
3. equitable distribution of the net benefits of hydrological measures among all countries affected.

At the UN Conference on Environment and Development in Rio de Janeiro in 1992, a separate chapter on water (Chapter 18) was formulated in AGENDA 21; most of the other chapters in this action plan also refer to water-related matters (WBGU, 1994).

Table 15: Examples of international regulations on soils and surface waters

Regulation	Year
Nile Agreement (Egypt / Sudan)	1959
Indus Agreement (India / Pakistan)	1960
International Rhine Protection Commission (all bordering countries)	1963
European Water Charter	1969
Stockholm Action Plan	1972
London Dumping Convention	1972
Joint Senegal Administration (Mali / Mauritania / Senegal)	1972
Paris Convention on Marine Pollution from Land Sources	1974
Helsinki Convention on the Protection of the Baltic Sea	1974
Ganges Agreement (India / Bangladesh)	1977 – 1988
Mar del Plata Action Plan	1977
UN Convention on Protection and Use of Transnational Water Courses	1991

Source: WBGU

The topic of soils was *not* treated in a separate chapter, but there are explicit references to soils in *several* chapters. Special focus was placed on topics which relate to the interconnections between soils and water bodies: integrated planning and management of land resources (Chapter 10), combating of deforestation and desertification (Chapters 11 and 12), Sustainable Development of mountainous regions (Chapter 13), support of sustainable agriculture and rural development in general (Chapter 14). Direct references to water and indirectly to soil can also be found in Chapters 19 to 21, which deal with the handling of toxic chemicals, hazardous wastes and sewage sludge.

Global institutions

In addition to the established international institutions that also perform tasks relating to soils and water bodies, such as UNEP, FAO, WHO and WMO, there are a number of *non-governmental* institutions and bodies which focus on global soil and water problems. Such institutions exist in the research field, especially, for example the *World Resources Institute* and the *Worldwatch Institute*, but also in economics. One example is the *Stockholm Water Symposium* organised by the Stockholm Water Works, which was established in 1989 in order to tackle problems affecting the Baltic Sea, as well as other water problems, at the international level and on a multidisciplinary basis; symposia have been held annually since 1990, the last one in August 1993 on harmful substance flows from soils to bodies of water (Hanneberg, 1993).

European institutions

Various institutional arrangements relating to water have been established at the European level (Lauber, 1989; McCann and Appleton, 1993). A number of frameworks with programmatic character have a global basis, especially the *European Water Charter* of 1969 and the related *Freshwater Europe Action Programme*, whose final report to the Parliamentary Assembly of the European Council is expected in 1994. The latter programme focuses on better regional planning, Sustainable Development and replacement of the curative approach with the precautionary avoidance of water and soil pollution. The objective is to purity water resources in Europe such that they can be used as drinking water without prior treatment. The European Union has a number of Directives in force which relate specifically to soils and water bodies, as shown in *Table 16*.

Since the end of the 80s concrete steps have been taken in Germany to formulate a soil protection concept that takes into account the close connection between soils and surface waters. Its implementation in a soil protection law may result in significant protective effects on soils as well as on surface waters and groundwater (BMI, 1985; Hübler,

Table 16: European Union regulations on soils and water recources

Regulation	Directive number
Directive on Groundwater (orientation to point sources, no quantity management, EC Commission's action programme and amendment proposal on the basis of a symposium ("Minister Seminar") in The Hague in November 1991 (22-point programme on environmentally sound and sustainable groundwater use))	80/68/EC
Directive on Drinking Water (currently being revised, hearing in Brussels in September 1993, controversy over raising of pesticide limits and thus transfer of clean-up efforts (and costs) from pesticide manufacturers and users to drinking water suppliers)	80/778/EC
Directive on Protection of Bodies of Water Against Contamination by Nitrate from Agricultural Sources	91/676/EC
Directive on Treatment of Municipal Sewage	91/271/EC
Directive on Distribution of Plant Protection Agents	91/414/EC
Directive on the Risk of Serious Accidents in the Course of Certain Industrial Activities	82/501/EC on the basis of 88/610/EC
EC Regulation on "Ecological Farming"	91/2029/EC

Source: WBGU

1985; BMU, 1986; SenStadtUm, 1986; Zieschank and Schott, 1989); this law should be implemented as soon as possible – even in the face of resistance from certain interest groups.

Research topics on the interrelations between soils and water

– Development of concepts for active soil and water protection on an international basis.
– Development of criteria defining the "critical variables" of water and wind erosion, as well as soil contamination by heavy metals, in relation to land use.
– Determining the influence of plant cover on the quality and quantity of groundwater, on soil contamination and on water exchange with the atmosphere.
– Development of decentralised water-saving irrigation systems for developing countries.
– Determining the influence of ecological farming on the quality and quantity of surface waters.
– Development of pesticide-free, ecological farming methods for renewable raw materials (such as coconut, sisal, kapok, hemp, etc.) according to the principle of controlled organic farming.
– Development of locally appropriate methods and processing guidelines for ecological farming in cooperation with institutions in the tropics, and especially in countries threatened by desertification.

1.3.1.3 Biosphere and soils

The specific components of the biosphere selected for describing the interactions with soils in this Report are biodiversity and forest ecosystems. Biodiversity refers to the number and variability of living organisms, both within one species and between the species and the respective ecosystems. Intact ecosystems are indispensable for the nutrient cycle, for the regeneration of soils and for climate regulation at local and regional level (Solbrig, 1991; Perrings et al., 1992); reference has already been made to the further significance of biodiversity in the 1993 WBGU Report (1994).

Within the biosphere, forest ecosystems (tropical forests, boreal forests and forests in moderate zones) play an important role, also on account of the biological diversity they contain. Inappropriate forest use and changes in the form of land use are causes of soil degradation. In forests at mid-latitudes, the chain of effects goes in the opposite direction: anthropogenic influences on the soil ecosystem result in impairment of forests, while both directions of influence can be observed in boreal forests. The destruction of tropical forests and the problem of forest decline at mid-latitudes have been described in an exemplary manner by an Enquete Commission of the German Bundestag (Enquete Commission, 1991) (see also Section D 1.3.1.3.3).

Although soils are an important component of all terrestrial ecosystems, they are often considered to be a separate ecosystem (Kuntze et al., 1981) in which a dynamic equilibrium exists between the abiotic domain (rock, soil, climate) and the biotic domain (autotrophic microorganisms and assimilating plants as producers, microorganisms as decomposers, animals and human beings as consumers). Soils and biodiversity are highly interdependent. Soils function as the location for useful and wild plants, which draw nutrients and water from the soil. Plant roots are able to penetrate into the smallest cracks in rocks and to accelerate weathering, the first stage of soil formation, via CO_2 and acid deposition. Vegetation cover, in turn, protects the soils against erosion.

Furthermore, soils are also the habitat for a great number of soil fauna and microorganisms. These remove vital substances from the soil, but also contribute to the maintenance of soil fertility by mineralising the organic substances (Potter and Meyer, 1990); at the same time, the activity of soil organisms provides for soil aeration (Ehrlich and Ehrlich, 1992).

The respective biodiversity depends on a number of factors. In addition to geographic (latitude) and biological factors (extent of predatation, degree of competition), climatic variability, physical and chemical heterogeneity and the size of a habitat play a role (Begon et al., 1991). It is generally assumed that favourable, growth-promoting environmental conditions will also induce greater biodiversity. The net primary production (NPP) of an ecosystem may depend on the one particular resource or factor (light, temperature, water, length of growth period) that limits growth the most. An increase in NPP is usually observed in connection with an improved supply of important nutrients like nitrogen, phosphorous and potassium.

Biodiversity, however, may also be linked to conditions of scarcity. For example, plant communities such as the fynbos in South Africa and the bush shrub of Australia, which are rich in biodiversity, are found on soils with very low nutrient content. Close-by biota on nutrient-rich soils, on the other hand, have lower biodiversity. Presumably, biodiversity is highest in places with a moderate nutrient supply. The greatest diversity of trees in the forests of Malaysia, for example, was found in areas having moderate phosphorous and potassium concentrations. Loss of biodiversity is primarily attributable to the destruction or fragmentation of habitats caused by the expansion of human activities, to overexploitation of natural resources, to increasing pollution and to inappropriate introduction of non-indigenous plant and animal species (UNCED, 1992; Ehrlich, 1992).

1.3.1.3.1 Changes in land-use patterns and biodiversity

Changes in land use, such as surface sealing and despoliation, clear felling of forests, the creation of livestock pastureland or the extraction of raw materials generally have adverse effects on soils – and indirectly on biodiversity.

Surfaces are considered sealed when the exchange between soils and the hydrosphere, atmosphere and biosphere is prevented, for example, by buildings or a cover of concrete, asphalt and pavement. Urban sprawl by uncontrolled development means that a landscape is fragmented. One can assume that surface sealing always has severe effects on the plant world (Schulte, 1988). Moreover, dry stress and heating effects alter the biomass production of plants as well as the species structure in favour of thermophile and light tolerant species. Habitats are diminished and fragmented, and “minimal habitats” increase.

Greater use of plant production agents and fertilisers causes the physical and chemical stresses on plants and plant communities to incise, which then leads to the extinction of specialised species and the favouring of non-specialised species. Numerous pollutants have a resistance-promoting and species-forming effect on plant communities.

Progressive surface sealing of soils also has a negative effect on fauna (Söntgen, 1988). As urban pressure grows, a decline in the typical species of a habitat becomes noticeable. On the other hand, species that can be classified as ecologically undemanding and thus insensitive (pioneer species, ubiquitous species) dominate more and more until the original spectrum is ultimately eclipsed by adapted species. Significant deviations in population dynamics become visible in many animal species. As environmental degradation due to urban influences increases, ubiquitous species emerge at high individual densities. They reach dominance values of up to 80%, as is characteristic for ecosystems subject to severe stress. Fragmentation prevents wider distribution, finally producing a genetic drift within isolated populations.

In urban regions, however, there are still areas (e.g. cemeteries) that meet the habitat demands of plants and animals (Sukopp and Wittig, 1993). Damage to soil organisms and their interactions occurs not only in urban agglomerations but also in rural areas. Certain agricultural and horticultural uses frequently have a very high biological exclusion effect (Wirth, 1988).

1.3.1.3.2 Agriculture, soil utilisation and biodiversity

Agriculture was and continues to be of particular importance for biodiversity. In the past, agricultural areas contained biotopes with very heterogeneous biocoenoses. The latter consisted of wild plants, a variety of insects and other animal species as well as non-indigenous cultivated species and the flora and fauna accompanying them. In this way, a great number of cultivated species have become indigenous to farming regions over the past centuries.

Recently, however, agrarian ecosystems have been used in a short-sighted way to achieve the highest possible yields in the shortest possible time (Lugo et al., 1993). This went hand in hand with the replacement of small-scale structures by larger field sizes, with a progressive decrease in biodiversity due to imbalanced crop rotations and with application of large quantities of fertilisers and pesticides. Such intensive agriculture impaires soil fertility, making agriculture the one sector of the economy that causes environmental changes and at the same time is directly affected by them.

To this day, the regulative function of cultivated soils is still overtaxed by excessive inputs of substances. As a consequence of this increased throughput of substances, these soils develop into a source of environmental stress. A serious conflict has resulted from this situation: on the one hand, intensive agriculture is necessary in order to meet the worldwide demand for food and animal feed as well as raw materials (Kühbauch, 1993); on the other hand, agriculture has turned into the main cause for declining biodiversity and the destruction of biotopes (Konold et al., 1991). Thus, in regions affected by malnutrition and hunger (Africa, India) it will be necessary to carry out more intensive land use with adapted methods, while at mid-latitudes a shift is required away from excessive intensification of agriculture in favour of a sustainable, environmentally sound and locally appropriate form of land management that largely dispenses with environmentally harmful chemicals and contributes to preservation or restoration of biodiversity.

Biodiversity is also necessary in order to maintain the stability of agrarian ecosystems. The question of how to measure biodiversity has yet to be clarified, however. The monocultures established all over the world (coffee and banana plantations in the tropics; cereal and corn crops in America and Europe) as well as imbalanced crop rotation lead to a one-sided alteration of soil organism communities, an increase in species-typical pathogens, the degradation of water resources and the accumulation of biogenic toxic substances that frequently inhibit the growth of the cultivated species itself (Geisler, 1988). To compensate for this, greater quantities of mineral fertilisers and plant protection agents are applied, thus causing additional stress to soils and possibly disrupting the natural symbiosis between plant roots and microorganisms (Klötzli, 1989).

Nutrient deficiency like nutrient excess leads to changes in biodiversity. As a result of an oversupply of nitrogen, for example, the dominance structure among the species in an ecosystem is altered (Mahn et al., 1988). The degree of coverage by cultivated species generally increases as the intensity of fertilisation and plant protection grows. The number of species and degree of coverage of wild plants, in contrast, drop as the intensity of fertilisation, pesticide application and crop rotation increases (Braun, 1991). The more intensive the agricultural use of a field, i.e. the better the conditions for cultivated plants, and the more space is taken up by the latter, the lower the biodiversity to be found there (Hanf, 1986). This is a typical feature of intensive agriculture. Animal populations (e.g. locusts, predatory arthropods) react to overfertilisation with a decline in individual density (van Wingerden et al., 1992; Basedow et al., 1991). Bauchhenß (1991) has also identified a decline in species and individual density among soil fauna as well.

The concept of “differentiated soil or land use” (Haber, 1992) emphasises the priority of intensive agricultural use only on high-grade, fertile soils. The basis of this ecological land-use concept is the spatial and temporal differentiation of use types and use areas in order to bring about a certain diversity of useful ecosystems, thus contributing to structural and biodiversity as well. Great importance is attached to the agricultural network of roads and the size of the cleared areas. An average of 10% of the agriculturally used area should be left as virtually natural biotopes; it is essential that the latter are connected to one another (biological corridors) so as to ensure preservation of the plant and animal species living there.

The system of “integrated cultivation” can contribute to a reduction of pollution and stress, especially in the field of animal pest control (Knauer, 1991). The natural enemies of these pests must be selectively aided as much as possible, a measure that can only be successful if the living conditions for the useful organisms are optimised. An adequate network of sub-habitats with suitable conditions is necessary, as exemplified by hedges and field margins rich in biodiversity.

Nowadays there is a gradual departure from the eradication of all “weeds” and pests. The so-called “damage threshold concept” is increasingly applied, according to which control of undesired competitors of cultivated species is not undertaken until a defined, species-specific threshold has been exceeded. Recently a certain change of attitude in the population has also become evident. For example, the term “wild herbs” is used instead of “weeds” (Holzner, 1991), since the presence of such plants in an agrarian landscape is certainly justified. Strips in and along the edges of fields are being set up with a great number of indigenous plant species, thus offering protection to many animals and providing nesting sites, etc. Programmes for strips around fields are aimed at encouraging farmers to set up such biotopes (Vieting, 1988; Klingauf, 1988; Raskin et al., 1992).

Extensive farming has a positive effect on biodiversity. The increase in humus content, crop rotation using a greater diversity of species, lower inputs of substances and reduced tillage all lead to a greater abundance of species in the biotic environments of field weeds and grasslands (Müller et al., 1987: Elsäßer and Briemle, 1992). Restoration of more diverse flora species also promotes biodiversity among fauna. Favouring predators of harmful insects in this way can also contribute to pest control. Alternative farming contributes to soil protection and the preservation of species and biotic environments by virtue of largely closed operating cycles based on natural cycles (Necker, 1989). The current compulsion to fallow agricultural land can produce special benefits if this is linked to measures for protecting the plant and animal world and for safeguarding the functions of the natural sphere (Haber and Duhme, 1990). It is possible to ecologically upgrade landscapes where overexploitation demands it, and to subsequently establish a form of “nature conservation” that integrates and networks the needs of both agriculture and nature.

1.3.1.3.3 Forest utilisation and soil degradation

The worldwide loss of arable and pasture land caused by erosion and soil degradation is attributable, in total, to overgrazing (35%), clearing of forests for cultivation (30%), farming (28%), overexploitation (7%) and industrial effects (1%) (Oldeman et al., 1991). Forest clearing alone is therefore one of the main causes of erosion damage, accounting for 30% of the total.

The destruction of forests that has been occurring since the middle of this century, and the soil losses and degradation this has triggered off are no longer limited to specific regions, but, for the first time in the history of humanity, extend through the tropical forests of South America, Africa, Asia, the mountain forests of the Himalayas and, last but not least, to the boreal forests (Herkendell and Koch, 1991). It is expected that the pressure to clear forests will continue to grow in the future (Cleaver and Schreiber, 1992) and that the problems associated with soil destruction will also increase in significance.

Loss and degradation of soils are attributable to different forms of forest use (WRI, 1992; WBGU, 1994) which can be allocated to the following areas:

– *Interventions* in the forest ecosystem: economic utilisation, overexploitation (exhaustion of resources, prevention of natural regeneration), mechanisation and use of chemicals in forestry, cultivation of monocultures, fragmentation of forest areas by settlements and roads.
– *Destruction* of the forest ecosystem: clearing of forests for cultivation (fire clearing, felling).
– *Transformation* of the forest ecosystem: changes in land use (introduction of agriculture and pasture farming, surface sealing).

As a rule, no value of its own is attached to soil preservation as a function of forest utilisation (Routledge, 1987). Some of the above-mentioned forms of forest use (e.g. economic utilisation) cannot be classified as forest- or soil-destroying per se, but in many cases are only inappropriate given the specific conditions of individual vegetation zones

Box 14

Deforestation and soil degradation in Costa Rica

Global deforestation

Open and closed forests still cover nearly 30% of the land area of the Earth today (Sharma, 1992). While the tropical deforestation rate has risen from 11.3 million hectares to 17 million hectares per year in the course of the 80s, no overall decline in forests has been recorded in temperate and boreal regions; the clearing phase took place a long time ago. Latin America accounts for the largest proportion of the destruction of tropical forests (WRI, 1992).

Causes of deforestation in the tropics:

The factor primarily responsible for deforestation is non-adapted land use, especially acquisition of agricultural areas, overgrazing of open forests, fuelwood harvesting and the commercial timber industry. In the tropics, 2.5 billion people are dependent on the forests as a natural resource for goods and services (Sharma, 1992). The most important causal factor of forest-destroying land use is failure on the part of the market as well as of politicians, e.g. lack of consideration given to environmental costs, promotion of forest-destroying activities and the increasing need for land in order to feed a growing population.

Consequences of deforestation in the tropics

Deforestation results in various forms of soil degradation, loss of biodiversity, changes in the local and possibly the global climate, disruptions of the hydrological cycle, particularly in water catchment areas, as well as loss of habitat for the population groups affected. Central America has the highest proportion of area (approx. 24%) affected by moderate to extreme soil degradation caused by deforestation (WRI, 1992).

Deforestation in Costa Rica

Almost 100% of Costa Rica was originally covered with forest, with a natural vegetation consisting of tropical rainforests, dry forests, cloud forests and mountain forests. In 1940, 67% of the country was still covered with forest while at the beginning of the 90s the figure had dropped to 17% (Hall and Hall, 1993).

Causes of deforestation in Costa Rica

The main cause of this rapid deforestation in Costa Rica is very clearly the demand for land, particularly for commercial activities, and not the demand for timber (see also Lutz and Daly, 1990). The demand for timber can be met, for the most part, from the “waste” produced during the clearing of forests for cultivation, which is carried out above all for (government-subsidised) acquisition of agricultural land. In contrast to timber, there is a receptive market for agricultural products, including exports.

Agriculture:

Pastureland now accounts for 70% of the agricultural areas in Costa Rica (O’Brian and Zaglitsch, 1993) or 44% of the total land area (1984) (Lutz and Daly, 1990). Beef production for export, i.e. to obtain foreign exchange, is the main driving force behind this development. It is also promoted by low labour and capital needs in comparison to other forms of land cultivation and the special status of livestock breeders in society there. Conversion of forest into farmland also plays a role. Farmland expands because of the growing food needs of the rapidly increasing population as well as the simultaneous losses of productivity on existing agricultural areas. Furthermore, there is a great demand for land on which to grow *cash crops* (acquisition of foreign exchange), such as bananas and coffee in particular, and sugar cane to a lesser extent.

Timber industry and forest management:

Timber is mainly used as firewood and for industrial purposes. According to available estimates, 60% of felled timber volume is lost due to inefficient processing. Until 1968, roughly, Costa Rica’s timber industry was predominantly exploitative. Since then, felling has been subject to various statutory regulations. This control is insufficient, however, since illegal felling of timber is just as widespread as legal felling. There is a lack of personnel to implement the regulations, and little interest among the population in preserving forest resources –

"untidy natural forests" are regarded as inferior to "tidy cultivated land". Furthermore, managed forests are exclusively in private hands, so their utilisation is largely a private matter. There is a general lack of economic incentives aimed at sustainable forest management. Prices for timber are very low on both domestic and export markets. Production volumes in the Costa Rican forestry sector have dropped accordingly over the last 30 years, from 5.9% to 3.5% of GNP (Sharma, 1992). Another important aspect is the connection between the development of transport routes and deforestation: in Costa Rica the two are closely correlated; there is very little forest left in the proximity of transport corridors (Brown, 1993). The last large contiguous remains of natural forest are located in regions that have not been opened up for transport, as in Talamanca and on the Osa Peninsula.

Consequences of deforestation in Costa Rica
All known degradation phenomena can be found in Costa Rica: soil erosion, and soil degradation caused by physical and chemical factors. Soil erosion is a frequent problem after vegetation losses (deforestation) because of the strong relief and high levels of intensive tropical precipitation. This applies particularly to the Pacific side of the highlands. More than 60% of the country can only be kept stable in the long term by means of forest cover (Repetto, 1991).

Erosion is aggrevated after the transformation of forests into agricultural areas due to non-adapted land use, such as overgrazing, the establishment of monocultures without adequate soil cover, the lack of erosion protection measures and burning off of vegetation remains at the end of the dry period. Estimates indicate that 680,000 t of soil are washed away from agricultural areas every year (Coseforma, 1993). The consequences of soil erosion include losses in agricultural productivity, damage to ecosystems, loss of biodiversity and touristic value, as well as deposition of the eroded topsoil in reservoirs, where they bring about losses in volume (limitations of hydroelectric power potential), and in coral reefs and mangroves, where they cause losses of biodiversity and disruptions in the fishing industry.

Physical degradation: Compaction of soils and structural destruction in Costa Rica are mainly the result of trampling by cattle and non-adapted farming methods (e.g. use of machinery), particularly in areas with precipitation over 3000 mm and with correspondingly wet soils.

Chemical degradation: In Costa Rica, losses of nutrients occur due to leaching and crop harvesting, while uncontrolled and excessive use of pesticides, especially in areas with monocultures, leads to contamination. Discharges of toxic substances into neighbouring systems, such as groundwater, rivers and seas, can be observed as a consequence of chemical soil degradation.

Measures to protect soils in Costa Rica
The following measures appear to be particularly suitable:
– Establishing protected areas, especially for existing forests.
– Sustainable agriculture, including agroforestry, i.e. environmentally sound intensification on areas already under cultivation.
– Sustainable forestry and timber industry, supplemented by new, environmentally sound uses such as eco-tourism, cultivation of medicinal plants, etc.
– Reafforestation of pastureland (secondary forests), plantations and shelterbelts.

To institute these measures, however, appropriate socioeconomic and political conditions or arrangements are necessary. These include:
– Land use planning and environmental legislation.
– Environmental information and education.
– Participation of affected population groups in land-use planning.
– Improvements to the economic attractiveness of the timber industry, i.e. economic incentives for sustainable land use.
– Reduced pressure to grow cash crops on unsuitable land.

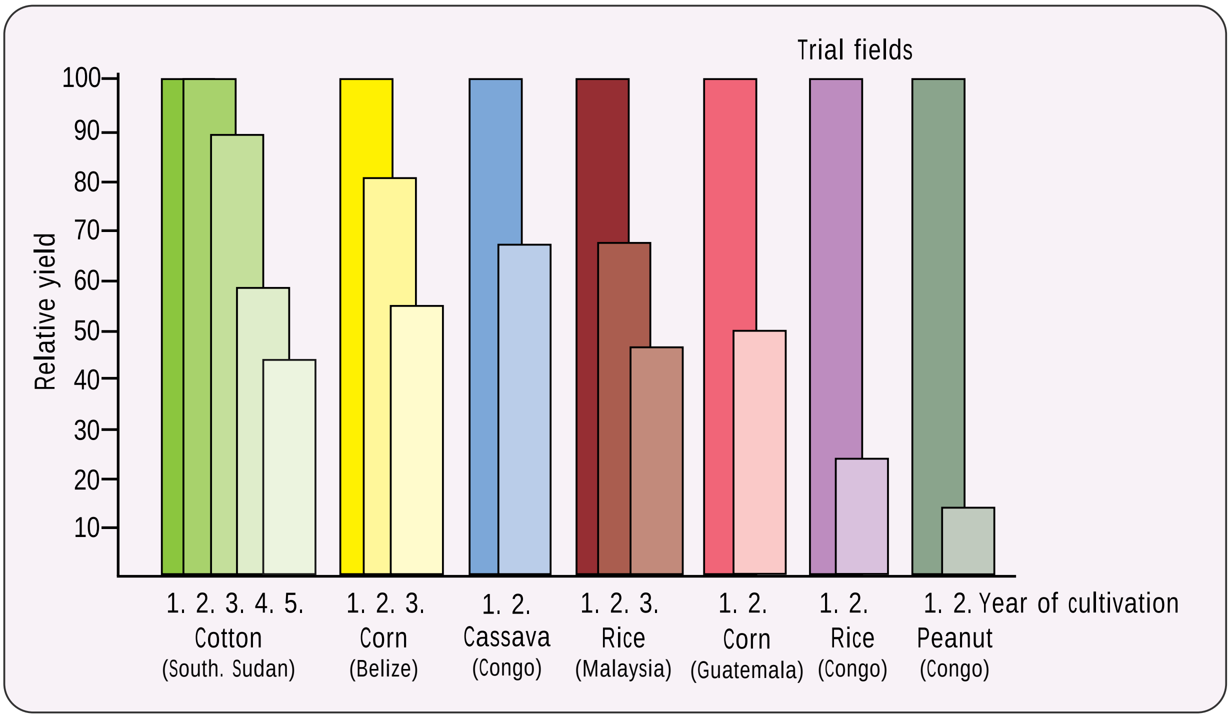
("non-adapted" forms of forest use) (Millikan, 1992; Jones and O'Neill, 1991; Cook and Grut, 1989); others, such as overexploitation, are disadvantageous for any forest ecosystem on the Earth.

The main problem consists of the continued *clearing of forest areas for cultivation in tropical and subtropical climate zones*. The protective function of the forest for soils is lost as a result of its destruction and, in many cases, the subsequent non-adapted utilisation of such areas. Nutrient losses occur relatively quickly, followed by erosion, impairment or even destruction of the regulation function of the soils within the balance of nature, especially in relation to water resources. Even in countries in temperate zones, unwise management of forested areas causes the loss of productive soil – one only has to think of the effects of forest fires in many Mediterranean countries. Broadly designed reafforestation programmes to combat erosion are now being implemented in many OECD countries.

Modern forms of agricultural land use (or changes in land use) are totally inappropriate for many tropical forest soils (*Fig. 19*) (Anderson, 1990). Tropical rainforests are unique in the world with regard to their species abundance and complexity, but at the same time most of them are among the most nutrient-deficient of all forest soils. The very dense network of roots close to the surface serves primarily to fix the trees in the ground, and less for nutrient uptake; the surface vegetation forms part of a nutrient cycle that is virtually closed: "The tropical rainforest lives de facto on, not from the soil" (Herkendell and Koch, 1991). Rarely is environmental destruction at once so severe, causal relationships so obvious and the damage so sudden as in tropical rainforests.

A special problem is posed by the *destruction of mountain forests* and their function as water catchment areas, in that lower-lying areas are also affected by erosion and deposition of soil and rock material. Among the most severely affected regions are the mountain regions and lowlands south of the Himalayas (Blaikie, 1985). "In the lowland regions of Pakistan, India and Bangladesh, 400 million people are completely dependent on how 64 million use their land" (Enquete Commission, 1991). The mountain forests of Nepal, for example, were reduced by half between 1960 and 1980. Exacerbated by unfavourable natural conditions, Nepal annually loses approx. 240 million m^3 of soil, which is washed away towards India. Increased quantities of water and sediment loads lead, in turn, to greater and incalculable flooding in India with substantial losses of human life, destruction of settlements, crops and livestock; the area threatened by flooding has more than doubled since the 1960s. Similar problems exist in the Philippines, China, Central America and in the foothills of the Andes from Argentina across Columbia to Venezuela.

Figure 19: Yield declines on tropical forest soils



Source: Mückenhausen, 1973

In the *boreal forests* of Russia and Canada, large-scale clearance of forests and rising clearance rates are the main problem (Diem, 1987; Rosencranz and Skott, 1992); in terms of absolute area and rate of clearance, the dimensions here are just as alarming as in the case of the destruction of tropical forests. More forested areas are being destroyed today in North America through clear felling than in the Brazilian rainforest (Hamm, 1993). Losses of biodiversity, changes in the microclimate and in water resources as well as effects on the soil ecosystem are the consequences. In particular, large-scale removal of vegetation cover combined with greater insolation leads to a progressive increase in soil temperature, leading to snow cover thawing more rapidly and an expansion of the summer thawing zone in permafrost regions. Another effect thus induced is greater degradation of the humus layer and faster release of stored nutrients. The reduced infiltration rate then results in greater surface runoff. The reduced water storage capacity causes erosion and waterlogging of soils to a major degree. Tundra tends to expand at the expense of forested areas. Finally, the use of harvesting and transport vehicles brings about compaction and destruction of the soil structure.

A special problem is the clearance of forest areas on mountain slopes, as occurs in the forests of North America. In northern California, Oregon, in the rainforests of the state of Washington and in neighbouring British Columbia, for example, entire mountains have been cleared. Severe erosion, sometimes in the form of landslides, is the inevitable result. Despite many regionally alarming effects on the pedosphere, however, such impacts do not seem to be quite as severe as the soil degradation and soil losses found in tropical zones.

Permanent forms of vegetation, such as forest, are very effective at preventing the pollution of groundwater with nitrate. Once forests have been cleared, a large proportion of the organic substance often remains in the soil; this decomposes in the course of time, thus increasing the input of nitrate into groundwater. In many cases the destruction of forests, with all the consequences for temperature and precipitation conditions and for energy supply this involves, ultimately leads to deterioration of the ecological and socioeconomic situation in regions concerned. Fuelwood scarcity in the Sahel, for example, resulted increasingly in dung being used as a substitute; this meant that it could no longer be used as plant fertiliser, thus contributing, in combination with other factors, to the desertification of further large areas (see also Section D 2.1). Large tracts of fertile soil are lost every year, or their utilisation becomes uneconomical, as a result of this mechanism. This often happens in precisely those regions where exponential population growth creates an enormous requirement for additional agricultural land simply to maintain the present food supply level.

1.3.1.4 Population and soils

The type and extent of Global Change are often determined by the interrelation between demographic and pedospheric developments: high population growth exerts enormous pressure on soil functions, on the one hand, while the soil degradation thus induced triggers off additional migrations and urbanisation processes, on the other, which in turn may lead to further stresses on soils elsewhere.

The higher the rate of global population growth, the greater the demands placed on soil functions. Current demographic trends are therefore of crucial importance when assessing the extent of global soil degradation caused by the interaction of population growth, migration and urbanisation.

1.3.1.4.1 Demographic developments

The global population growth trends described in the 1993 Annual Report remain unchanged in 1994. The political resolutions and action programmes initiated by the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro had not had any perceptible effect on population growth and its spatial distribution within the short period since UNCED. More recent expertises indicate, rather, that the medium-term population forecasts of the World Bank and UNPD would appear to be accurate (DGVN, 1993). As described in the 1993 Annual Report, this means an expected growth in the world's population to 10 billion people by the year 2050, with an increase of roughly 97 million people annually up to the end of the millenium (WBGU, 1994).

Regional differences in population growth display some obvious trends: one can assume, for example, that the additional world population will largely be concentrated in Africa, Asia and Latin America. The forecast growth rate for Africa is approx. 2.9%, for Asia approx. 1.8% and for Latin America approx. 1.7%, whereas the estimated figure for Europe is only 0.3% (WRI, 1994).

The fact that rapid population growth is particularly prevalent in African states means that any global approach would have to concentrate its focus on this continent (see Section D 2.1). One must ensure, however, that the issue of population growth is not subjected to further political polarisation as a result.

1.3.1.4.2 Intra- and international migration, urbanisation

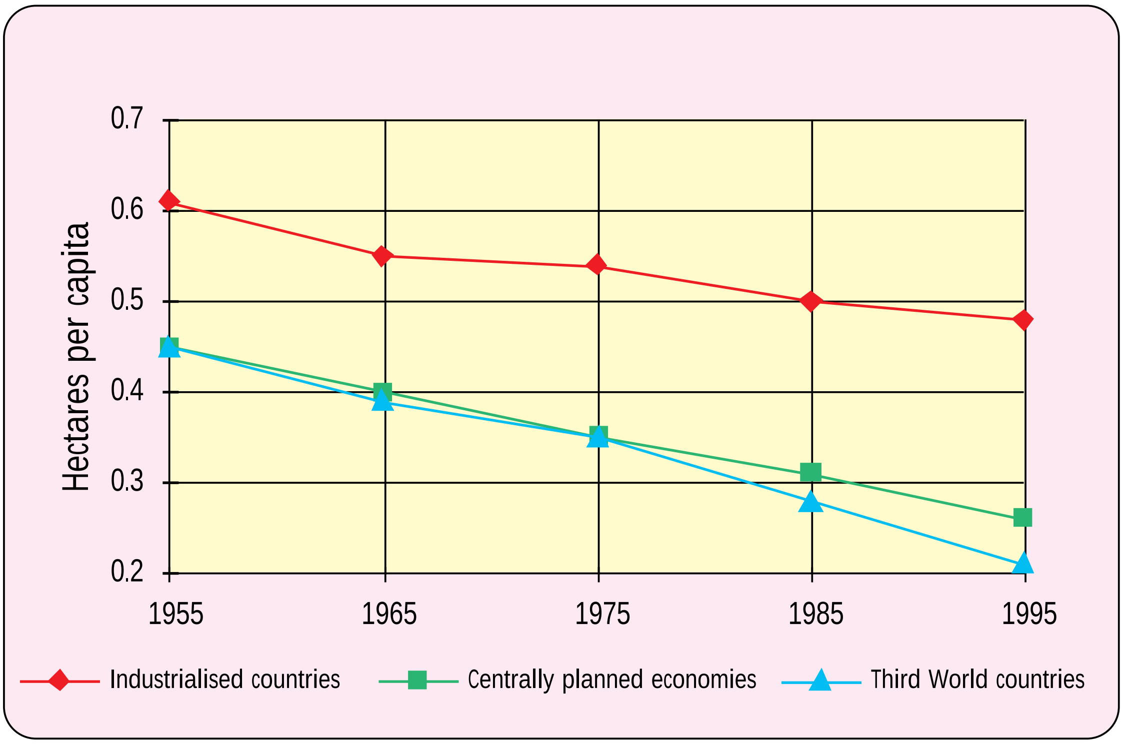
Increasing *intra- and international migrations* represent an already visible consequence of the relationship between the pedosphere and demographic development (see network of interrelationships, *Fig. 26*). However, mere awareness of this fact is not a sufficient basis for solving the problems, already described in the 1993 Annual Report, involved in identifying current migrational movements and forecasting future migrations. Intranational migrations, which predominantly occur as migrations from rural to urban areas and thus have a decisive influence on urbanisation, especially in the developing countries, continue to follow previous trends: the population in urban agglomerations is growing at a global rate of over 2.5%, as a result of which urbanisation-induced stresses on soils are significantly reinforced. The overproportionate growth of cities is particularly alarming in African countries, where the average rate of population increase is now 4.6% (DGVN, 1993).

1.3.1.4.3 Population growth and the carrying capacity of soils

To satisfy their basic needs, people are dependent on soils as the basis for food production, as a supplier of raw materials, as recreational space, a water filter and a location for housing and infrastructure. Given the limited availability of soils, the following options are open to human societies with rising population levels:

– increasing the capacity of soils, e.g. by applying innovative techniques or fertilisers,
– converting areas left in their natural state to anthropogenically utilised soils or
– increasing the production potential of soils by gearing anthropogenic land use more strongly to food production, e.g. by preventing or reversing the surface sealing of high-quality soils.

Figure 20: Estimated development of agricultural area per capita



Source: Wöhlcke, 1992

All of these options have their limits, however, resulting in a growing disparity between growth-related *demand* for and the *availability* of land. Many states are no longer capable of feeding their own populations with domestic agricultural products. This should not be taken to mean that a nation must be self-sufficient with respect to food supply, but that the utilised area per capita is already declining despite expansion of the total land surface used for agricultural production worldwide (*Fig. 20*). This expansion cannot keep pace with population growth, while at the same time a large potential of valuable soils is permanently lost (DGVN, 1992).

Not all people affected by the loss and destruction of farm and pasture land actually become environmental refugees, but this form of environmental damage certainly generates more environmental refugees than any other (Wöhlcke, 1992). Environmental refugees either look for a way to develop potentially useful areas elsewhere, or migrate to urban regions where they further aggravate the environmental problems there.

As already explained in the 1993 Annual Report, population growth renders it virtually impossible to reduce the *global* consumption of goods and services, even if highly developed countries were to voluntarily cut their consumption levels. The expansion of production necessary from a global perspective will lead, in all likelihood, to further environmental pollution, including increasing quantitative and qualitative pressure on soil functions. Raising per capita consumption in the developing countries would necessitate more extensive *exploitation of raw materials*, for example, even in a situation where the structure of goods is altered by substitution processes. Meeting the basic needs of growing populations also places greater demands on the *infrastructure*, however. More people require more *housing*, which in some cases is built on previously unused land. Population growth also places higher demands on *food supply capacities* and therefore on soils as a “location for plants”.

1.3.1.4.4 The subjective need for usable land

Demands for land result not only from an actual need, however, but frequently from a subjective need as well, as is the case with the supply of housing space. A trend towards single-person households can be observed in the industrial countries, leading to an increased demand for housing space and thus settlement area. In Germany, for example, the per capita housing space of the population increased from 15 m^2 sqm to 34 m^2 in the period from 1950 to 1981. This additional “requirement” is not usually met on existing settlement areas, for example by increasing the number of storeys. A tendency can be observed, especially among those with a secure occupation and rising income, to move to the green belts around cities where it is easier for them to regenerate naturally and to ensure that their children are brought up in an environmentally aware and health-conscious way. This suburbanisation is accompanied by a *displacement of supply functions*; besides an increased demand for housing space, there is also an increased demand for land on which to locate supply, educational and transport facilities.

1.3.1.4.5 Sustainable solutions?

As already stated, one can respond to the increasing pressure on the production function of soils by enhancing their productivity or by expanding the area of land in use (at the expense of the habitat function). The instruments available for these alternatives depend on local scarcities or local conditions and comprise an entire catalogue of measures ranging from the use of fertilisers and pesticides to mechanical intervention in the form of drainage or fire clearing. The application of such instruments can prove successful in the short to medium term, i.e. the supply functions can be maintained or even extended to a certain degree; as a rule, however, these measures have a severe impact on soils. Known manifestations include overgrazing, overfertilisation, incorrect crop rotation, insufficient fallowing and excessive use of agrotoxic substances. These result in erosion, compaction, acidification and salinisation which may lead in turn to the irreversible loss of soil functions, offsetting any positive effect achieved by the original measures. Instead of expanding the area of useful land, significant reduction of the available potential of such land may occur, which often amounts to the population losing its basis for existence, ultimately triggering intra- and international migration on a major scale.

The interactions between demographic development and soil degradation are gaining importance, particularly in those regions characterised both by population growth and low-yield soils. The UNPD has calculated that the average per capita land requirement for agriculture, road and settlement construction is 0.1 ha over the long term. Taking the mean population forecast of the UNPD as a basis, this means an additional demand for land of roughly 4.5 million km^2 by the year 2050; this corresponds to approximately two thirds of all protected regions of the world in 1989 (DGVN, 1992).

1.3.1.4.6 Problems in determining land use

The above figure is only a rough reference value, and indicates the difficulties involved when quantifying land needs and land consumption. In Germany, for example, a considerable improvement in land-use data can be expected as modernisation of the cadastral land survey progresses – land-use statistics now distinguish between *actual* and *planned* land use. A study conducted by the *Council for the Protection of Rural England* (1993), in contrast, determined that, in Great Britain, the conversion of natural soils to utilised land (at a rate of 130 km^2 annually) is almost triple the official estimates. If such shortcomings can be found in countries with modern surveying systems, far greater error rates can be expected in the land use surveys of developing countries.

1.3.1.4.7 Regionalisation and specification of land needs

On the basis of forecasted population growth to the year 2000 or 2025, additional land needs can be partially regionalised by taking the above-mentioned global average value of roughly 4.5 million km^2.

Such a rough estimate is not sufficient for a more precise analysis of the effects of population development on land needs, however; a more precise regional analysis is imperative here. Intra- and international migrational pressure is created and reinforced in regions where the basis for human existence is declining (also due to soil degradation), or where this basis is no longer adequate for a growing population.

The difference between the average available and average required area per capita can be regarded as an important indicator for the migrational pressure in the respective regions. If this balance is negative, a critical situation results for soil functions, in addition to the general migrational pressure (cf. criticality index, Section D 1.3.2), and there is a tendency towards overexploitation and changes in land use as well as a danger of supply bottlenecks.

To ascertain such “critical regions”, one requires national land balances; no statistical basis exists as yet for finer regional subdivisions. The area potentially available for human use (i.e. production, carrier and information function) has to be determined in each specific case, whereby the areas necessary for the habitat, regulation and cultural function of soils must also be taken into account. The amount of land needed for food production and other services to the local population (settlement, transport, recreation, etc.) must be compared to this potential useful area.

A negative balance (useful land potential minus land needs) at present or in the future can therefore be an important indicator pointing, for example, to the threat of inadequate supply, the acceleration of soil degradation, the threat of international migration and the necessity of securing a basis for existence in non-agricultural sectors (in order to guarantee the requisite food imports via international trade).

1.3.1.4.8 Minimum land requirements

To estimate the necessary minimum area per capita, regionally specific features, such as production conditions and food or consumption behaviour, must be taken into account. While *eating habits* in the Western world (Europe, North America, former Soviet Union) do not essentially vary, average food needs in Asia will not be as high as in Central Europe even in the year 2010. This average need was determined by the “Landbouw Economisch Instituut” in The Hague and compiled in the form of so-called “nutritional patterns”. The latter are based on existing, regionally specific staple foods and their composition corresponds to a person’s daily minimum requirements – or “net consumption”. The term “net consumption” stands for the fact that more food (calories) is produced than is consumed; waste is produced during food preparation, and other foods are fed to livestock or destroyed. In the Netherlands, for example, an average of 3400 Kcal per capita and day are produced while only 2380 Kcal are actually consumed (ISOE, 1993). In North America, Europe and Japan, total food production is approx. 1.5 times the quantity consumed. In the developing countries, roughly 10% of the production for human consumption is lost, a potential that is certainly of significance in view of rapid population growth and, not least of all, increasing soil degradation.

In 1987 the Brundtland Commission assumed that food can be produced worldwide on a total cultivable area of 1.5 billion hectares. A figure in this order of magnitude was also the basis for a calculation of potential figures carried out by the Commission: based on crop yields of 5 t of grain equivalent per hectare and year, the total potential is 8 billion t of grain equivalent (7.5 billion t from farmland and an additional 0.5 billion t from production on pastureland and from fishing). Given a current worldwide average consumption of 6000 Kcal per day of plant energy for food, seed and livestock feed, approx. 11 billion people could be fed with the production levels deemed possible. If, however, the average consumption climbed to 9000 Kcal (which certainly appears possible in view of growing demands), then only 7.5 billion people could be fed (Hauff, 1987).

The significance of this calculation is limited by the fact that no explicit regional differentiation was included. Carrying capacity calculations of this kind or similar require a regionalised analysis to be able to take distribution problems into account. Basing such calculations on total capacity is a mistake; the basic needs of people in their respective environments must be ascertained instead.

According to the 1992 World Population Report, the *area under cultivation* in 1988 was approx. 0.29 ha per capita worldwide. While the industrial countries utilised an average of 0.51 ha per capita, the figure for the developing countries was only 0.21 ha. For the year 2050, the FAO estimates a worldwide average value of 0.17 ha. The developing countries will then only be able to cultivate 0.11 ha of agricultural land per capita (DGVN, 1992).

On average, the *calorie requirements* in Africa are currently 2154 Kcal per person and day, 2253 Kcal in Asia, 2254 Kcal in Latin America, and 2353 Kcal in North America (ISOE, 1993). These figures must be adjusted in order to calculate the land requirements of individual countries since, for example, the number of household members in Africa will also be greater than in North America in the year 2010. Other variables include consumption behaviour, production and working conditions, the anatomy of human beings, the productivity of soils and the use of biological or artificial fertilisers. On this basis it would be possible to provide better information on actual land needs.

Another major factor determining land needs is progressive *soil degradation* and/or the net primary production that can be achieved with sustainable land use (see Section D 1.2.3). In the face of rapid population growth, many assume that an expansion of agriculturally useful land is an absolute prerequisite which must be satisfied if humanity is to have a stable food base. This is all the more relevant given the fact that human settlements usually expand at the expense of agricultural areas and not of deserts (DGVN, 1992). The UNPD, for example, forecasts an expansion in agricultural area of 1.76 million km^2 by the year 2050, of which 1.6 million km^2 are accounted for by the developing nations alone. Other publications (Hauser, 1991), however, indicate that a greater expansion of farming land is only possible in a few regions in Latin America and Africa, though prospects vary, of course, from one country to the next. For countries like Bangladesh, India or Egypt there is practically no way of expanding the agriculturally useful area.

ISOE (1993) assumes that, to attain the objective of “Sustainable Development”, an average of 0.183 ha of agriculturally useful land per capita will be needed worldwide in the year 2010: with this area, it would be possible to cover the minimum plant energy requirement of an individual person. In Europe, 0.119 ha per capita would be necessary, but 0.304 ha per capita in Latin America as a result of the prevailing environmental conditions there (see *Table 17* for a comparison with other regions). However, given that the *Sustainable Netherlands* study did not give explicit consideration to the use of innovative, environmentally sound technologies, a further reduction of land requirement can be expected; the Council suggests that a figure of 10% be assumed in order to have a minimum estimate.

Within the framework of a population carrying capacity study by the FAO, a value of 0.056 ha per capita was assumed for other land requirements, such as housing, transport and industrial or office space. This value must be differentiated, because the high mobility of industrial countries, for example, places very different demands on the transport infrastructure to those in developing countries having a low number of motorised vehicles. This modification was possible with available data material regarding transport, industrial and housing space. Three infrastructure indices were initially determined on a national basis from these data; these indices were then weighted according to their quantitative dimensions and compiled into an overall index.

Table 17: Determination of available and required agriculturally useful area (aua) per capita, in ha

Continent/Region	available aua according to ISOE	available aua according to WRI	necessary aua according to ISOE	necessary aua according to WBGU	necessary settlement area excluding aua according to FAO and WBGU index	Sum of needs in useful area according to ISOE	Sum of needs in useful area according to FAO and WBGU
Africa	0.25	0.26	0.19	0.17	0.026	0.216	0.196
Asia excl. China	0.16	0.14	0.20	0.18	0.026	0.226	0.206
China	0.08	0.08	0.16	0.15	0.018	0.178	0.168
Latin America	0.45	0.39	0.30	0.27	0.043	0.343	0.313
North America	0.55	0.97	0.12	0.11	0.082	0.202	0.192
Europe	0.26	0.25	0.12	0.11	0.057	0.177	0.167
former USSR	0.79	0.78	0.15	0.13	0.052	0.202	0.182
Oceania	1.81	1.87	0.23	0.21	0.099	0.329	0.309
World	0.25	0.26	0.18	0.16	0.056	0.236	0.216

Source: FAO (1982b), ISOE (1993), WBGU (1994) and WRI (1994)

1.3.1.4.9 Regionalisation of minimum requirements

On the basis of this data, the demand for land in terms of (absolute) minimum requirements in the respective region can now be determined. Overall, the following land requirements have been calculated for the individual continents or regions (*Table 18*).

If one relates the calculated figures to the demographic development of the continents or regions, the resulting land requirements are found to be significantly higher than the UNPD forecast (0.1 ha: DGVN, 1992).

Table 18 compares the WBGU calculations for the years 2000 and 2025 with the UNPD calculations. Even though the WBGU figures are substantially higher than those of the UNPD, it must be remembered that the WBGU calculations are based on person-related, regionally differentiated *minimum* requirements for useful land.

Table 18: Continental and regional requiremend for useful land, for the years 2000 and 2025, in thousand ha

Continent/Region	WBGU: Needs up to 2000	UNPD: Needs up to 2000	WBGU: Needs up to 2025	UNPD: Needs up to 2025
China	26,900	16,012	85,838	51,094
former USSR	3,598	1,977	11,539	6,340
Africa	43,996	22,447	187,158	95,489
Europe	1,943	1,164	2,777	1,663
Oceania	1,131	366	3,560	1,152
Latin America	26,761	8,550	107,237	34,261
Asia excl. China	90,595	43,978	265,402	128,836
North America	4,552	2,371	10,752	5,600

Source: DGVN (1992) and own calculations

The WBGU study results for the years 2000 and 2025 are presented cartographically at the nation-state level in *Figs. 27* and *28* (Section D 1.3.2).

1.3.1.5 Economy and soils

1.3.1.5.1 Decentralised coordination of soil functions?

The problems of soil degradation can be analysed from an economic perspective in different ways. As was done in the Sustainable Netherlands study (ISOE, 1993), for example, one could describe current and future economic trends and analyse the associated degradation effects. The global picture that would emerge from such an analysis – ignoring population growth for the time being – is that degradation is primarily caused by the advancement of certain forms of agricultural land use in connection with deforestation. The scarcity of fertile soil is becoming more and more noticeable, particularly in the developing countries. This scarcity is not only a consequence of high population growth, but is also the result of overexploitation and unwise use of soils. Soils in developing countries are deteriorating due to the removal of nutrients, while erosion is reinforced by large-scale and/or non-adapted utilisation and desertification, and accelerated where water is also scarce. In the industrial nations, on the other hand, soil degradation occurs as a consequence of agricultural land use, particularly in the form of contamination. This is compounded by the expansion of settlement areas, urbanisation, extraction of natural resources, industrialisation, etc., especially at the local and regional level (see Section D 1.3.3).

The underlying causes of these various forms of soil degradation become more apparent if one applies an economic analysis of land use (allocation theory). Above all, the question is to what extent the market is at all capable of guaranteeing a global solution to the problem – i.e. putting a stop to rapidly advancing soil degradation.

Soils perform a number of functions, i.e. they offer a range of different utilisation options, depending on their natural characteristics, some of which can be influenced by humans (see Section D 1.1.2.1). From an economic point of view, therefore, every area of land embodies a kind of production function, with soil characteristics representing the production factors and soil functions the output. The various soil functions, or categories of output, form a complex network of relationships with each other and also with the specific characteristics of the soil. In some cases, conflicting relations exist, i.e. utilisation of the soil for one function excludes other utilisation options or at least restricts them, whereas other cases may feature complementary relations. Another problem is that short-term use may contradict long-term objectives.

The economy, as the central element of the anthropogenic sphere, is the primary source of demand for soil functions and as such is primarily responsible, along with population growth and population distribution, for the degradation of soils. From an economic perspective, soil degradation is caused by inadequate resolution of the allocation problem along the temporal axis, i.e. by non-optimal allocation of scarce resources in order to achieve a long-term increase in net social welfare. In most countries on this planet the solution to the allocation problem, i.e. coordination of soil supply and demand according to the various soil functions, is provided through the interactions of market relations and state regulations (such as planning regulations that limit the scope for using specific areas of land). If one ignores natural influences for the time being, soil degradation is thus a consequence of market and/or political failure, although this "failure" is frequently only related to some soil functions. Attention is therefore focused in the following on specific aspects of market failure.

Market failure inducing soil degradation, meaning inadequate (long-term) coordination of the many anthropogenic demands with limited (or even declining) land use potential, can be expected if

– there is no clear definition and implementation of exclusive *property rights* to soils as functional entities (which can be attributed to political failure in many cases),
– for non-legal reasons (e.g. on the basis of physical soil characteristics), there is no possibility of excluding others from the use of soil functions, i.e. soils have the characteristics of a collective asset with regard to certain functions,
– individual knowledge of the long-term benefits and costs of exploiting soil functions or of the relations between the respective soil functions is inadequate, or where short- and long-term utilisation interests diverge to the extent that short-term considerations dominate to the detriment of crucial long-term needs,
– transaction costs are high (transactional market failure) and
– severe external effects occur (usually as a consequence of political failure) which subvert the control function of market prices.

Such failures are widespread and thus crucial factors contributing to the degradation of soils worldwide. Further explanation of this will be provided in the following.

If one examines these aspects, one after the other, it would appear that coordination deficits and thus soil degradation are firstly the result of *poorly defined soil and land use rights*. This is the case, for example, when the legal framework restricts or revokes the right of the owner to exclude others from using his land. The principle of liability is then restricted, it becomes more difficult to apply the "polluter pays" principle and a situation is engendered in which others can take (short-term) advantage of this non-exclusiveness – without having to invest in the sustainability of the land use. Any opportunity favouring "free-rider" behaviour – such as toleration of legally impermissible use of land by a third party – may thus lead to overexploitation or inappropriate use of soils (Hardin, 1968b). There are several basic ways in which land use rights are regulated.

Particularly problematic as far as the prevention of soil degradation is concerned are *open access* systems, where users who make endeavours to maintain long-term land use potential must constantly fear that others will harvest the fruits of their efforts (Hartje, 1993). This results in the threat of overexploitation, especially where population density and industrial land use are increasing. As a form of land use for long-term maintenance of the soil utilisation potential, common property regimes are regarded rather sceptically, but they can function under certain basic conditions – low opportunity costs, strict limitations on the number of users, pronounced homogeneity of interests, clear regulation of collective liability, etc. (Ostrom, 1990; Hartje, 1993). Considerable research efforts are being made in this area, especially in the U.S., guided by the notion of *common property resources* (*International Association for Common Property Resources*).

Soils lend themselves well, on account of their spatial delimitability, to a clear definition of property rights. Therefore, the accusation of market failure is not generally applicable; many manifestations of soil degradation must be attributed instead to political failure. Many countries still lack a clear allocation of property rights and/or any assertion of acquired rights (World Bank, 1992). In such cases, overexploitation or inappropriate use, i.e. degradation of soils, is the inevitable consequence. The allocation of clear property rights, combined with state guarantees for these rights, is a key recommendations for sustainable land use policies.

Allocating property rights does not suffice, however, as a means to prevent soil degradation. Rather, further coordination shortcomings that favour soil degradation and make additional measures necessary may even appear where a clear definition and implementation of *property rights* is guaranteed on the basis of the existing legal structure.

Such coordination deficits result from the fact that property rights can be defined primarily only for the carrier and yield function. This approach is doomed to failure in the case of other soil functions due to the operative mechanisms or natural soil characteristics (Micheel, 1994). Any restriction of the habitat function, for example, due to utilisation of the soil for pastureland purposes (clearing of tropical forests) not only has a direct effect on local or regional biodiversity, but also has global implications on account of the interlinkages between ecosystems. Consequently, with regard to soils one can designate

– the habitat function as a *global collective asset*,
– the regulation function as a *collective asset* whose spatial reference is determined by ecosystem interrelations, and
– only the production and carrier function as *individual assets*.

This means that the formulation of exclusive property rights and thus market-related coordination appear successful only for the carrier and production function, whereas this is not possible without qualification for the functions with collective asset characteristics. Use options therefore exist which do not involve any form of payment. In the short term it may be individually rational to exploit the existing utilisation potential as thoroughly as possible (see Hardin, 1968b; Buchanan, 1968; Weimann, 1991; Gschwendtner 1993 on "free-rider behaviour"). In that case one can expect an overexploitation of the global environmental functions of the soil, i.e. a conflict results between individually rational short-term behaviour and the globally desired objective of long-term maintenance of environmental functions (Althammer and Buchholz, 1993). This individual, short-term perspective may undergo fundamental change in the direction of long-term preservation of a specific resource if there is direct experience of environmental damage (Axelrod, 1986; Weimann, 1991). However, this can only be expected to a limited extent, because there is usually inadequate perception of global interrelations, especially of the individual's contribution to damage caused. A negative influence on long-term environmental preservation functions can especially be expected, when increasing scarcity of agriculturally useful land and high population growth induce a struggle for survival and thus an emphasis of the utilisation function of soils.

It is becoming increasingly evident that any assessment of the various soil functions depends on a country's level of development, population density, available land, the opportunities it has for importing food, and the extent of other land utilisation needs (e.g. for settlement purposes). At the same time, there is a growing realisation that special attention must be devoted to all measures that bring about a sustainable increase in yield capacity of soils (with respect to food production), given the rate of population growth and the global decline in agriculturally useful land. The Council therefore attaches special priority to recommendations aimed at achieving that objective.

Allocating definitive property rights is not sufficient to solve the problem of global coordination shortcomings, because most individuals concerned have inadequate knowledge of the long-term benefits and costs of soil function utilisation or of the relations between the individual soil functions, or because short-term utilisation interests dominate over long-term interests. A good example of these *information problems* that make market coordination difficult is that of the environmental impact on soils which result from utilisation in the past (problem of inherited pollution). In many cases, only previous owners possess sufficient information regarding possible restrictions of soil functions. As a result of the uncertainty involved in making a qualitative assessment of an offer, the potential users of production and carrier functions are then faced with the problem of

- either assuming the risk of having to accept possible utilisation limitations regarding the acquired land,
- making extensive investments to acquire information via external expertises, with a residual risk of undetected qualitative shortcomings
- or of accepting higher costs for conducting negotiations and drawing up a contract to ensure that the previous owner is liable for any limitations of utilisation.

These alternatives may involve such high risks and costs that a transaction does not take place. On the other hand, a seller of land may also be induced to dispense with a transaction because of the possible risk that an existing qualitative impairment of the soil functions is subsequently identified for which he must then bear the cost.

Such information problems thus lead to a situation in which also the soil functions that can be allocated individually are not subjected to market-based allocation (Hecht and Werbeck, forthcoming). One consequence of the inadequate market allocation of carrier and production functions is the inefficient utilisation of these functions within the spatial limits of the relevant land market. This may then result in global consequences if locally inefficient utilisation of the carrier and production function triggers direct effects on ecologically relevant global soil functions (as habitat function). Secondly, long-term transnational and global restrictions may result, through the international division of labour, from local restrictions of soil functions if the demand for these functions shifts to unused land in other areas, regions or countries (utilisation of marginal soils) as a consequence of local displacement of utilisation demands, where further qualitative impacts on soil functions then occur. This development could also reinforce, for example, the transfer of soil-sensitive economic activities from the OECD states to countries with a lower degree of industrialisation (Sorsa, 1993).

In many cases soil degradation problems can also be attributed to a *combination of information problems and a disparity in short- and long-term soil utilisation interests*. Enormous increases in food production per hectare have been achieved through the so-called "green revolution" (high-yield cereal varieties, large-scale mechanisation, fertilisation, application of pesticides and plant protection agents, etc.). In some cases, however, this increase was "bought" with soil erosion, overacidification of the soil or pollution of groundwater and surface waters with harmful substances, i.e. – as was not perceived until later – with a violation of important conditions for sustainability. Thoughtless application of such forms of soil utilisation to countries with different soils may even aggravate this problem of long-term loss of functions.

This clearly demonstrates the importance of *transaction costs* in land markets and how these can cause serious coordination deficits. In most cases, the bulk of transaction costs are incurred through the determination of concrete cause and effect relations and through negotiations, and less as a result of market implementation (*Box 15*).

This problem is aggravated by *external effects* since efficient allocation of soil functions is also obstructed in the event that others are impaired (or favoured), as a result of an economic activity, without being compensated accordingly (or

Box 15

Transaction costs are costs of

- defining and allocating property rights (costs of market implementation),
- determining cause and effect relations and thus the relevant target groups,
- coordinating divergent interests through negotiations in order to arrive at clearly defined regulations,
- safeguarding the outcome of negotiations by means of monitoring systems and sanctions.

Transaction costs may therefore exceed the benefits obtained through the global allocation of soil functions via market mechanisms; failure to reduce such transaction costs will hinder or even prevent market coordination at the global level.

having to pay). In the case of negative external effects, the scarcity of the utilised soil function is not conveyed, in the form of appropriate pricing. A striking example is impairment of soil functions due to depositions of pollutants from the air. If, for example, the production function of a forest soil is impaired by NO_x depositions caused by other agents, the holder of the property rights to this function, usually the forest owner, would, in fact, have to enter into negotiations with the emitter of the airborne pollutants in order to receive payment from the latter for use of the forest soil. However, clear verification of the extent of the reduction in function by a certain emitter of harmful substances is not possible as a rule because of the high number of potential polluters, the numerous synergy effects and the large transboundary area that is often involved. This problem is aggravated still further when there are different national implementation regulations regarding damage claims. In such cases, it is highly unlikely that soil functions can be efficiently allocated through decentralised negotiations.

1.3.1.5.2 The need for global action: Conclusions

The above analysis has shown that there are major shortcomings regarding the coordination of global land resources and the demand for various soil functions, a situation that is substantially responsible for soil degradation. This applies in particular to the regulation and habitat function. Clear definition and assertion of property rights thus requires market-supplementing and/or alternative forms of coordination of the individual demands placed on global soil functions. The following are of fundamental importance:

- greater orientation of the specific forms of soil utilisation to long-term sustainability conditions,
- consideration of soil functions with collective asset characteristics in those allocation decisions that have been oriented to the production and carrier function, and
- implementation of an allocation structure that takes better account of spatially divergent soil utilisation potential.

There is agreement – regardless of implementation problems – that defining a target efficiency level for the various functions at the global level makes little sense, given the heterogeneity of the basic natural and anthropogenic conditions at the aggregated level, and would probably be impossible to operationalise. The same applies to the operationalisation of distributional targets, given the different perception of socioeconomic values in individual cultures and heterogeneity of economic conditions. There would be a constant risk of having to impose targets on individual consumers or users in the respective countries which deviate from their own, targets that would be out of proportion to any benefits obtained from the efficient allocation of global soil functions. Therefore, establishing better worldwide coordination of individual demands on soil functions cannot be achieved with centrally defined specifications regarding the precise local forms of global soil function use. Instead, it is important to combat the causes of current deficiencies in decentralised allocation and to provide individuals with appropriate incentives, while developing the most efficient forms of utilisation in the light of possible “bottlenecks” in global soil functions. The following paragraphs deal with this issue.

Table 19 shows the main demands, indirect linkages, spatial reference and global or transnational interlinkages for the four main soil functions, entered as rows. Column 2 describes the demands on each function. These demands may be quantitative or qualitative in nature, as is also the case with their respective impacts. Individual economic activities display specific features with respect to the demands they place on soil functions. Characteristic of agriculture and forestry, for example, is their use of the production function for biomass transformation and exploitation. This is linked to a qualitative demand since the productivity of the activity depends on such factors as the nutrient composition of the soils used. Long-distance tourism, on the other hand, primarily involves utilisation of the regulation and habitat functions, since an intact local ecosystem enhances the attractiveness of the area. This implies qualitative demands on soil as the basis for the existence and functioning of living organisms.

Demand for a particular soil function directly reduces the capacity of that function, and can also have an impact on other functions. This may either be triggered off as a side-effect of the economic activity in question, or can come about as a consequence of interrelations between the soil functions. An example from the agricultural sector is the artificial input of nutrients to support the natural production function. If fertilisation is carried out beyond the needs and absorption capacity of plants, an increase in nitrogen and, consequently, an impairment of the regulation function may result with consequential negative effects for other environmental media. An additional consequence of anthropogenic influences on the nutrient balance is a change in the basic natural conditions for animals, plants and microorganisms, thus affecting the habitat function of the soil.

From an economic perspective, soils represent geographically immobile assets. Therefore anthropogenic influences on soils operate first and foremost at the local or regional level (*Table 19*, column 4), although transnational or global aspects are also involved (*Table 19*, column 5). Because consequential processes beyond the regional sphere are mainly of an indirect nature, questions emerge as to the time frame in which international problems are created; problems are also generated regarding the attribution of causes and effects. In addition, analysing time frames requires a focus on irreversible processes. When soils are built over, for example, their capacity to store CO_2 is lowered, with the possibility of irreversible losses of soil productivity in the long run. This makes it necessary to assess the benefits that could be derived from this soil productivity in the meantime so as to be able to compare it to the current benefits of building over the soil. Such an assessment, however, would require the most precise possible derivation of the effect that such building activity would indirectly have on soil productivity worldwide.

The economy is a complex system that can affect different networks of interrelations. These networks cannot be adequately portrayed for a global level of aggregation, but have to be regionalised instead. The countries of the world have been classified in *Table 20* into seven large country groups for this purpose. These country groups are distinguished according to their economic structure and the typical demands on soil functions derived from this structure. In addition, possible regional bottlenecks in the utilisation of soil functions are pointed out by comparing the demand profile with the respectively available soil function potential. It is characteristic of countries in groups (1) – (3), for example, that economic activities place extreme qualitative demands on the carrier function, leading directly or indirectly to immissions into the soil. Structural transformation in the countries of groups (1), (2) and (4), involving development towards services and higher-value industrial goods, also means altering demands on soil functions in these countries.

These changing demands imply not only a possible reduction in the qualitative impairment of soil functions due to emission transports, but also increased pollution of soils via highly contaminated waste depositions. Structural transformation is usually accompanied by an expansion of the directly quantitative use made of the carrier function in order to further develop a functional material infrastructure. At the same time, one can observe an increasing demand for unpolluted soils (growing importance of environmental quality of soils as a location factor) as affluence and tertiarisation rise. In view of the intensive use that has been made of soil functions to date, the result in most cases is further utilisation of scarce soil function capacity.

Table 19: Demands on soil function and global changes from the economic perspective

Soil function	Typical economic demands	Indirect links	Direct spatial reference	Global / transnational links
Production function	Transformation and exploitation of biomass, e.g. by agriculture and forestry, quantitatively and qualitatively	Qualitative demands on soil, effects on the regulation, habitat and carrier functions	Local	Primarily via world commerce, indirect effects on other ecosystems
Carrier function	Quantitative demands as a result of excessive building, qualitative through activities with direct or indirect contamination of soils	Reduced capacity of the regulation, production and habitat functions	Local	Primarily through international socioeconomic interlinkages, indirect effects on other ecosystems
Regulation function	Above all qualitative demands through activities which depend on functioning ecosystems, e.g. water supply	Standards demanded by consumers for production and carrier functions are met to a lesser degree	Dependent on the spatial reference of the ecosystem affected	Dependent on the ecosystemic relationships, such erosion, other environmental media
Habitat function	Qualitative demands through activities related to biodiversity, e.g. processing of raw materials in the broader sense, or tourism	Standards demanded by consumers for carrier and production functions are met to a lesser degree	Global, due to the irreversibility of species extinction	Direct ecosystemic links due to importance for biodiversity

Source: WBGU

Table 20: Regionally disaggregated analysis of demands on soil functions from the economic perspective

Regions / Characteristics	Geographical dimension	Degree of sectoral diversification	Soil function predominantly subjected to direct demands	Quantitative soil function potentials	Qualitative soil function potentials
(1) *OECD states with major quantitative land utilisation potentials*	USA, Canada, Australia	Very great, with potentials in all sectors	Production and carrier functions, strong quantitative demands	High	High degradation, strong natural and anthropogenic effects
(2) *OECD states with highly restricted quantitative land utilisation potentials*	European Union, Japan	Very great, with highly developed secondary sector	Carrier function, strong quantitative demands	Almost completely exhausted due to population density	Very extensive degradation, primarily anthropogenic factors
(3) *Former COMECON countries in Europe currently undergoing political and economic transition*	Central and Eastern Europe	Low, mainly primary and basic secondary sector	Carrier function, very strong qualitative demands	Low/Slight	Serious degradation, extreme anthropogenic effects
(4) *Newly industrialising countries in Asia*	APEC states, China and neighbouring states	Increasing, with a tendency to highly developed secondary and tertiary sectors	Carrier function, mostly quantitative demands	Almost completely exhausted	High degradation, mainly anthropogenic factors
(5) *Newly industrialising countries in Central and South America*	Mercosur states, Mexico	Low, mainly primary and basic secondary sector	Production function, both qualitative and quantitative demands	High	Serious degradation, severe anthropogenic effects
(6) *Countries with low per-capita income and quantitative land utilisation potentials*	Sub-Saharan Africa, Central America, Asian states from the former USSR	Very low, almost exclusively in the primary sector	Production function, both qualitative and quantitative demands	High, but accompanied by population growth	Moderate degradation, local anthropogenic effects
(7) *Countries with low per-capita income and minimal quantitative land utilisation potentials*	North Africa, Arabia, Indian sub-continent	Very low, mainly primary sector, establishment of a basic secondary sector	Production function, increasingly carrier function, high level of qualitative demands	Inadequate on account of population growth rate	Severe degradation, high proportion of natural restrictions at the local level

Quelle: WBGU

In contrast, the economies of the states in groups (5) – (7) are still strongly oriented to the forms of demand exerted by the primary sector, involving a quantitative as well as an increasing qualitative utilisation of production and regulation functions. Extending simple secondary sector activities in these countries induces forms of demand and action that directly involve an intensive qualitative utilisation of the carrier function as well as feedback effects, in particular on the regulation and habitat function. This means that the already limited functional potentials due to natural preconditions are additionally reduced in these countries. *Table 20* shows that the variety of demands directed at soil functions by the economy are not always adapted to the soil function potential of the respective regions. This has varying effects.

Declining yields, for example, may become a long-term bottleneck factor for agriculture. This is above all the case when irreversible functional restrictions emerge. Bottleneck situations are usually manifested at the regional level initially. Such situations can already be observed today for the production function (see *Table 20* with regard to quantity and quality) in some regions of groups (6) and (7), for the regulation function in numerous places spread over all regions examined and for the carrier function in regions (2) and (4). Given a accumulation of regional bottlenecks, certain economic activities as well as utilisation of the goods and services connected with the performance of these activities may be impaired on a worldwide basis.

To eliminate bottlenecks, there are basically three strategies available:

– Geographic redistribution of the bottleneck factor out of surplus areas.
– Development of efficient methods for utilising available resources via technological progress.
– Use or development of substitutive factors that enable a certain independence from the bottleneck factor.

Overcoming a particular form of scarcity will generally require a combination of these strategies. The respective mix depends on the specific extent of the bottleneck. Thus the first strategy, for example, is linked to the demand for a *better international division of labour*. Since soils are fundamentally immobile, their utilisation is particularly dependent on the diverging utilisation potential as well as on the subsequent large-scale distribution of soil products (trade). There are many indications that regional bottlenecks can be balanced out in a global context in the present and near future so that a sufficient food supply for the world's population still appears feasible (Crosson and Anderson, 1992). Keeping these considerations in mind, it would seem meaningful to exert influence on those factors that have a distorting effect on international trade or on the international division of labour. This point will be dealt with in more detail in Section D 1.3.1.6.

The second strategy, promotion of *technological progress*, is closely tied to the first. There are still significant technology-related differences in the extent to which the regional production function potential of soils is exploited. Progress can be achieved here by increasing the efficiency of soil utilisation or lowering the intensity of soil damage for the same level of use, or by reducing the costs of soil function utilisation via more efficient forms of access.

Since the very regions that are subject to special restrictions regarding the availability of soil functions typically have low technological potential, greater integration into the international division of labour in order to implement interregional technology transfer is recommended, due to the fact that international competition necessitates adjustment to international know-how standards. This adjustment to the current state of the art can alternatively be achieved through independent research, taking out licences or importing preliminary services or production stages, with the last two methods resulting in a considerable reduction of imitation costs. Furthermore, governments in the countries of the particularly affected groups (6) and (7) can induce technological progress by creating suitable basic conditions (World Bank, 1991).

Important factors in overcoming regional bottlenecks are the development of alternative processes with higher productivity or less utilisation intensity, a change to more productive foods matching the soil conditions as well as the field of biotechnology (for example, the development of resistance-promoting substances or further genetic development) (WRI, 1987; Crosson and Anderson, 1992). In many cases this means reactivating traditional methods of production. However, it must be taken into account here that research investments to date have been relatively low in regions (6) and (7), where the need for bottleneck elimination is greatest, so that extensive dependence on *technology transfer* from other regions exists. One problem with technology transfer is that of compatibility with the needs of the recipient countries.

An alternative strategy for overcoming bottlenecks is *substitution of soil function utilisation*. This can be done by substituting the respective utilisation with an alternative form of utilisation for the same function – for example, making use of the production function by growing a fruit that corresponds to the respective soil structures instead of growing monoculture products that were chosen to satisfy the food demands of other regions. On the other hand, this may also be accompanied by a complete change in function utilisation: for example, instead of using the production function of the soil for food supply, eating habits may shift towards products that do not directly require this function (e.g. nourishment from the sea with an indirect dependence on the regulation function).

The efficiency of a substitution strategy depends on several parameters, such as
– costs of changing an economic activity,
– effects of the activity on other environmental media (e.g. water),
– loss of benefits for users that have to adjust to changes in supply as a result of the substitution process,
– savings by virtue of altered or reduced utilisation of soil functions.

Against this background, it is not possible to evaluate a bottleneck due to declining soil function capacity until after the respective strategic potential for overcoming such shortage situations has been analysed. Development of this potential, however, is not foreseeable for the future because of the difficulty in assessing possible obstacles.

Dealing with the allocation of ecological soil functions is even more difficult than solving the problem of a more efficient global exploitation of the soil’s utilisation function within the framework of a global division of labour (including equalisation via international trade). To be able to determine globally significant geological soil functions better, it is first necessary to create an adequate information base. This requires stipulation of clear evaluation criteria as well as systematic recording and assessment of existing areas at the national and international level. These criteria should be specified as orientation parameters in international conventions or transferred to an international body of experts for continuous updating. In the end a global survey of soil functions is to be striven for globally relevant functions. Only in this way can those areas which need protection be identified. Agreements (global conservation policy) stipulating protection-related obligations must then be reached with respect to large protected areas of global importance (*global common goods*).

When implementing such conservation policies in practice, it is particularly important to provide incentives for changing individual behaviour towards an ecologically more advantageous approach: it must be in the interest of the people to use land environmentally sustainable. Only then will individual data on preferences and cost structures regarding soil functions be included in the restructuring process. The instruments for achieving this goal have to take into account that property rights already exist. Changing rights of use therefore involves an intervention into existing ownership conditions. Various options are open to the respective carrier levels, with a large number of institutional alternatives in the individual states. Measures may be directed at quantitative utilisation of various soil functions as well as at influencing soil structures, and thus qualitative components as well.

The need for institutional changes with respect to the production and carrier function involves, as already emphasised, the *definition of exclusive property rights* in order to enable decentralised allocation via the market. Concerning the transaction costs in the event of uncertainty about the qualitative state of the soil, *rules of liability*, particularly risk liability where the land user assumes responsibility for potential damage to the soil through his activity, may, in future, provide incentives to avoid such damage. Such rules would also remove uncertainties for users concerning any restitution of damages (Endres, 1989; Siebert, 1988; Karl, 1992). In the case of already polluted areas, however, there is then a danger that these are not offered on the market in order to avoid liability. Only systematic documentation of hazardous waste sites (*cadaster of hazardous waste sites*) and in many cases a remediation strategy or a pollution-oriented restriction of utilisation (*regional planning*) can help here.

If one examines possible ways of exerting institutional influence on the allocation of soil functions in Germany, for example, one finds that control of quantitative availability is essentially possible with the help of planning law. It must be kept in mind here, however, that this *planning law* is particularly effective when it has the character of negative planning (prohibition of problematic forms of soil utilisation), and therefore helps above all to protect the regulation and (nationally definable) habitat functions. Prohibiting certain function-impairing anthropogenic activities in specified areas under planning law is implemented most efficiently at the regional or local level in the majority of cases (exception: globally relevant nature reserves), since the greatest amount of knowledge regarding the potential competing forms of utilisation and their cost structures is available at this level of competence. Within local planning procedure, negotiations between the individual soil function users may also shed light on the respective preference structures. Conservation groups as well as business representatives which profit from intact ecosystems, such as the tourism sector or parts of the agricultural sector, may take part in negotiations aimed at protecting the regulation and small-scale habitat function. In the case of large-scale biotope structures, cooperation among these local units can also take place in order to make use of network effects in biotope networks. It is meaningful here to involve higher decision-making levels, which would then imply bilateral agreements or global specifications (*global common goods*) at the international level.

Efforts to influence the qualitative component must focus directly on soil pollution. This requires specific analyses of the effects of the individual substances, on the basis of which a graduated system of interventions can be set up. At the private sector level, the first step is to examine the possibility of liability rules. Other possible interventions into the use of substances include the imposition of *charges* and the introduction of *obligations to take back products*. Defined limits should be enforced for substances that lead to irreversible functional impairments when a threshold value is exceeded, while *bans* may be necessary in cases where effects are always irreversible.

In international agreements the dominant approach, besides propagating general objectives, is to stipulate standardised national limits, in some cases with a graduation in accordance with the respective level of economic development. In contrast to this, greater efficiency of soil function utilisation can be expected with instruments that are aimed more at the specific action-taking potential on the part of individual states. Thus international rules of liability, for example, can be introduced with a contractually fixed verification and sanction mechanism. The signatories then guarantee compliance with certain emission limits, e.g. with regard to some air pollutants, and agree on restitution in the event of violation. The manner in which this risk of contractual penalty is made clear to emitters in the contracting states is left to the legislators in the individual countries (Erichsen, 1993).

This instrument can be implemented particularly within relations and agreements between nations having a high economic and administrative levels (for approaches to the formulation of regulations between individual states on civil law liability in the case of transnational pollution, see Gehring and Jachtenfuchs, 1990). For countries with a low per capita income, the incentives for fulfilling the contract can be adapted, e.g. by granting decentralised aid if emission limits are complied with, or cuts in such aid in the case of violations.

1.3.1.6 Institutions and soils

1.3.1.6.1 Institutional causes of deficient allocation of global soil functions – intra-state regulations

Whenever reference is made below to institutional frameworks relating to soils, what is at issue is more than just national or international organisations. What is meant are all the settings that regulate or influence the inner-state and/or inter-state cooperation of economic subjects and political decision-makers in the utilisation of soil functions. For the international level, these generally take the form of legal frameworks and conventions. Arrangements within the European Union (EU) are treated in the following as inner-state regulations, since sovereignty rights have been transferred to the EU level.

Important for the topic at issue here are *constituting* stipulations concerning the creation of a certain economic system or a specific international economic order, as well as *regulating* stipulations that provide for targeted influence on individual economic sectors or within the international framework of nations, via development aid or inclusion in economic zones, for example.

Soil-relevant regulation activities in many industrial countries take the form of political interventions, especially *protectionist measures and support services in favour of the primary sector*, which are based on security interests of the individual state, such as maintenance of a self-sufficient supply (Haase, 1983; Schmitt and Hagedorn, 1985; Eickhof, 1989).

The various forms of regulation activities having an influence on soil utilisation and soil protection include:

– price support measures for agriculture,
– protectionist measures to safeguard certain sectors against those in other groups of countries,
– guaranteed economic benefits for raw material extraction when allocating soil function utilisation,
– price regulations, purchase guarantees and import restrictions for products obtained from raw material extraction.

The problem here is that the provision of such benefits to industrial and agricultural users of soil functions induces soil utilisation that is inappropriate in relation to the scarcity of soil functions.

However, stipulations of a more general nature may also play a role. In almost all industrial countries, for example, land use is subject to a state *planning law* that usually restricts the utilisation scope for individual areas (negative planning) and/or makes utilisation dependent on the fulfilment of certain requirements, e.g. by defining maximum quotas for surface sealing. This planning law influences the allocation structure of land use. It is frequently claimed that the former fails to give equal consideration to all soil utilisation interests (Bowers, 1993; Holznagel, 1990) and that it has an inhibitive effect on the process of social transformation due to lengthy planning procedures and the influence thus granted to particular interest groups (Olson, 1985a; Werbeck, 1993). These are not fundamental objections to planning law, however, but refer instead to structural problems. Of more importance is the objection that regional planning generally requires a relatively long time or a well-developed administrative infrastructure at the lowest (i.e. local government) level for successful implementation. On the whole, regional planning is well capable of asserting soil protection interests.

In contrast, many states with low levels of industrialisation have institutional deficiencies, in particular in form of *inadequate definition and allocation of clear property rights* for soil functions (see Section D 1.3.1.5). This is attributable to a lack of institutional prerequisites (administrative infrastructure) as well as to selective promotion of specific, usually agricultural, producer groups. One requirement, for example, is an administrative structure that enables clear demarcation, implementation and monitoring of individual rights. The existing structures in many developing countries do not fulfil this function due to shortages of staff, finance and technical facilities, or because they cater too much to the interests of the economically dominant agricultural sector (World Bank, 1992). The result is frequently a concentration of ownership rights in state collectives (Abdul-Jalil, 1988) or in the hands of individual large property owners (von Urff, 1992). These basic political conditions often mean that the scarcity of soil functions is not given adequate consideration during the allocation process; this failure is attributable to political factors ("political failure"), not the market itself.

The political interventions in the allocation of soils used for farming result, on the one hand, in the displacement of numerous small enterprises to marginal soils with insufficient production and regulation capacity (Blaikie, 1985; Harborth, 1992). In addition, large state- or privately owned agricultural enterprises are often based on leaseholding systems with contractual periods and payment conditions that only provide leaseholders with incentives to maximise short-term yields (Herkendell and Koch, 1991; Lachenmann, 1989). The result is overexploitation of soil functions.

In developing countries allocation is especially distorted by efforts to increase the degree of industrialisation. The policy in most cases is to grant subsidies for imports of capital goods and technical know-how as well as of capital (Amelung, 1987), combined with subsidisation of land prices to facilitate industrial and infrastructural utilisation of the carrier function of soils, and with inadequate institutional safeguards for the regulation and habitat function. In contrast to such policies, the agricultural sector is often hindered in its development through export duties and low, state-regulated pricing systems (see Olson, 1985b for an analysis of the low degree of organisation of interest groups in these countries compared to the situation in the OECD states).

1.3.1.6.2 Institutional causes of deficient allocation of global soil functions – international regulations

The articulation or non-articulation of particular interests in the decision-making of individual states also has implications for the articulation of interests in the global context. Distortions in the allocation of soil functions at national level are often reinforced by institutional arrangements at the international level, due to the number of international interlinkages. At the international level, the focus is on achieving economic benefits at the expense of other states. This *rent-seeking* depends significantly on the economic power of individual states, or a community of states that join forces to implement an international trade measure.

This network of effects can be illustrated with the following example:

– The starting point is the fixing of import quotas of a world gravitational centre (i.e. a powerful industrial nation) like the stipulation of a maximum import quantity (e.g. banana export quotas for individual Central American countries to the EU).
– The result on the protected market is a decline in supply and a price increase which is easy to implement given the low price elasticity typical of basic foods.
– The competitors of those affected by the quotas, in this case the banana suppliers within the EU and the ACP states, receive a higher price as a result, while consumers, on the other hand, must spend more for bananas.
– Importers can expect the reduced volume of sales to be compensated by the higher price.
– The producer countries, by contrast, are faced with the problem of having to either sell the goods on other markets or change their range of products if such demand does not exist on the world market, as is typical for bananas.
– The result is a higher price for banana consumers, an economic advantage for protected producers in the intervening country, a neutral effect for the transient vendors and a direct reduction of earnings for producers in the producing nations.

As a consequence, there is an influence on the utilisation of soil functions since the favoured groups feel compelled to expand their land use while the disadvantaged are forced to change their utilisation of the soil due to the trade restriction. Institutional arrangements must be established in response to these international pressures on soil functions, arrangements which prevent the interests of individual states being asserted in this manner.

In the field of global soil changes, it is useful to distinguish between three institutional options for shaping international law (Ipsen, 1990; Birnie and Boyle, 1992):

– customary law
– court rulings
– law of contract (including the authorities derived from law of contract).

The principle of territorial integrity, which regards a “significant” transboundary violation of environmental assets as illegal, is generally accepted in *non-codified international customary law* (Erichsen, 1991). This implies a basic recognition of an obligation on the part of individual states to provide compensation for damage arising in connection with the utilisation of soil functions (Erichsen, 1993). However, the word “significant” is subject to broad interpretation, and there are no sanctions against violations of the respective norms (Rest, 1991).

Implementation by the International Court of Justice is also based on voluntary recognition of decisions by those concerned. In legal practice to date, the principle of sovereign action by states has dominated (Bryde, 1993). State sovereignty, however, can be restricted by treaties and/or transferred to other organisations.

A number of *international treaties* that the Council regards as relevant for the domain of global soil change are analysed in the following. This analysis focuses first of all on the immediate objective of the treaty, classifies this objective with respect to compatibility with a global allocation objective for soil functions and examines the agreed coordination mechanisms in order to arrive at a possible consensus embracing the diverging interests of the contracting parties. The treaties are grouped according to five categories with a progressively narrow focus within the networked interrelations of economy and soil functions:

1. general political agreements
2. general environmental agreements
3. general economic agreements
4. agreements regarding environmental media
5. institutions for specific economic sectors

General political agreements

General political agreements are only useful for establishing the basic framework within which specific regulations can then be defined. Such treaties thus contain no direct reference to global soil functions. The basic global framework is provided by the United Nations, established by the UN Charter of 1945. This organisation has delegated specific environmental matters to special bodies described in more detail below. The general basis on which international treaties are concluded is the “Vienna Convention on the Protection of Treaty Rights” dating from 1969 (effective as of 1980). The main contents of the convention are (Birnie and Boyle, 1992; Ipsen, 1990):

– definition of the individual states as contractual subjects under international law,
– the possibility of reservation clauses in contracts,
– guidelines for the interpretation of treaties,
– regulations regarding the invalidity of treaties,
– recognition of general, or customary, norms, without defining their specific content.

This type of treaty therefore establishes a general framework within which the allocation of global soil functions has to be specified in detail.

General environmental agreements

This category includes, in particular, the special United Nations organisations dealing directly with the environment (Kilian, 1987). In addition to the UNDP, the UNEP – institutionalised as a result of the 1972 *United Nations Conference on the Human Environment* – functions as a body for the coordination of global environmental protection activities. The activities of these organisations are concentrated on improving the information base regarding Global Changes of ecosystems, as well as the initiation and coordination of international cooperation (Birnie and Boyle, 1992; Kilian, 1987). Decision-making in the special UN bodies is characterised by the principle of equal voting rights for individual states (“one country – one vote”). This means that representatives from countries with a low degree of industrialisation – particularly groups (6) and (7) in the regionalisation model outlined in *Table 20* – possess 39 of the 58 seats in the UNEP Executive Council. The UNEP is financed through funds from the general UN budget and from voluntary contributions. In view of its relatively minor potential for influencing decision-making, there is little willingness among countries with large amounts of capital – in the regional model the countries in groups (1) and (2) – to expand the financial endowment of the UNEP. Moreover, these countries generally show little willingness to extend the competence of the UNEP so that it can intervene directly in national sovereignty.

The *United Nations Commission on Sustainable Development* (UNCSD) was set up as a result of the 1992 UNCED conference in Rio de Janeiro. This Commission, which reports directly to the General Assembly and which carries out integrated analyses for the Economic and Social Committee (ECOSOC), has been charged with monitoring progress in the implementation of AGENDA 21. The latter contains numerous references to measures for influencing the allocation of global soil functions (WBGU, 1994). Implementation and funding these measures, however, is based on the principle of voluntary action. There is a strong likelihood that the work of this Commission will ultimately be limited to information, coordination and initiating functions, since the decision-making and financing rules are essentially the same as those of other UN organisations.

In summarising general environmentally agreements, two major interest structures can be identified:

– Those countries with the financial strength to determine the functional capacity of global agreements, and which therefore want some form of direct control over the size and allocation of these funds. This control is exerted through the principle of voluntary contributions, combined with restrictions on transfers from the UN budget and a limitation of competences to activities that do not represent a direct intervention into national sovereignty.

– Those countries with little finance view these institutions as an instrument for controlling, on their own terms, the reduction of their financial, technological and ecological deficits. They are aided by the principle of equal voting rights for individual states within the decision-making process.

These restrictions of competences according to particular interests lead to different assessments of the potential effect of these institutions. Whereas some analyses emphasise a positive, long-term development towards greater responsibility and a subsequent decline of interest conflicts following a steady change in awareness (Levy et al., 1993), others point out the high transaction costs and the lengthy negotiation processes (Rometsch, 1993; Klemmer et al., 1993). The urgent need for action means that global, environment-related agreements are only suitable to a limited extent as a means for remedying deficits in the allocation of global soil functions in the short term.

General economic agreements

The increasing interdependence between national economies, noticeable in the form of an intensifying international division of labour is also affecting the capacity for individual states to assert their sector-specific allocation interests regarding the utilisation of soil functions over the interests of other countries. This situation lends increasing importance to general economic regulations designed to control this interdependence with respect to very specific objectives.

GATT (*the General Agreement on Tariffs and Trade*), is of primary importance for the allocation of global soil functions, in that its purpose as a global trade agreement is to support the liberalisation and intensification of world trade, thus having direct and indirect effects on soil functions due to the various interdependencies that exist. The World Bank Group, the central institution for global cooperation in the field of development policy, must also be mentioned on account of its major potential for influencing a change in demand for soil functions.

Although from a legal point of view GATT has merely been a multilateral agreement until now, it has gradually assumed the character of an international organisation during the 50 years of its existence, covering a broad spectrum of tasks with over 100 full and approx. 30 associate member states. The objective is to achieve a worldwide increase in welfare by improving the international division of labour. Efforts are being made to completely integrate all world resources and to increase the exchange of goods. This has consequences for global soil functions, since eradicating allocation distortions in international trade is a prerequisite for balancing the actual benefits and costs of soil function utilisation. Central GATT principles include the “most favoured nation” clause, which requires that individual countries give equal treatment to all contracting parties within foreign trade (principle of non-discrimination), the principle of reciprocity, which makes reciprocity the basis of customs negotiations, as well as the principle of “fair trade”.

In addition to a General Assembly of the Member States, held at irregular intervals and whose decisions are usually based on a simple majority, there are the so-called “tariff negociations”, in which bilateral or multilateral negotiations are conducted on contractual modifications. Successes to date have largely been limited to the reduction of tariff-related trade barriers, which still leaves the member states with scope for protectionist measures, despite initial efforts to regulate quantitative, non-tariff trade barriers (Schultz, 1984). Even the latest GATT agreement, signed in Marrakesh in April 1994, and the treaty on the World Trade Organisation (WTO), which is to arbitrate trade conflicts in the future, has done little to change this situation since even this institution has only weak sanctioning powers. Another aspect is the increasing importance of regional trade associations (EU, NAFTA (*North American Free Trade Agreement*)) as a lever for protecting interests. GATT will only withstand new protectionist tendencies if contracting parties suffer severe penalties in the event of verifiable violations of contract, and can be kept from taking one-sided, bilateral measures.

Integrating environmental protection into GATT will play a greater role in future. There will be a focus on protective clauses and anti-dumping provisions (specification of minimum environmental and social standards) in regional agreements, for example, although compatibility with the GATT provisions or principles still needs to be clarified. This applies especially to the definition of so-called environmental dumping. Taking the soil conservation perspective, the Council believes that the primary focus should be on immissions-based criteria. Furthermore, the relevance of GATT for the allocation of global soil functions is still restricted by the fact that the agricultural sector, one of the most intensive user of the production function of soils, is excluded from central GATT principles.

Despite the formal principle of balance, the gravitational centres of world trade (countries in groups (1) and (2) in *Table 20*) have considerable de facto powers to assert their own interests through the agreed sanction mechanisms, which provide for the affected country to implement countermeasures in response to violations; countermeasures taken by the economically more powerful nations would have substantial impacts on those at the receiving end. Moreover, the importance of a global forum has diminished for the world gravitational centres due to the increasing number of regional integration zones under the direction of individual world gravitational centres (such as the EU and NAFTA), where the interests of individual states can be concentrated through the larger-scale harmonisation of aims. Extending GATT's competences and responsibilities to directly include the effects of trade on the environment, as demanded by numerous parties (Kulessa, 1992; Cameron, 1993), can only be expected to a limited extent at present in view of this constellation of interests. On the other hand, there is no doubt that the WTO and/or the next GATT round must deal with these issues.

The World Bank Group plays a significant role in the allocation of global soil functions insofar as demands and effects on soil functions stem from economic activities it initiates in countries with low per capita income (particularly the regions (6) and (7) in *Table 20*). The objective of this institution is firstly to legitimate its competences; secondly, its membership structure means that it is directed at expanding the economic influence of donor nations and obtaining direct benefits for the governments of recipient countries (Frankenfeld, 1991). Decision-making competences are distributed according to contribution levels, so that the types of measures taken are significantly influenced by the world gravitational centres as the largest contributors.

Until now, the World Bank Group has given direct consideration to environmental functions in very few of its activities. Because of the declining acceptance of its projects in recipient countries, however, environmental protection objectives have been explicitly included in its charter and statutes (Range, 1991; Goodland, 1992), and greater involvement of local decision-makers has been the result. There is now an independent commission that examines projects for their environmental impact on request. Compared to the general environmental agreements, the World Bank Group possesses enormous financial and technological potential, which could also be used to influence soil functions in countries with low per capita income (see Osten-Sacken, 1992 and Spangenberg 1992 on the agricultural research institutions relevant for the production function, i.e. the *International Agricultural Research Centers*, IARC and the *Consultative Group on International Agricultural Research*, CGIAR). By contrast, the funds of the GEF cannot be used for preserving and promoting soil functions (BMZ, 1993).

These institutions possess, on the one hand, a high potential for determining economic activities and thus for making use of global soil functions by virtue of the strong influence of the world gravitational centres. On the other hand, their objective to date has not centred directly on efficient allocation of global soil functions, but focuses primarily on issues affecting the interests of individual economically dominant states.

Agreements regarding environmental media

At the global level, the *World Soil Charter* adopted by the FAO in 1981 is of importance for soils and their functions. The Charter defines:

- principles of land use,
- guidelines derived from these principles regarding measures by individual states,
- international cooperation and information objectives.

This Charter is a general framework for dealing with soil functions. However, because objectives for individual forms of soil utilisation were not exactly defined, and due to the absence of regulations for financing the necessary measures and imposing sanctions in the event of failure to comply with specific elements, the Charter does not represent an intervention in national sovereignty rights. It functions as a mere appeal that can only trigger reactions if the individual states are convinced of the urgent need for action.

As a reaction to the *United Nations Conference on Desertification* that took place in 1977, the UN General Assembly commissioned numerous international studies on the technical and institutional implementation of the UNCOD recommendations for combating desertification (Ahmad and Kassas, 1987). Considering how unwilling those UN members that could provide financial and technical support are to accept binding regulations (principally the states in groups (1) and (2) of the regional classification in *Table 20*), one can only wait and see whether the "Desertification Convention" (see Section C 1.6) will have direct consequences for the allocation of the soil function. In this case, too, one can expect that the industrial countries will not be prepared to abandon national rights of sovereignty in view of the equal voting rights principle.

A number of international agreements exist for other environmental media that can affect soils via the dispersal of substances. For air quality, for example, the *Vienna Convention for the Protection of the Ozone Layer* and its subsequent protocols are of global importance, along with the *Framework Convention on Climate Change*, for which binding reduction targets have yet to be specified. The protocols define reduction targets and deadlines that effectively restrict the freedom of individual signatory states to take action. A greater willingness to cooperate on the part of the less developed countries was achieved by setting up a fund to support the reduction of substances endangering the ozone layer (see "Montreal Protocol" Fund, Section C 1.4.1). The industrial nations were prepared to accept this agreement because, on the one hand, they were affected by this environmental problem and, on the other, were in a position to develop and deploy substitute substances. There was therefore considerable homogeneity of the interests involved in this case.

Other international conventions aimed at reducing emissions were mostly signed by neighbouring states (such as the *Convention on Long-Range Transboundary Pollution* within the framework of the ECE, 1979), whose willingness to conclude the agreement was induced by the direct impacts they themselves suffered. The subject-matter of this agreement and its follow-up protocols is the definition of reduction values for individual substances, whereby the question of how to achieve these targets is left to the individual states (Levy, 1993). With regard to the international allocation of environmental functions, it should be pointed out that there are variations in the reduction levels which could be achieved by the individual signatories, resulting in different costs of emission avoidance. Fixing standard limits for the parties therefore leads to inefficient international allocation, also with respect to soil functions. Willingness on the part of individual states to transfer sovereignty rights to the international level is generally more pronounced where air as an environmental medium is concerned – in contrast to soil functions – since transboundary effects are easier to identify in the case of the former. One can hope that these differences will diminish in the future.

Sector-specific regulations

Sector-specific regulations are examined below with specific reference to those interventions which were agreed upon in order to influence the sectoral demand for soil functions. As an institution for the agricultural sector, the FAO will be looked at first.

- The primary objectives of the Food and Agriculture Organisation of the UN, established in 1945, are to raise food and living standards worldwide, to improve the production and distribution of agricultural products, and to improve the living conditions of the rural population.
- With a membership of approx. 170 states, one can assume a heterogeneity of interests, whereby 75% of the organisation's funds are provided by twelve OECD states (Gygi, 1990).
- In contrast to this disparity in the origin of contributions, the decision-making process is governed by the principle of equal voting rights for the individual states.
- To achieve its objectives, the FAO has set up a "World Food Council" as an executive body whose proposals regarding the operative aims as well as the budget structure have a decisive influence on the resolutions of the General Assembly, which consists of the responsible Ministers of Agriculture of all member states and meets every two years. The actual execution of its institutional mandate, however, is restricted in most cases to technical assistance in the form of disaster aid, support for development projects through cooperation with other international institutions, and the acquisition and evaluation of relevant data.
- In addition, general codes of conduct have been adopted that are not binding, however, on the member states (e.g. *Code of Conduct on Pesticides*).

Analogously to the other special UN organisations, the FAO has been granted little competence by the member states. This is mainly due to the minor influence that the financing countries can apply in the decision-making process. Therefore, the FAO's influence on the type and extent of soil function utilisation has been exerted only indirectly by offering information and technology whose quantity and quality, in turn, must be seen in the light of financial restrictions.

The Council recommends that the Federal Government take action to significantly strengthen FAO and UNEP activities related to soils, especially since soil protection is simultaneously a precautionary measure for avoiding conflicts. The following steps deserve special mention:

- Decisive improvement of the information basis on distribution, properties and stress-bearing capacity of soils; the latter applies to all soil functions.
- Establishment of a global monitoring system that also includes soils.
- Creation, in association with the latter, of an information system serving as the basis for global planning and action.

Another factor influencing the utilisation of the production function by agriculture is the 1973 *Convention on International Trade in Endangered Species of Wild Flora and Fauna* (CITES) with its follow-up conferences, which bans trade in certain animal and plant species and thus restricts the economic activities necessary for this trade (Cameron, 1993; Birnie and Boyle, 1992). The Convention provides for export and import controls by individual states, whereby classification of the species that are not to be traded is constantly updated by the Conference of the Parties (for details see Section C 1.5). Compliance with these provisions, however, depends on the individual states, which also have to sanction noncompliance.

Transferring biotechnological know-how acquired from genetic resources and applying this knowledge to achieve more efficient use of the production function of soils in states which suffer from scarcity of this function (particularly region (7) in *Table 20*), is one element of the *Convention on Biodiversity*, which provides in Art. 16 for easier access to information developed in regions (1) and (2). However, such access is still subject to national legislation and international law regarding intellectual property rights, so that there has not been any improvement in information exchange as yet.

One soil-related regulation that also deals with the effects of activities in other sectors is the 1989 *Basel Convention on the Control of Tranboundary Movements of Hazardous Wastes and their Disposal* which has been effective since 1992. This agreement provides for extensive avoidance of hazardous wastes, and stipulates that such waste be disposed of within the respective country as far as possible. The term waste applies here to hazardous waste that needs special storage. Transport to countries other than the member states is to be avoided. In addition to this regionally limited agreement, regulations prohibiting the acceptance of waste from OECD states have been adopted in other regions. Within the Organisation of African States, for example, there is the *Convention on Transboundary Movement of Wastes* (the "Bamako Convention").

Avoiding the export of wastes to countries whose disposal capacity and methods cannot be accurately assessed can only be welcomed if the objective is efficient utilisation of soil functions, especially since priority must be assigned to reducing qualitative stresses on the regulation function and avoiding the irreversible loss of soil functions.

The statements above lead to the following conclusions concerning the influence of global and international institutions on the allocation of global soil functions:

A consensus has existed among the overwhelming majority of nations since the 1992 Rio Conference, at the latest, that global environmental problems can only be solved through the joint efforts of the international community. All of the policies pursued in this "spirit of Rio" must, on the other hand, realistically take into account the action taken by countries for their own well-being. In many cases, a conflict of interests arises between countries with a highly developed economy and countries with a low per capita income. In the future, therefore, it will be especially important to increase general political awareness of the interdependencies that exist but which in many cases are difficult to see. It will then become clear that, considering the overall context (which also involves effects that have been externalised up to now, or a long-term perspective), apparent national sacrifices (such as contributions to international organisations or environmental policies requiring CO_2 reductions) will also be in the interest of individual states.

The analysis also showed that international conventions only make sense if the global relevance of the problem – and thus an integration of the national interests of all countries, as far as possible – exists sufficiently. If this is not the case, implementation will fail in some countries because they do not feel affected.

Emphasis must therefore be placed on the need for institutions which help to alleviate international conflicts of interest that stand in the way of environmental policy measures. An example from the area of political organisation is the instrument of "double-weighted majority", which guarantees a balance of interests between contributing and recipient countries within the framework of the GEF (see Section C 1.3). The principle of *Joint Implementation* of the Framework Convention on Climate Change also has the potential to overcome national interests regarding the implementation of globally agreed reduction targets (see Section C 1.4).

The Council will continue to devote itself to the topic of improving institutional arrangements at the international level and will examine the operation of instruments which conform to market principles. In particular, it will evaluate the possibility of establishing an international market in soil function rights.

These and similar procedures, which ultimately would be of benefit to all, along with the transfer of knowledge and creation of awareness, are of crucial importance. Further development of existing and/or the search for additional institutions aimed at an international balance of interests is a major prerequisite for the formulation and implementation of global action and thus one of the urgent tasks for the future.

1.3.1.7 Psychosocial sphere and soils

1.3.1.7.1 Significance of soils for human experience and behaviour

Soil is a habitat for people, animals and plants, and in many respects can be seen as the basis for individual and collective action on the part of human beings, as well as of social and societal organisations. Since virtually every human activity involves land and soil, every person is in some way or other a "land actor". This necessity of land use may have negative consequences for the soil, leading to degradation and, in extreme cases, its destruction.

From a human point of view, land performs fundamental functions (see also D 1.1.2.1). It is the indispensable source of nutrition, the fundamental basis determining where people live, work or play, and for the creation of the relevant infrastructures (e.g. roads and pathways), the basis for meeting human needs regarding control over space (territoriality), property and possessions. In addition, land appears as a distinct element of nature and landscape, forming part of the basis for the development of geographic spatial identity as a component of self-identity.

The social, economic, cultural and political differentiation of a society is reflected in spatial – and thus soil-related – structures (Bassand, 1990). The functional specialisation of land use typical of industrial societies in particular, above all the separation of "working" and "living" as functional domains, designates certain types of land and space utilisation (industrial areas, through traffic, "dormatory suburbs"). The division of space into segments (e.g. urban districts), often combined with monofunctional use, creates different livelihoods and ways of life (particular production methods, long distances to work, satisfaction of material, social and cultural needs) and thus different types of influence on soil as well. The social structure, above all the structure of power relations, and the spatial structure are mutually dependent and change in dependence on each other.

In accordance with the livelihoods and ways of life found in human societies, land is of special significance in agriculture and forestry, in the energy and raw materials sector, in industry and commerce, in settlement activities, transport, recreation and leisure time, as well as waste disposal. Within these various spheres, people in different positions, roles and social groupings (as workers, residents, persons organising their leisure time) find different ways of accessing and shaping land.

The very description of these broad manifestations and functions of land and soil for humankind makes it plain that, from the perspective of the social and behavioural sciences, people-soil relations must not be reduced to soil's function as a physical substrate. Rather, convincing approaches to soil degradation must be based on a broader concept of land (what land and soil *is*), going beyond natural science and economics and must expand the definition of functions (the purposes that soil/land *serves*) accordingly. A linguistic analysis of the words “ground”/“soil”/“land” provides sufficient legitimation for such an extended definition (*Box 16*).

As for the environment as a whole, soil as an environmental medium must be regarded and treated not only as a physical but also as a “social construct”, and consequently as a correlate of human perception and human behaviour (WBGU, 1994). Thus soil is experienced by individuals, groups or societies at different epochs with very different meanings (valences) that go far beyond the nature of a mere substrate. That which is nothing more than “dirt” for some and the basis of their nourishment and survival for others, can for a third be “holy ground”, whereby the basic substrate may have the identical physical composition. In its complex significances soil thus plays the role of an “archive” from which valences and actions of individuals, groups or entire societies can be reconstructed. Soil as an environmental medium thus fulfils an important cultural function by virtue of the fact that, to a certain extent, it contains the traces of actions and at the same time represents the space in which every culture develops.

The significance of this cultural function is demonstrated by the fact that land (or what land produces) numbers among the oldest and, even today, most important objects of human appropriation. The active confrontation of human beings with their natural environment leads to historical (phylogenetic) and biographical (ontogenetic) assimilation processes, within the framework of which people “make their mark” on the environment in a variety of ways and make it their own through their actions (Graumann, 1990). This appropriation may take place by taking possession of land (property

Box 16

Meanings of “ground”/“soil”/“land”

The term “ground” (Indo-German) is used in German, and in other languages, with a number of different meanings. This is demonstrated by, among other things, the variety of proverbs in which “ground” has appeared in the course of time.

The concept of soil as “physical substrate” corresponds to the use of the term in the natural sciences, in the sense of earth, ground or cultivated land; it designates the external layer of the Earth’s crust, the pedosphere, and is similar to the understanding of soil as a production factor, as a manipulable variable.

Another, more abstract meaning which can be described using the terms *condition* and *prerequisite* (something falls on “fertile ground/soil” or “the ground/soil is prepared” for it) is based on the natural qualities of this substrate (“solid ground”, in contrast to water). Closely related to this is the designation “ground” for a *basic area* and figuratively for the foundation (on the basis “of facts”, on the foundation “of the Constitution”) on which one moves (standing, more or less, “on firm ground”).

Characteristic of this area of meaning is the security embodied by the ground. This security aspect may also have a negative side to it, as when the “ground is cut from under someone’s feet” or to be on “shaky ground”.

Even further away from the physical substrate is the concept of ground in connection with territory, terrain or space, where it is frequently associated with power, influence, economic or military gain: thus one can, for example, “gain or lose or make up ground”.

In another context, ground may also refer to the very bottom of something, either literally or figuratively, e.g. “our hopes were dashed to the ground”, to get a project “off the ground”, the house burned “to the ground” or to run a car “into the ground” – thus often with a negative connotation.

In a historical perspective the significance of ground or soil becomes particularly visible in the pars pro toto identification of nature (as a third production factor in addition to labour and capital) with the ground, as in the case of the early economists (see Moscovici, 1982).

Sources: Beyer and Beyer, 1985; Drosdowski, 1963, 1976, 1992; Grimm and Grimm, 1860; Küpper, 1983.

ownership as a symbol of power and wealth; also: conquest), generally through utilisation and modification (exploitation, building development; structures created by humanity) or merely through naming or marking (symbolic definition of areas, e.g. as occupied, holy or taboo), through movement in space (creation of paths or roads by walking, driving) as well as through scientific or artistic representation (pictures, models, graphs) and through communication.

The soil's social function, which is directed at "spatial behaviour" that is always land-related (e.g. segregation processes, territorial behaviour, needs for proximity or distance, personal space), corresponds to its cultural function. On the one hand, the differential perception and evaluation of land, which must be seen against the background of the respective societal conditions, may lead to very different social conduct ("holy ground", for example, may not be built on). On the other hand, it is precisely social structures and human actions within these conditions (such as production methods, allocation of property rights, regional planning, control over land) that manifest themselves in different meanings of soil or ground or land.

We can conclude from the above that, in every confrontation with the topic of soil, even in an analysis of the carrying capacity of soils, the cultural as well as the social function has to be taken into account to a greater extent than has been the case to date, and that their significance for the impairment or preservation of the other soil functions must be researched.

1.3.1.7.2 Human perception of soil

More so than the environmental media of water and air, soil has the character of being taken for granted by humanity – at least in the industrial countries: the ground that we stand and walk on, that we cover with crops for nourishment, with factories, residential buildings and roads, that we want to possess, over which we attempt to exert control – that which is literally the basis of our existence is hardly perceived by us; it is experienced as having always been there and as correspondingly secure. As already indicated, however, there are culturally specific features here, a fact that has yet to be proven empirically for lack of suitable comparative studies.

The fact that we do not pay special attention to the soil is presumably connected with its generally low degree of perceptibility. In a highly industrialised country like Germany, soils are barely visible in their original form for many people due to the great extent of surface sealing (by building structures of every kind, and asphalting of even the smallest paths). When, however, soils do appear in people's everyday lives, as a meadow or field, as gardens or parks, then usually only visually and from a distance, as well as, in most cases, in a condition of "anthropogenic transformation". Only a few groups within our population have regular and direct contact with soils – miners, construction workers or farmers – though in the age of industrialised, intensive agriculture, the latter are frequently only familiar with soil from the "tractor perspective" and regard it as a commercial production factor. For all other population groups soil appears, above all, as a developed or built-over environment, predominantly in the form of buildings or streets. The resulting, purely functional perception of soil must certainly exert a considerable influence on people-soil relations and thus on the behaviour of individuals.

In interviews, for example, conducted by Knierim (1993) with crop farmers and livestock breeders from the ethnic group of the Peul in the Sahel Zone of Burkina Faso she observed that their perception of land and its changes differs, depending on the respective use, and – and closely associated with the latter – on ethnic origin. However, the degree of dependence on land as a resource is obviously reflected in the perception of the problems by those surveyed. For crop farmers, for example, the central environmental problem was the decline in soil fertility, which became visible for them through the decline of their crop yields. They believed insufficient rainfall and the growing population to be responsible for this situation, however (regarding both as beyond their control) while their own involvement in land changes (through deforestation, neglect of hedges that protect against wind erosion) was not mentioned in the interviews. For the livestock breeders among the Peul, on the other hand, the most important environmental problem was the quantitative as well as qualitative decline of certain tree and grass species that were essential for their economic survival. They, too, viewed reduced rainfall as the cause of declining vegetation, for which they held "Allah" responsible. Greater grazing pressure or overgrazing, however, was not regarded as a cause. Instead, they referred to the expansion of crop farming into traditional pasture areas.

In industrial societies, soil does not appear to be vitally necessary to most people. While depending on clean air and water in everyday life (and usually noticing negative changes in these immediately, classifying them as threatening), most of us live in our own or rented “four walls” and think about the supermarket shelf when we see meat, bread, fruit and vegetables; in all of this, however, there is no direct trace of soil.

Frequently soil is given attention in a society such as ours (as well as in that of the Peul in Burkina Faso, see above) only when soils *no longer* function in the way we otherwise take for granted, i.e. when a subjectively threatening, radical change in individual aspects of soils emerges in contrast to their normal state (e.g. through earthquakes, landslides, hazardous waste sites, mountain damage, flooding, planning procedure for a new landfill site). Not until the “discovery” is made (by the media, in many cases) that a residential area is located on a hazardous waste site, for example, that a degraded mountain forest can no longer prevent landslides, or that a landfill site is planned in the immediate proximity, does the public concern itself with soil. Then, however, only certain points regarding soil are usually dealt with – and this takes place all too often according to the so-called NIMBY principle (*not in my backyard*). The significant increase in the population’s sensitivity for environmental problems in recent years, combined with the addressing of relevant issues in the media, has resulted in a situation in which changes in the environment are perceived or anticipated earlier and experienced as threatening at an earlier stage.

In many cases, soils are threatened only locally and within defined boundaries (mountain damage, hazardous waste sites, etc.; the global relevance of soil problems primarily results from the cumulation of such local degradation symptoms). In addition, soils possess considerable buffer and self-cleaning capacities with respect to depositions of harmful substances, although irreversible damage frequently occurs when these capacities have been exhausted. Moreover, one hardly ever becomes aware of the quantitative use and consumption of land, since soil degradation often takes place indirectly and concealed from view and because there is often a spatial and temporal separation of causes and effects. The fact that air pollution, deforestation or urbanisation all involve soil is also ignored in many cases, as are “long-distance effects”, such as the spatial separation of element cycles induced by global trade in animal feed.

“Soil oblivion”, as was postulated for our culture, is demonstrated not only in the private sphere and in the absence of this topic in the media and in public debate (*Box 17*). Science and politics took up the topic of soil degradation at a relatively late stage (and then usually only half-heartedly) (Hübler, 1985). Forest decline, for example, was initially discussed and analysed purely in terms of air pollution.

Box 17

The soil problem as reflected in social scientific surveys

In social scientific surveys focusing above all on “environmental awareness” among the population and thus, depending on operationalisation, on its perception of environmental changes, the problems of soil degradation have received at best only marginal attention.

During a German general social scientific population survey (*Allgemeine Bevölkerungsumfrage in den Sozialwissenschaften* – ALLBUS), for example, the awareness of problems and concern among the population of Germany were surveyed in 1984 and 1988 with regard to six forms of pollution that can all be allocated to the environmental media of water and air (“industrial wastes in surface waters”, “industrial waste gases”, “traffic noise and automobile exhaust fumes”, “lead content in petrol”, “aircraft noise” and “nuclear power stations”). Environmental problems directly related to soil (e.g. problems concerning hazardous waste sites, intensive agriculture) are completely absent (Wasmer, 1990). In the questions posed by U.S. surveys on the perception of environmental changes, soils are very rarely given explicit mention as a potential problem area, as shown by a compilation of studies from 1950 to 1990 (Milavsky, 1991).

In contrast to this, the Eurobarometer Study (CEC, 1992) presented “agriculture” as an economic sector primarily affecting the soil in a series that also included “industry”, “energy”, “transport” and “tourism” and asked questions about feared environmental effects that might be produced by further development of these sectors.

Results showed that 54% of those surveyed in the 12 Member States of the Community were concerned about developments in the agricultural sector, which, however, ranked only fourth among the sectors mentioned (ahead of “tourism”). These findings were stable with respect to differences in gender, age and income of those surveyed, but displayed significant national peculiarities in some cases. Interviews from the Netherlands, for example, ranked “agriculture” third with respect to the negative environmental effects to be feared from this sector (ahead of “transport”), while in Spain “tourism” ranked ahead of “agriculture”.

When asked what was meant by “serious threat to the environment” in their view, 33% of all those surveyed indicated the “excessive use of herbicides, insecticides and fertilisers in agriculture” as among the four most significant factors. From a total of 13 items, agriculture thus ended up in 6th position, ahead of items like “traffic-induced air pollution” or “acid rain”.

In response to the question of the perceived threat to the environment in one’s own country, agriculture was again assessed comparatively high as a causal agent (for 82% of all those surveyed; rank 7 among 13 items). As far as perceived restrictions in the quality of the local environment were concerned (7 items), “destruction of the landscape” ranked 3rd (41% of all those surveyed complained about this), behind “transport” (54%) and “air pollution” (42%), while 31% of those surveyed complained about the “lack of green areas” (rank 6) (CEC, 1992).

Whereas the 1992 Eurobarometer Study predominantly asked about the perceived causes of soil problems, the study conducted by the IPOS Institute (Institute for Practice-Oriented Social Research, 1992) directed its questions at the perceived or feared problems themselves. Among the most feared environmental changes in the eyes of Germans (divided into east and west Germans) according to this study, “soil contamination” was ranked 9 (East) and 11 (West) among a total of 17 items, far behind issues such as the “ozone hole”, “waste problems”, “climate change” and “forest decline”, but ahead of “nuclear power”, “overpopulation” and “noise” (multiple answers were possible). When asked to assess the importance of eight different environmental protection measures, the item “protecting soils” was ranked 6 by east and west Germans. Protection of the ozone layer, abatement of air and water pollution as well as careful disposal of waste were regarded as more important, while saving energy (!) and noise reduction were deemed less important.

In a comparative analysis of the available studies it is striking that soil degradation phenomena as such (e.g. acidification, surface sealing and compaction of soil, erosion, problems related to hazardous waste sites) scarcely appear in the respective lists of questions. Rather, general mention is made of “soil contamination” (presumably via hazardous waste sites) or of “soil conservation”; in most cases, they remain at the causal level (“agriculture”) or problem areas are addressed that are “only” indirectly related to soil degradation (e.g. transport, industry, waste problems).

The questions asked in the individual surveys were prepared in advance by the researchers and presented to the population surveyed. They therefore say little about the actual cognitive perceptions (more about those anticipated). Whether the selection of questions merely reflects the preferences or tasks of the researchers and thus also the prevailing “fashions”, or whether the demoscopic neglect of soil problems has something to do with the complexities involved (multiple dependencies, indirect causal chains) must remain an open question for the time being.

When environmental legislation (based on environmental media) was first established in the former West Germany during the 1970s, soil as a separate asset and medium to be protected was simply forgotten. The Federal Government did not publish its soil conservation concept until 1985; two years later, in 1987, the Cabinet finally adopted a set of “soil protection measures”. A Soil Protection Bill has now been drafted. Individual objectives of the Bill are being undermined in some cases by expediting laws enacted in the meantime (SRU, 1994).

1.3.1.7.3 Human valuation of soils

The valuation of soil displays specific cultural and social differences and is subject to constant change (*Box 18*). New intellectual movements and scientific currents, concept patterns and modes of behaviour, which themselves are often stimulated or influenced by environmental changes, act in turn on the environment and thus (occasionally) on the soil, too.

In modern industrial societies “soil” still has a negative connotation if one associates it, for example, with “filth” and “dirt”. In a society committed to the ideal of purity such as ours, great pains are taken to discourage children from getting soiled, “making themselves dirty”, while the “dirty work” – in the original as well as the figurative sense – is left in any case to others.

A further cause of the low value placed on soil – at least in the highly industrialised, densely populated western societies – can be found in its increasing lack of perceptibility.

Box 18

Examples for the valuation of soils in the past

Until the Renaissance, it was commonly believed that soil, like rocks, plants or animals, was imbued with life and itself life-giving. Digging in the depths of “Mother Earth” was considered dangerous. Numerous ethical norms had an inhibitive effect in this connection (Merchant, 1987).

For the physiocrats of the 18th century, the Earth alone was regarded as productive, the fertility of the soil as a gift of nature and as a source of social wealth (Immler, 1985). At the same time the belief in emanations from the Earth occupied scientific debate in France (Corbin, 1988). The Earth as a store of products of fermentation and decay was considered threatening and incalculable; at every instant there was a danger that it could spit out its deathly vapours. People increasingly felt themselves to be victims of filth and dirt, especially under the restrictive living conditions in the cities. In Paris, for example, numerous soil samples were taken for analysis as early as in the 19th century. In the opinion of scientists at that time, the health of the cities depended on the past contamination of the soil: soil was considered to be a store of rotting elements from the past. The “refinement of the sense of smell” found by Corbin can also be interpreted as an indication of increased sensitivity to soil problems.

While soil was regarded as the main cause of contamination and thus as a direct threat to health during the pre-industrial age, the carrier media of air and water took over this role as industrialisation emerged (Schramm, 1987).

If, however, the meaning of “soil” is no longer based on the physical substrate, but on the possession or ownership of land, then “land” (especially in connection with speculative transactions) is also becoming a synonym for “wealth”, “status” and “power” in the sense of a stable and secure capital investment.

The high valuation of land ownership dates back to the period in which human beings became sedentary and began to cultivate land; at that time, land ownership meant being able to feed oneself sufficiently from the crops grown on it and has therefore provided security. Furthermore, it offered the chance of becoming rich and powerful – already laying at the same time the foundation for conflicts over the ownership of land, for robbery and war (Sanwald and Thorbrietz, 1988).

These examples make clear how closely perception and valuation of the soil are bound up with the respective social, political and cultural context. Residents of a non-industrialised Sahel region, for example, who have to secure their survival on a barren soil threatened with erosion and who defend what for them is a valuable piece of land by force of arms in some cases, certainly have another relation to this soil than residents of Western European countries, thus resulting in a very different behavioural relevance of soil problems.

The valuation of soil also develops in accordance with its significance as a production factor or its scarcity. In Switzerland, for example, where land is scarce from a purely geographic point of view (as building or agricultural land, for instance), soil problems are an important issue in politics and public debate (Häberli et al., 1991). In modern industrial societies, the value of the time factor is growing (e.g. *just-in-time* production with the consequence of a shift of storage capacities to the road). The extent to which this will have an effect on the valuation of soil must be examined in the future.

Box 19

Soil awareness: Approaches for environmental education in Costa Rica

Because of its function as the basis of food production, soil numbers among the most valuable as well as most greatly threatened resources of humankind. In comparison to other environmental problems, e.g. those connected with water or air, soil is (still) given too little attention. This, in addition to the minor significance attached to soil in environmental education programmes, is substantiated by survey results or studies on environmental awareness.

A different picture is found in Costa Rica, a country that today possesses only 17% of its original forest cover. What used to be enormous forest areas were transformed into pastureland for the profitable export production of beef or into farmland for the production of food for a rapidly growing population, as well as for products bringing in foreign exchange, such as coffee, cocoa or bananas (*cash crops*). The consequences of deforestation and non-adapted forms of land use for the soil are obvious (see *Box 8*).

The necessity of measures for the protection of the forest and soils has been recognised in Costa Rica. There are different strategies and concrete approaches for mastering the problems (see *Box 14*). It was also realised that extensive environmental education is necessary. In 1988 an initial basic programme on environmental education was submitted by the Ministry for Resources, Energy and Mining (MIRENEM) and by the Ministry of Education (MEP). In contrast to economic and political measures having short-term effects, educational programmes are designed more for a long-term effect, particularly if one attempts, as in Costa Rica, to reach the children during the first years of school. As part of the PRODAF Project (*Proyecto Desarollo Agricola Forestal*), a project supported by the MAG (Ministry of Agriculture), MIRENEM and the GTZ in Germany for the development of adapted, sustainable production systems in the agricultural and forestry sectors, a number of teaching materials were developed with the active participation of the local community. For lessons at school there are, for example, ten drawing books for different school levels in which the pupils first get to know the “tree”, the “forest” and “the soil” with their components, growth processes and functions as well as the structure of the “biosphere” or the functioning of “ecosystems”. In the sixth book the children already learn what must be kept in mind when planting a tree, and this knowledge is finally put into practice through tree-planting campaigns. An important topic is soil erosion: the pupils learn about the causes, consequences and, above all, remedial measures on the basis of a large puzzle. Through a before-and-after version, they experience how the various forms of soil degradation can be cured via individual remediation steps (*Fig. 21*). By 1993, 4500 children had taken part in such environmental education programmes at 75 schools – within the framework of this project alone.

Environmental education, however, is not restricted to programmes at schools. Instead, efforts are being made to reach all groups of the population, particularly those, like farmers, who are directly involved in tillage and forestry management. The principle of conveying knowledge is based on communication and participation. Nothing is forced on the farmers, who are considered to be self-assured know-it-alls. There is no instruction, instead, one builds on the existing knowledge and cultural convictions of the farmers in order to learn, together with them and motivated by them, techniques of sustainable land management.

If one knows about some of the systems of cultural belief and social norms that are widespread in Costa Rica, then it becomes obvious that there are many barriers to overcome in such a communication process:

– The forest is considered to be “hostile”, only conquered, controlled forests are “good” forests.

– Land must be “clean”, i.e. free of trees, roots, weeds. The cleaner the land, the higher the price one can obtain when selling it. Instead of front gardens, one frequently sees in the Costa Rican countryside bare earth that has been carefully surrounded with whitewashed stones and cleared of the last blade of grass.
– Livestock breeders enjoy the highest degree of social prestige. As a result, livestock is even kept on unsuitable soils, rather than adopting better adapted forms of land management.

One has to know about such notions and preferences if one wishes to make grown-ups as well as children and adolescents sensitive to environmental problems and to get them to use sustainable methods of handling natural resources.

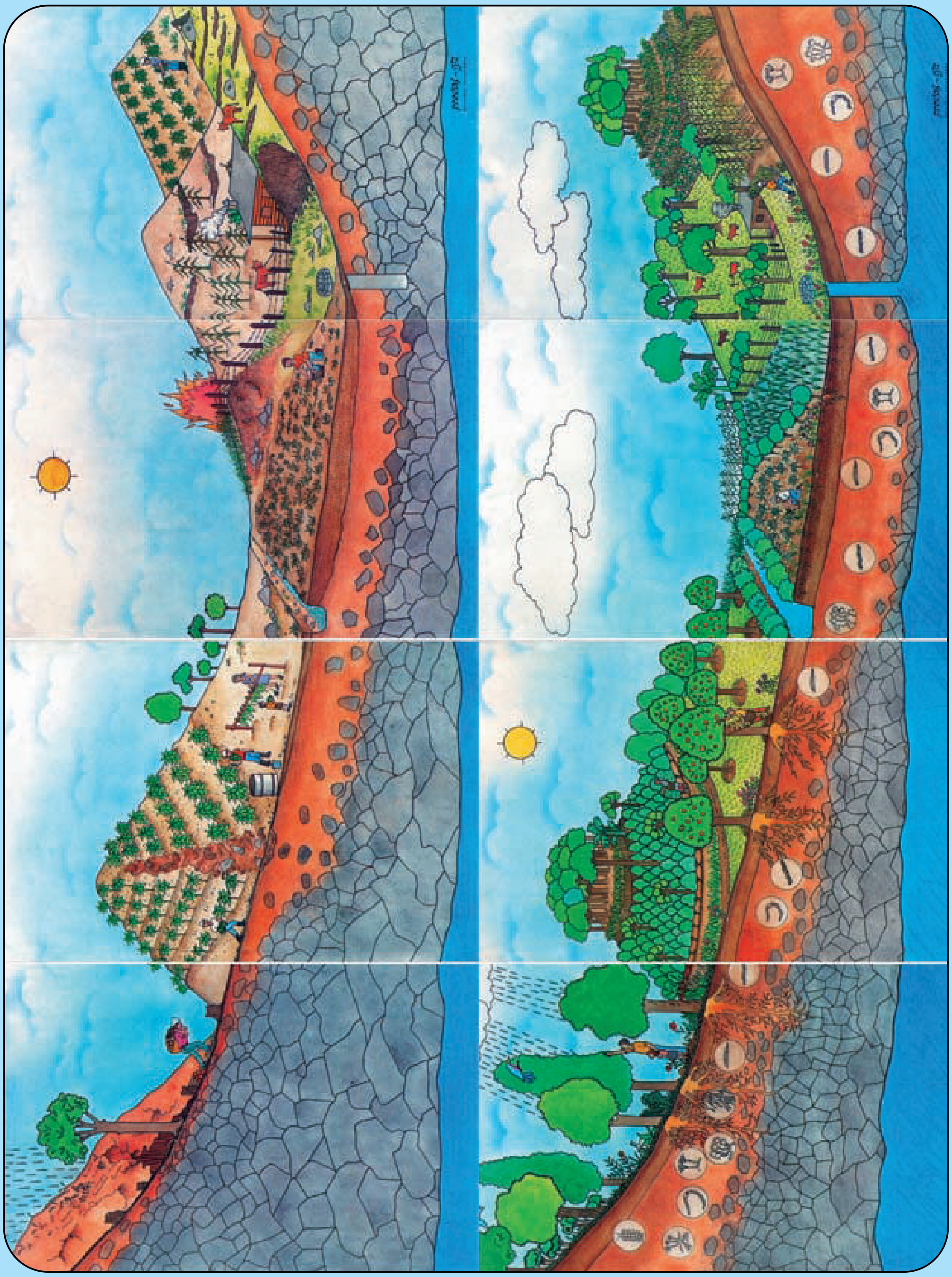


Figure 21: Teaching materials on soil degradation for schoolchildren in Santa Marta, Costa Rica

Source: PRODAF

The low regard for soil in everyday life, as can be observed in our western industrial societies, stands in contrast to the universally high esteem in which soil is held in religious-mythological contexts. Many religions and cultures (as, for example, in the Red Indian culture) pay homage to “Mother Earth”, above all as the goddess of fertility. In the Christian-Jewish mythology of the Genesis, humans are created out of clay by God, and, according to funeral rituals, return to the soil when they die (“ashes to ashes, dust to dust”).

Beyond religious beliefs, however, an extremely positive significance is often attached to the soil from a general, ethical point of view, namely as a physical substrate that is full of (micro)organisms and dependent on the respective biological processes in order to function. Soil itself represents a habitat and is an existential prerequisite for many other species (animals, plants, microorganisms). On the basis of this ethical valuation (“soil is life”), it seems only natural to grant the soil *rights of its own* (Ruh, 1988; Stone, 1987). Soil and soil functions are now defined in several countries as another protected asset.

1.3.1.7.4 Soil degradation and human behaviour

In contrast to other environmental problems, to which definable behavioural patterns can often be attributed as triggering or preserving factors (e.g. greenhouse effect: rising CO_2 concentrations due to the use of fossil fuels for heating, driving cars, etc.), soil degradation seems at first glance to be far removed from concrete individual actions. Long, indirect causal chains between individual modes of behaviour and resultant soil damage, such as between the consumption of pork in Germany and soil degradation due to overfertilisation of agricultural land in a developing country where animal feed is grown for German pigs (Buntzel, 1986), lead to a situation in which cause and effect relations are not cognitively represented and, accordingly, cannot become guidelines for action (see 1.3.1.7.2).

This is connected, on the one hand, with the large number of qualitatively distinguishable forms of degradation (e.g. compaction, acidification and surface sealing of soils) that are dependent on a whole range of different human actions (e.g. use of cars, heating, building), which may frequently have an additive or synergistic effect, however. On the other hand, the individual in his or her everyday behaviour can hardly be directly identified as the cause of soil damage. Rather, it appears that primarily supra-individual actors, such as agriculture (overfertilisation, soil compaction), industry (emissions, hazardous waste sites) or building and planning authorities (changes in utilisation, surface sealing), are responsible for what is usually long-term soil damage. Consequently, approaches for solving soil problems must be based on several levels and must also take into account that behind the anonymous actors mentioned are always people with their perceptions, attitudes, values and knowledge, who, however, in social roles act under certain influences and constraints. Of particular importance for the handling of soils are the ownership and property conditions as well as the durations of use associated with these (see *Table 21*).

In the search for the driving forces behind anthropogenic soil degradation, relatively little significance can presumably be attached to the factors presented in the previous sections (lack of perceptibility, lack of value, indirect nature of soil degradation processes). For the traditional industrial countries and for the *newly industrialised countries* (NICs) at least, one can assume that a major cause of soil degradation can be found in the prevailing type of economic activity and the corresponding structures (extreme geographic division of labour, specialised production and monofunctional use of land). Thus growth concepts and the logic of practical constraints in economic decisions often depict ecological damage merely as a side effect or necessary evil, for example to remain competitive as an industrial or agricultural enterprise or to be able to “survive”.

Behaviour that is aimed at short-term, individual maximisation of gain in many areas of the anthroposphere (e.g. improper disposal of products containing harmful substances, overfertilisation of agricultural land) frequently leads to long-term soil degradation, from which the general public has to suffer in the end.

However, the decisive “cause” of human interventions into soil can be found in a period far before the age of industrialisation. As human beings began to settle down roughly 10,000 years ago, massive interventions in the balance of nature became inevitable: clearing of woodland for cultivation and tillage of the soil offered the prerequisites for growing cultivated grasses in order to secure a food base. At the same time, the formation of human settlements also provided a decisive impulse for population growth and thus for the need of further exploitation of the soil as a resource: a process with a positive feedback effect was launched (Achilles, 1989).

Table 21: Taxonomy of soil-related behaviour

Type of behaviour	Status		
	Ownership	Possession	Temporary use
Agricultural production	Farmer	Tenant	
Structural consumption	Building owner, architect		Architect, building industry
Industrial consumption	Entrepreneur	Entrepreneur	
Infrastructural consumption	Operator		User
Recreational consumption	Owner (personal use)	Tenant	User
Ecological conservation			Conservationist
Monetarily oriented	Investor, landlord, lessor	Agent, investor	
Standard-setting			Legislator, planner

Source: Farago and Peters, 1990

Each and every individual contributes significantly to further pollution of the pedosphere every day, though only indirectly and, in most cases, without noticing it: the list of soil-relevant modes of behaviour in the broader sense ranges from the selection of one's place of residence and the (frequently related) mobility behaviour, to consumption of goods and services (e.g. type of food, waste production) and leisure-time activities (tourism).

A quantitative assessment of the respective share that human behaviour has in the overall phenomenon of soil degradation, as was carried out for the greenhouse effect (WBGU, 1994), appears to be virtually impossible. This does not mean, however, that one could discharge individual citizens of their daily (co-)responsibility for soils as a collectively important asset.

Box 20

The example of agriculture

In European agriculture an increasing process of intensification and "industrialisation" of production has been observed in recent years (due to advances in agro-technology and agro-chemistry, not least through the influence of EU agricultural policy), a process which has long since led to negative effects on soil as an environmental medium.

In some cases this development was accompanied by a rapid change in the social valuation of farmers, particularly in rural areas that had a farming tradition for generations (Buntzel, 1986): Whereas, until recently, they were still "peasants" and considered to be hard-working, tradition-conscious, conservative people with a direct emotional attachment to the soil, this picture has become a romantically transfigured cliché today, while the term "peasant" is used more and more perjoratively. The term, in German "Bauer", has been replaced by *agronomist*, i.e. *agricultural entrepreneur* (in German "Landwirt").

As such, farmers are independent, market-oriented entrepreneurs, striving to maximise their net product while using the production factor of the soil to secure their existence on the market as (small) suppliers and consumers. The notion that exploitation of the production possibilities is connected to sometimes severe ecological damage only emerged in the course of time, which additionally called into question agriculture's popular image of traditional attachment to nature.

Although the necessity of environmental protection is frequently perceived, the urge to increase production still dominates. Often there is only a choice between "growing or giving way", thus subordinating any sense of environmental responsibility to practical economic constraints (Buntzel, 1986). Moreover, the increasing mechanisation of agricultural operations is another factor which increases the distance between farmers and their production factors. Working with machines limits the sensory experience of work activities and the related possibility for controlling the work process ("The big tractor just isn't good for that because you sit up there and down there is where it happens; you just never see anything" or: "Up there on the tractor you always have to keep an eye on the machine, there is never time to look back and see what's happening to nature. Before, when you were outside doing work by hand, it was easier to follow everything" – Quotes from Pongratz, 1992).

From the current status of research, however, it is very difficult to arrive at conclusions on whether and to what extent farmers differ from the rest of the population in their environmental awareness (Fietkau et al., 1982; Pongratz, 1992). Soil degradation does not seem to be regarded as an urgent environmental problem by farmers. Industry and factories, car traffic and power stations, but never one's own economic activities are viewed as the causal agents of environmental problems.

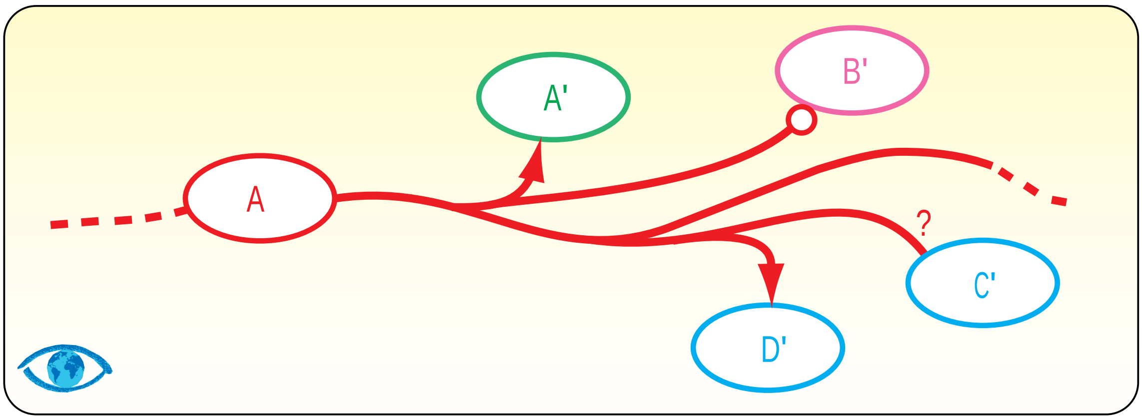
1.3.2 Soil-centred Global Network of Interrelations

In its 1993 Annual Report, the Council introduced a special method for organising the interdisciplinary synopsis of the main interactions within Global Change over the long term: significant trends – such as the progressive concentration of people in megacities in developing countries – are woven together to form a Global Network of Interrelations intended to show the mutual dependencies of worldwide developments.

This special "expert system" will gradually take shape by focusing on a new problem area in Global Change in each Report and by identifying the corresponding trends as well as their interactions. Only dependencies of the *1st order* (direct effects) have to be determined in each case here; the overall network is then generated automatically via an analysis of all compartments in the Earth System.

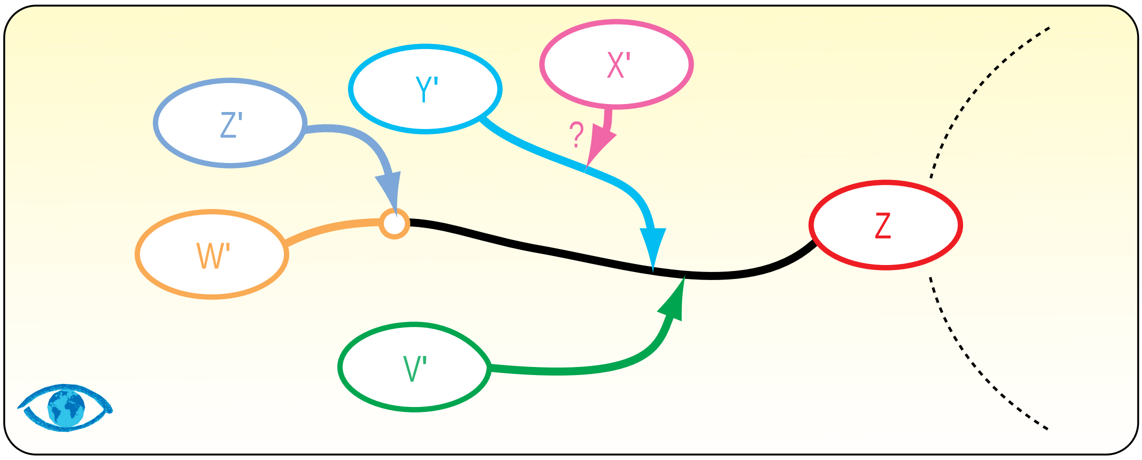
Reference is made to the 1993 Annual Report with regard to the basic rules for constructing the Global Network of Interrelations. *Cause and effect bundles* are now introduced as supplementary elements. In the first case we are essentially dealing with a graphic simplification: the connecting lines that symbolise the effects of a source trend A on a group {A', B', C', D',…} of other trends are combined into a tree-like structure (*Fig. 22*). The bundle also indicates that the causes recorded in this way are based on a common mechanism.

Figure 22: Example of an effect bundle



In the second case, one must distinguish between summary and synergistic effect bundles. A summary effect bundle is an inversion of a cause bundle, i.e. the overlapping influences (independent of each other in the first order) of a group {Z', Y', X', W', V',…} of trends on a target trend Z are graphically concentrated (*Fig. 23*).

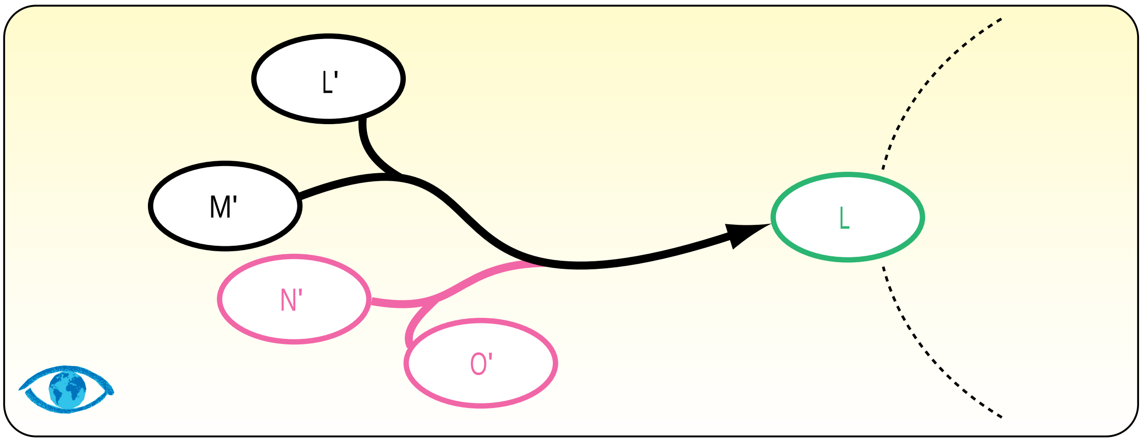
Figure 23: Example of a cause bundle



This summary indicates, again, that the effects involved are directed at a common aspect of the receptor trend.

A *synergistic effect bundle*, on the other hand, symbolises the non-additive (non-linear) interaction of trends (*Fig. 24*). These new basic elements can be combined into mixed forms as required.

Figure 24: Example of a synergistic effect bundle



The Global Network of Interrelations must not be thought of as a rigid instrument: in addition to technical improvements and amendments, the trends and interactions already recorded must also be examined and, if necessary, revised on the basis of progressive insights into the dynamics of Global Change in each annual step.

This principle is already reflected in this year's updating of the general trend analysis begun in 1993: the *soil-centred Global Network of Interrelations* is the result of an intensive analysis of worldwide developments affecting the pedosphere and lithosphere within the overall dynamics. This analysis shows, among other things, that the original description of the soil-related trends and those in closely linked compartments (particularly hydrosphere, economy and

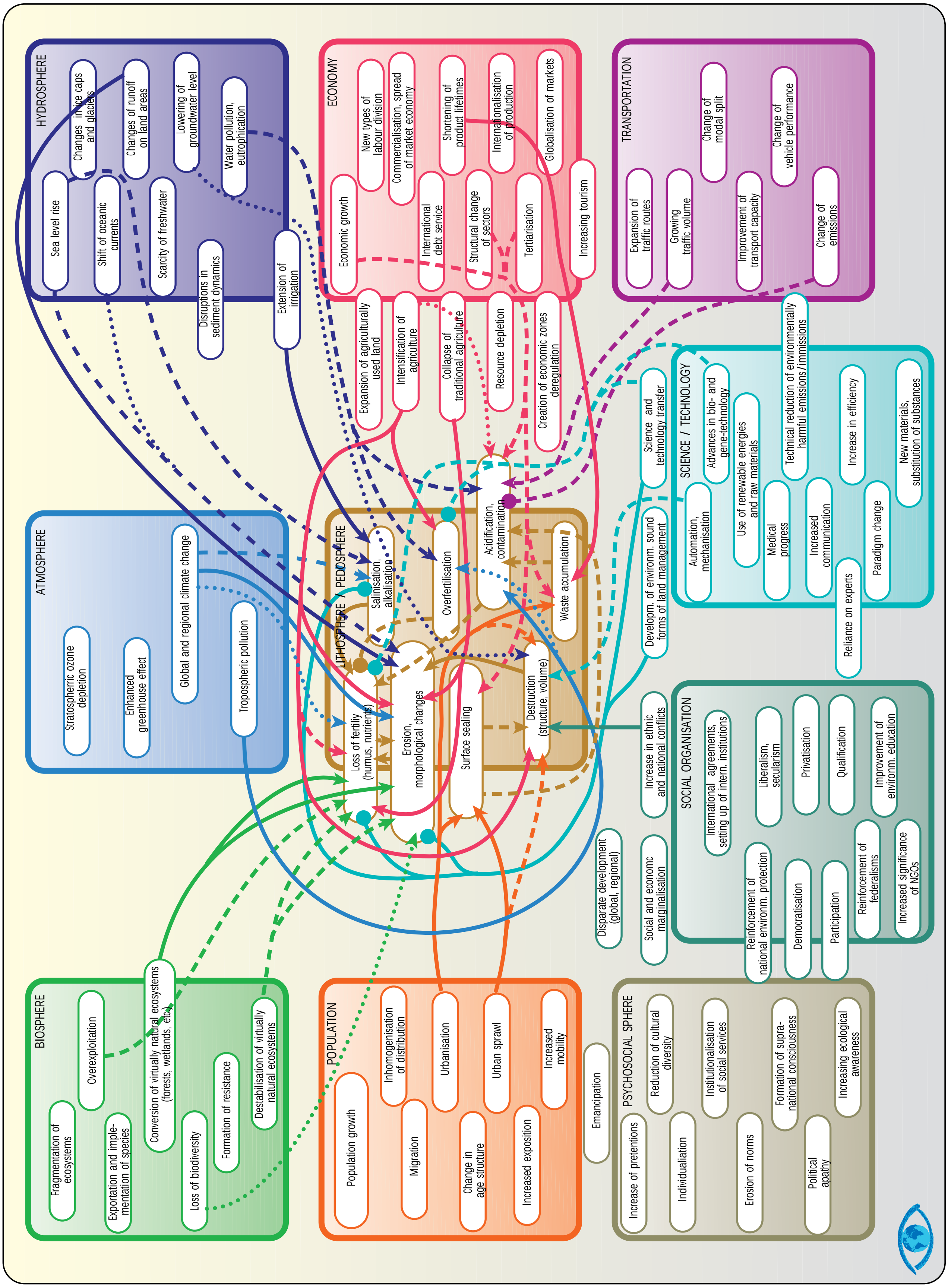


Figure 25: Soil-centred Global Network of Interrelations: impacts

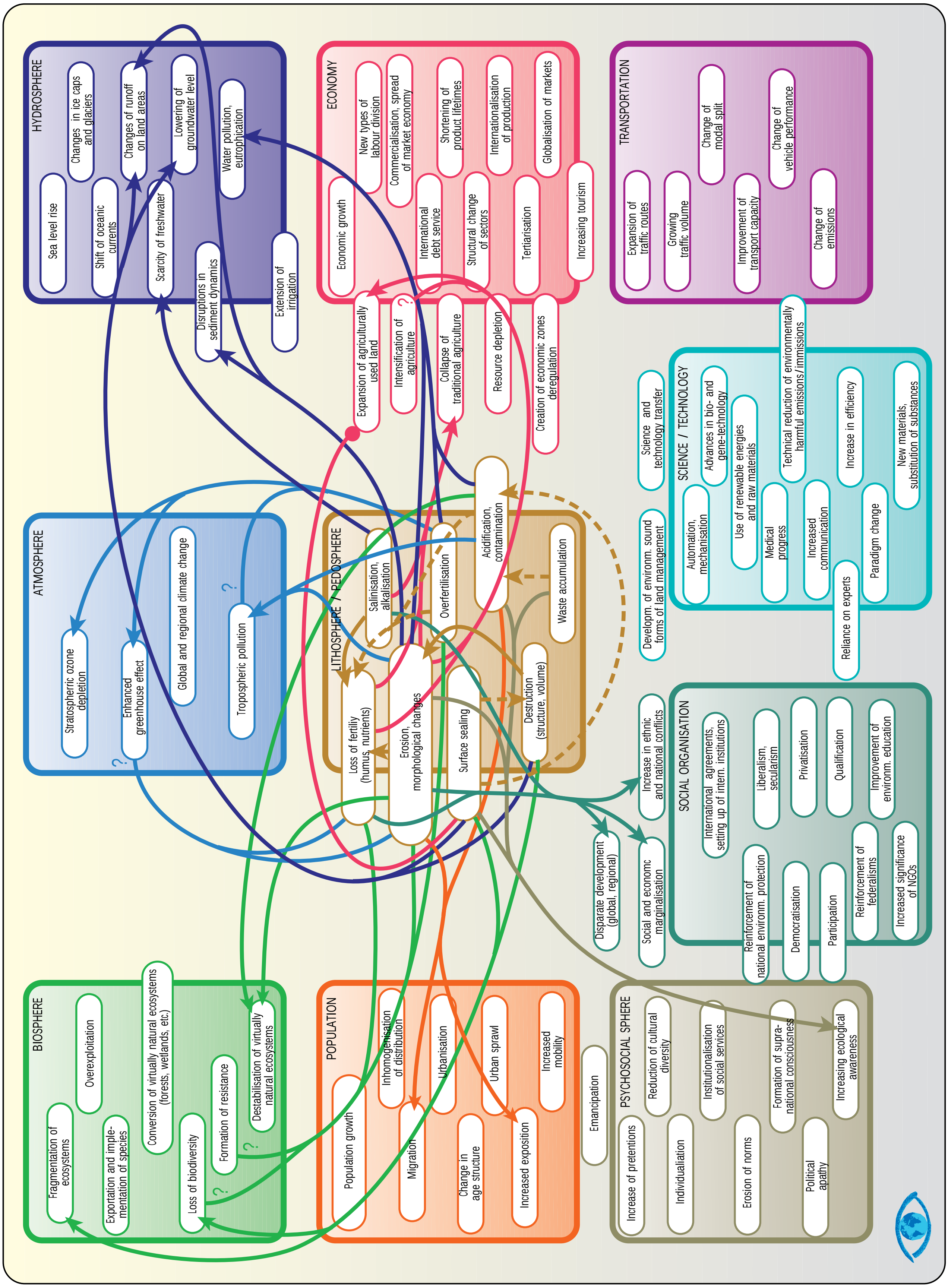


Figure 26: Soil-centred Global Network of Interrelations: effects

population) have to be refined or amended. Thus special emphasis is placed on *land use* as a major driving force behind reshaping the planet Earth.

The soil-centred Global Network of Interrelations can be regarded as the germ tissue of the gradually emerging Global Network of Interrelations. For reasons of clarity, this subnetwork is depicted in two steps, i.e. separated according to causes and effects.

The *cause diagram* (*Fig. 25*) identifies the direct influences on the main trends of soil degradation as well as the network of effects these trends have on each other. In addition, an attempt is made here to carry out a weighting (semi-quantitative assessment) of dynamics beyond pure “wiring”. The intensity of soil degradation trends is divided into three classes, symbolised by three different ellipse sizes corresponding to the total size of the globally affected areas. The significance of the causes is classified, again on the basis of the areas affected, in a three-stage ranking that is reflected by continuous, broken and dotted connecting lines.

The *effect diagram* (*Fig. 26*), by contrast, concentrates on the influences that the trends in the pedosphere/ lithosphere exert on other global developments. For the sake of completeness, the internal reciprocal effects are again shown; moreover, the effect arrows are marked in colour according to the compartment of their target trends. The latter is merely intended to make the diagram easier to read. (In the final Global Network of Interrelations all of these effect lines will, of course, be identified by the same colour allocated to the pedosphere/lithosphere.)

We have dispensed with weighting the effects here because this would require indicators for assessing all target trends and their susceptibility. As a rule, such indicators will be composite entries based on global data records. For example, one can measure the trends of soil degradation on the basis of the destroyed *food production potential*, instead of calculating the damaged area. Such a complex indicator which includes, among other things, the type of soil, regional climate, hydrology and socioeconomic factors, would possibly shift the problem focus from the developing countries to the industrial nations.

The Council wishes to tackle the creation of an appropriate, geographically explicit basis for the rated Global Network of Interrelations in cooperation with the Potsdam Institute for Climate Impact Research in 1994. By means of Geographical Information systems (GIS) this project will generate complex thematic maps, such as the display of a *criticality index K* of soil degradation. The latter can be defined as a “local” variable as follows:

$$K = \frac{\text{(soil degradation with unaltered forms of land use)} \times \text{(socioeconomic dependence on soil availability)}}{\text{(mitigation potential: soil resilience, available capital and know-how, industrial and political structures, etc.)}}$$

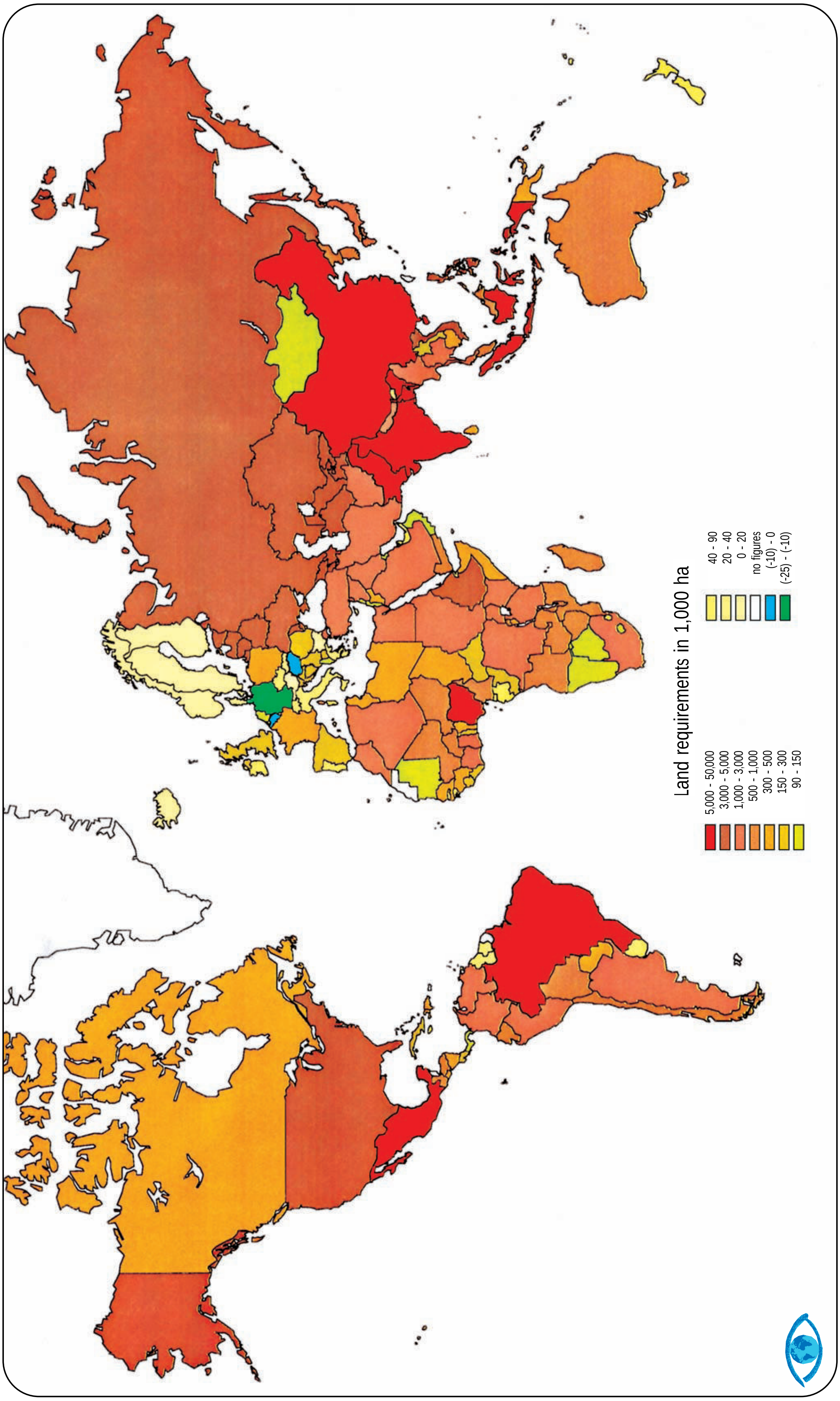
With the help of a criticality index one can, for example, identify the *hot spots* of soil problems as target areas of precautionary environmental policy.

One can develop a simple criticality index by directly correlating demographic trends to the area of agricultural production land. This index must take into account the loss of production capacities through soil degradation as well as the actual minimum needs to feed a person and technological innovations for increasing productivity in agriculture. Furthermore, disposable income and agricultural balances of trade should be included in the index as socioeconomic compensation parameters, since scarcity of land cannot be unconditionally equated with inadequate supply. For some industrial countries, for example, there is a considerable shortage of agricultural production area, but this can be compensated for by food imports. By taking into account characteristic data for infrastructure, such as road and rail sections per person, at a later time, this criticality index can be further developed into a realistic assessment instrument.

The elementary version of the indicator just described is shown in *Figs. 27 and 28* as a national land deficit for the years 2000 and 2025, respectively. These thematic maps represent an initial approximation to a geographic information system within the scope of a global criticality analysis.

Back to the soil-centred Global Network of Interrelations and its interpretation: both the cause and the effect diagram confirm the assumption that, of all environmental problems, global soil degradation is the most complex. This is

Figure 27: Example of a global criticality analysis. Deficits in useful land in the year 2000



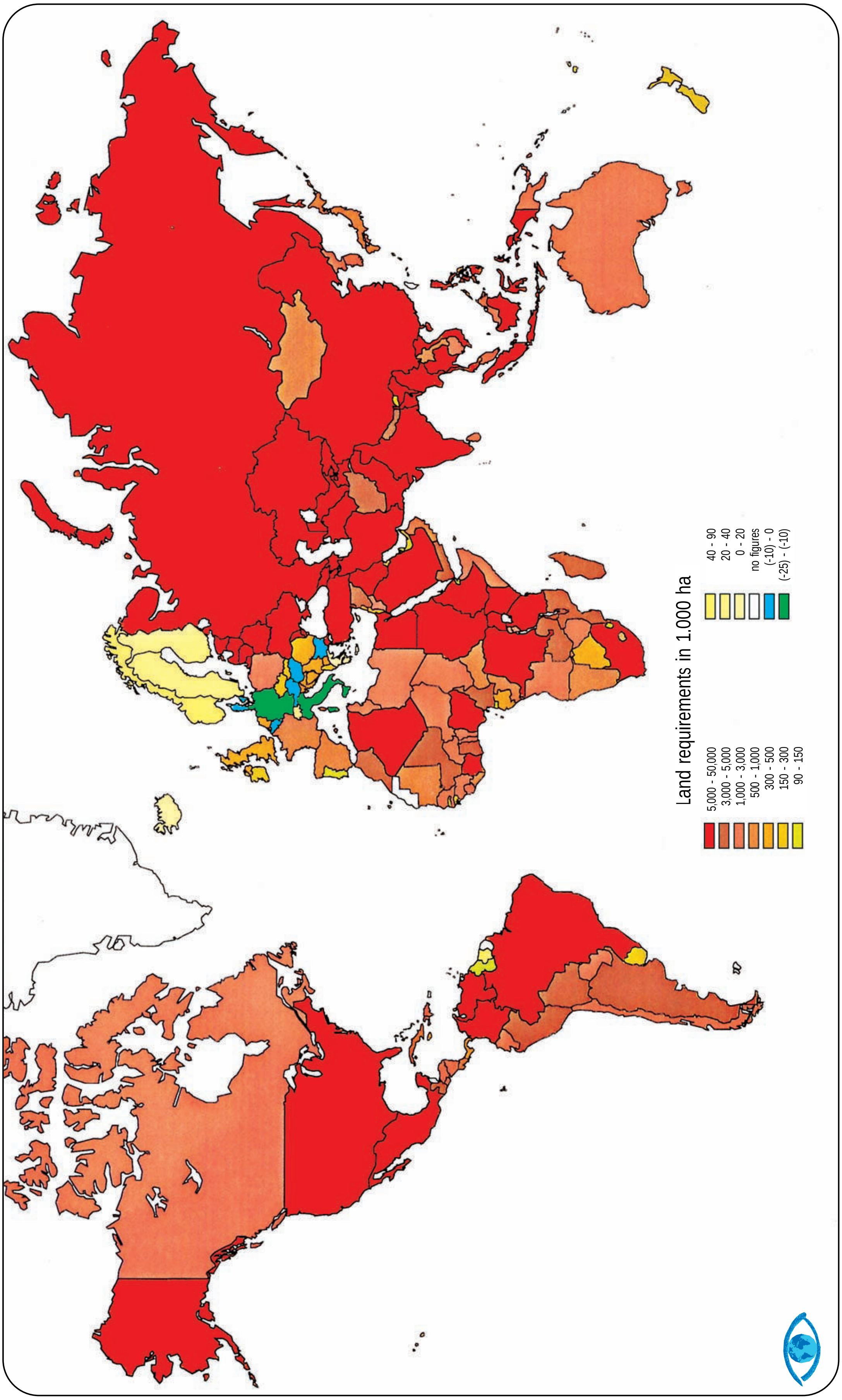


Figure 28: Example of a global criticality analysis. Deficits in useful land in the year 2025

connected with the fact that soils are “cross-sectional media” (overlapping of lithosphere, hydrosphere, atmosphere, biosphere and anthroposphere), and with the significance of local parameters due to the “immobility” of soils.

The individual interactions between the global trends are essentially derived from the “bilateral” analyses in Section D 1.3.3; detailed treatment of the individual elements would go beyond the scope of this Report. Nevertheless, important conclusions can be drawn from the overall result: first of all, there is a strikingly close link between pedosphere and hydrosphere, emphasising the necessity of integrated soil-water management for broad regions of the Earth. Furthermore, on the basis of the soil-centred charts, one can very clearly identify an overriding characteristic of overall Global Change, namely the growing distance between

– *Cause and effect*
  Example: The clearing of mountain forests leads to flooding in distant fluvial plains via erosion and sediment transport.

– *Intention and benefit*
  Example: Intensification of agriculture with the help of development funds and aimed to obtaining foreign exchange revenue can bring about an acute shortage of food supply among local producers in tropical countries.

– *Subject and object*
  Examples: The vanishing attachment of farmers to the “soil”, surface sealing of soils or the increasing significance of land as an object of speculation.

– *Causal agents and victims*
  Example: Population affected by long-distance transport of hazardous waste or by the accumulation in groundwater of herbicides and pesticides from industrial agriculture.

– *Producers and consumers*
  Examples: The globally organised flows of fertilisers, animal feed and food.

This extensive dissolution of natural or traditional (and directly expedient) links is reflected in the soil-centred Global Network of Interrelations as a series of blocks, i.e. in the resulting action flows between the compartments:

– A major causal agent of worldwide soil degradation is the global activity of the agricultural industry, which provides services for all sectors of the economy. The effect arrows of the corresponding degradation trends, however, do not primarily point back to the economy, but to the sphere of “population”. The present generations in the newly industrialised and developing countries as well as future generations all over the world are affected by this.
– The various forms of surface sealing of soils do not result so much from elementary need but rather from the demands for affluence on the part of a subpopulation of the species *Homo sapiens*. The effects, by contrast, are directed at the existential conditions of other species; i.e. the corresponding main effect path runs from the economy/transport/population complex to the biosphere via the pedosphere.
– An additional fundamental chain of effects links the psychosocial sphere/population complex to the pedosphere via the economy: the focus here is on the collapse of traditional agriculture due to marginalisation, migration, etc. along with the consequences for soil protection.

The latter chain of effects cannot be completely derived from the network of interrelations in the present form, however: to do this, *interactions of a higher order* would have to be taken into consideration. This is a further finding that is symptomatic for the mechanisms of Global Change. The traditionally dense network of direct local feedback effects (as in the case of sustainable subsistence farming) is giving way to a network of indirect long-range interactions. The resulting complex, however, is quite mysterious for the individual and is, for the most part, beyond the scope of individual or local management.

Only a synoptic instrument like the complete, weighted Global Network of Interrelations can help to overcome this dilemma. A symbolic representation makes indirect connections visible that would be lost in a descriptive representation. This is demonstrated here on the basis of the soil-centred Global Network of Interrelations, supplemented by some important interactions of a higher order.

Figure 29: Selected subnetworks of the Global Network of Interrelations with positive feedback (vicious circles): Expansion loop, loop of rural exodus, intensification loop

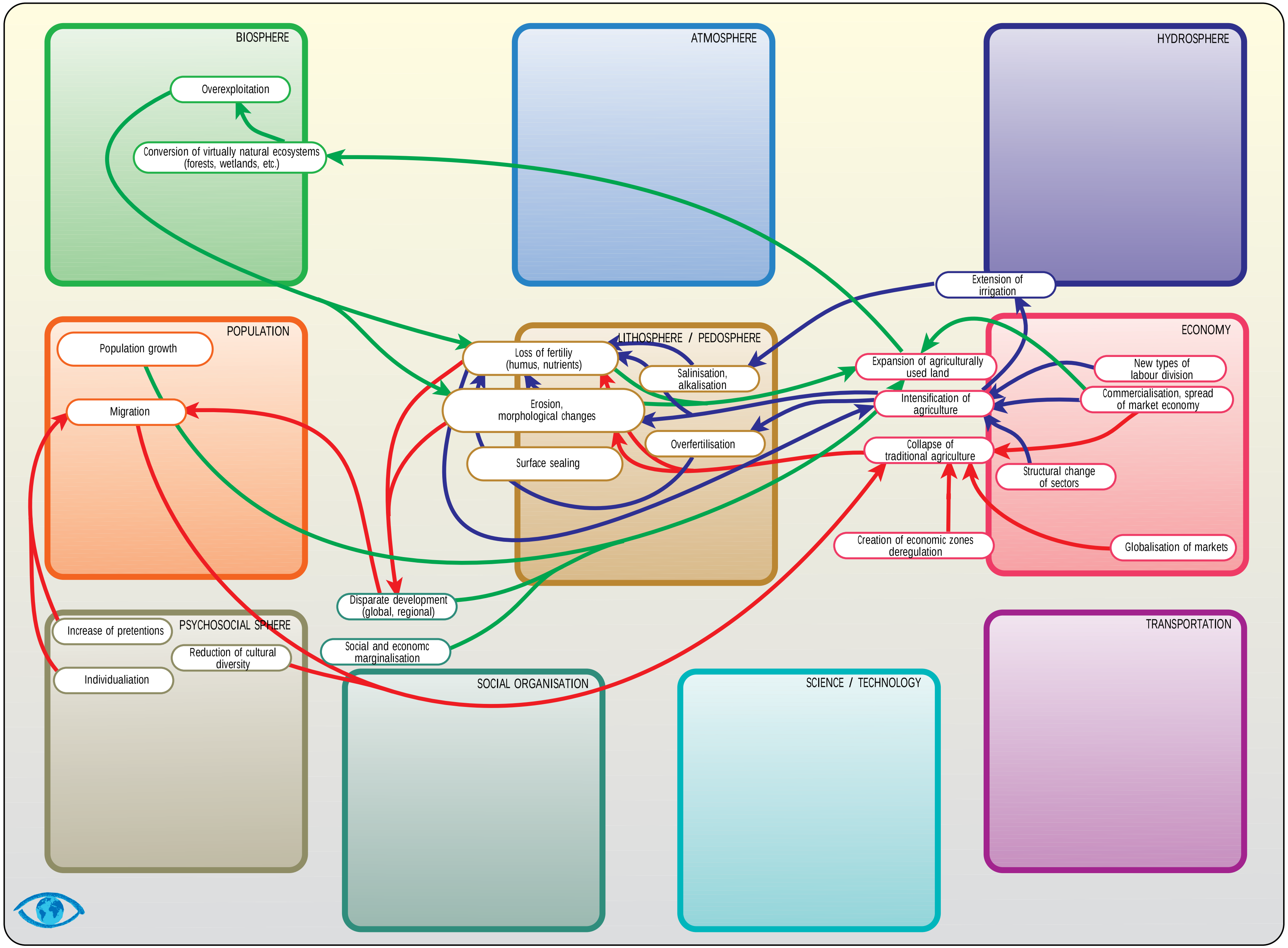


Figure 30: Subnetwork of trend relations

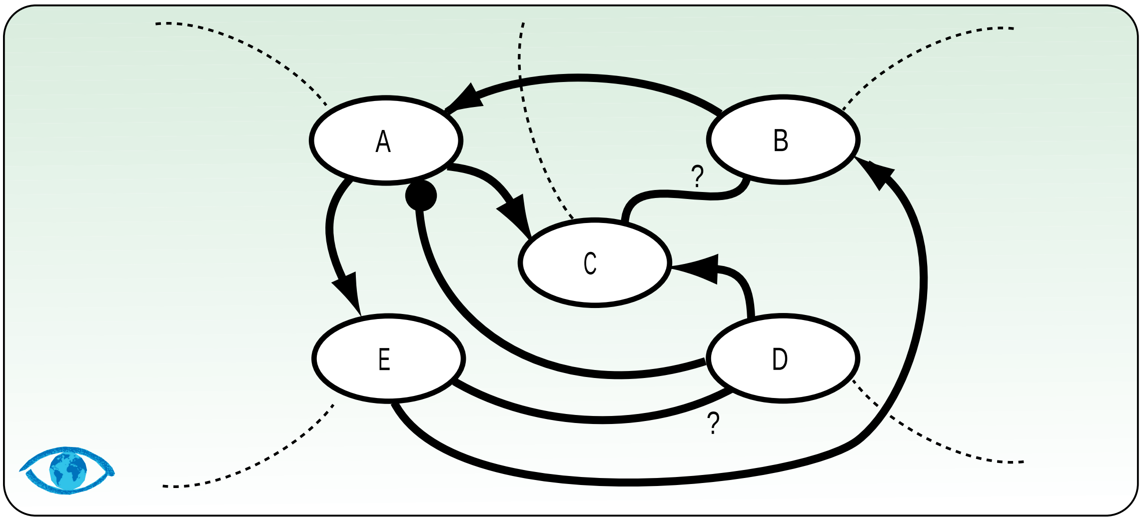
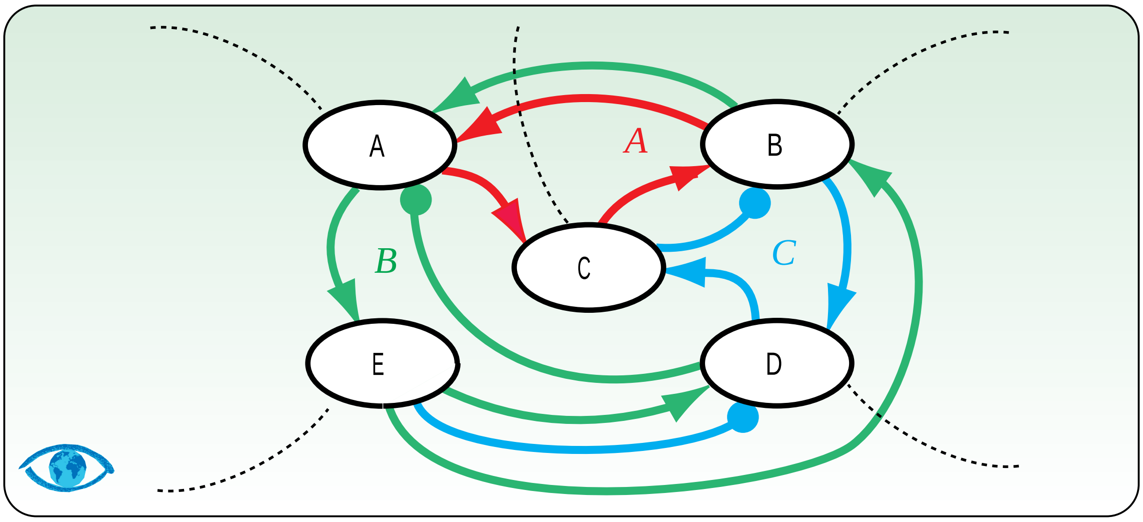


Figure 31: Pattern of effects



Positive feedback loops ("vicious circles") can be identified and arranged in the general dynamics in a straightforward manner. *Fig. 29* shows three main mechanisms of soil degradation as subcomplexes of the overall network: the *expansion loop*, the *intensification loop* and the *rural migration loop*. Note that the trends towards "soil erosion" and "loss of soil fertility" act as common nodes here.

The last observation indicates a disadvantage of compartment-based representation of the Global Network of Interrelations: for example, contributions to worldwide soil erosion are combined in a single trend although they differ according to cause, character and effects – as a consequence of the allocation to relatively independent subnetworks of interrelationships. These subnetworks combine disciplinary *symptoms* into effect-determined *syndromes* (see also Clark and Munn, 1986). Syndromes such as "acid rain" with all of its causes and implications are cross-sectional phenomena. The distribution of these phenomena is occasionally global, but usually patchy due to the geographic, economic and sociocultural factors.

Two major conclusions can be drawn from these considerations:

1. The disciplinary, symptom-oriented Global Network of Interrelations requires a *syndrome-oriented basis* of regional resolution that has to be constructed via an interdisciplinary approach right from the outset. Even if the

linkage structure thus defined no longer appears in the summary diagram, the corresponding information must be retrievable at any time in order to explain cause and effect mechanisms.

2. A cross-sectional analysis is not only a suitable basis for validating the Global Network of Interrelations in its original form, but also an alternative to an overall view of sectoral trends: syndromes themselves can be regarded as integral elements of a network that links entire *patterns* of Global Change to one another. The better the patterns are selected, the more decoupled are their dynamics ("diagonalisation").

A formal example will be presented to illustrate the outlined approach: the subnetwork of trend relationships (*Fig. 30*) is composed of the effect patterns *A*, *B* and *C* as follows (*Fig. 31*).

1.3.3 Main soil degradation syndromes

In the following, an attempt is made to develop a regionally based syndrome concept and to apply it to the worldwide problem of human-induced soil degradation. The focus here is on point 1 mentioned at the end of the previous section, i.e. construction of a mosaic-like foundation for the soil-centred Global Network of Interrelations.

The term "*syndrome*" is especially well-suited in this context: the loss of soil functions is expressed in terms of "clinical profiles" consisting of wind erosion, water erosion, physical or chemical degradation, etc. If soils are understood as the "skin" of Planet Earth, then the analysis of these syndromes is in a certain sense a "*geo-dermatological diagnosis*". Within the scope of this diagnosis, a "syndrome" is understood as the actual "clinical profile", with all causes and effects.

The twelve most important anthropogenic "soil diseases" are compiled in *Fig. 32*. The names chosen for the syndromes are deliberately symbolic , each one being taken from a selected geographical hot spot *or* a striking phenomenon accompanying the syndrome. However, the label always stands for a particular clinical profile that occurs or can occur in different regions of the world. The nomenclature is actually based on a more profound logic that classifies the damage complexes according to *main driving forces*. This results in a mapping of the syndromes into the two-dimensional space stretching between the axes of "economic geography" and "type of use".

This causally based decomposition of the overall phenomenon of "soil degradation" into globally or regionally distributed components cannot, of course, be completely well-defined: certain syndromes emerge jointly in some areas; special attention should then be given to the overlaps that ensue.

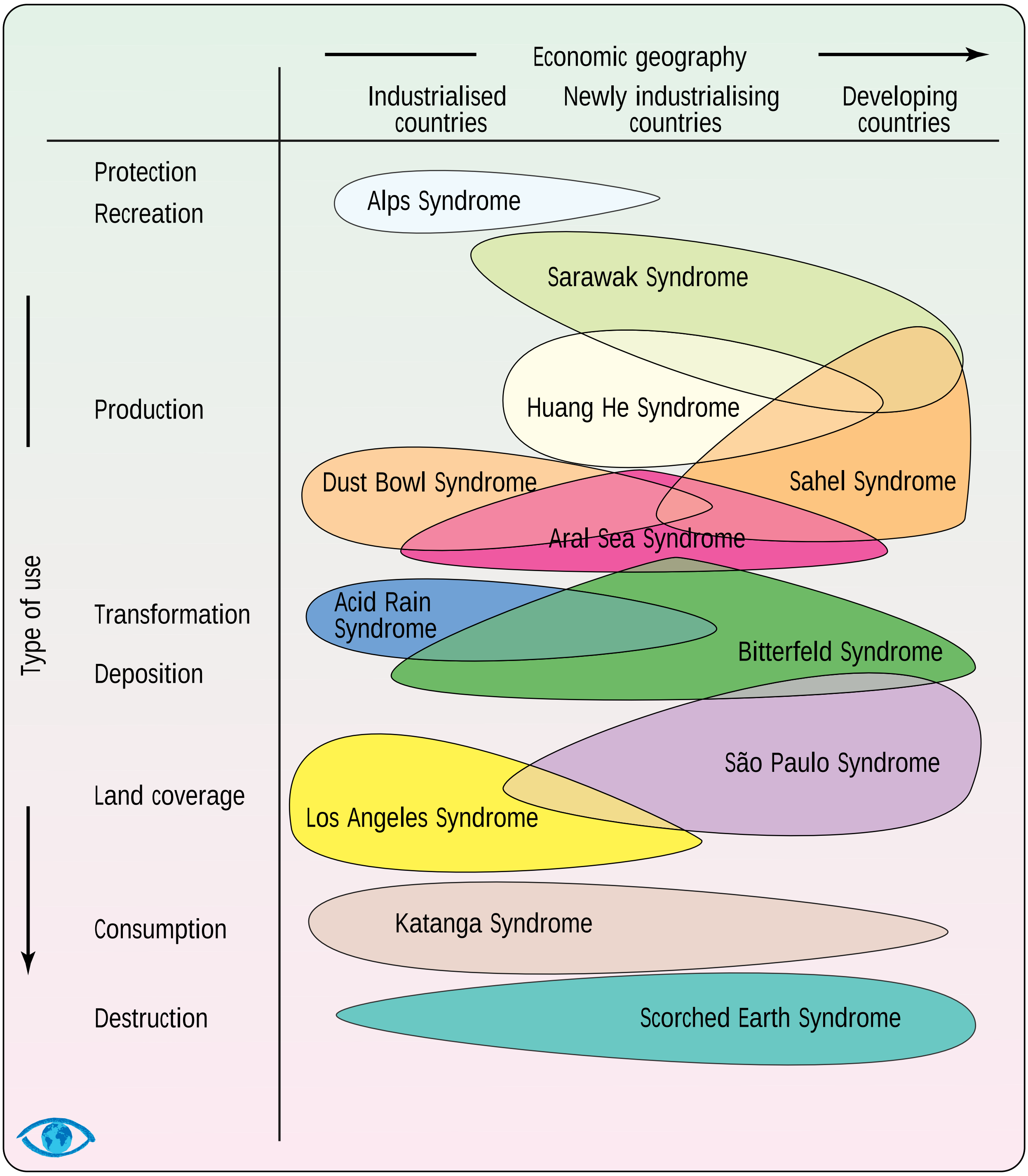
A brief description and analysis of the individual syndromes will now follow. The order is not random; rather, it represents an attempt to assess the relative significance of the individual damage complexes for the future of global soil resources. The basis of the ranking is the area of the soils that are particularly important for food production and are affected by the syndrome.

Each damage complex is translated into a syndrome-specific Network of Interrelations. The basic structure for this is formed by the soil-centred Global Network of Interrelations, whereby for each syndrome the trends that are not affected by first-order links are cut out. Symptoms that are regarded as significant for the respective syndrome, but which do not play a role within a global context, are identified by a rhomboid symbol. The totality of the twelve diagrams as an "atlas of relationships" forms the basis for the soil-centred Global Network of Interrelations and for further development of the complete Global Network of Interrelations.

1.3.3.1 Changes in the traditional use of fertile soils: The *"Huang He Syndrome"*

The Huang He (Yellow River, length: 5500 km) flows through the loess plateau of Shanxi Province in China. The fertile soils of this province number among the most severely eroded areas in the world. Erosion has been observed there since historical times (Jiang and Wu, 1980), but as soon as traditional methods of land use started changing, the loss of soils took on catastrophic proportions.

Figure 32: Main syndromes of anthropogenic soil degradation



Non-adapted farming on steep slopes has led to a situation in which roughly 1.6 billion t of highly productive loess soil is lost every year. The river transports the fine-grain soil as yellow-brown mud (thus the name), resulting in back-up and large-scale flooding after sedimentation. Over 600 million t of soil annually are washed into the sea. Wind erosion is also a problem: at the Mauna Loa Observatory (Hawaii) one can determine precisely when farmers in China begin ploughing on the basis of air samples (Brown, 1988).

The "Huang He Syndrome" thus describes soil degradation caused by the abandonment of previously sustainable land use on favourable soils. The traditional sustainable methods of agriculture are based on high personnel input. Labour-intensive, small-scale land care measures, such as maintenance of terraced slopes or measures taken against wind erosion (hedges, the most permanently closed vegetation cover possible through suitable crop rotation, etc.) are becoming increasingly unprofitable under altered basic economic conditions. As soon as protective and maintenance measures are neglected, soil erosion grows. Replacement of human labour by mechanised agricultural equipment requires a high capital input and frequently reaches its limits due to topographic conditions.

Besides the Huang He region in China, there are other areas affected by this syndrome, such as in the Philippines (Banaue), Indonesia and on fertile volcanic soil around the Great Rift Valley in East Africa.

Changing land use is promoted by different factors that sometimes act simultaneously. The financial burden of land users due to skimming of surplus value (capital outflow from affected regions in the form of taxes and rent to non-indigenous owners) is one cause. With the opening of subsistence farming to the world market one can often observe typical chains of events: first of all, local producer prices are adjusted to the low world market prices so that labour-intensive land management is no longer profitable. Secondly, the production and market risk is passed on to the land users through the transition to taxes and rent payments that are independent of yield. Due to the accumulation of debts from low-yield years, land users may end up in a "vicious circle" of growing debt and loss of property, and in the end lose control over their production. The consequence is centralisation and commercialisation of land ownership. These developments may finally result in greater control on the part of multinational agricultural enterprises over the supply of seed and fertiliser, mechanical equipment as well as processing and marketing. In this way the traditional forms of land use are definitively replaced. At the same time a transition to the "Dust Bowl Syndrome" is possible: *cash crops* are produced for export on fertile soils with a high input of capital as a consequence of this development. The rural population is pushed onto marginal soils, often with massive soil degradation effects ("Sahel Syndrome").

The necessity of feeding a large number of people leads to growing *pressure on land use*. This may lead to replacement of the traditional risk minimisation strategy by a yield maximisation strategy. At the same time traditional social structures are lost. This makes it increasingly necessary to introduce risky and soil-damaging methods that are more productive in the short run.

The negative influences of *centrally controlled agricultural policy* can be impressively described using the example of China. A major cause of soil degradation is the discontinuous planning policy. This initially resulted in a famine of dramatic proportions due to the neglect of agriculture, with more than 30 million victims between 1959 – 1961. The massive support of grain monocultures that subsequently commenced caused massive erosion, which then posed a threat to maintenance of a sustainable food base in the country. Only in recent times have adequate soil protection measures been propagated (e.g. the "Great Green Wall", the Chinese afforestation and soil conservation programme).

The above-mentioned causes of soil degradation may finally lead to a "vicious circle": neglect of resource protection results in land degradation (especially erosion), thus reinforcing marginalisation and impoverishment of the rural population due to losses in yields. Marginalisation causes non-adapted use when land users are forced to abandon traditional sustainable methods of use. In addition, maintenance of labour-intensive land management (such as terracing and intensive irrigation) is increasingly hindered by organisational shortcomings (collapse of local structures), lack of capital, but also by labour shortages, since rural outmigration to the cities is reinforced as a result of marginalisation and the attractive force of urban centres.

The major effects of the syndrome relate to the hydrosphere, as soil that is washed into river courses, reservoirs and into the sea due to erosion may cause substantial damage (silting, flooding, eutrophication of the bordering coastal waters). Pressure is also exerted on the biosphere because large-scale changes in land use disrupt the ecological balance and lead to reduction of biodiversity. Examples of atmospheric effects include increased emission of greenhouse gases from more intensified production (e.g. methane from rice farming) and a possible regional change in climate.

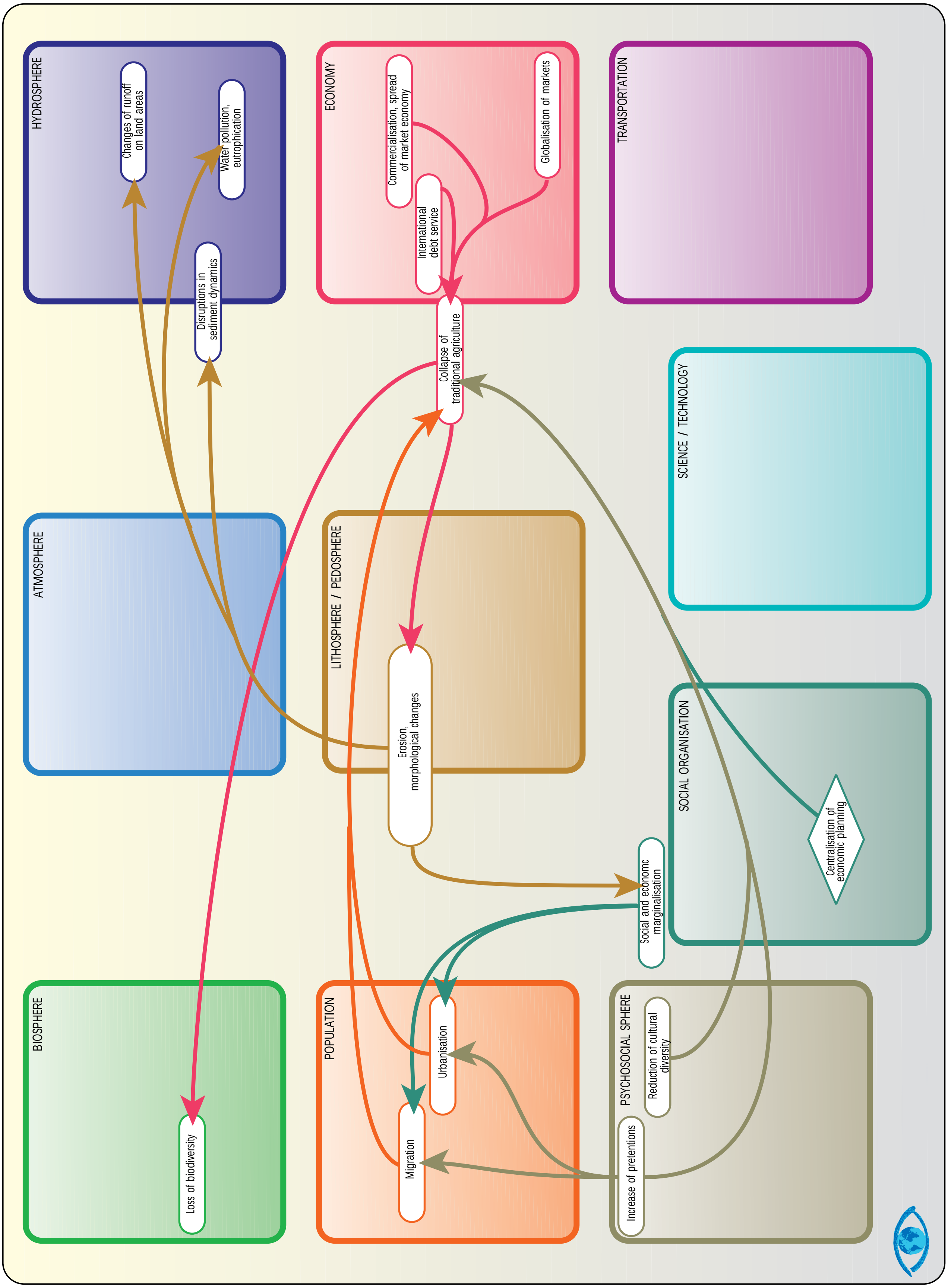


Figure 33: Syndrome-specific Global Network of Interrelations: The "Huang He Syndrome"

Potential remedies and remarks

A great number of options are available for protecting fertile soils against wind and water erosion, in particular

- reintroduction of adapted resource protection measures (e.g. terracing, planting of hedges, locally appropriate land use),
- if possible, soil planting or cover for the entire year, at least after the harvest, however, and during the seasons with a high erosion potential due to precipitation and storms.

Such measures to alleviate degradation must, however, be supported through appropriate agricultural policies. Moreover, specific incentives for responsible land management can be provided through allocation of property rights.

Additional reading:*

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Dixon, C. (1990): Rural Development in the Third World. London, New York: Routledge.
FAO – Food and Agriculture Organization of the United Nations (1992): Protect and Produce. Rome: FAO.
Johnston, B.F. and Kilby, P. (1975): Agriculture and Structural Transformation. Economic Strategies in Late-Developing Countries. New York, London, Toronto: Oxford University Press.
Stone, B. (1993): Basic Agricultural Technology Under Reform. In: Kueh, Y.Y. and Ash, R.F. (Eds.): The Impact of Post-Mao Reforms. Oxford, New York: Oxford University Press, 311-359.
Wang, Y.Y. and Zhang, Z.H. (Eds.) (1980): Loess in China. Xi’an: Shanxi Peoples Art Publishing House.
Zhao, D. and Seip, H.M. (1991): Assessing Effects of Acid Deposition in Southwestern China Using the MAGIC Model. Water Air and Soil Pollution 60, 8-97.

1.3.3.2 Soil degradation through mechanised farming: The *“Dust Bowl Syndrome“*

The interaction of environmentally destructive agricultural practices with the historic drought of the 1930s transformed the Wheat Belt in the west and southwest of the U.S. into the so-called “Dust Bowl” – a dry landscape where dust storms prevailed. “Black blizzards” swept away the nutrient-rich topsoil of the region - like the storm on 9th May 1934, which transported approx. 350 million t of dust from Montana and Wyoming via Dakota towards the east coast (Kellog, 1935). Under the impact of such “Dust Bowl” incidents, the first worldwide movement for the conservation of soil resources was born – its starting point the *U.S. Soil Conservation Service* established by President Roosevelt in 1933.

The degradation phenomena caused by industrial agriculture are summarised here under the name “Dust Bowl Syndrome”. This modern form of agriculture is particularly characterised by the fact that it attempts to achieve the largest possible short-term profit on the available area. Erosion and soil compaction as well as contamination of air and water can be designated as symptoms of this syndrome, which is typified by a minimisation of human labour input through the use of a wide range of machines on spacious, “cleared” agricultural areas and in “animal factories”. Attempts are made to maximise yield and capacity through

- monocultivation of highly productive kinds of plants,
- intensive livestock farming,
- large quantities of pesticides and medicine,
- intensive use of fertiliser and feed,
- intensive irrigation.

* Additional reading that is not quoted in the text is mentioned at the and of each syndrome section. Further literature on the syndromes that is quoted elsewhere is listed in the bibliography in Section E.

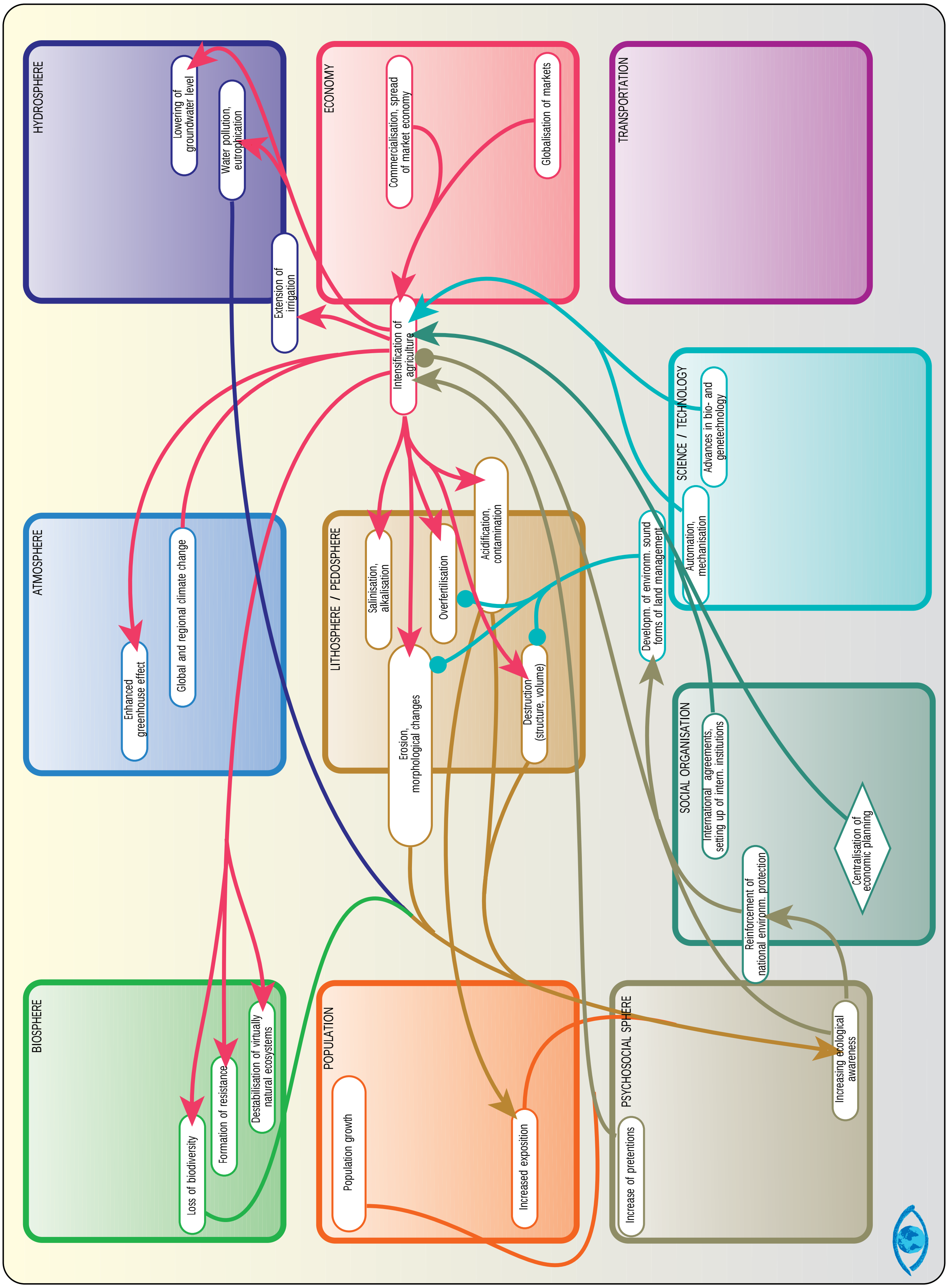

Figure 34: Syndrome-specific Global Network of Interrelations: The "Dust Bowl Syndrome"

The main symptoms of the corresponding soil damage profile are (WRI, 1992; WWI, 1992):

– great susceptibility to wind and water erosion as a consequence of the considerable exposition times of the ploughed-up soil, combined with the low degree of structuring of the agricultural landscape;
– destabilisation of turf and subsequent erosion through over-sized herds and overgrazing;
– loss of fertility due to deep ploughing, elimination of harvest wastes and monotonous crop rotation;
– reduction of soil drainage as a result of compaction by heavy agricultural machines;
– chemical soil pollution via overfertilisation and contamination (pesticides).

The focal points of this type of agriculture with its positive and negative consequences were originally on fertile soils, i.e. in Central and Eastern Europe, in the U.S., Canada, Argentina, South Africa and Australia, for example. Since the 60s, however, industrial agriculture has spread to regions on the globe that do not possess comparable fertile soils – in Mediterranean countries, Latin America, East Africa, in the Near East and South Asia.

The state-aided Dry Farming Programme powered by the export drive to war-torn Europe had “prepared the ground” for the “Dust Bowl” phenomenon in the U.S.: through the massive use of machines (tractor, disc harrow, combine, etc.) the Great Plains were transformed into a monotonous “grain factory”, whose broken-up surface remained exposed to the weather and unprotected for a large part of the year (Worster, 1988).

The “Dust Bowl Syndrome” as a consequence of industrial agriculture in the broader sense is the result of a continuous technical, innovative competition over regional and global markets for agricultural products, with allocative distortion of the various soil functions. A prerequisite for commercial success is a combination of factors: capital, know-how, social policy support (land consolidation) and favourable locational conditions (soil quality, climate, availability of water) (Blaikie and Brookfield, 1987). The driving force behind the “green revolution” is a mixture of commercial interests, the necessity of feeding a growing population as well as the strategies of national and international authorities and organisations (Herkendell and Koch, 1991). This is promoted by the inadequate internalisation of the external effects in the form of artificially lower-cost raw materials and energy (e.g. through the EU agricultural market regulation).

The practices of industrial agriculture and the soil degradation thus induced have a number of negative effects beyond the pedosphere (SRU, 1985), above all
– changes in hydrological conditions (groundwater level, surface runoff, infiltration, etc.)
– silting up of rivers and harbours
– diminishing water quality (eutrophication, contamination, sediment load), thus increasing costs for drinking water supplies (costly treatment, construction of long-distance water lines)
– reduction of biodiversity or shifts in the natural structure of species
– formation of resistance on the part of pests and pathogens
– accumulation of harmful substances in the food chain, thus endangering human health
– emission of greenhouse gases or substances having a chemical effect on the atmosphere.

Potential remedies and remarks

If environmental stress is to be brought under control, long-term perspectives are necessary that should combine the following measures in particular:

- increased diversity, i.e. abandonment of monocultures and introduction of multifarious crop rotations,
- setting up of smaller plots of arable land,
- development of agricultural machines for environmentally sound farming and dispensing with farming methods which degrade soils, such as deep ploughing,
- reduced nitrogen input,
- introduction of biological methods for fertilisation and plant protection,
- implementation of a regional planning law and land use plans.

Introduction of a nitrogen tax – which has already been proposed a number of times – should be considered. Networked thinking and planning are to be promoted through education and information, which must begin at school, so that the various interactions between soil management and effects on other elements of the global system can be recognised at an early stage. In this way long-term consequences are to be avoided or reduced.

Additional reading:

Crosson, P. (1990): Agricultural Development – Looking to the Future. In: Turner II, B.L. et al. (Eds.): The Earth as Transformed by Human Action. Cambridge, New York: Cambridge University Press.
OECD (1991): Umwelt – global: 3. Bericht zur Umweltsituation. Bonn: Economica.
Mellor, J.M. (1986): Agriculture on the Road to Industrialization. In: Eicher, C.K. and Staatz, J.M. (Eds.) (1990): Agricultural Development in the Third World. Baltimore, London: Johns Hopkins, 70-88.
Priebe, H. (1985): Die subventionierte Unvernunft. Berlin: Siedler.

1.3.3.3 Overexploitation of marginal land: The *“Sahel Syndrome“*

Another type of soil degradation that can be identified in many areas, the “Sahel Syndrome”, typically appears when agricultural use is made of marginal land. The syndrome encompasses the overgrazing and overexploitation of arid and semi-arid grasslands and the development of steep, structurally weak, erosion-prone soils.

In the Sahel Zone roughly 1.5 million hectares of agriculturally useful land has been lost every year due to soil erosion and degradation since the great drought in the 70s (Hahn, 1991). Now approx. 90% of the pastureland and 80% of the non-irrigated farmland has already been afflicted by at least a weak form of desertification. The hot spots in overexploitation of marginal land, apart from the Sahel Zone, are located in the Maghreb, East Africa, West Arabia, parts of East and Central Asia, India, Mexico, Central America and parts of east Brazil. In all these regions analogous complexes of causes lead to structurally similar soil symptoms of the “Sahel Syndrome” type.

The “Sahel Syndrome” describes the destruction of natural resources through non-adapted farming, overgrazing and fire (details on this in Section D 2.1). This has resulted in reduced productivity and an exceptionally high susceptibility degree of the natural environment to negative influences. Together with the often greatly fluctuating annual precipitation in arid regions, this leads to a degradation (variable in space and time) ranging from steppes or savannas to desert-like landscapes. The symptoms of such desertification are:

– degradation of the plant cover, decline of biomass production in primary vegetation as well as in agricultural vegetation
– changes in water resources (soil water, groundwater, evaporation, surface runoff)
– altered morphological processes, such as increased wind and water erosion and reactivation of dune shifts and formation of new dunes
– degradation of soils (aridification, reduced soil fertility, surface crusting, salinisation and alkalisation of soils, destruction of soil structure.

Land use change, ranging from subsistence farming to capital-intensive monocultural farming of *cash crops*, is to be regarded as a main cause (see also “Dust Bowl Syndrome” and “Aral Sea Syndrome”). As a result, the rural population is increasingly forced to move to marginal land. In connection with population growth, this leads to expansion of the agricultural areas and intensification of use. In addition, fuelwood is utilised while wood supplies become ever scarcer.

The influence of western cultures through colonisation and later via the modern media has initiated a number of *social or cultural changes* in the regions affected: consumption needs changed, monetarisation of economic relations, which were previously based on barter and mutual assistance, led to alienation from the natural basis of life. Traditional forms of living together in tribes, clans and villages have given way to increasing individualisation. One of the consequences is the loss of traditional knowledge about adapted agricultural practices along with the corresponding change of traditional agriculture.

With respect to *domestic policy*, these effects are particularly reinforced by the promotion of modern intensive agriculture, by centralist structures without adequate scope for participation on the part of the rural population, and by bureaucracy. Another factor is the tendency to place less value of traditional ways of life, often leading to repression (e.g. making nomads sedentary).

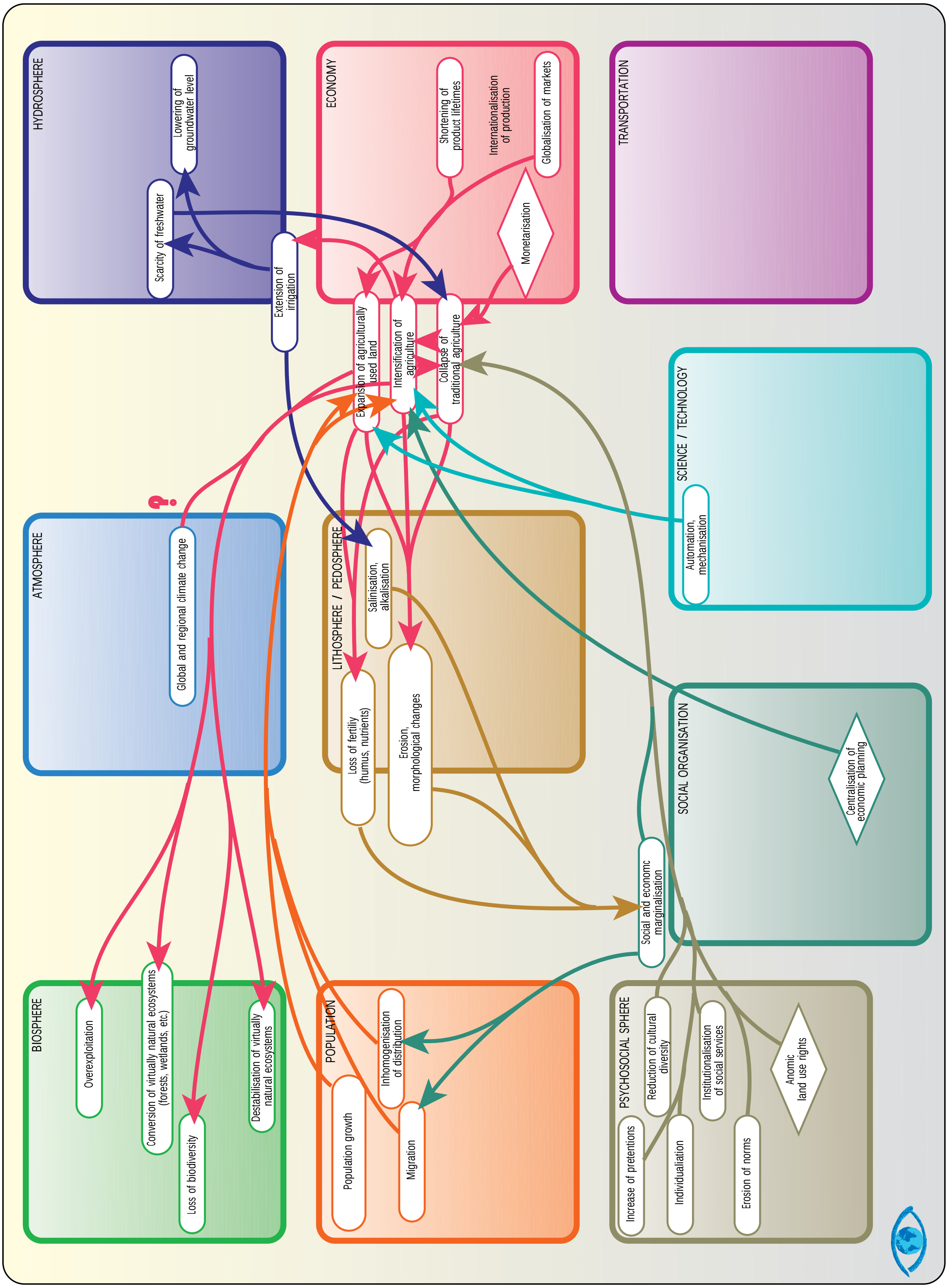

Figure 35: Syndrome-specific Global Network of Interrelations: The "Sahel Syndrome"

Foreign trade constraints are created through unfavourable *terms of trade* on the world market. The traditional export products of these countries are usually raw materials whose prices continue to drop. In connection with their high international debts, the countries affected are increasingly forced to obtain additional foreign exchange by growing cash crops.

Mismanaged development aid, which often gave priority to overhasty modernisation of agricultural (and economic) structures over local, adapted, small-scale projects and which took insufficient account of the needs and traditions of the local population, has also contributed to the problem, at least in the past.

The "Sahel Syndrome" has effects on the hydrosphere, where the result is scarcity of fresh water and sinking of the groundwater level. The biosphere is affected by the conversion of virtually natural areas (see also "Sarawak Syndrome") and by the intensification of utilisation, both of which lead to a loss of biodiversity. Local or regional climate changes may emerge following large-scale alteration of the vegetation. Soil degradation has considerable effects on the anthroposphere as well. The loss of cultivated land results, among other things, in impoverishment, deficient nourishment and famine, migration and further intensification and expansion of agriculture.

Potential remedies and remarks

Overexploitation of marginal land can only be alleviated by a combination of local measures, national political decisions and international agreements:

- adapted intensification of agriculture for a rise in food supply, while utilising sustainable farming methods (crop rotation, soil protection measures)
- development of alternative sources of income for the rural population
- protection of regional markets against subsidised agricultural imports, e.g. from the EU
- drawing up of state development plans
- selective (partial) cancellation of debts of countries concerned

Assistance must be furnished to those countries in which, even after introduction of soil-benign and yield-increasing agricultural practices, the food base is not secure. The deployment of funds needs to be better coordinated and monitored. In coordination with the government and the local population, assistance is to be directed, in particular, at education, the development of adapted technology, family planning and the setting up of local markets.

Additional reading:

Achtnich, W. (1984): Angepaßte Formen der Landnutzung im Sahel. Entwicklung und Ländlicher Raum, 18(6), 10 – 14.

Ibrahim, F. (1983): Sahel: Der Kampf gegen die Ausbreitung der Wüste. Entwicklung und Zusammenarbeit, 10/83, 26 – 29.

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Schiffers, H. (1971): Die Sahara und ihre Randgebiete. Vol. 3. Physiogeographie. München: Weltforum.

1.3.3.4 Conversion or overexploitation of forests and other natural ecosystems: The *"Sarawak Syndrome"*

The "*Sarawak Syndrome*" stands for the destruction or degradation of entire ecosystems (biomes), such as forests, savannas or marshlands. In Sarawak, a Malaysian province on the island of Kalimantan (Borneo) with an area of 124,500 km^2, large parts of the once abundant primary forest have been destroyed while the importance of the non-sustainable timber industry as a major source of income continues to increase.

A distinction must be made between *destruction* of the ecosystem with subsequent alternative utilisation (conversion) and *overexploitation* of virtually natural ecosystems if there is demand for individual services/ functions to an extent that exceeds the system's natural regenerative capacity.

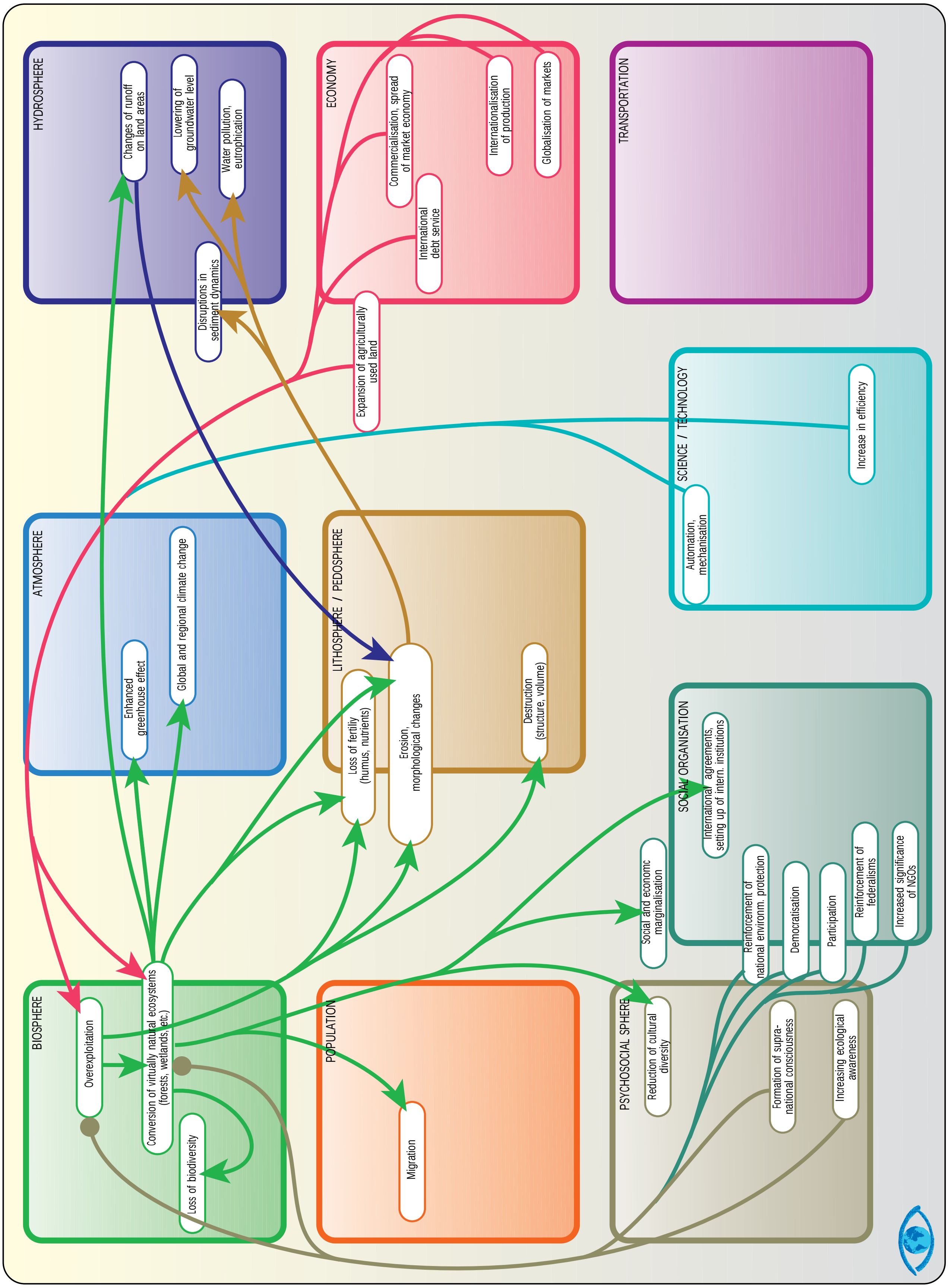

Figure 36: Syndrome-specific Global Network of Interrelations: The "Sarawak Syndrome"

The “Sarawak Syndrome” can be found in the form of destruction of forest ecosystems in tropical regions, such as in the Amazon and India, while boreal zones in Canada, the U.S. and Russia are also affected. A special problem is the destruction of mountain forests in China (Tibet) and Nepal. The “Sarawak Syndrome” also encompasses destruction and degradation of savannas (e.g. in Zaire and Sudan) and marshlands (e.g. the Danube delta, the mouth of the Guadalquivir in Spain and the Menderes Valley in Turkey).

Clearing of *tropical forests* leads to large-scale and usually irreversible destruction of soils via nutrient eluviation and soil compaction (WBGU, 1994). Interventions in *mountain forests* are a severe problem. Tibet, for example, has lost roughly 45% of its forest area since 1965 (this corresponds to the entire forest area of the territory of the Federal Republic of Germany prior to 1989). Due to the steep relief, rapid runoff and pronounced flooding take place in the lowlands (example: Bangladesh 1991). Seven of Asia’s large rivers, which supply approx. 47% of the world’s population with water, have their source in Tibet. Interventions in Tibet’s water resources and the contamination of rivers and groundwater thus have, in some cases, disastrous consequences for almost half of humanity (ECO-Tibet, 1994).

This problem also becomes evident with the economic utilisation of the boreal coniferous forests. The Russian forests with an area of 5 million km^2 are roughly double the size of the rainforest region in the Amazon and thus correspond to approximately half of Europe’s land area. Since commencement of the radical transformation in Russia, foreign companies have been allowed to utilise the boreal coniferous forest for industrial purposes. Deforestation is carried out on a large scale with a so-called “harvesting machine” which is able to cut down an average of 300 trees an hour. These heavy machines compact the soil and destroy the unusable saplings. Only half of the tree harvest is taken away for further processing. Contractually stipulated afforestation programmes are, as a rule, not carried out in exchange for acceptance of a, for the companies, negligible penalty. Because of the lack of tree cover, the permafrost ground can thaw, resulting in dessication, lowering of the groundwater level and greater methane emissions. As vegetation declines, one of the major sinks for the greenhouse gas carbon dioxide is reduced. The wood harvested in Siberia, for example, is shipped to South Korea; the cellulose produced there goes to Japan and other parts of the world. Germany is the second largest consumer of Siberian wood worldwide.

A general consequence of the “Sarawak Syndrome” is disruption of the equilibrium between the biosphere and pedosphere due to soil degradation and the conversion of ecosystems. Reduction of biodiversity, erosion and large-scale losses in the surface, nutrient-rich soil layers as well as changes in the hydrological cycle can be regarded as the most important effects.

Potential remedies and remarks

In its 1993 Annual Report the Council described in detail the options for taking action regarding protection of natural vegetation, particularly in tropical forests. In this context the most important options are underlined again here:

- adoption of a Forest Convention that is locally binding,
- reinforcement and expansion of international forest protection programmes,
- inclusion of sustainable forestry in international trade agreements,
- implementation of compensation systems.

Conversion and overexploitation of virtually natural ecosystems can be additionally slowed down by expanding nature reserves (e.g. biosphere reserves) and by introducing agro-forestry strategies.

Additional reading:

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Enquete Commission “Preventive Measures to Protect the Earth’s Atmosphere” of the 11th German Bundestag (1990): Protecting the Tropical Forests. A High-Priority International Task. Bonn: Deutscher Bundestag.

Ives, J and Pitt, D. C. (Eds.) (1988): Deforestation: Social Dynamics in Watersheds and Mountain Ecosystems. New York: Routledge.

1.3.3.5 Mismanagement of large-scale agricultural projects: The *"Aral Sea Syndrome"*

The ecological catastrophe in the Aral Sea region stands for similar hydrological engineering and agricultural projects that do not take into account the ecological potential of the region as a result of centralist planning and large-scale technology and in this way destroy the natural basis for humanity, animals and plants.

The Aral Sea was once the fourth largest fresh water lake on Earth, a water basin with no drainage, fed by two rivers (Syr Darya and Amu Darya), in a region with a desert-like climate. Fishing and agriculture were carried out in what was once a fertile region abundant in forests and species. For 30 years the feeders of the Aral Sea have been tapped, two-thirds of the water has been diverted to date, only roughly 10% reaches the sea, and supplied to the Kara Kum irrigation canal (length: 1300 km). The water level of the Aral Sea dropped, its surface area declined drastically and the salt content of the water rose. The surrounding farm lands are contaminated and salinated via large quantities of pesticides and fertiliser. The short-time expansion of agricultural production that has been possible has made large parts of the region unproductive due to its consequential ecological damage.

Other problems associated with the syndrome include large-scale dam projects or embankments, which result in soil degradation due to interventions in the water resources or to expansion of irrigation farming. Regions with such problems can be found in China where 50% of the large dams of the world are located, India, Indonesia, the United Arab Emirates, Libya and northeast Brazil.

Large-scale projects include:

– Aswan Dam / Egypt (soil degradation, lowering of river bed, lower water levels, salinisation, deposition of sediment in dam area)
– Theri Dam / India (planned) (drying up of river bed due to existing coffer dam to divert the river)
– Sardar Sarovar Dam / India (flooding of approx. 40,000 ha of farmland, roughly 100,000 people lose their land)
– Tamil Nadu / southern India (groundwater level is dropping rapidly, salt water intrusion into groundwater)
– *Great Man-Made River Project* / Libya (200,000 – 240,000 ha of land are to be irrigated with fossile groundwater)
– Embankment of the Lower Ganges / India (transmission of monsoon waves will be able to reach Bangladesh resulting in flood disasters).

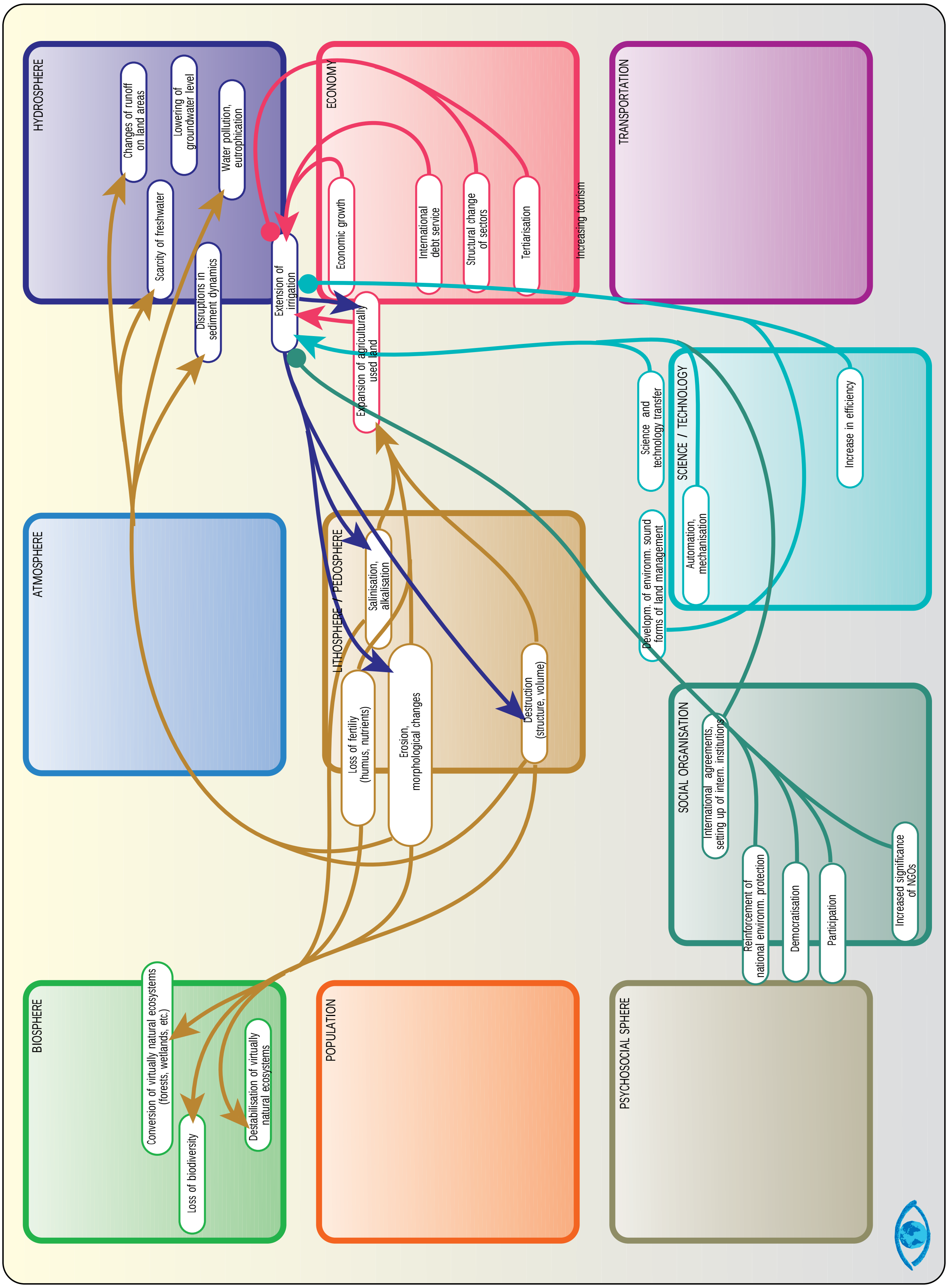
This and other projects were planned to intensify agriculture by means of irrigation and a high input of energy, fertiliser and pesticides. The monocultural areas were expanded, often with inefficient irrigation methods. In the Aral Sea region only roughly 50% of the water reaches its destination on an area of approx. 7.5 million ha.

The effects of such large-scale projects on soils are increases in wind erosion, chemical degradation (depletion of nutrients, salinisation due to non-adapted irrigation, development of salty soils on dried-up river beds and former lake bottoms), physical degradation (compaction and structural change, waterlogging) and contamination (pesticides and mineral fertilisers in soils and groundwater, transport of polluted dusts to surrounding and more distant areas). The effects on the atmosphere are regional climate shifts and changes in air humidity, and have effects on the number of rain days and on storm frequency.

Such projects have a great direct influence on water resources. In the Aral Sea the water level dropped by 16.5 m and its surface area declined by approx. 45%. The large-scale dam projects with their irrigation systems lead to a broad shift in drainage as well as to significant changes in the groundwater level. Surface and groundwater are contaminated. The projects also have direct effects on flora and fauna. They include the transformation of natural vegetation into cultivated land (and subsequently into desert in some cases), clearing or flooding of woodland for cultivation and the extinction of species (173 species in the Aral Sea region are now considered to be extinct, including all native fish species).

The population is affected by the contamination of food and drinking water and thus by increased health risks in the Aral Sea region: the rate of cancer is said to be five times higher than in the rest of the former Soviet Union, the rate of hepatitis has increased sevenfold, the typhus rate has risen fivefold and the death rate due to communicable diseases is also five times higher. Migration is often the consequence.

Figure 37: Syndrome-specific Global Network of Interrelations: The "Aral Sea Syndrome"



Economy and transportation are directly affected. Agricultural productivity initially rises, only to decline again when soil degradation sets in. Further processing of agricultural products increases. Product quality and export quotas drop. In most cases, high subsidies are used for countercontrol and local products are replaced by imports. Transport intensity increases indirectly as possible profit drops. Cultural and political effects include the loss of conventional forms of economic activity as well as local traditions and cultures.

The trends on which this syndrome is based involve, in particular, the neglect of sustainability criteria, central planning without consideration of local possibilities and borders, and a lack of communication between the regions and institutions concerned. In some cases, selective cultural overshaping and a centralist population policy also play a role.

Potential remedies and remarks

To avoid future mismanagement of large-scale agricultural projects, the following measures should be considered:

- environmental impact studies including long-term effects of the projects on soil degradation and biodiversity,
- participation of the population in the planning stage,
- water-saving irrigation techniques taking into account quantity and quality of sustainably available water.

General abandonment of large-scale projects, including their financing (target: World Bank), should be seriously discussed.

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1.3.3.6 Long-range transport of nutrients and pollutants: The “Acid Rain Syndrome”

Soil degradation brought about by pollutants and nutrients transported over long distances is called the “Acid Rain Syndrome”. This long-range transport mainly takes place via the atmosphere as well as via surface waters.

Depending on substance-specific degradability or non-degradability (persistence), emissions into the air and water are distributed locally, regionally and globally and accumulate in the environment (see “Bitterfeld Syndrome” with regard to local effects). Regions affected by urban centres are the most hard-hit; but often the entire globe is affected, even the most distant “clean air regions”. An example of this is the occurrence of accidents at nuclear energy plants where, as demonstrated by the Chernobyl disaster, deposition of radioactive substances (fallout) results in radiologically relevant doses even in very distant areas.

The syndrome is most evident in the symptom of soil acidification. Acids and acid-forming agents bring about nutrient losses in soils through reinforced leaching processes and the release of ecotoxically active substances. Deposition of the acid-forming nutrients ammonium and nitrate additionally contribute to eutrophication via an oversupply of nitrogen. A number of heavy metals and organic industrial chemicals also have an ecotoxic effect, though the specific form of their effect is frequently unknown (Howells, 1990).

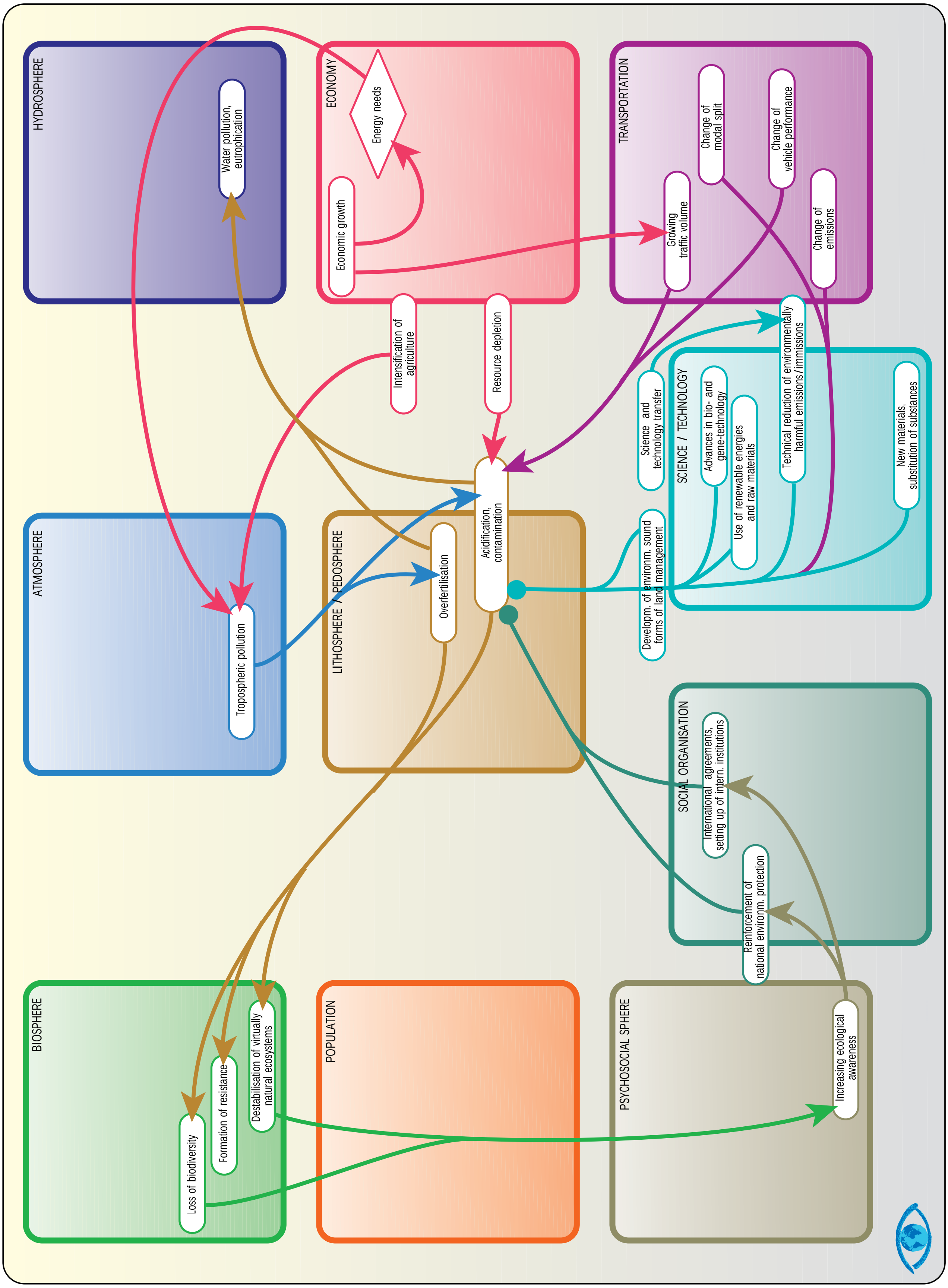

Figure 38: Syndrome-specific Global Network of Interrelations: The "Acid Rain Syndrome"

Today soil acidification primarily affects broad regions in Europe, North America and northern and southern China (Schwartz, 1989; Zhao and Seip, 1991). Especially neuralgic soils have a low buffer capacity. Regions with robust soils or a high mineral dust content are less threatened (the latter are mainly located leeward of arid regions and deserts). Soils having a low stress-bearing capacity can be found in northern Russia, Canada and Alaska, northern South America (excluding the Andes region), western and southwestern African coastal regions and the Congo basin, southwestern India and in large parts of Indochina and the Indonesian archipelago (Rodhe, 1988). The forecast for many of these regions is considerable economic growth in the near future, with the correspond-ing implications for intensification of substance flows.

Deposition of acid and acid-forming agents is a consequence of tropospheric pollution and of the pollution of flowing surface waters due to sulphur and nitrogen compounds and other substances. The most important sectors for anthropogenic emissions are energy (electric and district heating power stations), transportation and agriculture. In intensive agriculture the applied substances contribute to the total deposition into soils either intentionally (ammonium, nitrate and phosphate, pesticides) or unintentionally (ammonia emissions, contaminations in fertilisers). A fraction of nitrogen fertilisers is transformed into N_2O, emitted and thus reinforces the anthropogenic greenhouse effect (see Section D 1.3.1.1.2). Even the "new types of forest damage" in Central Europe have been discussed in connection with acidification and nitrogen depositions in forest soils (SRU, 1983).

Mobilisation of sulphur and nitrogen as a waste product of combustion (oil products, coal) or in connection with certain production processes as well as with use of substances in plant and animal production is generally accepted in industrial societies.

Because of the buffer capacity of soils (and surface waters), the overall extent of the damage cannot yet be determined. The ecotoxic effect of most industrial chemicals as well as of some heavy metals (including the synergisms of several substances) is unknown. For this reason and in view of the expected sudden release of toxic loads when thresholds are reached ("chemical time bombs"), the situation has to be described as serious.

Ecosystems are impaired (reduction of biodiversity, alteration of ecological structure and performance, reduction of forests and marshlands: *Box 8*), and the hydrosphere is particularly affected. The substances find their way into the food chain via the supply of drinking water. In many places nitrate, nitrite and organic chlorine compounds already represent great, sometimes unsolvable problems in the provision of drinking water.

Potential remedies and remarks

The soil degradation caused by remote transport of nutrients and pollutants can be checked by taking the following measures at the source:

- increasing energy efficiency,
- emission reductions at power stations with fossil fuels and in motor vehicles,
- development of production techniques with greatly reduced use of toxic substances and more recycling,
- adjustment of the use of fertilisers to soil quality and plant needs in order to avoid emissions (N_2O, NH_3).

National and international agreements to date (*Box 13*) regarding reduction of emissions must be implemented consistently. Here, efforts should be better coordinated on a continental basis. Regulations must be set up for trace metals and certain organic compounds. One important international measure might be the introduction of an international liability law.

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1.3.3.7 Local contamination, waste accumulation and polluted land: The *"Bitterfeld Syndrome"*

The "Bitterfeld Syndrome" characterises regions with extensive chemical, mining and energy industry activities, working with, in most cases, outdated equipment. The result is severe soil contamination. In these regions settlement and industrial wastes are disposed of at storage sites that do not (adequately) meet the pollutant potential. Waste depositing is usually carried out without sorting or control. Soil contamination with threats for human health and the natural environment produces hazardous waste sites.

The "Leipzig-Halle-Bitterfeld" agglomeration represents one example of this syndrome (see Section D 2.2). Brown coal mining in combination with its industrial activities like the large-scale chemical industry and energy production led to a profound transformation of the landscape and to damage and contamination of soils and surface waters.

Additional "hot spots" with this syndrome include Cubatao (Brazil), Donezk basin (Ukraine), Katowice (Poland), Wallonia (Belgium), Manchester-Liverpool-Birmingham (Great Britain), Seveso (Italy), Bhopal (India), Hanford and Pittsburgh (USA).

Both the lack of knowledge about the environment's absorption limits and professed ideologies, as in a planned economy, resulted in underestimation or ignorance of the potential danger of pollutants in soils. The handling and storage of toxic substances took place in a manner that led to soil pollution through leaks, losses of control, accidents, etc. Elimination of wastes was carried out in the least costly fashion, while accepting the possibility of pollutant release. In most cases there was a lack of regulations for adequate waste disposal. The technical means for protecting groundwater and soils were initially not available for the planning of landfills; later they were not utilised in full or not deemed to be necessary at all.

The ability of soils to absorb and store toxic substances varies greatly. There are regions in which the layers near the surface have a high retention capacity for inorganic and organic pollutants, while in other regions one can expect a quick passage of organic and inorganic pollutants from the soil zone into the groundwater. If a soil has a high pollutant retention capacity, the utilisation options are restricted if toxic substances are present, but it represents at the same time protection against rapid movement of pollutants into the groundwater. Conversely, sandy and low-humus soils have less capacity for storing pollutants so that in cases of damage, there is a great danger of rapid transport to the groundwater.

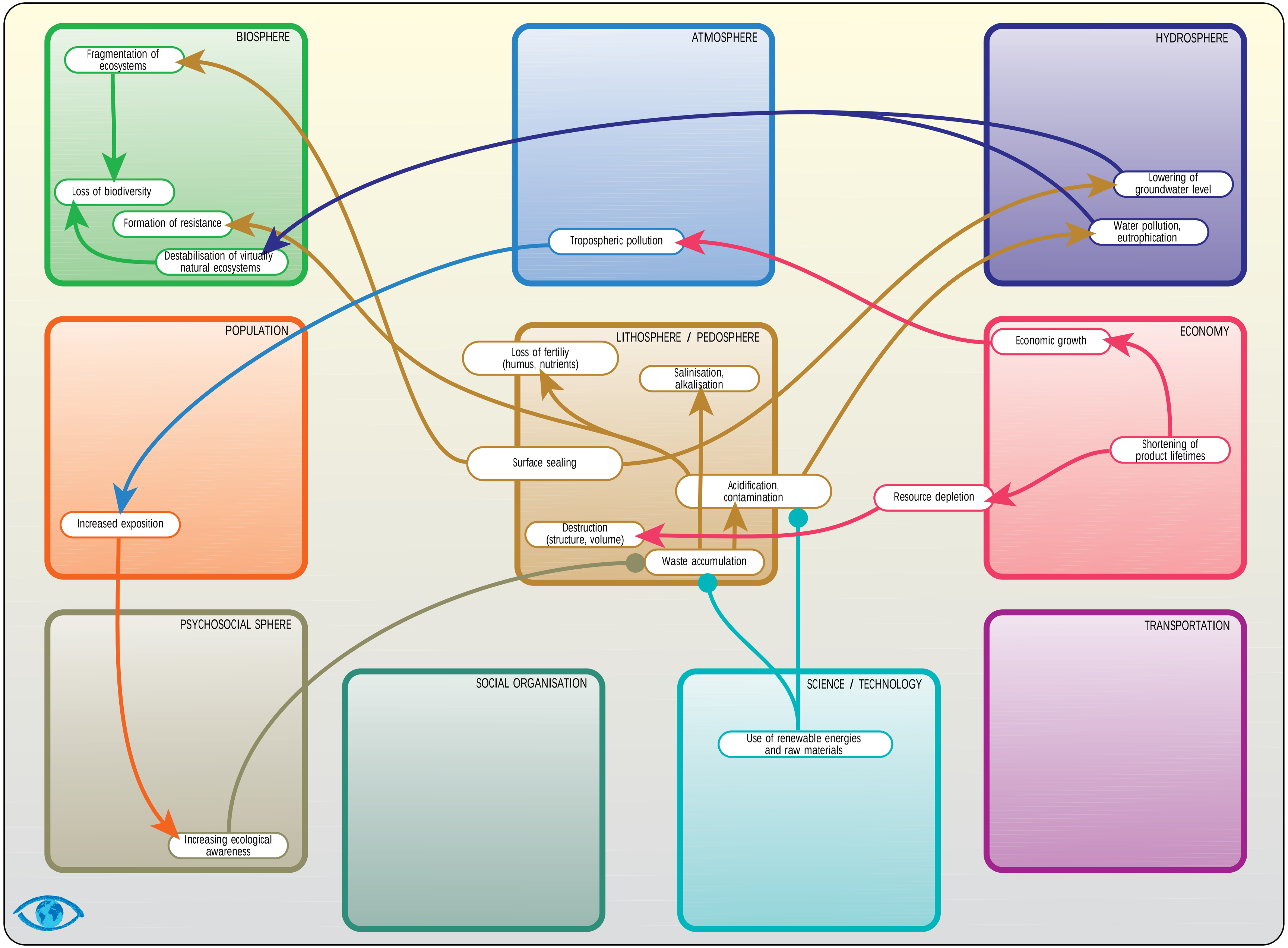
Whether in the short-, medium- or long-term, contaminated soils always lead to damage to the groundwater. Maintenance of this asset for the drinking water supply of the population is of great importance because of the continued high demand for water. Increasing pollution of the waters used for the drinking water supply brings about substantial cost increases for drinking water. Furthermore, contaminated soils have a negative effect on the biosphere, and in the end threats to humankind may result via the food chain.

The population in these regions is not only threatened by direct intake of toxic substances. Polluted land may also create psychosocial stress. For soil as a production factor contamination means a significant loss of value since changes in utilisation or construction activities are only possible to a limited extent or cannot be carried out at all, and considerable costs would be incurred for remediation measures.

Potential remedies and remarks

- Protective measures and utilisation restrictions are needed to prevent acute dangers.
- Safety measures (such as lining, lowering the groundwater level, gas detection and immobilisation) can be taken to break up the paths of contamination.
- Elimination of toxic substances in contaminated soils and groundwater is possible via decontamination measures, such as active hydraulic and pneumatic methods, chemical and physical treatment or biological methods.

Figure 39: Syndrome-specific Global Network of Interrelations: The "Bitterfeld Syndrome"



Removal ("excavation") and relocation of contaminated soils to landfills should only be done in exceptional cases. Remediation objectives oriented to the respective environmental asset and utilisation should be specified prior to each remedial measure, and cost-effectiveness analyses are to be carried out. In order to avoid contamination of soil and subsoil (groundwater channels) in the future, replacement of ecotoxic substances in addition to technical measures within the framework of integrated environmental protection must be pushed forward rapidly. Prevention also includes specification of basic conditions as a task for government regulation policy (soil protection law) as well as the introduction of strict product liability. Within the scope of technology transfer between partners, experience with remediation methods should be passed on to those countries (e.g. Eastern Europe, Brazil) that have to deal with the problem of contaminated soils now or in the future.

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1.3.3.8 Uncontrolled urbanisation: The *"São Paulo Syndrome"*

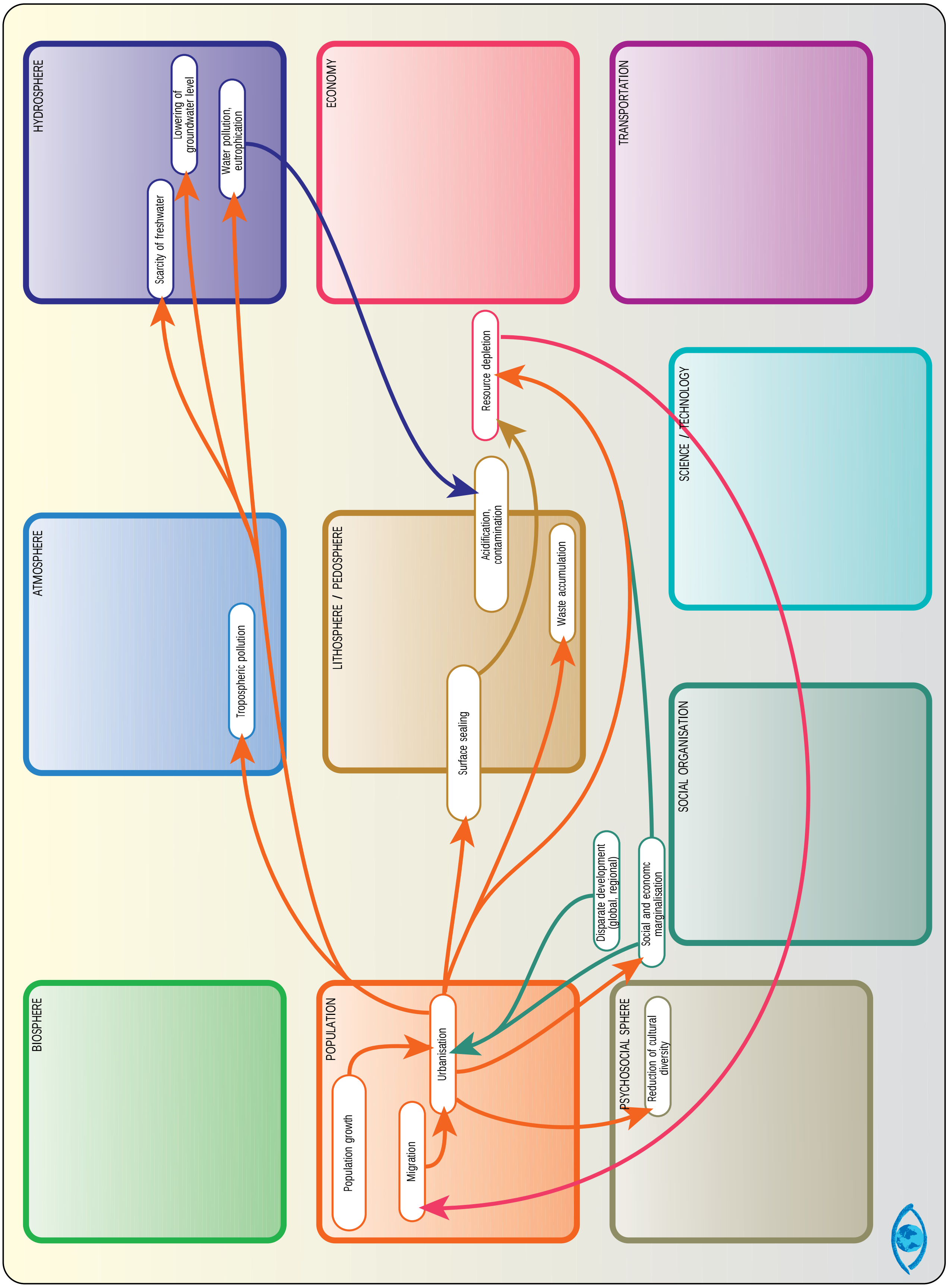
Whereas only three "megacities" worldwide existed in 1950 (New York, London and Tokyo), with megacities here referring to urban agglomerations with over 10 million inhabitants, 25 such cities are expected in the year 2000, 19 of which are located in developing countries and thus form the focus of the syndrome. The name of the syndrome refers to the typical problem structures of growing megacities in developing countries that are clearly visible in São Paulo.

With roughly 13 million inhabitants São Paulo is the home of approx. 10% of the Brazilian population on an area of 7,967 km^2. This megacity is characterised by a rapid development of economic activities (40% of the total national production in the industrial sector). Roughly 57% of the inhabitants are immigrants from rural regions. The population will probably double in fewer than 15 years. Today there are already over 500,000 people living in slums that sprout up uncontrolled. Settlement of land in peripheral areas by the middle class is increasing. Approx. 300 km^2 of land was illegally occupied and settled. The place of residence and the work site of most inhabitants are located far apart, thus resulting in great transportation problems and sometimes chaotic traffic conditions. An estimated 78% of household wastes are not properly disposed of and stored in open dumps that are frequently located near drinking water sources. As a consequence of poor sewage and pipe systems, the favelas are repeatedly subject to flooding, which leads to accumulation of excrement and toxic substances in the soil.

The cities with the highest population figures in the year 2000 and symptoms corresponding to the "São Paulo Syndrome" will probably include Bombay, Buenos Aires, Jakarta, Cairo, Calcutta, Manila, Mexico City, Shanghai and Teheran.

Of essential importance here is the fact that the area surrounding these cities and the entire nation are often characterised by a monocentric settlement structure; a polycentric structure with cities of a decentralised magnitude and corresponding "buffer functions" has not developed. The rapid growth of large agglomerations leads to significant

Figure 40: Syndrome-specific Global Network of Interrelations: The "São Paulo Syndrome"



pollution and overloading of municipal supply and disposal structures which, in the end, trigger new international migration, thus making the phenomenon a syndrome of global proportions.

The symptom is characterised by the interaction of various factors. A high degree of soil pollution occurs because of the intensive land use. The former is caused by direct deposition of pollutants from the atmosphere, waste accumulation and surface sealing. The soils are indirectly polluted via damage to vegetation which is, in turn, the consequence of human interventions. The latter also include changes in the local climate brought about by the high degree of surface sealing and energy consumption. Impairment of water resources due to unregulated disposal and high water consumption results in direct as well as indirect soil pollution via damage to the vegetation. These processes are closely interlinked and thus produce instability in the ecosystems of the regions affected.

Major causes of the "São Paulo Syndrome" include *rural migration to urban centres* as a consequence of insufficient development and often inadequate supply of the rural region, *population growth* as well as *increased demand for land* on the part of the population in cities. Also of importance are the centralisation of economy, infrastructure and politics in cities, the increasing mechanisation of agriculture, which is leaving more and more workers without work, as well as the concentration of land ownership combined with land use planning that does not take into account the needs of the rural population. It is imperative that these causes be combated so as to enable sustainable improvement of the situation and long-term functioning of urban structures.

Potential remedies and remarks

To alleviate the soil-degrading effect of uncontrolled urbanisation, various instruments can be implemented:

- promotion of polycentric urban structures through planning and regulatory measures
- introduction and maintenance of minimum standards for waste and sewage disposal
- limitation of soil compaction and surface sealing
- saving the most fertile soils from urban development.

An effective therapy for this syndrome would have to tackle the roots themselves, however, i.e. the driving forces of uncontrolled urbanisation. Appropriate socioeconomic measures, such as family planning, establishment of socially compatible access rights to land ownership, creation of jobs in rural regions, etc., require enormous efforts and are only feasible within the framework of an overall strategy of regional or global development policy. The effects on soils appear to be more of a marginal nature in this context.

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1.3.3.9 Urban sprawl and the expansion of material infrastructure: The *"Los Angeles Syndrome"*

The *"Los Angeles Syndrome"* describes the process of infrastructural expansion of cities with far-reaching environmental effects, predominantly in industrial and newly industrialised countries. Today the "Los Angeles Syndrome" can be observed in nearly all big cities and urban agglomerations of the industrial nations. They include cities such as London, Paris, Tokyo, New York and Hong Kong as well as urban agglomerations like the Ruhr region.

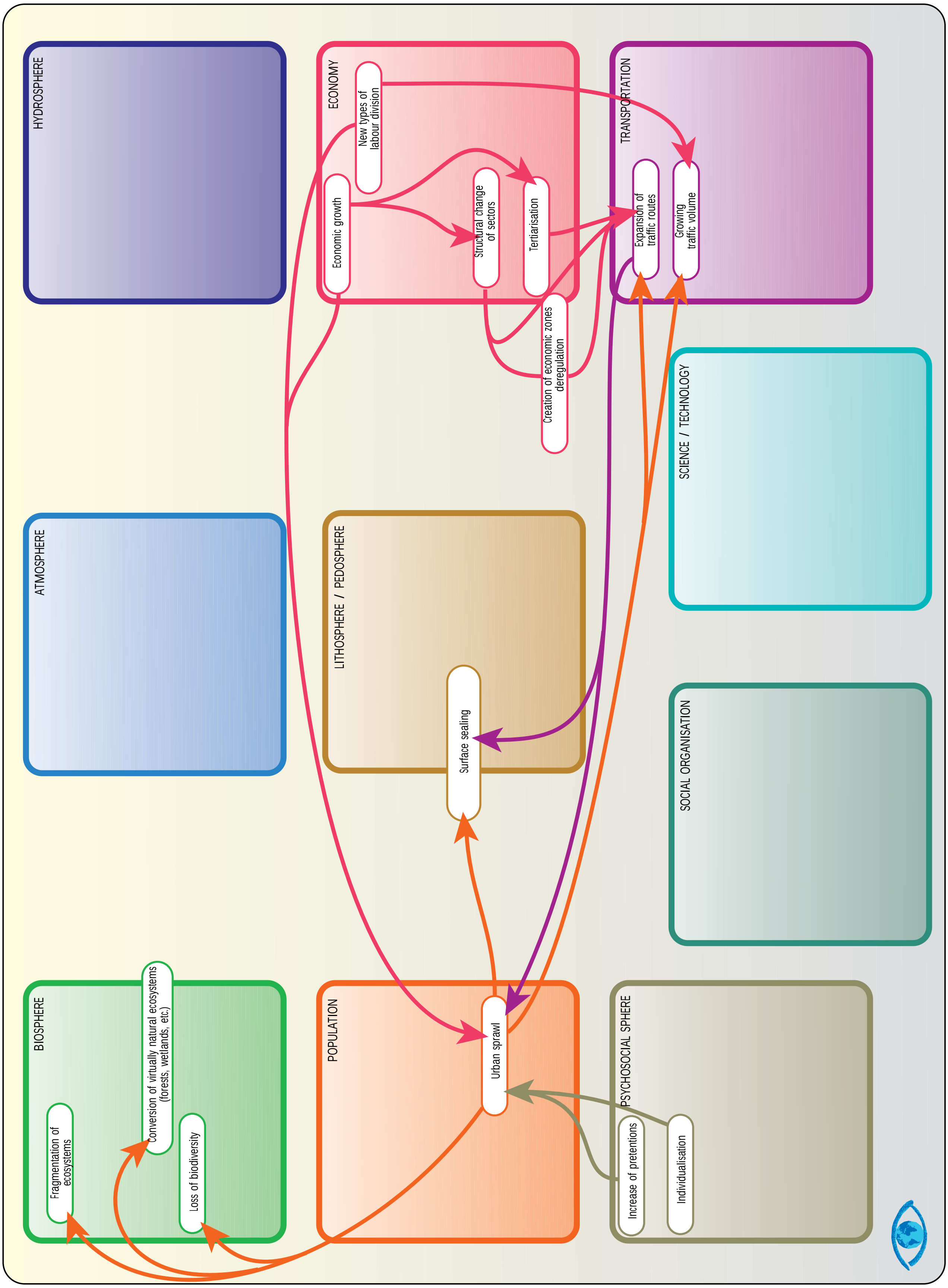

Figure 41: Syndrome-specific Global Network of Interrelations: The "Los Angeles Syndrome"

With regard to housing space, the demand in Germany from 1950 to 1981 rose from 15 m^2 to 34 m^2 (housing space per person). The causes for this enormous increase include the growing demands for home comfort as income rises as well as the tremendous changeover in forms of utilisation. Furthermore, in industrial nations there is a generally observed trend towards single-person households (in Germany the proportion is already 30%) which is accompanied by an increased demand for settlement area.

The demand for space to be used for supply, educational and transport facilities is also increasing. As a result, natural habitats are converted into useful infrastructural area, in Germany at a current rate of roughly 90 ha a day. In addition to the known phenomena of compaction and surface sealing of soils, consequences include a loss of biodiversity. It is estimated that in Great Britain, for example, approx. 30% of the animal and plant species have been permanently lost due to conversion of agriculturally useful land.

Regarding the transport sector, for the first time provision has been made in the German transport network plan for greater promotion of rail traffic in relation to road traffic. Nevertheless, the estimated investments required for new road construction, particularly trunk roads maintained by the Federal Government, are considerable. Given the planned distribution of funds, a change in the *modal split* in favour of local public transport can hardly be expected so that a further increase in motorised individual transport is probable. In freight traffic there is even more evidence of a rise in absolute and relative traffic on the road.

These developments lead to an increase in direct soil pollution by motor vehicle transport via depositions of substances in the form of exhaust fumes, tyre wear, oil residues, etc. In addition, soils are impaired by road traffic via damage to vegetation lining the road as a consequence of increasing immissions.

In the industrial sector growing mobility, rapid advances in telecommunications and, in particular, the structural transformation in the production process have made location-based calculations a less significant element in the decision-making process at many enterprises. *Just-in-time* and *lean production* increasingly bring about a spatial independence on the part of the producing and processing industry, if the logistical requirements are met. For the logistical requirements to be met is not least of all in the interest of the municipalities competing for municipal trade tax revenue. Designation and establishment of industrial parks in *green belts* after previous land-intensive connection to the national traffic network has come into fashion. Companies “consume” far more space at such decentralised production locations with low land prices in relation to their economic performance than enterprises subject to the substantial pressure of the land market.

The initial effect from an ecological point of view is structural destruction of soils via surface sealing. If enterprises are increasingly based at a greater distance from urban and residential areas, travelling expenses rise, especially for the people working there. The consequences of increasing traffic volume have already been explained in connection with freight traffic development in the 1993 Annual Report (WBGU, 1994).

Potential remedies and remarks

Overdevelopment can be countered with a number of combined strategies. The most important elements include:

- transport and housing concepts integrated into regional planning (mixture of work sites, service centres, residential areas and leisure-time facilities),
- increase in attractiveness and safety of city centres,
- correction of faulty market economy developments (land speculation, etc.) within the scope of housing construction policy and land use planning,
- limitation of peripheral infrastructure.

In contrast to the “São Paulo Syndrome”, the “Los Angeles Syndrome” is expressed more as a phenomenon related to affluence. Thus the remedies stated above are difficult to implement, but they are feasible in principle. A prerequisite for this, however, is a regional planning policy oriented more to environmental quality targets, not least of all in this context to soil quality targets.

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1.3.3.10 Mining and prospecting: The *"Katanga Syndrome"*

The province of Katanga (present name: Shaba) in southeast Zaire is known as one of the richest mining regions in the world with deposits of copper, cobalt, tin, uranium, manganese and hard coal. These minerals are primarily obtained via open-cast mining, a method which irreversibly destroys a large portion of the Earth's surface. The *"Katanga Syndrome"* stands for soil damage caused by the intensive mining of non-renewable resources, above and below ground, without consideration for preservation of the natural environment.

Examples of this type of mining are widespread; damage to soils can be particularly expected in areas where open-cast mining is carried out for coal and ores. Examples of coal mining are the Kölner Bucht, Niederlausitz and the eastern United States (Appalachians); important hot spots of ore mining include Carajás in the Brazilian state of Pará (iron ore, aluminium), Bougainville in Papua-New Guinea (copper) and Bingham Canyon in Utah, U.S. (copper).

Mining of non-renewable resources above and below ground has been one of the typical economic activities of humankind since the Iron Age. It fulfils "basic industrial and societal needs", similarly to agriculture. As a rule, a combination of the factors capital, know-how and favourable location (natural resources) is a prerequisite for commercial success. Although mining is usually only carried out temporarily (decades), it leaves behind permanent and in some cases irreversible damage to the environment almost everywhere.

The "Katanga Syndrome" is characterised by destruction of arable land that takes on very large proportions in developing and newly industrialised countries, while intermediate storage of this soil is prescribed by law in nearly all industrial countries. Moreover, changes in morphology take place through holes left by open-cast mining, tailings from open-cast mining and from underground mining and subsidence of the land surface. This, in turn, has significant effects on hydrological processes, such as surface runoff and the position of the groundwater level, as well as on erosion, in each case with feedback effects on soils. The physical processes in the soil are altered due to compaction and surface sealing. Deposition of heavy metals that may be detached from tailings leads to contamination of soils and surface waters. In connection with gold mining, special mention must be made of the substantial environmental dangers connected with the use of mercury-containing solvents. In general, one can state that the "Katanga Syndrome" appears wherever obsolete mining technologies are used with a low degree of energy and raw material efficiency.

The practices of intensive mining and the thus induced soil degradation have a number of negative effects outside of the pedosphere. There is a decline in water quality due to contamination and increased sediment loads as well as emission of greenhouse gases or other atmospherically active substances, especially in the case of ore processing. The negative consequences for the population in the immediate proximity of mining sites range from damage to health to the expulsion of, for example, indigeneous people in the "Gold Rush" region of the Amazon.

Potential remedies and remarks

The effects of mining, particularly of open-cast mining, and prior prospecting work are inevitably tied together with soil degradation. With regard to mining itself and to steps after mining is concluded, the following measures are important:

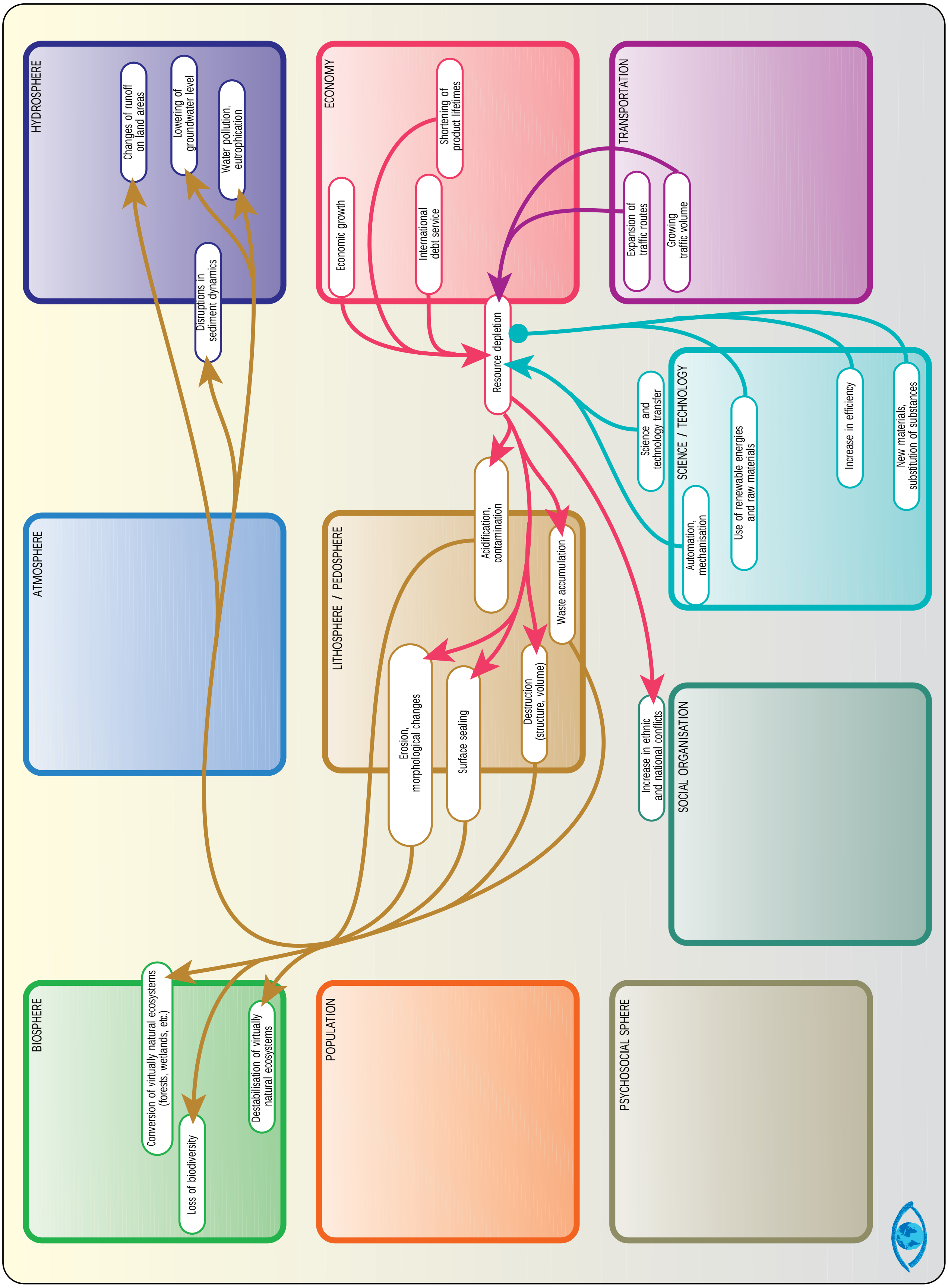

Figure 42: Syndrome-specific Global Network of Interrelations: The "Katanga Syndrome"

- separation and intermediate storage of arable soil for later recultivation, possibly agricultural and forestry use, recreation or creation of nature reserves,
- safeguarding of tailings to avoid soil contamination by heavy metals,
- filling in the rock again,
- restoring (raising/lowering) the groundwater level.

The syndrome could be alleviated by introducing modern technologies so as to increase the efficiency of raw material exploitation and energy supply; at the same time less carbon dioxide would be emitted, thus benefiting climate protection. In addition, efforts to reduce consumption and reinforce the recycling of metals and other raw materials would make it possible to stretch the limited reserves of non-renewable raw materials.

Additional reading:

BMZ – Bundesministerium für wirtschaftliche Zusammenarbeit (1993): Umwelt-Handbuch. Arbeitsmaterialien zur Erfassung und Bewertung von Umweltwirkungen. Vol. 2. Wiesbaden: Vieweg.

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Rybar, J. (1993): Ingenieurgeologische Aufgaben bei der Beherrschung der Umweltbeeinträchtigung durch den Rohstoffabbau. Zeitschrift der deutschen Geologischen Gesellschaft 144, 270 – 278.

Young, J. E. (1992): Mining the Earth. In: Brown, L.R. (Ed.): State of the World 1992. New York, London: W.W. Norton, 100 – 118.

1.3.3.11 Soil degradation through tourism: The *“Alps Syndrome”*

The constant increase in touristic activities all over the globe in recent decades has led to soil degradation to a significant degree. In the *Alps*, for example, ski lifts and hiking paths open up previously untouched areas, thus making expansion of space-intensive forms of sports activities. Consequences include destruction or impairment of the plant cover including trees, which results in soil erosion by wind and water in connection with great mechanical stress and other interventions in the balance of nature (levelling, corrections in the terrain, snowmaking machines). Some regions are now so damaged that residential settlements there are threatened by landslides or avalanches the whole year round.

A second major flow of tourism is directed towards *areas near beaches*. For soils mass tourism at beaches or on islands usually means additional land consumption via surface sealing of areas near beaches through the construction of touristic infrastructure, such as hotels, holiday homes and traffic routes (see “Los Angeles Syndrome”). In the Mediterranean region roughly 4400 km^2 of land are currently developed for touristic housing infrastructure, and a doubling of this figure is predicted by the year 2000. Moreover, this form of tourism induces a great increase in local traffic; the consequences are greater air pollution and further development of roads.

The strong and often seasonally fluctuating pressure on touristic areas brings about special problems regarding sewage treatment, possibly resulting in contamination and eutrophication of regions near the coast. In the Mediterranean region tourism currently produces roughly 2.8 million t of waste while approx. 10 million t are predicted for the year 2000. As a consequence, there is increasing demand for land for disposal facilities with related problems of groundwater contamination. Furthermore, touristic development in the regions concerned often results in a shortage of fresh water (swimming pools, high demand for water by tourists), which is scarce anyway in many cases. This leads to competition with the local population over water for their private use and for agriculture. Long-term effects may include lowering of the groundwater, dessication of the soil and erosion.

At present the following coastal areas and islands are particularly affected by the effects of the touristic activities represented by the “Alps Syndrome”: the Mediterranean, the subtropical islands near Europe (Madeira, Canary Islands), the tropical islands in the Caribbean, in the Indian Ocean (the Maldives, the Seychelles) and in the South Pacific. Especially hard-hit mountain regions include the Alps, mountain regions in North America, the Himalayas and the Andes to an increasing extent as well.

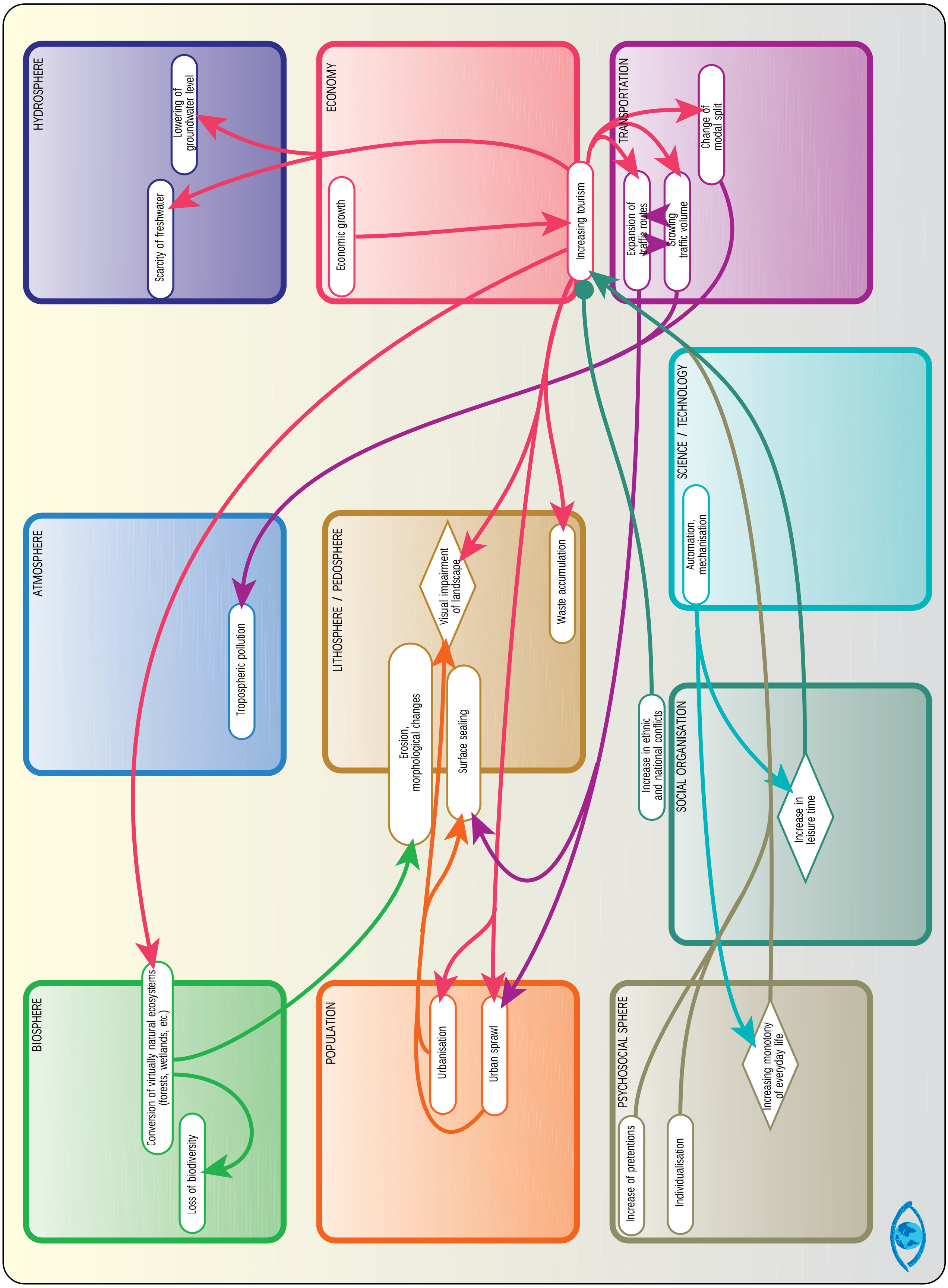

Figure 43: Syndrome-specific Global Network of Interrelations: The "Alps Syndrome"

The growing volume of tourism is directly induced by rising income in the industrial countries coupled with a drop in working hours, i.e. by more leisure time. The falling relative prices in this sector are an effect and cause of the problem at the same time. An additional important factor is the easy accessibility of almost all travel destinations, not only with regard to technical accessibility through the further development of infrastructure, but also with respect to a subjectively viewed problem-free overcoming of even extremely great distances.

For many regions tourism has become a major business sector, resulting in competition and an often destructive race to improve offered services (e.g. mechanisation of ski slopes and lifts). A further problem at the psycho-logical level is the fact that the connection between holiday activities and environmental stress is not recognised or is negated despite greater environmental awareness.

Otherwise the causes of the increasing volume in tourism from the industrial countries are extremely complex. The growing facelessness and anonymity of many housing settlements and the increasing volume in traffic in cities produce a need for recreation that no longer appears possible within this framework. In addition, a usually subjectively felt monotony of everyday life is a major factor behind the urge to experience something new and unusual. Furthermore, there is a connection between social status and holiday activity. Long-distance trips to exotic places play a very important role here. A higher level of education has also led to greater interest in foreign cultures and thus to increased travel activity.

Effects on the biosphere include damage to or loss of sensitive mountain and coastal ecosystems (e.g. dune landscapes, salt-water marshes), resulting in a loss of biodiversity. The hydrosphere is polluted, particularly in Mediterranean and tropical beach areas, due to deficiently treated sewage, bringing about eutrophication and impairing biodiversity. The increase in long-distance air travel in the last few years (in 1994 roughly 1.4 billion flight tickets were sold worldwide) has contributed to growing pollution of the atmosphere via deposition of air pollutants. Recently, remote and still untouched regions have been opened up, a development for which “ecotourism” has become a favourite catchword. In many cases, however, this also leads to destabilisation of fragile ecosystems along with, among other things, a loss of biodiversity.

Potential remedies and remarks

Negative effects of tourism on soils can be at least reduced by following certain rules, such as:

- concentration of touristic infrastructure (hotel buildings, development of accessways, roads, airport runways) in ecologically stable regions,
- development of soil-saving/soil-adapted touristic infrastructure (sports sites, car parks).

A spatial and/or time restriction of soil-damaging touristic activities must also be considered as a *curative* strategy, however. *Preventive* measures should include an environmental or soil-related impact study prior to setting up touristic infrastructure (ski slopes, lift facilities, car parks). Possible use of economic instruments (taxes) to control ecologically sensitive land use must also be examined.

Additional reading:

Dundler, F. and Keipinger, F. (1992): Urlaubsreisen 1954 – 1991. Starnberg: Studienkreis für Tourismus.

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Klingenberg, K.H., Trensky, M. and Winter, G. (1991): Wende im Tourismus. Vom Umweltbewußtsein zu einer neuen Reisekultur. Stuttgart: Verlagswerk der Diakonie.

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Krippendorf, J. (1986): Alpsegen – Alptraum. Für eine Tourismus-Entwicklung im Einklang mit Mensch und Natur. Bern: Kümmerle & Frey.

Opaschowski, H.W. (1991): Ökologie von Freizeit und Tourismus. Freizeit- und Tourismusstudien. Opladen: Leske & Budrich.

1.3.3.12 Soil degradation due to military impacts: The “Scorched Earth Syndrome”

Although soil degradation is very rarely seen in connection with military effects, special importance must be attached to the variety and quality of their damage symptoms. Their most extreme form is expressed in the term “Scorched Earth Syndrome”, which stands for a military strategy from the 2nd World War and involves unconditional destruction of the environment in order to impede the advance of the enemy.

In general, the most conspicuous characteristics of military and warlike actions include physical destruction of the soil structure as well as contamination and accumulation of wastes. Because of the further development of weapon systems and their mobility, units having a comparable troop size usually require approx. 20 times more land space today than during World War II. According to estimates, worldwide land consumption for military purposes represents an area of up to 1% of the Earth’s surface (approx. 1.5 million km^2) (Renner, 1994). For example, in the U.S. 200,000 km^2 (corresponding to 2.1% of the total area), on the territory of the Federal Republic of Germany prior to 1989 14,000 km^2 (corresponding to 5.6%) and on the territory of the former German Democratic Republic (GDR) 4,900 km^2 (corresponding to 4.5%) were and are used for military purposes (Renner, 1994). At the climax of the 2nd World War approx. 20% of the area in Great Britain was allocated to military use.

Regularly conducted military manoeuvres for preparation, exercise and deterrence

– often cause damage to the natural flora and fauna,
– lead to soil erosion and compaction,
– destroy the physical soil structure,
– and contaminate soils (e.g. with lead, explosives, fuels, highly toxic chemicals).

Examples of hazardous waste sites and remaining damage that have resulted from such use can be seen in the southern California desert where destruction and traces of tank manoeuvres conducted by General Patton are still visible, even after over 50 years. However, it is especially in the margins of the former military blocs that the “Scorched Earth Syndrome” manifests itself as a legacy of the “Cold War”. In the “new” German Bundesländer (territory of former GDR prior to 1989), for example, large areas used for military purposes have, in some cases, been severely degraded due to contamination stemming from oils, chemicals, old ammunition and soil structure destruction. These symptoms are also perceptible in places in the “old” German federal states (territory of FRG prior to 1989). An additional danger is posed by old armament sites with pollutants stemming from production and storage (see also “Bitterfeld Syndrome”). Explosives (nitrotoluenes, picric acid, nitrosamines, etc.) must be underlined here as being extremely hazardous because of their physio-chemical and toxicological properties (soluble in water, high toxicity). Groundwater studies in Vysoke Myto (former Czechoslovakia) found, in some cases, 30 – 50 times the permitted concentration of toxic substances.

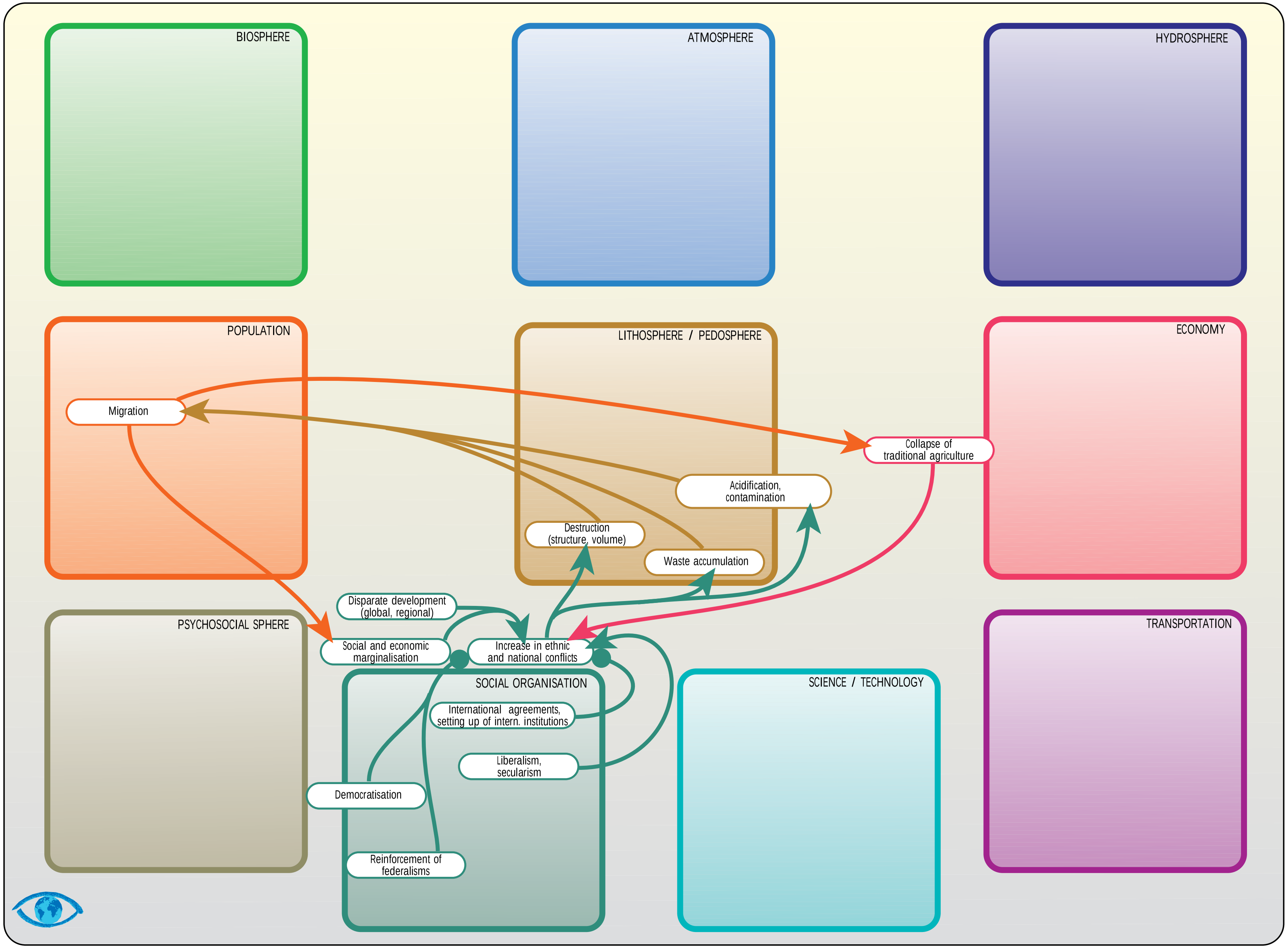
Hazardous waste sites stemming from ABC weapon production, trials and storage are of particular worldwide significance. The territory of the former GDR can be mentioned in this connection as a hot spot for contamination resulting from chemical weapons. From 1945 to 1961 over 100,000 t of toxic substances from production and storage locations were recovered there and even today conventional and chemical weapons are suspected at 49 sites.

Soils that were target areas for atomic arms tests, on the other hand, have been permanently damaged. Over 460 nuclear arms explosions were carried out up to 1980. In addition to the deserts affected (e.g. Mohave Desert in California), almost irreversible damage was caused on several islands in the Pacific (Bikini Atoll, Eniwetok, Muroroa, Fangataufa, etc.) and in eastern Kasakhstan.

Besides the soil degradation still “in the preliminary phase” or caused within the framework of deterrence, damage occurred and continues to occur through direct warlike actions: since the Second World War, the primary culprits in this context have not been wide-ranging, but regional conflicts with geographically limited but ecologically significant damage, where soil destruction was sometimes used deliberately as a weapon. Examples include (Matthies, 1988):

– Korean War (1950 – 1953) with large-scale destruction of urban agglomerations as well as forest and open countryside.
– Algerian War (1954 – 1962) with large-scale destruction of rural settlements.

Figure 44: Syndrome-specific Global Network of Interrelations: The "Scorched Earth Syndrome"



– Angola-Portugal Conflict (1961 – 1975) with use of herbicides, destruction of crops.
– Indochina Wars (1960 – 1975) with use of chemical and mechanical means of forest destruction, large-scale destruction of crops (Agent Orange), massive bombing of rural regions.
– Wars in the Horn of Africa (Eritrea-Ethiopia 1961 – today, Somalia-Ethiopia 1960 – today, Ogaden War 1977/1978) with large-scale destruction of villages and agricultural areas, hunger blockades; in 1984 approx. 43% of the area and roughly 30% of the population of Ethiopia were involved in acts of war).
– Gulf War Iran – Iraq (1980 – 1988) with large-scale destruction of cultivated and urban landscapes, destruction of oil production and loading facilities (contamination), damage to marine resources, use of poison gas.
– Gulf War Iraq – Kuwait (1992): destruction of oil production and loading facilities (contamination), damage to marine resources, use of mines (in Kuwait 60% of the 17,000 km^2 of area was covered with soot and oil).

A typical symptom of these regional conflicts is the increasing use of land mines that are sold as low-cost combat weapons for US$ 3 a piece and made use of within the scope of the, in most cases, short-term military strategies. The true explosive nature and long-term destructive potential of these cheap but highly effective combat weapons, however, do not unfold until later. Up to now it has not been possible to completely clear laid mines so that such mined areas have to be excluded from use for an extended period of time: the lifetime of a land mine is estimated to be 75 years on average. Thus in Poland, for example, approx. 40 deaths from mines occurred every year until 1977, and in northern Africa approx. 75,000 km^2 are still mined as a consequence of the Second World War. Estimates regarding the number of mines laid all over the globe range from 90 – 400 million mines affecting more than 60 countries (especially Vietnam, Cambodia, Central America, Africa, the Middle East and Afghanistan).

After the end of the “Cold War” with its numerous “representative conflicts” an increasing trend towards regional conflicts with ethnic and separatist causes is emerging as a result of the dismantling of the former blocs (Yugoslavia, areas in the former Soviet Union, Africa, Central America) as well as conflicts revolving around the competition for resources (minerals, oil deposits: Kuwait, food resources: Ruanda). Permanent soil destruction may result from this – in addition to the mine problem mentioned above – frequently due to overexploitation of the remaining marginal agricultural production areas as a consequence of refugee flows (Sudan, Ethiopia, Somalia, etc.).

This manifestation of the “Scorched Earth Syndrome” also appears in the form of a collapse of the food supply and destruction of the previous potential use of the soil in former Yugoslavia and will probably remain the predominant soil degradation syndrome having military causes, in addition to the problems related to hazardous military waste sites, in many places around the world.

Potential remedies and remarks

The most important measure is, of course, securing peace on a short- and long-term basis. However, major importance must also be attached to conventions that are binding according to international law and regarding the mine problem, for example, a ban not only on sale and export but *also* on the production of mines.

Additional reading:

Barcelo, N. (1992): Keine weiteren Siege wie diesen! Die ökologischen Auswirkungen des zweiten Golfkriegs. In: Umweltzerstörung. Kriegsfolge und Kriegsursache. Frankfurt: Suhrkamp, 117 – 127.

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Finger, M. (1991): The Military, the Nation State and the Environment. The Ecologist, (21) 5, 220.

Gantzel, K.J., Schwinghammer, T. and Siegelberg, J. (1992): Kriege der Welt: Ein systematisches Register der kriegerischen Konflikte 1985 bis 1992. Bonn: Stiftung Entwicklung und Frieden.

Haas, R. et al. (1991): Grundwasserbelastung durch Rüstungsaltlastemissionen. UWSF – Zeitschrift für Umweltchemie und Ökotoxikologie 3, 70 – 73.

Renner, M. (1992): Assessing the Military’s War on the Environment. In: Brown, L.R. (Ed.): State of the World 1991. New York, London: W.W. Norton, 132 – 153.

Rippen, G. (1992): Rüstungsaltlasten-Erkundung, Bewertung, Sanierungsverfahren. 8. Münchner Gefahrstofftage 1992

1.3.3.13 General recommendations for action

Various recommendations for action can be derived from an analysis of the syndromes. Since these *general* recommendations are of special significance because of the synergy effects expected from their implementation, they are presented synoptically and in the order of frequency of their occurrence in *Table 22*. The designations of the recommendations for action necessarily represent rough descriptions; therefore, they should always be interpreted in connection with the respective syndrome. The syndrome-specific remedial measures and remarks (see D 1.3.3.1 to D 1.3.3.12) should not receive less attention, because of the emphasis placed on *general* aspects.

As the synopsis (*Table 22*) of general recommendations for actions indicates, the *demand for "soil awareness"* is especially important. Currently soil problems with their interrelations are being given little attention by the majority of the population as well as by decision-makers and explicit soil actors (e.g. farmers). Therefore, it is necessary to make soil a subject of environmental education and information in all social areas.

Table 22: General recommendations for action regarding the syndromes of soil degradation

Recommendations	Syndrome											
	Huang He	Dust Bowl	Sahel	Sara-wak	Aral Sea	Acid Rain	Bitter-feld	São Paulo	Los Angeles	Katanga	Alps	Scorched Earth
Promotion of "soil awareness"	●	●	●	●	●	●	●	●	●	●	●	●
National soil conservation laws	●	●		●	●		●		●	●	●	●
Strengthening participation of citizens (participation; democratisation)	●	●	●	●	●		●		●	●	●	
Renaturing measures (incl. remediation)		●		●	●		●		●	●	●	●
Environmentally sound land planning (integrated settlement planning)		●	●	●	●			●	●		●	
Agrarian policy (adapted, decentralised, environmentally sound)	●	●	●	●	●	●		●				
Social integration of land ownership; curbing of speculation	●	●			●		●		●		●	
Emission reductions (policies in the fields of energy, transport, agriculture, etc.)		●				●	●	●	●		●	
Reduction of population growth and migration	●	●	●		●			●				
Eradicating poverty	●		●	●			●	●				
New/adapted technologies and technology transfer			●		●	●	●	●				
Urban development (to prevent migration from the cities, among other reasons)						●		●	●		●	
Allocation of land tenure rights, land reform etc.	●		●					●				
Redemption of debts			●	●								
Development assistance (giving consider-ation to the cultural and social function)			●					●				
Integration of housing, workplace and services						●			●			

Source: WBGU

In this process all levels of the humanity-soil relationship have to be taken into account in order to create an appropriate sense of responsibility. Thus it is just as important to convey knowledge on soils and on the connection between human behaviour and soil degradation as to promote emotional approaches to soil problems. Soils must be made “perceptible” and “comprehensible” and the concrete potential and competence for taking action with regard to soils (from working the soil and relieving the pressure on soils to the purchase of products made in compliance with environmentally sound methods) must be provided for. It may be possible to create a greater sense of responsibility for the soil in many areas by offering citizens more opportunity to participate in soil-relevant decisions.

These long-term measures in the psychosocial sphere must be supplemented by general measures of a legal and planning nature. The basic political conditions for *soil protection* (national soil protection laws, environmentally sound regional planning, agricultural policy, urban planning, allocation of property rights, concentration of housing, work and supply services) must take into account the significance of the problem, as must the technically oriented options for exerting influence (renaturalisation measures, reduction of emissions, new/adapted technologies) and *supporting measures with respect to population development* (reduction of population growth, combating poverty) and – not least of all – *development policy* (debt relief, technical and financial aid).

Some of the consequences of soil utilisation are long-term, some are irreversible and go beyond the land area actually used. Therefore, the interests of the general public in land, as a sort of social commitment or ecological obligation in connection with property ownership, should be taken into account in all soil-related instruments, in the law as well as in economic activity and politics.

2 Two regional case studies of soil degradation

The two following case studies are examples for the syndromes “Overexploitation of marginal land – the Sahel Syndrome” and “Local soil contamination, accumulation of waste and inherited pollution – the Bitterfeld Syndrome”. These analyses are intended to provide a general and syndrome-oriented basis, with specific regional reference, for the soil-centred Global Network of Interrelations. The multidisciplinary approach serves to identify central, regionally specific cause-effect mechanisms. To achieve this objective, detailed problem analysis must be assigned secondary priority.

Such cause-effect analyses can serve as a basis for studies with an even higher level of regionalisation and which analyse economic, political and sociocultural trends and their interactions in detail. Comparing and integrating analyses with different levels of resolution (from global to regional) is, in the opinion of the Council, a suitable method for dealing with problems which involve indirect interactions with wide range. The “Sahel” case study is representative for a major region on the Earth, while the “Leipzig-Halle-Bitterfeld” case study is representative for an urban agglomeration area.

2.1 The “Sahel” case study

This section analyses the syndrome characterised by “overexploitation of marginal land”, taking the Sahel zone as an example. The regional focus is on Burkina Faso, Niger and Mali, countries which are especially typical of the Sahel zone.

The Sahel was chosen for closer analysis on account of the *global significance* of its problems – ecozones with similar natural features as occur in the Sahel zone (savannas and steppes) account for a quarter of the Earth’s land surface, and approx. 37% of terrestrial net primary production (NPP) (Enquete Commission, 1991). Other drylands which, like the Sahel, are also threatened by desertification, and where climate changes would mean the loss of farm land, are the Maghreb, southern Africa, western Arabia, parts of southeast Asia, parts of Mexico and eastern Brazil. Areas which are similarly threatened by water scarcity and desertification can be found in the southwest of the USA, in Australia and the Mediterranean area (Enquete Commission, 1991; IPCC, 1990a). In total, approx. 135 million people live in areas that are acutely affected by desertification. Most LLDCs are situated in the dry regions of the Earth (Falkenberg and Rosenström, 1993), and the problem of environmental refugees is also concentrated there.

Reports on ecological crises in the Sahel zone (“Sahel”) and other regions threatened by desertification often refer to the interconnection of population pressure, overgrazing, deforestation and soil degradation. The starting point for the following study, however, is the assumption that soil degradation is in many cases not only a consequence of population growth, but of other social changes as well. In the following cross-sectional analysis, the causal chain referred to is supplemented by a series of socioeconomic factors, and the most important economic and social trends with impact on soil degradation are analysed.

2.1.1 Introduction: Geographical and social factors

Definition of the Sahel zone

Geographically the Sahel zone is a belt in Africa extending north and south of 15° N latitude from the Atlantic to the Red Sea. It is approx. 5,000 km long, and 400 km wide on average. The term “Sahel” originates from Arabic and means “shore” or “coast” – here the southern edge of the Sahara. Geo-ecologically, the Sahel is defined as the transitional zone between desert and savanna. The key factor is precipitation: the Sahel zone is demarcated by the 200 mm isohyet (isoline for equal precipitation) in the north and the 600 mm isohyet in the south. The following states are partly or wholly located in the Sahel zone: Ethiopia, Burkina Faso, Cape Verde, Gambia, Guinea Bissau, Mali, Mauritania, Niger, Senegal, Sudan and Chad.

Climate and water

Fig. 45 shows the band-like climate zones in the region, whereby the 200 – 600 mm precipitation zone roughly defines the Sahel.

Climatically, the Sahel zone is tropical arid to semi-arid, with high insolation, high temperatures and an extremely seasonal monsoon climate (i.e. summer rains and dry winters). The wet season lasts up to six months in the south, but only about one month in the north, with highest rainfall in August. Both the seasonal and spatial variation of rainfall are very great; the boundary of the zone providing minimum rainfall for cultivation (*Fig. 45*) can migrate by up to 450 km from one year to the next.

Water scarcity is therefore a typical feature of the Sahel; i.e. short periods of rainfall, low humidity during the dry season, with correspondingly high potential evaporation, but also low soil water storage capacity. Only in areas close to the large, permanent rivers, such as the Niger, the Senegal and the Nile, is surface water available throughout the year. When rains do fall, this is often with such intensity that spontaneous surface runoff, floods and inundation are the result.

More so than other regions, the climate in the Sahel can deviate considerably from the mean over protracted periods, sometimes taking the form of extreme droughts (1972/73 and 1983/84). The climatic situation is exacerbated by the fact that annual rainfall in the last three decades has declined by about 20 – 40% compared to the previous three decades, with rainy seasons being of shorter duration as well (Arnould, 1990; Nicholson, 1993).

Soils and vegetation

Soils and vegetation in the Sahel follow zonal patterns corresponding to those for rainfall. Increases in rainfall towards the south are accompanied by greater eluviation, weathering, iron content and redness than in the north. A large part of the Sahel consists of so-called “clad” or “fixed” dunes, i.e. Sahelian soils are sandy (“arenosols”, according to FAO nomenclature). They are poor in organic substance and the carbon content is mostly under 0.3%. Soil fertility is predominantly low, the cation exchange capacity critical for supplying plants with nutrients is low, as is the water storage capacity, the depth and the structural stability of the soils (Sivakumar et al. 1992). For this reason, the soils of the Sahel zone are very sensitive to anthropogenic interventions. As a result of climatic factors, these soils are very dry for about nine months of the year, and are therefore susceptible to wind erosion. As described in Section D 1.1.2, soils are generally slow to develop. The aridity in the Sahel slows down soil formation even further, which means that anthropogenic soil degradation can no longer be compensated for by natural means and hence can become irreversible.

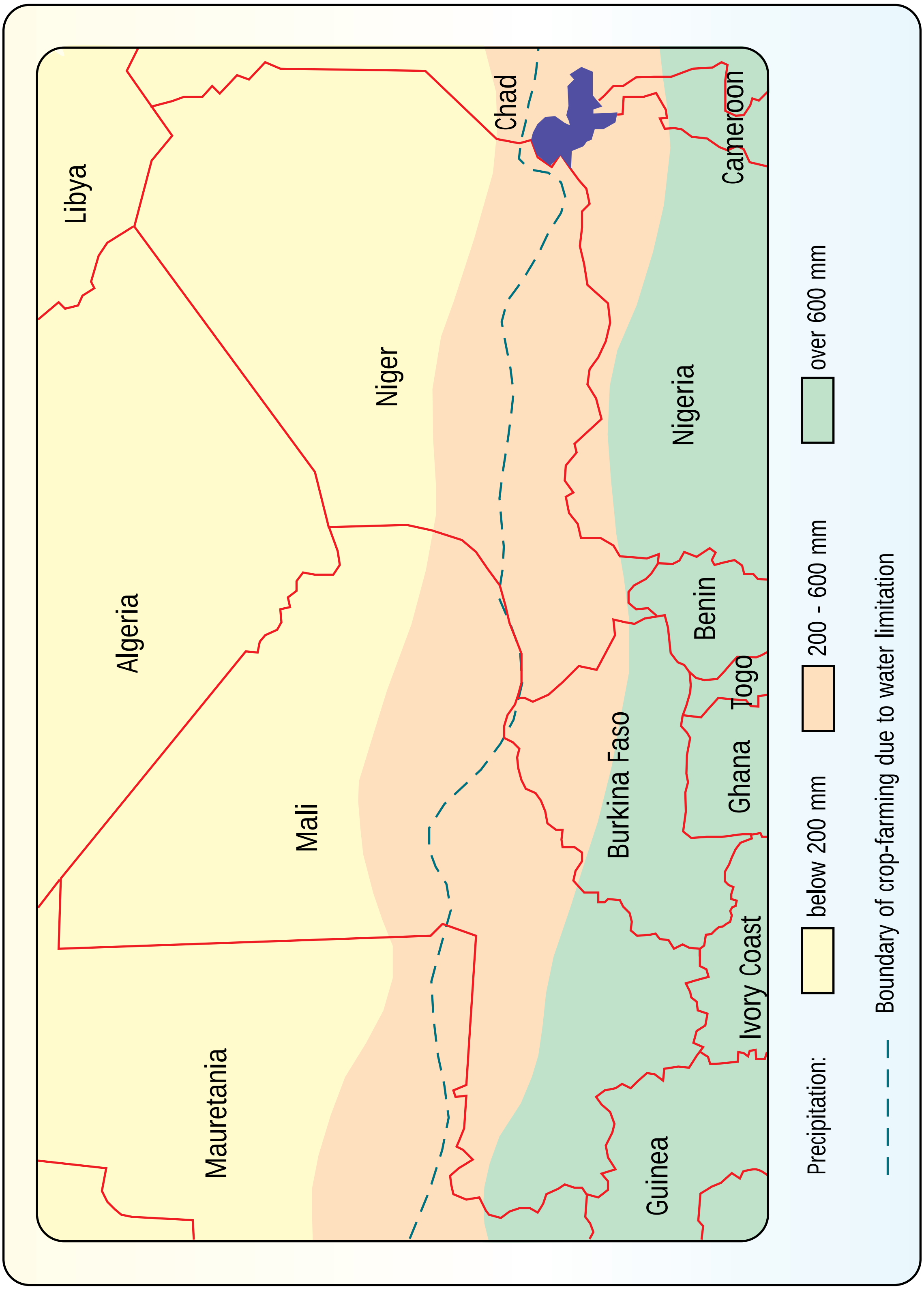
Vegetation in the Sahel (*Table 23*) follows the band-like zones of climate and soils, with a transition from pure grassland in the north to the dry savannas in the south, accompanied by an increase in the density of vegetation cover and biodiversity. The increasing precipitation as one moves south gives rise to longer growth periods, from less than 75 days north of 16° latitude to 150 days around the 14° latitude (FAO, 1982b). Accordingly, the potential productivity of agriculture increases towards the south.

Table 23: Climate and vegetation zones

Precipitation	Natural potential vegetation
100 – 200 mm:	Semi-desert dry grassland and grassy steppes with perennial horst grasses, contracted drought-resistant (xeromorphic) vegetation, primarily at favourable locations such as the margins of wadis; water availability in this zone restricts biomass production
200 – 400 mm:	Thorny savanna with thorny scrub and annual herbs or grasses
400 – 600 mm:	Dry savanna with dry wood and annual herbs; soil fertility restricts biomass production to a greater extent here than water availability

Source: Lambin et al., 1993

Figure 45: Precipitation in the Sahel zone



Source: Nohlen and Nuscheler, 1993

Inappropriate cultivation methods, grazing patterns and fire have virtually destroyed the primary vegetation of the Sahel, and the range of species has undergone severe changes. Dry forests have been transformed into secondary savannas. In arid areas, such degradation of natural resources is termed *desertification (Box 21).*

Box 21

Desertification

There is no standard or commonly accepted definition of the term “desertification” in the relevant literature. UNEP considers it be “land degradation in arid, semi-arid and dry sub-humid areas mainly as a result of human intervention”. The UNCED definition, on the other hand, places less emphasis on the responsibility of humans.

Desertification causes the degradation of steppes or savannas to desert-like landscapes. This process should not be conceived of as permanent desert encroachment, but as the degradation of separate and often unconnected savanna areas. The extension of the desert fluctuates depending on the amount of precipitation.

Land degradation in arid and semi-arid areas has various causes:

– One important *natural cause* is the decline of soil productivity and vegetation due to droughts; this is a consequence of high precipitation variability in the savanna and steppe areas.
– A critical *anthropogenic cause* is the inappropriate exploitation of and stress on natural resources.

Together, these factors give rise to a reduced capacity of natural vegetation and soils to regenerate.

Indicators of desertification are:

– Changes, thinning and finally loss of plant cover, followed by long-term and almost irreversible decline in biomass production. For example, perennial grasses are displaced by annual species and ultimately replaced.
– Changes in the water budget (soil water, groundwater, evaporation, surface runoff).
– Morphological changes, such as soil loss through wind and water erosion, remobilisation of stable dunes and new dune formation.
– Degradation of soils (aridification, reduced soil fertility, crusting, salinisation and alkalisation).

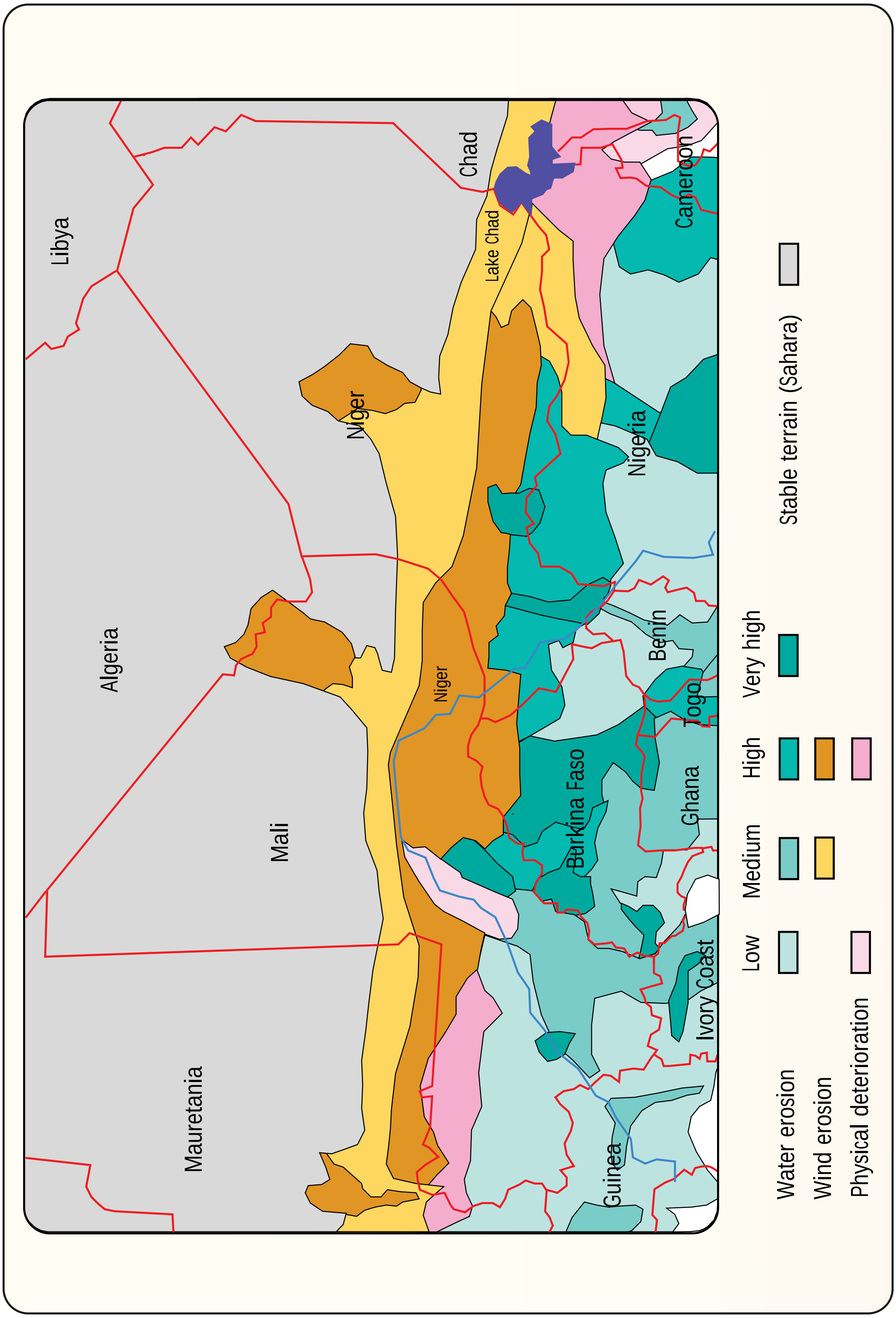
Estimates for the loss of agricultural land through desertification can vary greatly, depending on source. According to Hahn (1990), approx. 1.5 million hectares of agriculturally useful land have been and continue to be lost each year in the Sahel since the great drought of 1971/73. This means that about 90% of grazing land and 80% of non-irrigated arable land in the Sahel zone is affected by at least a mild form of desertification. To what extent such desertification processes are irreversible is a question that has yet to be clarified.

Fig. 46 shows the importance of different kinds of soil degradation in the Sahel. Wind erosion is clearly predominant in the dry northern areas, whereas water erosion is worse in the wetter south.

Population

As much as 90% of the Sahelian population lives in rural areas. However, the population structure is undergoing rapid change through *growth* and through *migration*. The growth rate of the Sahel population is one of the highest in the world, at about 3% annually. The average life expectancy is 51.8 years (UNDP, 1992). The high population growth rate is compounded by a deterioration in living conditions in the rural areas, which, together with droughts, reinforces migration from the countryside to the cities and the neighbouring coastal states. Temporary “labour migrants” are

Figure 46: Soil degradation in the Sahel zone



Source: ISRIC and UNEP, 1990

increasingly becoming permanent settlers in the geographically more favourable areas. It is estimated that the degree of urbanisation in Africa as a whole will rise from 16% in 1980 to a forecasted 24% in the year 2000, whereby the growth of cities has been largely uncontrolled to date.

Table 24: Population figures (in millions) for the focus-region of the Sahel

	1975 (FAO)	1991 (WB)	2000 (WB)	2025 (WB)
Mali	5.8	8.7	11	24
Niger	4.6	7.9	11	24
Burkina Faso	6.1	9.3	12	23

Sources: FAO, 1982b and World Bank, 1993

The *population density* of the Sahel countries shows a similar zonal structure, matching the geographical conditions. It increases with higher rainfall as one moves to the south; the most humid regions in the southern parts of these countries are less densely populated, however, since diseases spread more easily there as a result of climatic conditions.

Social structure

In cultural-historical terms, the Sahel is a complex zone of “contacts and conflicts” (Krings, 1993) comprising Arabo-Berber nomadic herdspeople and Negroid farmers and town dwellers. In addition to many differences in ethnic structure, there are also common social features, such as powerful kinship and village structures. Elements of previous caste systems had already been abolished in most areas by the turn of the century (Nohlen and Nuscheler, 1993), but a distinction between freemen and slaves continues to be made to this day by some population groups. This has effects on social relationships, for example marrying behaviour or the prohibition of particular cultivation tools (Knierim, 1993). The situation of women in the Sahel zone is characterised by a growing burden of work and a lack of access to education.

Political power in the Sahel countries is centralised, concentrating on the towns and cities. The rural population rarely has any local institution that could represent its interests. However, traditional authorities continue to enjoy a high level of esteem among the rural population, even if they effectively have no longer any political-administrative competence (Weiß, 1993). This inadequate representation of farmers and nomads often leads to social conflict. Participation in political elections is generally low, and especially low among the rural population. The political and social deficits in the structure of Sahelian societies are considerable, particularly since corruption and clientelism have so far prevented the development of democratic structures.

Economic structure

The socioeconomic data for the Sahel presented in this section are based on national surveys in Burkina Faso, Mali, Mauritania, Niger, Senegal, Sudan and Chad. These countries are among the poorest in the world (the *least less developed countries* — LLDCs). In 1991, for example, per capita income in Mali, Niger and Burkina Faso was between US$ 280 and 300 (the figure for the former West Germany is US$ 23,650, as a comparison). Gross national product (GNP) in the Sahelian countries is largely created by the agricultural sector. However, it is questionable whether GNP can be a reliable indicator for economic performance in developing countries such as those in the Sahel, in that it fails to take account of goods and services that are traded informally.

Africa is the only region of the world in which food production per head of population has declined over the last 25 years (Quiroga, 1990). In terms of food supply, the Sahel has a lower to middle ranking among the developing countries; the calorie supply in Burkina Faso, Mali and Niger is less than 2200 kcal per person per day, and is thus below the UN standard (FAO, 1993b). Dependence on food imports, mainly wheat and rice, is high.

Box 22

Soil degradation in the Sahel

Four different categories of soil degradation can be found in the Sahel zone: water erosion, wind erosion, degradation caused by chemical factors and degradation caused by physical factors. Because these are often the result of inappropriate land use practices, they are presented in the following in association with the respective type of land use.

Farming: Substitution of natural vegetation and the removal of remaining vegetation (trees and shrubs) in the process of land cultivation and the cultivation of monocultures leads to greater exposition and erosion of the soil; unsuitable tillage methods can accelerate this process even further. Moreover, prevailing cultivation methods also result, through harvesting, in the permanent extraction of nutrients from the soil, which already has a low nutrient content, without any nutrient replenishment (nutrient mining).

Lowering of the ground water table through *overexploitation of water resources* reduces soil moisture and thus the supply of water to plants. When artificial irrigation is introduced in response to water scarcity, inadequate drainage causes salinisation or alkalisation of topsoils.

Where land is used for *grazing livestock*, perennial grasses are replaced by annual grasses, which can then survive thanks to faster seed germination. This leads to changes in species composition, up to and including desert-like plant communities. The rooting depth declines, and with it the protection of soil against erosion. Continued pressure through livestock grazing, including livestock consumption of woody plants, leads finally to loss of vegetation cover and to soil degradation. Lack of vegetation cover further increases the erosive effect of water and wind. Trampling of the ground by livestock causes further degradation, because it destroys the soil structure (Klaus, 1986). Organic substances and nutrients, which used to be fixed in the topsoil and were therefore well protected against eluviation, are lost by the system.

Deforestation due to high fuelwood requirements far exceeds regeneration of new trees – by approx. 30% in the Sahel as a whole (Timberlake, 1985). In Burkina Faso, for example, over 90% of the national energy requirement is obtained from wood. Where fuel needs can no longer be met by burning wood, dried cow dung is used instead; however, the latter cannot then be used as fertiliser any longer, thus leading to further nutrient depletion of soils.

The increasing exposure of soil to very intensive insolation and the altered microclimate that results when vegetation cover declines lead to increased *desiccation* of soils. Ground temperatures of 60°C and more are reached, which in turn causes aridification of the soil, increased susceptibility to wind erosion and extreme environmental conditions for those plants which manage to survive. At the same time, the physical properties of the soil also undergo changes. For example, if the water storage capacity of the soil is lowered, the dry period for plants is made longer, and the locational situation favours drought-resistant (xeromorphic) plants and the species composition changes.

As vegetation cover is reduced, the *rains* which fall in the Sahel with considerable impact are no longer cushioned, thus causing the destruction of soil aggregates and the blockage of soil pores with fine particles. Reinforced by crust formation following subsequent drying, the ground surface becomes increasingly sealed. This reduces infiltration, which in turn has negative effects on the groundwater recharge. At the same time, surface runoff becomes more pronounced, further eroding the soil. These effects are made even worse if the ground has been compacted by livestock trampling.

Wind erosion is a common occurrence in the arid and semi-arid tropics. The cause is almost always the loss of natural vegetation cover. In West Africa, 400 – 600 million t of soil are blown away by wind (Herkendell and Koch, 1991). The hot Harmattan winds of the dry season play a particularly destructive role in this respect.

Water erosion is much more widespread in tropical soils than in soils of more temperate zones due to their fragile soil structure and the heavy rainfalls that occur (Sivakumar et al., 1992). Rates of erosion are determined by the volume and intensity of rainfall, as well as the angle of slope and extent of vegetation cover (Lal, 1987). However, figures for erosion and the methods used to measure it are a subject of some controversy. The most important erosion effect, for both water and wind erosion, is the loss of topsoil.

In order to identify the specific interactions typical for the Sahel Syndrome, a cross-sectional approach has been chosen in which distinctions are drawn between the dominant land-use forms in the Sahel zone, namely livestock grazing (*nomadism*), farming (*subsistence farming*) and intensive farming (*cash crops*).

2.1.2 Nomadism and overexploitation of land and soils

The term nomadism includes a wide spectrum of mobile ways of living and economic activities within an environment that has insufficient natural resources to allow the permanent survival in a given area by livestock farming. This distinguishes nomadism from other forms of mobile livestock farming (Scholz, 1991).

2.1.2.1 Traditional nomadic ways of living

Traditional livestock farming methods as practised by the nomads and semi-nomads in the Sahel are generally considered to be an example of the most environmentally adaptive use of water, soil and grazing land (Fuchs, 1985). This adaptiveness is assured through the spatial and organisational flexibility of these methods. The basic principle of flexibility and self-reliance is supplemented by a strategy of minimising risk – behavioural norms are centred in this traditional system on risk minimisation, not profit maximisation. Mobility, herd sizes and herd composition are determined by the yields offered by the grazing land they find. Self-imposed regulations for the use of resources and the setting aside of specific areas for times of emergency, i.e. non-utilisation over protracted periods of time, restrict grazing, so that it is possible for vegetation to recover from overgrazing. Furthermore, livestock diversification avoids one-sided grazing patterns and thus an imbalanced utilisation of plant resources, which would substantially change the ecosystem.

The strategies applied to ensure spatial and organisational flexibility, and hence the environmental adaptiveness of land use are supported by a variety of social security strategies. Survival is assured above all through various forms of division of labour and social systems for spreading risk, especially through a household organisation safeguarded through herd size and the number of workers. Greater income security is also achieved by keeping different types of useful animals, through the sale of milk and animals, and a range of other activities (e.g. art and crafts) (Lachenmann, 1984).

For almost all groups in the Sahel, social solidarity means kinship solidarity. The greater the number of relatives and the more they are distributed geographically, the less the individual risk for family members. Within these “social networks”, reciprocal rights and obligations are institutionalised. In addition, the distribution of risk is based on the principles of reciprocity and redistribution (Weiß, 1990).

This system of reciprocity reaches its limits when famine affects large geographical areas. None of the socioeconomic systems in the Sahel is adequately geared to economic self-sufficiency in all fields; instead, each economic unit, be it a nomad camp or a village, extends its ecological basis through a network of what are mainly non-monetary barter relationships (Fuchs, 1985). This spatial and organisational flexibility has assured the survival of human beings over centuries, and protected scarce resources through periodic non-utilisation. In recent times, however, this traditional, sustainable way of living has undergone major changes.

2.1.2.2 Transformation of traditional ways of living

The traditional nomadic ways of life have been in decline since the middle of the last century. Visible signs are the decline in traditional forms of nomadic economy, sedentarisation, and the reorganisation and abandonment of traditional (grazing) lands (Scholz, 1991). A number of endogenous and exogenous factors have caused and reinforced these changes, with various consequences for land use and soil degradation.

2.1.2.2.1 Changes in land tenure law

The Sahel region originally had a wide variety of traditional land tenure systems, depending on geographic and sociopolitical conditions and population density. However, there were also important common features. They were mostly *common property regimes (Box 23)*: members of specific ethnic groups had access to defined grazing land, and traditional authorities exercised supervisory functions and imposed sanctions for non-adherence to these rules. Although these rights were not formally defined, there was still sufficient quasi-legal security.

Some of these traditional land tenure systems still exist today at the local level. At the same time, many Francophone states in the Sahel retained the French system of land law following independence. The “mixed system” that resulted is very centralised, highly complex, with little transparency and therefore rather ineffective.

Changes in land tenure rights had wide-ranging consequences for the nomads. Power was transferred from separate nomadic groups to central government, and led to a system with more resemblance to a free access system than any common property regime (Hartje, 1993), with negative effects on soil protection. In an effort to enhance legal security, many governments have switched to a strategy of declaring land to be state property and/or selling it to investors or leasing it out. The insecurity this has caused for property relations tends to make any soil conservation measures with only long-term benefits unattractive for groups and individuals.

Political developments following independence have exacerbated these problems. The redrawing of state borders has split groups with the same ethnic identity and made mobile livestock farming more difficult. Centralistic political structures hardly allow participation and democratic representation of rural interests, and are inappropriate to local needs. The tribe’s function as a social and political reference system and as an organisational “guarantee of survival” has declined in importance (Scholz, 1991). The marginal areas used mainly by nomads are increasingly treated economically and administratively as peripheral regions, and continue to be without adequate infrastructure.

The nomadic way of life is generally held in low estimation in all the Sahel states. A large proportion of nomadic population is considered to be backward and political action is thus often directed at sedentarisation of the nomads. The fact that poor vegetated soils in these countries can still be used by mobile livestock farming, thus acquiring value for the economy, is neglected (Scholz, 1991). Agrarian policy is directed at the promotion of arable farming, sedentary forms of production, or at investment in irrigation projects, thus depriving pastoralists of grazing land.
As far as land tenure rights in the Sahel are concerned, one can speak of *anomic conditions* existing today, i.e. there is uncertainty regarding the validity of norms and regulations. Traditional regulations are no longer officially valid, but

Box 23

Land tenure rights

In the development literature the hypothesis can be found that soil degradation is a consequence of undefined land tenure rights. Inadequate definition and allocation of property rights, especially, are made responsible for the fact that nobody can be excluded from using a resource, so that a particular user behaves in an individually rational way if he exploits this non-exclusion to his own advantage. This phenomenon, described by Garrett Hardin in his classic essay, “*The Tragedy of the Commons*”, is often used as an argument for privatisation by national governments and international development agencies. On the other hand, it is disputed that private property is the only environmentally sound form of land tenure (e.g. Hartje, 1993; Ciriacy-Wantrup and Bishop, 1975; Ostrom, 1990).

Private property
Private property is a system in which individuals to whom the resource belongs have the right to exclude others from using that resource (*principle of exclusion*). The following arguments are put forward to demonstrate that this form of land tenure protects soils:

- the owner of these rights has an individual interest in maintaining and caring for the soil resource, since he is also the beneficiary of quality improvements and because “good” land has a higher market value;
- where the principle of exclusion applies, land is exploited by only a few or only one user, and is hence less

intensive;
- soil protection measures can be very costly; financial institutions are more likely to grant credit to private land owners because such land can be used as collateral.

Clark (1973) and others believe, however, that it can also be economically rational in certain circumstances to overexploit the resource, even when it is private property.

Common Property Regimes
Unlike *open access* (q.v.), *common property* regimes are regulated land-use systems. Precisely defined, groups regulate access to the resource among themselves. Empirical studies have shown that under certain conditions, especially where social control mechanisms still function, this regime does not produce a free rider mentality and that, despite several users, there is little risk of resource degradation (Stevenson, 1991).

Successful *common property regimes* are usually based on agreements between those groups who use the resource. These agreements regulate the number of users and the limits of the resource, adaptations to changing properties of the resource, collective decisions and the internal supervision of resolutions relating to the resource, as well as procedures and sanctions in the case of conflicts (Hartje, 1993). However, there are a number of fundamental preconditions that must be met for common property regimes to function:

– a limited number of people using the resource; the greater this number becomes, the higher the costs for reaching consensus,
– homogeneously structured interests within the user group,
– low opportunity costs; the higher the anticipated gain from violating the rules, the higher the opportunity costs (loss of profit) incurred by observing the regulations.

Open access
In an open access land-use system, all users have the same rights to the resource. The Hardin tradition assumes that this free access causes competition between all those with a vested interest in the resource for as big a share of the resource, in this case land, as possible. Overexploitation can be expected, because those willing to cooperate must fear that others will benefit from their behaviour. Overexploitation is also probable when the resource is scarce and/or there are too many parties with an interest in it.

It can be concluded that answering the question whether a particular land tenure system leads to soil degradation requires a careful analysis of many parameters: land availability, suitability of the land for utilisation, population density and social behaviour.

the state does not have sufficient legitimacy to implement new regulations. As a result long-term investments, especially soil protection measures, are unattractive.

Such legal uncertainty prevents flexible land use by nomads, and does not consider the necessity of transit rights and grazing lands set aside for emergency cases. Furthermore, the privatisation of resources pushes the nomads into a marginal position. Because nomads rarely have private land title rights, they find it very difficult to obtain credit and hence to participate in the market. Numerous other factors reinforce their economic insecurity.

2.1.2.2.2 Destabilisation of traditional societies

The various nomadic groups in the Sahel zone are being increasingly affected by the growing commercialisation of land resources, wage labour and market processes (Weiß, 1990). The latter give rise to new opportunities for earning income which could contribute, in theory at least, to an improvement of the food situation. However, the various forms of voluntary reciprocal help are becoming increasingly monetary in character. Monetarisation is accompanied by individualisation tendencies, i.e. ever-smaller units of production, consumption and lifestyle. Monetarisation and individualisation together contribute to a general situation with the following characteristics: declining identification with larger social units such as tribes, decreasing influence of traditional mechanisms of mutual assistance and regulation of access to resources, and altering strategies to gain security.

Market integration thus contributes to the dissolution of traditional relations, which in turn forces the respective population groups to be more dependent on successful participation in the market. All this is problematic in the current situation, however. On the one hand, the nomads are compelled to sell livestock, especially during droughts, i.e. periods where herds are over-sized and hard to sell, and, on the other, they are exposed to competition from sedentary livestock farmers. Another obstacle to their market participation is their cultural heritage, in which animals are not only a status symbol, but the symbolisation of interpersonal relations, so that a livestock owner cannot dispose his herd at will. Livestock is used as lien, and, under normal circumstances, an acute scarcity of livestock can be balanced out by presents or the loan of objects, if this is necessary to feed the family or for the reproduction of the herd. Selling off livestock is traditionally equal with the termination of relationships based on mutual assistance.

If market integration fails for one of the reasons mentioned above, and if there are no other possibilities for ensuring survival, migration is the consequence, starting with the young men. Depending on how high the payments are to other family members back home, migration can have positive effects, but there remains a lack of working force (Ibrahim, 1989). The women, children and elderly family members left behind cannot move long distances, and shorter distances to new grazing land result in local overexploitation of land.

Because market integration does not yet operate successfully in the Sahel zone, while old strategies for survival no longer function to an adequate extent, the affected groups are threatened in their existence. Sedentarisation or migration are often seen as the only means of escaping the threat of poverty and result in population pressure and the concentration of herds.

2.1.2.2.3 Displacement of nomads by sedentary livestock farmers

Since the mid-1970s, the number of sedentary livestock farmers in the Sahel has increased dramatically. These are mainly private investors from the urban and political elites, as well as farmers who keep animals in order to ensure an adequate food supply. With the exception of drought periods (1972/73, 1983/84), where millions of animals died, this has led to a substantial increase in livestock levels (*Fig, 47*).

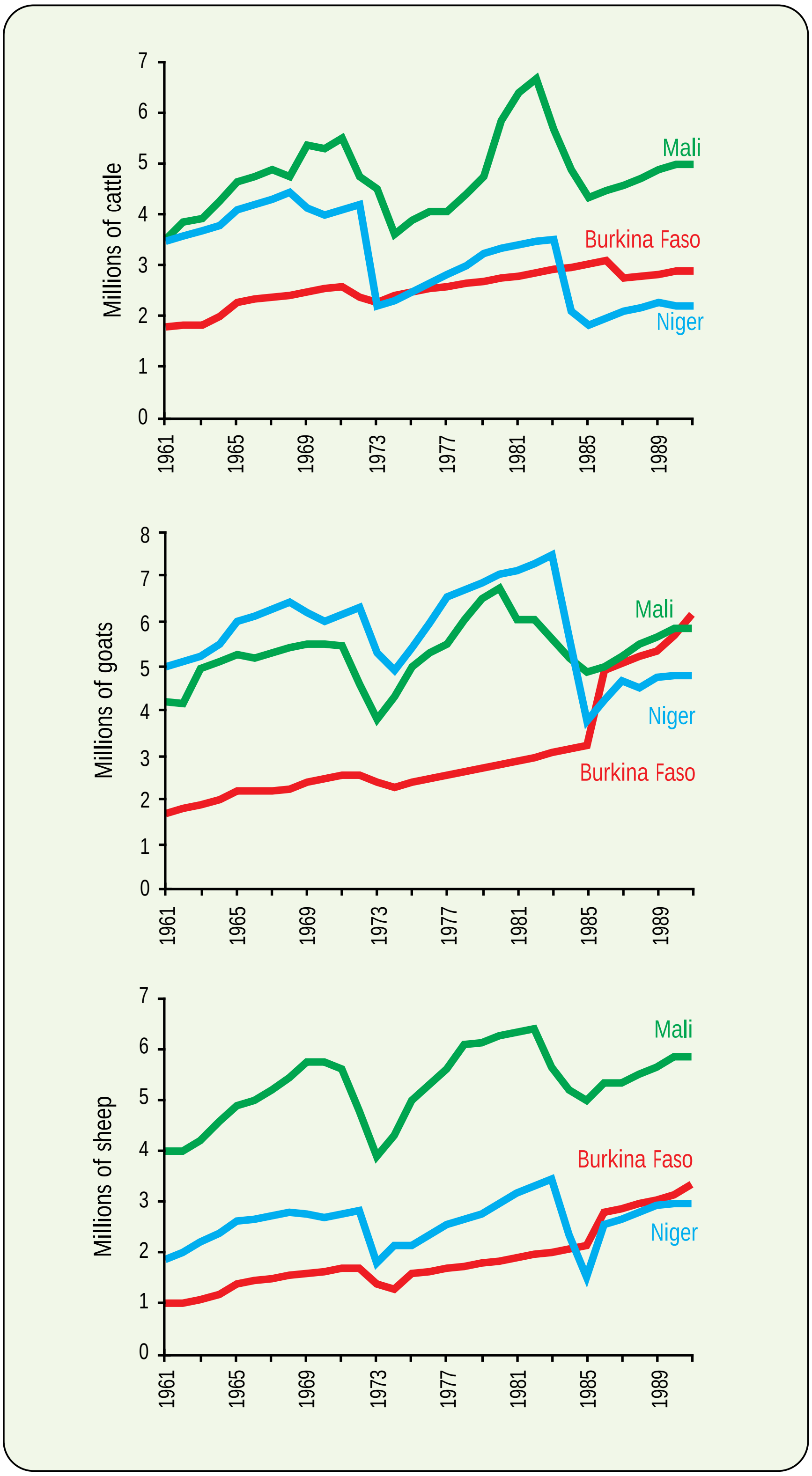
One consequence of increasingly concentrated livestock farming in the vicinity of urban settlements, e.g. in the form of feedlots, is local overexploitation of resources and soil degradation (circles of degradation) (Krings, 1993).

Nomads have been successively displaced by livestock owners, firstly through the transfer of grazing rights to sedentary farmers, and, secondly, by the latter’s market strength, as evidenced by their control over mercantile networks. These factors have contributed to the weakening of the economic situation of the nomads in favour of sedentary livestock farmers, making market integration more difficult for them to attain. Furthermore, sedentary livestock farmers often deploy wage-labour herdsmen whose interest in land conservation is low and who often fail to comply with grazing regulations. In the different regions of Mali, for example, 25-60% of the herds are owned by *absentee pastoralists*, in other words livestock farmers who themselves do not take care of the grazing lands (OECD et al., 1988).

The situation is exacerbated further by the fact that many valuable forage grasses which used to be available to the nomads are now harvested and sold to sedentary livestock farmers. The consequence is that the nomadic groups have to buy additional fodder on the market, often incurring debts in the process.

In total, the low competitive strength of the nomads described above promotes further overexploitation of local resources.

Figure 47: Numbers of livestock in selected Sahel countries



Source: FAO, 1992

2.1.2.2.4 Displacement of nomads by farming

While the number of nomads and semi-nomads in the Sahel decreases further, mixed cropping and grazing systems operated by farmers or former nomads, and especially modern farms owned by urban landowners, are becoming increasingly prevalent. The symbiosis between nomads and farmers within the nutrient cycle of cultivated land is declining: grazing on harvested fields, thus returning nutrients to the soil in the form of manure, is becoming rare (Johnson, 1993). This symbiotic relationship is being replaced more and more by relationships based on competition and conflict.

Traditionally, nomadism does not compete with farming, especially since it is concentrated on lands where environmental conditions would hardly permit any other form of land use. Only recently the pressures to exploit the land have lead to the expansion of farming at the expense of grazing lands, especially where irrigation is involved. Moreover, important grazing opportunities on floodplains are lost for dry periods, e.g. those of the River Niger. Such areas show an increasing tendency to switch from rainfed cropping to permanent cropping without fallow periods, by aid of irrigation systems. Nomads are displaced to marginal zones with low grazing capacity. The result is deforestation of the savannas, leading to over-sized herds and intensified land use, and subsequent degradation (Ibrahim, 1989).

2.1.2.2.5 International influences on nomadic livestock farming

The endogenous causes of economic and social transformation of nomadism in the Sahel, as outlined above, are reinforced by exogenous factors. In the following, we discuss two important international influences – development cooperation and meat imports.

Development cooperation

In the past, development projects in the Sahel zone were predominantly technologically oriented and paid less attention to socioeconomic conditions. Many of these projects, e.g. ranches and feedlots, the utilisation of scarce groundwater reserves through the application of capital-intensive technologies (e.g. sinking free-access boreholes), large-scale irrigation projects and vaccination programmes for cattle, have proved to be neither economically nor socially meaningful. Nomadic herding routes and traditional grazing systems are often ignored, with the result that the nomadic habitat has shrunk and natural resources have been depleted. External aid programmes offering “convenient” alternatives pose a fundamental threat to the traditional knowledge of nomadic cultures. Particularly problematic for land use were the approaches geared at short-term profits as pursued by local governments and countries giving assistance, as well as by the frequently impoverished user groups (BMZ, 1993). What is required here are long-term programmes which offer those affected a stable basis.

AGENDA 21 (Chapter 12 on “Combating desertification and drought”), and the Position Paper of the BMZ (1993) reflect a change in thinking. Recent development cooperation focuses increasingly on improved resource management. There is a growing consensus that participation by the population and its self-help organisations is a critical success factor. Because planning is normally carried out for large geographical units, e.g. river catchment areas, the development potential of the region itself was often left untapped. Local populations think in terms of locally-related social categories, e.g. village boundaries. For this reason, the smallest social units, village communities, should be the basis for acquiring and communicating knowledge about interconnected problems, the formulation of objectives and the mobilisation of organisational potential. Initial successes in connection with integrated land-use planning at village level have already been achieved (GTZ, 1992a).

In addition to the above, *concerted action* by all those bodies involved in development cooperation is important. Action to be taken should be prepared through the coordinated efforts of the various governmental and non-governmental organisations (NGOs). Transfer of know-how gained from experience occurs all too rarely. Steps should be taken to counteract all forms of bureaucratisation, such as those engendered by financial aid to states in the Sahel zone (Stryker, 1989).

Meat imports from the European Union

The most important basis supporting the Sahelian nomads was and still is cattle. However, beef is traditionally a major export product. The export markets for Niger, Mali and Burkina Faso are the large cities in the coastal states of West Africa, from Senegal, through the Ivory Coast and Nigeria to Cameroon.

These traditional markets for Sahelian livestock are severely threatened by export policy of the European Union (EU). Since the mid-1980s, the EU has been exporting subsidised beef to West Africa, above all to the Ivory Coast, Ghana and Benin. In 1991 and 1992 alone, these exports amounted to more than 50,000 tonnes annually, or about half the total meat requirement of the region. This meat is subsidised surplus production, often of lower quality, and is sold in Africa at dumping prices. The price per kilogram of beef in summer 1991 in Abijan, for example, was US$ 2, with a EU-subsidy of US$ 2.5 per kilogram. These export subsidies are therefore higher than for any other region to which the Community exports. In total, subsidies in 1991 amounted to approx. US$ 125 million (FIAN and Germanwatch, 1993). Even though these exports account for only 5% of the total meat trade and only 0.6% of total meat production, the entire regional meat trade in West Africa is greatly disrupted. Up to 1993, for example, the price for cattle from Burkina Faso had fallen to half the normal level (Eurostep, 1993).

The situation was further aggravated by the fact that, in the early 1990s, the EU also imported a total of around 500,000 tonnes of fodder annually from West Africa, a source of demand that makes animal feed in these countries more expensive, thus undermining nomadic pastoralism further. According to estimates, these EU policies are threatening the survival of between two and three million nomads (Deutsches Allgemeines Sonntagsblatt, 9.7.1993).

Paradoxically, these measures run contrary to other political efforts of the EU. There are several EU development aid projects under the Lomé III Agreement which are aimed at supporting the establishment of local cattle ranch enterprises, such as slaughterhouses with refrigeration in Ougadougou and Bamako. Germany alone provided more than US$ 53 million for projects like these in West Africa up to 1988 (GTZ, 1992b). It is doubtful, however, that these can still operate at a profit given the falling beef prices (FIAN and Germanwatch, 1993).

Initial efforts have been made by the EU to address this problem: in June 1993, subsidies for beef exports to West Africa were cut by 20%. However, prices for EU meat are still lower than that of African sellers, and exports from the Sahelian countries have not yet risen again.

2.1.2.3 Impacts on soils

Three main effects of changes in nomadic land use in the Sahel can be described which lead to soil degradation:

1. Nomads are being restricted in their mobility and flexibility, causing the loss of many elements of traditional land use. Examples include the non-utilisation of grazing lands for longer periods of time, or the symbiotic relationship between pastoralists and farmers. The concentration of livestock farming and other forms of land use in areas where the nomads are becoming (or being) sedentarised causes overexploitation of local resources.
2. Competition from other forms of land use leads to displacement of nomads to marginal lands which are less suitable for grazing. The total surface of land available for grazing herds is also reduced, with overexploitation of soils again being the result.
3. Changing herd compositions (more goats, sheep and cattle) also lead to changes in resource utilisation, because different animals graze in different ways. Goats feed on bushes and trees, while intensified cattle-grazing will cause soil compaction through trampling. In addition, over-sized herds produce an increase in total grazing pressure.

The immediate impact on soils that is produced by these effects is described in *Box 22*.

2.1.3 Subsistence farming and overexploitation of soils

Subsistence farming refers to a type of farming conducted on a small scale, with minimal capital input, and where production is mainly to satisfy the needs of the family. Typical forms in the Sahel are shifting cultivation and rotational bush fallow systems which utilise new areas, or areas which have lain fallow for protracted periods. Traditionally, this type of farming is almost exclusively rainfed farming, i.e. cultivation which does not require irrigation. For a long time, subsistence farming was one of the predominant forms of economic and social organisation in the Sahel.

2.1.3.1 Traditional cultivation systems

The traditional agriculture of savanna farmers, mostly shifting cultivation, can be characterised by periodic use of resources, great variation in the type of crops grown, a complex spectrum of products and low investment in the land. The main crops are various varieties of millet, sorghum, rice, maize, beans or groundnuts. Millet and sorghum, two particularly drought-resistant crops, are grown on 50-70% of the land. The requirements of the various crops are taken into consideration in different crop rotation and mixed cropping systems, with fallow periods to enable the soil to regenerate. Varying crops in this way makes optimal use of the highly variable rainfall.

This form of agriculture is aimed, similar to the traditional grazing methods of the nomads, at minimising risks. Staggering the seeding and harvesting times of the various crops spreads labour demands more evenly throughout the year. The different storage systems used by farmers, and the diversification of livestock rearing and farming are other examples of risk minimisation. All these methods help them to cope with climatic risks more easily.

Risk-minimising forms of crop management also include the cultivation of several plots at different locations by different farm workers. Cattle herds are sent to distant grazing areas under supervision, while milk goats are tended by children in the vicinity of the settlement. Other traditional sources of income in the Sahel are craftwork and the gathering of fuelwood, fodder grass and gum arabic (Ibrahim, 1989).

Box 24

The traditional relationship to nature in the Sahel

The concept of nature prevalent in traditional West African societies is not one in which nature is subordinated to Man and hence exploitable, but rather a specific understanding of the interdependencies between nature, the social world and the spiritual world. Interventions into natural processes are legitimated within the general cultural and social rules of behaviour, integrated within cultural rituals and can thus be kept under control (Lachenmann, 1990).

In most cases, for example, land could not be purchased under the traditional system, but only inherited. What is inherited is a mythical attachment to the land, since land consists not only of the actual soil material, but also has an immaterial aspect. The earth on which one lives is viewed as a divine entity, a godhead, and only the person who has a cultic relationship with this godhead, i.e. the “lord of the land”, a direct descendent of the first owner (sometimes a woman) obtains the right to live on that land and to determine how it shall be used.

The “lord of the land” is also responsible for enacting the cult, determines when seeding and harvesting take place and administers the land for the community, whereby he may assign hereditary land-use rights to others. If basic existential needs are satisfied, no additional work is performed. The reason for this is not indolence, but the declining marginal yields when more labour is invested, and the considerable amount of time that social life commands in the Sahel (Fuchs, 1985).

What is typical, therefore, is the diversity of sources from which a household earns its living. The flexible organisation of households with respect to the composition of members and the division of labour led to different forms of income at different times during the year. Kinship links, patronage and migrant labour offer the possibility of profiting directly or indirectly from better rainfall distributions in other regions.

Institutions such as the “lord of the land” (*Box 24*) act to regulate the periodic redistribution of land. The size of the production unit and its social organisation are aimed at preserving a balance between work force and food. There are also other social systems based on mutual solidarity with risk-minimisation functions.

Taken together, these social and economic strategies for ensuring survival enabled sustainable, environmentally sound and locally appropriate land use in the past, thus securing the carrying capacity of the region. As with nomadism, the preconditions for this way of life have declined since the colonial period, the traditional values and structures described above, however, have not disappeared entirely. The section that follows takes a closer look at these changes and the impact they have on human societies and nature.

2.1.3.2 Change of traditional cultivation systems

Reports on the environment and famines in the Sahel zone over recent decades have mostly focused on natural conditions rather than social and political causes. However, it has been changes in precisely these causal factors, especially the displacement of small farmers and the destabilisation of their traditional way of life, that have contributed to the loss of sustainability in subsistence farming, to soil degradation, and thus to the food crisis.

The majority of farmers in the Sahel zone now apply mixed cropping methods, i.e. they cultivate *cash crops* for the (export) market as well as food for their own consumption. This corresponds to their need for food security, on the one hand, and cash income, on the other.

High population growth, especially, has necessitated changes in Sahelian agriculture. Because traditional farming methods were low in productivity and used very little agricultural machinery, increasing food production has been achieved by expanding the area under cultivation (*extensification*), in the process of which traditional *fallow periods* were often abandoned under the pressure of food and land scarcity. *Intensification* of agriculture also occurred, primarily at more favourable locations and especially through the use of ploughs (mostly ox-drawn ploughs). This involves higher input of labour (e.g. care of the animals or the removal of roots from the ground), which explains why the productivity per unit area and unit of labour has not increased accordingly.

To prevent soil erosion, intensified cultivation must be accompanied by more intensive soil conservation measures. However, due to the greater input of labour required, such efforts usually fail. Moreover, most farmers do not have the financial means to invest in soil conservation. Ploughing has therefore led to increased damage through erosion, especially on marginal lands (Fahrenhorst, 1988). Women play a key role in the exploitation and management of natural resources, and therefore in measures for changing land-use patterns; they are affected by poverty to a high degree.

2.1.3.2.1 The influence of agricultural policy

Non-democratic political structures and the neglect of subsistence farmers’ interests are often identified as the endogenous, domestic causes for the crisis of Sahelian agriculture. However, the political interests of the colonialism also play a role in this context.

The economic policies of the colonial powers were focussed on the production of export crops. This promoted agrarian structures which subsequently led to the displacement of subsistence farming. Sustainable agriculture based on crop rotation and long fallow periods was often supplanted by monocultures. The agrarian policies of the colonial powers have found their way into the development plans of the newly-independent Sahel states since the 1960s. New national élites took over the political power (Krings, 1993), implementing economic policies governed by the notion that development is achieved first and foremost through urban and industrial development (*urban bias*).

A look at the national budgets and expenditure of the Sahel states reveals that food production has been neglected since independence was achieved. Scarce financial resources were mainly spent on establishing an (unprofitable) industrial sector, on urban areas and, last but not least, on numerous client relationships (Weidmann, 1991). Low expenditure on the agricultural sector contrasted with relatively high tax revenues from farmers. The government of Mali, for example, has constantly extracted more money from agriculture than it has invested in that sector (OECD, 1986). What little funds were provided for the agricultural sector were primarily invested in large-scale agricultural projects which were capital- but not labour-intensive. This one-sided support for modern production systems had serious impacts on both environment and society: the need for land was a contributory factor leading to the displacement of poor farmers and nomads from good farming land and grazing areas.

In addition to these misguided agricultural policies, state control of prices and products led to imbalances in the agricultural sector of the Sahel states. The fixing of low food prices by the state was as a means of supplying urban consumers, the main source of political support, with affordable food, but gave farmers little incentive to produce more.

Even though the disparity between relatively high export prices and low domestic prices for food has been somewhat reduced in the meantime as a result of policy reforms (e.g. in Mali), the conditions under which subsistence farmers are expected to produce are still unfavourable. An OECD study on income trends among Mali’s farmers showed that, despite a six-fold increase in the price of farm products between 1960 and 1982, farmers’ real income fell by approx. 25% (OECD, 1986). On account of their comparatively low economic power, subsistence farmers have been hardest hit by the negative effects of misconcepted agricultural policies. The relatively high prices for agricultural inputs, combined with low prices for farm products, have economically weakened them substantially. One consequence is that they are increasingly unable to afford qualitatively good land and must move to marginal locations instead. Attempts are now being made in some Sahelian countries to improve rural living conditions, e.g. through improved access to urban markets. Despite this, the degree of self-sufficiency continues to deteriorate in almost all Sahelian states. Major food supply problems are caused by inadequate infrastructural links and administrative deficits, particularly after bad harvests.

2.1.3.2.2 International influences on subsistence farming

Besides the endogenous factors mentioned above, the crisis of subsistence farming in the Sahel has also been influenced and exacerbated by a number of international factors. *External food aid*, on which Africa is increasingly dependent, is one such problem. The level of need during the 1991–1992 period was estimated at approx. 6 million tonnes (Roth and Abbott, 1990). Without this external input, it would be impossible at present to ensure an adequate supply of food for the population. Such aid has an enormous impact on African economies, however.

External food aid influences the economic decisions taken by farmers, in that it pushes down local grain prices. The more aid that is provided, the lower the prices for grain produced in the respective country. External aid was also one of the factors which has led to changes in consumption patterns in Sahelian cities, with rice and wheat replacing traditional grain types to an increasing extent. Reduced demand for locally grown grain, combined with falling prices, has resulted in lower incentives to produce food and conserve the soil, leading in turn to greater dependency on external aid. The willingness of the international community to provide food – especially in times of food crisis – also reduces the pressure on the respective national governments to design and implement functioning and sustainable agrarian policies.

Decisions taken within national agricultural policy are increasingly influenced by the situation on the *world market*. The Uruguay Round of the GATT negotiations has produced a situation in which import duties will be reduced by up to 30% and agrarian subsidies by up to 20%. The African continent will have little share in the prosperity gains that ensue worldwide; on the contrary – since food prices are expected to increase by approx. 10% over the next few years as a consequence of lower subsidies to agriculture, the African continent will probably suffer losses of around US$ 2.6 billion annually if conditions remain unchanged (by way of comparison, the gains in prosperity worldwide as a result of the Uruguay Round are estimated at approx. US$ 210 billion annually) (Goldin et al., 1993). The Sahelian states already have to use a large proportion of their export revenues for food imports; in Burkina Faso, the figure was over 60% on average for the 1972–1980 period, in some years over 100% (Roth and Abbott, 1991). This deterioration can only be combated if higher market prices provide incentives to increase domestic production.

However, the anticipated increase in agricultural production that this would lead to would not produce a direct positive impact on soil fertility and the containment of soil degradation. In the Sahel region, the commercial agricultural sector (large enterprises) in particular takes a market-oriented approach, with higher prices for agricultural products inducing greater incentives to produce more, thus leading to further intensification of agricultural production and the possible expansion of areas under cultivation. Such intensification and/or expansion of land use in such an environmentally sensitive region can create additional problems for soils (Lutz, 1992). While intensification of agriculture is necessary, it is also essential that methods typically applied in temperate zones only be implemented if they are adapted to local circumstances, i.e. if they integrate the knowledge and experience of traditional Sahelian agriculture. Such adaptation must also involve the use of labour-intensive methods, since capital available in Sahelian countries is generally low.

2.1.3.2.3 Destabilisation of traditional ways of living

The developments referred to above have led to a situation in the Sahel zone in which subsistence farming is no longer the predominant means of earning a living. Some production is for the market, since monetary income is needed to cover expenses for taxes, agricultural machinery, food, clothing, school fees, etc. Like the nomads, however, subsistence farmers cannot participate in the market adequately, since they cannot respond to increases in prices for farm products in the same way as larger and better equipped agricultural enterprises, which are able to increase their production much more easily, nor can they obtain cheap credit (Leisinger and Schmitt, 1992). Thus, subsistence farmers simply do not possess the means to compete with large farming enterprises. This leads them to either increase labour input or expand the area under cultivation – soil degradation being the inevitable result (Krings, 1993).

Destabilisation of subsistence farming also effects changes in the way that households earn their living. The need for cash income drives male family members to seek work in the cities during dry periods, or is met by women and men working as wage labour on farms in other areas. This produces additional strains, since those who migrate to cities must often be supported with food from subsistence farming without their labour being available at home. The destruction of traditional family structures means that the prerequisites for the operation of small farms (the labour of at least two people, in addition to the labour required for child raising) no longer exist.

Individualisation and impoverishment often go hand in hand with the expansion or overexploitation of cultivated areas, excessive strains on labour and shorter intervals in which soils can regenerate. The dissolution of family and clan structures is also accompanied by numerous Western influences, in particular the needs and wishes produced by the new consumer society model. These changes tend to produce a loss of traditional knowledge of land use, the loss of cultural and social identity, but also the loss of traditional mythical attachment to the soil.

2.1.3.3 Impacts on soils

Two main trends affecting subsistence farming in the Sahel lead to soil degradation:

1. Subsistence farmers are being *displaced* to marginal lands unsuited for cultivation. The low productivity of these areas compels farmers to use them intensively, resulting in overexploitation of these fragile soils and ecosystems.
2. Subsistence farming is being *intensified*. Partial mechanisation and the introduction of irrigation are changing the way in which resources are used, and hence the impact that this form of agriculture has on the environment. Mechanisation is accompanied by expansion of land areas under cultivation, but not by the requisite soil conservation measures (e.g. to prevent soil erosion). Fallow periods are also reduced, thus depriving the soil of a chance to regenerate. This leads to deterioration of soil quality and the destruction of soil structure.

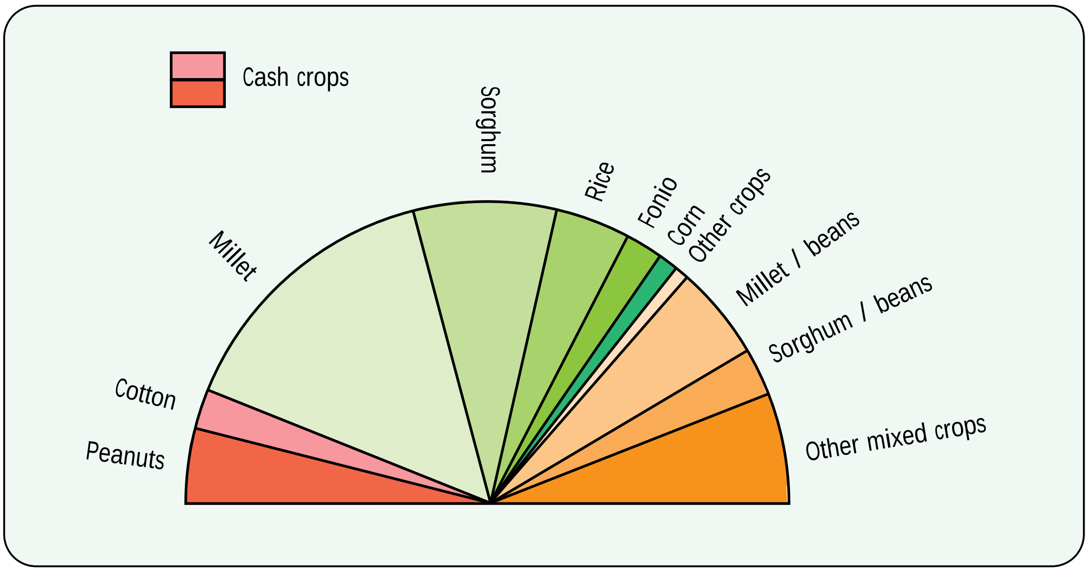
2.1.4 Cash crops and overexploitation of soils

Cash cropping refers to the large-scale production of agricultural products, not for domestic subsistence, but for the export market. It generally takes the form of monocultures. Cash cropping in this form is assigned to the “Dust Bowl Syndrome” (Section D 1.3.3.2). However, it is mentioned in connection with the “Sahel” case study in order to provide a full picture of soil degradation and its interactions with subsistence farming.

The expansion of cash cropping in the Sahel began during the colonial period mainly with the cultivation of cotton and groundnuts. The dominant crop in Mali and Burkina Faso today is cotton, production of which has increased by a factor of five over the last 20 years (Grainger, 1990). Substantial increases in yields per hectare have been achieved here, contrasting with the production of staple foods. Groundnut cultivation was greatly encouraged during the 1950s and 1960s; Niger, for example, increased its area under groundnuts six-fold, even though the basic requirement – minimum rainfall of 500 mm per annum – is only met in the most southern regions of the country. Burkina Faso and Mali also saw a continuous expansion of groundnut cultivation. One of the reasons for this change in land use was the high price for groundnuts guaranteed by France, which granted subsidies in an attempt to combat a US campaign to penetrate the European vegetable oils market (Grainger, 1990).

In terms of area, however, cash cropping accounts for a relatively small proportion of the land. In Mali, for example, only about 10% of the area suitable for agricultural production is used for the cultivation of cash crops (*Fig. 48*), and the figure for the entire African continent (12.8%) shows that this is no exception (Barbier, 1989). However, absolute area is a misleading criterion if the issue is the actual impact that cash cropping has on soils. Cash crops are often grown on the best land, which means that these are no longer available for the production of national food requirements.

Figure 48: Main crops grown in Mali



Source: Traore, 1980

2.1.4.1 International influences on cash cropping

The political mistakes which were a major cause of the problematic land use for cash cropping were largely the same as those described in Section D 2.1.3.2.1. These were supplemented by external political and economic factors that have further exacerbated the problems in recent years. The supranational development institutions have relied on cash cropping for a long time as a means of solving economic problems of the Sahel. Major mistakes occurred with respect to the concepts they developed.

For example, land in the Senegal and Niger valleys was privatised and allocated to producers who received credits to cultivate rice as part of various *World Bank projects*. Approx. 150,000 hectares of the Sahel is now used for irrigated rice cultivation, mainly in areas close to rivers. While crop yields are increasing, the assessment of the sustainability of rice cultivation, however, varies considerably. Irrigated rice cultivation on the relatively saline soils of the region demands regular and sufficient drainage, an aspect that these projects have given little or no attention to. The gradual salinisation of topsoils is therefore the result of project policies that were insufficiently geared to sustainability. Another aspect that received too little consideration was the absence of any tradition of rice cultivation among the indigenous population and therefore the fact that the acceptance and ultimately the productivity of this type of farming in the Sahel are not comparable to other rice farming regions in the world.

Another factor which is indirectly related to the soil problem is the prices for raw materials on the international market, which have been at a low level since 1988. Africa’s export revenues are therefore declining, while the cost of imports has continued to rise. African states suffer from increasing deterioration of their balance of payments, partly due to higher prices for fossil fuels, causing rapid growth in their international indebtedness. Worsening terms of trade have meant that more and more cash crops must be exported simply to keep export revenue more or less *constant*. The consequence for soils, specifically, is that either the area under cultivation is expanded further, or farming intensified (Pearce and Warford, 1993).

The debate on the role of international economic influences on Sustainable Development repeatedly focuses on yet another problem complex, the interrelationship between a country’s external debt and the influence this exerts on the environment. It is important when analysing the debt situation of the Sahel to realise that the LLDCs, the Least Less Developed Countries, do not profit from the various rescheduling schemes of recent years to the same extent as other developing countries.

Firstly, most of these countries only have long-term credits from multilateral institutions, credits which are subject to special conditions:

- they cannot be renegotiated,
- they have to be paid back in full, with no possibility so far of extending the term of repayment or cancelling the debt, as is sometimes the case with private banks.

Secondly, although private debt has been reduced by various programmes, the remaining debt accounts for a disproportionate share of total interest paid. It has been calculated for the sub-Saharan economies that only 16% of all debts are private, but that these make up over 30% of total debt servicing (Ezenwe, 1993). Some Sahelian countries are among those with the highest debt servicing rates in the world, e.g. Sudan, where the rate is over 300% (1989). The foreign debt of most Sahelian countries has also risen in absolute terms; in Mali, Niger and Burkina Faso by over 60% between 1985 and 1991, from roughly US$ 3.2 billion to US$ 5.15 billion (World Bank, 1993). There is a close relationship between the external debt situation and environmental problems, especially soil degradation. For the Sahel, two such links are:

1. Sahelian countries must grow cash crops for export in order to earn the foreign currency needed to reduce the level of foreign debt. Cash cropping has a number of negative consequences, however, including soil degradation.
2. The poverty which results from foreign debt contributes to soil degradation through the overexploitation of resources. External debts are therefore a primary obstacle to sustainable, environmentally sound and locally appropriate agriculture.

Structural adjustment programmes

A total of 14 African countries, including Mali, Niger and Burkina Faso, devalued their currencies (the CFA and the CF) on 12th January 1994, partly in response to the debt problem. This devaluation was carried out under the auspices of the so-called *enhanced structural adjustments facilities* of the IMF, i.e. IMF credits with macroeconomic conditions attached. Devaluation was one of those conditions, cuts in public spending and import liberalisation being two others.

Devaluation was aimed at improving the international competitiveness of these countries’ export products, since it made these cheaper and increased demand for local products on the world market. The higher import prices that also resulted were intended as a means of making local products more competitive on the domestic market. It was hoped above all that higher import costs for agricultural products would provide greater incentives for domestic food production and for the preservation of soil quality that is essential for this. What actual effects devaluation will have for the countries of the Sahel has yet to be seen.

The IMF is meanwhile attempting to counteract the negative environmental and social impact of structural adjustment programmes. The original programmes, which were based purely on macroeconomic reforms, were supplemented by social safeguards and increased technical assistance. Burkina Faso, for example, has agreed to improve the primary education system, the health services and the training of unemployed people as a condition for receiving its latest credit amounting to US$ 25 million (March 1994) (IMF, 1994); in Niger (new credit in excess of US$ 26 million credit, January 1994), the possible negative effects are to be cushioned by food aid to particularly disadvantaged sections of the population.

Experience with structural adjustment programmes in the countries of Africa varies on the whole (Commander, 1989). The *relative* improvement in the economic situation of small farmers is an important feature deserving special attention (Rauch, 1991). Currency devaluation, reduced subsidies, dismantling of price controls and a general, forced tendency towards privatisation and liberalisation have effectively favoured small farmers, who produce labour-intensively and with local resources, because their low-input production methods are largely independent of foreign currency, and therefore of expensive import products such as mineral fertilisers, machinery and pesticides. However, this is no guarantee that the increases in food production urgently needed to ensure food security will actually materialise.

2.1.4.2 Consequences of cash cropping

The introduction and promotion of cash cropping on a large scale has led in the wetter areas of the Sahel to subsistence farming being displaced to marginal areas. Cash cropping has also meant expansions of the area under cultivation, the establishment of permanent crops (without fallow years) and to intensification of agriculture. The nutrient and water requirements of most cash crops, especially cotton, are very high (Grainger, 1990). Favourable areas such as river valleys are therefore preferred for cash crops, areas which used to serve local subsistence needs. These river valleys were traditionally used during the dry season for grazing. Cash cropping now forces the dry savannas to be used throughout the year as grazing land, with overgrazing being the obvious consequence (see also Sections D 2.1.2 and 2.1.3).

The cultivation of cash crops in the Sahel has overall had a negative impact on soils: the mechanisation of tillage increases the risk of erosion considerably, and if extracted nutrients are not replaced sufficiently, soils will degrade. Cotton is usually cultivated in the Sahel in irrigated monocultures. Artificial irrigation in arid areas is often linked to salinisation or alkalisation, depending on the mineral composition of the soil. Soils in Mali and Niger are naturally very saline. Due to insufficient drainage, there is a tendency for topsoils to become salinised (see rice cultivation).

In addition, where intensive use of water resources has occurred, the hydrological cycle has also undergone changes (Arnould, 1990). Water levels of surface waters sink; e.g. large quantities of water are still being removed from Lake Chad for irrigating cotton crops, so that it can be expected to dry up to an increasing extent. Inundations by river floods are also declining, and ground water tables are sinking. Because modern mechanised boreholes are often indispensable for irrigating cash crops, non-renewable sources of water are being overexploited to an increasing degree.

Natural vegetation cover is often removed to enable mechanised farming (Krings, 1986). Pesticides (including pesticides which are prohibited in the industrial nations) are a means for controlling pests and weeds in monocultures, but they often have a serious impact on people’s health and on soils. Another effect is that more foreign currency is required by these countries in order to purchase the pesticides in the first place. Cultivation of cotton is particularly problematic in this respect. Cash crops are more demanding with respect to site conditions, thus explaining the greater susceptibility of such crops. Unlike traditional mixed crops, cash crops lack the requisite variability which permits some species to survive even under extreme environmental conditions. Large-scale agricultural projects are also less labour-intensive per unit area than subsistence farming. Redundant labourers who do not migrate to the cities tend to cultivate any marginal land that remains, thus contributing to the further expansion of agriculture.

2.1.4.3 Impacts on soils

The most important effect that cash cropping has on soils in the Sahel zone is indirect, namely the displacement of farmers to marginal lands. Intensive cash cropping in monocultures involves greater mechanisation, with direct effects on soils (which in the Sahel typically demonstrate a low level of structural stability) in the form of compaction and other structural changes that adversely affect vegetation and water resources. Another aspect is that soils are more susceptible to wind and water erosion following mechanised tillage.

Increased use of pesticides leads to soil contamination, especially when they are not biodegradable. As already described in the section on subsistence farming, intensification of agriculture means that no recourse is made to fallow periods, thereby reducing the regenerative capacity of the soils. The combination of pesticide use and lack of fallow vegetation also has an adverse effect on biodiversity.

Investigations must be carried out in future to see how both forms of crop cultivation, subsistence farming and cash cropping, can be operated alongside each other in an environmentally sound manner. Any assessment of the environmental impact of cash crops must first clarify which alternative cultivation methods are available for existing cash crops, and whether other cash crops are better suited to Sahelian conditions. The various cash crops differ considerably in their environmental impacts, groundnut cultivation, for example, is especially damaging. Consideration should also be given to the fact that production can be intensified still further on favourable land. This intensification is absolutely essential given the poor food supply situation faced by the Sahel population; however, it has to be environmentally sound and adapted to the prevalent social structures.

2.1.5 Migration in the Sahel

Among other effects, soil degradation in the Sahel also leads to a decline in the carrying capacity of the region, and especially in its potential regarding food security. This, in association with growing population levels, forces many people to migrate, in search of work. Such migration is mainly to the geographically favourable areas and countries along the coast. The total number of persons migrating out of the Sahel zone greatly exceeds the level of immigration. In Burkina Faso, for example, as many as 2 million people migrate, either seasonally or for longer periods, mainly to the Ivory Coast. Mali also has approx. 2 million inhabitants who migrate cyclically to the cities or abroad, especially to the Ivory Coast and Senegal (Statistisches Bundesamt, 1992). Moving to more southern areas is only possible within certain limits, so that greater pressure is also exerted on arid areas (Stryker, 1989).

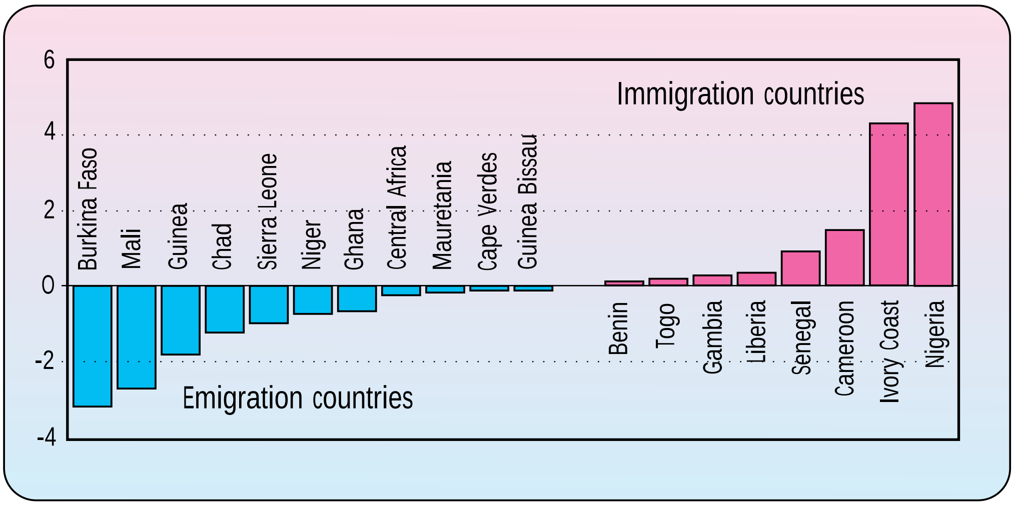
One reason for migration is exceedance of the carrying capacity of soils. The concept of carrying capacity (see Section D 1.2) is only of limited use for describing the situation in the Sahel, however. In addition to the spatially defined concept of carrying capacity, consideration should also be given to the social carrying capacity, which integrates not only population level and the resource base, but also socioeconomic factors into the analysis (Manshard, 1988).

People in the Sahel are often forced to migrate from their home areas due to environmental conditions (*Figs, 49* and *50*). Desertification and migration are closely related: the flow of refugees swells up regularly during drought years. These environmental refugees are not only particularly affected by soil degradation, but they also exacerbate it by overexploiting resources elsewhere (e.g. by fuelwood cutting). Increasing soil degradation and scarcity of land can also produce an increase in the number of military conflicts.

Another reason for migration is the lack of jobs, training opportunities and other infrastructural elements, especially in rural areas. Migration resulting from the uneven distribution of living conditions puts pressure on less densely populated areas as well as on towns and cities.

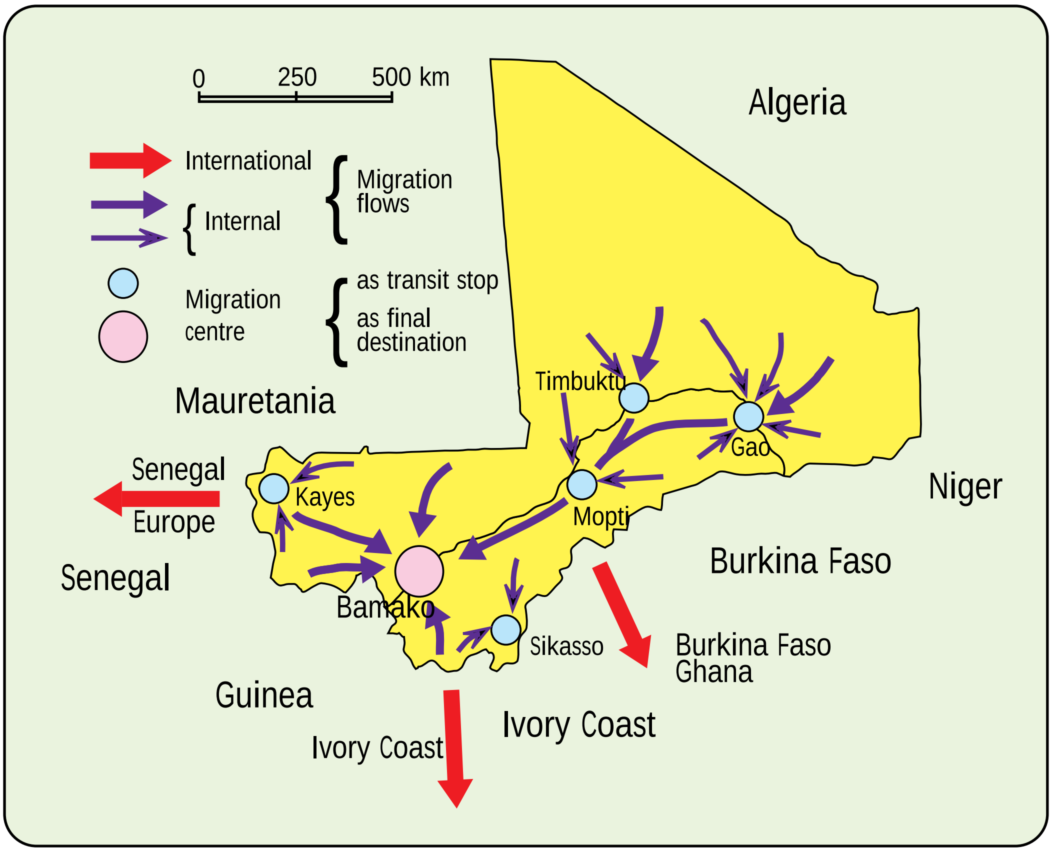
To date about 20% of the population in Mali, Niger and Burkina Faso lives in towns and cities which are growing at a rate far above that of the population as a whole. More than half these countries’ urban populations live in the capital cities (Bamako, Niamey and Ouagadougou), where civil service, industry and infrastructure are concentrated. Attempts at decentralisation through the creation of smaller towns (*counter-magnets*) have proved unsuccessful so far (Salan, 1990).

Figure 49: Comparison of migration in West African countries between 1960 and 1990



Source: OECD et al., 1988

Figure 50: Population mobility in Mali



Source: Barth, 1986

Increasing population concentration in the cities is causing overexploitation of resources there, too. Circles of desertification occur around the cities, particularly through livestock farming and deforestation. Migrants continue their traditional way of life as far as possible in marginal groups (marginal in spatial terms as well, in that they often live in slums on the outskirts of cities without adequate supply and disposal systems). Pressure on timber resources imposed by cities is enormous: the fuelwood consumption of Ouagadougou is estimated to be about 95% of Burkina Faso’s total annual incremental timber growth. Other resources, such as fodder and drinking water, are extremely overexploited in areas surrounding cities.

2.1.6 Possible solutions

The Sahelian states are among those with the lowest per capita income in the world, partly as a result of natural geographical conditions. Most forecasts for these regions are correspondingly pessimistic. This implies a special obligation to provide assistance on the part of the international community, and Germany in particular. More aid for this region also makes sense in terms of cost-effectiveness: much can be achieved for relatively low amounts of input and/or know-how transfer. Reference is made here to the options provided by *Joint Implementation* (see Section C 1.4). Such assistance is also advisable on account of the migrational flows, to European countries as well, with the corresponding social and environmental problems.

The prime objective in the search for solutions to soil degradation in the Sahel must be to ensure an adequate food supply for the population while protecting the soil and the other natural resources (*Sustainable Development*). To achieve this objective, it is essential that agricultural production be sustainable, environmentally sound, appropriate to local conditions and involve no further expansion of land use as far as possible.

Soil conservation measures can only succeed if they tackle the socioeconomic causes which have been analysed and are based on precautionary action. This means taking steps to fight poverty and marginalisation within the population, build capacities and promote democratic structures, e.g. through decentralisation or through more power being allocated to intermediary institutions which mediate between central government and the local level. Such organisational decentralisation must be accompanied by the reorganisation and redistribution of budgetary powers. Even if an adequate national planning and control capacity were to be successfully created, these aims can only be achieved in the long term.

Participation by the population must be ensured not only when implementing development projects, but at an earlier stage – in the analysis of problems and during the planning phase, and in subsequent evaluation of projects implemented as well. The rationale for action of the Sahelian population, especially their risk-minimisation strategies, must be taken into consideration when planning any soil-related measures, as well as in the context of environmental education and training. Development strategy must be geared much more to surviving Sahelian culture than to any modern, Western standards.

In general, traditional farming can no longer be practised in its original form, because traditional social mechanisms have collapsed and/or economic conditions have changed. In such a situation, an attempt must be made to recreate the balance of interests between the various user groups and soil conservation, or to institutionalise it in a different form. This is not possible without a legal framework governing land and land use that provides a stable legal basis for responsible use of resources. In view of the variability of natural conditions in the Sahel, ensuring flexible forms of land use is of key importance. One instrument for this could be regional and local land-use plans which ensure local units the greatest possible freedom and flexibility in land use, in accordance with the principle of subsidiarity.

Germany’s options with respect to the Sahel zone are not restricted to bilateral development policy. It can also use international trade and finance policy to a greater degree as a means for solving the structural problems faced by the Sahel.

One important improvement in the economic situation of the Sahelian countries could be achieved through international finance policy, if the net transfer from the Sahel countries were to be stopped and payments to these countries substantially raised. Reference is made once again in this context to the Council’s recommendation in the 1993 Annual Report, namely to increase German development aid to 1% of GNP.

At the same time, given the international nature of the Sahel’s development and environmental problems, account must be taken of the fact that bilateral policies have limits. The Sahel zone is correctly defined as a region that, while politically organised into nation-states, has problems which are partly due to precisely that organisation. What is needed is better coordination of soil-related projects and strategies. The responsible international institutions (such as the FAO, the UNDP, the World Bank and the IMF) must improve the exchange of information, joint planning, the implementation and evaluation of measures, and in this way create links between local, regional and global perspectives. A suitable range of analytical instruments capable of showing interacting trends of relevance to soil degradation and bringing together expert knowledge from the respective disciplines, especially the social sciences, is still not available.

2.1.6.1 Syndrome-related recommendations for action

The section that follows presents suitable measures for implementing the above principles and objectives, with specific reference to the three cross-sectional themes (nomadism, subsistence farming and cash crops):

2.1.6.1.1 Nomadism

Nomadic pastoralism is the land use system operating over extensive dryland areas that is environmentally, socially and economically best adapted to local conditions. In its traditional form, nomadic pastoralism in the Sahel has experienced severe decline due to the various influences described above. However, conditions in the Sahel continue to provide a good basis for other forms of mobile and flexible livestock farming.

The countries of the Sahel must be given external support in creating such land-use forms and in implementing soil conservation strategies, at least until their own efforts to promote the agricultural sector bear fruit. Efforts must be made in bilateral and multilateral negotiations to ensure that nomads are granted secure and long-term land tenure rights, especially grazing land in the dry season and transit rights. Measures which preserve and develop traditional knowledge, and which promote the self-help institutions of land users are also essential. In general, pastoralist land-use systems must be given support at the political level within the Sahelian states.

In the view of the Council, EU subsidies for meat exports should be reviewed in order not to destroy the Sahelian nomads’ already limited economic basis. Furthermore, the European Union’s trade policies in general should be analysed for any negative impacts on the environment.

2.1.6.1.2 Subsistence farming

Traditional subsistence farming, a self-sufficient farming system serving the needs of the local population in the Sahel, can no longer be carried out under present-day conditions. It is becoming increasingly difficult to feed the growing population and at the same time to ensure the conservation of natural resources. In addition to the need for intensification of agriculture, it is also necessary that additional sources of income be created for the rural population. These could include small businesses and craft enterprises based on existing skills and social networks, which can be given assistance in the fields of design and marketing. Sahelian traditions and culture suggest that industrial products will probably become competitive in the long term only. Further processing of agricultural products therefore seems the more likely alternative.

As far as existing subsistence farming is concerned, priority should be given to the promotion of basic soil conservation measures. Elements of appropriate land use could be: agroforestry, silvopastoral systems, organic fertilising through the integration of farming and livestock breeding, grazing controls, crop rotation, mixed cropping, and the cultivation of drought-resistant crops.

If natural resources are to be preserved at the same time as increasing yields, then measures to prevent erosion and increase infiltration are called for, such as contour ploughing, “stone lines”, barriers and dams in gullies, terracing, windbreaks and dune-fixing techniques. To improve soil fertility it is necessary to break up soil crusts, other possibilities being the cautious application of fertilisers and the use of nitrogen-fixing legumes.

The serious problem of wood depletion in the Sahel must be combated with projects for planting new trees and shrubs, aimed at ensuring the long-term regular supply of timber for construction and as fuelwood, controlled felling of trees, protection against soil erosion and preservation of biodiversity. The use of ovens requiring less fuelwood must also be propagated, and practicable utilisation of solar energy must be supported until a breakthrough is achieved. Nine Sahel states, including Mali, Niger and Burkina Faso, have meanwhile decided to adopt solar energy techniques. These efforts should be actively supported with funds and technical know-how. However, such technical operations have to take account of social factors as well, so that they can sustain operations in the long term.

2.1.6.1.3 Cash crops

As already shown, large-scale cash cropping in the Sahel cannot be continued in its present form. Thus, there is an urgent need to restructure agriculture in the direction of sustainable, environmentally sound and locally appropriate land use. In future, cash cropping should no longer be restricted to monocultures, but should be based on crop rotation methods and/or mixed cropping. In particular, cotton and groundnut cultivation is in need of innovative change, taking local conditions into consideration (susceptibility to erosion, water scarcity, risk of salinisation). Only in this way can soil conservation be maximised. Another requirement which is related to the need for diversification of income for the rural population is that prices for farm products be sufficiently high to prevent further expansion of the area of land under cultivation, and to enable farmers to finance their own soil conservation measures.

2.2 The "Leipzig-Halle-Bitterfeld" agglomeration case study

2.2.1 Geophysical situation

Penck (1887) once called the "Leipzig-Halle-Bitterfeld" region the "heart of Germany". Today the boundaries of this urban agglomeration have yet to be clearly defined. Schönfelder (1993) allocates the following 25 regional units with a total area of 9114 km^2 (distribution of area in *Table 25*) to this region:

- the three cities: Leipzig, Halle and Dessau,
- the 10 districts of the agglomeration: Altenburg, Bitterfeld, Borna, Delitzsch, Hohenmölsen, Leipzig-Land, Merseburg, Saalkreis, Weißenfels and Zeitz,
- the 12 districts of the peripheral region: Eilenburg, Eisleben, Geithain, Gräfenhainichen, Grimma, Köthen, Naumburg, Nebra, Querfurt, Roßlau, Wittenberg and Wurzen.

Zeuchner (1992), who divided this region into labour market districts, additionally includes the districts of Bernburg, Hettstedt, Sangerhausen, Torgau and Zerbst (districts in peripheral area of the agglomeration), while Wittenberg is not included. This is of negligible significance for statements on the economic and social situation, however.

Table 25: Land distribution in the "Leipzig-Halle-Bitterfeld" agglomeration, in ha

Total area	Agriculturally useful land	Mining area
911,400	537,345	46,647

Source: Statistisches Bundesamt, 1993

Geologically speaking, the subsoil close to the surface and the relief in the Leipzig lowland bight came into being during the tertiary period; the loess layer was deposited in the quaternary period. Alluvial fans spreading from the south were covered by sea sediments. Four brown coal seams were found that were suitable for mining and have been mined since 1698: the Saxon-Thuringian lower seam, the Borna main seam, the Bitterfeld seam complex and the Miocene seam of the Lausitz group. The Saale, Weißer Elster and Mulde Valleys divide the region, but because these rivers are old, flatly profiled meltwater channels, they play an insignificant structural role.

With respect to the *natural environment*, the Leipzig-Halle-Bitterfeld region is defined by the central Elbe Valley in the north, Dübener Heide in the northeast, the western portion of the loess belt (loess section of eastern Harz foothills and of Leipziger Land) and by the eastern portion of the loess belt (Saxon loess section). The prevailing types of soil are the loess black earth of the Köthen loess plain and of the Halle loess hills, clay-differentiated brown soils on sand loess cover layers and small-grained loess derivatives in Leipziger Land as well as in the Weißenfelser loess hills and Altenburg-Zeitzer loess hills. Up to now these soils have been subject to intensive agricultural use because of their high humus content and good absorption capacity. The low degree of ecological diversity can be seen in the monotony of the landscape. In the past mining and industry acted as relief-shapers and thus represented an additional burden for the landscape, which is barren and unattractive anyway.

With regard to *climate*, the region is partially located in the rain shadow of the Harz Mountains and of the Thuringian Forest; this results in low annual precipitation, particularly in the area around Halle. The inner lowland area is subject to a continental influence in the northeast and east, and maritime in the northwest. The average annual air temperature is approx. 9°C; the average precipitation is 476 mm in Halle, 586 mm in Leipzig, 635 mm in Grimma and 711 mm in Narsdorf.

2.2.2 Economic and social situation

Historical economic development

By virtue of the concentration of brown coal and the chemical industry, the Leipzig-Halle-Bitterfeld region is a typical declining industrial region, comparable with areas in Poland (Upper Silesia), in former CIS states (Donezk and Kusnetzk basins, Ural) or in Romania. Industrial development in the cities of Leipzig and Halle commenced about 1850. With the transition to large-scale industry and the changeover to machines brown coal became the most important source of energy in the region.

Besides the establishment of large urban settlements, it was above all the development of the surrounding brown coal mining area that contributed to the formation of the agglomeration. Because of the high content of water (50 – 70%) and ash (15%), brown coal transport over long distances is uneconomical. Therefore, the successor industries (mechanical processing, power generation, etc.) established themselves near the open-cast mining sites. Since the turn of the century, there have been five brown coal mining areas in this region, around which large chemical enterprises formed in Bitterfeld/Wolfen (paints), Leuna (methanol, nitrogen) and Buna (synthetic rubber).

After the end of the Second World War many enterprises in the Soviet occupation zone had been destroyed. Cut off from the supplier industry, they became an isolated economic region. In the subsequent German Democratic Republic the country created its own capacities in the primary industry, in the electrical engineering sector and in heavy-duty machine production. Whereas it was initially planned to change over production to the petrochemical industry in the early 70s, the brown coal based chemical sector was pushed forward at the end of the decade due to lack of foreign exchange. In addition, households were not converted from coal to oil or to gas heating. The growth targets could not be met because of foreign debt, increased prices for raw materials, promotion of armament and subsidy burdens. Beginning in 1988, there were increasing signs of an economic crisis: planned targets were not met, there were gaps in supply and delivery bottlenecks grew more frequent (Zeuchner, 1992). The tense economic situation of the GDR as well as an ideologically induced bias led to a criminal neglect of ecological interests, which made itself extremely noticeable in the industrial agglomerations. Due to central state control, agriculture developed from individual farms into large enterprises of an industrial scale. That meant setting up large fields as well as intensive livestock farming and subsequently further decline in diversity of species and varieties.

Basic conditions and current situation

The region surrounding the Leipzig-Halle-Bitterfeld agglomeration encompasses the urban centres of Berlin, Dresden, Chemnitz, Prague, Nürnberg, Würzburg and Kassel as well as the Magdeburg-Braunschweig-Hannover city axis. Motorway connections exist to some of these regions. Because of the predominant north-south orientation in the former GDR, however, there is a lack of good connections to the Ruhr area and Cologne-Bonn region.

Although the infrastructure is being rapidly improved, particularly with regard to telecommunications, considerable quantitative (lack of east-west links) and qualitative shortcomings (condition of traffic routes) can still be noted in the traffic network. Incorporation into international aviation routes is striven for via expansion of the Leipzig-Schkeuditz Airport. Through the airport and the rail traffic network to be extended, Leipzig is developing into a traffic node and is gaining increasing importance as a site of international trade fairs; Leipzig and Halle are becoming communication and media centres of the region. All these factors will certainly have a positive effect on the economic, social and cultural development of the entire region in the medium term.

For historical reasons, the proportion of the total economic output accounted for by industry is very high in comparison to other regions of the former GDR. In 1989 the percentage of workers employed in industry was between 40% and 50%. While Leipzig’s labour market (consisting of the city of Leipzig and surrounding districts) displayed a broad sectoral structure, the other labour market districts were strongly oriented to the chemical sector, i.e. they were monostructured. After 1989 the planned economy system in the GDR as well as in the Eastern European states collapsed, resulting in the loss of the eastern markets. In the Leipzig-Halle-Bitterfeld region this also led to a substantial dismissal of workers. As an example, we refer to the increase in unemployment at one of the most important enterprises in this region, the Mitteldeutsche Braunkohlen-AG (MIBRAG) (*Table 26*).

The proportion of employed persons in the processing industry is currently 56 per 1000 inhabitants in Leipzig. By contrast, the corresponding figure for Hannover is 147, for Frankfurt/Main 155 and for Stuttgart 207 per 1000 inhabitants (Neumann and Usbeck, 1993). This comparison also illustrates the employment problems in the region.

Women, persons of a high working age as well as those with low or no longer needed qualifications are especially hard hit by unemployment. When workers are placed in new jobs, it often represents a loss of position; skilled workers, for example, frequently perform unskilled labour tasks (Kabisch, 1993).
The labour potential is (still) not regarded as a bottleneck factor for regional development (Zeuchner, 1992); the proportion of working-age persons in the population is declining, however. This may become problematic since mobile qualified workers, in particular, leave the region, usually towards the “old Bundesländer” (Neumann and Usbeck, 1993). A population decrease was already noted in previous years, however (*Table 27*).

Table 26: Development of unemployment in the “Leipzig-Halle-Bitterfeld” agglomeration – the MIBRAG example

	Date	Number of employees
	1.7.1990	56,584
	1.1.1992	27,496
	31.12.1992	17,439
	1.1.1994	7,349
Shutdown of open-cast mines from Dec. 1990 – March 1992:		11
Workers affected:		9,741
Shutdown of briquette factories from Aug. 1990 – June 1992: 21		
Workers affected:		6,647

Source: MIBRAG, 1992

Whereas the decline in population figures in the years prior to 1989 took place primarily as a result of migration of persons of a younger age to the Berlin region (which meant a disproportionate number of elderly people in the remaining population), a decline in births in addition to migration has been noted since 1991 due to the uncertain economic situation (Usbeck and Kabisch, 1993).

Table 27: Development of population in the “Leipzig-Halle-Bitterfeld” agglomeration

Year	Population	Period	Population decrease	
			Difference	per year
1970	2,696,048			
1980	2,573,593	1970 – 1980	-122,455	-12,456
1989	2,436,157	1980 – 1989	-137,436	-15,271
1992	2,242,583	1989 – 1992	-193,574	-64,525

Source: Schönfelder, 1993

The educational level formally corresponds to that in the “old Bundesländer”, but there are substantial deficits regarding knowledge of foreign languages and of commercial and administrative matters. On the basis of the existing universities and polytechnics, however, the educational structure offers good prerequisites for making up these deficits.

The tense economic situation and the high rate of unemployment lead to the “solutions” described in more detail in Section D 2.2.3, such as the rapid expansion of roads and establishment of companies on previously non-surface-sealed areas with the related damage to and loss of soils.

Effects on health

The population in the Leipzig-Halle-Bitterfeld region has constantly suffered from air pollution and the related negative health effects since its development into an industrial agglomeration (Herbarth, in preparation). The extreme level of pollution (SO_2, dusts and dust precipitation) has led to delayed bone growth and a negative influence on breathing function, blood count and the immune system among children. In addition, a higher frequency of bronchitis, croup and coughs was recorded, and restricted liver function was often observed among those examined. The influence of high concentrations of pollutants resulted in a predisposition to illnesses that remained within the scope of the physiological norm, but created chronic damage under long-term pollution conditions.

Halle is located in the region having the highest bronchitis morbidity in all of eastern Germany. Overall, in the government districts of Leipzig and Halle 88% and 76% of the population, respectively, were affected by SO_2 pollution and 77% and 53%, respectively, by increased levels of dust precipitation up to 1989. The mean annual figure for SO_2 content, which was around 0.3 mg per m^3 in the period from 1984 – 1987 (and whose 30-min. mean value even increased to 4.5 – 5 mg per m^3 for short periods), dropped to approx. 0.11 mg per m^3 in 1990 due to a decline in industrial production (UBA, 1992). In February 1992 the 24-h mean value for SO_2 was roughly at the limit (0.15 mg per m^3; Regierungspräsidium Leipzig, 1992). A changeover to other sources of energy reduced emissions while a rise in car traffic has increased emissions since 1990. Thus, in the case of nitrogen oxides, for example, the trend towards higher figures continues (Herbarth, 1991).

Further major sources of pollution of soils as well as of the groundwater consisted of the decentralised, usually disorderly landfills and intensive agriculture (liquid manure, agro-chemicals and nitrates) in the former GDR. Large-scale studies on the dangers to health stemming from food or contaminated drinking water have not been conducted yet, however. Direct contact with the existing soil contamination rarely occurs, but is possible at children’s playgrounds (Herbarth, in preparation).

The water supply for the population in the Leipzig-Halle-Bitterfeld region poses a special problem. The drinking water furnished by the central water supply enterprises contains high concentrations of sulphate, chloride, iron and manganese. Although there is no direct danger to health linked to this, the formation of trichloromethane and other organic chlorine compounds via non-optimised chlorine disinfection has reached alarming levels at nearly all waterworks. The drinking water from individual water supply facilities that receive groundwater from layers near the surface has nitrate levels which, in some cases, significantly exceed the limits (Plassmann, 1993).

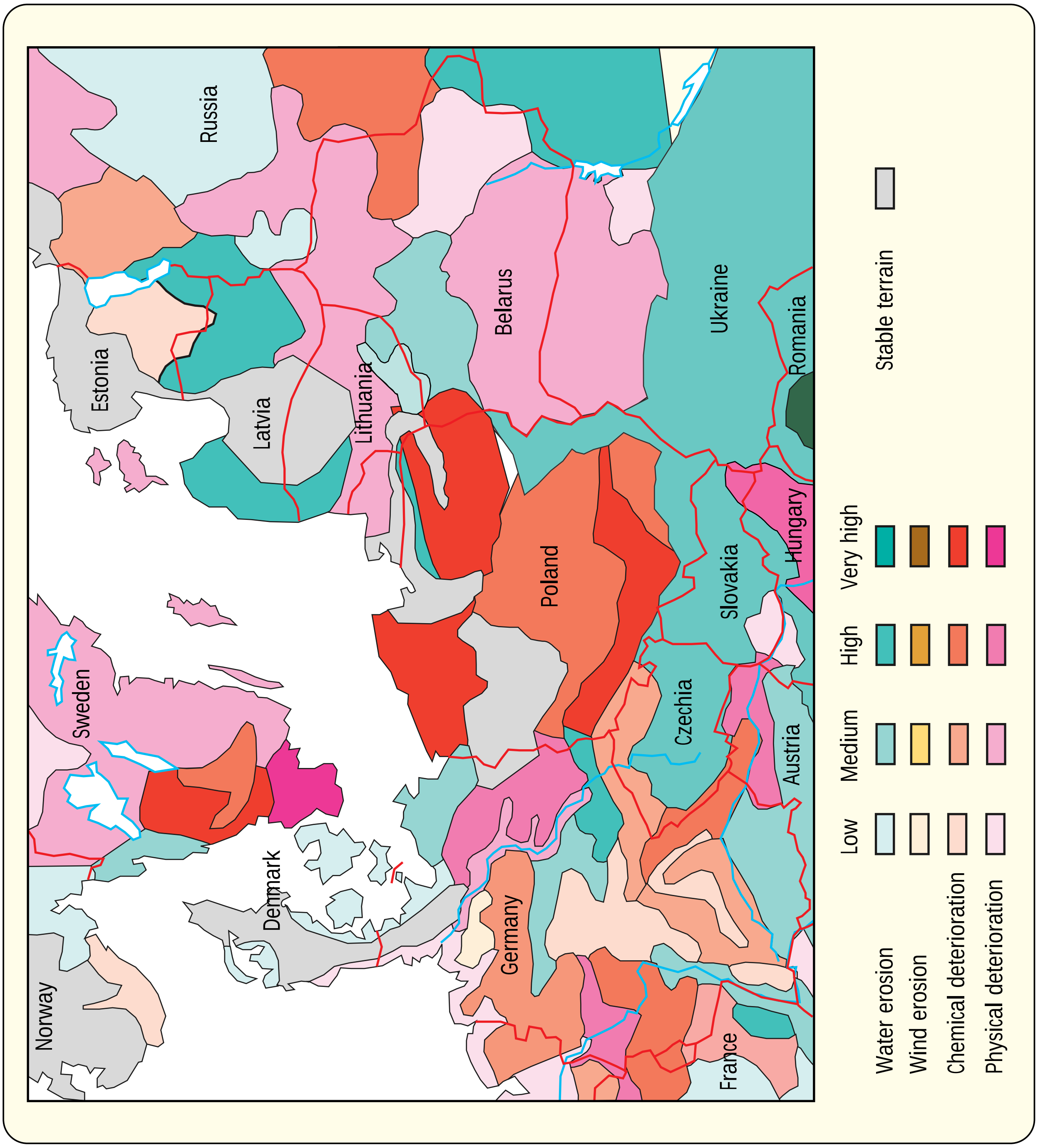


Figure 51: Soil degradation in Central and Eastern Europe

Source: ISRIC and UNEP, 1990

2.2.3 Soil pollution

The Leipzig-Halle-Bitterfeld region has one of the highest environmental pollution levels in Europe (*Fig. 51*). This pollution is attributable, in particular, to the use of sulphur-containing brown coal in the energy sector and to the concentration of the chemical industry in the region. Significant degradation of the landscape and soil takes place. Thanks to the shutdown of old facilities, however, a substantial decline in *airborne depositions* has been recorded since 1989. The SO_2 pollution through Chemie-AG Bitterfeld, for example, dropped to 45% while the dust and nitrogen oxide pollution fell to 30% and 35%, respectively, of the previous values. Similar tendencies can be noted for the big cities of Leipzig and Halle (Haase et al., 1993). Another interesting finding is that a shift in soil pH from “acid” to “alkaline” occurred in zones near emitters in Dübener Heide due to alkaline airborne dusts. Varying proportions of individual *heavy metals* in sedimentation dust exist in water-soluble form, thus making them available for plants; the figures for cadmium (approx. 80%) and zinc (approx. 60 – 75%) are particularly high. By contrast, only roughly 30 – 40% of the copper and lead can be easily or moderately rapidly mobilised.

The accumulation of harmful substances in plants, taking into account the influence of air and soil, can be illustrated using the example of rye-grass (*Table 28*).

Table 28: Metal concentrations in rye-grass from the “Leipzig-Halle-Bitterfeld” agglomeration

Element	Total content (mg kg^{-1} dry substance)	Pollution
Zinc	72.00	moderate to high
Copper	7.70	low to moderate
Lead	2.09	low
Cadmium	0.27	low

Source: Haase et al., 1993

Calcium, aluminium, SiO_2, carbon as well as a great number of organic compounds were detected in the sediment dusts. Although dust pollution has decreased, these particle-bound substances represent a potential danger; however, clear identification of the sources is not yet possible. A high deposition of organic pollutants is not observed everywhere in the agglomeration; the peak pollution values are strictly delimited in space and time (e.g. urban centres during the winter months).

The emission of *organic compounds* through home heating systems is still relatively high. According to measurements for the city of Leipzig during the 1992/93 heating period, 65,417 kg of benzene and substituted benzene, 25,493 kg of polycyclic aromatic compounds and 5,552 kg of hetero-compounds were emitted (Haase et al., 1993). Soils and dumped substrates in the immediate proximity of industrial facilities showed high amounts of heavy metals. An analysis of sedimentation dusts, however, demonstrated that they do not stem from brown coal filter ash but represent contaminations of industrial origin.

A study on agriculturally used soils did not find any large-scale heavy-metal pollution, though the values for agricultural areas near urban centres and industrial complexes were higher than those for other areas. Contamination at a level of the reference values of the “Dutch List” was generally not observed. *Groundwater pollution* with nitrogen compounds in agricultural landscapes, however, is obvious. Intensive, environmentally harmful land management by large enterprises must be held responsible for this.

Long-term overfertilisation on large fields and industrial livestock farming have led to nitrogen surpluses of more than 110 kg per ha, which remain in the soil and pose a great threat to the groundwater. On sand-loess locations the limit for groundwater of 50 mg per l is exceeded by two- to threefold while the limit is reached on loess, grey-brown podzolic soil. Despite the decline in livestock farming, the consequences of this pollution will remain perceptible in the years to come (Krönert, 1993). For this reason the region does not yet have its own water supply but is dependent on an outside supply system, although it possesses a relatively ample volume of groundwater. The rivers also continue to be polluted with high amounts of harmful substances.

Table 29: Number of enterprises, area of agriculturally useful land and average land area farmed per enterprise (1955 – 1992)

	Number of enterprises	Agriculturally useful land	Useful area utilised per agricultural enterprise
		1,000 ha	ha
	1955		
Saxony	155,404*	1,137.7	7.3
Saxony-Anhalt	184,388*	1,366.7	7.4
	1961		
Saxony	12,096	1,120.4	92.6
Saxony-Anhalt	13,213	1,348.2	102.0
	1989		
Saxony	1,733	978.6	564.7
Saxony-Anhalt	1,859	1,217.0	654.6
	1992		
Saxony	4,100	804.5	196.2
Saxony-Anhalt	2,781	1,037.1	372.9

Sources: Deutsche Demokratische Republik, 1956, 1962, 1990; Statistisches Bundesamt, 1993

* agricultural and forestry enterprises with a useful area of over 0.5 ha

The suitability, capacity and resilience of various types of soil in the region are very different regarding *multiple utilisation*. The capacity for decomposing xenobiotic substances (regulation function) as well as for farming (production function) is assessed as

– high for loess black soils,
– moderate to high for loess, grey-brown podzolic soil,
– moderate for grey-brown podzolic soil on sandy loess,
– moderate for meadowland soils and
– low for most sandy soils in Dübener Heide (Haase et al., 1993).

Only the soils in the porphyritic hill landscape near Halle and in the heath landscapes are regarded as suitable for recreation; their suitability can be assessed as “moderately high”. The sandy loess plains are threatened by wind erosion and the loess hills by water erosion.

Hazardous waste sites represent an especially severe problem in the Leipzig-Halle-Bitterfeld region. They can be described as “... water or soil contamination created in the past by human actions in connection with old deposits or old industrial locations from which hazards or degradation that is relevant according to public or private law emanates (may emanate)” (SRU, 1991; Müller and Süss, 1993a and b). The landfills in the Bitterfeld district are considered to be extremely hazardous for the environment. Dangers are also posed by the sedimentation basins in Buna, Leuna and from several holes left over from open-cast mining into which acidic resins and other wastes were dumped. Over the past 100 years approx. 560 km^2 of agriculturally useful land, forests and settlement areas in the region have been destroyed through *brown coal mining*. Restoration of the regional water resources has proven to be a difficult task in this connection. Large-scale lowering of the groundwater level was carried out in conjunction with open-cast mining advance. Groundwater streams were removed or mixed, leading to a disruption of the groundwater network. Additional impairment was caused by elimination of stationary waters and relocation of flowing waters.

Mining areas offer certain possibilities for recreation in the region as well as for biotope and species protection; however, flooding of holes left over from open-cast mining or irrigation of meadowland forests threatened by drought, for example, with untreated Pleiße or Elster water is not possible because of the greatly polluted river sediments (heavy metals), as shown by the following quantities of heavy metals in the sediments. The sum of heavy metal concentrations of lead, cadmium, chromium, copper, manganese, zinc, nickel and arsenic in the sediment of the Elster basin is roughly 4500 – 6000 mg per kg of dry substance. In individual cases up to 6000 mg per kg of zinc, 300 mg per kg of nickel and 10 – 15 mg per kg of cadmium have been detected in sediment (Haase et al., 1993).

It is foreseeable that future *changes in land use* will have far-reaching consequences for the landscape balance. Soils will be subject to surface sealing; in the Leipzig administrative district (which belongs to the agglomeration, except for three districts) approx. 108 km^2 (which corresponds to 2.6% of the total area) were approved for building purposes between 1990 and 1993. Of that area, approx. 50 km^2 are for commercial purposes, 27 km^2 for housing and approx. 23 km^2 for miscellaneous uses. Almost all municipalities of the region have an industrial zone that was established in the countryside and has led, and continues to lead, to considerable soil degradation. The autonomy of the towns makes coordination of a long-term regional development concept difficult.

Though the planned new traffic routes are important for the economic development of the region, they fragment the landscape. This has negative effects on biodiversity since populations or biocoenoses require a certain area size to survive. If the area is reduced in size, as in the case of fragmentation via road construction, the continued existence of the population is questionable. Taboo zones should be established in this context so as to prevent extinction of rare species (SRU, 1994).

2.2.4 Possible solutions

Because of the above described economic structure and the resulting problems, the region was the focus of a number of studies (TÜV Rheinland, 1991; Zeuchner, 1992; Haase et al., 1993; Neumann and Usbeck, 1993), from which proposals for further development were derived. In particular, the following must be kept in mind from an *economic point of view*:

– establishment of legal certainty in questions of ownership, especially regarding property
– sector-specific training for employees
– improvement of material infrastructure (transport, supply and disposal).

The economic support provided by the federal, state and local governments as well as by the EU should be set up such that regional differences in income level can be eliminated quickly, while the economy should be stabilised by abandoning monostructures. This means great diversity and thus a reduction of economic and structural proneness to crises. Zeuchner (1992) rightfully advocates a shift in decision-making to the regional level and the working up of development concepts. *Structural change* that provides relief for the environment is to be promoted; the funds to achieve this should not become subsidies for maintaining obsolete economic structures, but be employed for promising sectors. Of course, efforts must also be made to improve environmental quality, though the responsibility for this does not lie in the hands of the region, but in the hands of the state and federal governments. The soil protection concept (Bundesregierung, 1985) and the measures for soil protection (Bundesregierung, 1987) are generally intended to point the way with regard to soil as an environmental asset and its functions and should be implemented in the region as soon as possible.

In the TÜV report (1991) it is assumed that adjustment and modernisation of the economy in the “new Bundesländer” will be achieved by the year 2000. The proportion of jobs in the processing sector will decline from over 40% (1989) to 28% while the percentages for the service sector, trade and the building industry will increase. With parallel advancement of ecological rehabilitation the overall economic situation can be stabilised in spite of the expected loss of jobs in large industries. The TÜV expertise estimates that employment opportunities could be offered for over 800,000 people in the region.

Neumann and Usbeck (1993) are of the opinion that enterprise-oriented services, such as economic services, technical services, advertising and data processing, will play a key role in the economic structural transformation. At the same time, however, they plead for creation of favourable basic conditions to enable stable development of the processing industry. A special advantage for Leipzig is the fact that the city possesses a broad-ranging sectoral structure.

Privatisation of East German chemical enterprises will not be possible by the end of 1994; currently consideration is being given to transforming the Central German chemical sector with locations in Leuna, Buna, Bitterfeld and Böhlen into a state-owned company which will later be privatised as was done with VEBA and VIAG. Lucrative production divisions, such as the Leuna refinery, have already been privatised.

With regard to rapid economic development, an assessment should be made in the agglomeration concerning the contribution that so-called “hard” location-related factors, such as availability of space, traffic connections, proximity to suppliers, markets, qualified employees, training and continuing training institutions and research institutes in addition to “soft” location-oriented factors, such as the behaviour of public administration, the economic climate, the political and social climate, employee mentality, the housing and recreational value, available educational and cultural activities, personal preferences of the entrepreneurs and the image of the area, make to economic development and protection of the environment. Clear distinctions between these types of factors cannot be made.

It would also be important for the region to search for possible ways of effecting *interstate administration and planning* (Schönfelder, 1993). One approach could be the development of a special purpose association (e.g. transport network) and its step-by-step expansion into a municipal or regional planning network.

Rehabilitation of the soil and *elimination of hazardous waste sites* are essential for ensuring economic and, at the same time, ecologically sound development of the region. Müller and Süss (1993a and b) refer to the difficulty of obtaining scientifically precise data to determine which pollutant concentrations in the soil are linked to what concrete risks for humanity and the environment. The question of whether and to what extent soil contamination poses a threat primarily depends on the existing or planned utilisation of the property in question. Higher quality demands are to be placed on areas that, in the broadest sense, serve plant production than on the base surface of production and storage buildings.

Laws on wastes, contaminated land and soils exist in all “new Bundesländer” now. They regulate the liability and rehabilitation responsibility for ecological damage as well as the handling of hazardous waste sites and soil rehabilitation. The Waste Management and Soil Protection Act of the Free State of Saxony, for example, treats the problems of hazardous waste sites from the point of view of soil protection. Soil pollution is defined there as follows: They are “... changes in the state of the soil, particularly through material effects, which are a cause of concern that the functions of the soil as a natural body or as the basis of existence for humanity, animals and plants will be significantly or permanently impaired”. In addition to studies, rehabilitation and safeguarding steps, “measures for prevention, reduction or elimination of impairment of the well-being of the general public” can be demanded according to the law. Thus, the basic legal conditions have been created to make former industrial locations reusable for the establishment of innovative branches of industry, a step which might stop the surface sealing currently carried out on undeveloped land to a massive degree.

Elimination of hazardous waste sites is cost-intensive, however, and cannot be charged to the new owners of degraded land alone. These owners can apply for exemption in the “new Bundesländer” if the land continues to be used for commercial purposes. With a share of approx. 10% assumed by the owners themselves, it is agreed that the remaining expenses will be shared by the federal and state governments at a ratio of 60 : 40 for medium-sized enterprises and 75 : 25 for large industrial projects. Basic funding of US$ 625 million is provided for the “new Bundesländer” during the first ten years. In 1993 the Federal Government decided to rehabilitate particularly contaminated industrial areas in the “new Bundesländer” in order to be able to make industrial and commercial use of the industrial locations again, while taking ecological aspects into consideration. One of these large projects involves the Bitterfeld-Wolfen industrial area. A rehabilitation concept that is currently being drawn up has been agreed upon between the Treuhandanstalt and the state of Saxony-Anhalt. This example shows, however, that rehabilitation of regions with such pronounced industrial characteristics as the “Leipzig-Halle-Bitterfeld” agglomeration require considerable state support.

The TÜV report (1991) demanded improvement of the *drinking water quality*, especially reduction of the nitrate content, in order to protect and/or rehabilitate the environment. This demand is essentially aimed at redirecting agriculture towards *environmentally sound land management*. Agricultural overproduction in the European Union will have consequences for the previously intensively utilised agricultural areas of the region. The required fallow period in crop rotation for reduction of grain production, however, should be replaced by use of a lower amount of fertiliser and release of agricultural land for cultivation purposes in order to improve the regulation potential of the landscape and ensure long-term, sustainable multi-purpose use of the landscape (Haase et al., 1993).

An increase in the area percentage of undergrowth for protection against erosion is also important. This would not only protect the soil but also surface waters against contamination. Additional habitats could come into being in loess agricultural landscapes and the recreational function would be enhanced.

In sandy heath landscapes there is a tendency to abandon the use of agricultural land; this has an unfavourable effect on the recreational function of the landscape and on formation of new groundwater. However, more detailed scientific studies are required here in order to determine the extensification needs and willingness of the population to support such action. Development of methods for systematic monitoring of changes in land use is just as important a prerequisite for improvement of the regulation potential of the landscape. A restructuring process should be initiated that maintains agricultural areas as an important part of the cultivated landscape so that they fulfil *multiple functions*.

Air pollution control plans have been drawn up to improve *air quality* (e.g. Air Pollution Control Plan; Regierungspräsidium Leipzig, 1992). Such plans are a requirement for the designation of nature reserves, enacting and implementing smog regulations. In this way a ban on motor vehicle traffic as well as production restrictions for facilities requiring approval would be possible under low-exchange weather conditions.

The “Leipzig-Halle-Bitterfeld” agglomeration is currently involved in a rapid economic, ecological and social upheaval. Therefore, it is not typical for regions that have long had market economies. On the basis of previously similar economic and political structures in the states of Central and Eastern Europe, however, its development may become exemplary for polluted economic zones in these countries.

3 Focus section: Research recommendations

3.1 Soil research and Global Change

Germany has a certain tradition of research into the properties, location and functions of soils, and this tradition is anchored in many institutions. The main focus of such research was centred for a long time on how to secure and increase yields in agriculture and forestry, and producing inventories of soils as a resource. Research was carried out either as basic research, mainly at universities, or as applied research in state and federal departments and institutes. Environmental problems in a true sense did not become a subject for soil research until the last two decades. Many individual projects were supported by the BMFT, and by BMU or BML programmes as part of research into soil conservation, forest decline and ecotoxicology. Based on this experience, the soil research of the BMFT was included in recent years in various integrated research approaches, such as ecosystem research, urban ecology research, or research on the protection of biotopes and the protection of species. Important areas of soil research were therefore dealt with at national level, although with major deficits, as shown in the 1993 Annual Report.

This contrasts to some extent with the international integration of German soil research. Scientists have repeatedly made important contributions to the investigation of soils outside Europe, but these activities were made as part of individual interest rather than as comprehensive strategy aimed at solving global soil problems. Therefore, participation of German soil scientists in the design and implementation of international research programmes has been a rare occurrence to date, and this is also the case with respect to publications in internationally relevant journals.

Recent years have seen a certain reorientation regarding the promotion of soil-related research. For example, topics of relevance to soils are being dealt with under the tropical ecology programme of the BMZ. The SHIFT project (*Studies on Human Impact on Forests and Floodplains in the Tropics*) and the BMFT focus on “Agriculture and Trace Gases” are both concerned with problems affecting tropical soils. The Council welcomes this development, although these activities can only be seen as a starting point for much greater participation in action-oriented research aimed at solving global soil problems.

Inadequate participation of German researchers in bilateral and international programmes is all the more regrettable in that the scientific potential is available and because global soil conservation, as shown in this Report, may not only be a contribution to ensuring sufficient food supplies for the rapidly growing population of the world and for preserving biodiversity, but also for preventing social conflicts. In order to eliminate this shortcoming, research needs to be conducted in the following fields.

3.2 Global soil inventory

Knowledge about the spatial location of soils and their properties is still inadequate. In areas where the issue is how to implement this knowledge in order to develop sustainable, environmentally sound and locally appropriate land-use strategies, spatial resolution and key data are deficient. Obtaining the requisite information often demands time-consuming surveys. There is therefore a need for the application of remote sensing methods to obtain data on soil, vegetation and the changes that occur in them. Existing know-how in Germany both in the remote sensing field and in soil and ecosystem research should be put to greater use in order to develop user-friendly and reliable systems for monitoring and analysing that can be linked to land-use models. Such systems could then be used in regions for which little data is available.

3.3 Habitat function

The habitat function of soils has mainly been investigated in relation to plants and their supply of water, oxygen and nutrients. In contrast, the importance of soils as a habitat for other organisms and the processes they regulate has been inadequately researched. The latter is of great significance when reactions of soil organisms to changes in land use and climate are to be estimated, or when organisms are to be deployed for regenerating soils. Research on the ecology of microorganisms and soil fauna urgently needs more support.

There is also a need for intensified basic research into the role of soil organisms in the synchronisation of element cycles and hence for the stability of terrestrial ecosystems. This applies in particular to the characterisation of biological diversity in soils. If methods for determining these parameters and processes are not improved, many issues in ecotoxicological research will remain open.

The Council therefore recommends that an indicator system be developed which would enable a quantitative description of the biotic states in soils. Without such a system, interventions by human beings cannot be evaluated. Previous approaches are unsuitable for application at the system level.

Almost all the Earth’s soils possess a highly-developed recycling system for organic substances. The metabolic outputs of the microorganisms involved have been the subject of little or no research to date. Based on the knowledge to be acquired in this area, regeneration strategies should be developed which use the biotic components of soils and their stabilisation potential. However, this requires deeper insight into the interactions between vegetation cover, water retention and soil mechanics.

3.4 Regulation function

A number of separate investigations have been conducted into the regulation function of soils which describe the internal fluxes of energy and elements as well as their exchange across soil boundaries, but the findings obtained on specific aspects cannot be translated into practical recommendations without further refinement. One important task in coming years is therefore to extrapolate measurements for small units to larger ones. This applies both to biotic, chemical and physical soil states, as well as for soil processes and the transformation and transport of substances associated with these. To answer these questions, an integrated programme should be set up. The German Research Council (Wissenschaftsrat) programme focusing on water could form the nucleus of such an endeavour.

Another central focus should be the quantification of the biogeochemical cycles of carbon, nitrogen, sulphur and phosphorus in soils. These elements and their compounds play a crucial role with respect to atmospheric chemistry and the greenhouse effect, as well as the contamination of bodies of water; they are also important nutrients for plants, however. Their use in fertilisers deployed to secure an adequate food supply for the Earth’s population is always bound up with the risk of environmental damage. Understanding the biotic regulation of transformation processes in the basis for sustainable, environmentally sound and locally appropriate soil management, and for estimating the risk that emanates from anticipated changes in land use or climate (trace gases, water contamination, loss of diversity).

Acidic loads and other organic or inorganic pollutants represent stresses on soils and their organisms. In order to prevent lasting or irreversible damage, it is therefore necessary to systematically determine the stress-bearing capacity of soils in specific areas and to integrate this knowledge in a comprehensive evaluation concept.

The Council emphasises the fundamental importance of soil-climate interactions within the global system. Research on the impacts of possible climate changes on emissions from soils, and on the feedback effects they have on the atmosphere is essential.

3.5 Utilisation function

Securing an adequate food supply for the Earth's rapidly growing population demands greater efforts to improve agricultural and forestry production and to check any further degradation of soils. It is essential that sustainable, environmentally sound and locally appropriate land use strategies be developed for agriculture and forestry which take the abiotic and biotic potential of soils into account, and which can maintain or protect these by implementing suitable measures. Joint execution of projects by scientists from Germany and developing countries should therefore be promoted. Such "in situ" research performs an important multiplier function. It is recommended that the BMZ provide substantially higher funding levels for supporting research into soils and soil degradation in the developing countries. These activities should be coordinated with the BMFT and the BML. To achieve more effective integration of the existing research potential at the universities, the DFG should also be involved in the design of relevant programmes.

One primary objective should be the development of decentralised systems for water harvesting, water conservation and water utilisation. Effective use of water for plant production is a major challenge for technicians and farmers. The use of renewable energy sources in connection with water harvesting should be supported, as should efficient and well-managed irrigation techniques for increasing food production.

A system for the economic assessment of soils should be developed that includes assets not normally included in balance sheets, such as biodiversity, clean groundwater and surface water, and soil fertility.

The social prerequisites for and impacts of the global introduction of sustainable, environmentally sound and locally appropriate land use should be investigated in a systematic way. Ignorance about local soil conditions and biological diversity continues to be the cause of much degradation or use-related damage to the environment. The lack of concepts for evaluating use over and beyond purely economic aspects has also contributed to this state of affairs. The extended concept of critical loads presented in this Report (and currently being developed for substances by the "Soil Conservation" working party of the major research institutions) is one tool for achieving progress in this field.

The Council recommends that the development of a comprehensive soil evaluation concept be continued and intensified. It is important in this context not only to define the basis for scientific analysis but also to develop an information system for applying the knowledge that is available.

Building on this, locally specific carrying capacity concepts should be developed oriented towards sustainability and environmental protection. Such carrying capacity concepts represent one basis for the economic development of regions and countries. They enable possible conflicts to be identified at an early stage and preventive action to be taken.

The rapid increase in urbanisation throughout the world, and the growth of international trade in agricultural products are accelerating the further decoupling of production and consumption. This leads, firstly, to the depletion of nutrients and other substances in soils, and, secondly, to the massive accumulation of substances. For ecological and economic reasons this problem, which arises at both national and global level, must be subjected to a systematic analysis.

3.6 Cultural function

Human societies are dependent on soils and their functions, and highly developed industrial societies are no exception. This fact is being increasingly forgotten, however. The Council views this lack of "soil awareness" as one of the principal causes of soil degradation. To produce greater acceptance in future for soil-conserving behaviour in the economy, at work and during leisure time, the subject of "soils" should be put on the social science research agenda and given more public attention. This applies in particular to research into specific cultures and the comparative analysis of cultures, and to the historical analysis of people-soil interactions. Special importance should be attached to an analysis of the perception and evaluation of soils and changes in soils in the respective social, cultural, historical and economic context. Existing studies on these topics should be systematically linked.

In addition, “soils” should be investigated in interdisciplinary projects, with greater consideration being given to action-oriented concepts from the social and behavioural sciences. A model and a starting point for activities by German researchers could be the project jointly conducted by the IGBP and HDP entitled “*Land use and land cover change*”.

4 Focus section: Recommended action

4.1 Introductory remarks

The Council has focused on the subject of soils and soil degradation considering this as one of the five main global environmental trends, and because this particular trend has been least analysed and tackled by environmental policy. Soils are essential for the survival of humanity on this planet. They are impaired by the way in which people treat them, directly and indirectly, intentionally and unintentionally.

The Council understands soil degradation as the impairment of four key functions of soils:

– the *habitat function*, which is intimately related to biodiversity,
– the *regulation function*, especially the role played by soils in the global carbon and nitrogen cycles,
– the *utilisation function*, in particular for food production,
– the *cultural function*, the specific relationship between people and nature.

The importance of the cultural function is seen above all in the fact that, of all the measures aimed at curing the various soil degradation syndromes, promoting "soil awareness" is the only single measure which plays a significant role for all twelve syndromes at the same time (*Table 22*).

The topic dealt with in the first of the recommendations for action that follow, namely the global food problem, must be seen in terms of the interplay between these four functions. In many areas, soils are being lost, damaged or sealed at a faster rate than new soils are being created. In total, the per capita area of land available for food production is declining. The central issue is therefore: How can the rapidly growing population be fed on a lasting basis?

Besides this major question, three others must also be answered: How can the habitat for wild fauna and flora, and thus biodiversity, be adequately protected? How can the role of natural ecosystems and their soils in the global climate system be preserved? How can soil-conserving forms of human behaviour be developed and promoted as quick as possible? In sum, how can the anthropogenic utilisation of soils, plants and animals be shaped as close as possible to nature so that it is locally appropriate, sustainable and environmentally sound?

A number of measures have been specified which were thought to provide quick solutions to the problem. These included, for example, the abandonment of marginal agricultural land, reducing meat consumption in the industrial countries, minimising losses incurred during storage and through transport to consumers, dispensing with ploughs, using less pesticides, changing over to mixed cropping and agroforestry. It is also commonly held that freedom of action and property rights should be defined and assigned. All these measures *cannot* solve the world food problem, either because they require a major change of values *or* cannot be implemented due to excessive population density. *Increased yields per unit area* are therefore essential if humanity is to have enough food in the long term.

The discussion of the twelve syndromes of soil degradation in Section D 1.3.3 showed that four of these syndromes are of cardinal importance:

– Soil degradation through structural changes in traditional farming practices (the so-called "Huang He Syndrome").
– Soil degradation through industrialised agriculture (the so-called "Dust Bowl Syndrome").
– Overexploitation of marginal soils (the so-called "Sahel Syndrome").
– Deforestation and subsequent short-term agricultural exploitation (the so-called "Sarawak Syndrome").

Because the properties and the stress-bearing capacities of soils vary even within relatively small areas, and the cultural and societal forms which determine how soils are used and treated differ from one region to the next, there are no generally applicable soil conservation measures. In the following, therefore, we present *global*, *highly generalised* recommendations for action, while *special* recommendations regarding the individual syndromes can be found in the respective sections of this Report.

Some of these syndromes also occur in Germany, e.g. the “Acid Rain Syndrome”, the “Bitterfeld Syndrome” and the “Alps Syndrome”. The Council assumes that the soil problems thus referred to will be given consideration by environmental policy-makers in Germany (see the Bundesregierung 1994 Environment Report) and by the relevant advisory institutions such as the Council of Experts on Environmental Issues.

4.2 Global food security

4.2.1 Guiding principle

The most important question concerning soils and soil degradation is whether and how the constantly rising global population can be fed in the long term, given the limited area that can be used for agriculture, and how this can be achieved where supply bottlenecks are especially critical. Based on this question, the Council proposes the following *guiding principle* for land use:

Agricultural production must be adjusted to suit the stress-bearing capacity of soils; it should be carried out primarily in areas where this can be done sustainably, with little damage to the environment, cost-effectively and with high yields.

This guiding principle seeks a path between the notion of complete autarchy and that of unrestricted free trade in agricultural products. Because neither of these extremes is feasible, or even desirable if sustainability is the objective, this guiding principle outlined above offers a realistic “Middle Way”.

Complete autarchy is rendered unfeasible by the very fact that, in the future, many developing countries will have too low a level of food production to be able to feed their own populations, i.e. they will be dependent on net imports of food. In order to finance these, purchasing power must be created by means other than agricultural production, i.e. through adapted forms of industrialisation and service industries. These countries have limited opportunities for creating the requisite capital; some will have to be provided externally. Financial assistance will therefore have to be given to many such countries at favourable conditions. In the light of this requirement, the Council again repeats the recommendation made in its 1993 Annual Report, that German development aid be raised to 1% of GNP.

4.2.2 Recommendations for action

The principal objective with respect to *fertile soils* is the long-term assurance of their productivity.

– This relates first of all to favourable soils, as are found in the USA or Germany. The limits to their exploitation are provided by the “Dust Bowl Syndrome”, yet in many cases further and sustainable intensification of use is still feasible. Compulsory fallowing only makes sense, if at all, if there is a risk of degradation, but not if global food production aspects are taken into account. Agrarian policy-makers in Germany and Europe face a major challenge in this respect – they have to strike the right balance between the demands of global food supply in the future, the reduction of soil degradation, the opening of agrarian markets for developing countries and assuring an adequate income for domestic farmers. Support should be given to German and European contributions for increasing productivity in the developing countries, e.g. through the use of plants and animals better adapted to local conditions.
– There are more favourable soils in the tropics than the common notion of “tropical soils low in nutrients” would suggest. Production on these soils should be increased, particularly since these are often regions with very high rates of population growth. The limits for such increases are encountered when the habitat function starts to be adversely affected.

On *less fertile soils*, production must be increased in a sustainable manner. Where this is not possible because serious degradation results, usage has to be reduced.

– The contribution that these soils make towards ensuring the global food supply is marginal. However, they are very important as a regional food supply, in the Sahel zone for example, particularly since many of these regions have a high rate of population growth.

– Sustainable, environmentally sound and locally appropriate land use must be enabled on a worldwide basis through the provision of advice and the transfer of technologies. Where this does not suffice to ensure an adequate food supply, advice must extend to the creation of jobs outside the agricultural sector. This represents a special challenge for those countries and institutions providing such advice; coordination of agricultural and non-agricultural projects must be improved, and institutions providing support must coordinate their efforts to a greater extent than has been the case so far. These objectives should also be integrated into the development aid provided by Germany.

4.3 Integrating the habitat function into food security

4.3.1 The other problems

The guideline defined above is formulated on the basis of sustainability and environmental conservation. Violations of the sustainability principle reduce the basis for food supply in the long term, as well as the supply of renewable raw materials. Some of the environmental stresses which result from such violations are of a more *local* or *national* type and must therefore be combated by the countries affected. This also applies to environmental stresses caused by the exploitation of soils, such as the contamination of groundwater, silting and eutrophication of water bodies or filling of dams with sediment. Other environmental stresses are *global* in nature. The damage caused is liable to affect all countries in the world and a large proportion of humanity. Examples for such global stresses include, in addition to the long-range transport of pollutants, the destruction of the habitat function of soils for wild fauna and flora, i.e. the reduction of biodiversity. Deforestation, dessication of wetlands etc. involve losses for the particular country affected, but are also globally relevant.

4.3.2 Recommendations for action

Locally appropriate optimisation of natural soil productivity should in the long term reduce the pressure to exploit soils and/or to degrade them further through overexploitation. A substantial contribution to the preservation of the habitat function can be made in many areas. However, protecting the habitat function for wild fauna and flora must be achieved in a different way than securing adequate provision of food, especially in view of the different interests involved. Whereas the interests of human beings are at stake in the case of food, so that individual self-help can be relied upon, protecting the habitat function for flora and fauna must be achieved collectively, i.e. through political insight and political decisions. However, consideration must be given to the fact that not every habitat is equally worthy of protection, and that international efforts must concentrate, if only for financial reasons, on critical sectors of these habitats. Securing the habitat function of certain soils can ultimately be achieved only through legally binding regulations. As land-use planning only operates at the national level, if at all, economic instruments must be created at the international level (i.e., levies, permits, funds) as an incentive for alternative uses of soils.

The Council refers in this connection to the proposal made in its 1993 Report, namely that an international fund be created for the preservation of the tropical rainforests, in order to finance alternative uses of soils and the abandonment of certain previous uses. Such a fund could ensure the preservation of the habitat function in one crucial area – the tropical rainforests.

Similar solutions must also be striven for with respect to other problems affecting soils and for which compensatory instruments should be created. The Federal Government should develop a strategy for these issues, which will very probably be brought up within international discussions on a possible United Nations Framework Convention on Soils and Soil Degradation (*“Soil Convention”*).

4.4 Population pressure and soil degradation

In its 1993 Report, the Council identified population growth as a major trend of Global Change. This must again be stressed, with particular reference to the problems of soil degradation. Population pressure and the subsequent pressure on the utilisation function of soils also threaten their habitat, regulation and cultural functions.

Even if, at the present moment, the Federal Government does not lay particular emphasis in the international arena on the problem of population growth, the Council has to point out the seriousness of the problem. The foreseeable food supply problems of the future result from a combination of soil degradation and high rates of population growth in many regions of the world where the agricultural sector will not be able to feed the growing population over the coming decades, or only to a limited extent (see *Figs. 27* and *28*).
Given the fact that food production will not be sufficient for the growing world population, countries with low or stagnating population growth rates are called upon to participate in solving the problems facing soils – for the following reasons:

- Problems related to soil degradation will increase in severity and will pose a challenge for environmental policies at the international level, i.e. will require a growing commitment on the part of Germany as well.
- If non-agricultural sources of income are not generated as a means of paying for food imports, local and regional malnutrition and famines will be the result, which in turn
  - will require higher financial transfers to these countries, or
  - will lead to migration of "environmental refugees", who may then become a national political problem for the possible target countries, including Germany.

Preventing soil degradation is therefore not simply a means for sustainably assuring an adequate supply of food for an ever-increasing global population, but can also help to prevent future international crises. The conceptual and financial support of active family planning policies can prove to be a cost-effective measure for countries threatened by undernourishment and soil degradation, but also for the target countries of migration.

4.5 Towards international regulations

4.5.1 Placing emphasis right

From the global perspective, not all forms of soil degradation are equally serious. The Council holds four of the twelve syndromes to be particularly crucial: (1) soil degradation caused by structural change of traditional agriculture (the "Huang He Syndrome"), (2) soil degradation through industrialisation of agriculture (the "Dust Bowl Syndrome"), (3) overexploitation of marginal soils (the "Sahel Syndrome") and (4) deforestation and subsequent short-term agricultural utilisation (the "Sarawak Syndrome"). Other syndromes considered less serious from the global perspective include, for example, exploitation by tourism (the "Alps Syndrome") and non-agricultural contamination (the "Bitterfeld Syndrome"). The latter can have catastrophic effects on particular regions, as the Chernobyl disaster has shown; at the global level, however, this syndrome affects only a small proportion of the total usable land area, and has less relevance for the central problem – ensuring an adequate future basis for feeding the world's population. For this reason, those syndromes of greater global importance should be given prime consideration when formulating the objectives and applying the various instruments of the relevant international regulations on soils (the *"Soil Convention"*).

4.5.2 Taking the variety of soil problems into account

Given the great variety of soil problems, the Council recommends that the scientific and political spheres in Germany deal more intensively with the urgent global issues involved (for details, see the research recommendations in Section D 4.4).

Development cooperation efforts should focus to a greater extent than before on sustainable, environmentally sound and locally appropriate land use. An extended and integrated concept of "carrying capacity" should be developed for soils which also embraces the impairment of the habitat, regulation and cultural functions of soils. Based on such a concept, processes and rules for sustainable land management should be developed for those countries worst affected by soil degradation. This could take a form similar to the proposed rules for land management in Germany, i.e. a kind of “Technical Guide for Agriculture” (see SRU, 1985), combined with the EU directive on “Ecological agriculture”.

4.5.3 Creating international regulations

Given the high level of international coordination required to tackle the variety of soil problems, and because the syndromes and corresponding therapies are different and difficult, soil conservation measures at national level have often had to wait until other environmental media have been dealt with, while at international level nothing has occurred beyond mere declarations. The only international convention on soils to have been formulated so far deals with only one specific type of soil problem, desertification (the “Desertification Convention”), while only one type of land use, the forest, is the subject of an international declaration – the “Rio Declaration”. In the light of the above, what aspects would have to be governed by future international regulations?

1. Any declaration or convention should commence with the statement that soil is recognised as an environmental asset similar to water or air, and therefore in need of institutional regulation. The four soil functions should then provide the basic framework, and impairments to these would have to be combated with specific aims requiring formulation. Most importantly, food production must not be threatened, and sustainable, environmentally sound and locally appropriate land use must remain a feasible option.
2. The four soil functions, especially the utilisation and habitat functions, should be defined internationally as worthy of protection. Criteria would have to be laid down which permit the individual country to determine which soils are particularly affected by the regulation. Definitions of these criteria could be made in the agreement itself, or be assigned as a task for an international panel of experts. In order to speed up this international work, the German Federal Government should commence respective efforts within the EU.
3. With the aid of these criteria, comparative data on soil degradation and the stress-bearing capacity of soils should be gathered worldwide and applied to sustainable, environmentally sound and locally appropriate land use. This data could provide the basis for a globally coordinated soil survey. In order to apply available knowledge more intensively, data on economic and sociocultural conditions which have a bearing on soils should also be acquired.
4. If international financial compensation mechanisms are to be agreed upon in addition to the above measures, e.g. by including soil problems in the GEF financing system, then a “Soil Declaration” will not suffice – a global “Soil Convention” would be necessary instead.
5. Special consideration should be given to the question whether new, additional instruments need to be developed. The Council has discussed in this context the idea of risk liability, the concept of threshold values and the idea of an international market for soil function rights.
6. Finally, clarity must be achieved on whether or which new institutions are needed to implement an international agreement on soils. If new institutions are to be created, the habitat function could be transferred to the UNEP, and the utilisation function to the FAO. In any case, the institutional anchoring of a “Soil Declaration” or “Soil Convention” should be at a level high enough to ensure it is implemented.

In the view of the Council, the German Federal Government can make an immediate contribution to the establishment of sustainable, environmentally sound and locally appropriate land use in the developing and newly industrialised countries by taking action within the GATT talks and the new World Trade Organisation (WTO) against efforts to exploit environmental aspects in order to legitimate a new wave of protectionism on the part of the wealthy nations. This applies not only for agricultural, but also for industrial products which countries with little food production of their own have to export in order to pay for their food imports.

The Council considers the creation of new institutional arrangements for coping with global soil problems to be a matter of great urgency. The German Federal Government should make a definitive statement as to whether a differentiated “Soil Declaration” is sufficient or whether a global “Soil Convention” should be striven for instead. The “Desertification Convention” will deal with some aspects of the problems involved, and a “Forest Convention”, as called for by the Council in its 1993 Report, could be a means for tackling another critical syndrome. This Annual Report provides the relevant arguments for a global “Soil Declaration” or “Soil Convention”.

Climate change is now the subject of relatively intensive political efforts, despite the fact that its effects can only be seen in the long term. The impact of soil degradation, on the other hand, is already visible today and will worsen in the near future. *The German Federal Government should therefore strive to have a similar degree of international attention being paid to global soil conservation as has already been achieved in the field of climate protection.*

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F Acronyms

BMFT	Bundesministerium für Forschung und Technologie [Federal Ministry for Research and Technology]
BML	Bundesministerium für Ernährung, Landwirtschaft und Forsten [Federal Ministry for Food, Agriculture and Forestry]
BMU	Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit [Federal Ministry for Environment, Nature Conservation and Reactor Safety]
BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit und Entwicklung [Federal Ministry for Economic Cooperation and Development]
CITES	Convention on the International Trade in Endangered Species of Wild Fauna and Flora
DFG	Deutsche Forschungsgemeinschaft [German Research Council]
ECE	Economic Commission for Europe (UN)
ECOSOC	Economic and Social Council (UN)
EU	European Union
FAO	Food and Agriculture Organisation (UN)
GATT	General Agreement on Tariffs and Trade
GEF	Global Environmental Facility
GIS	Geographic Information System
GNP	Gross National Product
HDP	Human Dimensions Programme for Global Environmental Change
IGBP	International Geosphere Biosphere Programme
IIASA	International Institute for Applied Systems Analysis
INCD	International Negotiating Committee for the Elaboration of an International Convention to Combat Desertification
LLDCs	Least less developed countries
MIBRAG	Mitteldeutsche Braunkohlen-AG [Central German Brown Coal Mining Company]
NAFTA	North American Free Trade Agreement
NGO	Non-Governmental Organization
NPP	Net Primary Production
OECD	Organization for Economic Cooperation and Development
SHIFT	Studies on Human Impact on Forests and Floodplains in the Tropics
SRU	Rat von Sachverständigen für Umweltfragen [Council of Experts on Environmental Issues]
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCOD	United Nations Conference on Desertification
UNCSD	United Nations Commission on Sustainable Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFPA	United Nations Trust Fund for Population Activities
UNPD	United Nations Population Division
WBGU	Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen [German Advisory Council on Global Change]
WHO	World Health Organization
WMO	World Meteorological Organization
WTO	World Trade Organisation

G Glossary

acid rain
Excessive acidity of rain and mist, above all through sulphuric acid and nitric acid. These acids are formed in the atmosphere by the pollutants sulphur dioxide (SO_2) and nitrogen oxide (NO_x). Acid rain and acid fog have acidity levels ten to one hundred times higher than natural rainwater. Acid rain can lead to → soil acidification.

agroforestry
Any form of tree cultivation incorporated into crop farming in order to produce wood and other forestry products.

alkalisation
Processes which lead to the formation of soils with a pH greater than 7; alkaline soils usually occur in arid and semi-arid climates on clay substrates with poor drainage characteristics (e.g. mismanaged irrigation systems) and typically feature high concentrations of chlorides, sulphates and carbonates.

allocation
The distribution of scarce goods so that they are used in the economically most efficient manner.

anomie
Breakdown of social norms, e.g. traditionally accepted rules governing the use of land.

arid climate
Any dry climate with less than three wet months per year (→ aridity index).

aridity index
The aridity index is the ratio between precipitation and loss of soil moisture through evaporation. The aridity index differentiates between hyperarid, arid, semi-arid, sub-humid and dry regions, depending on the extent of moisture deficiency.

atmosphere
Derived from *atmos* (Greek: vapour, steam) and *sphaira* (Greek: (Earth's) sphere). The gaseous layer enveloping a celestial body, in particular the air surrounding the Earth. The main components of the Earth's atmosphere are nitrogen, oxygen, argon, water vapour and carbon dioxide. The mean vertical distribution of temperature results in zonation of the lower atmosphere into the following distinct layers:
Troposphere — the lowest layer of the atmosphere; most weather phenomena occur here. The troposphere extends to the tropopause, the boundary layer situated 8 – 17 km above the Earth's surface.
Stratosphere — commences above the troposphere and extends to the stratopause at an altitude of approx. 50 km. The stratosphere contains the ozone layer.

biocoenosis
The community of living organisms belonging to a → biotope.

biodiversity
→ biological diversity.

biological diversity
The variability among living organisms of all origins, including terrestrial, marine and other aquatic ecosystems and the ecological complexes to which they belong. This encompasses the diversity within and between individual species, in addition to the diversity of ecosystems (synonym: biodiversity).

biosphere
That part of the environment which is inhabited by living organisms.

biotope
The sum total of all environmental factors having an effect on the location of a ➝ biocoenosis.

boreal forests
Forests in the cold temperate zones in Europe, Asia and America.

cash crop
Crops cultivated for export and which therefore provide foreign currency revenue for a country; examples include groundnuts and cotton, but also animal feed (see Section D 2.1.4).

CO_2 fertilising effect
Enhancement of plant growth through higher CO_2 concentration in the atmosphere, and hence improved supply of carbon to plants. Such enhanced plant growth results in additional CO_2 being extracted from the atmosphere.

common burden principle
The principle by which government funds are used to mitigate environmental damage directly or indirectly, rather than making the polluter pay (➝ “polluter pays” principle).

common property regime
Land, usually heathland and forest, classed as “common land”, i.e. owned commonly by village inhabitants and used by them on a shared basis. Hardin (1968b) referred to common property regimes as an example for the ecological and social dilemma posed when a finite natural resource can be overexploited by individuals who are purely interested in their own immediate gain, thereby ignoring the long-term consequences for the community (*“The tragedy of the commons”*). (see *Box 23*, Section D 2.1.2.2.1).

contamination
Stress or pollution of ➝ environmental media with harmful substances such as heavy metals, hydrocarbons, radioactive substances, bacteria, etc. Contamination in soils can only be decomposed by microflora to a marginal extent, if at all, and therefore leads to depositions, accumulations or leaching (see Section D 1.1.2.3).

critical loads concept
Concept of impact thresholds below which stresses imposed on an ➝ environmental compartment by one or several contaminants do not cause harmful effects to the ecosystem, according to present knowledge. The concept of critical loads does not give adequate consideration to synergisms of different contaminants (see *Box 9*, Section D 1.2.1).

desertification
A term for which there is no clear definition, but which is generally taken to mean ➝ soil degradation in arid and semi-arid regions (➝ aridity index) (see *Box 21*, Section D 2.1.1).

developing countries
Countries with much lower wealth in terms of per capita income and various other indicators than industrial countries. Compared to the socioeconomic situation in industrial countries, they are classified as “underdeveloped”. There are currently about 130 countries, most of which are in the southern hemisphere. The poorest countries have been identified by the UN as “Least Less Developed Countries”; in 1992, this group comprised 38 states with a total of over 300 million inhabitants, i.e. 10% of the total population in the Third World. Developing countries are characterised, among other features, by low industrialisation, high population growth, poverty and unemployment, poor health care, high illiteracy rates and high indebtedness.

ecosystem
Any system in which there is interaction between living organisms and their abiotic environment, which is open but at the same time capable of a certain degree of self-regulation.

El Niño
The intense and prolonged warming of the surface of the ocean off the coast of Peru and along the equatorial Pacific to temperatures significantly higher than the annual mean. This phenomenon occurs every few years and has climatic effects that extend far beyond Peru and South America.

environmental assets

Environmental assets are goods and services provided by the natural environment which must be protected against damages and risks. With respect to Global Change, they can be assigned to one of the following spheres: → Atmosphere, → Hydrosphere, → Soils/landscapes, → Biosphere (fauna, flora, microorganisms and their → biological diversity).

environmental compartment

Any unit within the environment that has a definable boundary, examples being → soils, water and air.

environmental media

Environmental media or → environmental compartments refer to the → hydrosphere, → pedosphere, → atmosphere and → biosphere as spaces with a homogeneous capacity for the absorption, distribution, decomposition or accumulation of substances, and their subsequent release to a different medium.

erosion

Removal of the uppermost loose layer of weathered rock material (→ soil) by the action of wind and water, a process which is accelerated by human activities such as unwise land use (see Section D 1.1.2.3).

eutrophication

Changes induced in aquatic ecosystems following excessive inputs of nutrients (especially phosphorus and nitrogen). Typical features are algal bloom and the excessive stress on the ecosystem that decomposing algal bloom leads to.

evapotranspiration

Total loss of water from living organisms (transpiration) and from soil, rock and surface water bodies (evaporation).

external costs

Costs incurred to society and/or the environment that do not appear as costs in private or public budgets.

favourable soils

Soils which provide favourable conditions for agricultural production.

greenhouse effect

The greenhouse effect is caused by gases in the atmosphere which allow the sun's short-wave radiation to reach the Earth's surface, while they absorb, to a large degree, the long-wave heat radiation from the Earth's surface and from the atmosphere. Due to these gases' capacity to function as heat insulators, the temperature close to the Earth's surface is nearly 30° C higher that it would otherwise be (the *natural greenhouse effect*). In the aftermath of the increase in → trace gases due to human activities, the greenhouse effect is expected to intensify (*additional or anthropogenic greenhouse effect*), and temperatures to rise accordingly.

Human Development Index (HDI)

The HDI is a new yardstick for measuring human and social development. In the UNDP Human Development Report, HDI has been used by combining three indicators: purchasing power, education and health.

humus

Decayed material in and on soils that is derived from the decomposition of plant and animal remains, with the exception of fresh vegetable litter in the form of leaves, twigs, trunks and roots. Humification involves a number of complex processes, including mineralisation and humic acid formation.

hydrosphere

All the components of the hydrological cycle: oceans, surface waters, groundwaters and water in the atmosphere.

internalisation of external costs

Inclusion of → external costs in prices, thus ensuring that economic subjects who cause external effects (external costs) bear the consequences of their actions (→ "polluter pays" principle).

Joint implementation

Instrument of the Climate Convention with which the signatories can meet their emission targets not only through emission reductions on their own territory, but also by financing mitigation, adjustment or preventive measures in other countries (see Section C 1.4.1).

lithosphere

The outer layers of rock in the Earth's crust.

Montreal Protocol

The provisions adopted in 1987 for implementing the Vienna Convention for the Protection of the Ozone Layer (1985), which is in effect since 1.1.1989. The Protocol regulates the production and consumption of the most important fully halogenated CFCs and certain halons. The Conferences of the Parties to the Montreal Protocol held in London in 1990 and Copenhagen in 1992 agreed on even tougher restrictions.

Net Primary Production (NPP)

The net amount of atmospheric carbon that is sequestered by green plants over a specified period of time, equal to the gross carbon flux to plants that is fixed by photosynthesis minus the CO_2 lost through respiration. The result is a net increase in biomass.

newly-industrialised countries

→ Developing countries at a relatively advanced stage of development.

NIMBY phenomenon

The NIMBY phenomenon ("Not In My Back-Yard") refers to the common situation in which a local population opposes environmental hazards, especially technical installations with a certain risk potential (e.g. nuclear power stations, chemical engineering plants, landfill sites), even though they may well accept the necessity of such in principle.

non-governmental organisations (NGOs)

A generic term for non-state organisations, mainly used to refer to groups active in new social movements (environmentalism, peace movement, etc.).

overfertilisation

Overfertilisation occurs when the supply of nutrients in soils, in the form of mineral or organic substances, directly or indirectly exceeds the (physiological) requirements of the respective ecosystem. This leads either to nutrient enrichment in the system itself, or to stresses being imposed on neighbouring systems through the transfer of the surplus substances as gas or leachate. Overfertilisation is not only economically wasteful, but can also have negative effects on vegetation, the ground and above all water.

pedosphere

The zone occupied by soils; a boundary of the Earth's surface where rock, water, air and living organisms interpenetrate and where soil formation processes occur.

pesticides

Chemicals designed to kill organisms considered to be undesirable. Examples include: herbicides or arboricides to kill certain plants so that others can be cultivated; insecticides for eradicating insects, or fungicides against fungi as part of forest and wood protection. Pesticides, or their decomposition products, can accumulate in the organisms of food chains.

"polluter pays" principle

The "polluter pays" principle means that the costs for avoiding, removing or mitigating environmental damage must be borne by the person or persons who "caused" it. The idea is ultimately that natural assets be utilised in an economically meaningful and environmentally friendly way. All environmental protection measures (or instruments) which base their orientation on this principle are designed to integrate the costs of environmental damage, as far as possible, into the accounting systems of polluters as "→ external costs" and/or "incremental social costs" of consumption and production, in other words to "→ internalise" these external costs.

precautionary principle
The precautionary principle states that environmental measures and other actions be instituted in such a way that environmental risks be excluded from the very outset, and irreversible damage be prevented.

price elasticity
The relationship between a relative change in demand and the relative price change which causes it.

primary forest
Primary forest; in the strict sense of the term, an authochthonous forest stand that has been influenced so little, if at all, by human activity that its climax state has been essentially shaped and determined by its natural environment (→ secondary forest).

resources
Broadly defined, resources comprise all stocks of the factors labour, → soil and capital that can be employed to produce goods. In the narrower sense, resources refer to natural capital, raw materials, energy sources and environmental media, with a distinction can be made between (relatively) renewable resources and non-renewable resources.

secondary forest
A natural successional stage resulting after the original → primary forest or secondary forest has been cleared away or altered, either by human activities or natural disasters (e.g. fire or insect attack).

sink
A sink is an → environmental compartment in which substances are accumulated or from which substances can be eliminated through decomposition.

soil (soils)
Soil is that part of the upper Earth's crust between hard or loose bedrock below, vegetation cover or the airshed above, and neighbouring soils to the side. It is a dynamic system in an equilibrium of flux. Soil systems react to changes in boundary conditions over periods which can range from only a few years (as is the case with soil acidity), to millennia (soil texture and structure) (see Section D 1.1.2).

soil acidification
Decreasing pH-value of soils as a result of severe contamination by emissions of pollutants to the air. The occurrence, development and scale of such acidification depends on location, population and land management factors.

soil compaction
Reduction of the total volume of soils through pressure or settlement. The bulk density, pore space and pore size distribution are altered as a result. This induces a reduced infiltration rate, greater surface runoff and hence the threat of erosion (see Section D 1.1.2.3).

soil degradation
Anthropogenic soil degradations are permanent or irreversible changes in the structure and function of soils as a result of physical, chemical or biotic stresses induced by humans and which exceed the stress-bearing capacity of the respective systems (see Section D 1.1.2.3).

soil fertility
The fertility of soils depends on the natural supply of nutrients and the volume of water available for plant growth. Virtually natural soils, such as river marshes or moorlands, are especially fertile.

soil functions
A distinction is made between four important functions of soils: their habitat function, their regulation function, their utilisation function (comprising the production, carrier and information functions) and their cultural function (see Section D 1.1.2.1).

soil salinisation

Accumulation of salts in and on soils, especially in semi-arid and arid climatic zones (→ aridity index) and mostly as a result of mismanaged irrigation systems. Groundwater conditions are adversely affected, with saline water rising to the surface but not drained away, so that the salts are deposited when the water evaporates. Such soils are then infertile.

soil structure

The configuration of solid soil components. In addition to other factors (soil texture, soil depth), soil structure has a major influence on → soil fertility. Soil structure depends on the shape, size and arrangement of soil particles, organic substance, water content and external factors.

soil type

In the German soil classification system, the soil type is smallest spatial unit within which all soils display the same combination of vertical configuration (soil horizons) and origin (pedogenesis).

subsidiarity principle

A principle of social and political organisation, according to which superordinate bodies (e.g. national states) take action only if and insofar as the objectives of such action cannot be achieved at the subordinate level (e.g. local communities).

subsistence farming

A self-sufficient farming system in which food is only produced to meet the needs of the farm household. Subsistence farmers have little need of money, since surpluses are not produced in order to be sold. The number of people who live from subsistence farming continues to rise, and is currently in the order of 300 million (see Section D 2.1.3).

sustainability

A term originally used in forestry to describe a criterion for forest management designed to preserve tree stocks, but now used in a wider sense as a criterion for → Sustainable Development.

Sustainable Development

A term for which there are various definitions, translations and interpretations. It refers to a concept for environment and development that was articulated in the Brundtland Report, among others, and further refined at the 1992 UN Conference for Environment and Development in Rio de Janeiro. The Brundtland Report defined the term as follows: “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”

terms of trade

A term used in international trade to describe the current trading prospects of a particular country. It is reflected in the relationship between the export price index and the import price index, both in the currency of the country in question. If the export prices rise while the import prices decrease or remain constant, or if the import prices decline while the export prices stay constant, then the terms of trade improve because more goods can be imported for the same volume of exported goods. Deteriorating terms of trade are experienced by many developing countries, whose export products, primarily raw materials, almost fetch progressively lower prices on the world’s markets in relation to the goods they import (machinery and other finished goods), prices for which tend to increase.

tertiarisation

The service sector (tertiary sector) accounts for an increasing proportion of gross domestic product in industrial countries, relative to the primary and the secondary sectors (agriculture and industry, respectively) (“transformation to a services society”).

trace gases

Gases present in the atmosphere in very small amounts, e.g. CO_2, N_2O, CH_4, CFCs, but important on account of their effects as greenhouse gases or ozone depletion potential.

transaction costs

Costs which are incurred through economic activities (e.g. barter transactions on the market), and which can be information procurement costs, negotiation costs, risk management costs, etc. (see *Box 15*, Section D 1.3.1.5.1).

ultra-violet radiation (UV radiation)

Short wavelength (< 400 nm) electromagnetic radiation within the visible spectrum. Three types of UV radiation are distinguished: UV-A (320 – 400 nm), UV-B (280 – 320 nm) and UV-C (40 – 290 nm). Excessive UV radiation causes damage to living organisms.

H The German Advisory Council on Global Change

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I Joint Decree on the Establishment of the German Advisory Council on Global Change

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" shall be established with the Federal Government.

Article 2

(1) The Council shall annually submit a report to the Federal Government by the first of June 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 will be published by the Council.

(2) While preparing the reports, the Council shall allow for the Federal Government to give an opinion on central questions arising from this task.

(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 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, for a period of four years. 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 only subject to the fulfilment bound only to the brief defined by this Decree and is otherwise independent to determine its own activities.

(2) Members of the Council must neither belong to the Government or a legislative body of the Federal Republic or of a Land nor to the public service of the Federal Republic, of a Land or of any other juristic person of the Public Law other than as a university professor or as staff member of a scientific institute. Furthermore, they may not be representatives of an economic association or an employer's or employee's organisation, or be attached to these by the permanent execution of services and business in their favour. They must not have held any such position during the last year prior to 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 an all-inclusive compensation as well as a reimbursement of their travel expenses. The amount of the 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, e.g. 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. Suggestions on how to avoid and correct maldevelopments.

In its reporting the Council should also consider ethical aspects of global environmental change.