



**German Advisory Council on Global Change**

Wissenschaftlicher Beirat der Bundesregierung  
Globale Umweltveränderungen

(WBGU)

**World in Transition:  
The Research Challenge**

**Annual Report 1996**

**Summary**

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Secretariat of the  
German Advisory Council on Global Change  
Alfred Wegener Institute for Polar and Marine Research  
PO Box 12 01 61

D-27515 Bremerhaven, Germany

Phone: 0471/4831-723

Fax: 0471/4831-218

Email: [wbg@awi-bremerhaven.de](mailto:wbg@awi-bremerhaven.de)

Internet: <http://www.awi-bremerhaven.de/WBGU/>

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**German Advisory Council on Global Change  
(Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen)**

**Members as at June 1, 1996**

*Prof. Friedrich O. Beese*

Agronomist: Director of the Institute of Soil Science and Forest Nutrition at the University of Göttingen (Institut für Bodenkunde und Waldernährung an der Universität Göttingen)

*Prof. Gotthilf Hempel*

Fishery biologist: Director of the Centre for Marine Tropical Ecology at the University of Bremen (Zentrum für Marine Tropenökologie an der Universität Bremen)

*Prof. Paul Klemmer*

Economist: President of the Rhenish-Westphalian Institute for Economic Research, Essen (Rheinisch-Westfälisches Institut für Wirtschaftsforschung in Essen)

*Prof. Lenelis Kruse-Graumann*

Psychologist: Specialist in "Ecological Psychology" at the Open University, Hagen (Schwerpunkt "Ökologische Psychologie" an der Fernuniversität Hagen)

*Prof. Karin Labitzke*

Meteorologist: Institute for Meteorology at the Free University of Berlin (Institut für Meteorologie der Freien Universität Berlin)

*Prof. Heidrun Mühle*

Agronomist: Head of Department of Agricultural Lands at the Environment Research Centre Leipzig-Halle (Projektbereich Agrarlandschaften am Umweltforschungszentrum Leipzig-Halle)

*Prof. Hans-Joachim Schellnhuber (Vice Chairperson)*

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*Prof. Udo Ernst Simonis*

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*Prof. Hans-Willi Thoenes*

Technologist: Rhenish-Westphalian Technical Control Board, Essen (Rheinisch-Westfälischer TÜV in Essen)

*Prof. Paul Velsinger*

Economist: Head of the Department of Regional Economics at the University of Dortmund (Fachgebiet Raumwirtschaftspolitik an der Universität Dortmund)

*Prof. Horst Zimmermann (Chairperson)*

Economist: Department of Public Finance at the University of Marburg (Abteilung für Finanzwissenschaft an der Universität Marburg)

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## Introduction

For the first time in history, human activities are having impacts of planetary scale. The resultant changes in the global environment are reshaping the relationship between humankind and the natural basis on which its existence depends. This transformation process, called global change, is occurring at unprecedented speed and involves many risks. It can only be understood if Earth is conceived of holistically as a single system. Global change poses a major challenge for the scientific community, which must describe and explain how the Earth System is altered by human intervention, how these processes are influenced in turn by natural changes in the Earth System, and, finally, whether and to what extent there are ways to control global change.

Anthropogenic climate change is a good example for the sheer dimensions of human-induced effects on the global environment. Carbon dioxide emissions from transport in Germany contribute towards rising sea level and the expected disappearance of coral islands 20,000 km away, thus robbing the inhabitants of such islands of their very habitat. Humankind is thus confronted not only with a major ethical dilemma, but also with a complex of difficult research issues and problems which have to be resolved as quickly and as competently as possible. These problems can only be solved by *interdisciplinary* and *international* research networks in which, alongside climate modeling and hydrography, for example, other disciplines such as the philosophy of law and cultural anthropology must also play a role.

Global change research poses an enormous challenge for the researchers themselves, for the bodies funding and promoting such research as well as for those who base their decision-making on its findings, and demands integrative capacity, flexibility and imaginative power from scientists, research promoting organizations and users. Innovative guidelines and structures are necessary for handling the complex problems and for developing the problem-solving competence. "Traditional" environmental research has so far proved inappropriate to meet these demands.

In its 1993, 1994 and 1995 Annual Reports, the Council has identified and described the core problems associated with global change – on the one hand, the changes in people's natural environment (the "ecosphere"), on the other, the changes with society itself (the "anthroposphere"). The 1996 Annual Report now focuses on the organization of global change research and examines the conditions for enhancing Germany's contribution.

Suspicious have often been voiced that calls for more research serve only to divert attention from the necessity of environmental action. However, research explicitly geared to *solving specific problems* is indeed relevant for political action, improving the decision-making competence on which any such action depends.

The Council's focus in this year's Annual Report embraces not only the "classical" fields of environmental research within the natural sciences, but also the economic and sociocultural dimensions of global change. The methodological foundations have been established in previous Reports through the development

of an integrative research approach based on the analysis of *syndromes* (WBGU, 1993 and 1994). This approach permits the operationalization of the networked thinking that is essential for mitigating global change and offers new options for the design and organization of global change research.

When public funds are scarce, clear-cut priorities are required in order to achieve maximum efficiency in the selection and execution of research projects. To this end, the Council has elaborated *relevance criteria* and *integrational principles* for global change research. These criteria and principles could also be applied in the current reshaping of Germany's environmental research programs. The Council welcomes the interministerial initiative of the Federal Ministry for Education, Science, Research and Technology (BMBF) and the Federal Ministry for Environment, Nature Conservation and Reactor Safety (BMU) for a new environmental research program to succeed several specialized programs and government support frameworks for global change research in the fields of climate, marine, polar and ozone research.

In this year's Report, the Council develops guidelines for the essential restructuring and reorientation of selected areas within Germany's global change research, while taking established structures into consideration. This entails, on the one hand, a description of integrated research approaches, as illustrated by a case study, and, on the other, a survey of the classical sectors within global change research, an evaluation of Germany's involvement in international research programs, and the identification of research gaps in specific sectors.

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## Integrated global change research

### Systems approach

A cardinal feature of global change is that humankind itself is now an active factor within the Earth System, playing a significant role at the planetary scale. Human interventions in that system, as manifested in the depletion of raw materials, shifts in material and energy fluxes, changes to large-scale natural structures and critical stresses on environmental assets, are altering the very character of the Earth System to an increasing degree. The complexity of these processes poses a major challenge for the scientific community and generates a number of new research issues, listed below. Finding answers to these questions will be of increasing importance in the years to come:

- How are changes in the ecosphere produced and how are these linked to global development problems?
  - How can they be identified or even predicted at an early stage?
  - What risks do they involve?
  - How must humankind act in order to prevent negative developments at the global level, to avert threats and/or mitigate the consequences of global change?
- Such research should be guided by the principle of *sustainable development*.

The crucial element of this concept, now generally acknowledged, is the interdependence of environment and development (AGENDA 21). This reflects a growing insight that human beings and their environment are closely integrated within a system of mutual interaction. Research on global change is therefore confronted with two fundamental problems. Firstly, the investigation of the Earth System requires an integrative approach because the interactions between its components operate across the boundaries of single disciplines, sectors or environmental media. The second fundamental problem is the enormous complexity of the dynamic interrelationships involved, which makes a distinct description, any overall analysis and modeling much more difficult. The only approach capable of responding adequately to these problems is one that is networked and interdisciplinary. The sectoral bias within research must be supplemented by a systems approach that establishes cross-linkages between different strands of research.

The Council has proposed a new *method* for holistic analysis of the present crisis of the Earth System (WBGU, 1993 and 1994). The elements chosen for that analysis are not, as is often the case elsewhere, a set of easily indexed base variables, such as atmospheric concentrations of CO<sub>2</sub>, size of population or gross national product. Instead, the most important global trends are being used as qualitative elements. They are termed *trends of global change* and provide information about the dominant features of global development. The development of the Earth System is then described using this set of trends. While there are highly complex natural or anthropogenic processes considered, the internal processes are not lost in sight.

Those trends possessing special relevance for global change are selected on the basis of educated guesses. They are not evaluated at the outset; problematic processes such as climate change, loss of biological diversity or soil erosion are placed alongside other trends – like globalization of markets, or progress in biotechnology and genetic engineering – which can have positive or negative impacts depending on the perspective taken and the specific manifestation of the trend in question. Another category of trends are those which may lead to the mitigation of global problems, e.g. strengthening of environmental protection efforts at national level, growing environmental awareness, or the growth of international regimes.

The various trends and their interactions can be combined in a qualitative *global network of interrelationships*, which describes global change as a system and which represents the starting point for more extensive analysis of the Earth System's dynamics. With the help of this empirical-phenomenological description of global change, it is possible to design qualitative models, the subject of a current BMBF research project.

### Syndrome concept

Networks of interrelationships can be developed for other levels besides the global. A regionalized analysis of the Earth System using this instrument shows

clear indication that the interactions in certain regions between human societies and the environment frequently operate along typical patterns. These *functional patterns (syndromes)* are unfavourable and characteristic constellations of natural and civilizational trends and their respective interactions, and can be identified in many regions of the world. The Council's underlying thesis is that complex global environmental and development problems can be attributed to a discrete number of environmental degradation patterns.

Syndromes are transsectoral in nature; while specific problems may affect several sectors (such as the economy, the biosphere, population), they are always related, directly or indirectly, to natural resources. Syndromes are globally relevant when they modify the Earth System and have a noticeable impact, directly or indirectly, on the basis of life for a major part of humankind, or when global solutions are needed to surmount the problems. This year's Report includes an attempt at identifying the globally significant syndromes under which Planet Earth is suffering (*see box "Overview of Global Change Syndromes"*).

The syndrome concept provides a new basis for global change research, which used to be organized according to the environmental media or core problems. Given the desiderata for global change research – *interdisciplinarity, internationality and problem-solving competence* – it is obvious that future environmental research should be structured along transdisciplinary lines. In this connection, the Council's syndrome concept offers new options for shaping research activities. It is therefore recommended that these syndromes be adopted as the central objects of future global change research.

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#### Relevance criteria and integration principles

The importance of global change for the future development of humankind, and the uniqueness, complexity, variety and dynamics of the phenomena involved, make it necessary to deploy a number of additional relevance criteria for research policy. Putting these criteria into operation can fulfill a dual purpose – orienting research activity to the cross-sectional character of environmental issues, and achieving more efficient prioritization when financial resources are scarce. The Council's recommendation is that the following criteria in particular be applied when selecting research topics in the field of global change:

- *Global relevance:* Are key parameters, basic patterns or core problems in the Earth System being investigated? Are large numbers of people affected by the problem? Is the research likely to generate new options for controlling the environment/development process?
- *Urgency:* Are answers needed quickly in order to prevent irreversible environmental or socioeconomic developments with severe negative outcomes?
- *Gaps in knowledge:* Can serious gaps concerning a holistic view of the global environment and its dynamics be closed?
- *Responsibility:* Are problems being investigated for which Germany is directly or indirectly responsible (e.g. through greenhouse gas emissions or as participants



**BOX: Overview of global change syndromes***Utilization syndromes*

1. Overcultivation of marginal land: *Sahel Syndrome*
2. Overexploitation of natural ecosystems: *Overexploitation Syndrome*
3. Environmental degradation through abandonment of traditional agricultural practices: *Rural Exodus Syndrome*
4. Non-sustainable agro-industrial use of soils and water: *Dust Bowl Syndrome*
5. Environmental degradation through depletion of non-renewable resources: *Katanga Syndrome*
6. Development and destruction of nature for recreational ends: *Mass Tourism Syndrome*
7. Environmental destruction through war and military action: *Scorched Earth Syndrome*

*Development syndromes*

8. Environmental damage of natural landscapes as a result of large-scale projects: *Aral Sea Syndrome*
9. Environmental degradation through the adoption of inappropriate farming methods: *Green Revolution Syndrome*
10. Disregard for environmental standards in the context of rapid economic growth: *Asian Tigers Syndrome*
11. Environmental degradation through uncontrolled urban growth: *Favela Syndrome*
12. Destruction of landscapes through planned expansion of urban infrastructures: *Urban Sprawl Syndrome*
13. Singular anthropogenic environmental disasters with long-term impacts: *Disaster Syndrome*

*Sink syndromes*

14. Environmental degradation through large-scale dispersion of emissions: *High Stack Syndrome*
15. Environmental degradation through controlled and uncontrolled waste disposal: *Waste Dumping Syndrome*
16. Local contamination of environmental assets at industrial locations: *Contaminated Site Syndrome*

on the world market)? Does the topic relate to general ethical principles (e.g. preservation of life on Earth)?

- *National impact:* Are problems being researched which could have direct or indirect effects on Germany (e.g. impacts on climate, environmental refugees)?
- *Research and problem-solving competence:* Does the research relate to areas where Germany contributes substantially on account of its scientific, technologi-

cal and infrastructural potential? Can research on the topic lead to further improvement of that potential and thus to enhancement of Germany's attractiveness for investment?

Since it is neither reasonable nor feasible for German global change research to cope with all syndromes simultaneously, priorities should be set with the help of the above criteria. Moreover, investigation of the various syndromes should be pursued by the international scientific community. A survey conducted within the WBGU on the basis of the relevance criteria produced an initial ranking of the syndromes. Seven syndromes were given uppermost priority (listed in alphabetic order):

- *Contaminated Site Syndrome*
- *Dust Bowl Syndrome*
- *Mass Tourism Syndrome*
- *Sahel Syndrome*
- *High Stack Syndrome*
- *Urban Sprawl Syndrome*
- *Waste Dumping Syndrome*

The specific recommendations are:

- to discuss and improve the syndrome concept in a series of symposia involving research scientists and decision-makers from different sectors of society. The current list of syndromes may undergo further modifications in the process;
- to produce an improved ranking of the syndromes based on a *Delphi study*;
- immediately establish three research networks among existing establishments for pilot studies of the *High Stack*, *Sahel* and *Urban Sprawl* syndromes. These integrated studies could function as key projects under the Federal Government's new Environmental Research Program.

Achieving a global perspective requires collaboration between and the integration of different disciplines, interest groups and actors. The diversity of concepts for communicating environmental knowledge means that many problems must be overcome for such integration to occur. The key issue for researchers concerns the principles according to which the requisite synthesis is to be realized. Simply calling for "networking", "interdisciplinarity" or "interaction" is inadequate as an approach - what is needed are principles and instruments providing a concrete basis for the holistic analysis of global change syndromes.

In this year's Annual Report, the WBGU puts forward a number of principles that may prove helpful in the implementation of integrated environmental research (integration principles). These principles relate to analytic, methodological and organizational aspects, as well as certain implementation aspects.

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### The problem-solving process

Research on decision-making processes in the field of environmental policy-making has mainly been concerned with problems of national environmental policy. Although this has led to findings that have a bearing on the environmental

decision-making process in the international and global framework as well, the situation is more complex. Global problems tend to be long-term in nature, which gives rise to major problems with regard to diagnosis and forecasting. This results in demands on early-warning systems and planning instruments, as well as on research methods and instruments. Global problems are also much more complex than environmental problems at the purely national level, with all the implications for the necessary consensus-formation. In an international context conflicts are more difficult to resolve due to differences in culture, religion and especially the level of development.

Research methods and approaches guided by national environmental policy must therefore be adapted in such a way that they can also be applied to the elements of the decision-making process relating to global environmental change. The focus should not be restricted to specific disciplines. Rather the various elements constituting the problem-solving process should be structured first. Then it should be asked which disciplines have already contributed or which disciplines should make a greater contribution to interdisciplinary research in future.

The next step is to ascertain which results are already available and in what respects they require supplementing. Distinction can be drawn between the following elements of problem-solving processes:

- *Initial treatment of the problem.* The starting point for solving global change problems is analysis, i.e. the identification of causes and effects and the assessment of future trends (*forecasts*). Due to the complexity of the subject and the need for integrated research approaches, it is necessary to have an adequate methodology, such as *systems analysis*, for describing and explaining the problem and arriving at forecasts.
- *Guiding principles and objectives.* Once the problem has been analyzed, it is necessary to define *guiding principles* and objectives. In the view of the Council, there are serious gaps in research into guiding principles, which needs to be oriented towards the concept of sustainable development and made more specific by means of relevant principles for action and appropriate indicators.
- *Responsible bodies.* Policies for influencing global environmental change require appropriate bodies at various levels (global, regional, national and local). Because sovereign states are the bodies which take action at international level, special attention must be focused on the mechanisms of decision-making and action which take place there. The specific *constellation of responsible bodies* and the problem of how to achieve *effective cooperation* between these bodies must therefore be studied in greater detail. Suitable methods for such research have to be selected and/or refined, *game theory* being one example in this context.
- *Instruments.* Agreement on objectives is achieved using instruments which are either already available to global environmental policymaking or which have yet to be developed. Research into the strength and effectiveness of these instruments is needed and must be advanced further. In particular, research is needed on transsectoral instruments, such as the various international environmental conventions, but also on the various subordinate instruments which operate under those conventions.

- *Implementation.* Once international conventions have been adopted, the next question concerns their implementation and enforcement as well as options for imposing sanctions. In view of the fact that problem-solving processes often stagnate at precisely this stage, the obstacles which arise in this context must be subjected to precise analysis.
- *Research into decision-making and risk management processes.* In addition to research into the above elements of the decision-making process, especially the problem of responsible bodies and the effectiveness of policy instruments, it is essential to conduct research into *decision-making* and *risk management*, which involves investigating two specific features of the problem-solving process, namely the problem of consensus-formation in cases where there are fundamental disparities of interest, and the question how to handle uncertainty.

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### Sectoral research on global change

In this chapter, the Report describes the current status of German sectoral research on global change, including international involvement, and identifies the research gaps.

#### Climate and atmosphere research

The advanced level of German research in this field must be maintained through continuous improvement of the existing infrastructure. German climate research, for example, occupies a leading position in the world in the development of coupled ocean-ice-atmosphere models, thanks to consistent support from the BMBF, the Max Planck Society (MPG) and the German Research Foundation (DFG). This position can only be maintained through adequate human resources policy, continuous modernization of computing capacities and constant refinement of models. Research tasks of special relevance to global change are:

- Further development of coupled *ocean-ice-atmosphere models* for predicting climate along different spatial and temporal scales, and of integrated models for climate impact research.
- Research into the Earth's *paleoclimate* using ice cores and marine and limnetic sediments. There is a general lack of data from tropical regions and the Southern Hemisphere in this field.
- Continuation and/or commencement of measurements of the *composition of the atmosphere* (various guiding substances) at selected stations in Germany and northern Europe (stratosphere monitoring), as well as at sea and in the tropics (troposphere monitoring) in the context of international monitoring programs.
- Systematic analysis of existing data from different parts of the atmosphere in order to improve our understanding of *climate variability*.
- Development and evaluation of *satellite experiments* for measuring parameters and trace gases of relevance for the climate.
- Investigating the influence of *aerosols and clouds* on climate.
- Experimental studies of *tropospheric chemistry* at low latitudes (using research

aircraft).

Climate and atmosphere research, in the narrower sense, is conducted primarily by natural science. Research on the impacts of global change (especially *climate impact research*) should involve the human sciences as well. What is needed is:

- greater development of *Regional Integrated Models* (RIM),
- organization of transdisciplinary and transinstitutional *research networks* for studying issues of sectoral and political relevance.

#### Hydrosphere research

As with climate research, it is essential that the advanced level of German research in this field be maintained through continuous improvement of the existing infrastructure. A committed role in the Joint Global Ocean Flux Study (JGOFS), Global Ocean Ecosystem Dynamics Programme (GLOBEC) and Land-Ocean Interactions in the Coastal Zone Programme (LOICZ), all core projects of International Geosphere Biosphere Programme (IGBP), is essential. Research tasks of special relevance to global change are:

- Development of the scientific foundations for an operational *global ocean observation system* (GOOS).
- Research into human-induced impacts on marginal seas and coastal zones, and the development of the scientific basis for *integrated management of coastal regions*.
- Research into the *polar oceans*, with special reference to climatological aspects.

With regard to the global aspects of water resources, there is an enormous need for research into the causal interlinkages between climate, vegetation and anthroposphere, and for the development of environmentally sound land management practices that ensure water resources in the long term, as envisaged by the Land-Use and Land-Cover Change Programme (LUCC) and Biospheric Aspects of the Hydrological Cycle Programme (BAHC) core projects of IGBP.

Freshwater is a vital resource in all areas of life and society, functioning as a nutrient, a cultural asset and a production factor simultaneously. The WBGU considers it extremely important that research into freshwater resources be intensified. Research tasks of special relevance to global change are:

- Research into the conditions for *increasing the supply of water* for a growing world population.
- Research into the conditions for *thrifty and sustainable use of water resources*, in the sense of careful management of water resources in the various sectors of use (agriculture, industry, private households) and the equitable sharing of available water (intra- and intergenerational equity).
- Research into the conditions for *preventing the pollution* of surface water and groundwater stocks.

The main focus here is to develop dynamic models of the regional and global water balance, including feedback effects to the climate system, the biosphere and the anthroposphere.

#### Soil research

Soil research focuses primarily on the local and regional level, but it must now integrate global changes in climate, water balance and land use. The following fields are especially important in this connection:

- Quantification of the *soil functions*: as storage media in the biogeochemical cycles of carbon, nitrogen, and sulfur, as well as the trace gas compounds of these elements which are responsible for climate forcing. Assessment of the potential influence on transformation processes exerted by changes in climate and land use.
- Degradation of soils due to the *decoupling of element cycles* through utilization. Impacts on the productivity and sustainable utilization of soils, and on the stability of recipient systems. Research activities at local, regional and national level.
- *Effects of particulate substances removed from soils* (through erosion) on the biotic components of neighboring limnetic and marine ecosystems (main focus on rivers, coral reefs and mangroves).
- Intensified use of *remote sensing* for Earth observation, and of computer simulation techniques for describing changes in terrestrial ecosystems at regional and global level.

#### Biodiversity research

Biodiversity, as a dimension of global change, is of such importance for the functions, stability and development of ecosystems that the Council considers it central to its recommendations. German biodiversity research still tends to focus too much on single disciplines and the purely national level. Wider conceptual frameworks and interdisciplinary links between the biosciences and the human sciences are still under development. The Council recommends that research be focused on the following areas:

- The basis for any assessment, preservation or restoration of biodiversity is a *modern taxonomy* that utilizes the methods and techniques of molecular biology more intensively, including advanced information technology. Research and educational facilities in this field are urgently in need of expansion if German researchers are to be involved in international biodiversity inventory projects and biogeographical assessments of biodiversity.
- Research should also focus on the dichotomy between the conservation and utilization of terrestrial and aquatic ecosystems. In particular, the *interrelationships between diversity, stability and performance of ecosystems* must be analyzed more intensively. Expanding research on population biology in order to improve nature conservation activities plays an important role in this connection. This calls for new approaches going beyond the all-too-narrow focus on biotope and species protection.
- High priority must be assigned to research into the *impacts of environmental changes* of varying quality, intensity and speed on populations, ecosystems and ecosystem functions (such as biogeochemical cycles). Such work should be based on findings from the areas specified above.
- Another important research field concerns the *political efforts of the international community* for the conservation and sustainable use of biodiversity. Research

into the economics of biodiversity and the design of international environmental agreements is urgently needed.

#### Population, migration and urbanization research

Population trends, migration and urbanization are key factors in the analysis and management of global environmental problems. Population growth and poverty are powerful driving forces behind an overall trend that is now affecting industrialized countries as well, primarily in the form of mounting migrational pressure. Research in Germany is still inadequate, with respect to theoretical foundations, empirical case studies and simulation models, to analyze, forecast and respond to these trends. The following topics should be focused on:

- *Rural-urban-relations* must be re-investigated and re-assessed, taking into account the transfers between urban areas and the subsistence economy of surrounding rural areas (reversal of the push-pull approach).
- Identifying potential sources of migration and migration flows is an increasingly important task for *international migration* research. In particular, systematic research must be conducted into the motivational factors driving migration.
- The *determinants influencing the individual's decision to migrate* must be identified in terms of sociocultural nexus and the private household context. Traditional flow analysis must be enhanced through migration system research.
- *Malnutrition, undernourishment and famine* are major causes of migration. Research on food security and water availability must therefore be intensified.
- The *informal economy* plays a central role in providing a minimum level of social security for the urban poor. In-depth research into the development potential of this sector is therefore essential.
- Our knowledge about the increasing number of *megacities* and *large-scale agglomerations* and how these operate within the global system is still fragmentary. There is also a lack of research on the informal growth of cities. To understand how "unplanned" megacities function, it is necessary to examine the systemic interrelation of these urban structures. The Second UN Conference on *Human Settlements* (HABITAT II) showed that the creation of adequate housing is an acute problem affecting the welfare of more than one billion people. Policy-oriented research should also be conducted in connection with *international conferences* (preparation and follow-up).

#### Economics research

The Council sees a need for global economics research in the following three fields :

- *Research on the objectives and impacts of global environmental policy.* A key focus here should be the *operationalization of the sustainable development principle*. Above all, this requires the identification of the essential, i.e. non-renewable elements of natural capital, the assessment of the costs of neglected environmental protection, the evaluation of intra- and intergenerational distribution, especially the scientific debate on "correct" discounting methods, and the specification of criteria regarding the economic and social compatibility of sustain-

able development.

- *Research on agencies responsible for global environmental policy.* A principal research focus should be the *economic analysis* of the behavior of globally relevant actors – both political and private (such as multinational corporations). One major issue concerns the development of strategic behavioral options which produce benefits for the overwhelming majority of those involved.
- *Research on the instruments of global environmental policy.* Due to the limited planning, regulatory and fiscal options at the global level, environmental regimes are usually implemented through *treaties, conventions* and *economic incentives*. Research on economic instruments should therefore concentrate on further development of the tradable quotas/permits option (including *joint implementation*), the law of liability and global funds. Another issue, parallel to these, is the question of sanction mechanisms to be applied when treaties or conventions are violated by one or more parties.

#### Research on societal organization

Research by political science on environmental topics has mainly focused on the national level, so it must now adopt a more global perspective. The problems experienced by newly industrializing nations and their growing importance for global change deserve special attention. Policy concepts relating to global environmental protection must also take into account the sociocultural and economic conditions and international law.

International environmental research must widen its focus to embrace not only global climate issues but also other problems such as soil degradation, loss of biodiversity, and the scarcity and contamination of water resources. In view of the discrepancy between environmental awareness and the policies which are actually implemented, analysis must center, as a matter of priority, on the process of political will-formation and the implementation of international treaties. Political research must also dedicate attention to the prevention of environmental conflicts. The following tasks need to be accomplished:

- Investigation of the socioeconomic, political and cultural *restrictions on action* and problems related to the implementation of international environmental treaties.
- Development of concepts on which to base *problem-solving strategies* for overcoming the typical obstacles encountered in global problem-solving processes (global commons, compliance issues, etc.).
- Analysis of the *functional operation of international negotiation systems*, with special reference to the uncertainty factor in global environmental change. Further, it is necessary to develop concepts for decision-making under uncertain premises.

The *jurisprudence* is examining the options for adopting and enforcing effective measures relating to global change. The legal issues include restricted national sovereignty, customary international law and ecological solidarity. Against this background, the Council recommends that the following legal issues be tackled:

- Clarification of the current body of *extra-treaty standards* and *international customary law* relating to global environmental problems, in order to react more flex-



ibly to the latter.

- Defining a *general obligation of ecological solidarity* on the part of industrialized countries vis-à-vis the developing world.
- Clarification of the *status* of non-governmental organizations in international law.
- Clarification of legal issues concerning damages caused by global environmental change.
- Further development of *enforcement mechanisms, decision-making procedures and dispute-settlement procedures* in connection with international treaties.

#### Research on the psychosocial sphere

The scientific disciplines covering the psychosocial sphere are devoting increasing attention to important issues in the analysis of the causes and effects of global change and interventions to remedy the problems which exist. This research is still little developed in Germany, with most projects involving only one discipline and decentralized organization. The following topics should be focused on, preferably by joint projects:

- Research into *guiding principles* of sustainable development, from basic ethical principles to operationalization and empirical analyses.
- Studies on the *determinants of behavioral traits* relevant to global change (perception and assessment of global change phenomena, motivation, etc.) and on strategies for modifying behavior.
- Investigation and evaluation of *interventions* (specific contexts and groups of actors), in terms of the interactions between technical, economic, legal and psychosocial measures.
- Development, systematic application and evaluation of *global change relevant education*.
- Development and establishment of a worldwide, comprehensive system of *social monitoring* (analogous to environmental monitoring).

Accomplishing these tasks requires more cultural and cross-cultural comparative research on social actors in the form of comprehensive, transdisciplinary case studies, whereby studies should be conducted across a wide range of spatial and temporal scales.

#### Technological research

Technological research is a key factor to manage problems of global change. A prime example is the *further development of energy technologies* aimed at an environmentally, economically and socially acceptable energy mix. The main focus should be placed on researching and developing different energy options, including:

- Research on solar *photovoltaics*.
- Research on the utilization of *wind energy*, especially in developing countries.

In addition, the Council recommends the promotion of research programs on the impact of air transport on climate, and the development of air transport along environmentally acceptable lines. At the interface between technology and eco-

nomics, the Council proposes the following research topics:

- Examination of the appropriateness and effectiveness of *jointly implemented activities* to reduce greenhouse gases.
- Development of *cost-efficient reduction strategies* for greenhouse gas emissions, taking all climatically trace gases into account.
- Research concerning techniques for *removing and storing CO<sub>2</sub>*, with special reference to ecological and economic aspects.
- Analysis and quantification of the *impacts of greenhouse gas emissions* on the emissions of other mass contaminants of the atmosphere and other environmental problems.
- Development of cost-efficient strategies for *reducing tropospheric ozone*.
- Development of *logistics-oriented production processes* (e.g. reduction of transport within the production process).
- Identification of *environmentally sound industrialization processes* in developing and newly-industrializing countries, taking into consideration the local technology and human resource potentials.

Practical, technology-based solutions to complex environmental problems require cooperation between various disciplines, depending on the respective project and the specific problem it addresses. The following fields have a role to play in this context:

- Technologies: engineering science.
- Materials: chemistry, biology and geology.
- Planning and design: economics and social sciences.
- Applications and effects: social and behavioral sciences, environmental medicine.

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### The organization of research

German research must undergo major structural improvements if it is to meet the needs of modern global change research. These include improvements to existing institutions, incentives for innovative research projects, especially in university education, and enhanced coordination of research and research promotion. Demands for greater investment in research are frustrated by the scarcity of public funds. Lack of finance is a major obstacle, blocking further growth in research personnel and equipment budgets and, through non-selective staff cuts, deprives research institutions of opportunities to explore new research pathways. Shortage of public funds has imposed a restrictive framework that must be taken into consideration whenever organizational recommendations are made. The research community is therefore compelled to think about structural changes which might generate improved efficiency. Nevertheless, for all the problems that exist, Germany's research organization has many advantages.

The strengths of a federal and pluralist structure, and the number and variety of research institutions this entails, stems from the fact that individual groups can tackle new issues flexibly and choose their own partners, especially when scientific

encouragement or financial incentives are provided. On the other hand, this structure is highly intricate, which in turn hinders the concentration of research capacities under one central topic and the execution of long-term projects within international programs.

The German Science Council has given attention to these problems facing and has drawn up a set of recommendations for transdisciplinary environmental research at German universities, polytechnics and other research establishments. The obstacles are even greater for global change research, however, on account of the international context and the need to carry out investigations with foreign partners. This also explains why, in certain areas of global change research, German involvement in international programs and cooperation with developing countries is relatively confined.

Against this background, the Council puts forward a number of general organizational recommendations, grouped under three headings:

- Strengthen existing facilities and utilize approved instruments.
- Create new facilities.
- Coordinate the promotion of research.

#### **Strengthen existing facilities and utilize approved instruments**

Existing research establishments must be given the capacity to continue ongoing projects in the field of global change research and/or to relate projects to global problems, and to start new projects involving cooperation at national and/or international level. This recommendation is directed at universities and polytechnics and to extra-university research establishments such as the Max Planck Society (MPG), the Helmholtz research association (HGF), the "Blue List" research institutes (WBL) and the Fraunhofer Society (FhG), as well as the research facilities operated by certain federal agencies. Impulses in this direction must come from the facilities themselves or from the bodies which operate and control them, i.e. by redefining the priorities and content of research and by organizational restructuring.

What is absolutely essential, however, is the use of *approved support instruments* on the part of the BMBF (joint projects, research networks) and the DFG (priority programs, collaborative research centers). Research groups and graduate colleges are suitable instruments, whereby the restrictive principle that research units must be located in a single institution should be relaxed in view of the technical opportunities provided by modern telecommunications.

All these integrating measures should also be applied in the *education and training* of domestic and foreign students and prospective scientists. Aspects of global change should be referred to during basic level courses, and studied in greater detail in advanced courses.

*Major items of research equipment* are absolutely essential in many areas of global change research. These includes equipment for remote sensing and climate research using supercomputers, research vessels, remote sensing satellites and

monitoring stations. Global change research also needs large-scale, comprehensive and long-term observation data on the environment, the economy and sociocultural aspects. It relies on comparisons between cultures and ecosystems and must build on detailed and broadly conceived case studies as well as complex models.

The Council attaches considerable importance to ensuring continued provision of these basic requirements. Germany's participation in international programs varies in quality, and in some important areas is in need of expansion. The Council recommends continued involvement in international institutions and Secretariats, in terms of input, staffing and financial contribution, whereby greater integration of German researchers by such institutions would be desirable.

#### Create new facilities

The Council recommends the establishment of a *German Strategy Center on Global Change* in order to enhance problem-solving capacity with respect to global change and to strengthen interdisciplinary cooperation. The Center would carry out complex problem analyses, using as well external experts to provide scientific support for decision-making processes. It should take up suggestions of policymakers and the public to translate these into research issues, as well as process existing scientific knowledge to support decision-making processes in politics, industry and society in general.

Small *research centers* should be set up at or around universities *for limited periods of time*; these would work on acute problems in the field of global change research over 10 years or so, and ensure German participation in international programs.

In addition, the Council recommends the creation of *research networks* as long-term, purpose-made alliances between independent research institutions for joint work on complex issues, such as a specific syndrome, and for further refinement of methodologies. These should include the use of modern technologies for data acquisition, storage and transmission within national and international frameworks. Responsible research bodies (MPG, HGF, WBL and FhG), the DFG, the BMBF and specialized research establishments and university departments should jointly create flexible institutions to deal with specific global change problems (inter-institutional research).

The Council appeals to industry and commerce, especially the multinational corporations, to set up a *Global Change Foundation* as an expression of environmental self-commitment. Such a body would help compensate for the financial restrictions referred to earlier. The Foundation should promote a dialog between the scientific community, economic policymakers and the media on global change issues. It could also be present at EXPO 2000 World Exhibition in Hanover, Germany.

#### Coordinate the promotion of research

The two most important institutions providing funding and support for research in Germany are the BMBF and the DFG. The BMBF has several ministerial departments and various project support units responsible for specific research fields relating to global change. The same is true of the DFG, which is organized according to scientific disciplines. Both institutions must strengthen their efforts towards *transdisciplinary planning and assessment*. There is also a need for closer coordination between the DFG and the BMBF regarding the deployment of instruments for promoting global change research.

Within the Federal Government, *supervisory control of global change research* is not confined to the BMBF. Although the BMU does not operate its own research establishments, it supports a number of global change research projects through the Federal Environmental Agency (UBA). Major research facilities and projects are also operated by the Federal Ministry of Traffic (BMV), Federal Ministry of Economy (BMW), Federal Ministry for Food, Agriculture and Forestry (BML), Federal Ministry of Economic Cooperation and Development (BMZ) and Federal Ministry of the Interior (BMI). The Council states a need for coordination here, which should go beyond the work of the Interministerial Working Group (IMA) on Global Change.

The Council is monitoring with great interest the efforts of the DFG to establish a *German Global Change Committee*, comprising functional units of the Senate Committee for Environmental Research (SAUF) and the German IGBP Committee, for the purpose of planning and supporting research involvement in international global change programs. This National Committee could also play a role in coordinating the various global change research activities in Germany.

The Council also recommends that the Federal Chancellery produce an integrated *Global Report* in the middle of each legislature period. In view of the processes triggered off by UNCED in Rio de Janeiro, the Report should provide information on Federal Government activities concerning global change and sustainable development. Policymaking and research activities in Germany should be analyzed in terms of their environmental, economic and sociocultural impacts within the global network of interrelationships. The Council firmly believes that such a report would become an important source of information for the general public in Germany and for foreign institutions, and that it would exert a consolidating and integrating influence on global change activities in the various federal ministries.

The work of the *German Parliament's Enquete Commissions* has had an integrating effect on German research and government support agencies. An Enquete Commission on "Global Change" could continue on the work of the Enquete Commission on "Protection of People and Environment", whereby the focus should be placed on implementing the recommendations of the scientific community as advanced, for example, by the German Advisory Council on Global Change.

For some time now, there have been discussions about establishing a *German Academy of the Sciences*, similar to those in other countries, which could state its position on issues of national importance with a high degree of independence and

authority; were such an academy to be created, the problem of global change would certainly be an important topic for it to consider.

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### Prospects

Considering its population, Germany is highly responsible for the causes of global change. Its contribution towards global change research, albeit substantial, must be radically increased. The primary requirement is not so much a major increase in research funding, or the founding of new large-scale research establishments, but the efficient use of data and knowledge already available and the synthesis of that knowledge to solve complex problems. What is also needed are organizational measures to ensure that existing global change research potential is deployed more effectively, and that gaps in the various research fields can be closed by providing a modest level of extra funding.

Transnational networking and integration into international programs at European and global level are crucially important for German global change research. According to Germany's role in the world economy, German research should play a leading role in creating and expanding research capacities in the developing countries.

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