The Development of a Sustainability Geoscope: An Interim Report

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I. Conceptual Background

1. The Vision of a Sustainability Geoscope

The Geoscope is an instrument for globally comparative observation and analysis of regions with respect to measurements that have an impact on sustainability. In this sense, the Geoscope is an observation instrument for the anthropocene. This is the era which humankind has just entered and where the tight interlinkages between human and natural environment have become obvious and are taken into consideration in an integrated worldview. The present global economic and social development is in many respects not sustainable. It cannot be maintained in this form without irretrievably destroying the natural life support functions for human society.

In order to understand Global Change and to create a transition to a sustainable development, human societies need appropriate instruments and methods which distinctly go beyond the methods that are presently available. These new methods can be summarized under the concept of "sustainability science". Sustainability science understands and treats the Earth system as a whole. This requires that the Earth system is observed in its entity, that there are methods for an integrated analysis of the Earth system, and that – proceeding from this analysis – recommendations can be given to politics and the wider public which will lead to sustainable development once they are applied. Some kind of integrated Earth system management, which is not necessarily meant to occur in a centralised manner, should be the ultimate goal.

One important step on the way to a sustainability science is to bridge the gaps between the traditional scientific disciplines. Sustainability science can only be appropriately pursued in close cooperation between natural and social sciences as well as the humanities. This alone is a great challenge that will only be managed in an iterative process. The Geoscope is an instrument for systematic collection of congruent, natural-scientific and socio-economic data on Global Change that enable a first validation of integrated views of human-environment dynamics. Proceeding from these observations, the interdisciplinary perspective can then be enlarged and deepened, which will again have an influence on additional data to be collected.

In terms of an actual implementation of this vision, the Geoscope shall "investigate selected regions on a global scale with regard to sustainable development by using remote sensing as well as observations on the ground ". Comparable criteria are to be defined, time series that should be as long as possible are to be created, and a network with other relevant research programmes is to be established. Thus, the Geoscope is also an organizational framework for the development of indicators, theories, models and political instruments for an integrated Earth system management. Within this framework, a close cooperation and division of labour between the industrialized countries in the North and the developing countries in the South is envisaged, in order to strengthen the perspective of the poorer countries regarding global challenges.

In a wider sense, new images and worldviews may be created by the Geoscope since the observation of an object always involves surprises. The combination of remote sensing data with on-the-ground-observations and the combination of natural and social sciences will create new pictures and a new understanding of interrelations in the world. Thus, the Geoscope can also be regarded as a sense organ of humankind in the transition to sustainability.

2. Components of a Sustainability Geoscope: Analysis – Observation - Action

2.1. Key Questions on Sustainability and Sustainable Development

The development of a Geoscope should be based on central research questions in order to keep the process as targeted as possible. The focus will be on global problems while emphasizing the perspective of developing countries in the South, where generally a high vulnerability to Global Change effects prevails. Based on these research questions, specially concerned and relevant regions may then be defined for observation. Within these regions, the most important actors as well as the parameters and indicators for measuring sustainability are to be determined. The following list of global problems, which is by no means regarded to be complete, covers relevant research topics for a sustainability science.

- Sustainable technology development and global diffusion
- Water supply and quality
- Biodiversity
- Health
- Urbanization and mega-cities
- Reform of the energy system, and mobility
- Changes of lifestyles
- Food supply and soil erosion
- Dynamics of conflicts

2.2. Earth System Analysis – Theories and Models

The concept of "sustainability" is difficult to define and does not imply a homogeneous theory. This concept was created in a public-political process and is dynamically progressing in a way that the requirements with respect to explanation patterns for sustainability are likely to change constantly in the future. Nevertheless, a sound observation of the Earth system requires a theoretical background which puts us in a position to ask relevant questions and to manage the complexity of the object of observation – the Earth system as a whole.

Theories can be understood as "edifices of arguments" that mutually combine observations and actions. The Geoscope as an observation instrument needs good arguments as to which parameters and indicators are important for sustainability and why these should be observed. These observations should help to examine not only alternative actions but also alternative arguments (or theories). Thus, the Geoscope can support the development, refinement and selection of different theories (or edifices of arguments) for sustainability. Observations and arguments mutually influence each other: new observations promote the development of new arguments and actions, and new arguments and actions require on the other hand new observations to examine them. One could start by systematising the presently existing observations (e.g. numerous indicators for sustainability) in the sense of a Geoscope to test presently existing arguments. The definition of required new observations can then be developed from this process.

In different scientific disciplines, prevailing theories are reflected in formalized models. These formalized models usually have well-defined information requirements in order to represent certain aspects of a more complex formulation of a problem. Models are important to formalize and comprehend complex chains of argumentation. In sustainability science, the integrated modelling of human-environment dynamics is of special importance. However, integrated modelling, with both natural and social scientific methods being included, is not a trivial process. Here a Geoscope should contribute substantially by providing a standardized consistent data base which is currently not available in the required form.

2.3. Earth System Observation – Methods of Data Collection and Systematisation

In order to be able to observe the Earth system with reasonable effort, a systematisation in different respects is required. The parameters to be observed are to be stratified as to their temporal, spatial, technical and thematic characteristics. One can distinguish between area-related data (e.g. remote sensing data), demographic data (statistics, administrative information) and personal data (motives, preferences). The spatial scaling can for example be done on three levels: global, regional (supranational) and local (sub-national).

In all these categories, one can then distinguish between data to be primarily collected and data that have to be synthetically derived as for example by aggregation, indicator formulation or modelling. Within the Geoscope framework it is likely that data processing will directly focus on synthetic or secondary data, whereas primary data can be collected using and coordinating the services of already existing institutions and programmes. The determination of relevant synthetic data can be based on diverse initiatives working on sustainability indicators, e.g. UN CSD, World Economic Forum/CIESIN, CGSDI, UNEP/Human Development Index, EUROSTAT/TEPI, EU/PPI. Various aspects of sustainability have already been compiled and described within the broad categories environment, society, economy and institutions. They should be examined, refined, systematised and theoretically founded within the framework of a Geoscope. The closely related development of "dashboards" as visualization tools allows for interactive planning exercises with these indicators, their weighting schemes and mutual influence (see also http://esl.jrc.it/dc). The Geoscope can also build upon this and contribute valuable extensions mainly in the fields of theoretical underpinning and modelling.

The combination of remote sensing data and/or integrated geo-data with socio-economic data from administrative collection systems and in-situ observations will be the central component of a Geoscope. Remote sensing is already now used within the framework of integrated GIS applications to investigate biodiversity, land use, settlement structures and risk mapping. In the future, these applications will be further developed within the framework of the European GMES initiative. The Geoscope should be in close interaction with GMES to substantially contribute to the thematic orientation of the initiative as well as to the development of remote sensing in general. Above all, some kind of "socio-economic remote sensing" should be developed, i.e. the possibilities of remote sensing should be utilized better than in the past.

With respect to ground observations, systematic comparative case studies play a central role and are already widely applied in projects like LUCC, HERO, DEVECOL or the "syndromes" approach. The strategic orientation of the Geoscope makes it necessary to define at an early stage how area-related and agent-related data can be consistently brought together. This is a fundamental aspect in securing the quality of information to be collected.

With respect to spatial scaling an efficient sampling strategy has to be developed. The great challenge here is to find model regions for which many of the already mentioned key questions for sustainability are relevant. One possibility would be to define a "loosely nested, regional structure" as it has been done for the presently on-going Millennium Assessment. Here, the local observation regions are mostly, but not exclusively, located within the next higher level of supranational regions. These in turn define on a global scale those core regions that are especially relevant for sustainability questions and are to be monitored. A first version of a list of potential regional sites may contain the following: Sub-Saharan Africa, Maghreb, Southern China, India, Amazonia, USA, Central Europe, Siberia, Australia.

2.4. Earth System Management – Communication and Courses of Action

The development of courses of actions within the framework of a Geoscope will certainly only become relevant after the above-mentioned aspects of observation and analysis have been defined quite clearly. The necessity of some kind of Earth system management should, however, be kept in mind as a guiding objective, since the relevant key questions are ultimately derived from it.

For an effective Earth system management, it is necessary to identify the most important actors and stakeholders in the Global Change process. Integrated scenario development and modelling

consequently has to include modelling of political processes (e.g. political-economic aspects). In this context, conflicts as a risk for sustainability are important, which means that within the framework of a Geoscope psychological key variables like attitudes, social relationships, knowledge, preferences und behavioural options have to be considered. Sensible political strategies and instruments could then emerge from the interplay of Earth system analysis and an intensive stakeholder dialogue.

Crucial questions that are to be answered in this context are related to the control of the system (central vs. de-central) as well as to the democratic structure and participation of relevant groups in the decision and design process.

The successful communication of complex relationships emerging from Earth system analysis requires a well-developed communication strategy and technology. This includes interactive decision support tools, simulation games and an Earth system atlas which presents not only the state of current knowledge but also the "empty pages" with respect to sustainability assessment. The "dashboards" that have already been mentioned are again a good starting point for future developments.

3. Chronology of Activities and Diffusion of the Idea

The original development of the Geoscope idea is based on intensive efforts of the German National Committee on Global Change Research as well as on the exchange and support within the International Human Dimensions Programme on Global Environmental Change. In the following, the steps taken so far towards a Sustainability Geoscope are listed.

Summer 2000	Emergence of the Geoscope idea from discussions in the Scientific Committee of IHDP
Oct 2000	At a meeting of the German IGBP, the idea of a Geoscope was informally supported
Nov 2000	First conceptual refinements of the Sustainability Geoscope with German and international participation at the first German Geoscope Workshop of the National Committee in Bad Honnef
Jan 2001	Geoscope presentation at the Global Change Conference of the National Committee in Bad Honnef with a Geoscope paper being published afterwards
Jan 2001	PIK initiates a Geoscope project; an additional researcher is hired for this project
Spring 2001	The National Committee and IHDP decide the further development of concepts to realize a Sustainability Geoscope
Mar 2001	Geoscope discussions at a GMES conference of the European Science Foundation in Brussels with positive responses of European science managers
Jul 2001	Geoscope presentation at the IGBP Open Science Conference in Amsterdam establishes international relations
Sep 2001	Basic elements of a German framework programme for Geoscope research are developed together with representatives from social and natural sciences at the Second German Geoscope Workshop in Weilburg
Oct 2001	Considerable support for the Geoscope concept by leading international scientists and organizations at the First International Geoscope Conference in Berlin
Oct 2001	First concrete plans and agreements with international projects on "water and sustainability" as pathfinders for a Sustainability Geoscope
Nov 2001	Third German Geoscope Workshop in Berlin; preparation of draft programme proposals within the framework of a Geoscope Research Initiative
Dec 2001	Programme proposals for a Sustainability Geoscope submitted to the National Committee

About one year ago it was still unclear whether a Geoscope initiative that so far had been only roughly defined would find large and open support in the scientific community, which was a prerequisite to have it initiated at all. The workshops therefore served not only in the national but also in the

international context as a test to find out if different disciplines would be willing to support a Sustainability Geoscope not only ideally but also to actively participate in the further development of it. This necessary intention was shown more clearly than expected during the workshops and in other discussions in different scientific committees and at some conferences. It is important to note that well-known scientists and institutions have expressed their feeling that a Sustainability Geoscope is "the right idea". Thus, an atmosphere around the Geoscope has been created that is determined by a spirit of openness and cooperation. A productive dialogue, even with some sceptics, has been initiated.

The following scientists who participated in the international discussion have shown their active interest in a Sustainability Geoscope: Arthur Alexiou, UNESCO; Robert Corell, Harvard University; Jean-Louis Fellous, CNES; Marina Fischer-Kowalski, University of Vienna; Helmut Geist, LUCC; Pavel Kabat, Wageningen University and Research Centre, Dialogue on Climate and Water; Marc Levy, CIESIN/Columbia University; John Marks, Netherlands Organisation for Scientific Research; Eugene Rosa, Washington State University; Jean-Claude Worms, European Science Foundation; Brent Yarnal, Pennsylvania State University, HERO.

The Sustainability Geoscope has now become an established element in the national as well as international discourse about next steps to be taken in Global Change Research. This is an important result, as it shows that the Geoscope idea meets, in the view of various actors, the necessities of the next phase of research. On this basis, further development of a Sustainability Geoscope seems to be reasonable.

Around the theme "Sustainability and Water" personal and conceptual alliances have been established to the IGBP/IHDP Cross Cutting Theme on Water and the Dialogue on Climate and Water. In the field of "Earth remote sensing and socio-economic research", a dialogue was initiated with DLR. On the international basis, a cooperation with CIESIN has been agreed through which the connection with data processing activities at NASA will be developed. The Geoscope may also play a pioneer role within an integrative programme component of the European programme GMES.

Many discussions revealed that the main challenge for a Geoscope is to combine a synoptic global worldview with a local, site-specific, case-dependent perspective. Top-down and bottom-up approaches have to be combined through a suitable connection of global models with inter-linked regional case studies. Similar approaches can be found in projects like LUCC, HERO or DEVECOL to which personal connections have been established. The development of corresponding data sets from satellite remote sensing on the one hand and ground observations on the other is generally desirable, however, it is still a great challenge to actually implement it.

The Geoscope has basically two large tasks to fulfil. First, it has to provide data for integrated scientific analysis of Global Change processes (theory building, modelling, scenario development) and, second, it has to support public and political decision processes within the framework of Earth system management activities (communication of results, highly aggregated representations, decision support tools). Since these two areas may have very different information requirements, it has to be clarified more precisely how this can be organized within the framework of a potential multi-stage Geoscope.

II. Practical Implementation

1. General Criteria for Geoscope Research Programmes

The development of a comprehensive Geoscope can only be done step by step in a recursive learning process. Main emphasis is put on the establishment of a global network of already existing research programmes and initiatives (public and private). The Funding of this endeavour should primarily be based on the international coordination of national research support activities. Without doubt, the development of a Geoscope as it is defined here will require a time period of at least 20 years. This is confirmed by experience from other projects, e.g. the coordination process on sustainability indicators in the UN CSD, or the harmonisation in ecological environmental observation in Germany over the last decade.

The development of a Geoscope may include the following concrete steps:

1. Quality-oriented screening of already existing data bases and combination of data from existing projects in a meta data system (Geoscope as a clearing house for existing information and projects)
2. Screening of integrated Global Change models to identify data gaps and needs
3. Focusing of future work along key research questions
4. Identification of critical parameters in a scientific discourse
5. Design of the Geoscope for the collection of newly required primary and secondary data.

Comparative regional studies on various topics should be carried out as a central component of the Geoscope idea. They should empirically evaluate actions and measures that are relevant for a "sustainability transition". Even actions and measures that work against a "sustainability transition" should be considered here. The following keywords can be used as a theoretical scheme for comparative case studies:

- The regions [context, actor, problem]
- Ex-ante analysis [goals, expectations, options]
- Ex post analysis [effects, mechanisms, feedbacks]
- Conclusions [lessons for the future, open questions]

Within the framework of these comparative case studies, a small number of variables should be identified and collected in a large (potentially global) sample in such a way that long-term comparable time series emerge. Very different problems may be investigated with the main emphasis on the treatment of water as a pathfinder theme. The development of a Sustainability Geoscope is based on synergies between different funding instruments and research projects that promise interesting results in this perspective. As a prerequisite for integrative research approaches, it may be requested that each research group should consist of a disciplinary mix of environmental scientists as well as social scientists and specialists for remote sensing and/or GIS.

2. Programme Proposals for a Geoscope Initiative

2.1. Geoscope Competition

An international competition for excellent research questions and comparative regional studies in the area of sustainability research will be initiated within the next weeks. This activity will be organized within the framework of the Geoscope and will be supported by important international organizations like e.g. IHDP. Details about the rather symbolic awards are still to be defined. Through this competition, Geoscope can for the first time appear as a platform for an interdisciplinary exchange of knowledge in the area of Sustainability Science, and the Geoscope website will be used for this purpose.

2.2. Geoscope – Technology Development

It is urgently required to link Global Change Research with research in the field of engineering and technology development. An open call for proposals (CFP) by the DFG may be an appropriate instrument to sponsor this kind of integrated research. The following preliminary sketch suggests the direction of such a CFP. This draft will be further developed by a Geoscope working group until mid-January.

Sustainable Technology Development - Technologies for Sustainable Development

One of the great challenges of the 21st century is how to deal with scarce resources and how to manage the unavoidable uncertainty related to it. The growing influence of human interferences on the Earth system will have long-lasting and unpredictable effects. Technologies will play a crucial role in achieving a sustainable development. Therefore, new kinds of technology development are necessary, which have to be supplemented by a pro-active management of long-term and global changes.

Technology development and its influence on a sustainable development are cross-cutting themes that can only be investigated in an integrative and trans-disciplinary context. Technology development in this context cannot simply be planned at the drawing board, due to existing non-linearities, indeterminacies as well as social and economic interactions. Those sciences that deal with the development and diffusion of technology have not yet been sufficiently included in Global Change Research (GCR). On the other hand, engineering may be able to benefit much more from GCR than in the past. Therefore, the competences of GCR and engineering have to be integrated and/or brought together.

There are two communities in this debate. One group emphasizes that there is a large number of technological options that are not being utilized. The other group argues that markets usually achieve a nearly efficient allocation, and such "no-regret-options" are apparently not exploited for certain reasons. This requires a meta-theory which can bring together competing approaches and from which courses of action can be derived.

Economic models are as a rule calibrated to efficient conditions (rational behaviour of individuals), although it is clear that not all influencing factors are adequately represented in the models. An integration of determinants of human behaviour – institutional, social and cognitive restrictions – that have so far not been considered offer the chance to improve economic models.

Engineering has already provided important knowledge about the interaction between technology, humankind and the environment. The next challenge will be to relate this understanding systematically to global and long-term changes. The effects of technological developments on sustainable resource use should be fed into the engineering process in the same way as e.g. local customer orientation. This is the only way to avoid misplaced investment of material, intellectual and financial resources.

Research approaches to be funded should focus on the following themes:

1. Renewable Resources
   Focus should in the first place be put on renewable resources (water, biodiversity, soil, landscape) to avoid valuation problems with non-renewable resources.

2. Measures
   Actual measures and actions should be the starting point of the projects in order to systematically guarantee a learning-by-doing process. Measures should include technical and economic, legal and planning actions of governments as well as non-government actors.

3. Reactions on measures
   Both the development of technologies as a reaction to the described measures as well as socio-economic adjustments are to be investigated.

4. Results
   The results of measures and actions are to be documented in a trans-disciplinary way and to be analysed with regard to causal mechanisms. This will yield knowledge about the interaction of various influencing factors. Against this background, the results of the measures considered are to be compared with previous expectations of the actors concerned. Otherwise,

fundamental knowledge cannot be generated in this field. Moreover, it is necessary to include natural-scientific results in the evaluation process, e.g. sustainability of resource use.

5. Regional comparison
   The projects should cover several regions. A systematic knowledge can only be reached by regionally comparative research. At the same time, the required profoundness of data collection can only be realized by focussing on selected regions.
6. Long-term connectivity
   The studies are to be designed in such a way that they can also be used for other comparative studies in the same and in additional regions. For this purpose, it would be desirable if a methodological frame were provided for the projects.
7. Global embedding
   Regions should not only be investigated separately but their interactions in the global context should also be included.

An overall methodological framework could look as follows:

- Connection between quantitative and qualitative analyses
- Explicit representation of uncertainty
- Spatial and temporal comparability
- Focus on empirical work
- Integration of spatially explicit data with non-spatial data
- Reproducibility of empirical steps
- Documentation of data and results
- Suggestions for selected indicators for evaluation

A special aspect is the reference to natural sciences and remote sensing, i.e. mainly the development of methods and algorithms to derive patterns and indicators from remote sensing data, which allow for a combination with spatial units of the socio-economy. Here, a dialogue and a tight cooperation between remote sensing data analysts (in particular physicists, computer scientists and geo-scientists) and socio-economists is necessary. The subsequent new requirements for remote sensing measurements, which are not yet covered by existing sensors, have to be communicated to sensor developers.

The integrative treatment of the aforementioned research themes exceeds the capabilities of the scientific communities concerned and requires initiation through the funding instrument of an open CFP. By means of such a CFP, the DFG will be able to give new impulses for a stronger coverage of this problem and promote trans-disciplinary research. Thus, it would be possible to create a trans-disciplinary research network and to initiate a number of innovative research approaches.

2.3. Geoscope – Data Management and Indicators

The Geoscope may become an actively or passively structuring element in a system for sustainability monitoring. Important actor levels are:

Important information demander (politics, economy, media)
Action
Important information and data users (e.g. CIESIN, sustainability indicators)
Theory and analysis
Geoscope
Observation
Data infrastructure (e.g. GMES)

This results in the following practical tasks for a Geoscope:

- Screening of existing indicators as to their relevance
- Extension / consolidation of existing data (which data bases have to be processed and made accessible?)
- Targeted measures to close data gaps, new data types

Further areas in which the Geoscope is actively and passively structuring:

- Consolidation and continuity of indicators ("sustained and sustainable indicators")
- Consistence of data definition and methods
- Continuity of availability of data and models
- System to evaluate data as to their relevance, quality, informational content (spatial, temporal)

Thematic focuses:

- Landscape and land use development (politics, economy, users; data required, models, co-operations; typical remote sensing patterns that reflect political measures)
- Attitudes, lifestyles, social dynamics (socio-economic surveys in many regions of the world)
- Infrastructure of mega-cities (interaction between urban structure, water supply, food production, socio-economic structure, world trade, regional political structures)
- Developing countries and climate change (Which variables? Which problems? Which monitoring of adaptation, mitigation, risk?)
- Spatial mapping of available aggregated socio-economic data with remote sensing data
- Algorithms for the production of socio-economic parameters from satellite observations (settlement structures, types of cities, types of houses; agricultural signals: fallow periods, crop periods, sowing periods, irrigation patterns, crop rotation, forest farming, deforestation)
- Goal conflicts (biodiversity, bio-fuels, global food security, tourism)
- Innovative data (e.g. corruption)
- Soil moisture, water: political and economic effects

Environment for research projects

- Integrated modelling of political and economic measures for sustainability, global treaties, regional decisions
- It should be seriously reflected whether the questions posed to the models can be falsified or verified
- Each project has to show how it is linked with other projects and how it refers to the entire Geoscope concept
- Data sets and models have to " live on"

Methodological application

- GIS systems, other data systems
- Participation (north/south, insider/outsider)
- Institutional structures
- Securing of data quality

Socio-economic remote sensing

One focus in this area is the identification of spatial and temporal patterns which can be globally mapped and explicitly related to certain socio-economic patterns (e.g. typical patterns of deforestation by different social groups and economic interests, irrigation patterns in agriculture, fragmentation of landscape). Path breaking innovative research should prove that certain data sets of remote sensing will only become significant importance if they are evaluated together with basic socio-economic information and, on the other hand, some socio-economic information will get a spatial and temporal dimension that is mapped with remote sensing. Generally, we want to demonstrate how the role of

remote sensing can be implemented in a future global information system that is not primarily focused on natural scientific research. Here, close relationships can be found to the European information system GMES that is based on space data and was initiated by the EU Commission and ESA, for which Geoscope could be a think tank in the sector of information analysis and evaluation.

Cornerstones of a research programme would be:

- Informational value of remote sensing for socio-economic research ("socializing the pixel")
- Sensitivity of parameters and indicators for the analysis of development and sustainability
- Spatial transformation and scaling of socio-economic statistical data ("pixelizing the social")
- Coupling of natural-scientific and socio-economic models
- Use and parameterization of socio-cultural factors for the analysis of development and sustainability

2.4. Geoscope – Water

Following the comprehensive experience gained from GLOWA, stronger integrative research approaches seem to be possible. The following aspects should be understood as suggestions for a possible extension of the GLOWA programme.

With a view to enhance the existing activities in the different GLOWA projects with the intentions of Geoscope and to extend them, river basins were considered to be natural units and thus a scale that will remain relevant and favourable for future research. From the Geoscope side, the following areas seem to be a promising stimulus for further development of the GLOWA projects, where suggestions should be made both on the scale of individual projects and beyond them:

1. The theme "health and water" is of special relevance for the Geoscope, since local and regional conditions are increasingly combined with global aspects and thus the basic question of the Geoscope can be addressed in terms of bridging the gap between these scales. Moreover, this theme is of high relevance and has generally been treated insufficiently so far. The basic research question could be: *How does water stress and water pollution affect health, especially with regard to the epidemiology of infectious diseases, health systems and health policy?*

   Additional thematic areas that are considered to be import from the social-science perspective of the Geoscope are: conflict processes, the dynamics of social adjustment processes and especially a catalogue of necessary political, technological and instructional measures.

2. The desired condensation of *joint perceptions* and *possible synergies* between already existing partial projects of GLOWA, e.g. with regard to key indicators relevant for the Geoscope, is of a rather methodological and conceptual kind and thus runs across the thematic contents of the Geoscope.

3. Moreover, it is required to have a long-term integration beyond the existing borders of the different GLOWA regions by asking concrete questions as e.g. *Which supra-regional factors influence problems on the scale of the river basin area and how can the relationship between different scales be taken into account?*

The concrete goal of a Geoscope-motivated further development of the GLOWA projects could be to create first prototypical "products" for a Geoscope on the basis of knowledge already gained as well as further ongoing process analyses. It was discussed to jointly develop a GLOWA-CD with a platform for data, analyses and simulations from single GLOWA projects. Moreover, this CD could provide the possibility to use the existing indicators somehow in the form of sustainability dashboards and should give access to the results of GLOWA as a kind of "result-experience-CD".

2.5. Geoscope – Biodiversity

Within the framework of the Geoscope approach, it seems to be reasonable to suggest an integrative extension of the already existing programme BIOLOG and/or BIOTA with a focus on socio-economic aspects. Against the background of already on-going but rather natural-scientific oriented projects, societal prerequisites and framework conditions for management and sustainable use of biodiversity should be investigated more precisely within such a programme.

The following exemplary themes could be the focus of a multi-factoral and multi-scale investigation:

- The importance of perception, knowledge and evaluation of biodiversity against the background of its direct or indirect use depending upon culture, history, religion, lifestyle and economy and the evaluation of its future potential.
- The investigation of prerequisites of a trend reversal required in the respective systems
- The relevance of economic steering factors like ownership, property rights, resource access as well as suitable markets, trading chains and distribution possibilities.
- The role of controlling institutions on local, regional, national and international levels (standards, rules, laws, conventions).
- The importance of teleconnections and their increase due to globalisation, especially migrations and invasions, as well as markets and international regulation system.

Within the framework of the investigation, where the disciplines concerned should already be fully integrated when formulating the research questions, the comparison of local or regional case studies, including already existing networks for biodiversity research, the analysis of measures for sustainability or the design of conservation measures may be in the centre of interest and possibly be combined with remote sensing and modelling (e.g. coupling EO data with socio-economic or other GIS data, spatial and temporal). In favour of a coherent overall approach, the interdisciplinary groups of scientists are expected to be willing to participate in the development and transformation of standardized data acquisition protocols and concepts with a necessary regional adjustment.

The projects should either comprise the interpretation of time series in the sense of a long-term monitoring or should at least (immediately or later) enable temporal comparisons. Still, the derivation of suitable indicators may be reasonable or problematic, depending on actual circumstances. The covering of concrete measures that can be interpreted as part of a transition towards sustainable management is desirable but not mandatory. A participative approach is favoured on the level of the host countries and also the local analyses of biodiversity users.

2.6. Geoscope – Mega-Cities

Within the Geoscope initiative, the theme urbanization and mega-cities should for the time being focus on water problems, in order to establish this problem area as a pathfinder theme and an overall link between the different programme conceptions.

The management of water resources is mostly seen as a regional or even local problem. The regional problems that we face today due to Global Change have to be seen from the global perspective as well. This is in particular true for cities. Urbanization makes more and more people live in mega-cities. This trend is even more increased by migration flows. The material supply for these mega-centres changes the flow of goods on a global level. A Geoscope programme has to deal with the analysis of the causes and consequences of these changes.

The following important categories were identified to structure the research questions:

- SCALES OF ANALYSIS
  - Interaction Global Change - urbanization
  - Interaction urban - rural
  - Interaction population-technology-environment in urban areas

- CROSS-CUTTING THEMES
  - Health
  - Centralization - Decentralization (technology AND institutions)
  - Structure of water management (organizational forms) - e.g. extreme scenario of total privatisation with a few firms that control the global market
  - Strategies to secure water supply by managing local, regional and global water flows (including "virtual" water)
  - Water as an economic commodity – differentiated view, fair price structures and mechanisms of allocation

Hypothesis: Planning strategies and technical solutions that were developed under well controlled boundary conditions with a good information base in industrialised countries cannot be adjusted to the present situation of developing and threshold countries.

The analysis and comparison of the strategies in urban planning (infrastructure, institutions) and the growth dynamics of urban centres in developing and threshold countries with regard to Global Change should be the focus of activities. Remote sensing serves here as a central instrument to detect the growth of urban centres (in the past and in the future) and to develop scenarios on this basis. Different groups of actors should be included in water management to develop new concepts of participative planning on all scales. It should also be investigated if new concepts (e.g. decentralised systems) can be transferred from one scale to the other, i.e. between settlement, town and mega-city.

Possible research questions are:

1. Global Change and cities
   - Where is the connection between global climate change, migration and water supply?
   - How can globalisation be taken as a chance for a sustainable water management in cities?
   - Which are suitable institutional framework conditions in different cultural contexts to secure water supply and waste water disposal?
   - What are the forecasts for water supply in connection with urbanization, development and lifestyle?
   - Which role do cities play in the global water cycle (incl. virtual water)?
   - Which role do water concerns play with regard to water-political decisions in cities?
   - Which financial investments in urban water supply are caused by climate changes?
2. Interaction urban / rural
   - What are the reasons for the competition between urban and rural demands for water resources that become more and more scarce?
   - What are the advantages/disadvantages of technical, urban solutions compared to integrated river basin management, in order to secure water supply?
   - Which water supply systems are susceptible to a changed climate variability?

3. Relationship population-technology-environment in cities
   - Water as a limiting factor for urban development? (industry settlements - economic development)
   - How can it be secured that the needs of the population will not be neglected due to economic interests and power structures (corruption index as indicator)?
   - Symbolic importance of water in urban life – influence of technology and lifestyle.

- What is the effect of water stress and pollution in different regions on health, especially with regard to the epidemiology of infectious diseases, on health systems and health policy – influence of migration and poverty?
- How effective are urban planning measures (e.g. reduction of paved surfaces) to reduce flood events?

2.7. Geoscope – Health

Relevance of health for a Sustainability Geoscope

Global changes that are caused by human activities could have an immense influence on human health. These global changes form a group of unprecedented environmental disturbances (e.g. soil degradation, water shortage, loss of biodiversity, changes in the lower and medium atmosphere). Impacts of global environmental change on human health are: newly affected areas for various vector-borne infectious diseases as a consequence of climate change, land use and socio-demographic changes; respiratory problems due to air pollution; increased cancer and eye diseases due to ultraviolet radiation; cardiovascular and respiratory diseases caused by heat waves mostly in cities. Moreover, many health problems are due to complex and interconnected sequences. Fast economic and demographic development and rapid global environmental changes in today's world require a broad perception of the factors determining public health. A deficit in social capital, for instance, has an influence on the health perspectives due to the widening gap between rich and poor and a weakening of the health systems. One major goal of human development is the protection of human health in view of the rapid Global Change. In order to secure sustainability, the development of a methodological framework to identify present and future health problems becomes necessary. A change from the identification of the risk factors of diseases to system-oriented studies on the large-scale influences on health is indispensable. This should come along with the identification, quantification and reduction of the risks for health that are based on specific local, social, behavioural and environmental factors. It is increasingly recognized that it is necessary to critically assess the ecological conditions under which health improvement can be achieved and maintained for the entire world population. Sustainable good health of the population needs an appropriate management of social resources, economic relationships and the environment. Moreover, health is the basis and prerequisite for productivity and economic development. The great uncertainty as to the degree of possible effects caused by Global Change, the uncertainties in modelling (e.g. vector ecology as a factor in malaria models) and the poor data situation require research, especially interdisciplinary research, that considers and integrates the theme health across all questions of Global Change as well as the development of early warning systems. Both approaches should be based on the „precautionary principle“. The goal of a Sustainability Geoscope – with regard to health – and also the content of a call for proposals should therefore be the development of early warning, mitigation and adaptation strategies as well as political interventions for a sustainable development.

The basis of a project within the framework of a Sustainability Geoscope should comprise the following components (cross-cutting themes):

- Inclusion of remote sensing/GIS technology
- Consideration of vulnerability
- Consideration of socio-economic factors
- Combination /integration of natural and social sciences
- Research on the epidemiology of transferable and non-transferable diseases
- Consideration of the health system
- Coping mechanisms and adaptation strategies
- Sustainable development

An overall goal should be to collect consistent data with different methods in different disciplines and on different scales (from local to global and even space). Based on this knowledge, recommendations

should be formulated for adaptation strategies, interventions and development cooperation on individual, household, national and global levels.

These cross-cutting themes should be considered for the following fields:

Important fields of Global Change and their direct and indirect consequences for health that should be considered within the framework of a Geoscope would be:

- Impacts of climate change on transferable and non-transferable diseases (modelling, scenarios)
- Effects of increased ultraviolet radiation, especially on the immune system
- Loss of biodiversity
- Destruction of marine ecosystems
- Freshwater shortage
- Soil degradation
- Urbanization
- Social and economic development

Overall methodological approaches could be:

- Evaluation of possible consequences for health from global environmental change with methods exceeding conventional risk analyses with regard to existing exposition;
- Investigation of the dynamics of the non-linear nature of changes in large complex systems, the interaction and the reference to future scenarios;
- Data collection (data rich sentinel sites);
- Mathematic modelling, historical analogies and forecast;
- Development and improvement of early warning systems through ground-based data collections, supplemented by remote sensing;
- Complex scenario-based impact analyses.