A Sustainability Geoscope: defining an integrated information base for interdisciplinary modeling of global change

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Abstract

The 21st century will be characterized by global change at an unprecedented scale. Human activity on the planet has reached a dimension which alters the earth system as a whole, mainly as a combination of population growth, resource use, waste disposal, and technological advances. In order to meet the challenges of global change, human society has to develop a more comprehensive global information base to guide informed economic, social and environmental action in a transition to sustainability. An emerging sustainability science and its cross-disciplinary theoretical concepts will require more integrated data sets and modeling tools to provide systematic, structured analyses of global change issues. Integrated modeling efforts will contribute to bridging the traditional gaps between natural and social sciences, and this will in turn raise the demand for data of a new quality, especially in economics and social sciences. At the Potsdam Institute for Climate Impact Research (PIK) recently the idea of a "Sustainability Geoscope" has evolved. The Geoscope will provide a framework for an observation and monitoring system on a global scale, comprising economic, social, environmental and institutional issues. Data sources will be a combination of satellite remote sensing with on-the-ground observations. The objective of this paper is to present the Geoscope idea and discuss possible connections and mutual benefits with recent efforts in global economic data collection and analysis. [2]

Keywords

Sustainability Geoscope, Sustainability science, Global change, Sustainability transitions, Earth system analysis, Earth system management, Sustainability indicators, Integrated modeling

1 Introduction

The 21st century will be characterized by global change at an unprecedented scale. Human activity on the planet has reached a dimension which alters the earth system as a whole, mainly as a combination of population growth, resource use, waste disposal, and technological advances. In order to meet the challenges of global change, human society has to develop a more comprehensive global information base to guide informed economic, social and environmental action in a transition to sustainability. This requires new theoretical concepts, continuous data streams with sufficient spatial coverage, and improved modeling activities for simulating complex scenarios of the human-environment interaction. Major issues with a strong need for interdisciplinary approaches include

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[2] This paper is the outcome of a workshop series over the last 18 months and of numerous discussions with our colleagues at the Potsdam Institute and elsewhere. We are grateful for the stimulating exchange with a number of workshop participants and for the enthusiastic spirit which has evolved around the Geoscope idea. For updates on this initiative please visit www.sustainability-geoscope.net .

transitions in the global energy system, regional and global water use, land use dynamics and soil erosion, and biodiversity loss.

First steps towards an integrated assessment of the earth system have been taken, based on research experience from global climate change and the International Geosphere-Biosphere Program (IGBP). These efforts were made possible through the development of global observation systems based on satellite remote sensing, weather stations and other monitoring tools. However, coverage of human activities and economic developments, especially technological change, have been unsatisfactory. The International Human Dimensions Program on Global Environmental Change (IHDP) has initiated several research projects to fill these gaps. In terms of economic modeling, the Global Trade Analysis Project (GTAP) provides an example of a joint international effort which has over the last years created a common database and a modeling framework for consistent global economic analysis. One of the major virtues of GTAP is the establishment of a harmonized economic information base on a wide range of diverse countries and data sources. So far, however, coverage of environmental factors has been rather limited, thus restricting the application of truly integrated modeling approaches.

An emerging sustainability science and its cross-disciplinary theoretical concepts will require more integrated data sets and modeling tools to provide systematic, structured analyses of global change issues. Integrated modeling efforts will contribute to bridging the traditional gaps between natural and social sciences, and this will in turn raise the demand for data of a new quality, especially in economics and social sciences. At the Potsdam Institute for Climate Impact Research (PIK) recently the idea of a “Sustainability Geoscope” has evolved. The Geoscope will provide a framework for an observation and monitoring system on a global scale, comprising economic, social, environmental and institutional issues. It will be built upon well established efforts and experiences in economics and social sciences, like IHDP and GTAP, and the natural sciences, like IGBP, as well as numerous activities for the development of sustainability indicators. Data sources will be a combination of satellite remote sensing with on-the-ground observations.

The objective of this paper is to present the Geoscope idea and discuss possible connections and mutual benefits with recent efforts and achievements in global economic data collection and analysis.

2 Sustainability science and the Geoscope vision

The present global economic and social development path is in many respects not sustainable. It cannot be maintained in this form without irretrievably destroying the natural life support systems for human society. Humankind has entered the "anthropocene", a new era in which the tight inter-linkages between human society and the natural environment have become inseparable and are taken into consideration in an integrated worldview (Crutzen, 2000).

In order to better understand global change processes and to achieve transitions to a sustainable development path, human societies need appropriate instruments and methods which go beyond the methods that are presently available. These new methods can be summarized under the concept of "sustainability science". Sustainability science seeks to understand the fundamental character of interactions between nature and society (Kates et al., 2001). Hence it understands and treats the Earth system as a whole. This requires that the Earth system is being observed in its entirety, 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 (Schellnhuber and Wenzel, 1998; Schellnhuber, 1999). Some kind of integrated “Earth system management”, which is not necessarily meant in a centralized manner, should be the ultimate goal.

One important aspect on the way to a sustainability science is to bridge the gaps between 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 development of a sustainability science has to comprise the following segments:

- Observation: What is actually happening? Very diverse methods have been developed in the different scientific disciplines, including remote sensing, weather stations, national economic accounting, surveys and household panels. To combine these methods in a meaningful way will be the task of a GeoScope.
- Mapping: Where does it happen? Spatial extension and explicitness matters when it comes to analyzing nature-society interaction. Geographical information systems (GIS) provide a powerful toolkit for combining a wide variety of data and qualitative information and for conducting multi-layered analyses. As a segment of sustainability science this may be called GeoGraphy.
- Analysis: Why is something happening? New information and new images of our world have already led to a new mindset, something like a "global subject" emerges (Schellnhuber, 1999). Humankind has developed a range of models and simulation tools and begins to understand the Earth system as a whole. A GeoMind manifests itself e.g. in new global treaties on climate protection.
- Decision-making: What kind of world do we want? What must we do to get there? Decisions on required actions involve all levels, from individuals and small social groups to nations and ultimately the global society. The GeoMind will express itself in numerous activities and measures with global relevance which may be summarized as GeoAction.

Effective GeoAction will require a powerful and well-structured "management information system", i.e. a global monitoring and observation system which covers environmental as well as social and economic conditions. This instrument is some kind of “macroscope" (de Rosnay, 1975, 1995) which reduces the size of the observed object to a manageable scale. 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, 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 programs 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 labor 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.

Effective Earth system management will also require to identify the most important actors and stakeholders in the global change process. Integrated scenario development and modeling consequently has to include modeling of political processes (e.g. political-economic aspects). In this context, conflicts as a risk for sustainability are important, which means that psychological key variables like attitudes, social relationships, knowledge, preferences and behavioral 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.

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 a transition to sustainability.

3 Research questions for a sustainability transition

Interesting scientific discoveries can only be achieved if the right questions are being asked to begin with. It has been suggested that an emerging sustainability science should focus on a set of core research questions. The questions, which are listed below, should cover the fundamental character of interactions between nature and society and on society's capacity to guide those interactions in the future along more sustainable trajectories than in the past (Kates et al., 2001):

- How can the dynamic interactions between nature and society – including lags and inertia – be better incorporated into emerging models and conceptualizations that integrate the Earth system, human development, and sustainability?
- How are long-term trends in environment and development, including consumption and population, reshaping nature-society interactions in ways relevant to sustainability?
- What determines the vulnerability or resilience of the nature-society system in particular kinds of places and for particular types of ecosystems and human livelihoods?
- Can scientifically meaningful "limits" and "boundaries" be defined that would provide effective warning of conditions beyond which the nature-society systems incur a significantly increased risk of serious degradation?
- What systems of incentive structures – including markets, rules, norms, and scientific information – can most effectively improve social capacity to guide interactions between nature and society toward more sustainable trajectories?
- How can today's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition toward sustainability?
- How can today's relatively independent activities of research planning, monitoring, assessment, and decision support be better integrated into systems for adaptive management and societal learning?

The new challenges related to monitoring and observation of global environmental and social conditions will be the core agenda of a Geoscope. 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 affected 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 initial list of global problems, which has been developed during a Geoscope workshop series, covers relevant problem areas to be covered by sustainability science and to be observed by a Geoscope. The list is certainly not complete and will have to be further extended and refined in an ongoing process.

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

More detailed research questions on these general problems have been defined during the first international Geoscope workshop in 2001 and have been summarized in a workshop report (Lotze-Campen, 2001).

4 Challenges of Earth system modeling and analysis

The concept of "sustainability" is difficult to define and is not rooted in 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 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 systematizing the presently existing observations (e.g. numerous indicators for sustainability) in the sense of a Geoscope to test presently existing arguments. Additionally required observations may then be defined during 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 comprehend complex chains of argumentation. In sustainability science, the integrated modeling of nature-society interactions is of special importance. However, integrated modeling, with both natural and social scientific methods being included, is not a trivial process. A Geoscope should contribute substantially to facing this challenge by providing a standardized and consistent global data base, which is currently not available in the required form.

The economic discipline has a strong record not only in describing a complex system like a national economy with a very limited set of key indicators, but also in rigorous modeling approaches and analytic tools. Economic theory and methodology have a strong influence on public planning and political decision-making. This will remain the case in the 21st century, but matters of long-term sustainability will increasingly be on the agenda as it becomes obvious that a too short-sighted policy is ultimately self-defeating (Sachs, 1999).

In the relatively new field of Integrated Assessment studies strong efforts have been made to develop integrated modeling tools, primarily for analyzing effects of energy consumption and global climate change. In the future, these efforts have to be extended to new thematic fields, like the ones mentioned in the previous chapter. At the Potsdam Institute for Climate Impact Research (PIK) a core project deals with the development of a next generation of Integrated Assessment modules[3], which comprise a range of modeling tools from both natural and social sciences that may be combined in various constellations according to the actual problem to be analyzed. This decisively modular approach is in contrast to the construction of a single mega-model. The crucial challenge here is to come up with efficient methods for consistent coupling of a variety of models, from comparative-static economic models to fully dynamic models of vegetation development or climatic change.

Truly integrated modeling means that e.g. models of the biosphere have to take human action explicitly into account, while in the other direction socio-economic models have to treat the natural environment as more than just a static set of boundary conditions and constraints. The current state of the art in global dynamic vegetation modeling does not include any human management decisions, e.g. in agriculture, forestry or urban development. However, it is obvious that human action is considerably shaping the Earth surface and there are no longer distant places to refer to as "fully natural". On the other hand, most economic models do not take the natural environment endogenously into account, but rather as exogenous constraints to human behavior. This shows that by lowering the disciplinary boundaries and approaching each other in a constructive manner, both sides could benefit from the knowledge gained in the other research community.

So, with respect to general equilibrium modeling the question may be asked: How "general" is the GE approach really? It certainly provides an almost complete and theoretically consistent description of all economic actions and resource flows within a national and global economy. However, in order to become an integral part of an emerging sustainability science, economic analysis and modeling have to face a number of challenges.

- Spatial explicitness: one of the major differences between biosphere and climate models on the one hand, and socio-economic models on the other is the treatment of spatial dimensions. Whereas economic analysis is mostly agent-based and usually takes transportation costs as the only spatial aspect into account, models of the biosphere and climate conditions put a strong focus on spatial distribution and dynamics, place-based phenomena and scaling problems. This goes down all the way to data gathering and observation, as economic data are usually only available as summary indicators related to specific administrative units, whereas environmental data are regularly collected in a GIS compatible format at various grid sizes all over the globe.
- Long-term dynamics: the definition of “long-term” differs significantly between e.g. climate models and economic models. While climate projections over a century or more are regularly conducted, the forecast of economic trends beyond a decade quickly enters the area of pure speculation.
- Equilibrium theory vs. Critical thresholds: is it realistic to model the interactions between the human sphere and the environment as a system which always returns to a stable equilibrium? Or are there critical thresholds which must not be surpassed without the risk of irreversible damages to natural life support systems for humankind? Recent advancements in economic theory and modeling which deal with lock-in effects, path dependence and bifurcations should be further explored in order to become more compatible with modeling approaches on biosphere and climate dynamics which include possible structural breaks and necessary guardrails.

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[3] Potsdam Integrated Assessment Modules (PIAM), see www.pik-potsdam.de/topik/t4egs/piam/ .

- Diffusion of lifestyle patterns: individual preferences and lifestyles have a strong influence on human action and hence their effects on the natural environment. However, “lifestyle” is very diffuse concept which is not easily defined and consistently modeled. It is clear that changes and diffusions of lifestyles are at the heart of all globalization processes which heavily shape our present state of the world. But very little is understood of how certain preference changes emerge, how they are amplified and how they spread locally as well as on a global scale. It may be the case that any kind of “transition” which involves human action can only be understood if the underlying causes of preference changes can be explained.
- Induced innovation: The true nature and potential of technological change and innovation, including institutional design, has to be further explored as it crucially defines the adaptive capacity of human society to global environmental problems and challenges. This aspect has by far not fully taken into account in the assessments of global environmental impacts on human welfare. The question of how resilient social and economic systems are to external shocks from changing environmental conditions, is viewed very differently in the socio-economic disciplines and the natural sciences. The strong disciplinary divide has led to very different perceptions: while economists usually consider the natural environment as a fairly resilient system which absorbs almost any pressures from human behavior, many environmental scientists take quite the opposite view that nature is highly vulnerable to human impacts while society has a high adaptive capacity.[4]
- Optimizing behavior vs. learning-by-doing: In the past a worldview has dominated human action, which was based on the assumption that, based on scientific theory and the derived measures and technologies, most problems could be solved by some kind of engineering solution to be constructed on the drawing board. This also corresponds with economic models which center around human actors with perfect foresight and a set of preferences which are applied to optimize their behavior in a given environment. While this approach is very powerful in explaining economic processes under many different circumstances, it is questionable whether this style of thinking will suffice to guide political and economic action in a transition to sustainability. The challenges ahead imply high uncertainty about future conditions and potential critical thresholds. It is likely that instead of a “geo-engineering approach” humankind needs to cope with continuous transitions and needs to adopt an adaptive management attitude which involves learning by doing, trial and error as well as permanent feedback loops between decision-making, observation, and analysis or assessment.

5 Methods and tools for Earth system monitoring

In order to be able to observe the Earth system with reasonable effort, a systematization 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. from remote sensing, weather stations, and buoys), demographic data (national statistics, economic accounting, administrative information) and personal data (e.g. preferences, intentions). The spatial scaling may be done on the global, regional (supranational) and local (sub-national) level.

In all these categories, one can then distinguish between primary data to be collected and secondary data that have to be derived by aggregation, indicator formulation or modeling. Within the

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[4] This easily transfers into fierce political debates as shows the recent controversy on *The Skeptical Environmentalist* (Lomborg, 2001) which at the same time appeared in a whole spectrum of publications, e.g. *Science, Scientific American* as well as *The Economist.*

Geoscope framework it is likely that data management will mainly focus on secondary data, whereas primary data may be acquired through the services of already existing institutions and programs. The determination of relevant secondary data can be based on diverse initiatives working on sustainability indicators.[5] Various aspects of sustainability have already been compiled and described within four broad categories: environmental, societal, economic and institutional. These previous efforts should be examined, refined, systematized 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.[6] The Geoscope can also build upon this and contribute valuable extensions with respect to theoretical underpinning and modeling.

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 a central component of a Geoscope. Satellites provide spatial and temporal mappings of earth surface features which are not available consistently from other sources, but understanding their significance in depth is impossible without numerous associated parameters that can only be observed on the ground, e.g. through statistical services and empirical social research. (Liverman et al., 1998). For example, satellites may well observe the global patterns of agricultural activities, but its relationship to nutritional habits, agricultural policy and historical-cultural developments are the indispensable basis for understanding these patterns and their significance.

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 initiative on Global Monitoring of Environment and Security (GMES). The Geoscope will be in close interaction with GMES and may contribute substantially 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 in a wider thematic context than in the past.

With respect to national and global economic data the GTAP consortium provides an excellent basis, not only for widening the scope of integrated analysis and methodological advancement, but also as an operational example of an international research and information infrastructure, from which the Geoscope initiative could learn and benefit. In this respect, the global database on elasticity parameters for economic modeling, which has been discussed in the GTAP community for some time, could be a starting point for cooperation. Furthermore, the Geoscope may coordinate and contribute a range of environmental data, e.g. on land use, water availability and withdrawal, and climate impacts, which may add valuable content to the GTAP database.

With respect to place-based ground observations, systematic comparative case studies will play a central role and are already widely applied in projects like Land Use and Cover Change (LUCC), the Human-Environment Regional Observatory (HERO), or the Development Ecology Information Service (DEVECOL). 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 in which many of the already mentioned key questions for

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[5] Some important examples are the indicator list by the UN Commission on Sustainable Development (CSD), the Environmental Sustainability Index by the World Economic Forum, the Consultative Group on Sustainable Development Indicators (CGSDI), the UNEP Human Development Index, or EUROSTAT's "Towards an Environmental Pressure Index" (TEPI).

[6] See http://esl.jrc.it/dc for more information on the Dashboards for Sustainability.

sustainability have a high relevance. One possibility would be to define a "loosely nested, regional structure" as it has been done for the on-going Millennium Assessment. Here, the local sample sites are in most cases located within the next level of regional observation areas. These in turn define on a global scale those core regions that are especially relevant for sustainability questions and are to be monitored in depth. A preliminary list of potential regional Geosocpe sites may contain the following: Sub-Saharan Africa, Maghreb, Southern China, India, Amazonia, USA, Central Europe, Siberia, Australia.

6 Next steps towards an integrated global information base

The original development of the Geoscope idea is based on intensive efforts by the German National Committee on Global Change Research as well as the support and exchange within IHDP. Since the end of the year 2000 three German workshops and one international workshop have taken place as well as numerous internal discussions and several presentations at inter-disciplinary conferences. The Geoscope initiative is in close contact with the Forum on Science and Technology for Sustainability at Harvard University.[7]

In early 2001 it was still unclear whether a Geoscope idea that so far had only been roughly defined would find large and open support in the scientific community, a prerequisite to have it initiated at all. The workshop series 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 renowned scientists and institutions have expressed their opinion that a Sustainability Geoscope is "the right idea". Thus, an atmosphere around the Geoscope has been created that shows a spirit of openness and cooperation. A productive dialogue, even with some skeptics, has been initiated.[8]

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 the German Center for Space Research (DLR). On the international level, a cooperation with the Center for International Earth Science Information Network (CIESIN) has been agreed and high-level contacts to GMES have been established.

The Sustainability Geoscope has now become an established element in the 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.

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.

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[7] See www.sustainabilityscience.org.

[8] See Lotze-Campen (2001) for participants and results of the first international Geoscope workshop.

From the very beginning, the Geoscope has to prepare for two different tasks. First, it has to provide data for integrated scientific analysis of Global Change processes (theory building, modeling, 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 potentially multi-stage Geoscope or even several Geoscopes.

Given the vision of a Geoscope as it has been outlined in this paper, it is clear that such an endeavor can only be achieved in a step-by-step approach which might take several decades to be completed. The design and construction process itself will involve a lot of uncertainty and requires continuous learning by doing in addition to well-structured planning. In any case, a start has to be made with a core set of activities and a clear focus on manageable problems, which may then be extended over time. In the German as well as the European context several groups have started to develop a concept for a first approach towards a core Geoscope. As an example, one of the first operational building blocks, which is currently being defined, will deal with regional aspects of Global Change and public health related to deterioration in water systems and changes in land use. Other core activities will emerge during the next months. Over time this core set of activities may then be extended in the dimensions of temporal and spatial coverage as well as disciplinary and thematic integration (see Figure 1).

[Insert Figure 1]

In order to integrate a strong economics component within the envisaged global information system, appropriate links and potential synergies with the GTAP consortium should be investigated soon. A Sustainability Geoscope may benefit from the long lasting experience of GTAP with respect to data harmonization and management, modeling expertise and infrastructure development, and research community building in an international context. On the other hand, the GTAP consortium may be able to broaden its scope towards environmental data and analysis through the emerging Geoscope network and resource base.

An important task for creating the necessary resource base is to define appropriate funding structures in an international context. In the initial phase, this will be a pure research effort which will have to coordinate various funding sources on the national level. The 6th Framework Programme as initiated by the European Union will be an important initial step for a supranational funding structure. In the long term, possibilities for continuous funding through infrastructure investments have to be explored, if such a global information and monitoring system is to become fully operational.

In parallel to these structural efforts which have been recently initiated around the Geoscope idea, a research team at the Potsdam Institute for Climate Impact Research has announced an Internet-based competition for Geoscope-related ideas and findings.[9] In the spirit of the famous mathematician Stefan Banach, who in the early 20th century announced symbolic prizes for the solution of various mathematical problems he had defined, several international institutions have agreed to sponsor a similar procedure to create a research community around the Geoscope. A number of symbolic prizes have been made available and will be awarded to individuals or institutions who contribute substantially to the development of the envisaged observation instrument. Achievements to be accepted for the award will include project ideas, recent findings

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[9] For more details see www.sustainability-geoscope.net .

and completed studies, or relevant data sets, which relate to comparative regional case studies on sustainability questions on a global scale.

The Geoscope initiators hope that this competition will create the right spirit and scientific atmosphere, in which fundamental inter-disciplinary discoveries related to Global Change are being made and important contributions to an emerging sustainability science may evolve.

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8 Figures

Figure 1: Step-by-step approach to developing a Sustainability Geoscope