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- FLUGVERKEHR UND KLIMASCHUTZ
- SUSTAINABLE USE OF SOILS

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Land Use Options – Strategies and Adaptation to Global Change

Terrestrial Environmental Research

Global and climate change have many interlinkages with conditions and processes at regional scales. The collaborated research topic Land Use Options – Strategies and Adaptation to Global Change *focusses on the regional consequences of recent and expected patterns of Global Change.*

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In 2009, the Helmholtz Association started the second period of its programme oriented research. In doing so, researchers from the Helmholtz Centre in Munich and the Helmholtz Centre for Environmental Research in Leipzig and Halle set up a collaborated research initiative focussing on the regional consequences of recent and expected patterns of Global Change. With the research topic *Land Use Options – Strategies and Adaptation to Global Change* the Helmholtz programme *Terrestrial Environment* seeks for methods and tools to derive management options for sustainable land use on a regional scale. This effort, thus, requires a truly integrative approach incorporating natural and social scientists ranging from experimental work towards monitoring, model development, social science surveys as well as governance research.

Point of Departure

Global Change is constituted by the driving and interacting processes of climate change, land use change and urbanisation and is connected with societal transformation processes. Global Change has impacts on the availability and distribution of resources as well as on the dynamics and stability properties of ecosystems and hence on ecosystem processes and services. These impacts, such as changes in climate states and their variability or altered production patterns, are most pronounced on a regional scale with its specific conditions. Therefore, on this scale measures for the mitigation of or adaptation to the impacts of Global Change are particularly necessary and challenging, with mutually overlapping trends having to be considered. In spite of the fact that an important share of food, energy and information are globally distributed, we still depend on our regional environment and, at the same time, shape this environment by the ways in which we use land for agricultural production, urbanisation or measures of nature protection and conservation.

The point of departure thus is the limited resource land. Its use for one purpose often excludes others: bioenergy production can compete with food production, settlement development with biodiversity conservation, enlargement of recreation areas with the production of renewable resources. These trade-offs are aggravated under conditions of Global Change when demands of goods and services increase due to growth of population. At the same time, land use management in Europe offers a broad range of options for adapting to and mitigating Global Change impacts, both technically and in terms of institutional arrangements.

Approach

To cope with the complexity of interactions, a systemic approach is needed. Our research programme is driven by scenario analysis techniques, stakeholder involvement, experimental work, model development and application. A main thread of the research in the topic is the application of the ecosystem services concept and to link ecosystem functioning and human needs. To bring this concept into practice it is essential to involve stakeholders, e. g., in the identification of desired ecosystem services or by informing them about possible trade-offs regarding the interplay of human well-being, decision making and environmental impacts. Several challenges for developing land use options that maintain ecosystem services derive from these considerations:

- Consistent scenarios on a regional scale are needed for an integrated impact assessment of Global Change patterns. They are based on congruent storylines including socio-economic developments as well as changes in the environmental states, and they address the needs of decision makers.
- Research is grounded on experimental work at agricultural platforms with a long history in data integration, like sites in Scheyern and Bad Lauchstädt in Germany. These sites perfectly match the needs for new experimental facili- >

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ties. Moreover, both sites are part of TERENO regions[1], which allows the use of large-scale monitoring strategies (box 1).

- To include urban-rural interlinks land use change in terms of settlement development and its economic, social and demographic drivers will be monitored and assessed. Urban vulnerabilities to climate change are in the focus to explain growing inter-regional disparities in coping and adaptation capacities.
- The development of methods, tools and models that help to inform stakeholders about both, possible consequences and uncertainties, are required to allow elaborating desirable development paths and strategies. Besides the scenario approach the ecosystem services concept supports the integration of natural science and social science research. However, biophysical specification of ecosystem services and ecosystem functioning requires a wide range of modelling tools and instruments such as process based (differential equations), rule based (such agent based modelling), statistics and data mining approaches. Inherit methodological research focuses on uncertainties and data assimilation from monitoring projects.
- Understanding of current governance structures – as a means to develop and implement innovative institutional solutions and policy instruments – is necessary. Furthermore, the active involvement and incorporation of stakeholders and support for the interplay of science and policy is required – already in the status of conceptualising specific research (box 2).

1 See Helmholtz TERENO, an initiative on monitoring: *www.tereno.net*.

Structure of the Research Programme

Research is structured in six research clusters, each organising the work of two to six research projects (with approximately three to ten scientists each; see figure, p. 80). The framework for all activities is provided by integrative regional scenarios developed in cluster 1. Clusters 2 to 5 focus on the analysis of various impacts of Global Change: cluster 2 provides insights into the impacts of climate change on various species, their ranges and community compositions, together with stability properties of ecosystems and the services provided. Cluster 3 and 4 analyse land use conflicts that originate from an increasing production of bioenergy and a general reduction of soil quality for agriculture due to climate change. While cluster 3 focusses on modelling on the landscape level, cluster 4 has an experimental focus: It aims at the compilation of management knowledge for steering agro-ecosystems. Cluster 5 focusses on an improved understanding of the human-driven dynamics of land use change in urbanised regions and their impacts on land resources. Cluster 6 analyses and develops governance options and integrated strategies for adaptation at the regional level, but taking into account interlinkages from other levels (like EU directives, national laws or international obligations). Building upon the scenarios and the improved system understanding provided by clusters 2 to 5, management options and policy instruments to assess land use conflicts and to optimise land use patterns will be developed. In the following, we describe the work of the six clusters in more detail.

Research Cluster 1:
Regional Scenarios, Combined Effects and Management Options

Currently, expertise on scenario development is available at the global and continental scale whereas regional scenarios are only scarcely available. Therefore, existing scenarios on economic development, climate change and land use change will be used as a basis for the analysis of Global Change impacts on terrestrial systems at a regional scale. At the same time, scenarios serve as a communication tool to elaborate options of management strategies for mitigating the impact of Global Change or for adapting to it. The goals are:

1. to develop integrated regional scenarios that form the basis for studying impacts of Global Change at landscape and ecosystem levels and provide a frame for experimental approaches;
2. to assess different drivers of change in combination, i. e., analysing combined effects and identifying hierarchies of importance of the various drivers and pressures;

BOX 1:

Global Change Experimental Facilities: Experimental Sites in Scheyern and Bad Lauchstädt

New complexes of field experiments will soon be set up on the TERENO platforms (initiative on monitoring, see *www.tereno.net*) of the Helmholtz Centre for Environmental Research – UFZ and the Helmholtz Centre Munich, and are focussing on experimental sites at Scheyern farm and Bad Lauchstädt, including complete agrosystems on the farm scale, and factorial combinations of land use (intensive vs. organic crop rotations, monocultures vs. multispecies mixtures for biomass production, secondary succession) and varying climatic parameters (temperature, precipitation, CO_2). Additionally, specific effects of single factors on ecosystem processes such as matter fluxes or biotic interactions will be analysed in lysimeters, greenhouses and growth chambers.

Based on a long-term and inter-disciplinary field experiment, UFZ scientists investigate together with collaborators from several universities how species diversity of forest trees influence ecosystem processes and services, such as productivity, carbon sequestration, litter decomposition and nutrient cycling.

3. to combine explorative scenarios describing different possible future worlds with those providing trajectories to attain desirable aims of future worlds (i. e., normative scenarios).

Research Cluster 2:
Impacts of Climate Change on Ecological Patterns and Processes

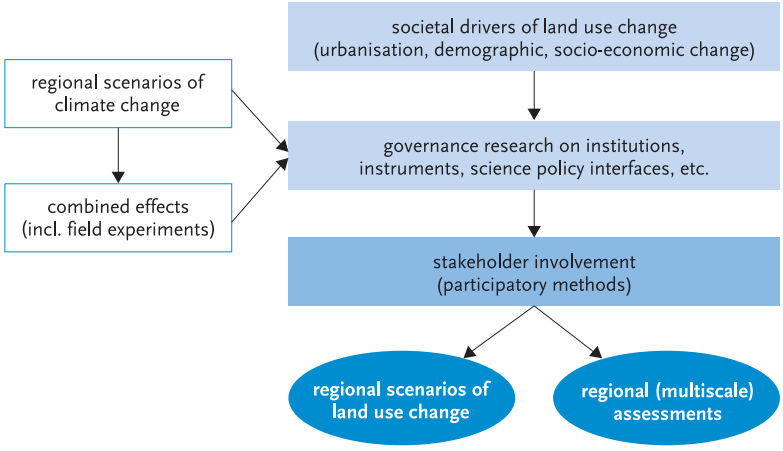
Climate change has already left its footprints on the environment, effecting organisms as well as ecosystems and landscapes. Present models of large-scale range shifts of species contain specific assumptions (such as species-climate equilibrium, full dispersal ability, constant biotic interactions and spatial independence) which are not met in reality. It is a special challenge to assess climate change impacts on the regional scale. Most of the impacts of climate change on small-scale processes (such as competition, mutualism, herbivorous and predatory relationships), interactions with other drivers (such as land use) and their feed-back to larger scales are still unknown. The goal is therefore to provide better knowledge about impacts of climate change on ecological systems by combining different modelling approaches and recognising functional traits of the organisms more explicitly. Focal organisms will comprise selected sets of plants as primary producers and bees and butterflies as pollinators and phytophages.

Research Cluster 3:
Land Use Conflicts Related to the Production of Bioenergy

Especially in Europe, the production of bioenergy is politically enforced to meet the increasing demands for energy (e. g., electricity and fuels) and to reduce climate-critical carbon dioxide emissions. This drives land use changes, altering landscape structure and dynamics, for example towards monoculture plantations with significant impacts on habitats. Environmental stress is expected to increase, and conflicts with other goals such as water protection, food production and biodiversity conservation are obvious. The cluster aims at developing options for reconciling the production of bioenergy with the goals of international environmental policy (as described, e. g., in the *Convention on Biological Diversity [CBD]* or EU directives). This also represents a way of developing mitigation strategies for land use conflicts.

BOX 2: Stakeholder Involvement and Societal Relevance of Research

Results from our research are translated in governance strategies to ensure societal relevance of our research and to improve decision-making on land use change. This step requires research on the impact of societal drivers of land use change, in particular of urbanisation, demographic and socio-economic change. Decision-makers and stakeholders from different sectors of society are involved to develop governance options and to evaluate institutional options and policy instruments. Specific products that will be delivered are regional or multi-scale assessments and regional scenarios of land use change (see figure below).



Research Cluster 4:
Steering Key Functions of Agro-Ecosystems for Optimising their Sustainable Use

Tremendous changes will take place in agricultural landscapes in the form of land use change as well as adaptations to climate change. Mismanagement in the past resulted in a continuous loss of soil quality, biodiversity and ecosystem functions, such as filtering of water and balance of greenhouse gases. The major scientific challenge is to understand and predict the responses of agro-ecosystems to possible land use change and climatic constraints, resulting from complex interactions of biological, chemical and physical processes at a variety of temporal and spatial scales.

Therefore, the cluster aims at developing strategies for an improved use of agro-ecosystems based upon experiments at various scales, incorporating Global Change scenarios. Most of the ecosystem services are related to biological communities including microbial activities. Their genetic resources together with abiotic site conditions form the most important basis for steering and managing ecosystem processes. On this basis, new indication systems will be developed and coupled with soil physical properties.

Research Cluster 5:
Impact of Urban Dynamics on Land Use Options

Urbanisation is one of the most important drivers of Global Change. In 2007, for the first time in history, more people lived in cities than in the countryside. As a consequence, the UN are now focussing on the sustainable use of scarce resources in urban regions. It is the overall goal of cluster 5 to support the management of land resources by analysing the driving forces and impacts of complex urban dynamics. We will:

1. develop scenarios for urban regions including the urban-rural gradient that specifically study how incompatible stakeholder interests drive land use changes;
2. specify different resource use patterns;
3. analyse changing institutional frame conditions including national and in- >

ternational law, as well as programmes and strategies.

4. Develop an indicator system to assess impacts and vulnerabilities regarding, e. g., loss in biodiversity, lack of green space, transportation, increase in flood risk or social exclusion.

The research will be based on both quantitative and qualitative methods of the social sciences and spatially resolved monitoring techniques. One innovation will be the combination of these methodologies with agent-based modelling.

Research Cluster 6:
Governance and Integrated Strategies for Adaptation

High uncertainties regarding regional impact and rate and their mutually reinforcing dimensions of Global Change pose major challenges for governance strategies including accelerated institutional change: norms, laws, and policy instruments, formal and informal rules used in individual and societal decision-making are shifting more quickly. Institutional change in itself also represents a driver of environmental change: it can aggravate existing problems or even create new risks (e. g., the large-scale monoculture production of bioenergy crops as a threat to biodiversity). The adaptation to such institutional change – what we can call "second order adaptation" – could be even more challenging than direct impacts of climate change. The general goal of the cluster is to develop new methods and tools to strengthen the ability of societies to adapt to and to govern

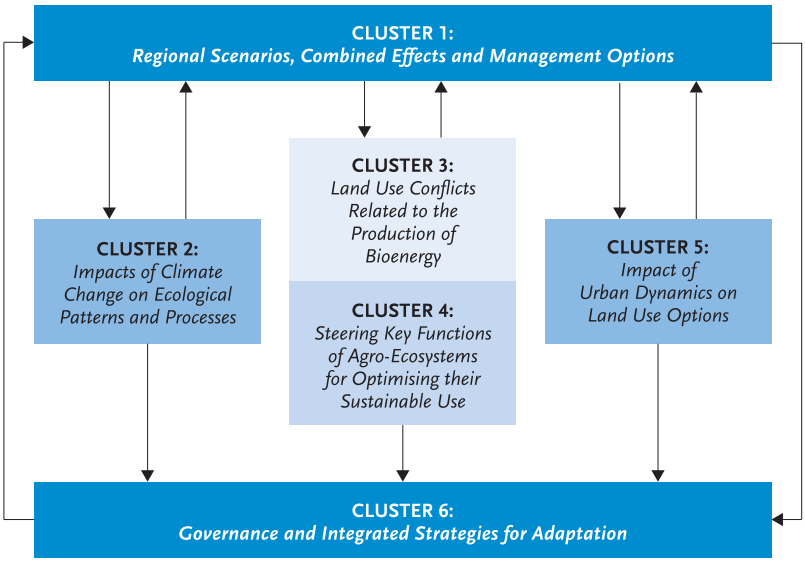


FIGURE: Structure of the clusters in the research project *Land Use Options – Strategies and Adaptation to Global Change*. Each research cluster organises the work of two to six individual projects with two to six scientists each.

Global and especially climate change. To achieve this goal, we will build on regional scenarios (cluster 1) and take into account the impacts of climate change, land use change and urban dynamics (clusters 2 to 5). Cluster 6 develops appropriate governance options and integrated strategies for land management in rural and urban areas. Innovative policies and novel governance instruments will be designed to shape institutions for adaptation to climate and Global Change.

Perspective

The described programme starts in 2009 and is scheduled to run until 2013. After a considerably intense preparation phase (including programme defence in spring 2008), the involved groups have achieved a high degree of integration and cross-fertilisation amongst different scientific fields. Thus we strongly believe that this project structure will sustain research on land use management beyond 2013. As the whole project will continually evolve, there will be opportunities to participate and join in other third-party funding initiatives. Moreover, we will enlarge and deepen our international research cooperation, e. g., with Latin American partners. Contributions, such as research collaborations, joined case studies, etc. are always welcome.