

## NWO strategy 2008-2011

### Theme Sustainable Earth

JUNE 2008

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## **O. BACKGROUND**

### **O.1 INTRODUCTION**

*Sustainable Earth* is one of the research themes that has been developed as part of NWO's strategic action line 'Science for Society'. This broad multidisciplinary theme will study interrelations between men and environment on different spatial and temporal scales. The present document is based on work by a scientific committee and intensive discussions with stakeholders and scientists on policy questions and national and international scientific developments. Within three policy/research domains, a number of subthemes and research lines has been worked out. Their selection of was based on:

1. urgency and relevance;
2. available expertise in the Netherlands; and
3. complementarity to other ongoing or new research programmes.

The present document has been approved by the participating NWO bodies and will provide guidance for the implementation<sup>1</sup>. The actual implementation and governance are dealt with in a separate document.

### **O.2 POLICY AND SCIENCE FOR SUSTAINABLE DEVELOPMENT**

Sustainable development and environmental objectives have a prominent place in Dutch policy. An overview can be found in the *Government Agreement* of February 7, 2007 which provides "pillars" for current priorities. Pillar III "Sustainable Environment" focuses on new technologies, energy transition, water, production and consumption. Pillar II "An innovative, competing and enterprising economy" emphasises the role of basic research, in particular on energy and water. Pillar I concerns development and international collaboration. The objectives fit in with many international policy frameworks e.g., the Wetland Convention, UNFCCC (1992), the CBD (1992), the MDG (2005) and EU SDS (2001).

More specifically Pillar III, Sustainable Environment, considers mitigation of environmental impacts:

1. Speeding up the introduction of new clean technologies, in particular in the sectors of energy, water and food industry. The objective requires new administrative rules, technological innovations, investments in concerted actions by government, industry and other stakeholders. In modern terminology this is called transition.
2. Transition towards a sustainable and efficient energy supply, in particular energy saving, sustainable energy, reduction of emissions of greenhouse gases.
3. Revision of the water management in view of climate change.
4. Where market mechanisms have insufficient impact, introduction of additional (positive or negative) financial administrative measures to foster sustainable production and consumption.

In addition, in the framework of spatial planning, adaptation to climate change is given a prominent role in the future spatial development of the Netherlands. Pillar II pays attention to knowledge and innovation, and refers to investment in scientific research, in particular in relation to sustainable energy, human care, energy and water management. Pillar I, under the heading of development cooperation, refers to the Millennium Development Goals. In a policy briefing to

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<sup>1</sup> Formal approval is expected in July 2008

parliament, minister Cramer presented eight priority subjects for policy on environment and spatial planning and confirmed the urgency of the above subjects.

All of these issues are (in)directly related and call for a knowledge base from which actions can be taken. In 1979 already, the UN-World Meteorological Organisation raised concern about a possible impact of human activities on climate and organised the first World Climate Conference. This has stimulated worldwide research under the umbrella of organisations such as WCRP, IGBP, IHDP and Diversitas, involving a very large number of scientists. Their results have been summarised for policy makers in several influential assessments, such as the Millennium Assessment and the Fourth Assessment Report of the IPCC. These global assessments have been complemented by more specific local activities. For example, KNMI developed climate scenario's for the Netherlands. However, despite a number of robust findings, many uncertainties and challenges remain. As a result, the KNMI scenarios span a fairly wide range of possibilities, and, to the best available knowledge, global temperature rise in 2100 is likely to lie in the range from 1.1 to 6.4 °C, the implications varying from almost negligible to disastrous. It is obvious that more research is needed. For improved understanding, better predictions, innovation and better support for policy development.

### 0.3 THE NWO THEME SUSTAINABLE EARTH

NWO has a longstanding experience in mobilising the scientific community and fostering excellent research. Independency in review processes, careful selection procedures, objectiveness and a broad international expert network guarantee the funding of outstanding research. The current NWO strategy has three action lines. One of these action lines, 'Science for Society', consists of several themes. Sustainable Earth is one of these. The new theme partly builds on earlier programmes..

The scope of Sustainable Earth is best given with the help of a scheme, representing the domain of "Earth System Science":

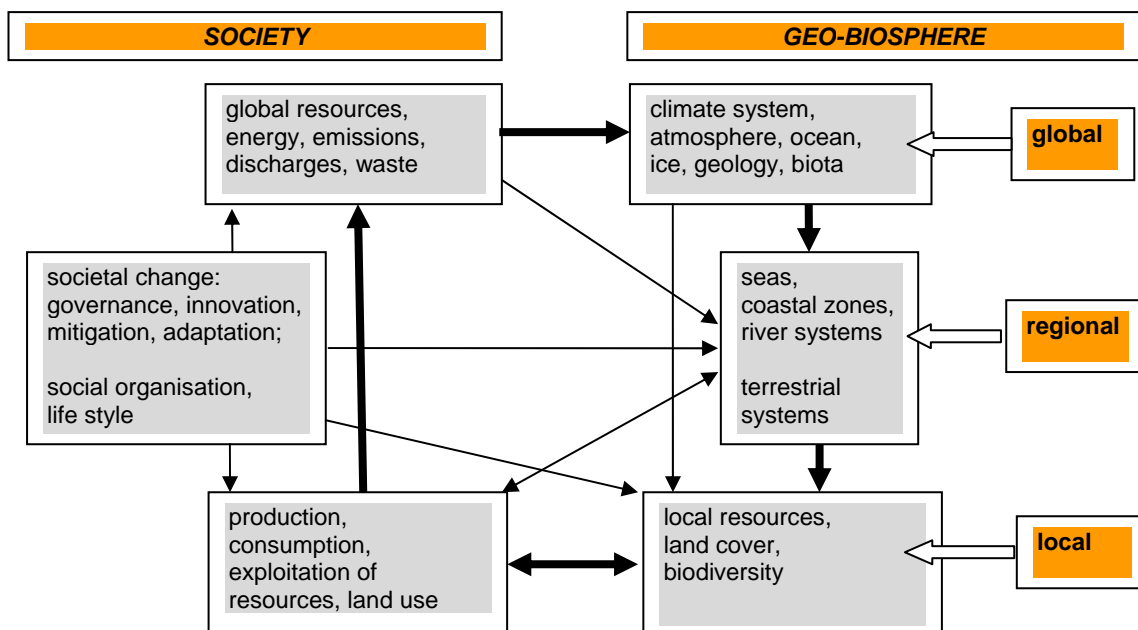


Figure: the domain of Earth System Science

On the right the geobiosphere is depicted; the left represents human society. Spatial scale decreases from top to bottom. Arrows indicate interactions. On a global scale the exploitation of resources, energy use, emissions, discharges and waste affect the geobiosphere as a whole, with significant regional consequences, which in turn affect local resources, land cover and biodiversity. These local resources are essential for society which exploits them for production and consumption and other use. It is this very exploitation that leads back to global perturbation of the geobiosphere. This process however is strongly modulated by economical development, life style, social organisation and governance, involving innovation, adaptation and mitigation.

Of course, the above scheme is a grand simplification. The full Earth System comprises a very large number of processes interrelated through a myriad of interactions. Both the scientific study and the governance of this complex system form an enormous challenge, requiring understanding of these processes and their interactions on global, European, national and local scales.

The emphasis in the present NWO theme will be on creating focus and critical mass in research areas which are not yet covered by other programmes and where the Netherlands science community has a prominent international position, such as Climate, Sustainable Energy transition, Geodynamics, Water, Coastal and Marine research and Biodiversity. This has resulted in three main domains of policy relevance, namely

1. Energy and resources
2. Global change and environmental variability
3. Global concerns, regional and local solutions

The "Energy and resources" part has a focus on the socio-economic study of transitions and does not include technological innovation in energy systems as this is part of a separate NWO theme. In the second field the current emphasis is on climate variability and climate change (but a future broadening of the scope is not excluded). Within the third field "Global concerns, regional and local solutions" a number of specific research areas have been selected, namely deltas, drylands and biodiversity. For each subtheme a set of program lines has been identified on issues which are currently high on the research agenda.

Sustainable development is a long-term objective. Therefore, research within this theme will address both mid-term (2020-2050) and long-term issues. The generic outcome will consist of

- o increased understanding
- o improved projections and scenarios
- o improved capabilities to design and implement solutions.

These assets will contribute to future assessments by the IPCC and e.g., environmental agencies and to the capability of the Dutch research community to provide new knowledge to policy makers and the general public. In addition, development and maintenance of scientific expertise on environmental issues is necessary, to provide a constant information flow for short-term assessment, advice and consultation in the Dutch (policy) context.

Interaction with stakeholders and peers has been an essential element in the development of the present theme. This interaction will also be essential during the implementation and execution of programmes. Outreach will be organised while the programmes run, rather than at the end. Communication at the programme level will be complemented with more integrated activities at an

overarching level. Scientific progress and policy relevance will form the basis for this communication. Policy prescriptiveness will be avoided.

The recently established Netherlands Partnership for Sustainable Earth Research (NPDA) will provide an effective mechanism for interaction with other programmes, such as the new FES programme Knowledge for Climate (KvK) which has an emphasis on adaptation in the Netherlands, and the national Sustainable Energy Programme (still under development) which will focus on the development of new technological options.

#### **0.4. AN INTEGRATING FRAMEWORK FOR SUSTAINABLE EARTH RESEARCH**

Sustainable Earth will be more than a set of loosely connected projects because the same overarching questions (do we understand the observed changes, what can we say about the future, and what are policy relevant findings) will be addressed in all programmes. Nevertheless, it will be essential to relate results from different programmes. To facilitate this, use can be made of the integrating framework provided by Systems Theory. This framework for interdisciplinary research may serve as common ground and can enable the dialogue between very diverse fields of research from the life sciences, the earth sciences, and the social sciences.

From a Systems Theory point of view the Earth System can be seen as complex adaptive system at various spatial scales, relating the spheres of the earth to domains in society. The complexity arises from the multiplicity of interactions, including positive and negative feedbacks between elements of the system. Faced with this complexity four issues were identified that might serve the integration of the theme both within and among the subthemes. These are a. Integrated modelling; b. Unresolved processes and behavioural responses; c. Quantifying uncertainty; and d. Governance and decision support. We will deal with each issue briefly.

##### *Model integration*

Modelling dynamic systems has become a crucial element of linking theory to observations and of understanding cause and effect chains in both the natural and the social sciences. Earth Science models now deal explicitly with the interaction between the various spheres on earth (i.e. the atmosphere, the hydrosphere, the lithosphere and the biosphere). In Regional Science, models of population, land-use and transportation have been integrated to study the environmental impact of human activities. In Life Sciences, modelling food webs integrates animals, vegetation, soils, humidity, and hydrology. The models differ widely in substance and in scales both of time and of (three-dimensional) space. Yet they do share a number of elements that provide some common ground and ways for improvement. The first is system closure. Phenomena placed outside the model are erroneously regarded as external forcing or simple output, while in reality they may provide important feedbacks and should be included in the algorithms. Integrating models not only enhances the scientific or predictive value of the model, but also the social relevance as it may provide insight into the complex interactions of seemingly unrelated phenomena. A second element is up- and downscaling. Spatial and temporal scales are often chosen for pragmatic reasons, like data-availability, tradition, and the like. Scalability is not straightforward. Driving forces could be very different at various scales and causality might even reverse. The up-scaling and downscaling of models is therefore a scientific endeavour that could greatly enhance our understanding of the phenomena at hand. The development of integrated, scalable models will therefore be a priority within each of the subthemes and could lead to learning effects across the subthemes. In particular, quantitative global models can integrate information about global adaptation and mitigation capacity. The regional subthemes (delta's, drylands, etc) will both contribute to and benefit from these models.

#### *Unresolved processes and behavioural responses*

Models simulate dynamic processes at the level of the system and make assumptions about the behaviour of the smallest unit in the system, the agents. Agents come in a wide variety, ranging from humans and plants to rock grains, aerosols and ozone molecules. The critical part is that these agents interact with each other and their environment. In Earth Science unresolved processes are usually parametrised. These parametrisations are based on theoretical and experimental knowledge about the behaviour of the specific agents. Similarly, in life sciences, and notably in social psychology and economics controlled experiments are a common way to study behavioural responses to external forcing. So far the applications of experiments in social psychology and economics to issues of sustainability have been limited and they might provide a step forward in understanding how the social system reacts to climate change and resource conflict. The interaction among agents is even more complicated than their response to their environment, in particular in strategic situations when the 'choices' of agents depend on the behaviour of others in the system. Game theory has successfully been applied in economics, in political sciences and in biology to handle this complexity. A deeper understanding of behavioural responses and the development of agent based models is a common priority in each of the subthemes.

#### *Quantifying uncertainty*

Research in the present theme will certainly contribute to improved understanding and provide a better scientific basis for making forecasts, but it is an illusion that uncertainty could be eliminated. Of course, we hope that uncertainties can be reduced, but there is no guarantee that this is possible. Actually it might increase, if more is known about the system. The most promising way to quantify uncertainty is scientific pluralism. In the field of climate change multi-model ensembles, involving different models, have already proven their usefulness. It seems useful to extend this to the broader biogeo-socio-economic domain. Stimulating different approaches and developing a variety of models is probably the best way to find the frontiers of our knowledge, both national and international. Bringing together researchers from various disciplines that are willing and able to work at the crossroads of their fields is part of this strategy. The *raison d'être* of the present theme is to organise this pluralism.

#### *Governance and decision support*

One of the more fundamental uncertainties in the system is the human factor, as the system is open to policy interventions from both the public and the private sector. The system is not only complex but also adaptive as these actors learn and put new knowledge into practice. This implies that the research should provide decision support in various formats, from scenarios to foresee a variety of plausible futures, to evidence on the effectiveness of existing instruments, to improved methods of comprehensive valuation of the financial and social returns on investments, and so forth. But it also implies that the governance itself will have to be object of research as this is a crucial aspect of how the systems will evolve in the future and in particular in the way the impact of global change will be met by local solutions.

## 1. ENERGY AND RESOURCES

The overarching aim of the Energy and Resources domain would be to improve understanding of interactions between the exploitation of energy and other resources. Energy is fundamental to economic growth and social welfare, but energy production and consumption also lies at the root of the most pressing resources, security and environmental problems. For reasons of resource depletion, climate protection and energy security, a switch away from fossil and towards renewable sources of energy is planned at a global scale. This transition to more sustainable energy systems demands radical shifts in the sources, conversion and uses of energy.

Three fundamental interactions will unfold in this transition to more sustainable energy systems:

- o between fossil and renewable sources of energy
- o between different forms of renewable energy (water, sun, wind, geothermal)
- o between renewable energy and other resources (such as food, water, biodiversity).

Such interactions (both trade-offs and synergies), and the complex of behaviours, markets and technologies that shape them will frame the key societal and economic challenges related to energy over the coming decades.

The scientific challenge is to understand and model these resource interactions, to investigate how these trade-offs are being transformed by economic and technological change, and to examine the sustainability of alternative approaches to resolving them. Since energy and related resources and the trade-offs between them stretch from the global to the local scale, research will need to span different scales, spatially and temporally. In seeking to understand the current and future structure and dynamics of energy and resources use, we are confronted with major uncertainties that will play a key feature of research.

Research questions would include: what is the distribution, across different scales, of fossil and renewable energy resources? What combinations of energy sources, conversion technologies and consumption patterns currently exist of materials, transportation fuels, electricity and heat, and how might these change in the future? What are the important trade-offs (environmental, economic, societal) between fossil and renewable-based energy systems? What will be the continued role for fossil-based energy? How could the growth of renewable energy conflict with production and consumption of other resources? How could it stimulate rural development, prevent erosion, preserve soil quality, improve access to water and reduce poverty? Is governance being effective in stimulating a transition to sustainable energy and what alternative models and measures are there? How can we govern resource conflicts that will arise in the energy transition?

The objectives of the Energy and Resources domain in the Sustainable Earth are:

- o to develop scalable, integrated and dynamic models of renewable and non-renewable energy, food and water resources
- o to generate and debate long-term scenarios for the development and trade-offs and synergies between energy, food and water resources at multiple scales (time and space) of analysis
- o to analyse the sustainability of alternative combinations of energy sources, technologies and patterns of consumption
- o to propose novel concepts for the future governance of renewable and non-renewable resources
- o to contribute to Dutch, European and international debates about the exploitation and stewardship of natural resources.

The Energy and Resources domain is complementary with the proposed Dutch Sustainable Energy Programme. It will not investigate specific energy technologies in The Netherlands, but will analyse the relationship between energy and other resources in their social, economic, institutional and technological context. Energy production and consumption will be considered in the round, rather than in terms of separate energy supply and conversion technologies alone. In particular, the Energy and Resources domain will encourage the integration of natural science perspectives on energy, food, water, biological and agricultural resources, with social science perspectives on innovation, valuation and governance of these resources.

#### *Research lines and topics*

##### **1.1 Analysing fossil to renewable energy transitions**

This line will focus on the transition itself, and comprises the following topics

- o quantifying and modelling energy and other resources
- o production and consumption options for sustainable energy
- o theories and models of transitions
- o scenarios for energy transitions (NL, EU, global)

##### **1.2 Resource interactions**

Interactions between resources will be increasingly important. Therefore, in a separate research line the following issues will be addressed.

- o sustainability assessment of renewable-based energy systems (bio-energy, wind, solar, hydro)
- o trade-offs between renewable energy and other resources
- o technological, economical and sociological research on potential strategies for managing conflicts and synergies between resource uses

##### **1.3 Governing trade-offs**

The governance of energy transition is highly challenging. Research should be aimed at three topics:

- o governance and transitions
- o international and European context of energy transitions
- o integrated energy and resources policy

## GLOBAL CHANGE AND ENVIRONMENTAL VARIABILITY

### 2. CLIMATE VARIABILITY AND CLIMATE MODELS <sup>2</sup>

In the 4<sup>th</sup> assessment report of the IPCC climate models play a major role. These models simulate the state of the climate in the 20<sup>th</sup> and 21<sup>st</sup> century. The results form the basis for impact models which estimate the impacts in natural and societal systems. By (future) observations the quality of these model results can be assessed. By analysis of deviations the weak links in climate and impact models can be identified and possibly be improved.

There still are many weak spots in global and regional climate models and impact models. In a recent GCOS/WCRP/IGBP workshop (Sydney, October 2007) an overview of the weak links has been presented. These are manifold, e.g., the representations of the indirect aerosol effect, of the effect of clouds on radiation, of the melting of ice caps, of mixing processes in the ocean, of precipitation and more general the hydrological cycle and of the carbon cycle. Some of these weak links are in particular important for the results of climate models up to 2035, others on the long term (2100 and beyond). Three central questions are still insufficiently answered:

- what is climate sensitivity?
- to what extent is climate predictable?
- what are possible abrupt climate changes?

Insufficient understanding hampers the development of optimal strategies for adaptation and mitigation, as is aimed for in the FES-programme Knowledge for Climate (KvK).

#### BOX *FES-programme Knowledge for Climate (KvK)*

In this programme the research is aimed at the short and middle term (up to 2050) with focus on development of adaptation strategies for a number hotspots in The Netherlands, e.g. Schiphol airport, the harbour of Rotterdam, lowland rivers. A central role in the programme is for the Climate Knowledge Facility, constituted of a model platform and a research platform. In the model platform support will be given for the development and use of the new global climate model EC-Earth, for a regional climate model for the surroundings of The Netherlands and for a range of impact models. The results of these models provide the quantitative information which is needed for effective adaptation. Within the model platform problems will be handled which are relevant for all hotspots in the programme. This may include local level issues, methodological issues, and also the weak links in climate and impact models.

In addition to KvK, the theme Sustainable Earth is necessary to develop knowledge for quantifying uncertainties in the climate system, in particular (but not exclusively) for the long term (beyond 2050). An interdisciplinary approach is aimed for to improve understanding of feedbacks and quantification of variability in the earth system. In particular, knowledge is needed to improve weak links in climate models like the representation of biological and anthropogenic processes.

In the 'Aspen white paper' (2007) WCRP and IGBP have made the first step for the contributions of the science community to the 5<sup>th</sup> IPCC report. Two approaches for research were distinguished. The first is aimed at the short term (up to 2035) with focus at adaptation and regional scenarios of

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<sup>2</sup> The research lines in this field are complementary to the climate research in the planned FES-program Knowledge for Climate (KvK).

change. KvK will contribute to this approach. The second approach aims at feedbacks and impacts on the long term (2100 and beyond). This will be the focus in theme Sustainable Earth, and will contribute to the broad, global research agenda.

The EC-Earth model will fulfil a central role, linking both approaches. Coordination of these approaches should allow linkages between emissions, land use, climate response, impacts and mitigation strategies, resulting in consistent scenarios for adaptation and mitigation.

**BOX**     *The role of EC-Earth*

The EC-Earth model serves as an integrator for the Dutch climate research in both Sustainable Earth and KvK. By improved fundamental understanding of processes – which is the objective of climate research in Sustainable Earth- better results can be achieved with climate and impact models. This will also contribute to improved input for the adaptation studies in KvK. The EC-Earth model can form the basis for further development towards a global earth system model which integrates knowledge on geosphere and biosphere, energy, economy and society. Such integration (an IMAGE-plus model) fits with the ambitions of the Netherlands Partnership for Sustainable Earth research (NPDA).

This part of the subtheme will be structured along a number of different research lines (basic physical, biological and anthropogenic processes; the role of the ocean; the use of climate models for the study of climate variability and climate change and climate change impacts). Sea level change is of great importance for the Netherlands. This change consists of two components, namely a change in the absolute sea level and changes related to deformation of the earth crust. This latter aspect will be addressed in a separate research line.

*Research lines and topics*

**2.1 Basic physical and chemical processes in the climate system**

Insufficient understanding of basic physical processes hampers improvement of climate models and scenarios. Major sources of uncertainties concern:

- o melting of glaciers and ice caps and impact on sea level
- o sources and sinks of greenhouse gases and aerosols and impact on the radiation balance
- o hydrological processes on land
- o interaction between radiation, chemistry and dynamics, stratosphere-troposphere interactions
- o cloud formation

**2.2 Basic biological and anthropogenic processes in the climate system and the representation in climate models**

Biological and anthropogenic processes may have considerable impact on climate, but are still insufficiently understood. Improvements are needed on the following topics:

- o marine and terrestrial processes that play a role in the biogeochemical cycles,
- o representation of biological processes in climate models
- o impact of land use change
- o coupling of these processes with physical and chemical processes.

### **2.3 Ocean circulation: climate, biogeochemistry and biodiversity (Sea and Coastal Research)**

Oceans play an important role in the physical climate system and because of their ability to absorb anthropogenic greenhouse gases. This research line will focus on three aspects:

- o oceans and climate
- o an integrated study of biogeochemistry and ecosystems
- o biodiversity in relation to exploitation

### **2.4 Climate models and the study of natural variability and global change**

Models are essential tools in the study of climate variability and climate change. Knowing the natural variability and spatial patterns of climate is essential for detection and attribution of anthropogenic climate change and for prediction of climate in the next 50 years. Understanding of natural variability in the past is increasing, and will be used to improve climate models. The following topics will be studied:

- o natural variability of the climate system on time scales of days to millennia (storm tracks, the North Atlantic Oscillation, El Nino and the Pacific Decadal Oscillation, land-atmosphere interactions on decadal time scale, the Little Ice Age, Dansgaard-Oeschger oscillations, etc).
- o structure and stability of the global ocean circulation (including Rapid Climate Change).
- o predictability of natural and forced variations in the climate system
- o the role of feedbacks in the carbon cycle on climate change predictions

Also the impacts of climate change and CO<sub>2</sub> increase need attention. Examples are:

- o critical thresholds of adaptation of ecosystems
- o development of new ecosystem models to quantify the impact of climate change.

### **2.5 Sea level rise: the role of soil subsidence and deformation of the earth crust**

The soil level in The Netherlands is gradually changing due to deformation of the earth crust, plate tectonics and postglacial rebound. More local but faster soil subsidence occurs above exploitation of reservoirs of oil, gas, rock salt, groundwater (in particular peat polder areas). These processes add to changes in sea level and river discharge. Research will be aimed at:

- o to monitor continuing deformation of the crust, soil subsidence and seismicity
- o numerical modelling and prediction
- o to analyse the distribution of tensions in the crust in relation with soil subsidence and seismic activity in the Netherlands' delta.

## **GLOBAL CONCERNS, REGIONAL AND LOCAL SOLUTIONS**

Societal trends such as population growth, economic growth and increasing wealth, and the consequent growing demand for residential and industrial areas and infrastructure lead to more and more claims on land, water resources, and nature. There is a growing concern in all parts of the world about degrading environmental quality, land degradation and desertification, biodiversity loss and climate change. Moreover, climate change will have impacts on all land and water related sectors and therefore on spatial planning and management of coastal zones, river basins, and rural and urban areas. In many parts of the world such competing claims on natural resources are part of a complex of overlapping problems related to ecological stability, political conflicts and chronic poverty.

Solutions for these problems have to be found at the regional and local level in developed as well as in developing countries. Sustainable environmental management cannot be attained without addressing these related issues with integrated or interdisciplinary approaches.

Governance strategies should be designed for finding a balance between socio-economic needs and environmental constraints, in developed as well as in developing countries> These strategies have to be based on adequate knowledge and information. Integrated assessments of resource use dynamics and strategies for sustainable rural and urban development are needed.

### **3. INTEGRATED MANAGEMENT IN DELTAS<sup>3</sup>**

Formidable challenges are in deltas and coastal zones in which a large number of people live. The diversity in situations varies wildly, from highly industrialized countries like the Netherlands, to extremely vulnerable deltas as the Mekong or in Bangladesh. In these areas enormous efforts will have to be made both at infrastructural and institutional level to ensure the continued existence of natural resources as well as the survival of the populations present.

#### *Research lines and topics*

##### **3.1 Urban planning and environmental quality**

The quality of environmental conditions in urban areas continues to be a concern. Citizens of urban areas are expressing greater interest in and demanding improvement of environmental conditions within cities. Over the last 10-15 years, urban environmental planning has shown a gradual change from generic, sectoral and norm-based planning to more decentralised and integrated forms of planning. Urban planners have been given more freedom in formulating area-specific environmental ambitions that are (more) based on existing functions and characteristics of urban areas. Vice versa, planners are (increasingly) stimulated to take environmental conditions or ambitions as guiding principles for further spatial developments in certain urban areas. National policy is aimed at promoting both forms of integrating environmental and spatial planning. Strict environmental standards were felt to impede spatial developments in urban areas, whereas in spatial planning opportunities were missed to improve environmental quality, e.g. because the incorporation of environmental aspects only occurred in a late stage of planning. Additionally, it is felt that the potential contribution of environmental policy to spatial planning and spatial quality is under-utilised. Policy integration, facilitated by more local policy space in determining area-based

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<sup>3</sup> Items related to adaptation to climate change in The Netherlands will be covered by the planned FES-program Knowledge for Climate (KvK).

environmental ambitions, is expected to reduce such conflicts and enhance the synergy between both policy domains, resulting in more sustainable urban planning. Further research is required for understanding what governance strategies are favourable for promoting the above forms of environmental policy integration, and under what conditions. Relevant research topics are:

- mobility
- the impact of road traffic and neighbourhood degradation on human well-being
- socio-spatial inequalities in health and well-being
- integration of environmental and spatial planning
- governance strategies.

### **3.2 Sustainable accessibility of the Randstad (DBR)**

The internal and external accessibility of the densely populated Western Holland urban agglomeration is a serious challenge. This relates to mobility of people, goods and information streams. New approaches are needed. Central research questions relate to:

- which gaps in understanding exist, when reasoning from a desired situation in the future (2040)
- how can standards for accessibility be defined and quantified from a network perspective
- what will be the impact on internal and external accessibility of climate change, new water management directives and energy transition
- which options exist for a no regret policy in view of the many uncertainties about the future.

### **3.3 Changing carrying capacity of the Wadden Sea (Sea and Coastal Research)**

Coastal areas exhibit a natural morphological development and respond to changing environmental conditions and human intervention. Increasing urbanisation on the one hand and the combating of coastal erosion on the other have led to the coast becoming increasingly wedged in. Further the sea and coast are being used for a growing number of functions. The effects of these new types of use need to be investigated, as equally the carrying capacity of the system for these functions. Four societal relevant topics are:

- Morphodynamics of the coast  
Dynamic development of the shape and nature of the coast has a very high societal relevance and is directly related to the issues of safety, spatial planning and nature.
- Water quality  
Substance flows (silt, nutrients) with their indirect effects (e.g., light climate and microbial activity) are very important drivers for the ecosystem.
- Carrying capacity of ecosystems  
For the relation between economic yield and nature the ecosystem is the starting point. It is the ecosystem that provides us with services and this is increasingly the starting point for policy.
- Biodiversity  
The coastal systems (shores and mud flats and salt marshes and tidal flats) host living communities that are characteristic for our coastal areas and rare in Europe. This is particularly the case for flats and water birds. Although protective measures are in force, there are still major unresolved questions about recovery and management.

### **3.4 Integrated water system research**

Expected climate change poses new challenges by changes in the external hydrological conditions like temperatures, rainfall, river discharge and sea level. The KvK programme is in place already for development of knowledge for adaptation in The Netherlands, which is -among others- aimed at practical solutions for prospective risks of flooding and droughts. In the theme Sustainable

Earth is aimed at research on fundamental aspects with regard to water systems and water management. This will also be a spearhead for international cooperation, e.g. with China. Fundamental research on this topic will be focussed on improving understanding of the many and complex relationships within water systems. Results may feed into the research in KvK aiming at adaptation to climate change.

Day-to-day water management concerns mainly the water inside the dikes, brooks and rivulets. The key target of adjustment of groundwater levels is to optimise conditions for land use. Research aims at the combined impacts of climate variability, land use change, spatial development and other human drivers, e.g. soil subsidence by draining of peat lands. Also the impacts need to be considered in coherence, including water quantity and quality, ecology and socio-economical aspects. The implementation of the EU Framework directives on Water and groundwater will lead to research questions how water management can contribute to achieving the ecological targets. Options for management will be investigated by system analyses of both the water systems and society on different spatial and time scales.

This topic addresses fundamental questions in order to improve the scientific basis of water management. Improved understanding of the linkages in water systems between quantity, chemistry and ecology will allow for more effective measures on different time and spatial scale. Moreover this will contribute to the applicability of scientific understanding in other delta areas and wetlands. Improved understanding requires research on:

- impacts of climate on the discharge of rivers
- sediment budgets, nutrients and morphology
- experimental and integrated modelling including the economical and other human interests. The way of handling uncertainties requires more attention.

### **3.5 Informed wetland management**

Using on-line information (satellites, sensor networks) improves understanding of processes, management and maintenance of rules for water abundant areas and wetlands and provide valuable information for adaptive management of complex dynamic systems, e.g. coastal wetlands like the Wadden Sea but also abroad. Innovative elements are to be expected with regard to:

- on-line information systems
- coupling of monitoring with modelling
- hydrological processes on different spatial and time scales
- integration of various abiotic and biotic processes in systems.

### **3.6 The impact of sea level rise on delta systems (*international*)**

Projections of sea level rise (SLR) still vary considerably. The risks are high, in particular for delta systems elsewhere in the world (China, Bangladesh). Combined natural and social science research is needed. The research will involve experiments and modelling of sedimentation and erosion processes and calibration of experiments by geological records. Satellite observations and GPS will provide input. Predictions will form the input for social and economical impact studies.

- predict the impacts of different scenarios of SLR on sedimentation and erosion, estuarine inundation, flooding and nature
- accurately monitor variation in sea level and vertical motion of the solid earth
- evaluate risks and social and economical consequences of SLR
- develop adaptation strategies based on physical, spatial and socio-economical mechanisms.

### **3.7 Social science analysis of extreme changes and events<sup>4</sup>**

Extreme events are rare and the predictability of them is low. Extreme events may occur – or not, and the timing is uncertain. There is little if any experience with such events. In traditional social science the impacts of extreme events can hardly be covered. The field of “disaster studies” may form the basis for a new, comprehensive multidisciplinary approach. Relevant topics are:

- o External and internal forcing and reinforcing mechanisms in natural and social systems, cause-effect chains
- o Risk evaluation of natural systems and society, resilience and vulnerability
- o Risk perception, behaviour, policy
- o The role of government (at different levels), individuals and the insurance sector
- o Economical aspects of extreme events, adaptation, recovery.

## **4. SUSTAINABLE LAND USE IN DRYLANDS**

Climate variability in especially dryland areas keeps populations trapped in food shortages caused by periodic droughts. As a result of this food markets fluctuate wildly causing chronic food insecurity. Weak governance structures are not capable to solve conflicts, administering law and to provide the institutional capacity to ensure sustainable use of natural resources, let alone the changes accompanying climate change. Furthermore, lack of basic economic and physical infrastructures hamper interventions and adaptation strategies. Ideally these challenges incorporate all land use claims in order to find societal win-win situations. Therefore, not only innovative approaches in water management, land use planning, adaptation to climate change, and biodiversity conservation and restoration are required, but also governance structures have to be strengthened and basic infrastructures have to be improved to let these solutions not fall onto barren ground. These dryland areas require regional and local solutions, but are indeed of global concern, as political insecurity forms a threat to the sustainability of global security and peace and are often the stake in global conflicts about (mineral) resources and oil.

### *Research lines*

#### **4.1 Conflict, land use and climate**

Conflicts and synergy are inherent to drylands, e.g. in view of the relations between town and rural area, crop farming versus cattle farming. Objectives, practices and regimes on international level vary, e.g. WTO, UNCCD, CBD, FCCC and FAO.

Climate and land use are coupled. Will climate change hamper or advance transition to sustainable land use? And how does this influence the relations between stakeholders with different interests? On regional scale relations between areas may change, in particular in relation to water availability.

#### **4.2 Connections and comparison of areas**

Dryland areas are connected, e.g., by water systems and dependencies, ecological corridors, migration. Towns can influence transitions in rural areas as market, as source of capital and knowledge. Such relationships should be included in the research line.

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<sup>4</sup> Research will be developed in close cooperation with KvK as a complementary generic approach.

Comparison of different areas may contribute to the understanding of the systems, in particular if they differ in e.g., phase of technological development or transition of agriculture.

## **5. BIODIVERSITY**

The need to combat the worldwide loss of biodiversity is recognised, e.g. in the Convention on Biodiversity. Still, the aim of halting the loss of biodiversity is still far from being reached.

The processes responsible for the loss of biodiversity are manifold. The conditions in societies for conservation of biodiversity vary in the areas of the world, but also on ecosystem level. Much research is being done, but the knowledge is fragmented. Integrated, multidisciplinary research on biodiversity and the linkages with society is needed to develop understanding of generic processes, and to identify conditions for effective conservation and options for restoration of biodiversity. Many ecosystems in the world are rapidly losing biological diversity: extinction of species, loss of local populations, and loss of genetic variation. Also interactions between species, specific habitats and ecosystems are under pressure. Loss of biodiversity may affect functions and services of ecosystems. Availability of clean water, food production, regulation of climate and recreation values are related to biodiversity and ecosystems. This research line aims to improve understanding of the underlying processes and conditions for maintenance and restoration of biodiversity. The research line aims at terrestrial and fresh water systems, as other initiatives deal with the marine biodiversity.

### *Research lines and topics*

#### **5.1 Understanding of biodiversity patterns**

For a while, ecology was dominated by research on the functioning of ecosystems in terms of energy and nutrient flows and productivity. This didn't explain the large spatial and temporal variation in species and species numbers. A revival of research on biodiversity aims at explanation of biodiversity and patterns in terms of evolutionary mechanisms and interactions between (mostly only two) species. New research should aim at the combination and integration of:

- the evolutionary dynamics of species
- the relations between species in complete ecosystem perspective including all trophic interactions (food webs)
- properties of species, ecosystem functions and relations between species.

#### **5.2 Explanation of loss of biodiversity**

Mankind changes the boundary conditions and internal functioning of ecosystems. Research has increased understanding of mechanisms in specific cases, e.g. impacts of N-deposition, acidification, fragmentation. New research should be aimed at:

- up-scaling from the specific single factor cases to a general concept for multifactor impact
- analyse how human induced influences "branch" through food webs and ecosystems
- relations between habitat specialisation and risk of extinction
- to study invasive species as model systems.

#### **5.3 Relations between biodiversity, ecosystem functions and society**

Recently research has started to investigate utility values of biodiversity. Some progress has been made for a few ecosystems and a limited number of ecosystem functions. New research should be aimed at:

- really important ecosystem functions in international context; e.g. impact of land use change on the hydrology in semi-arid regions, impact of deforestation on erosion, the carbon-sink role of forests, disturbance of nutrient cycles
- interactions between trophic levels with regard to the relation between diversity and ecosystem functions (e.g. molecular methods to study of the role of micro-organisms) and spatial context (e.g. with high resolution and hyperspectral remote sensing)
- ethical and economical valuation of biodiversity and ecosystem functions.

#### **5.4 Sustainable management of biodiversity**

A large number of institutions (national and international) is involved in protection and restoration of biodiversity. However, management of biodiversity has little scientific basis and few research is driven by practical needs. New research initiatives should aim at both major gaps in scientific knowledge and the practical needs of managers and policy makers, e.g.:

- impacts of grazing by large herbivores
- management of biodiversity in tropical and sub-tropical systems
- analysis of the coupling between natural systems en society (e.g. land use change, poverty, health), in particular on larger spatial scales
- relations between governance on local, regional and (inter)national levels; e.g., interactions between policy objectives, legal frames (e.g. property), socio-economical drivers ranging from individuals to institutions.