Scientific aspects

Content

1. Description of the research programme

1.1 Problem definition, aim and central research questions

Societal problem definition

Rural areas play an important role with respect to climate change. On the one hand climate change will impact on rural areas, as hazardous weather events such as droughts, heat waves, torrential rainfall and subsequent floods are likely to become more frequent. On the other hand, the rural area has the potential to provide services that can relieve the pressure of climate change, such as water buffering, prevention of soil subsidence, carbon storage and facilitating a northward migration of species. In order to do so, rural areas have to adapt to the changing environment, so as to mitigate pressures and capitalize on opportunities. In this respect, a broad view is necessary. Besides nature and agriculture more land-uses need to be taken into account, such as recreation and heritage. This research programme is based on the concept of the metropolitan landscape. This concept aims to avoid oppositional and negative connotations between urban and rural, because this distinction has lost most of its relevance in a densely populated country such as the Netherlands.

Adaptation will happen – both planned and autonomously, at various levels and with different aims. Most land in the Netherlands is privately owned, and farmers and resource managers are autonomous decision makers with different goals. The challenge is to combine certain governmental and societal demands (e.g. storing water surpluses, meeting EU nature conservation standards, maintaining strong and competitive agriculture, preserving cultural and natural heritage, etc.) with the individual objectives of the land owners (farmers and nature organizations) as much as possible.

Scientific problem definition

In spite of considerable research effort, we still have insufficient knowledge about how the biophysical system, institutions and people will respond to climate change. What is particularly lacking is interdisciplinary research about the interactions and trade-offs between different sectors and across adaptation options. Vegetation responses to new hydrological circumstances are insufficiently known, and current models do not allow such assessments. Whether or not particular nature targets – obligatory by law – are realistic for the future is not clear. Also, little is known about the effects of extreme weather events on the survival of species in ecological networks, and the adaptation required of such networks to make them climate-proof.

Moreover, whilst there has been much research on the impacts of climate change and other environmental change drivers on rural systems, the assessment of *human adaptation* to change is much less developed. Better understanding of adaptation is urgently needed for society to be able to cope with the consequences of climate change. Human adaptation strategies are essential processes for all societies to consider, but the large uncertainties associated with the behavioural aspects of adaptation strategies make research in this area difficult.

Aim

Our central aim is to assess the effects of climate change and adaptive strategies (i.e. sets of concrete adaptation measures) on agriculture, nature and other land-use functions in the rural landscape of the Netherlands. To reach this aim, we focus on two climate scenarios and on four case study areas measuring a few tens to hundreds of square kilometres. For EU-policy, demography, and market two plausible existing scenario will be defined and integrated into the contrasting climate change scenarios. In addition to these exogenous scenarios we will investigate, in a case-study specific setting and in close co-operation with the stake-holders, the feasibility and effectiveness of adaptation strategies. These strategies are meant to:

- Achieve a climate-versatile ecological structure that allows meeting high-standard, climate-adjusted nature targets;
- Achieve good prospects for agriculture, the drinking water sector and other land-use functions;
- Whereby the overall functionality of the landscape, in terms of water management, biodiversity, agriculture, drinking water and recreation is optimized.

We believe that policy has the highest chances of success when it works, as much as possible, with the autonomous responses of hydrology, nature and agriculture and their actors to climate change. Policy should facilitate favourable developments and, where necessary, intervene locally to prevent negative impacts. Therefore, we aim to predict the autonomous developments of hydrology, nature and agriculture under a range of future conditions. These conditions will comprise two contrasting exogenous scenarios (i.e. integrating a high temperature increase with a ‘global economy’ and a moderate temperature increase with a ‘regional economy ‘. Furthermore, the conditions are defined by a number of region-specific policy

options (concerning spatial planning, drainage, water prices, etc., to be defined together with stakeholders). Policy recommendations will be formulated, following an integrated impact assessment of the autonomous adaptation strategies under the various policy options.

Central research questions

- Which adaptive measures in water management, nature and agriculture are feasible options to help eliminate potential climate change threats and create opportunities for nature restoration? Where and how should the National Ecological Network be strengthened? Do nature targets have to be adjusted, and how? What is the attitude of resource managers towards these options?

- How are different types of farms and farmers distributed over the rural area, currently and in the future, and what is their attitude towards different adaptation strategies? What are promising adaptation strategies, what are their effects, and what will be the trade-offs with other functions?

- What are the cross-sectoral effects of adaptation? How do adaptation strategies within the agricultural sector and the drinking water sector affect ecosystem functioning and water management, and how does adaptation of ecosystems and water management affect agriculture? Can the exploitation of new ecosystem services attenuate the possible detrimental impacts of one sector's adaptation on another sector?

- Which adaptation strategies have the highest potential to serve society, agriculture, nature and water management in multifunctional landscapes in an effective manner? What is their viability in terms of support from local decision makers?

1.2 Programme outline and research approach

The programme consists of three work packages (see Figure 1).

WP1 'Integration: multifunctional adaptation to climate change' is the coordinating and integrating work package. WP1 Phase 1 will coordinate contacts with the regional case studies and the project scenario development. Two consistent national scenarios will be developed based on climate and socio-economic variables. From these regional case-study specific scenarios will be developed in interactive sessions with stakeholders.

In WP2 'Water and biodiversity in the future climate' the impacts of climate change on water balance components, vegetation composition and population dynamics will be studied and adaptation strategies proposed. The spatial and abiotic requirements for adaptation measures will be quantified and attitudes of nature managers towards adaptation options will be explored. Questions answered are: Which adaptive measures in policy, nature and water management are feasible options to help eliminate potential climate change threats and create opportunities for nature development?

In WP3 ‘Drivers and consequences of adaptation by farmers’ the driving factors behind adaptation strategies for different farm types will be analyzed. Questions answered are: What are the consequences of agricultural adaptation strategies to climate, market and environment and how can ecosystem services provided by farmers contribute to water and nature adaptation?

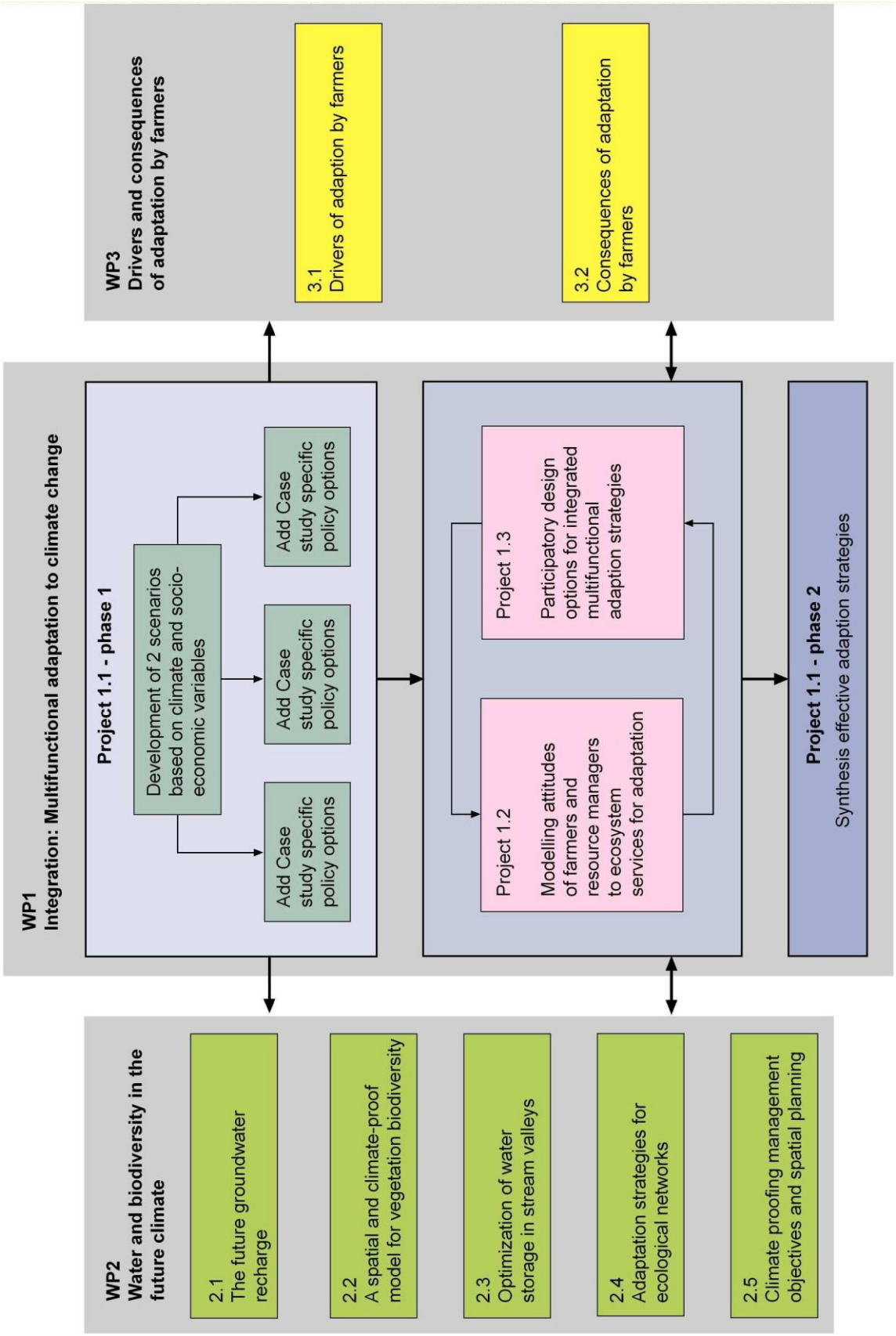
In projects 1.2 and 1.3, the actual integration and design of regional adaptation strategies for the case studies takes place, using knowledge about the needs and opportunities derived from the WP2 and WP3 projects. Questions answered are: Are provided ecosystem services in the right locations and is the robustness of these services adequate? How can financial and spatial incentives help to bring together required and offered ecosystem services?

In project 1.2 agent based models will generate understanding of where farmers and other landowners (nature managers, estate owners) are willing to provide ecosystem services and thus where opportunities for adaptation will occur. The model will also be used to explore how policy options and (spatial) incentives might improve adaptation opportunities.

In project 1.3 design options for the optimal allocation of adaptation measures will be generated for landscapes in a broader context including e.g. recreation, heritage, land subsidence and carbon storage. Options for integrated multifunctional adaptation will be developed in interactive sessions with the stakeholders. The pros and cons of multifunctional integration will also be explored.

Finally, project 1.1 (WP 1, Phase 2) will undertake an interpretation of the new knowledge and insight into the adaptive capacity of land managers to climate change, generated by the various WPs of the project. This synthesis of the project outputs will include a comparison of the efficacy of alternative adaptation options within different biophysical and socio-economic contexts and future environmental change scenarios.

Figure 1: Schematic overview of the research programme



1.3 Innovative aspects and scientific output

Previous climate change studies that have attempted to model feedbacks between e.g. the biotic and the abiotic system or between nature, agriculture and society, have largely ignored the climate dimension. In studies in which the climate dimension has been the research focus, modelling of feedbacks and cross-sectoral aspects has largely been ignored. For ecological modelling this means that most current vegetation models are unsuitable for assessing climate effects since (a) they use indirect relationships based on the climate of the 20th century, (b) they omit critical climate variables such as temperature and CO_2, (c) they neglect important feedbacks in the soil-water-vegetation system; and (d) our understanding is limited of the effects of climatic extremes on population fluctuations and - survival and on the functioning of ecosystems. For agricultural modelling, studies that have addressed the vulnerability of agriculture to climate change have focused on potential impacts without adequately addressing adaptation strategies at multiple scales (field, farm and region). When adaptation strategies are considered, socioeconomic conditions and farming systems are often ignored, although these strongly influence current farm performance and are likely to also determine adaptation to future change. The research proposed here will focus explicitly on filling these gaps in knowledge and expertise.

Another aspect that requires a more innovative approach is how local actors will respond to climate change. Many integrated assessments of climate change and global change tend to use models that look for optimal land use and land management. These are useful explorations of the potential of a certain area or system, but they have limited value when one wants to know more about *feasible and plausible* developments, especially in areas that are as human-controlled as the Netherlands. In the 'Routeplanner Klimaataanpassing' the social complexity of adaptation strategies is considered to be a bottleneck for adaptation strategies (as is the institutional complexity, but this falls within the scope of Theme 7). Without acknowledging the important role of human perception and response, which often deviates strongly from what policy-makers wish it to be, a realistic assessment of possible adaptation strategies cannot be made. The proposed agent-based modelling approach allows assessment of subjective human perception and response, and is therefore a promising research tool for (small-scale) land use/management modelling.

In addition to these scientific innovations, the proposed research will address important issues raised by stakeholders in the region. We aim to answer stakeholder questions concerning future farm management by studying farmer attitudes towards different adaptation strategies and simulating the future spatial distribution of different farm(er)-types. The proposed research will also address region specific questions concerning nature targets. Which nature targets are appropriate for the long term, and how can they be achieved? With respect to ecological networks and spatial planning: how and where should connectivity be achieved to facilitate migration and dampen effects of weather extremes, and how can this be achieved with green infrastructure in multifunctional landscapes? Will migration rates be able to keep up with the rate of climate change? Finally, the proposed research plans to address questions concerning freshwater availability and water quality and the consequences for nature and agriculture, and climate change effects on the groundwater system and its consequences for groundwater management.

We will develop a conceptual framework based on the provision of ecosystem services for the integration of nature, water and agricultural management. We will synthesize the new generated knowledge into alternative adaptation options available to land resource managers and policy makers. These adaptation strategies should minimize the negative effects of climate change on rural areas and maximize the opportunities.

Output with respect to the scientific innovations will be in the form of peer-reviewed international publications; output with respect to the stakeholder questions will be in the form of joint learning about climate change, impact and adaptation, with the goal of identifying shared recommendations toward decision makers and policy makers. The latter will be achieved through a variety of participatory methods and dissemination strategies, including workshops, map table sessions and a website.

1.4 Relevance of the research programme in an international context

The innovative elements of this proposal are fundamental issues that are relevant to the international context. The vegetation models developed here will be applicable to a much wider area. Furthermore, the international climate change debate is moving from biophysical impact assessment to human response mechanisms, and the research proposed here will make a valuable contribution to this debate.

Furthermore, many of the issues addressed in the case study areas are relevant for other densely populated Delta regions. In many such regions, policy makers are looking for the right balance between maintaining current functions, which may require mitigation (i.e. relieving pressures that arise in the future); and adopting new functions by adapting to the new states that arise from future pressures.

In this research we plan to investigate the potential of water buffering, which can be considered a ‘climate service’. Following the success of the so-called green services (where farmers receive subsidies for managing their land in an environment- and animal-friendly manner), climate services have the potential to become part of internationally adopted adaptation policies.

The new knowledge generated through the implementation of this research programme will be upplemented by a literature review of the various options for adaptation available to land resource managers and policy makers. This review will include research undertaken outside of the Netherlands that will serve to put the adaptation measures addressed here into an international context.

In accordance to the EU Climate Change Framework Programme (ECCP) attention will be paid to the socioeconomic cost-effectiveness analysis (social costs, private and public) of different adaptation options, and to the integration of the analysis of the adaptation options into the EU policies (CAP, WFD, Natura 2000). The proposed site-specific actions in the selected hotspots will be linked to the EU policies, which will increase the policy relevance of the programme. In this respect, the CARE programme may be used to develop specific guidelines and tools. On these topics we strive to cooperate with the Theme 8 consortium (inclusion of socio-economic sciences).

1.5 International cooperation

An Edinburgh-based postdoc will develop the agent-based model that links the environmental and human, and agricultural and natural systems. We anticipate that this postdoc will cooperate closely with the two postdocs appointed in projects 2.5 and 3.1 (based in the Netherlands), who are concerned with collecting the information from local decision makers using interviews and surveys. Each postdoc will make at least two stays of one week in the other postdoc(s)' institution(s), in order to ensure optimal communication and exchange of knowledge and skills. The Edinburgh-based post-doc will also contribute to the final synthesis project in WP1. He or she will carry out an international review of the various options for adaptation that are available internationally. This will serve to put our proposed adaptation measures strategies in an international context. Furthermore, we will aim for endorsement by international networks such as:

- The Global Land Project (GLP), which is particularly interested in the coupling of human and environmental systems and whose members are in the scientific frontier when it comes to novel techniques such as agentbased modelling (http://www.globallandproject.org/);
- The Partnership for European Environmental Research (PEER) network, of which the aim is to build an open European platform that brings together expertise and exchanges information on the best approaches to mitigate and adapt to climate change (*http://www.peer.eu/*);
- DIVERSITAS on biodiversity science (http://www.diversitas-international.org/), the Global Environmental Change and Food Systems (GECAFS) programme on understanding the links between food security and global environmental change (http://www.gecafs,org/), and the International Human Dimensions Programme (IHDP) on global environmental change (http://www.ihdp.unu.edu/).We also aim to cooperate and communicate with European research projects such as EcoTRADE that studies the applicability of tradable development rights to biodiversity conservation (http://www.ecotrade.ufz.de/index.html), CLIMSAVE that is modelling adaptation to climate change and ECOCHANGE that is developing Agent-Based Models of land use change and ecosystem

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2. Interdisciplinarity

Capturing the impacts of climate change on the diversity of species and the functioning of ecosystems requires the combination of different disciplines. Effects are both direct − through changes in CO_2, temperature and precipitation, and indirect − through changes in water related habitat factors and land use change. The proposed research will combine the required hydrological, physiological and ecological knowledge to fill the gaps in knowledge as described in 3A3.

Even more challenging is the proposed coupling of the human and environmental system, requiring the combination of biophysical, economic and social modelling paradigms. Biophysical and (traditional) economic models comprise functional relationships between variables (i.e. whole-system, equation-based modelling). Agent-based models are the social-science analogue of computational simulations that explore complex nonlinear processes. However, contrary to whole-system (reductionist), equation-based modelling, agent-based modelling assumes that system properties emerge from the simulation of interacting agents given their attributed goals, decision-rules, and the constraints faced and "sensed" by each agent. An agent-based model thus allows the overall behaviour of the system to emerge from the actions of the individual agents, without presupposing the outcome.

The interdisciplinary nature of the research allows identification of the cross-sectoral effects and trade-offs of different adaptation strategies. Until now, little emphasis has been made on the cross-sectoral effects of climate adaptation, as most studies tend to focus only on one sector. Such models generally lack the ability to connect between sectors and do not explicitly include feedbacks from agriculture to nature and vice versa. Consequently they are likely to either over- or under-estimate the effects of climate change impacts and adaptation.

Our project brings together the needs and opportunities for adaptation to climate change. This approach requires the effective combination of knowledge from various disciplines from the natural as well as the social sciences. This is mirrored in the composition of our consortium.

3. Coherence between and synthesis of outcomes from the individual work packages

The coherence between the work packages and the projects is depicted in Figure 1 in Section 3A2.

Scenarios

The coherence of the programme as a whole is organized in WP1. WP1 coordinates the contacts with the regional case studies and the scenario development within the project as a whole. Two consistent national scenarios for the year 2050 will be developed based on climate and socio-economic variables. The climate scenarios, W and W+, are based on General Circulation Model simulations published in the Fourth Assessment Report of the IPCC and include changes in temperature, precipitation and reference crop evapotranspiration. The climate change scenarios will be integrated with two contrasting socio-economic scenarios: 'global economy' and 'regional economy' (e.g. WLO scenarios). Within each scenario, we will distinguish three weather years: an average year, a dry year and a wet year. To this end, we will transform time series of 30 years of climate variables to the 2050-climate, using transformation software supplied by the Royal Netherlands Meteorological Institute. Moreover we will use frequency figures of climate variables to assess the effects of weather extremes on agriculture and nature.

Based on the national scenarios more detailed regional case-study-specific scenarios will be developed in interactive sessions with regional stakeholders. This allows for an active contribution of stakeholders in the definition of regional problems in the face of climate change and potential adaptation options. Specific

questions on effects of climate change and possibilities for adaptation that have come up at these interactive stakeholder sessions will be studied further in the projects of WP2 and WP3.

Design options for regional integrated adaptation

In project 1.2 agent based models will generate understanding of where farmers and other landowners (nature managers, estate owners) are willing to provide ecosystem services and thus where opportunities for adaptation will occur. The model will also be used to explore how policy options and (spatial) incentives might improve adaptation opportunities. Both WP2 and WP3 contain a project that generates input to the agent-based model. These two projects investigate the goals of nature managers (project 2.5) and farmers (project 3.1) and their motivation for adaptation options, which will be translated into decision rules for the agent-based model. Whether the simulated adaptation is sufficient from a biophysical perspective (are spatial and abiotic conditions met) is evaluated in the WP2 and WP3 projects.

In project 1.3 design options for the optimal allocation of adaptation measures will be generated for landscapes in a broader context including e.g. recreation and heritage. Options for integrated multifunctional adaptation will be developed in interactive sessions with the stakeholders, taking into account the needs and opportunities from WP2, WP3 and 1.2. The pros and cons of multifunctional integration will also be explored.

Synthesis of effective adaptation strategies

The project will generate new knowledge and insight into the adaptive capacity of land managers to climate change. Phase 2 of 1.1 will undertake an interpretation of this new knowledge by synthesising the adaptation options and strategies available to land resource managers. This synthesis will include a comparison of the efficacy of alternative adaptation options within different biophysical and socio-economic contexts and future environmental change scenarios.

4. (Expected) cooperation and coherence with other research themes

There are connections with the themes 2, 4, 6, 7 and 8. In Theme 2 attention is paid to saline agriculture and to the effect of salinization on nature targets. The knowledge that will be generated may be relevant for understanding future agricultural development as outlined in WP 3. Furthermore, together with Theme 2 we will work on a common case study. This is the so-called “Groene Ruggengraat” (Green Backbone) in the western part of the Netherlands (see also under 4A).

With Theme 4 (WP 3, project 3.7: urban design and spatial planning for climate change adaptation in metropolitan areas) an arrangement is made to actively cooperate on the importance of urban development for rural areas and vice versa. It is envisaged to link “new” land use options that will result from project 3.7 with new functions in the countryside and from there with possibilities of new sources of income. This cooperation is also expected to be fruitful for our analyses of the metropolitan landscape in WP1, project 1.3.

From Theme 6 we hope to receive regional climate scenarios that will be the basis for our analyses on the regional level in the case study areas. Theme 7 is important for us when dealing with the governance aspects of the projects, in particular the projects in WP 1 and projects 2.5 and 3.2. Therefore, we will strive for intensive cooperation with Theme 7. Finally, with Theme 8 we expect to cooperate on tools for public participation, such as the map table. In this respect it is an advantage that the research group working on these tools in Theme 8 also participates in this consortium.

The expected cooperation with the other KfC themes mentioned above will be elaborated within the first six months after the start of this research programme.

5. Connection to finalized and current projects in KfC and other research programmes

This programme is related to several finalized and current projects in KfC:

- VBR-12: Klimaatverandering en het effect op natuur & landbouw
- VBR-17: Klimaatbestendig ecohydrologisch modelleren
- HSOV1A: Climate effects on decomposition in drained peat meadows: implications for peat subsidence and water quality
- HSOV1B: Climate influence on water quality: which trends are already apparent?
- HSOV1C: Managing climate effects in peat meadows and shallow lakes
- HSHL01A: Klimaat in ruimtelijke keuzes
- HSHL06/HSHL12: Brede, gebiedsspecifieke verkenning van effecten van klimaatverandering in samenhang met toekomstscenario's en trendmatige ontwikkeling

The project can be regarded as a follow-up of the first tranche of KfC research for Hotspot Dry Rural Areas, titled An inventory of strategies to cope with climate change in dry rural sandy areas with a temperate climate: a case study in the Province of Gelderland ('Integral point of view Baakse Beek') and the province of Noord-Brabant ('Combining spatial claims of land use functions and adaptive strategies to climate change in densely populated rural areas').

This programme also relates to, and builds on, several projects within the Climate Changes Spatial Planning programme. These projects are in particular:

- A1: Biodiversity in a changing environment: predicting spatio-temporal dynamics of vegetation
- A2: Adaptation of the National Ecological Network
- A19: The assessment of the adaptive capacity of Dutch agriculture to the effects of climate change under different market and policy scenarios
- A21: Climate and agriculture in North Netherlands

- IC03: Designing national land use adaptation and mitigation strategies under changing climate conditions (LANDS)
- IC11: Socio-Economic scenarios for climate change assessments
- IC12: The Dutch institutional framework and governance of adaptation strategies
- ME06: Spatial decision support for management of Dutch fen meadows

Furthermore this programme relates to:

- Knowledge Programme Leven met Water, in particular the *Waarheen met het veen* project
- Research vision KWR Watercycle Research Institute (http://www.kwrwater.nl/page.asp?id=136)
- WUR Strategic Research Programme 'Sustainable development and adaptation of ecosystems and landscapes in a metropolitan context' (http://www.kennisonline.wur.nl/KB/KB-01/beschrijving.htm)
- Deltaplan Hoge Zandgronden by the provinces of Noord-Brabant and Limburg, Staatsbosbeheer, farmer's and nature management organisations, water boards and drinking water companies.