Climate Adaptation for Rural arEas (CARE)

Midterm review report
Knowledge for Climate Theme 3

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Climate Adaptation for Rural Areas

Knowledge for Climate

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Photo front page: Multifunctional rural area in the Blauwe Bron case study area. Source: Minkman and Hoekstra, 2012, p. 37.

Contents

1. Introduction

This midterm review report presents the structure, progress and first results of the Knowledge for Climate Theme 3 research programme Climate Adaptation for Rural arEas (CARE). This research programme aims to generate the fundamental knowledge that is necessary to design and evaluate adaptation strategies to cope with the impacts of climate change on rural areas in the Netherlands. Acknowledging the important role of human perception of and response to climate change and its consequences in the development and implementation of adaptation strategies is one of the innovative aspects of this research programme. Other innovative aspects include in particular the application of agent-based modelling (ABM) as a scientifically challenging tool to understand human dimensions of adaptation, and the development of a conceptual framework based on the provision of ecosystem services for the integration of nature, water and agricultural management. Local and regional stakeholders are involved in all stages of the research since their opinions, attitudes and other input are fundamental for the scientific outcomes and for the translation of these outcomes into climate adaptation strategies.

The research is conducted by a multidisciplinary team consisting of researchers from Wageningen University and Research Centre (WUR; lead partner), Vrije Universiteit Amsterdam (VU), Utrecht University (UU), Deltares, KWR Water Cycle Research Institute, and University of Edinburgh (UoE). A scientific Steering Board, consisting of independent scientists, representatives of the co-financing partners (provinces and water boards), and the national government (Ministry of Economic Affairs, Agricultural and Innovation) monitors the progress, quality and coherence of the research, and advises both the consortium and the KfC Board.

The structure of this report is as follows. First, we give an overview of the rationale and aim of the CARE research programme (Chapter 2). Then, the structure of CARE and the principles of our agent-based model are explained in more detail (Chapter 3). The next Chapters (4-6) contain a description of the work packages, their individual projects, and intermediate results. The final Chapters pay attention to stakeholder involvement (Chapter 7), communication, publications and dissemination of results (Chapter 8), and the research activities in the 2nd half of the programme (Chapter 9).

The annexes contain facts and figures of CARE (Annex 1), information about stakeholders and hotspots, including co-financing (Annex 2), communication activities and peer-reviewed scientific articles, produced in the 1st half of the programme (Annex 3), and planned publications (Annex 4).

2. Rationale and aim of the CARE research programme

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, rural areas have the potential to provide services that can relieve the pressure of climate change, such as water buffering, 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.

Adaptation will happen – both planned and autonomously, at various levels and with different aims. In order to design successful policy, it is important to acknowledge the fact that 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 a competitive agricultural sector, etc.) with the individual objectives of the land owners (farmers and nature organizations) as much as possible.

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 (see for example Kabat et al., 2005; Rounsevell et al., 2006; Botkin et al., 2007; Blennow and Persson, 2009; Reidsma et al., 2010) 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.

The central aim of the CARE project is to tackle these unresolved issues, by combining the expertise of scientists from different disciplines. We use agent-based modelling as the vehicle to unite these disciplines and allow communication between them. In doing so, we will eventually assess the effects of climate change and adaptive strategies on agriculture, nature, and other land-use functions in the Dutch rural landscape. The Netherlands is a small and flat country with a temperate sea climate that has small spatial differences in meteorological conditions. The mean summer and winter temperatures are 16^{o}C and 3^{o}C respectively, the mean yearly precipitation is 770 mm and the mean yearly Makkink (1957) reference evapotranspiration is 563 mm. We investigate two existing climate scenarios developed by the Royal Netherlands Meteorological Institute (KNMI), the G and the W+ scenarios, with +1^{o}C and +2^{o}C temperature rise by 2050 respectively (Van den Hurk, 2006). We combine these climate scenarios with two contrasting socio-economic scenarios: Global Economy and Regional Communities (see Chapter 5, Project 1.1 for more details). In addition to these "exogenous" scenarios we define a set of policy options (strategies) with our stakeholders, which they would like be evaluated. These strategies are meant to:

- Achieve a climate-versatile ecological structure that allows meeting high-standard, climate-adjusted nature targets;
- While maintaining 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.

Initially the research focused on all rural areas in the Netherlands, in particular the Knowledge for Climate hotspots Dry rural areas, Shallow water and peat meadow areas, Wadden sea, and South-West Netherlands Delta. However, because predominantly policy makers from the eastern and southern parts of the country (hotspot Dry rural areas, characterized by Pleistocenic sandy deposits) showed particular interest in this project, we have targeted our efforts mainly on this part of the country. Two particular case study areas have been identified by the stakeholders, which are the Baakse Beek catchment (approximately 30 by 10 km between the village of Lichtenvoorde and the IJssel river), and the Tungelroyse Beek catchment (a similar sized region in the south of the Netherlands). Both catchments consist of a rather flat cover-sand landscape with shallow groundwater levels and brooks, dominated by pasture, maize fields and small nature reserves. In CARE, an agent-based model (ABM; see Chapter 4) will be developed to simulate the future configuration of land use(rs) in both areas.

A third case study area, the Blauwe Bron catchment, measures approximately 25,000 ha and includes an elevated ice-pushed ridge with woodlands and heathlands, where water infiltrates. The major question for this area is how the groundwater recharge of the ice-pushed ridge will be affected by climate change, and how this will influence drinking water abstraction and nature development in lower discharge areas (Minkman and Hoekstra, 2012).

Additional work is or will be done in individual projects in other regions: an interactive workshop with farmers about the consequences of climate change for the fresh water quality on the isle of Texel (hotspot Wadden sea) and application of the CARE approach in the Groene Ruggengraat area (hotspot Shallow water and peat meadow areas), together with the Theme 2 consortium (Fresh Water Supply). However, as this midterm review focuses on integrative research, we focus on the two case study areas in which the entire package of sub-projects is carried out.

The location of the case study areas is illustrated in Figure 1.

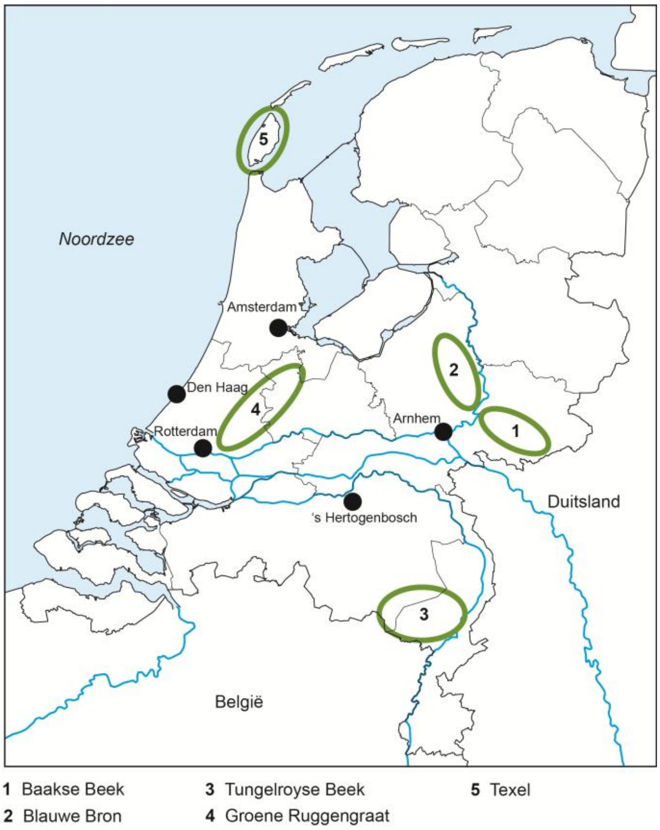

Figure 1: Location of the CARE case study areas.

The CARE programme partly fulfils the needs of a coalition of provinces, water boards and other organisations of the elevated southern and eastern part of the Netherlands. At a symposium ‘Hoog & Droog’ (High and Dry), 6 June 2012, this coalition suggested that their ‘high’ region got insufficient attention in the national Delta programme. In a manifesto they called for more attention to climate change, and to reserve adequate financial resources for the required measures (Anonymous, 2012).

3. Structure of CARE

The CARE programme consists of three work packages (WP; see Figure 2). WP1 is the coordinating and integrating work package. Both WP2 and WP3 contain subprojects (yellow) that generate input for the agent-based model (ABM; see Chapter 4) that is developed in Project 1.2 (WP1). These subprojects investigate the goals and drivers of nature managers (WP2) and farmers (WP3), which are translated into decision rules for the ABM.

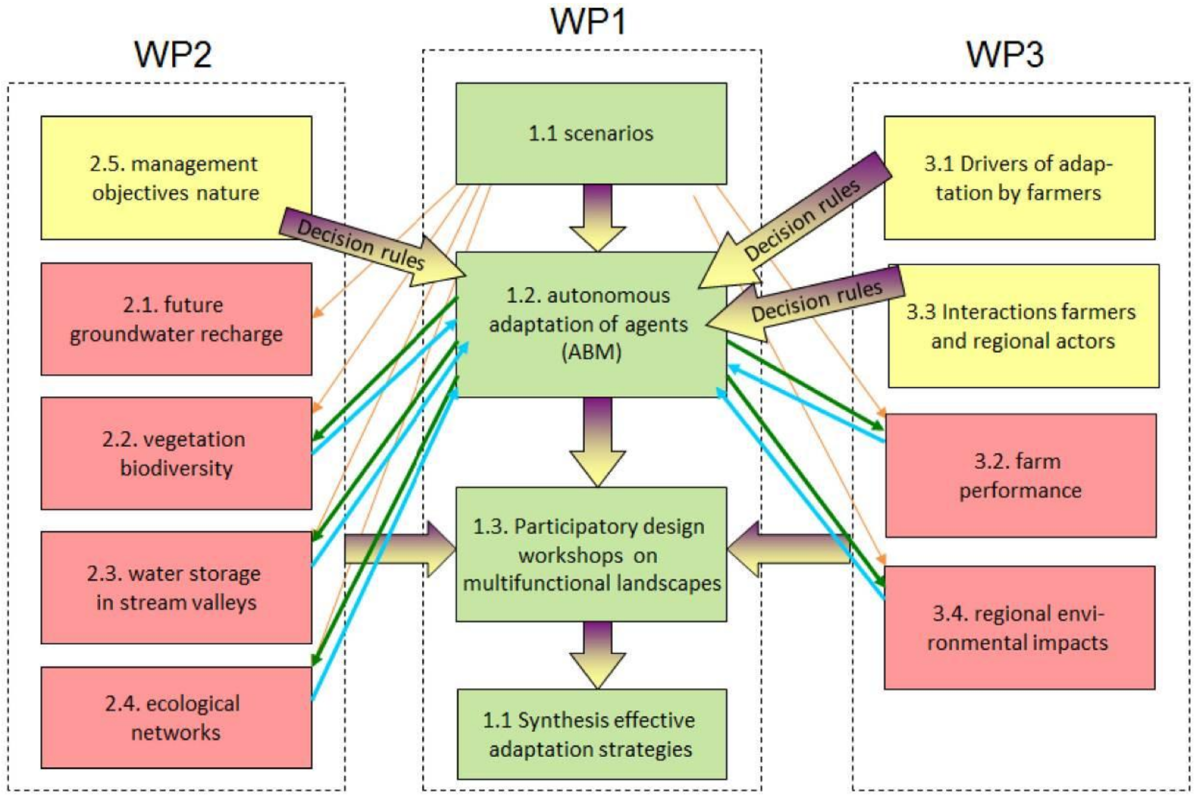

Figure 2: Structure of the CARE research programme, division of work packages, and relations between the individual projects. For explanation, see text.

Project 3.1 (drivers of adaptation by farmers) investigates which farmers are willing to sell land, and which farmers are willing to buy land. In addition, it provides the ABM with information on how farmers perceive the attractiveness of parcels, so that the ABM can use that information to simulate actual land transactions. In a similar fashion, Project 2.5 (management objectives nature) investigates the purchasing power of the different nature organizations, and it also provides the ABM with rules on how these organizations valuate available parcels. The agent-based model will take the current distribution of (types of) farmers and nature managers as a starting point and simulate (a) the decision making of all agents (i.e. sell, buy, or do nothing), (b) the land transactions between agents, and (c) development of all agents.

How actors will behave depends on circumstances, and these circumstances are defined by Project 1.1 (scenarios) in the form of climate and socio-economic scenarios. For example, economic developments in combination with climate change will determine the economic performance of different agricultural sectors. In the ABM, a relative benefit of, say, the horticultural sector, can be incorporated and may lead to relatively more expansion of horticulture farms. More locally, climate change may lead to certain parcels losing their attractiveness, as a result of drought or waterlogging. Economic scenarios will also define the purchasing power of nature organizations.

The ABM will have stochastic elements, which will result in each model output to be different, even if all settings and scenarios are similar. As output, we will produce for each scenario/policy-option a range of, say, 100 realizations of ABM output. We will summarize the overall trends in a set of summary measures for presentation to stakeholders, and provide the other CARE projects in WP2 and WP3 (red boxes in Figure 2) with one representative outcome, plus an indication of the uncertainty. Comparing the outputs of different policy options will allow the stakeholders to evaluate the impacts of the policy options.

Hence, the “red” projects within CARE will receive a spatially explicit land use/management map from the agent-based model, which they will use as input for their simulations. At each 5 or 10-

year time slice (depending on the dynamics of the produced output) an interaction between the output of the other subprojects in WP2 and WP3 and the ABM is established.

The final projects in WP1 (Project 1.3: participatory design workshops on multifunctional landscapes, and an extension of Project 1.1: synthesis effective adaptation strategies) will collect all the indicator performances for each map, and identify synergies and conflicts between the various indicators. The final results show for each scenario/policy-option combination a map indicating the (multi)functionality of the landscape. Also for the individual functionality-constituents (i.e. the indicators evaluated in WP2 and WP3) maps will be generated. Such maps demonstrate the impact of policy on the landscapes in the context of global and climate change. It may turn out that some locations always develop in a favourable way, while other locations always develop in an unfavourable way, regardless of the policy. For these locations it is important that the individual projects and/or work packages will all aim at identifying the success and failure factors.

All individual projects within the CARE programme have achieved considerable progress. Details on this progress can be read in the description of the individual projects (Chapters 5-7). In this Chapter, focus is on the integration between the projects, i.e. the arrows in Figure 2.

At this stage, most progress with respect to integrative activities have been the block arrows from Projects 2.5 (management objectives nature) and 3.1 (drivers of adaptation by farmers) to the ABM. The functionality of the ABM has been defined, based on the most important processes identified by Projects 2.5 and 3.1. Furthermore, these projects also provided the ABM with calibrated quantitative decision rules.

Defining the functionality of the ABM also allows us to define the nature of the data flows that is represented by the other arrows between the projects. Although these data flows are not yet operational, we can already be more specific about what they represent:

- The block arrow from Project 1.1 (scenarios) to the ABM represents the time series of input data for the ABM. These are: trends in product-value indices for different agricultural sectors; maps of climate-induced yield losses for arable crops and grassland; budgets for nature organizations; and specific policy-options on the stimulation of water retention and green-blue infrastructure.
- The block arrow from Project 3.3 (interactions farmers and regional actors) to the ABM represents information on how organizations that do not own land themselves influence the decisions of the land owners. The nature of this information needs to be specified in more detail in the coming half year.
- The orange arrows from Project 1.1. (scenarios) to the projects represent time series of climate and economy data that feed directly into these projects.
- The green arrows from the ABM to the sub-projects represent (time series) of land use maps. Currently, these land use maps comprise the following categories: arable cultivation, dairying, horticulture, pig-breeding, mixed farms, and nature. In addition, for each parcel or nature area information is available on the type of owner (e.g. intensifying farmer, expanding farmer, Natuurmonumenten, Staatsbosbeheer, etc.). Output will also comprise farm delineations, from which conclusions can be drawn about (loss of) green-blue infrastructure. Furthermore, in due time another layer will be made available indicating the willingness of farmers to participate in agri-environmental schemes.
- The turquoise arrows from the projects to the ABM represent feedbacks. This concerns variables to which the agents in the model are sensitive. For instance, economic farm performance (Project 3.2) or the achievement of certain nature targets (Project 2.2). When actors in the ABM fail to meet their targets (performance criteria will need to be defined by the sub-projects), the ABM will make them change their strategy.
- Block arrows into Projects 1.3 (participatory design workshops on multifunctional landscapes) and 1.1 (synthesis effective adaptation strategies) need to be further specified in due time.

These data flows represent the current state of integration within the CARE programme. A first application of the full package of all projects including integration via the ABM is expected to be run by the end of 2012 for the Baakse Beek study area. In the meantime, several projects will already have started with data collection for the Tungelroyse Beek study area. It is expected that once the Baakse Beek pilot has successfully run, Tungelroyse Beek can follow quickly.

4. The principles of agent-based modelling in the CARE programme

The agent-based model (ABM) can be considered as the hub and most scientifically challenging part of the entire CARE project. It simulates the future spatial distribution of nature areas and different farmer types, i.e. it generates future land use/management maps. The simulation reflects autonomous behaviour of land-using actors (i.e. governmental and private nature organizations, and farmers) that all strive to achieve certain (personal) goals against the background of certain given conditions (specified by the future climate and socio-economic scenario and policy options).

More specifically, the ABM focuses on land exchange between different actors. As in many rural areas in developed countries, many farmers sell land as a strategy to cope financially, or in a deliberate attempt to quit farming. At the same time, other farmers are willing to buy land so that they can expand and reap economies of size. Also nature organizations are seeking to expand their current property by buying land of farmers, and therewith compete with the expanding farms for land that becomes available. Land exchange between farmers is probably the dominant process behind categorical land use change, and is therefore the focus of the ABM.

Concerning land exchange, ABMs have been developed to simulate land transactions (c.f. Filatova et al., 2008; 2009). However, these models have mainly focused on the simulation of land market processes in urban areas. The RUral Land EXchange (RULEX) model developed for the CARE project focuses on land use changes in rural areas. This is assumed to result from land exchange between autonomous and heterogeneous agents representing farmers and nature managers from the case study regions. Figure 3 illustrates the sequence of events outlining these processes (i.e. the conceptual algorithm).

5. Work package 1: Integration: multifunctional adaptation to climate change

Content

The central aim of this work package is to learn how landscape planning, design and management could be organized in order to be effective, efficient and sustainable. This work package brings together climate adaptation needs for water management agriculture and nature management and develops options for regional integrated adaptation together with stakeholders in different case study areas. The work package analyses if and how climate adaptation measures can be integrated on a regional level. The effectiveness of various decision-making strategies of policy makers, nature managers and farmers are explored and cross-sector benefits and disadvantages of different adaptation options become explicit.

The work package will synthesize new knowledge on which adaptation strategies (ecosystem services) are available to land resource managers and policy makers and which seem most beneficial for rural areas. The synthesis will include a comparison of the efficacy of alternative adaptation options within different biophysical and socio-economic contexts and future environmental change scenarios.

Better understanding of adaptation is urgently needed for society to be able to cope with the consequences of climate change. Importantly, adaptation has to be framed within the wider context of land use change and not just climate change alone. Whether a regional adaptation strategy will be effective depends on both biophysical as well as socio-economic components.

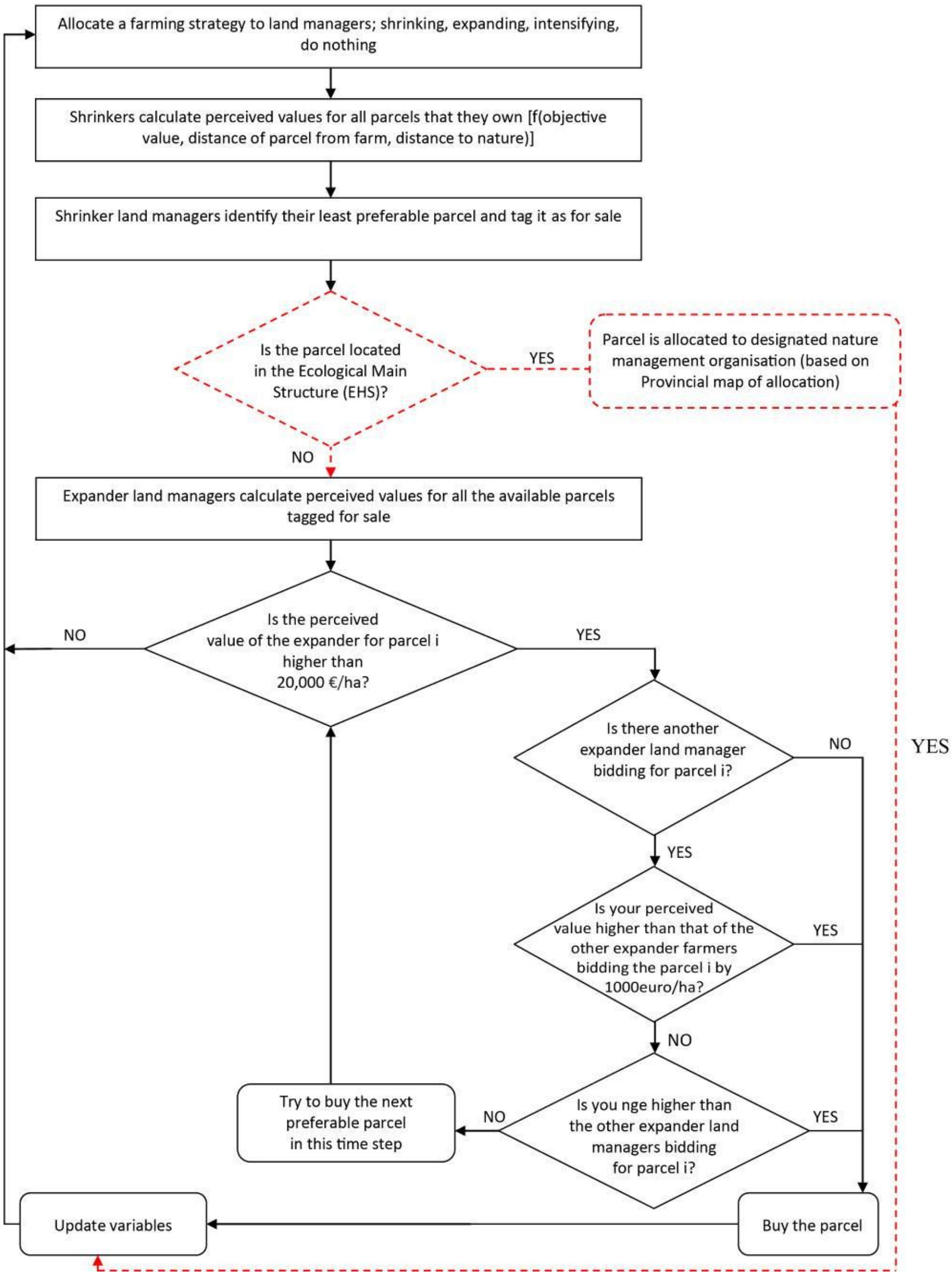

Figure 3: Conceptual algorithm of RULEX v.0 model. Red dotted lines indicate the processes that will take place until 2018 when the areas designated for nature management (Ecological Main Structure) are allocated to the appropriate nature managers. After that, farmers and nature managers follow the same process (indicated by black lines) when selling or buying land.

From the biophysical point of view a regional adaption strategy would be regarded effective when the problems caused by climate change for different functions in the regions are solved. From the socio-economic perspective, effective implementation of regional adaptation strategies also depends on the willingness of actors to participate. For instance, are farmers willing to carry out particular ecosystem services on their land that contribute to the adaptive capacity of ecosystems or regional water storage?

Achievements thus far are the development of the ABM model RULEX in close consultation with stakeholders (first comprehensive application Fall 2012), the preparation of several papers to international journals, the interactive workshop at the isle of Texel, and a climate adaptation landscape design study in the Blauwe Bron area by MSc students of Wageningen University (Minkman and Hoekstra, 2012).

Project 1.1. Development of scenarios, coordination of case studies and synthesis of effective adaptation strategies

This project coordinates the development of scenarios and policy options for the case study area and the integration of knowledge towards effective adaptation strategies. It develops new knowledge on effective regional adaptation strategies based on the CARE results and literature review.

Two climate change scenarios are used in combination with two contrasting socio-economic scenarios. In 2006, based on general circulation model simulations published in the Fourth Assessment Report of the IPCC (IPCC, 2007), the Royal Netherlands Meteorological Institute (KNMI) issued four climate scenarios (Van den Hurk et al., 2006). Here, we focus on two scenarios, the G and the W+ scenario, which comprise a +1 or +2 ºC global temperature increase by 2050 respectively. On an annual basis, the W+ scenario has the lowest potential precipitation excess. A second distinction between the two scenarios is the anticipated circulation regime change: a strong change of circulation, which induces warmer, and moister winter seasons and increasing the likelihood of dry and warm summertime situations (W+), and a weak change of circulation (G).

We use two contrasting socio-economic scenarios, Global Economy and Regional Communities (WLO, 2006), which were recently updated for agriculture. The Global Economy scenario stands for deregulation and liberalization of agricultural policy, while in the Regional Communities scenario agriculture is subsidized, for instance for the provisioning of ecosystem services.

In landscape planning, the response of the landscape system to physical change is rarely considered. Impacts of human actions on landscapes is the domain of environmental sciences, and this knowledge base has not been mainstreamed in planning sciences. However, understanding whether and how the landscape system responds to climate adaptation measures by retaining its capacity to provide desired benefits and values is an essential feed-back in the social-ecological system (Holling, 2001; Termorshuizen and Opdam, 2009).

The definition of adaptation of the Intergovernmental Panel on Climate Change refers to an 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC, 2007). As was already observed by several authors (e.g. Adger et al., 2011; Engle, 2011) this definition of adaptation to climate change shows strong resemblance with the resilience concept where climate change can be regarded as a specific type of disturbance.

Integrating resilience strategies and climate adaptation strategies, we have developed three generic spatial characteristics of the landscape pattern that could be used as key principles for the adaptive capacity of the physical landscape: 1) Size, where the mere size enables (eco)systems to absorb change or recover from disturbances; 2) Heterogeneity causing a buffering capacity for disturbances; and 3) Connectivity to link processes at multiple scales, facilitating change or recovery. The usefulness of these indicators in diagnosis and design of climate-proof multifunctional landscapes by local communities is tested in two case studies: Baakse Beek and the city of Gouda (Vos et al., *in prep*.).

As a result of the CARE project a synthesis of effective climate change adaptation options for the rural landscape will be developed. As a first step a systematic review was started to identify adaptation measures that are currently applied in regional adaptation plans and to assess their impact on the adaptive capacity of social-ecological systems in rural areas (Karali et al., *in prep.*). RULEX models land use change in a bottom-up approach: what actions will landowners (farmers, estate owners, nature managers) take in the context of climate change and socio-economic developments? The potential future land use maps will be analysed by the other models and give insight into the regional adaptive capacity of different sectors (farmers, water management and nature) and how policy options can influence this process.

Project 1.2. Modelling different farm types and resource management strategies based on an analysis of the attitudes of farmers and resource managers to ecosystem services

Urbanisation and nature management decrease farmland in the Netherlands by 0.5% every year (LNV, 2006). Moreover, farm size increase and dominance of certain farm types (i.e. dairy farms) (UN, 2008) suggest an intensive change of land owners within the agricultural sector. Land transactions are often accompanied by changes in the use and/or management of farmland, resulting in modifications of the landscape structure and the provision of ecosystem services.

In the context of climate change, the aforementioned highlight the need to better understand land exchange processes. To achieve this objective Project 1.2 (autonomous adaptation of agents – ABM) aims at developing the RUral Land EXchange (RULEX) model to simulate land manager decisions regarding land exchange and explore their effects on land use patterns and the provision of ecosystem services. For more information, see Chapter 4.

As a result of the CARE programme, Project 1.2 is expected to provide 2D maps showing the patterns of land use types (arable, dairy, horticulture, pigs, mixed, nature) and land managers' behaviour (an example output map is shown in Figure 4).

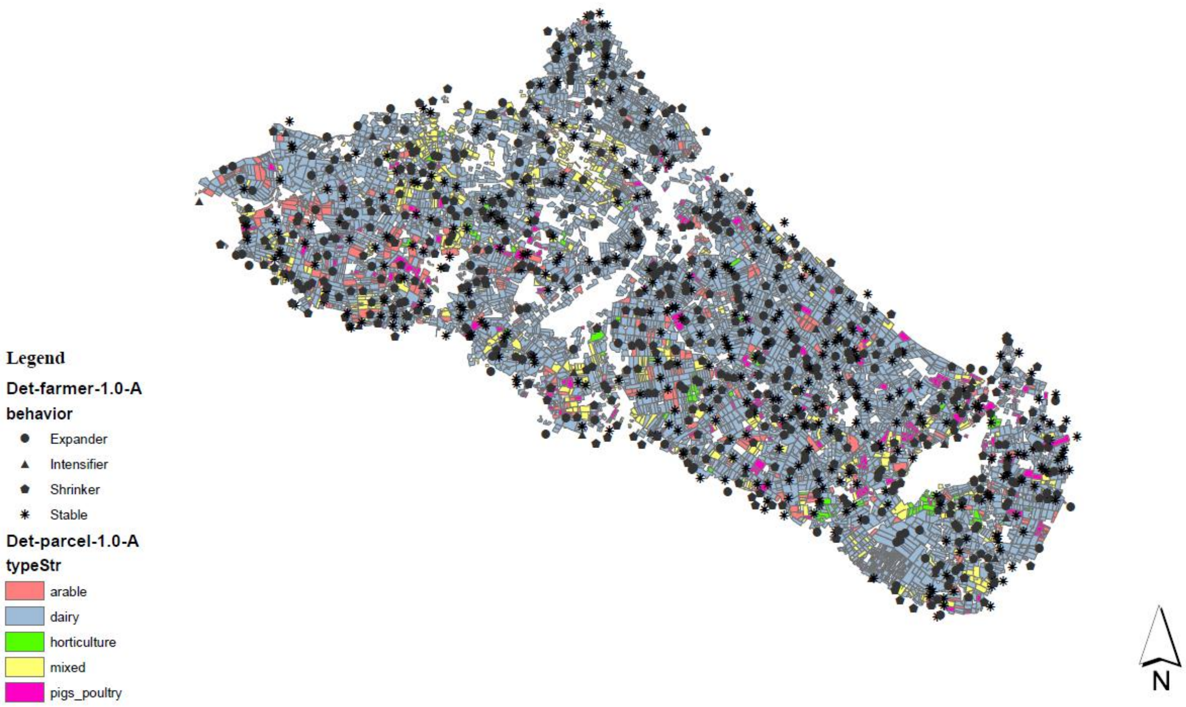

Figure 4: An example model output map produced after a preliminary application of the RULEX v.0 to the Baakse Beek area. Five different land use categories are distinguished at parcel level, and four different strategies at farm level. The temporal resolution is annual, although most other projects in CARE will be provided with land use maps of 2020, 2030, 2040 and 2050. Further output (not shown here) concerns farm attributes (farmer age and economic and physical size), and spatial delineations of farms.

Simulations are scheduled to run for 50 years. The output described above will be available for each year, scenario and study area, at a sector or aggregate level. The RULEX model also provides information about the proportion of land use types and land managers' behaviour, the spatial delineation of farms and trends in farm size and land managers' willingness to participate in environmental schemes.

The output of Project 1.2 will allow us to detect changes in the patterns of land use types, farm delineation and land managers' willingness to participate in environmental schemes in different study areas and under the assumptions of different scenarios. It will help to better understand the driving forces that underpin land exchange and the resulting land use change. This information will also indicate whether or not land managers will be willing to provide ecosystem services, and if and where opportunities for adaptation to climate change might occur.

Project 1.3. Design options for integrated multifunctional adaptation strategies

In the light of the development of integrated multifunctional climate adaptation strategies it is important to understand the concept of integration in more detail. The work packages 2 and 3 produce knowledge about the biophysical and human responses to climate change in nature and agriculture respectively, including cross-sectoral effects. Based on these insights, Project 1.2 will generate understanding about the opportunities for climate adaptation through the provision of ecosystem services by farmers and nature managers. Project 1.3 is to explore design options (spatially explicit visioning) for the implementation of integrated adaptation strategies, in participatory workshops of stakeholders and scientists. In this way it will be possible to answer questions about the effectiveness and robustness of these strategies, and about the location on which the ecosystem services will be provided.

The research and design process focuses on exploring the meaning of 'integration' (Stremke et al., 2012a; 2012b) and the criteria that may be used to understand the integrative aspects of the landscape. The next step will be to study the way in which these criteria may be applied in the development of design options for integrated multifunctional adaptation strategies in the case study areas. In other words: How should landscape planning, design and management be organized in order to be effective, efficient and sustainable? Finally, it will be explored on what locations the ecosystem services will be provided and whether the robustness of these services is expected to be sufficient. And how can financial and spatial incentives help to bring the required and offered ecosystem services together?

Figure 5 gives an overview of the approach of project 1.3 in the case study area Baakse Beek. Some of the expected results are 1) an array of possible adaptation measures (no regret and the bandwidth of options), and 2) plans, visualizations and descriptions of climate robust rural landscapes. The idea is to generate maps from RULEX that present likely land use changes. RULEX accommodates both climate and socio-economic scenarios. These outputs present the input for the 1st participatory workshop and will then be tested through another run in RULEX. All adaptation options will be shared and discussed with stakeholders in the 2nd participatory workshop. For an overview of interactions and dependencies between project 1.3 and RULEX and the other CARE projects, see Figure 6.

The interactive sessions in project 1.3 will serve as an opportunity to involve stakeholders in the development of the RULEX model. After each stakeholder meeting, the RULEX team will update the RULEX model, in response to the received feedback. These sessions may also contribute to the development of further research questions.

The project will provide important knowledge for stakeholders and policy makers within the following fields: (1) Understanding the concept of integration and the pros and cons of applying this concept in practice; (2) Opportunities for the multifunctional allocation of land-use types and ecosystem services in a metropolitan landscape to increase regional adaptive capacity; (3) The role of financial and spatial incentives for the implementation of ecosystem services; (4) Developing ownership on possible adaptation strategies through an interactive approach.

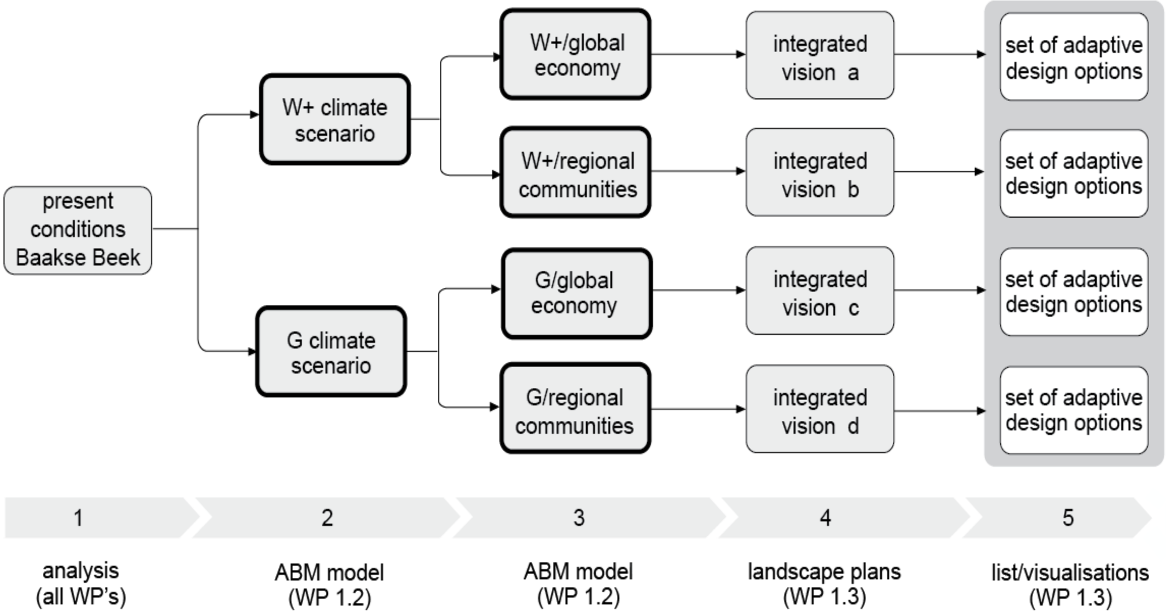

Figure 5: Methodological framework to identify different adaptive design options for the Baakse Beek case study. Please note the dependency of WP 1.3 on input from WP 1.2 and other WP's (boxes with bold frame).

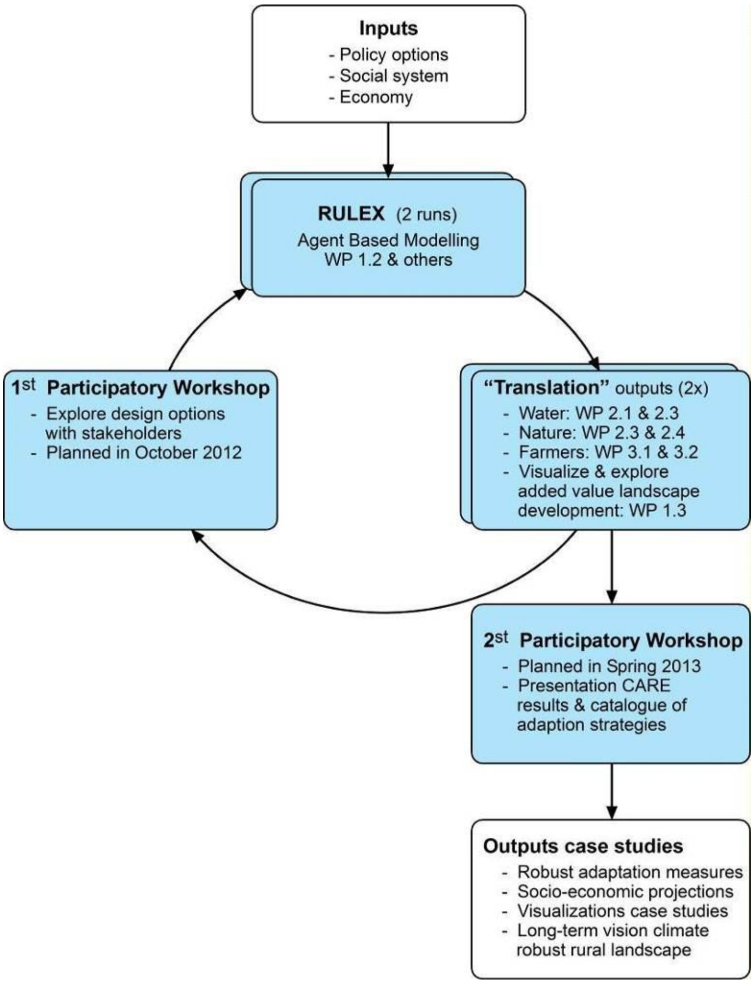

Figure 6: Interaction between project 1.3 and other projects for the Baakse Beek case study area.

6. Work package 2: Water and biodiversity in a future climate

Content

Both observations and model simulations indicate that the climate of our earth is changing at an unprecedented pace. It is foreseen that not only temperature will rise, but also that more prolonged dry periods will alternate with more intensive rainfall events, both within and between years. This will change, among others, soil moisture dynamics. Soil moisture is the most important environmental filter of local terrestrial plant species composition, as it determines the availability of both oxygen and water to plant roots and, with that, indirectly other habitat factors that are essential for plant growth, such as soil acidity and nutrient availability. In view of the projected change in climate and hydrology, it is questionable whether target ecosystems for nature preservation may still be attained under a future climate. This is important, since most of such targets are legally enforced, e.g. by the European Habitat Directive and by the Water Framework Directive. For a timely response to climate change, as well as to avoid measures that may be ineffective, policy makers and spatial planners require information about the feasibility of nature targets under a future climate. It is inevitable that models are used for this purpose, because the empirical bases for climate change effects in the recent past, across transects that cover different climate zones, is too small.

The central aim of this work package is to assess the effects of climate change and adaptive measures on the hydrology and the conservation value of rural landscapes of the Netherlands. To this end we study the effects of climate change on the water cycle (project 2.1), on vegetation biodiversity (Projects 2.2 and 2.3), and on the ecological networks of plants and animals (Project 2.4). Moreover, we try to understand and forecast how natural resource managers try to achieve their goals (Project 2.5).

This work package is carried out in close co-operation with stakeholders as they are responsible for the hydrological modelling of the case study areas. For the case study area of the Baakse beek catchment, the NMDC team (National Model and Data Centre; Van Ek et al., 2012) a coalition of five research institutes) dynamically simulated the current and future ground- and soil water system. To this end, a transient groundwater model (MODFLOW) was coupled to a model for surface water flow (MOZART), and a model for soil water flow (MetaSWAP) that interacts with a model for crop growth (WOFOST).

Achievements thus far are quantitative knowledge about the groundwater recharge on elevated sandy soils (Project 2.1), the nutrient richness of soils in nature areas (Project 2.2), the effects of inundations on plant traits (Project 2.3), spatial adaptation measures for ecological networks (Project 2.4) and about the way nature management adapts to climate change (Project 2.5).

This work package is carried out in close co-operation with stakeholders as they are responsible for the hydrological modelling of the case study areas. For the case study area of the Baakse beek catchment, the NMDC team (a coalition of five research institutes) dynamically simulated the current and future ground- and soil water system. To this end, a transient groundwater model (MODFLOW) was coupled to a model for surface water flow (MOZART), and a model for soil water flow (MetaSWAP) that interacts with a model for crop growth (WOFOST).

Project 2.1. The future groundwater recharge: evapotranspiration response of natural vegetation to climate change

Climate change will affect the amount and temporal distribution of both precipitation and evapotranspiration. In the Netherlands, summer droughts are expected to occur more often and last longer, and rainfall is expected to be concentrated in more intense showers (Van den Hurk et al., 2006). These changes will alter the amount of water that percolates to the saturated zone, the groundwater recharge, as well as the size and dynamics of fresh groundwater bodies. Fresh groundwater is a prerequisite for many land use functions in the Netherlands: ecosystems with high conservation values are often confined to places with shallow groundwater, especially when fresh and alkaline groundwater exfiltrates at the soil surface; high groundwater tables supply agricultural crops with water via capillary rise and; the major source of drinking water in the Netherlands is fresh groundwater.

Current knowledge, however, is insufficient to reliably estimate the effects of climate change on future groundwater recharge and freshwater availability (Wegehenkel, 2009; Witte et al., 2012). Future recharge can only be assessed if we understand how vegetation responds to changing climatic conditions and how these vegetation changes will feedback on groundwater recharge due to altered actual evapotranspiration. In this project we mainly focus on the effects of climate change on evapotranspiration characteristics on elevated sandy soils, since here we expect that especially here vegetation will adapt to climate change (Bartholomeus et al., 2011; Witte et al., 2012). Special emphasis lies in studying the effects of the vegetation structure on the water balance.

In the process of this study we found counter intuitive results on the effects of mosses and lichens on the soil water balance. From lab experiments (see Figure 7) we conclude that mosses and lichens evaporate much less than barren soil which points forward to complex facilitating effects between cryptograms and vascular plants (Voortman et al., in prep.-b). Climate change induced shifts to more moss dominated vegetation structures might result in an increase of groundwater recharge due to tempering effects of cryptograms on evaporation. In 2012 we will perform field measurements to study the relation between drought and the fraction of mosses, lichens and vascular plants in the vegetation. We will combine mini-lysimeters with ground based remote sensing techniques to measure evapotranspiration of plots with bare soil, moss, grass and heath vegetation (Voortman et al., in prep.-a). The field measurements will be used to parameterize models to simulate evapotranspiration under changing climatic conditions.

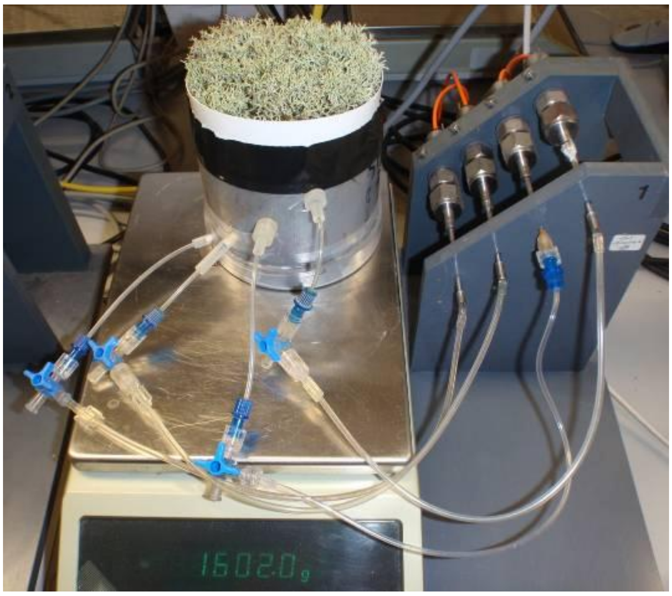

Figure 7: Lab measurement on a soil core to determine the hydrological characteristics of a lichen (Cladonia portendosa) (photo credit Bernard Voortman).

The results of this project are needed to accurately simulate future evapotranspiration, moisture regime and groundwater recharge on elevated sandy soils. As such, they are inevitable to model in a climate versatile manner the hydrology of areas like the Veluwe and the coastal dunes. Reliable hydrological simulations are a prerequisite to assess the effect of climate change on nature, agriculture, drinking water abstraction, and other land-use functions.

The results are probably not available in time for the RULEX application of the Baakse beek and the Tungelroyse beek case study areas. Presumably this is not such a problem, since these catchments hardly consist of elevated sandy soils. However, the results are needed in case we would want to apply RULEX also for the Blauwe Bron area.

Project 2.2. A spatial and climate-robust model for vegetation biodiversity

Changing climate will influence habitat factors for plant communities, leading to changes in their functioning and biodiversity. We aim at making prediction of such changes in vegetation, by developing process-based modules of habitat factors (moisture, pH, and nutrient availability) and by exploring climate-robust relationships between habitat factors and functional characteristics of plants. So far, the relationship between nutrient availability and plant responses is only poorly understood, causing an uncertainty in our prediction of vegetation. To improve the relationship, it is needed to properly incorporate hydrology in nutrient models, so that nutrient availability reflects soil moisture conditions in a climate-robust way (Bauer et al., 2008) . Results will be incorporated in PROBE-2, a climate versatile vegetation model (Douma et al., 2012; Witte et al., 2010).

In 2011 we collected field data on soil nutrients, plant characteristics and vegetation composition of a large number of plots throughout the Netherlands. We adapted the well-known carbon and nutrient model Century (Parton et al., 1987) to plots that are influenced by high groundwater levels. On the basis of our simulations we showed that including local hydrological information in Century improved the prediction of soil N supply rates across a wide range of natural ecosystems in the Netherlands (Fujita et al., *submitted*). However, the model improvement was highly dependent on the way soil moisture was estimated in the hydrological submodel and the way moisture effects on soil organic matter decomposition was formulated in the nutrient model. Coupling a simple hydrological sub-model (such as a tipping-bucket model, which is commonly used in existing models) to Century led to a very poor model performance for specific soil types. This highlights the importance of applying process-based, well-validated models to predict habitat factors under changing climate. We will further work on improving the relationships between habitat factors and plant responses in order to increase the robustness of our prediction on vegetation type.

In most vegetation models, the moisture regime of the vegetation is usually described by characteristic groundwater levels, such as the average groundwater level in spring. Climate versatile predictions should, however, be based on factors that directly influence plant performance. To this end, on the basis of a complex model of Bartholomeus et al. (2008) we developed repro-functions to simulate the water and oxygen stress in the root zone of plants, two factors that directly influence plant performance. These functions we applied to the Baakse beek catchment to simulate the moisture regime of natural vegetation.

The main output of this project will be the predictions of potential vegetation types, and their associated conservation values, under different climate scenarios. The predictions are visualized in maps, in which the types of the most likely vegetation in the cell, as well as the probability of occurrence of the vegetation type, are shown. These maps will be used in the project 2.4 (adaptation strategies ecological networks) as the habitat suitability map, with which dispersal of species will be further modelled to study the spatially-explicit consequence of climate effects. Furthermore, the conservation value map will be used in project 2.5 (management objectives and spatial planning of nature) for the decision making processes of spatial planning of nature.

The maps of predicted vegetation and association conservation values provide information for RULEX for selecting policy options. The information to be provided includes location and spatial configuration of suitable habitat conditions to develop nature areas, and vulnerability of each vegetation type under specific scenarios of climate change.

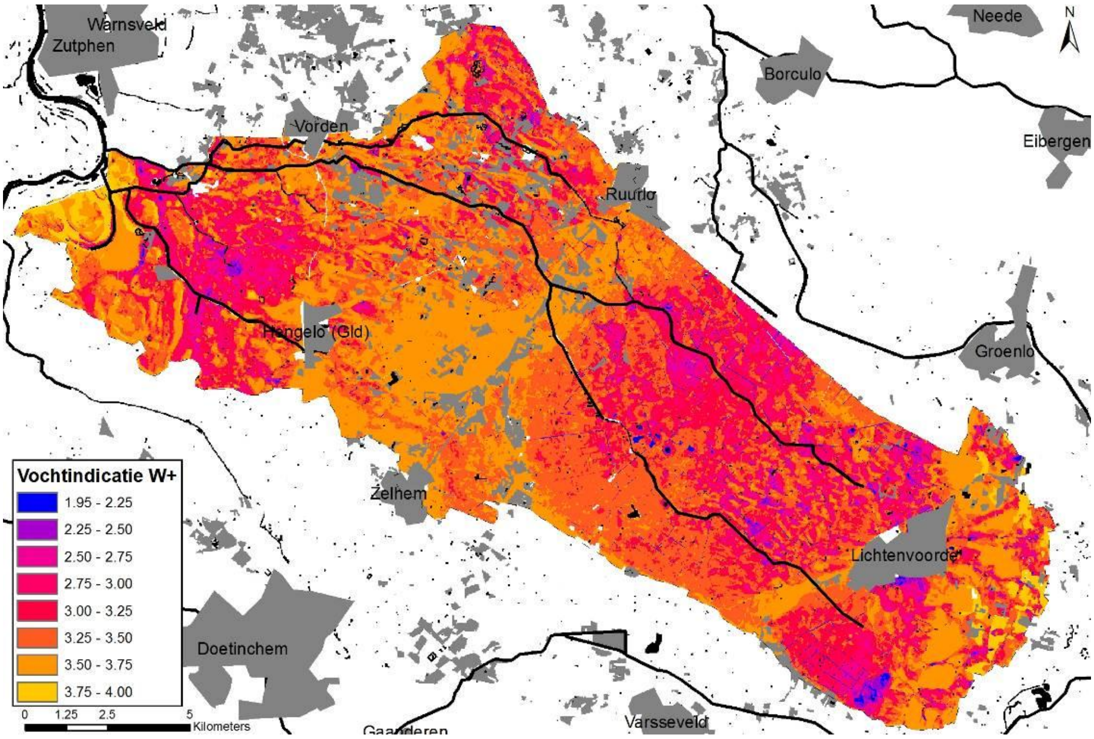

Figure 8: Simulate moisture status of the Baakse Beek catchment (W+ scenario, 2050), based on two climate versatile measures: water stress and oxygen stress. Moisture status is expressed on a scale running from 1.95 (wet; blue) to 4 (extremely dry; yellow) (Witte et al., in prep.). Where the mean groundwater level in spring (a traditional and correlative proxy for moisture status) hardly responds to climate change, both water stress and oxygen stress, two factors that directly affect plant performance, increase significantly under the W+ scenario.

Figure 9: Collecting field data on soil nutrients, plant characteristics and vegetation composition for the validation of our climate versatile vegetation model PROBE-2 (photo credit Flip Witte).

Project 2.3. Optimization of water storage in stream valleys in the elevated cover-sand landscape with respect to nature, agriculture and water supply

The aim of this project is to investigate how we should configure the spatial arrangement of landscape elements in stream valleys to optimize biodiversity under various scenarios of water storage and climate change. This will be done by 1) conducting an inundation and drought experiment, in which we tested the effects of climate extremes and extreme sequences on vegetation, of which little is known at present (Jentsch et al., 2007), 2) extending a state-of-the-art hydrology model (IBRAHYM) and adjusting the trait-based vegetation model (PROBE-2) to allow application to stream valley vegetation, 3) link the two models and validate them, 4) use the models to predict the effects of climate change and different water storage scenarios on vegetation distribution in catchments.

In a pot experiment we imposed a variety of plant species to different drought and inundation regimes and subsequently measured the response of important plant traits and plant performance. In addition to this experimental work and current modelling work, we will also conduct field work in a case study area; the Tungelroyse Beek in Limburg. The data collected here, as well as data from literature will serve as a validation of the coupled models. The future climate scenarios will be applied with and without water storage strategies to determine its impacts on hydrology and other environmental services in the catchment. This research will contribute to a better understanding of the possibilities of water storage in stream valleys in a future climate, of which little is known at present.

Projects 2.1 (future groundwater recharge) and 2.2 (modelling vegetation diversity) both contribute to the knowledge of future hydrological conditions and the effects of that on vegetation composition, and the feedback of changes in vegetation composition on hydrology. Part of that is also the main interest in this research, although in this project the focus is especially on stream valleys, combined with water storage possibilities. The output of this project can serve as input information for Project 2.4 (adaptation strategies ecological networks) in the way that this project estimates the future chances in vegetation distribution which has consequences for the future green infrastructure. The knowledge gathered in this project can be combined with the information from Project 2.5 (management objectives and spatial planning of nature) to make sound predictions and prepare sound management for managing nature areas in stream valleys.

RULEX can contribute significantly to this project by indicating where water storage is a realistic option, based on land use change predictions simulated in the ABM. Changes in land use can lead to changes in hydrology, by increasing or lowering the groundwater table in an agricultural area. That does not only have implications for the land area where the changes are applied, but also for surrounding (nature) areas, which can lead to changes in vegetation composition. Water storage in nearby areas might offer the opportunity to buffer the effects of groundwater table changes, which can minimize possible negative effects on vegetation distribution and composition. Therefore, the land use changes modelled in RULEX can have important implications for future hydrological conditions which are important to take into account on modelling water storage scenarios in this project.

Project 2.4. Adaptation strategies for ecological networks; quantifying spatial adaptation measures to compensate for additional population fluctuations and to facilitate species range shifts

The project focuses on two generic effects of climate change that increase species' extinction risk:

- Spatial shifts in the suitable ranges of species: areas where species are currently occurring may become unsuitable, other areas may become suitable, but species only benefit if they are able to colonize these new areas.
- An increase in population size fluctuations to enhanced environmental stochasticity (extreme weather events, shifts in seasonal patterns) (Van Teeffelen et al., 2012).

Increasing the amount of Green Infrastructure (GI), in the landscape has been named as a strategy to support biodiversity conservation under climate change (e.g. Heller and Zavaleta, 2009; Vos et al., 2008). Empirical studies (e.g. Grashof et al., 2009) and simulation models (e.g. Schippers et al., 2009) suggest that GI can strengthen ecological networks. However, studies are few, and whether this effect also holds for networks under climate change is yet unknown (but see Hodgson et al., 2011). We therefore ask the following question: Can ecological networks be strengthened with GI, to allow a range of different species to cope with the effects of climate change?

To test this for a real landscape, we simulate population dynamics for a range of species under different climate scenarios, in the Baakse Beek region varying the amount of GI in the landscape.

The GI-metapopulation model develops quantitative adaptation measures on the required density of GI in the landscape for different levels of biodiversity. Based on the GI density requirement stakeholders can decide on the biodiversity targets they want to achieve in the study area. These results will be discussed in the stakeholder meeting in the Baakse Beek area.

In cooperation with the agricultural modelling in project 3.1 (drivers of adaptation by farmers) the costs and benefits of different levels of GI in the Baakse Beek study area will be analysed. The additional costs of GI for different farm types and the benefits for the ecological network in the study area will be calculated for different climate change scenarios, levels of GI in the landscape and socio-economic scenarios.

RULEX produces possible future land use maps for the Baakse Beek study area, for different climate and socio-economic scenarios. One of the outputs is the willingness of farmers to participate in agri-environmental schemes contributing to the GI in the landscape. The GI-metapopulation model will be applied to determine to what extent the predicted ABM land use patterns consisting of a network of nature areas and densities of GI is expected to strengthen the ecological networks in the study area. These results are discussed with the stakeholders.

Project 2.5. Climate proofing management objectives and spatial planning of nature

Climate change poses a number of challenges for nature management. Distribution ranges of species shift northward as the climate becomes warmer and changes in precipitation and evaporation lead to changes in the hydrological and biogeochemical conditions for many plant species. Project 2.5 is studying how nature managers will adapt their management to the effects of climate change and also how this will affect their interaction with other stakeholders.

Climate adaptation by nature managers is studied using a combination of policy document analyses, interviews, database analyses and (agent-based) modelling. The results are used to project future land use claims by nature managers under different socio-economic and climate scenarios. In combination with projections of land use claims by other stakeholders and biophysical conditions for nature, this will enable us to identify effective adaptation strategies for nature management.

Transitions towards a sustainable society, whether they entail adaptation to climate change, diffusion of sustainable technologies or land use changes for biofuels or nature conservation, all have one thing in common: they depend on human behaviour and decision-making in response to current environmental problems and interactions between different stakeholders. It is therefore surprising that most models assessing the impact of environmental change on natural and societal systems rely on simpler steady state scenario approaches, rather than include human behaviour as the dynamic and interactive process it is.

Using the newly developed agent-based modelling approach, it is now possible to include behaviour of individual stakeholders or organizations in spatially explicit modelling. Such an agent based model is currently being designed in the CARE project to model future land use change under different socio-economic and climate scenarios. Within Project 2.5, a module representing behaviour and decision making regarding land acquisition by nature managers has been designed, which will be part of the agent based model. The design of this module was informed by an empirical study based on qualitative interviews with stakeholders involved in nature management in the Baakse Beek area (Natuurmonumenten, Staatsbosbeheer, Geldersch Landschap and private landowners).

The results from Projects 2.1 (future groundwater recharge) and 2.2 (modelling vegetation diversity) will be used to evaluate adaptation strategies against future biophysical conditions for nature, given different climate scenarios. These results will also be used to determine the perceived value of land for nature managers as input in RULEX. Project 2.3 investigates the possibilities for water storage in combination with biodiversity conservation. The results from project 2.5 can be used in project 2.3 to evaluate the feasibility of design options for water storage. Project 2.4 studies habitat networks, which partly consist of nature reserves. In order to design such networks, it must be known where the possibilities for nature management are and will be in the future, given climate adaptation and interaction between different stakeholders. The other way round, successful nature management depends in part on the presence of ecological networks because they influence species dispersal through the landscape.

Since nature managers are considered as separate agents within RULEX, the results of project 2.5 feed directly into the model and the researchers of project 2.5 are directly involved in the model development. The decision-making process of nature managers and their interaction with other agents in the model (farmers) will explicitly be modelled based on interview data and other stakeholder input from project 2.5. RULEX will be used by project 2.5 to test the effects of different adaptation strategies on nature targets.

Figure 10: Grassland vegetation of wet and mesotrophic soils in nature reserve Koolmansdijk in the Baakse Beek catchment (photo credit Jerry van Dijk).

7. Work package 3. Drivers and consequences of adaptation by farmers

Content

This work package seeks to gain insight in how farmers will adapt to their changing environment, and how this will affect their livelihood, the viability of the agricultural sector as a whole, and the landscape. The changes to which farmers are exposed are, besides a changing climate, diminishing subsidies and changing prices of agricultural produce and costs. In addition, the on-going process of increasing farm size commensurate to a decreasing number of farms is likely to continue. The work package aims to capture all these processes, so as to put the pressure of climate change in the appropriate perspective.

Adaptations of farmers are therefore not confined to adaptations to climate change, but refer to anything farmers do to get by. This can involve the adoption of new crops or production ways, but also selling or buying land is an important 'survival' strategy. The consequences of farmers' actions determine to an important extent the possibilities for policy makers in the region to develop climate robust nature. Farmers constrain the expansion of the EHS by holding on to their land for instance. In addition, intensive livestock breeding in the vicinity of a nature reserve may lead to eutrophication of the groundwater, hindering the achievement of certain nature targets within that nature reserve.

The work package initially consisted of two projects: one concerning drivers of adaptation (3.1), and another concerning consequences of adaptation (3.2). In the course of the first project year, two additional projects were started that are funded from an alternative source (Kennis Basis). One project supports the "drivers of adaptation" project, but with a specific focus on regional actors (within the CARE context referred to as Project 3.3); the other project supports the "consequences of adaptation" project, and has a specific focus on regional environmental impacts (here referred to as Project 3.4).

A first achievement of all four projects within this work package was to map out the agricultural sector and the involved actors in the study area Baakse Beek. A geographical database was compiled that combined agricultural census data, maps of biophysical properties, a sample of economic farm accounts, and an inventory of important organizations related to agriculture. This data base, in combination with the exploratory interviews held within Project 3.1, formed the basis for further analyses.

As for this further analyses: Project 3.1 has provided the ABM (Project 1.2) with the conceptual model of land exchange on the one hand, and with quantitative decision rules on the other hand. Projects 3.1 and 2.5 (management objectives and spatial planning of nature) have developed a strategy in which farmers and nature managers are identified in a similar way, so that the ABM can incorporate both types of actors in a consistent manner. Projects 3.1 and 3.3 are in the course of identifying a strategy to assess innovative behaviour in agriculture: the uptake and the spread of innovations are probably facilitated by regional actors, which is the focus point of project 3.3. Projects 3.2 and 3.4 have achieved the integration of two models: the FFSIM model to simulate farm performance based on optimization techniques, and the INITIATOR model that operates at the landscape level to simulate regional environmental impacts. This way, the consequences of farmer adaptation will not only identified at the farm itself, but also for its surroundings. Furthermore, a procedure has been designed that ensures a coupling between the choices made at farm level in terms of crop palette, and the economic farm size numbers that feed into the ABM. In addition, Project 3.2 facilitates the data flow from climate scenarios to ABM input.

Project 3.1. Drivers of adaptation by farmers

This project aims at identifying the strategies of farmers to cope with change, and the underlying factors that determine these strategies. The project provides RULEX with (a) the process description of land use change, and (b) the parameters of all equations and rules that are contained in the ABM. Based on in-depth interviews the most important processes underlying categorical land use change were found to be transactions of rural land among farmers. The strategies relevant for this type of land use change are considered to be: 1) increasing farm size, 2) intensifying, 3) selling land, and 4) doing nothing. Statistical analyses of agricultural census data allowed inferring these strategies from farmer attributes such as farmer age, economic size, physical size and farm type. In addition, the willingness-to-buy and willingness-to-sell parcels was calibrated using a database of historical land transactions in the research area. The project is state of the art, in that it develops techniques to incorporate empirical evidence in (a) behavioural profiles, and (b) quantitative decision rules needed in the ABM (Robinson et al., 2007; Bakker and van Doorn, 2009). Until now, most ABMs mostly used profiles that were developed in other disciplines (e.g. innovator, traditionalist) and which were attributed randomly over the farmers in the ABM (Schreinemachers and Berger, 2011; Acosta-Michlik et al., *in preparation*). Furthermore, the actual decision making in the ABMs came from qualitative decision rules that were based on so-called expert knowledge (Karali et al., *in review*).

This project is strongly integrated with the ABM. It is one of the few projects that is "delivering to" RULEX, rather than "receiving from". The rules and equations that compose RULEX are, in both qualitative and quantitative terms, generated by this project. Via RULEX, the outcomes of this project are fed to the other projects. For example, the probability distribution of farmers being intensifiers, expanders, or shrinkers results in some areas being less available for nature expansion than others. The willingness to pay equation may result in some areas with unfavourable properties for agriculture to be less susceptible to scale enlargement, and therefore more likely to become available for nature organizations. Furthermore, the spatial distribution of farmers willing to participate in various subsidized schemes for green blue services will come from this project, which is an important determinant of success or failure of such schemes.

Furthermore, the researchers closely cooperate with the researchers in Project 2.5, who do a similar exercise for nature managers. Regular meetings are held to ensure consistency in the approach and type of output that is fed to RULEX. Secondly, close cooperation occurs with the researchers from Project 3.3, who investigate the role of so-called indirect actors, such as organizations that stimulate innovation or service provision by farmers. The cooperation between these projects aims at exploring the mutual influence of farmers' strategies and the policy of these organizations. Finally, Project 3.1 cooperates with Project 3.2 which looks at adaptation strategies within the course land use categories in more detail. In particular the willingness of farmers to participate in agri-environmental schemes is identified by a mutual effort of this project and Project 3.2.

Project 3.2. Consequences of adaptation by farmers: farm performance

This project aims to identify the economic, environmental and societal consequences of agricultural adaptation strategies to climate, market and policy changes on different farm types in multifunctional landscapes, with the Baakse Beek as main case study. The projects has four focus areas: 1) impacts on crop yields, 2) impacts on farm performance, 3) cross-sectoral adaptation, i.e. agri-environmental schemes, and 4) linking farm performance to regional environmental impacts. Impacts on crop yields are assessed by using the coupled hydrological and crop simulation models (Meta)SWAP-WOFOST, and in addition the semi-quantitative method Agro Climate Calender (Schaap et al., 2011) is used to assess impacts of extreme events and to identify adaptation measures. Innovative is the linkage of different models and methods to better identify the spatial variability, the impacts of extreme events and to identify adaptation measures, while most studies have focused on crop modelling only (Easterling et al., 2007; Reidsma et al., 2010). Impacts on farm performance are assessed with the Farming Systems Simulator (FSSIM; Kanellopoulos et al., 2010) using individual farm data. This allows farmers to 'learn' from their neighbours and ensures that suggested adaptation measures are feasible in the region. Adaptation measures to increase income include participation in agri-environmental schemes, which is needed for nature to reduce fragmentation and adapt to climate change. Factors influencing farmer's willingness to adopt agri-environmental schemes are assessed using available data and additional stakeholder workshops, and will be explored for future scenarios. Lastly, results from the farm level analysis are coupled to the INITIATOR model to assess regional environmental impacts.

Project 3.2 is strongly related to Projects 3.4, 3.1, 1.2 and 2.4. Results from the farm modelling with FSSIM are coupled to the INITIATOR model (Project 3.4) to assess the impacts of farm level changes on regional environmental impacts. Project 3.1 provides the link to RULEX (Project 1.2) as described below. Also the willingness of farmers to participate in agri-environmental schemes is identified by a mutual effort with Project 3.2. Project 2.4 assesses the impacts of different arrangements of nature on biodiversity, and by combining information on farmers' willingness and biodiversity values, recommendations can be made on the best strategies to improve both farm performance and biodiversity.

This project provides input to RULEX mainly via Project 3.1. This project aims at identifying factors that determine categorical land use change, and provides the ABM (project 1.2) with process description and parameters of equations and rules. Project 3.2 focuses on impacts and adaptation measures in agricultural land use categories in more detail, and output can be used in Project 3.1. For example, spatially explicit maps of crop yields produced in Project 3.2 are used in Project 3.1 to analyse the influence of land quality on the perceived value to sell/buy land. In addition, changes in average economic size of different agricultural sectors simulated in Project 3.1 can be used to estimate the willingness to buy or sell over time. Output of RULEX on changes in land use categories in different scenarios will be used to up-scale results from farm modelling with FSSIM to the regional level.

Project 3.3. Interactions between farmers and regional actors

This project focuses on the qualitative socio-economic aspects in terms of regional actors of agricultural adaptations. The aim is to understand what moves regional actors and to classify them according to their preferences and perspectives. In this way the (current and future) adaptation preferences can be identified in a spatially-explicit manner; and policy instruments can be tailored to achieve maximum efficiency. The insights gained are input for the ABM by submitting likelihood-rules for adaptation strategies of relevant regional actors. Within CARE, the ABM will simulate changes in land management and land use, based on the likelihood of farms to adopt adaptation strategies. With the contribution of the currently proposed project, RULEX will (besides farmers) also explore the potential response of regional actors to climate change, e.g. recreation boards and farmers' organizations. The specific aim of this project is the identification of motives of regional stakeholders that influence agriculture and nature management and rephrasing this to input for an ABM, being part of a multi-actor spatial planning system that is currently poorly understood and poorly represented by ABMs.

This project closely collaborates with Project 3.1. The farmers that are subject to investigation in Project 3.1 are believed to be influenced by regional stakeholders. Particularly the intensifying group of farmers, who achieve the necessary growth of their farm by increasing added value per hectare, depend on information and ideas they get from e.g. feed suppliers and the farmers' organization or from demand-for-services stimulation by organizations such as recreation boards. The strategies of these organizations to achieve this influence are investigated in this project. Moreover, the regional actors may also adjust their strategies based on the decisions made by the farmers, which is an additional element that is investigated in this project.

The idea is to incorporate two typical regional agents in the ABM: one that stimulates innovation for the farmers that maintain a focus on food production, and another that stimulates a market for services provided by farmers that shift towards multifunctionality. The motivations of the latter category are still poorly understood, and regional actors are believed to play an important role herein. Who takes up an innovation, and via what channels the innovations spread through the community, is probably influenced strongly by actors such as LTO and feed suppliers, who are strongly concerned with the viability of the agricultural sector. By incorporating regional agents in the ABM, feedback mechanisms can be incorporated that result in non-linear responses that are so typical for complex human-environmental systems.

Project 3.4. Consequences of adaptation by farmers: regional environmental impacts

This project aims to identify the regional environmental consequences of agricultural adaptation strategies to climate, market and policy changes. This project contributes to this aim by assessing the impacts of agricultural adaptation strategies on nutrient and metal leaching, ammonia and greenhouse gas emissions at landscape scale. For this purpose, the landscape model INITIATOR is coupled to the farm model FSSIM as used in Project 3.2. Specific attention is given to the impact of agricultural management on the surrounding nature through effects of NH_3 emissions on N deposition and thereby on plant species diversity. The innovation in this project lies in the use of these models for integrated assessment of adaptation strategies to climate change, and specifically in translating farm type level results to the landscape level on the one hand, while including socio-economic objectives and constraints in a regional environmental model at the other hand. Milk quota, manure policies, nutrient and water regulations and biodiversity targets are environment related issues influencing farm performance, and optimal adaptation strategies need to consider both farm level constraints and environmental impacts. The project is state of the art, in that it further adapts and develops the landscape scale model INITIATOR (De Vries et al., 2005) in interaction with the bio-economic farm model FSSIM (Janssen and van Ittersum, 2007; Van Ittersum et al., 2008; Kanellopoulos et al., 2010) that will be amended and exploited to assess the consequences of adaptation strategies (and therewith the viability of their adoption).

Project 3.4 is strongly related to Projects 3.1 and 3.2. The drivers of adaptation are assessed in Project 3.1 by identifying the goals, decision-making processes, and the constraints faced and perceived by farmers from observed behaviour (available statistics) and from interviews and questionnaires. Project 3.2 provides results at farm level including crop yields and animal numbers, which will be included in the landscape model INITIATOR to assess environmental impacts. Iterations are foreseen to provide adaptation strategies optimal at both farm and regional level.

This project uses the results of RULEX in terms of changes in land use and livestock, as described in detail in Project 1.2. The ABM delivers spatially explicit land use and management maps. The triggers and constraints to which the virtual farmers in the agent-based model are sensitive, partly come from the conditions imposed (global and climate change scenarios), but also result from their own autonomous behaviour. The results of Project 1.2 will be used by this project to compute the consequences of different adaptation strategies. This project investigates if the strategies chosen by the individual farmers do not lead to important conflicts with environmental policies regarding the emission and leaching of nutrients. In case they do, a feedback must be established so that the agents in the ABM receive a penalty for the externalities they produced.

8. Stakeholder Involvement and Societal Impact

Stakeholders fulfil an important role in the transfer of area-specific information to the researchers, such as understanding socio-economic, political, and spatial contexts and the way these contexts influence the behaviour of farmers and nature managers. (Note that within the CARE project, the term stakeholders is reserved for the co-financing parties, while in RULEX farmers and nature managers are referred to as autonomous agents.) Stakeholders help the researchers to gain better insight in the various ways possible adaptation measures might be implemented against the background of the historical context and sentiments in the region, factors that are difficult to reveal through statistical analyses. Therefore, the researchers have established good and productive relationships with the stakeholders, and have invited them to participate in CARE workshops and other meetings, as was already explained in several of the previous Chapters. This approach of close cooperation with stakeholders has proven to increase considerably the social acceptance and relevance of the research results.

An example of this is the interactive workshop on the consequences of climate change for agriculture on the isle of Texel, held in October 2011 (case study area Nr. 5; see Figure 1). Several farmers and representatives of the municipality of Texel and the water board Hollands Noorderkwartier participated in this workshop, organised by CARE researchers in collaboration with the water board and Geodan (group of spatial information companies). They discussed the impact of changing water conditions on agricultural activities by comparing the current situation with future climate change scenarios. On the basis of several KNMI (Royal Netherlands Meteorological Institute) scenarios these conditions were modelled for the year 2050. It became very clear to the farmers that conditions would change considerably and that, as a consequence, a more economical use of scarce fresh water would be urgently necessary. Together with experts from the water board they discussed several possible solutions by making use of a so-called touch table, on which the present and future conditions for agriculture and horticulture were presented on an interactive map. The participants could consult different maps on top of each other, zoom in and out and add information on the spot (see Figure 11).

Some of the conclusions of the workshop were that rainwater should be stored for a longer period of time, for which the water storage capacity should be increased. Furthermore, the potential of purifying sewage water for agricultural purposes should be studied, as well as options for brackish cultivars. The workshop was very instructive for both farmers and the water board, as it resulted in concrete ideas about how to change water management conditions in relation to climate change. Apart from these region specific conclusions, the case study was also relevant for other CARE case study research, because it resulted in better insight in the possibilities of how to use interactive maps and a touch table in solving spatial problems. This part of the research was done in collaboration with KfC Theme 8 researchers (Decision Support Tools).

Figure 11: Farmers discussing the implications of future water management conditions on the isle of Texel by making use of a touch table (photo credit: water board Hollands Noorderkwartier).

The involvement of stakeholders also plays a prominent role in the case study Baakse Beek. During the 2011 annual meeting of the CARE consortium a field trip was made to the case study area, together with several stakeholders. Furthermore, for the development of the agent-based modelling and translation of the research results into possible adaptation strategies a series of three area-based interactive workshops are scheduled. The first of these workshops (*Raising commitment*) took place in May 2011. About 25 participants, quite diverse in background but all very dedicated to the area, got to know each other and their interest in CARE, discussed preliminary results of several individual research projects, learnt about the principles of RULEX and expected outcomes, suggested aspects or data to include or not include, and took part in a questionnaire on landscape preferences and ecology/nature maintenance. At the end of the day these stakeholders expressed they were happy with the information they had got and the open atmosphere of discussion by which they felt invited to participate and give input.

At the next workshop (*Making choices*), scheduled October 2012, the results of RULEX will be presented and discussed, together with preliminary results of other research projects. Based on the RULEX output, possible land use changes due to climate change will be visualized, and participants will be invited to weight their preferences for several policy options. This will be continued and expanded at the third workshop (*Towards realization*), scheduled Spring 2013, when a catalogue of adaptation strategies, both generic and specific in nature, and organized according to time horizon, will be presented and discussed. This final workshop will have a 'design character', i.e. the emphasis will be on creative synthesis (using a touch table or comparable tool) of research results and stakeholders' input into effective adaptation strategies, and exploration of added values of climate-conscious long-term landscape interventions and transformations. Finally, the workshop aims to result in explicit conclusions about what is needed by whom and when to realize each adaptation strategy, which, as a follow-up of the workshop, may result in commitment packages between stakeholders.

The same approach will also be applied in the Tungelroyse Beek case study, for which preparations have already been started. Also in the case study areas Blauwe Bron and Groene Ruggengraat stakeholders are or will be consulted. Moreover, representatives of the case study areas are invited to participate in the annual meetings of the consortium, while several stakeholders also take part in the Steering Board.

9. Communication, Publications and Dissemination of Results

Until now the CARE community has published three Newsletters (in Dutch) in which the research programme is explained to a broader public, accounts are given of workshops and other meetings (such as annual consortium meetings and meetings of the Steering Board, consultations with the KfC Programme Bureau), and individual researchers present themselves and their research. These Newsletters are distributed via email to the stakeholders in the case study areas and to a broader audience through internet. The communication activities are guided by a Communication Plan (only available in Dutch). The guiding principle of our communication activities is that the research is well-embedded in the hotspots and the problems that are at stake there, and that the research results contribute to the formulation of adaptation strategies by the stakeholders in these hotspots. In general, the communication aims at:

- Optimisation of knowledge development within our Theme;
- Knowledge exchange;
- Network building;
- Creating societal support for the knowledge development as well as the expected results;
- Knowledge dissemination (intermediate and final research results);
- Encouraging the implementation of the research results.

The Communication Plan makes a distinction between *internal* communication (i.e. among the consortium members) and *external* communication (i.e. with stakeholders or, in a wider sense, people and organizations that are directly or indirectly involved in the research). The internal communication focusses on cooperation and knowledge exchange in and between the individual projects, in and between the work packages, and on programme level. Communication is considered to be a common responsibility, which means that all researchers take their share in the communication activities. The same principle applies to external communication. Examples are: writing contributions for the Newsletters, lecturing or giving presentations on seminars and workshops, and taking part in meetings. This is coordinated by the core team of the consortium: programme leader, work package leaders and communication officer. The stakeholders that are directly involved are invited to take part in the workshops etc. in the case studies. The stakeholders that are indirectly involved are addressed through the Newsletters, personal contacts, presentations, and scientific and professional publications. Our communication activities and publications thus far are listed in Annex 3.

The consortium has made a Publication Plan (see Annex 4), in which the intended scientific publications are listed, including their relation to the work packages, the first author and co-authors, and the journal(s) at which the paper aims. Through the collaboration between authors and the provisional titles of the papers, this plan also reflects the multidisciplinary character of the CARE research programme.

10. Outlook 2nd half programme

In the 2nd half of the programme the CARE consortium will continue its research activities in the individual projects and hotspot case study areas. An important event will be the second workshop in the Baakse Beek area this fall. At this workshop the outcomes of RULEX will be presented to and discussed with stakeholders. This will be the first occasion that this innovative part of the programme will be publicly put to the test: Do the results make sense, are the stakeholders willing to trust the modelling and support its outcomes, are they able to use these outcomes for developing adaptation strategies, etc.? Another test will, of course, be the submission of papers on RULEX to scientific journals (see Annex 4).

Furthermore, the ABM research will be extended to the case study areas Tungelroyse Beek and Groene Ruggengraat. Preparations have started and contacts with relevant stakeholders have been made. Projects in WP 2 and WP3 continue to contribute to this research.

Consortium members will present research results on (inter)national scientific and professional conferences. Within the KfC community the consortium will organize a workshop to discuss in ABM research in several KfC consortia (Themes 3, 5 and 8). Furthermore, the consortium will submit a proposal to organize a “CARE session” at the European Climate Change Adaptation (ECCA) conference *Integrating Climate into Action*, Hamburg, March 2013. This conference is an excellent opportunity to critically discuss CARE research with an international scientific audience. Finally, the consortium aims to organize a national conference in 2014 to present the final research results to a broad audience of scientists, professionals and stakeholders.

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ANNEX 1 FACTS AND FIGURES

<table>
<tr><td>Theme 3</td><td colspan="4">Exploring the Potential for Climate Change Adaptation Strategies in Rural Areas</td></tr>
<tr><td>Title (short)</td><td colspan="4">Climate Adaptation for Rural arEas (CARE)</td></tr>
<tr><td>Duration</td><td colspan="4">January 1 2010 – December 31 2014</td></tr>
<tr><td>Consortium leader</td><td colspan="4">Prof.dr.ir. Adri van den Brink
Environmental Sciences Group Wageningen University
Wageningen University</td></tr>
<tr><td>Financial officer</td><td colspan="4">Wilma van der Straten (Alterra Wageningen UR)</td></tr>
<tr><td>Communication officer</td><td colspan="4">Annelies Bruinsma (Alterra Wageningen UR)</td></tr>
<tr><td>Project coordinator KfC</td><td colspan="4">Monique Slegers</td></tr>
<tr><td>Consortium partners</td><td colspan="4">▽ Wageningen University and Research Centre
▽ Vrije Universiteit Amsterdam
▽ Utrecht University
▽ Deltares Delft
▽ KWR Watercycle Research Institute Nieuwegein
▽ University of Edinburgh</td></tr>
<tr><td>Website</td><td colspan="4">http://knowledgeforclimate.climateresearchnetherlands.nl/climateadaptationforruralareas</td></tr>
<tr><td rowspan="5">Finance</td><td colspan="2">Initial[1]</td><td colspan="2">Actual prognosis</td></tr>
<tr><td>Minimum total budget</td><td>€ 3.000.000</td><td>Total budget[2]</td><td>€ 3.037.465</td></tr>
<tr><td>Maximum KfC subsidy</td><td>€ 1.700.000</td><td>KfC subsidy[2]</td><td>€ 1.700.000</td></tr>
<tr><td>Minimum matching</td><td>€ 1.300.000</td><td>Matching knowledge institutes (own contribution)</td><td>€ 770.000</td></tr>
<tr><td></td><td></td><td>External matching[3]</td><td>€ 530.000</td></tr>
<tr><td>Steering board</td><td colspan="4">• Prof.dr.ir. A.. Veldkamp, University Twente, president
• Drs. E.R. de Haan, Province of Zuid Holland, also on behalf of hotspot Shallow waters and peat meadow areas
• F.B.A. van Lamoen, Province of Noord Brabant, also on behalf of hotspot Dry Rural Areas
• Prof.dr.ir. A.K. Bregt, Environmental Sciences Group, Wageningen University
• Vacancy, Ministry of Economic Affairs, Agriculture and Innovation
• Ir. T.J. Spek, Province of Gelderland, also on behalf of Water Boards
• M. Verkerk (Deltaplan HZ, Water Board AA & Maas)
• L. Gerner (Water Board Rijn en IJssel)
• Dr. M. Slegers, Program Office Knowledge for Climate
• Dr. M. Bakker, secretary</td></tr>
</table>

ANNEX 2 Hotspots & stakeholders

Co financing, matching, in kind contributions

Hotspot Dry Rural Areas

Stakeholder organisations involved	Case study	Co financing	In kind participation
- Province of Gelderland	Case study Baakse Beek / Blauwe Bron	180 k€	Preparation workshops by Teun Spek. During workshops: - 3 pers - 4 pers
- Waterboard Veluwe	Case study Baakse Beek / Blauwe Bron	70 k€	- 1 pers
- Waterboard Rijn en IJssel	Case study Baakse Beek / Blauwe Bron	80 k€	Preparation workshops by various people. During workshops: - 2 pers - 9 pers
- Vitens	Case study Baakse Beek / Blauwe Bron	60 k€	
- Province of Noord Brabant	Case study Tungelroyse Beek	50 k€	
- Waterboard Aa en Maas	Case study Tungelroyse Beek	50 k€	
- Municipality Apeldoorn	Case study Baakse Beek / Blauwe Bron		- 1 pers
- Municipality Epe	Case study Baakse Beek / Blauwe Bron		- 2 pers
- Municipality Heerde	Case study Baakse Beek / Blauwe Bron		- 1 pers
- Waterboard Vallei en Eem	Case study Baakse Beek		- 1 pers
- LTO	Case study Baakse Beek		- 2 pers
- Municipality Oost Gelre	Case study Baakse Beek		- 1 pers
- Municipality Bronckhorst	Case study Baakse Beek		- 3 pers
- DLG	Case study Baakse Beek		- 2 pers
- Gelders Particulier Grondbezet	Case study Baakse Beek		- 1 pers
- Bureau Achterhoek en Liemers	Case study Baakse Beek		- 1 pers
			-

Hotspot Shallow waters and peat meadow areas

Stakeholder organisations involved	Case study	Co financing	In kind part.
- Province of Zuid Holland	Groene Ruggengraat	40 k€	

Hotspot Wadden Sea

Stakeholder organisations involved	Case study	Co financing	In kind part.
- Hoogheemraadschap Holland Noorderkwartier	Case study Texel	20 k€	Preparation workshop: 100 hours.

			During workshop: 12 pers
- LTO (farmers' organization)	Case study Texel		- 1 pers
- Stichting Waddengroep	Case study Texel		- 3 pers
- Geodan	Case study Texel		- 2 pers
- Municipality Texel	Case study Texel		- 2 pers
- Agrarische Natuurvereniging 'De Lieuw'	Case study Texel		- 1 pers
- Farmers Texel	Case study Texel		- 10 pers

ANNEX 3 Communication activities

	Newsletters
March 2011	Nieuwsbrief KvK thema 3: Klimaatbestendig maken van het platteland. Nummer 1, maart 2011
November 2011	Nieuwsbrief KvK thema 3: Klimaatbestendig maken van het platteland. Nummer 2, november 2011
July 2012	Nieuwsbrief KvK thema 3: Klimaatbestendig maken van het platteland. Nummer 3, juli 2012

	Brochure and fact sheets
2010	Climate Adaptation For Rural Areas. Flyer on theme 3, Knowledge for Climate.
2010	Theme 3: Climate Adaptation for Rural Areas (2010). Work package 1: Integration: multifunctional adaptation to climate change.
2010	Theme 3: Climate Adaptation for Rural Areas (2010). Work package 2: Water and biodiversity in the future climate.
2010	Theme 3: Climate Adaptation for Rural Areas (2010). Work package 3: Drivers and consequences of adaptation by farmers.

	Case study meetings with stakeholders: Texel
April 20, 2011	Workshop with policy makers and hydrologists HHNK
May 15, 2011	Climate change on Texel, an exploration
October 14, 2011	Workshop Climate change on Texel
January 12, 2012	Evaluation with stakeholders HHNK

	Case study meetings with stakeholders: Baakse Beek
March 24, 2011	Stakeholder meeting Baakse Beek
May 23, 2011	CARE Workshop Baakse Beek / Blauwe Bron
May 31, 2011	Workshop Baakse Beek / Blauwe Bron with stakeholders
November 10, 2011	Field visit Baakse Beek area (annual meeting CARE team)
January 12, 1012	Follow up meeting Baakse Beek / Blauwe Bron organized by Province of Gelderland
May 14, 2012	Stakeholder meeting Baakse Beek

	Case study meetings with stakeholders: Blauwe Bron
May 23, 2011	CARE Workshop Baakse Beek / Blauwe Bron
May 31, 2011	Workshop Baakse Beek / Blauwe Bron with stakeholders
January 12, 1012	Follow up meeting Baakse Beek / Blauwe Bron organized by Province of Gelderland
July 3, 2012	Presentation Master thesis Blauwe Bron (M. Minkman, J. Hoekstra)

	Case study meetings with stakeholders: Tungelroyse Beek
	Case study meetings with stakeholders: Groene Ruggengraat
April 18, 2011	Theme 2, Meeting Groene Ruggengraat
	Meetings CARE-core team
September 16-17, 2010	Kick of meeting CARE, Wageningen
January.. , 2011	ABM meeting, Wageningen
June 16-17, 2011	ABM meeting, Edinburgh
September 30, 2011	ABM meeting, Amsterdam
November 10-11, 2011	Annual meeting CARE team (in presence of Baakse Beek stakeholders), Arnhem
	Meetings Scientific Steering Committee
2010	Constitution of the Scientific Steering Committee
June 1, 2011	Meeting Scientific Steering Committee
	Participation in Knowledge for Climate activities
September 29 – October 1, 2010	Delta Conference, Rotterdam
March 7, 2011	International Advisory Meeting
April 7, 2011	Project day, Knowledge for Climate
December 1, 2011	Meeting 'Knooppunt Klimaat', Amersfoort

Publications

Type	Year	Reference
Brochure (public site)	2010	Brink, A. van den (2010). Climate Adaptation For Rural Areas. Flyer on theme 3, Knowledge for Climate.
Media (public site)	2011	www.telegraaf.nl (2011). Droogte levert Nederland geld op, 27 mei.
Popular Article about Science (public site)	2010	Bartholomeus, R., F. Witte, P. van Bodegom & J. van Dam (2010). Nieuwe maat voor bodemvochtregime ook geschikt onder toekomstig klimaat. H2O 43: 37-39.
Popular Article about Science (public site)	2010	Bartholomeus, R.P., B. Voortman & J.P.M. Witte (2010). De toekomstige grondwateraanvulling. H2O 17: 35-37.
Popular Article about Science (intranet)	2011	Witte, J.P.M., R. , D.J. van der Hoek, A. van Loon, R. Bartholomeus & P. van Bodegom (2011). Is het Nationaal Hydrologische Instrumentarium gereed voor het voorspellen van natuureffecten? Stromingen 17(2): 15-27.
Popular Article about Science (public site)	2011	Spek, T., B. Kiljan, B. Verboom, L. Gerner, J. Moorman, M. van Aken, J. van Engelenburg, R. Meijer, W. Geertsema, E. Steingröver, H. Runhaar en F. Witte (2011). Wetenschappers en veldwerkers in Gelderland bespreken gevolgen klimaatverandering. H2O 06: 13-15.
Popular Article about Science (public site)	2011	Witte, J.P.M., T. Strasser & R. Slings (2011). Kwantitatieve vegetatiewaardering beperkt bruikbaar. Landschap 28(2): 56-66.
Popular Article about Science (public site)	2011	Van Bodegom. P.M., J. Verboom-Vasiljev, J.P.M. Witte, C.C. Vos, R. Bartholomeus, A. Cormont, W. Geertsema & M. van der Veen, 2011. Vochtige ecosystemen kwetsbaar. Landschap 28(2): 92-103.
Popular Article about Science (public site)	2011	Bartholomeus, R.P., Voortman, B. and Witte, J.P.M. (2011). De toekomstige grondwateraanvulling. Vuurwerk, 22(3): 13.
Poster (intranet)	2010	Schaap, B. P. Reidsma, F. Ewert, A. Kanellopoulos, M. Mandryk, J. Verhagen, J. Wolf, M. van Ittersum (2010). Climate change adaptation in agriculture; the use of multi-scale modelling and stakeholder participation in the Netherlands. XIth ESA Congress, Montpellier, France, August 29 to September 03, 2010. Montpellier, France.
Poster (intranet)	2010	Bartholomeus, R.P. (2010). Climate change hampers endangered species through intensified moisture-related plant stresses. Latsis 2010 International Symposium on Ecohydrology, Lausanne, Switserland.
Poster (public site)	2010	Brink, A. van den (2010). Poster of theme 3; Climate adaptation for rural areas. Poster for the Deltas in Times of Climate Change Conference, 29 September – 1 October, Rotterdam.
Poster (public site)	2010	Witte, J.P.M., R.P. Bartholomeus, & D.G. Cirkel (2010). Climate change effects on vegetation characteristics and groundwater recharge. Latsis 2010 International Symposium on Ecohydrology, Lausanne, Switzerland.
Poster (public site)	2010	Witte, J.P.M. & J. Runhaar (2010). Eco-hydrological impact of climate change. Preliminary sketch map (W and W+ scenarios, 2050). Latsis 2010 International Symposium on Ecohydrology, Lausanne, Switzerland.
Poster (public site)	2010	Bartholomeus, R.P. (2010). Climate change effects on vegetation characteristics and groundwater recharge. EGU General Assembly, 2010, Vienna, Austria.
Poster (public site)	2010	Cirkel, D.G., S.E.A.T.M. Van der Zee & J.P.M. Witte (2010). Spatiotemporal variability in soil acidity, the role of microtopography and plant-soil interactions in wet meadow habitats. Latsis 2010 International Symposium on Ecohydrology, Lausanne, Switserland.
Poster (public site)	2011	Bartholomeus, R.P., J.P.M. Witte, P.M. Van Bodegom, J.C. van Dam & R. Aerts (2011). Climate change hampers endangered species by stronger water-related stresses. EGU General Assembly, Vienna, Austria.

Poster (public site)	2011	Bezlepkina, I., J. Wolf, R. W. Verburg, P. Reidsma P.J.G.J. Hellegers, M.K. van Ittersum (2011). Methodologies to assess climatic change impacts on sustainability of agriculture at different levels. International conference 'Problems of adaptation to climate change': Moscow, Russia, 7-9 November 2011.
Poster (public site)	2012	Fujita, Y., P.M. van Bodegom, H. Olde Venterink, J. Runhaar, J.P.M. Witte, (2011). Predicting nitrogen availability on a regional scale: on the necessity to include intricate interactions with local hydrology in a SOM model. Netherlands Annual Ecology Meeting, Lunteren, The Netherlands, February 7-8, 2012.
Presentation (intranet)	2011	Kros, J., W. de Vries, G.J. Reinds (2011). Effect of resolution of input data on modelled N2O fluxes at landscape scale. Presentation on the Sixth International Symposium on Non-CO2 Greenhouse Gases (NCGG-6), Wageningen, The Netherlands, November 2 - 4, 2011.
Presentation (intranet)	2011	De Kleijn, M.T.M. (2011), Klimaatveranderingen op Texel: Een interactieve discussie met lokale boeren. ESRI Conferentie 29 september 2011, track Water en Natuur.
Presentation (intranet)	2011	Sieber, S., H. König, K. Müller, P. Reidsma, I. Bezlepkina, (2011). Ex-ante Impact Assessment: Participative concepts versus modelling approaches for operational policy advice. XIIIth Congress of the European Association of Agricultural Economists, 30 August-2 September 2011, Zurich, Switzerland.
Presentation (intranet)	2011	Scholten, H., N. Omtzigt, M. Schreijer, M. Boomgaard, L. Kohsiek, T. Eikelboom, A. Koekoek, M. de Kleijn (2011), Workshop: Klimaatverandering op Texel, 14 november, Texel.
Presentation (intranet)	2011	De Kleijn, M.T.M. (2011). Climate change on Texel; Touch Table demo on Participatory Planning. UNIGIS Annual Conference, 24 April, Amsterdam.
Presentation (intranet)	2011	Van der Knaap, Y.A.M. (2011). Effects of inundation and drought events on stream valley vegetation. Department of Ecological Science Symposium, 13 December, VU Amsterdam.
Presentation (intranet)	2011	Dijk, J. van (2011). Using Agent-Based Models to model human behaviour and decision-making. Guest lecture Sustainability Science course, 8 December, Utrecht University, The Netherlands.
Presentation (intranet)	2011	Vos, C.C. & Van Teeffelen, A.J.A. (2011). Green Infrastructure: an integrating concept for regional climate change adaptation? Presentation at Ecosystem Services: integrating Science and Practice. 4th International ESP Conference, Wageningen, the Netherlands, 4-7 October 2011.
Presentation (public site)	2011	Brink, A. van den (2011). Climate Adaptation in Rural Areas: Nature and Agriculture. Presented at UNIGIS Conference & Alumni-day, 24-6-2011, VU Amsterdam.
Presentation (intranet)	2012	Kanellopoulos, A., Reidsma, P., Wolf, J., Mandryk, M., Schaap, B. & Van Ittersum, M. (2012). Exploring adaptation strategies for climate change in the Netherlands: a bio-economic farm level analysis. Proceedings of the conference of international Microsimulation Association, Paper number 91, Food Research Center (TEAGASC), Ashtown, Dublin, 17-19 May 2012.
Proceedings (intranet)	2010	Bartholomeus, R.P., B. Voortman & J.P.M. Witte (2010). Climate change effects on vegetation characteristics and groundwater recharge. Abstract H43J-04 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.
Proceedings (intranet)	2010	Cirkel, D.G., S.E.A.T.M. Van der Zee & J.P.M. Witte (2010). Microtopography as a key driving force for biodiversity in seepage dependant fen meadows. Latsis 2010 International Symposium on Ecohydrology. Abstract book Latsis 2010, Lausanne, Switserland, pp. 80.
Proceedings (intranet)	2010	Witte, J.P.M., R.P. Bartholomeus & D.G. Cirkel (2010). Climate change effects on vegetation characteristics and groundwater recharge. Latsis 2010 International Symposium on Ecohydrology. Abstract book Latsis 2010, Lausanne, Switserland, pp. 72.
Proceedings (intranet)	2010	Bartholomeus, R.P., J.P.M Witte, P.M Van Bodegom, J.C. Van Dam & R. Aerts (2010). Climate change hampers endangered species through intensified moisture-related plant stresses. Latsis 2010 International Symposium on Ecohydrology. Abstract book Latsis 2010, Lausanne, Switserland, pp. 79.

Proceedings (intranet)	2010	Bartholomeus, R.P., J.P.M Witte, P.M. Van Bodegom, J.C. Van Dam R. & Aerts (2010). Climate change hampers endangered species through intensified moisture-related plant stresses. Abstract H33H-06 presented at 2010 Fall Meeting, AGU, San Francisco, Calif., 13-17 Dec.
Proceedings (intranet)	2010	Schaap, B. P. Reidsma, F. Ewert, A. Kanellopoulos, M. Mandryk, J. Verhagen, J. Wolf, M. van Ittersum (2010). Climate change adaptation in agriculture; the use of multi-scale modelling and stakeholder participation in the Netherlands. In: J. Wery, I. Shili-Touzi & A. Perrin (Eds.), Proceedings of Agro 2010, the Xith ESA Congress, Montpellier, France, August 29 to September 03, 2010 (pp. 431-432). Montpellier, France.
Proceedings (intranet)	2010	Bartholomeus, R.P., J.P.M. Witte, P.M. Van Bodegom, J.C. van Dam & R. Aerts (2010). Climate change hampers endangered species through intensified moisture-related plant stresses. EGU General Assembly 2010. Geophysical Research Abstracts, Abstract EGU2010-3406, Vienna, Austria.
Proceedings (intranet)	2010	Witte, J.P.M., R.P. Bartholomeus & D.G. Cirkel (2010). Climate change effects on vegetation characteristics and groundwater recharge. EGU General Assembly 2010. Geophysical Research Abstracts, Abstract EGU2010-3401, Vienna, Austria.
Proceedings (public site)	2010	Mandryk, M., P. Reidsma, M. van Ittersum (2010). Scenarios of farm structural change for assessing adaptation strategies to climate change: a case study in Flevoland, the Netherlands. Scaling and Governance Conference: Towards a New Knowledge for Scale Sensitive Governance of Complex Systems. Wageningen, 11-12 november 2010.
Proceedings (intranet)	2011	Voortman, B.R., Bartholomeus, R.P. and Witte, J.P.M., (2011). The future groundwater recharge: evapotranspiration response of natural vegetation to climate change. Abstract 102 presented at HydroEco2011, Hydrology and Ecology: Ecosystems, Groundwater and Surface Water - Pressures and Options. Vienna, Austria, 2-5 May, p. 46.
Proceedings (intranet)	2011	Voortman, B.R., Bartholomeus, R.P. and Witte, J.P.M., (2011). The future groundwater recharge: evapotranspiration response of natural vegetation to climate change. In: S. Keesstra and G. Mol (Editors), Wageningen Conference on Applied Soil Science Soil Science in a Changing World 18 - 22 September 2011, Wageningen,The Netherlands.
Proceedings (intranet)	2011	Kanellopoulos, A., J. Wolf, M. Mandryk, P. Reidsma, B. Schaap, M. Van Ittersum (2011). Assessing the adaptation of arable farmers to climate change using DEA and bio-economic modelling. World Congress on Conservation Agriculture & Farming Systems Design, 26-29 September, Brisbane, Australia.
Proceedings (intranet)	2011	Bartholomeus, R.P., Witte, J.P.M., Van Bodegom, P.M., Van Dam, J.C. and Aerts, R. (2011). Climate change threatens endangered plant species by stronger and interacting water-related stresses In: Symposiumgids, Samenvattingen Bodem Breed 2011. P. Van Mullekom (Editor), Bodembreed symposium 2011. SKB, Lunteren, pp. 80.
Proceedings (intranet)	2011	Bartholomeus, R.P. and Witte, J.P.M., (2011). Drought stress and vegetation characteristics on sites with different slopes and orientations, EGU General Assembly 2011. Geophysical Research Abstracts, Abstract EGU2011-2184, Vienna, Austria.
Proceedings (intranet)	2011	Bartholomeus, R.P., Witte, J.P.M., Van Bodegom, P.M., Van Dam, J.C. and Aerts, R., (2011). Climate change hampers endangered species by stronger water-related stresses, EGU General Assembly 2011. Geophysical Research Abstracts, Abstract EGU2011-2177, Vienna, Austria.
Proceedings (intranet)	2011	Bartholomeus, R.P., Witte, J.P.M., Van Bodegom, P.M., Van Dam, J.C. and Aerts, R. (2011). Climate change threatens endangered plant species by stronger and interacting water-related stresses In: Symposiumgids, Samenvattingen Bodem Breed 2011. P. Van Mullekom (Editor), Bodembreed symposium 2011. SKB, Lunteren, pp. 80.
Proceedings (intranet)	2011	Kros, J. and W. de Vries (2011). Evaluation of the impact of low versus high resolution data on nitrous oxide emissions from a rural landscape. Proceedings of the Sixth International Symposium on Non-CO2 Greenhouse Gases (NCGG-6), Wageningen, The Netherlands, November 2 - 4, 2011. http://www.ncgg.info/.
Proceedings (intranet)	2012	Sieber, S., König, H., Bezlepkina, I., Reidsma, P. (2012). Different levels of stakeholder participation for Sustainability Impact Assessment Tools - A comparative requirement analysis of four research approaches. 6th International Congress on Environmental Modelling and Software (iEMSs). 1 - 5 July 2012, Leipzig, Germany.

Proceedings (intranet)	2012	Bartholomeus, R.P., Witte, J.P.M., Van Bodegom, P.M., Van Dam, J.C., Aerts, R. (2012). Contrasting extremes in water-related stresses determine species survival, EGU General Assembly 2012. Geophysical Research Abstracts, Vol. 14, EGU2012-1845,Vienna, Austria.
Project Factsheet (public site)	2010	Theme 3: Climate Adaptation for Rural Areas (2010). Work package 2: Water and biodiversity in the future climate.
Project Factsheet (public site)	2010	Theme 3: Climate Adaptation for Rural Areas (2010). Scientific aspects.
Project Factsheet (public site)	2010	Theme 3: Climate Adaptation for Rural Areas (2010). Societal aspects.
Project Factsheet (public site)	2010	Theme 3: Climate Adaptation for Rural Areas (2010). Summary.
Project Factsheet (public site)	2010	Theme 3: Climate Adaptation for Rural Areas (2010). Work package 1: Integration: multifunctional adaptation to climate change.
Project Factsheet (public site)	2010	Theme 3: Climate Adaptation for Rural Areas (2010). Work package 3: Drivers and consequences of adaptation by farmers.
Project Newsletter (public site)	2011	Theme 3 Newsletter Climate Adaptation for Rural Areas (2011). Nummer 1, maart 2011.
Project Newsletter (public site)	2011	Theme 3 Newsletter Climate Adaptation for Rural Areas (2011). Nummer 2, november 2011.
Project Newsletter (public site)	2012	Theme 3 Newsletter Climate Adaptation for Rural Areas (2012). Nummer 3, juli 2012.
Report (intranet)	2010	Wolf, J., M. Mandryk, A. Kanellopoulos, P. van Oort, B. Schaap, P. Reidsma and M. van Ittersum (2011). Integrated assessment of adaptation to climate change in Flevoland at the farm and regional level. AgriAdapt Reports no. 4&5, Wageningen UR.
Report (intranet)	2010	Wolf, J., M. Mandryk, A. Kanellopoulos, P. van Oort, B. Schaap, P. Reidsma and M. van Ittersum (2010). Methodologies for analyzing future farming systems in Flevoland as applied within the AgriAdapt project. AgriAdapt project report no. 1, Wageningen UR.
Report (public site)	2010	Witte, J.P.M. & T. Strasser (2010). Geautomatiseerde waardering van vegetatieopnamen en vegetatietypen. Beschrijving computerprogramma ASTER en vergelijking van waarderingsmethoden. KWR rapport BTO 2010.035(s), Nieuwegein.
Report (public site)	2011	Bartholomeus, R.P., Voortman, B.R. & Witte, J.P.M. (2011). In search of the actual groundwater recharge. KWR rapport BTO 2011.039(s), Nieuwegein.
Report (intranet)	2011	Schaap, B., P. Reidsma, M. Mandryk, K. Verhagen, M. van der Wal, J. Wolf, M. van Ittersum (2011). Adapting agriculture in 2050 in Flevoland; perspectives from stakeholders. AgriAdapt Report no. 6, Wageningen UR.
Report (public site)	2012	Hoekstra, J., M. Minkman (2012). Adaptive Landscape. Towards a climate robust future for the 'Blauwe Bron'. Master thesis Landscape Architecture, Wageningen University, Wageningen.
Report (public site)	2012	Wolf, J., P. Reidsma, B. Schaap, M. Mandryk, A. Kanellopoulos, F. Ewert, P. van Oort, C. Angulo, C. Rumbaur, R. Lock, A. Enders, M. Adenauer, T. Heckelei, R. Rotter, S. Fronzek, T.R. Carter, A. Verhagen, M.K. van Ittersum (2012). Assessing the adaptive capacity of agriculture in the Netherlands to the impacts of climate change under different market and policy scenarios (AgriAdapt project, final report project Climate changes Spatial Planning A19). KvR report number KvR 059/12, The Netherlands, ISBN/EAN 978-90-8815-051-7.

Report (public site)	2012	CARE (2012). Verslag Bijeenkomst Baakse Beek 14 mei 2012, Zelhem.
Scientific paper peer reviewed (public site)	2010	Ordoñez, J.C., P.M. van Bodegom, J.P.M. Witte, R.P. Bartholomeus, H.F. van Dobben & R. Aerts (2010). Leaf habit and woodiness regulate different leaf economy traits at a given nutrient supply. Ecology 91(11): 3218–3228.
Scientific paper peer reviewed (public site)	2010	Ordoñez, J.C., P.M. van Bodegom, J.P.M. Witte, R.P. Bartholomeus, J.R. van Hal & R. Aerts (2010). Plant Strategies in Relation to Resource Supply in Mesic to Wet Environments: Does Theory Mirror Nature? American Naturalist 175(2): 225-239.
Scientific paper peer reviewed (intranet)	2011	Kros, J., K.F.A Frumeau, A. Hensen and W. de Vries, (2011). Integrated analysis of the effects of agricultural management on environmental quality at landscape scale. Environmental Pollution 159: 3171-3182.
Scientific paper peer reviewed (public site)	2011	Bartholomeus, R.P., Witte, J.-P.M., van Bodegom, P.M., van Dam, J.C. and Aerts, R. (2011). Climate change threatens endangered plant species by stronger and interacting water-related stresses. Journal of Geophysical Research, 116(G4): G04023, DOI: 10.1029/2011jg001693.
Scientific paper peer reviewed (public site)	2011	Bartholomeus, R.P., Witte, J.P.M. and Runhaar H. (2011). Drought stress and vegetation characteristics on sites with different slopes and orientations. Ecohydrology, DOI: 10.1002/eco.271.
Scientific paper peer reviewed (public site)	2011	Kros, J., K.F.A Frumeau, A. Hensen and W. de Vries, (2011). Integrated analysis of the effects of agricultural management on environmental quality at landscape scale. Environmental Pollution 159: 3170–3181.
Scientific paper peer reviewed (public site)	2011	Bartholomeus, R.P., Witte, J.P.M., van Bodegom, P.M., Van Dam, J.C., De Becker, P. and Aerts, R. (2011). Process-based proxy of oxygen stress surpasses indirect ones in predicting vegetation characteristics. Ecohydrology, DOI: 10.1002/eco.261.
Scientific paper peer reviewed (public site)	2012	Douma, J.C., R. Aerts, J.P.M. Witte, R.M. Bekker, D. Kunzmann, K. Metselaar & P.M. van Bodegom (2012). A combination of functionally different plant traits provides a means to quantitatively predict a broad range of species assemblages in NW Europe. Ecography 35: 364–373. doi: 10.1111/j.1600-0587.2011.07068.x.
Scientific paper peer reviewed (public site)	2012	Douma, J.C., J.P.M. Witte, R. Aerts, R.P. Bartholomeus, J.C. Ordoñez, H. OldeVenterink, M.J. Wassen M.J., & P.M. van Bodegom (2012). Towards a functional basis for predicting vegetation patterns in a changing world; incorporating plant traits in habitat distribution models. Ecography 35: 294–305. doi: 10.1111/j.1600-0587.2011.07140.x.
Scientific paper peer reviewed (public site)	2012	Stremke, S., F. Van Kann, J. Koh (2012). Integrated Visions (Part I): Methodological Framework for Long-term Regional Design. European Planning Studies, 20:2, 305-319. doi:10.1080/09654313.2012.650909.
Scientific paper peer reviewed (public site)	2012	Stremke, S., J. Koh, K. Neven A. Boekel (2012). Integrated Visions (Part II): Envisioning Sustainable Energy Landscapes, European Planning Studies, 20:4, 609-626. doi: 10.1080/09654313.2012.665617.
Scientific paper peer reviewed (public site)	2012	Mandryk, M., P. Reidsma, M.K. van Ittersum (2012). Scenarios of farm structural change for assessing adaptation strategies to climate change: a case study in Flevoland, The Netherlands. Landscape Ecology 27 (4), 509-527. doi 10.1007/s10980-012-9714-7.
Scientific paper peer reviewed (public site)	2012	Douma, J.C., B. Shipley, J.P.M. Witte, R. Aerts, and P.M. van Bodegom (2012). Disturbance and resource availability act differently on the same suite of plant traits; revisiting assembly hypotheses. Ecology 93: 825-835.
Scientific paper peer reviewed (public site)	2012	Rounsevell, M.D.A., D.T. Robinson & D. Murray-Rust (2012). From actors to agents in socio-ecological systems models. Philosophical Transactions of the Royal Society B, 367: 259-269, DOI:10.1098/rstb.2011.0187.
Scientific paper peer reviewed (public site)	2012	Van Teeffelen, A.J.A., Vos, C.C., Opdam, P. (2012). Species in a dynamic world: Consequences of habitat network dynamics on conservation planning. Biological Conservation, 153, 239-253.

ANNEX 4 Publication Plan CARE (version August 2012)

This is work in progress. Please note that all info is provisional and that the titles, the names of authors as well as the selection of journals is not final yet. Only peer-reviewed papers are listed here. Additional publications in professional journals and conference proceedings are planned in 2012/2013. Articles already published are not included.

WP 1

Publication # 1-1
Title:
Community-based adaptation to climate change: governing/indicators for the adaptive capacity of the physical landscape.
Intended Journals:
Global Change Biology, Climate Change
First author:
Claire Vos
Possible co-authors
Paul Opdam , Carla Grashof-Bokdam, Astrid Van Teeffelen, Sven Stremke, Adri van den Brink

Publication # 1-2
Title:
Synthesis of adaptation options and strategies in response to climate change that reflects the diversity of biophysical and socio-economic contexts.
Intended Journal:
Mitigation and Adaptation Strategies for Climate Change
First author:
Claire Vos
Possible co-authors:
Mark Rounsevell, Adri van den Brink, Martha Bakker, Flip Witte

Publication # 1-3
Title:
The meaning of integration in the planning and design of multifunctional landscapes
Intended journal:
Landscape Journal (special issue Spring 2013)
First author:
Marjo van Lierop
Possible co-authors:
Sven Stremke, Fennie van Straalen, Adri van den Brink, Ingrid Duchhart

Publication # 1-4
Title:
Prescription vs. projection: Exploring synergies between participatory intentional design and agent-based modelling
Intended journal:
Landscape Research, Landscape and Urban Planning, European Planning Studies
First author:
Sven Stremke
Intended co-authors:
Adri van den Brink, Ingrid Duchhart, Claire Vos and Mark Rounsevell

Publication # 1-5
Title:
Climate change adaptation in rural landscapes: Special issue peer-reviewed journal
Intended journal:
Sustainability, Landscape Ecology
First author (editors):
Adri van den Brink and Sven Stremke
Intended co-authors:
Other Care partners

Publication # 1-6
Title:
Exploring market effects on land consolidation in the Baakse Beek region, the Netherlands: An empirical agent-based model
Intended journal:
Landscape Ecology, Computers, Environment and Urban Systems, Ecology and Society
First author:
Martha Bakker/Shah Jamal Alam
Intended co-authors:
Eleni Karali, Jerry van Dijk, Mark Rounsevell

Publication # 1.7
Title:
Climate change effects on landscape and provision of ecosystem services in rural Netherlands
Intended journal:
Landscape Ecology, Land Use Policy
First author:
Eleni Karali
Intended co-authors:
Martha Bakker, Shah Jamal Alam, Jerry van Dijk, Mark Rounsevell

Publication # 1.8
Title:
Evolving competition strategies for nature managers in a land transaction market model
Intended journal:
Adaptive Behavior, Mind & Society
First author:
Shah Jamal Alam/Martha Bakker
Intended co-authors:
Jerry van Dijk, Eleni Karali, Mark Rounsevell

Publication # 1.9
Title:
A systematic review on regional adaptation strategies available to policy makers and land managers in temperate regions.
Intended journal:
Mitigation and Adaptation Strategies for Global Change, Climatic Change
First author:
Eleni Karali
Intended co-authors:
Claire Vos, Mark Rounsevell, Martha Bakker, Shah Jamal Alam, Jerry van Dijk,.....

WP 2

Publication # 2-1
Title:
Hydraulic characteristics of mosses
Intended journal:
Vadose zone journal
First author:
B.R. Voortman
Intended co-authors:
H. Gooren, R.P. Bartholomeus, P.M. van Bodegom S.E.A.T.M. van der Zee, J.P.M. Witte

Publication # 2-2
Title:
Quantifying evaporation and transpiration based on comparison of surface temperature with mini-lysimeters
Intended journal:
HESS
First author:
B.R. Voortman
Intended co-authors:
R. de Jong, R.P. Bartholomeus, S.E.A.T.M. van der Zee, M. Bierkens, J.P.M. Witte

Publication # 2-3
Title:
The role of mosses and lichens in the soil water balance of drift sand ecosystems
Intended journal:
Ecohydrology
First author:
B.R. Voortman
Intended co-authors:
R.P. Bartholomeus, P.M. van Bodegom, J.P.M. Witte

Publication # 2-4
Title:
Optimization of the vegetation structure: a valuable tool for predicting climate-vegetation feedbacks in harsh environments
Intended journal:
Ecology
First author:
B.R. Voortman
Intended co-authors:
R.P. Bartholomeus, P.M. van Bodegom, S.E.A.T.M. van der Zee, M. Bierkens, F.J.A. Daniëls, M. Henschel, J.P.M. Witte

Publication # 2-5
Title:
De sturende rol van vegetatie op de grondwateraanvulling in het toekomstige klimaat
Intended journal:
H_2O
First author:
B.R. Voortman
Intended co-authors:
R.P. Bartholomeus, S.E.A.T.M. van der Zee, J.P.M. Witte

Publication # 2-6
Title:
Towards proper inclusion of hydrological information to predict soil nitrogen mineralization rates of natural ecosystems with shallow groundwater.
Intended journals:
Soil biology & biochemistry, Soil Science Society of America Journal
To be submitted in 2012
First author:
Yuki Fujita
Intended co-authors:
Flip Witte (KWR), Han Runhaar (KWR), Harry Olde Venterink (ETH Zurich), Peter van Bodegom (VU)

Publication # 2-7
Title:
Linking plant functional traits to short-term and long-term nutrient availability in soil
Intended journal:
Functional ecology
To be submitted in 2013
First author:
Yuki Fujita
Intended co-authors:
Flip Witte (KWR), Han Runhaar (KWR), Peter van Bodegom (VU)

Publication # 2-8
Title:
The sequence of extreme drought and inundation events determines riparian plant performance
Intended journal:
Functional Ecology
First author:
Y.A.M. van der Knaap
Intended co-authors:
R. Aerts, P.M. van Bodegom
Status: will be submitted in 2012

Publication # 2-9
Title:
Successfully modeling stream valley hydrology: a case study
Intended journal:
Journal of Hydrology (IF: 3.118)
First author:
Y.A.M. van der Knaap
Intended co-authors:
J. Hoogewoud, R. van Ek, M. Bierkens, P.M. van Bodegom, R. Aerts

Publication # 2-10
Title:
Modelling the impact of hydrology on stream valley vegetation
Intended journal:
Ecohydrology (IF: 1.835)
First author:
Y.A.M. van der Knaap
Intended co-authors:
P.M. van Bodegom, J.P.M. Witte ,R. van Ek., M. Bierkens, R. Aerts

Publication # 2-11
Title:
Climate change effects on stream valley vegetation
Intended journal:
Ecology (IF: 4.782)
First author:
Y.A.M. van der Knaap
Intended co-authors:
P.M. van Bodegom, J.P.M. Witte, M. Bierkens, R. van Ek, R. Aerts

Publication # 2-12
Title:
Hoe behouden we de biodiversiteit van het beekdallandschap in het toekomstige klimaat?
Intended journal:
H_2O
First author:
Y.A.M. van der Knaap
Intended co-authors:
P.M. van Bodegom, M. Bierkens, R. van Ek, R. Aerts

Publication # 2-13
Title:
Green Infrastructure as a regional climate adaptation strategy for ecological networks
Intended journals:
Conservation Letters; Biological Conservation; Landscape Ecology
First author:
A.J.A. van Teeffelen
Intended co-authors:
C. Grashof-Bokdam, H. Baveco, C. Vos

Publication # 2-14
Title:
Design rules for green infrastructure as a climate change adaptation option for biodiversity
Intended journal:
Landscape and Urban Planning
First author:
A.J.A. van Teeffelen
Intended co-authors:
C. Vos and others

WP 3

Publication # 3-1
Title:
Improving assessment of climate change impacts and adaptation in water management on crop yields at regional level
Intended journals:
Agricultural Systems; European Journal of Agronomy; Agricultural Water Management
First author:
P. Reidsma
Intended co-authors:
J. Wolf, Z. Zhou, P. Boogaart, P. Schipper, M. K. Van Ittersum

Publication # 3-2
Title:
Assessing adaptation to impacts of changes in climate, markets and policy on dairy farming in a Dutch region using Data Envelopment Analysis and Bio-economic farm modeling
Intended journals:
Agricultural Systems; Agriculture, Ecosystems and Environment; Environmental Science & Policy, Environmental Management; Regional Environmental Change
First author:
P. Reidsma
Intended co-authors:
A. Kanellopoulos, B. Schaap, J. Wolf, M.K. Van Ittersum

Publication # 3-3
Title:
Bridging ecology and agronomy: Designing a green infrastructure network optimal for biodiversity and farmers' objectives
Intended journal:
Agriculture, Ecosystems and Environment, Landscape Ecology, Journal of Environmental Management
First author:
P. Reidsma
Intended co-authors:
A. van Teeffelen, B. Schaap, M. Bakker, C. Vos

Publication # 3-4
Title:
Linking farm models to regional environmental impact models: assessing impacts of global change and searching for optimal economic and environmental adaptation
Intended journal:
Agriculture, Ecosystems and Environment, Environmental Pollution
First author:
W. de Vries
Intended co-authors:
J. Kros, P. Reidsma, A. Kanellopoulos, J. Wolf, M.K. van Ittersum

Publication # 3-5
Title:
Integrated assessment of agricultural practices on the loss of ammonia, greenhouse gases, nutrients and heavy metals to air and water.
Intended journal:
Nutrient Cycling in Agroecosystems
First author:
W. de Vries
Intended co-authors:
J. Kros, J. C. Voogd and G.L. Velthof

Publication # 3-6
Title:
Efficiency of agricultural measures to reduce nitrogen deposition on Natura 2000 sites.
Intended journal:
Environmental Science & Policy
First author:
J. Kros
Intended co-authors:
T.J.A. Gies, J.C. Voogd, R. Smidt and W. de Vries

Publication # 3-7
Title:
Impact of spatial resolution of input data on nitrogen losses to air and water from a rural landscape.
Intended journal:
Geoderma
First author:
J. Kros
Intended co-authors:
W. de Vries

CARE GENERAL

Publication # 0-1
Title:
Special Issue CARE
Intended journal:
Landschap, Tijdschrift voor Landschapsonderzoek
First author:
…
Intended co-authors:
CARE researchers