Integrating and downscaling national socio-economic scenarios

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1 Description work package

1.1 Problem definition, aim and central research questions

The development of effective regional climate adaptation perspectives not only requires information on climate change but also calls for the consideration of changing economic and societal conditions. Land-use models are suitable tools to downscale existing national scenarios into changes in local land-use patterns and thus provide the relevant context for the development and evaluation of climate mitigation and adaptation measures. The Land Use Scanner model was successfully applied in this context in the current CcSP and KfC programs. These applications have, however, indicated two important drawbacks: 1) current regionalised sector-specific outlooks on the future based on national scenarios lack a thorough integration; and 2) the translation of sector-specific development (e.g. number of new residences) and spatial measures for climate adaptation into a related demand for space (in hectares) used in the land-use model lacks the accuracy and flexibility needed for climate-related impact assessments and the development of adaptation alternatives. Moreover, multiple functionalities on the same land area are not fully considered. Multifunctionality of land is a high priority in the densely populated regions of the Netherlands and often a means of adapting to climate change conditions.

This work package thus has the following objectives:

1. better align and integrate the sector-specific models for, amongst others, residential, commercial and agriculture development. This integrated approach will ensure a more robust link with the underlying scenario assumptions and allows for the incorporation of feedbacks between climate-induced and other developments in different economic sectors. This work will be performed in cooperation with the Netherlands Environmental Assessment Agency (PBL).
2. revise the model to allow the incorporation of functional units (e.g. residences, water storage quantity) rather than hectares. This enables a more flexible inclusion of issues such as land-use intensity and multifunctionality, allowing, for example, a more accurate assessment of flood risk and a wider scope of adaptation measures.

1.2 Interdisciplinarity and coherence between the projects

Land use is the result of a complex interplay of factors and mechanisms related to, amongst others, climate, technology, economics and planning. The analysis and modeling of land-use change is thus an interdisciplinary form of research that has to pay attention to the economic processes related to, for example, residential and commercial development and the biophysical conditions (climate change, ecological processes and hydrological properties) that are more important for agricultural and natural types of land use. Both proposed projects are highly complementary and connected and aim to offer an integrated approach that addresses both urban and rural types of land use.

This research calls for the cooperation of specialists in such varied fields as economics (to explain urbanization processes and incorporate the rationality in agricultural practices), geography (to understand integrated land-use systems) and information technology (to build efficient computer models). These disciplines are available within the WP-team that consists of the Faculties of Earth and Life Sciences and Economics and Business Administration at the VU University Amsterdam. Additional programming expertise is available from the Object Vision company that has its office at the university and then can be subcontracted when necessary. This work will be performed in close collaboration with PBL and will be tuned to the PBL project “development LUMOS”.

1.3 Stakeholders

The EC-Joint Research Centre (JRC) and Netherlands Environmental Assessment Agency (PBL) are very interested in the proposed model improvement as part of their ongoing land-use model development projects. Carlo Lavalle (JRC) and Arno Bouwman (PBL) will therefore participate in the project as part of an advisory group that will be informed about project progress and consulted about potential developments.

Of particular interest to local and regional stakeholders are the updated land-use change assessments that will become available as part of this work package. In addition, the revised model can help better address several planning-related issues for which intensity and multifunctionality of land use are important. This is, for example, the case in flood risk assessments in which damage and casualty

estimates are greatly influenced by the expected land-use intensities. Therefore, the results of this work package will strongly enhance the possibilities and results of the other work packages in this project.

The enhanced modelling framework will be applied in three specific cases to demonstrate its potential for supporting climate adaptation questions. These will focus on the Haaglanden area and dry rural areas and have been defined in cooperation with the hotspot representatives.

The potential of the land-use projections to help define climate adaptation policies will initially be explored in the dry rural area hotspot in cooperation with Frank van Lamoen (Province of Noord-Brabant) in year 1. The newly created maps of future land-use patterns will be provided to the „Groene Woud" case study to indicate the spatial context in which climate adaptation should take place. Potential spatial conflicts between different policy ambitions will be highlighted. The experiences in this case study will be used to adjust the modelling framework to better incorporate intensity and multifunctionality.

In subsequent case studies the potential of the model improvements will be tested (in year 2 and 3). Project 1 will provide the scenario-based outlooks on the demand of land for specific sectors, whereas project 2 will focus on the spatial implications of including land-use intensity and multifunctionality. The case study of year 2 will focus on the Haaglanden hotspot and will be used to simulate different intensities of urban land-use types. This case study builds upon the work currently performed in the Haaglanden hotspot and will be carried out in close cooperation with Carl Pauwe (Waterkader Haaglanden).The case study in year 3 will again focus on rural areas and assess the potential of multifunctional land use to adapt to climate change. This study will be performed with Frank van Lamoen (Province of Noord-Brabant) in cooperation with WP4 (led by Hasse Goosen). The study will focus on the „Peel" area and looks into various services (ecological, hydrological and water management) that can be delivered by farmers on their land.

2 Project 1.1 Integrating sector-specific models in a land-use modeling framework

Project leader: prof.dr. Piet Rietveld (VU/FEWEB)

2.1 Problem definition, aim and central research questions

To provide the relevant context for the development and evaluation of climate mitigation and adaptation measures land-use models are suitable tools to downscale global and national scenarios into changes in local spatial patterns (Koomen et al., 2008; Van der Hoeven et al., 2008). In the Dutch modelling context global and national socio-economic scenarios are initially downscaled to the regional level by means of sector-specific models (Borsboom-van Beurden et al., 2007). Such models provide future projections of, for example, residential, commercial or agricultural development according to the best available methodological approaches, data sets and assumptions. This application of state of the art sector-specific models comes at the cost of potential inconsistencies in underlying initial conditions, scenario-based-assumptions and a more general lack of feedback between sector-specific developments

(Dekkers and Koomen, 2006). The incorporation of such feedbacks would allow a more integrated assessment of issues such as the relation between residential and commercial development under conditions of an increased (perception) of flood risk in certain regions. A more integrated modelling framework would allow the incorporation of changes in the locational preferences of firms in simulations of future availability of jobs and the resulting impact on the regional demand for housing.

This project aims to establish a more robust link between existing spatial-economic models for residential and commercial development and incorporation of their key-results in a refined land-use model. More specifically attention will initially focus on the PRIMOS-model for regional scenario-based population, households and housing demand projections (Heida and Van der Meer, 2007), the BLM-model that provides scenario-based projections for formal business sites, harbour areas and other work locations (Traa and Declerck, 2007) and the Land Use Scanner model (Hilferink and Rietveld, 1999) applied in Dutch spatial planning and climate adaptation related research. A short review of new developments in these and related sector-specific models (see, for example, Van Oort et al., 2005) will be performed to asses the potential of these new developments in enhancing the existing modelling framework. Especially the ongoing model development projects at the Netherlands Environmental Assessment Agency (PBL) will be monitored that relate to, amongst others, the upgrading of demographic PEARL model (De Jong et al., 2005) and the linking of the land-use model with the TIGRIS transport model (Zondag and Borsboom-van Beurden, 2008). Based on this initial inventory a methodology will be proposed to adapt the existing modelling framework to incorporate feedbacks between the regional demands for housing and commercial areas.

Research questions, for this project are:

1. To what extent can the description of the current situation in existing sector-specific models for residential and commercial development be matched with available land-use data sets?
2. What are the main similarities and differences in the initial conditions and scenario-based-assumptions in the sector-specific model applications that underlie the land-use projections used in current climate adaptation studies?
3. How can the observed differences be bridged to better link the sector-specific models?
4. To what extent do recent research efforts in these and other sector-specific models offer more integrated alternatives to the incorporation of the de demand for residential and commercial development in a land-use model?
5. How can the existing land-use modeling framework be enhanced to incorporate feedbacks between residential and commercial demand?
6. How can this revised modeling tool be applied in a regional case study?

2.2 Approach and methodology

This project is organised in three subsequent phases.

An initial review phase will analyse the current limitations in the links between sector-specific model focussing on the demand for residences and commercial facilities. This phase will rely on a review of the

existing literature and in-depth interviews with those active in the application and development of new model components.

A second, model specification, phase will propose an enhanced land-use modelling framework to incorporate feedbacks between residential and commercial demand. This link may be established in a separate layer that steers the simulation of the urban functions, for example through a regional spatial interaction model. Ideally this interaction model would make use of an underlying transport network as offered by the TIGRIS model. The proposed model enhancement will be discussed on its scientific merits and applicability with an advisory group consisting of fellow-scientists and modellers at universities and research institutes such as the Netherlands Environmental Assessment Agency (PBL). These discussions will ensure a proper alignment with other ongoing model development projects.

The third and final application phase will implement the suggested changes in the modelling framework to test their potential in establishing feedbacks between residential and commercial demand.

2.3 Scientific deliverables and results

1. A review-type paper documenting the current limitations in the links between sector-specific model focussing on the demand for residences and commercial facilities in current land-use modelling efforts to be presented at a conference focussing on urban modelling (possibly ERSA or AGILE).
2. A peer-reviewed book chapter or journal paper describing the proposed enhancing of the land-use modelling framework to incorporate feedbacks between residential and commercial demand.
3. A peer-reviewed book chapter or journal paper describing the actual implementation of the suggested changes in the land-use modelling framework in a case study focusing on a climate adaptation issue.

2.4 Integration of general research questions with hotspot-specific questions

The scenario-based projections of future land use are useful to describe the autonomous developments in, for example, urban and agricultural development and thus sketch potential boundary conditions for climate adaptation in the hotspots. This is especially interesting for those hotspots that consider spatially-explicit policy interventions, such as dry rural areas and the peri-urban Haaglenden. The potential of the land-use projections to help define climate adaptation policies will initially be explored in the „Groene Woud" case study. This study is part of the dry rural area hotspot and will be performed in cooperation with Frank van Lamoen (Province of Noord-Brabant) in year 1. The newly created maps of future land-use patterns will indicate the spatial context in which climate adaptation takes place. By using different spatially explicit indicators, potential spatial conflicts between different policy ambitions will be highlighted. The experiences in this case study can be used to help adjust the modelling framework to better incorporate intensity and multifunctionality which is the topic of project 2 in this work package.

In addition, project 1 will provide the input on sector-specific developments for two additional case studies (in year 2 and 3). The case study of year 2 will focus on the Haaglanden hotspot and be used to simulate different intensities of urban land-use types. This case study builds upon the work currently performed in the Haaglanden hotspot and will be carried out in close cooperation with Carl Pauwe (Waterkader Haaglanden).The case study in year 3 will again focus on rural areas and assess the potential of multifunctional land use to adapt to climate change. This study will be performed with Frank van Lamoen (Province of Noord-Brabant) in cooperation with WP4 (led by Hasse Goosen). The study will focus on the „Peel" area and looks into various services (ecological, hydrological and water management) that can be delivered by farmers on their land.

2.5 Societal deliverables and results

4. A revised modeling framework that will become available to the Dutch research institutes to assist in climate adaptation issues at the national and regional level. The current project specifically aims to underpin the ongoing land-use model development process at the Netherlands Environmental Assessment Agency.
5. A conference presentation of the revised modeling approach for Dutch research institutes involved in spatial modeling (e.g. the annual Ruimteconferentie).
6. As part of the service function associated with this project a revised assessment will be made of the scenario-based projections of land-use change for 2040 according to the standard scenario-set of the Dutch research institutes (CPB et al., 2006). A first update will be based on the existing modeling framework and inclusion of an updated (2006) basic land-use map (www.CBS.nl) and published in cooperation with the Netherlands Environmental Assessment Agency. Subsequent updates will become available when the modeling framework is updated. These basic land-use maps can act as important input to other research and adaptation projects and can be distributed through the „climate impact guide" website managed by the Royal Netherlands Meteorological Institute as part the KfC-Tailoring project.

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3 Project 1.2 Incorporating intensity and multiple functionality in the land-use model

Project leader: prof.dr. Piet Rietveld (VU/FEWEB) and dr.ir. Peter Verburg (VU/IVM)

3.1 Problem definition, aim and central research questions

Land use change is a result of complex dynamics across multiple scales, sectors and dimensions (GLP, 2005) To a large extent this complexity is due to two specific characteristics: the intensity of land use varies greatly across space and land often has multiple functions at the same location, e.g., a spatial overlap of agricultural production and landscape preservation for natural and recreational uses (Verburg et al., 2009). In analogy to the definition of ecosystem services by Millennium Ecosystem Assessment, different categories of land functions can be distinguished: (i) production services, i.e., the goods and services produced by the land use system such as agricultural production or the provision of space for various types of urban development; (ii) regulation services, e.g. the capacity of the land use system to regulate climate, hydrological and biological processes; and (iii) cultural services that relate to the

benefits people obtain from ecosystems through recreation, cognitive development, relaxation, and spiritual reflection or the provision off attractive housing and living conditions.

Especially for the densely populated rural area of the Netherlands, the intensity and multiple functionality of land are key aspects in land-use planning. In view of expanding demands for rural space for, among others, residential building, infrastructure, recreation and nature development schemes, pressure on the current land area in the Netherlands can be expected to further increase in the coming decades. Both the adaptation and mitigation requirements of land use toward climate change may require a further intensification and multifunctionality of the land use. Therefore, there is a strong need to upgrade existing spatial support systems in order to deal with the intensity and multifunctionality of land use. Efficient land use management and planning needs to consider the costs of maintaining and managing landscapes, as well as the benefits derived from land uses in the form of various land use services. In assessing the efficiency of land use management and planning, the full set of services supplied by land use should be considered.

A key element in assessing the efficiency and sustainability of land use management and planning is the analysis of the dynamics of the land use system, i.e., the changes in land use and its capacity to supply services over time. Land use and ecosystems do not change in a gradual and reversible manner but often change in much more complex ways. Complex dynamics comprise irreversible, non-linear and/or stochastic responses of the land use system to human and/or biophysical events and drivers (Rindfuss et al., 2008). Irreversible changes can not, or only to a limited extent, be undone. The complexity of adequately capturing land use is exemplified by the fact that key data sets in this field are, to a large extent derived from remote sensing or aerial photography and thus mainly reflect land cover. In practice, land cover is the indirect effect of the demand for a number of land use functions and ecosystem services and should be analyzed in interaction. Hence, there is an urgent need to further refine the concept of land-use intensity and to examine environmental functions and multifunctionality in its spatial context and to develop specific methodologies to include these in land use models. This requires innovative approaches to achieve the integration of the „functionality concept" in spatial modeling (Verburg et al., 2009).

As a first step towards the much-needed shift from a land-cover to a land-use based approach we propose to focus on two key issues: 1) the inclusion of residential densities instead of residential areas in the land-use model; and 2) the inclusion of multiple services for rural land use. To test the concepts that are to be developed to tackle these issues we propose to base the innovative aspects on the structure of the existing Land Use Scanner model that has been applied extensively in spatial planning and climate adaptation research in the Netherlands (Koomen et al., 2008; Loonen and Koomen, 2009; Van der Hoeven et al., 2008). This will ensure a good fit with the existing scenario studies in the region while at the same time allows building on progress in land function modeling in other contexts (e.g. Nelson et al., 2009).

The central questions, related to the two main research foci, are:

1. How can residential densities be incorporated in a Dutch land-use model? And more specifically:
    - ∇ How can current residential densities in the Netherlands be adequately described?
    - ∇ How can these descriptions be linked with existing sector-specific projections of residential development in, for example, the often used PRIMOS and PEARL models?
    - ∇ How can actual numbers of residences (rather then their expected land area) be included in the land-use model?
    - ∇ How can the future demand for residences be used in land-use simulation?
2. How can multifunctionality of land uses be included in a land-use change model? And more specifically:
    - ∇ What are the most important determinants of land-use service supply in the Netherlands and how does this relate to land cover?
    - ∇ Which methods are suitable to include these dynamics in land-use models?
    - ∇ How can multiple functionality of land use be included in model-based scenario studies and provoke discussion among stakeholders?
    - ∇ How can scenarios of climate change adaptation measures be simulated in land-use change models that pay specific attention to multiple functionality of land use.

3.2 Approach and methodology

The analysis starts with empirical spatial analysis using recent, detailed geographical data sets related to land cover, soil sealing, population density and service provision at the national and regional case-study level following documented approaches to describe intensity and multifunctionality in urban and rural areas (e.g., Batty et al., 2004; Willemen et al., 2008; Kienast et al., in press). Based on these empirical analyses, complemented with detailed information of climate adaptation options, the main determinants of land use functionality will be determined and represented in maps indicating the spatial variation of service provision. These maps will both indicate the current level of land use service supply but as well the potential capacity of the location to supply these functions. Such maps can already be used to target adaptation measures to the most suitable locations.

Based on the thus analyzed relations between location and contextual factors and the functionality of the land an existing land use model for the Netherlands will be modified to incorporate residential densities and to deal with the service provision of multiple, interacting services. This model enhancement will call for an improved specification of the land demands and the allocation procedure that are used in the model. The revision of the allocation procedure may benefit from initial experiences with the incorporation of ecosystem values in a comparable land-use modeling framework (Hartig et al., 2009; Willemen et al., subm.). Specific attention will be given to conflicts between different functions as well as to synergies (Willemen et al., 2010). Based on the simulation results an analysis of hot-spots of future land use change can be made that identifies potential conflicts between different functions.

3.3 Scientific deliverables and results

1. Two conference papers focusing on the description and analysis of residential land-use intensity and the multifunctionality of land uses.
2. Two peer reviewed journal papers or book chapters focusing on the innovative methodological issues involved in incorporating residential land-use intensity and the multifunctionality of rural land use in an operation model of land-use change.
3. Conference presentation of Dutch modeling results for a scenario including climate adaptations for the Dutch or international climate change research community.

3.4 Integration of general research questions with hotspot-specific questions

The enhanced modelling framework will be applied in two specific cases to demonstrate its potential for supporting climate adaptation questions. The benefits of incorporating residential densities will be tested in a regional case study where urban densification is prominent policy issue (Haaglanden hotspot). The incorporation of multifunctionality will be explored in a case study in a dry rural area (the „Peel" region in Noord-Brabant, together with Frank van Lamoen and Hasse Goosen). The latter case will use scenarios with different demands for land functionalities, including regulating services to adapt to climate change. This exploration of changes in the functionality of land use is essential to provoke discussions among stakeholders, assess the effects and tradeoffs of potential impacts and to support decision makers at various levels in the identification of options for transitions to efficient and sustainable land use. The description of work package 1 (under stakeholders) discusses the different case studies in more detail.

3.5 Societal deliverables and results

4. A revised modeling framework that will become available to the Dutch research institutes (such as the Netherlands Environmental Assessment Agency) to assist in climate adaptation issues at the national and regional level.
5. Improved understanding of the supporting conditions and constraints of multiple functionality of landscapes in the Netherlands obtained documented in a concise case study report.

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