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Exploring integrated scenarios of socio-economic and climate change in the Netherlands

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Abstract: Socio-economic and climate changes are expected to alter the current land-use patterns in the Netherlands. In order to study these uncertain developments and propose adaptation and mitigation measures to cope with the possible changes in the physical and societal environment a set of future scenarios is developed. These scenarios integrate possible socio-economic and climate changes and are used in the Land Use Scanner model to simulate future land-use patterns. Based on these results sector-specific adaptation and mitigation measures will be developed in related research projects.

Keywords: adaptation; climate change; land use; spatial planning.

1 Introduction

It is widely believed that climate change and increased climatic variability will impact land use through affecting different economic sectors such as agriculture, housing, nature and ecosystems, and by changing the water resources system (Commissie Waterbeheer 21e eeuw, 2000; IPCC, 2001; Verbeek, 2003). Climate change directly affects, for example, local agricultural and hydrological conditions and consequently influences the economic development potential. Climate change thus modifies the demand and supply for space, as well as the suitability of space for certain uses (Beinat and Nijkamp, 1998). These processes can be assessed through land-use simulation models that integrate sector specific demands (for housing, agriculture, etc.) and land suitability for certain uses and provide an indication of the likely land use in the future under different climate conditions. Climate change modifies the mechanisms of the demand-supply interplay as well as the boundary conditions and scenarios within which it unfolds. The main processes through which climate change and socio-economic developments may affect demand and supply of space are:

- The physical modification of the suitability of certain areas for some uses of the land;
- The modification of productivity and production processes within sectors such as agriculture, forestry, and nature;
- Changes to the primary functioning of economy and society leading to a different set of policies that influence for instance economic development (growth) or the type of development (e.g. free market versus government);
- The extra demand for space as a result of adaptation strategies within various sectors.

In order to accommodate these impacts, pro-active adaptation measures within the area of spatial planning are prerequisite to cope with climate change and will offer new opportunities for rearranging land use (Parry, 2000a; Parry, 2000b). However, such rearrangements will pose challenges and conflicts between the national and regional policy levels, and between sectors. For instance, when problems concerning water storage and flooding are tackled with spatial rather than technical measures, the capital-intensive agricultural or urban functions of these buffering areas will be highly restricted (Borsboom-van Beurden et al., 2005).

The research programme 'Climate *changes* Spatial Planning' aims to develop an adequate and timely set of policies for mitigation and adaptation to cope with the impacts of climate change in the Netherlands. The research programme is centred on four main research themes:

- Climate scenarios: climate scenarios and climate data management for decision support in spatial planning;
- Mitigation: decreasing greenhouse gas emissions in relation to land use and spatial planning;
- Adaptation: dealing with the effects of climate change in spatial planning;
- Integration: methods for research exchange and integration.

Obviously, climatic change is not the only factor driving land-use change. Socio-economic developments are another major driving force. In fact, these developments interact with climatic changes (Dale, 1997; Watson et al., 2006). For example, economic and population growth cause increased emission of greenhouse gasses, which influence the global climate. As a result, changes in annual regional rainfall patterns could impact agricultural production or cause the tourist industry to migrate to other regions. Prolonged droughts and other extreme weather are other examples of climatic changes that impact the economy.

Integration of climate-change and socio-economic factors is, in our opinion, thus needed in any long-term study on future land-use configurations and related spatial planning measures. However, the scenarios used in most land-use allocation models, are usually neutral to climate change, as only socio-economic factors are taken into account. This assumption appears inappropriate in the case of the expected major climatic modifications.

In this paper different future scenarios, based on socio-economic scenarios and climate models, will be presented. These scenarios are used as input in various sector-specific models and are subsequently fed into the Land Use Scanner model for an initial simulation of land-use change. In a following phase these results will be analysed on their possible adverse impacts on different sectors. Based on this analysis sector-specific adaptation and mitigation measures can be drafted that can eventually be fed into the Land Use Scanner to come to an integrated view on possible land-use changes that results from expected societal and climatic developments.

This paper starts by introducing the renewed Land Use Scanner version that contains a 100 metre grid and offers a discrete description of land-use limited to only one type of use per cell. This model differs considerably from the previous version that contained a 500 metre grid with a continuous description of the fraction that all land-use types took up in a cell. We then go on to describe the socio-economic and climatic characteristics and land-use simulations of the proposed future scenarios. The paper concludes with a discussion on the possible use of the presented results.

2 Simulating land-use change

In this long-term scenario-study we use the Land Use Scanner. This GIS-based model produces simulations of future land use that are based on the integration of sector specific inputs from dedicated models (Dekkers and Koomen, 2007; Hilferink and Rietveld, 1999). The model is based on demand-supply interaction for land, with sectors competing for allocation within suitability and policy constraints. Land-use simulations are generally scenario driven, with series of coherent assumptions regarding variables such as economic growth or level of government intervention, determining the way the land demand-supply unfolds (Borsboom-van Beurden et al., 2007; Koomen et al., 2005). The renewed model-configuration used for this project applies a 100-meter grid offering a very detailed view on possible spatial patterns in the future. It distinguishes 17 land-use types, out of which the model allocates 11. The remaining six land-use types, mainly related to infrastructure and water, have a pre-defined location that is not influenced by model-simulation. Their location is either a continuation of current land use or consists of pre-defined, approved plans, as is the case with, for example, long-planned railway links. For a more detailed description of the most recent model version and its calibration and validation the reader is referred to other publications (Loonen and Koomen, 2007; Tijbosch et al., 2007).

Unlike many other land-use models the objective of the Land Use Scanner is not to forecast the dimension of land-use change but rather to integrate and allocate future land-use demand from different sector-specific models or experts.

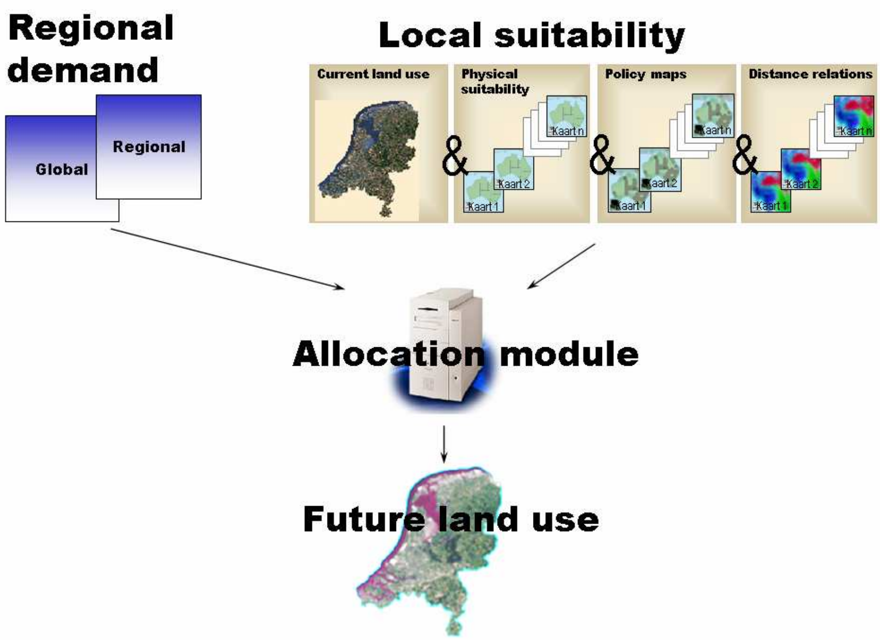

Figure 1. Basic layout of the Land Use Scanner model.

Figure 1 presents the basic structure of the Land Use Scanner model. External regional projections of land-use change, which are usually referred to as demand or claims, are used as input for the model. These are land-use type specific and can be derived from, for example, sector-specific models of specialised institutes. The predicted land-use changes are considered as an additional demand for the different land-use types as compared with the present area in use for each land-use type. The total of the additional demand and the present area for each land-use function is allocated to individual grid-cells based on the suitability of the cell. This definition of local suitability may incorporate a large number of spatial datasets referring to the following aspects that are discussed below: *current land use*, *physical properties*, *operative policies* and *market forces* generally expressed in distance relations to nearby land-use functions.

Current land use, of course, offers the starting point in the simulation of future land use. It is thus an important ingredient in the specification of both the regional demand and the local suitability. Current land-use patterns are, however, not necessarily preserved in model simulations. This offers the advantage of having a large degree of freedom in generating future simulations according to scenario specifications, but calls for attention when current land-use patterns are likely to be preserved.
The *physical properties* of the land (e.g. soil type and groundwater level) are especially important for the suitability specification of agricultural land-use types as they directly influence possible yields. They are generally considered less important for urban functions, as the Netherlands have a long tradition of manipulating their natural conditions.
Operative policies, on the other hand, help steer Dutch land-use developments in many ways and are important components in the definition of suitability. The national nature development zones and the municipal urbanisation plans are examples of spatial policies that stimulate the allocation of certain types of land use. Restrictions are offered by various zoning laws related to, for example, water management and the preservation of landscape values.
The *market forces* that steer, for example, residential and commercial development are generally expressed in distance relations. Especially the proximity to railway stations, highway exits and airports are considered important factors that reflect the locational preferences of the actors that are active in urban development. Other factors that reflect such preferences are, for example, the number of urban facilities or the attractiveness of the surrounding landscape.

The selection of the appropriate factors for each of these components and their relative weighing is a crucial step in the definition of the suitability maps and determines, to a large extent, the simulation outcomes. The relative weights of the factors that describe the market forces and operative policies are normally assigned in such a way that they reflect the scenario storylines. These scenario-related suitability definitions can, of course, not be validated as they essentially reflect the imagination of the modeller. Instead, the current calibration effort is aimed at assessing the performance of the available allocation algorithms. Another objective is to help pinpoint the most important location factors in the suitability map definition. We furthermore want to evaluate the relative weighing of the suitability values for the different land-use types, as a recurring issue in their definition is how to scale the values of, for example, residential land use in relation to agriculture.

The following sections describe the new allocation algorithm and the simulation method applied in this application.

2.1 The discrete allocation model

The Land Use Scanner's new discrete allocation model allocates equal units of land (cells) to those land-use types that have the highest suitability, taking into account the regional land-use demand. The solution of this discrete allocation problem is considered optimal when the sum of all suitability values corresponding to the allocated land use is maximal.

This allocation is subject to the following constraints:

- the regional demand for the individual land-use types has to be met
- each cell has to be completely filled with a land-use type

These constraints are similar to the demand and supply balancing factors applied in the original logit-based version of the model (Dekkers and Koomen, 2007; Hilferink and Rietveld, 1999). In fact, all the extensions to the original model related to the fixed location of certain land use types, the use of regional claims, the incorporation of minimum/maximum claims and the monetary scaling of the suitability maps also apply for the discrete model. Similar to the original model, the applied optimisation algorithm aims to find shadow prices for the regional demand constraints that increase or decrease the suitability values, such that the allocation based on the adjusted suitability values corresponds to the regional claims. The main difference of the discrete model is that each cell only has one land-use type allocated, meaning that for each land-use type the share of occupation is zero or one. From a theoretical perspective the models are, however, equivalent when the β-parameter, that allows the tuning of the model, would be infinitely large. In the latter case the continuous model would also strictly follow the suitability definition in the allocation and produces homogenous cells. This procedure is however theoretical and cannot be applied in the calculations.

The problem at hand is comparable to the well-known Hitchcock transportation problem that is common in transport-cost minimisation and, more specifically, the semi-assignment problem (Schrijver, 2003; Volgenant, 1996). The objective of the former problem is to find the optimal distribution in terms of minimised distribution costs of units of different homogenous goods to a set of destinations under constraints of a limited supply of goods and a fixed demand. Both are special cases of linear programming problems. The discrete allocation algorithm has two additional characteristics that are not incorporated in the classical semi-assignment problem formulation: (1) we can specify several, non-overlapping regions for the claims; (2) it is possible to apply minimum and maximum claims.

Our problem, with its very large number of variables, calls for a specific, efficient algorithm. To improve the efficiency we apply a scaling procedure and, furthermore, use a threshold value. Scaling means that we use growing samples of cells in an iterative optimization process that has proven to be fast (Tokuyama and Nakano, 1995). For each sample an optimization is performed. After each optimization, the sample is enlarged and the shadow prices in the optimization process are updated in such way that the (downscaled) regional constraints remain respected. To limit the number of alternatives under consideration we use a threshold value: only allocation choices that are potentially optimal, are placed in the priority queues for each competing claim. An important advantage of the applied algorithm is that we are able to find an exact solution with a desktop PC (Pentium IV-2.8 GHz, 1 GB internal memory) within several minutes, provided that a feasible solution exists.

2.2 simulation method

Land-use simulation starts by creating a 2015 land-use map from a 2000 base map (Figure 2). In this step current, explicit land-use plans, mainly taken from the new map of the Netherlands survey (NIROV, 2005) are included in the simulation to represent autonomous developments. Based on this situation the simulations for 2040 are made for the different scenarios according to the specific assumptions and sector-related developments discussed in the following sections. The general scenario descriptions have been made spatially explicit with the help of several sector-specific models and a number of additional assumptions. These calculations have been performed by various specialised institutes: CPB and ABF have provided the expected amount of residential development (ABF, 2006; CPB et al., 2006b), CPB has delivered the demand for industrial and commercial land use and office space (CPB, 2002; CPB et al., 2006b) and LEI the projections for agricultural land-use changes (Helming, 2005). A concise description of the basic characteristics of the underlying regional models and a short discussion on the related quality issues is provided elsewhere (Dekkers and Koomen, 2006). The demands were subsequently inserted in the Land Use Scanner model together with a spatially explicit translation of the scenario-assumptions into suitability maps.

The presented land-use simulations integrate expert-knowledge from various research institutes and disciplines and thus represent the best-educated guess regarding the possible spatial patterns. It should be noted however that the simulations are based on many assumptions. They can by no means be seen as exact predictions and should therefore not be treated like that.

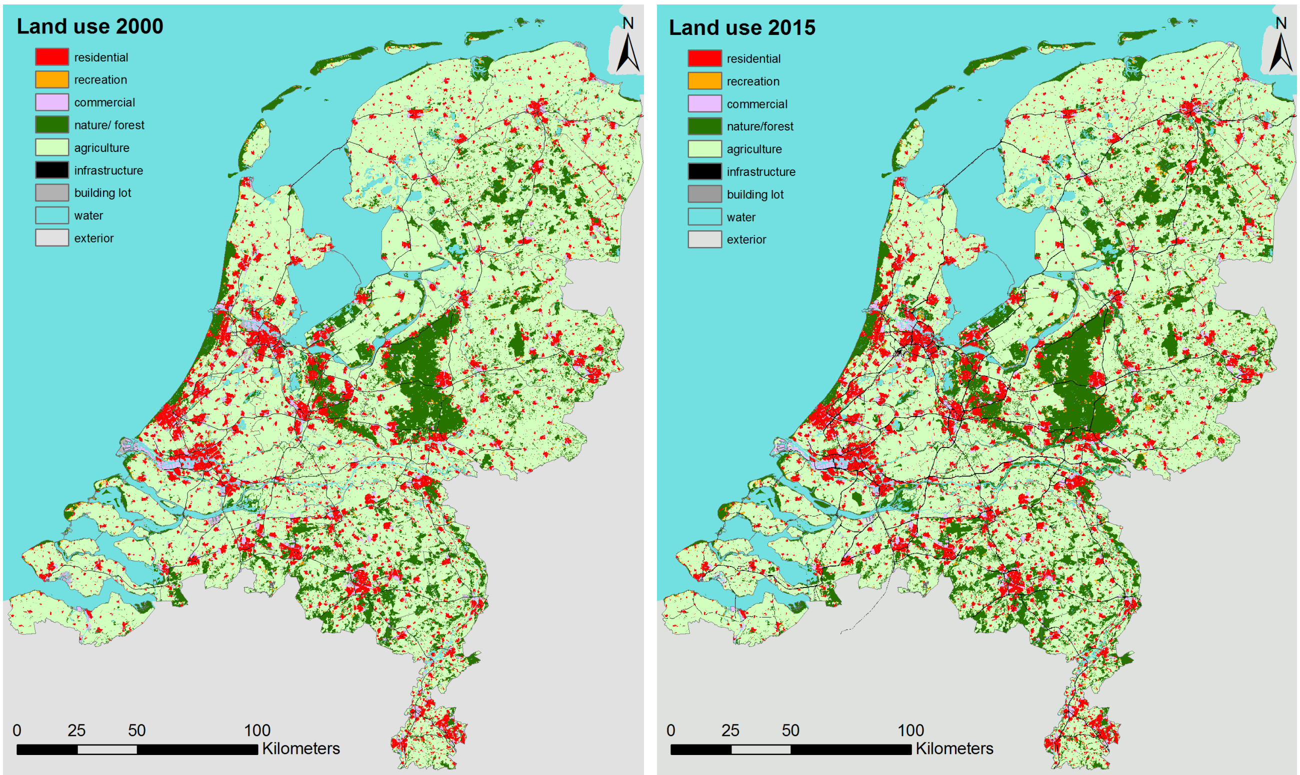

Figure 2. Land-use base maps of the Netherlands for 2000 and 2015 following autonomous developments.

3 Integrated scenarios of socio-economic and climate change

This section presents the socio-economic and climatic dimension of the proposed scenarios. These scenarios are used in the LANDS project and related projects in the 'Climate changes Spatial Planning' programme. We refer to these scenarios as the G and W scenarios, following the names of the original climate scenarios that are central to whole the research programme. To these scenarios we have added the socio-economic components of the scenario study 'Prosperity, well being and quality of the living environment' (CPB et al., 2006b) according to the relations we have established in the previous chapter. A further addition consists of the regional projections of anticipated land-use change and the related land-use simulations. An extensive report on the presented scenarios is provided by Riedijk et al. (2007).

3.1 The G scenarios
The G scenarios have the following general characteristics:
- Moderate population growth until 2010 and a slight decline thereafter;
- Modest economic growth;
- High unemployment rate;
- Trade blocks and taxes for protection of the environment;
- Emphasis on national environmental policy;
- Increased public environmental awareness;
- Extension of rail and motorway infrastructure.

This section first summarises the macro-economic changes and their regional impact (3.1.1) as well as the related sector specific developments (3.1.2). We then describe the more detailed land-use projections (3.1.3) and finally provide the climatic projections for the G and G+ scenarios (3.1.4).

3.1.1 Macro-economic changes and regional distribution
The expected macro-economic changes in the G scenarios can be grouped into four themes. The main characteristics of each theme are provided below and in Table 1:
- *Population forecast*: As compared to the 1971-2001 period, population growth is expected to slow down in the future, but considerable differences exist between the scenarios. In the G scenarios population increases until 2010. Afterwards it decreases due to strict immigration policy and low birth rates, leading to approximately the same population size in 2040 as in 2000. In spite of this more or less stable population, the number of households will increase slightly due to ageing and increased prosperity.
- *Employment*: Due to ageing, the potential labour force decreases severely. Labour supply decreases each year by nearly 0.5% due to a stagnating population growth and increasing ageing pressure. However, this is partly compensated by increased labour participation of women and elderly.
- *Economic growth:* Gross Domestic Product (GDP) per capita rises due to increasing labour productivity. Despite the fact that the working population shrinks, this scenario will have a modest increase in prosperity: GDP will grow 1 % per year until 2020, and 0.5% between 2020 and 2040.
- *Economic structure:* The physical environment is not only influenced by the magnitude of economic growth, but also by the performance of different economic sectors. The sector-specific prospects influence to a large extent the actual spatial developments and emission rates. In line with recent trends, the sectors agriculture, industry, energy and building will decrease marginally, whereas commercial services, health care and public services will grow slightly in this scenario.

Both scenarios indicate that the amount of land used for sectors such as residences, industry, nature and recreation increases at the expense of agriculture. Figure 3 depicts these national changes and especially shows that the increase in residential land is more moderate in the G scenarios. However, urban sprawl is expected to continue due to the continuing demand for rural residences and green, spacious urban housing. The extent of this sprawl is limited however, due to population growth coming to a halt in all regions. The regional development in employment is strongly related to the provision of consumer services. Employment in this type of services (banks, care institutions, retail etc.) increases mostly in the Intermediate Zone. A further decrease is expected in agriculture and industry, mostly in the Randstad. Unemployment rates are slightly higher in the Periphery, leading to a marginal migration towards the Intermediate Zone and Randstad in the long term. Furthermore, the willingness to commute will increase. Most commuter traffic takes place within the so-called COROP regions.

Indicator	**G scenarios**	**W scenarios**
Population, in millions	15.8	19.7
Households, in millions	7.0	10.1
Labour participation (as % of the professional population)	68%	74%
Ageing population (share 65+)	25%	23%
GDP per capita (2001=100)	133	221
Increase in energy usage per capita, compared to 2002	-5%	+30%
Increase in car use in kilometres, compared to 2002	+5%	+40%
Increase in goods traffic, ton per kilometre, compared to 2002	-5%	+120%
Increase waste total	+11%	+100%
Increased land demand for waste disposal in other countries	+4%	+55%
Housing demand, compared to 2002 (excl. demolition):		
• Single family dwellings, in millions	+0.3	+1.9
• Multiple family dwellings, in millions	+0.1	+1.2
Commercial area demand, compared to 2002, per type		
• Business parks	-3%	+43%
• Offices	+1%	+34%
• Informal locations	+7%	+46%
• Sea harbour	-9%	+30%
Rural area development:		
• Area agriculture, compared to 2002	-10%	-15%
• Area cultivation under glass, compared to 2002	-45%	+60%
• Dairy farming, compared to 2002	-15%	+25%
• Pigs, compared to 2002	-55%	-5%
Demand for nature and recreation, compared to 2002, x1000ha	+123	+115
• Demand nature, compared to 2002	+10	+49
• Demand recreational green, compared to 2002	+2	+20
• Demand sports fields		
Additional area for water retention, compared to 2002, x1000ha	+2	+5
• Near major rivers	+2	+3
• Near urban extensions		

Table 1. Overview of socio-economic, demographic and land-use change indicators for the G and W scenarios in 2040 (CPB et al., 2006b).

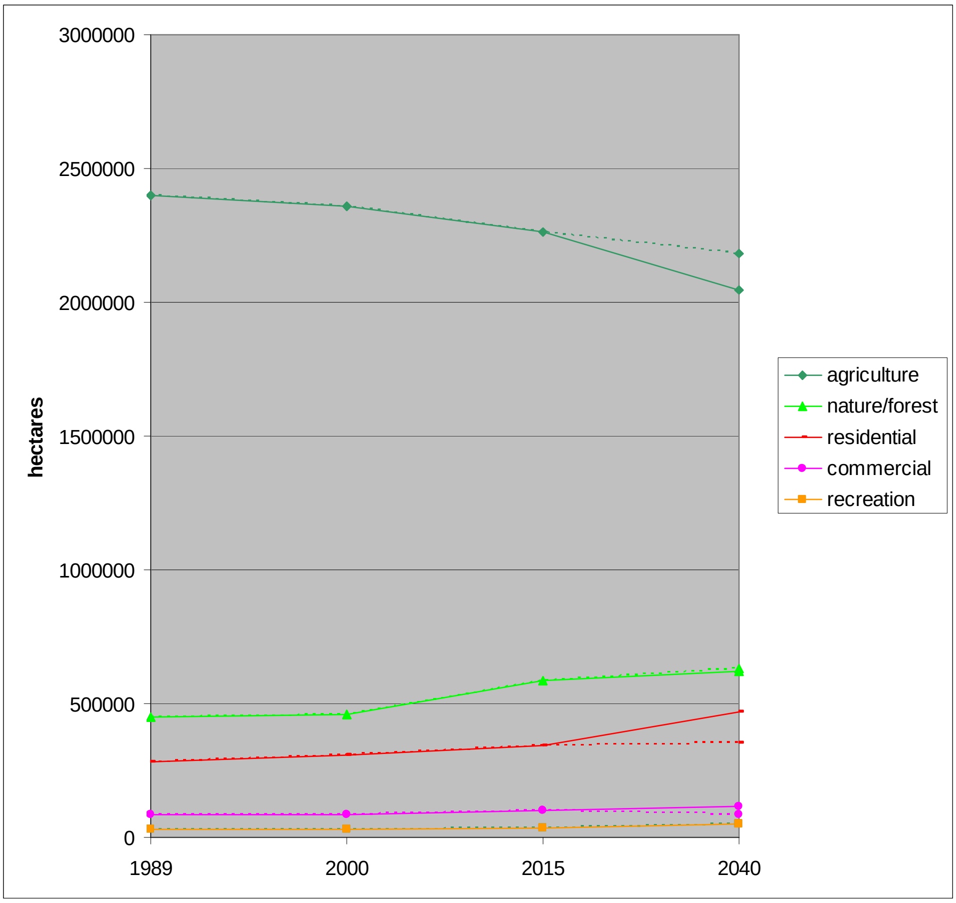

Figure 3. Land use in the Netherlands 1990-2040. The land use in 2040 is shown for both the G (dotted line) en W (solid line) scenarios.

3.1.2 Sector-specific developments

Based on the aforementioned assumptions related to macro-economic changes and their regional impact a number of developments are anticipated in specific socio-economic sectors (CPB et al., 2006b). These are listed below:

<u>Housing</u>

Housing demand, especially for owner-occupied housing and apartments, increases in line with household growth until 2020. This will result in a demand for residential land. From 2020 onwards population decrease may result in unoccupied houses in all regions, but probably most in the Periphery. Until 2020 annual housing production will be around 30,000 new houses (including 20,000 to 30,000 houses that will be replaced). After 2020 more houses are expected to be demolished than to be built.

<u>Industry, commerce and offices</u>

Until 2020 the demand for office space will increase by 10% compared to the total area in 2002. From 2020 onwards the total demand will be -14% leading to obsolete office buildings. This may results in a decrease in the price of land and an extensification in its use. Other consequences can be the deterioration of these areas or a change in their function for, plausibly leading to a mixing with other types of activities.

Mobility

The extensions of road and rail infrastructure as proposed in the National Traffic and Transport Strategy (V&W and VROM, 2006) will be realized by 2020. This construction of an extra 2900 kilometres of traffic lanes increases the length of the main road network with 23%. Because traffic problems will not be fully solved then, it is assumed that between 2020 and 2040 the main road network will expand by a more moderate 14%, or about 2000 kilometres of new traffic lanes. Parking prices and tariffs for public transportation do not change. Depending on the density of the built-up areas, people will use public transportation more frequently. The amount of private cars will increase from the current 7 million to about 8 million in 2040. Passenger traffic by train will not increase during off-peak hours, but more commuter traffic is expected during peak hours. Total freight transport stays at the current level, but the share of road transport increases. In all, the pressure on the road network will increase by 20% due to developments in passenger traffic, freight transport and infrastructure expansions. Congestion hours however will decrease by 70% and the emission of carbon dioxide will decrease by 5%.

Agriculture

Agriculture will face a continuing demand for space from residential and commercial functions, infrastructure, recreation, water and nature development. Competition will be high since the market values for these sectors are much higher than for agriculture. Also, European environmental policy is assumed to play a role in limiting the growth potential of agriculture. Still, agriculture is expected to cover about 93% of its current surface area in 2040. Arable farming will concentrate in the Peripheral areas. In the Randstad and Intermediate Zone, the agricultural area decreases due to the demand for land of other functions. The greenhouse horticulture area will decrease by 50% due to strong environmental policies and inflexible labour relations. Employment in the agricultural sector will decrease by 50 to 65% in 2040. The characteristic values of the agricultural landscape related to, for example, biodiversity, cultural history will partially be preserved or even restored through (European) subsidies.

Energy

This scenario does not foresee a global climate policy but the Netherlands will have agreements with neighbouring countries, resulting in a carbon dioxide price of €20 per barrel from 2030. Current subsidies for renewable energy will continue. Demand for energy will decrease slightly leading to a decrease of carbon dioxide emission. The share of renewable energy in 2040 will be at least 10%. Dutch gas fields will decrease their production, making the country more dependent on imported energy.

Environment

The limited economic growth in this scenario will lead to a modest increase in the amount of waste. Accumulation of phosphor in soil decreases when international environmental policy remains effective. The leaching of nitrogen to groundwater will diminish because of national regulations. In general, emissions will further decrease because of the continuation of existing national and international policies.

Nature, biodiversity and outdoor recreation

Nature areas, biodiversity and outdoor recreation areas remain under pressure because of the continuing demand for land from other functions. At the same time, the demand for nature and recreation areas increases with the growing population and prosperity.

The biodiversity in surface waters will improve as a result of strict environmental policies, but the biodiversity in agricultural areas is expected to decrease slightly. In this scenario, 25,000 hectares are reserved for nature development in National Landscapes such as the Achterhoek and Limburg. Furthermore, the standard in town and country planning of 75m^2 of outdoor recreation area for each house is expected to be realised. This standard already exists, but is currently not met. On top of that, the Government will develop about 20,000 hectares of recreational area outside the cities to solve the current shortage. In addition, the demand for sports fields and golf courses will increase.

3.1.3 Land-use simulations

The resulting simulation (Figure 4 at left) shows a modest increase in residential areas, despite the fairly limited population growth. This growth can be largely ascribed to the minor increase in households and residential preferences for a rural living environment. Urban growth is most notable in the central and western part of the Netherlands. Arable farming diminishes strongly in this scenario. Greenhouse horticulture disappears in many areas; especially from its current stronghold south of The Hague. From the map it can be concluded that existing nature areas are enlarged in a number of cases. New nature areas are developed along the rivers Waal, Rhine, Meuse and IJssel. Clusters of outdoor recreation arise in attractive landscapes, in particular in the northern and western part of the Netherlands.

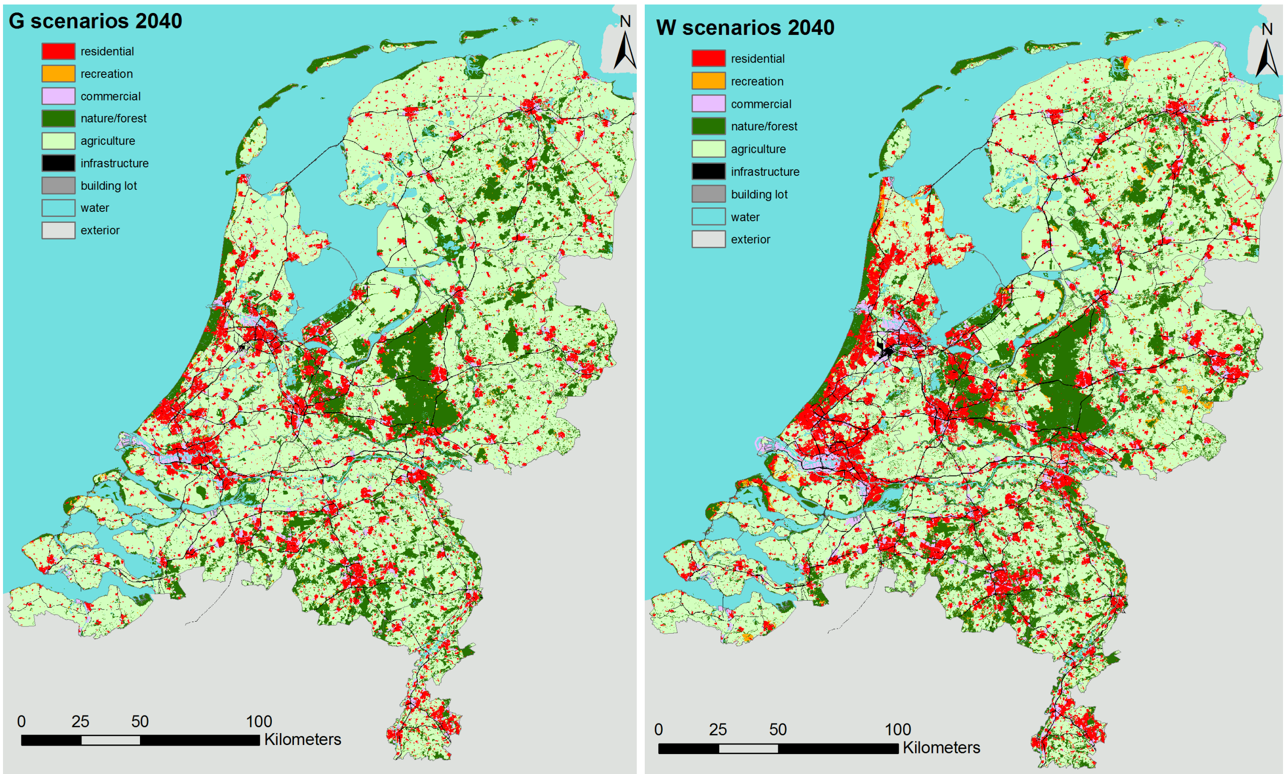

Figure 4. Simulated land use for the G and W scenarios.

3.1.4 The climate dimension

The G scenarios are characterised by a 1 degree Celsius temperature rise between 1990 and 2050. Due to a change in atmospheric circulation the winters (December, January and February) will be mild and wet because of increased westerly winds in the G+ scenario. Summers (June, July and August) will be warmer and dryer because of increased easterly winds in this scenario.

WINTER	**G**	**G+**	**W**	**W+**
Mean temperature	+0.9ºC	+1.1ºC	+1.8ºC	+2.3ºC
Yearly coldest day (K)	+1.0ºC	+1.5ºC	+2.1ºC	+2.9ºC
Mean precipitation (%)	+4%	7%	+7%	+1.4%
Wet day frequency (%)	0%	1%	0%	2%
10 year return level daily precipitation sum (%)	4%	6%	8%	12%
Yearly maximum daily mean wind speed (%)	0%	2%	-1%	4%
SUMMER				
Mean temperature	+0.9ºC	+1.4ºC	+1.7ºC	+2.8ºC
Yearly coldest day (K)	+1.0ºC	+1.9ºC	+2.1ºC	+3.8ºC
Mean precipitation (%)	3%	-10%	6%	-19%
Wet day frequency (%)	-2%	-10%	-3%	-19%
10 year return level daily precipitation sum (%)	13%	5%	27%	10%
Potential evaporation (%)	3%	8%	7%	15%
Absolute sea level rise	15-25 cm	15-25 cm	20-35 cm	20-35 cm

Table 2. KNMI '06 Dutch climate change scenarios for 2050 relative to 1990 (Van den Hurk et al., 2006).

3.2 The W scenarios

The W scenarios have the following general characteristics:

- High population growth;
- High economic growth;
- Expansion of the EU to the east;
- Global free trade without political integration;
- No initiatives on international environmental agreements;
- Extension of rail and motorway infrastructure

This section first summarises the macro-economic changes and their regional distribution (3.2.1) as well as the related sector specific developments (3.2.2). We then describe the local land-use projections (3.2.3) and finally provide the climatic projections for the W and W+ scenarios (3.2.4).

3.2.1 Macro-economic changes and regional distribution

The anticipated macro-economic developments for the W scenarios are provided below and in Table 1:

- *Population forecast*: In this scenario, population increases to 20 million people in 2040. This is caused by a high birth rate and an open immigration policy that brings many new people to the country. The total number of households increases even more as a result of further individualisation and ageing.

- *Employment:* The working population decreases due to ageing but this will be counterbalanced by increased labour participation women and elderly (50+) people.
- *Economic growth*: Gross Domestic Product (GDP) per capita will more than double as compared to 2001.
- *Economic structure:* A further shift towards a service economy is the main underlying trend in this scenario. Nevertheless, all economic sectors show an increase in the volume of production in this particular scenario. Also agricultural production increases significantly. The total employment in this sector, however, decreases. The same development is seen in the industrial sector. The demand for health care increases significantly, as well as employment in this sector.

Well-educated immigrants are expected to come to work in the Netherlands in this scenario. They will spread across the country but will, relatively, reside more in the Intermediate Zone where employment is growing strongly. Urban sprawl is anticipated to continue due to the need for rural living. This domestic migration process will first focus on the Intermediate Zone but later also spread to the Periphery. Regional employment development is influenced by an increase in consumer services like banks, care institutions and retail. Employment in this sector increases most in the Intermediate Zone. Employment decreases strongly in agriculture and industry, mostly in the Randstad. Just as in the G scenarios, unemployment rates are slightly higher in the Periphery, leading to a marginal, overall migration towards the Intermediate Zone and Randstad in the long term. Furthermore, the willingness to commute will increase, with most commuter traffic taking place within COROP regions. A detailed account of the projected regional land-use changes is provided in Appendix 2.

3.2.2 Sector-specific developments

The developments anticipated in specific socio-economic sectors as a result of aforementioned macro-economic changes and their regional impact are listed below (CPB et al., 2006a). These developments show some overlap compared to the G scenario developments, but they are reiterated in this paragraph to make the two scenario storylines independently readable.

<u>Housing</u>

Housing demand increases in line with the enormous household growth. Until 2020 the annual housing production will be around 120,000 new houses (including 30,000 houses that will be replaced). After 2020 the annual production will be 105,000 houses. Due to income increase, owner occupied private properties will become more popular than rental houses. The average size of these houses will also increase with increased prosperity, thus causing a large demand for residential land. This land demand will be highest in the Randstad. The relative increase in residential land will be largest in the Intermediate Zone, possibly causing conflicts with nature and landscape development without proper government intervention. In the Periphery the demand for housing will be marginal.

<u>Industry, commerce and offices</u>

Until 2020 the demand for extra land for office parks will be 36% compared to 2002. From 2020 till 2040 this demand will be 7%. The demand for industrial development will be highest in the Randstad and in the province of Noord-Brabant. The relative centre point or all commercial activity will move from the Randstad to the Intermediate Zone from 2020 onwards.

Mobility

The current planned extensions (an extra 3000 kilometres of traffic lanes) of the road network will be executed before 2020. From 2020 to 2040 the road network will be expanded with another 2000 kilometres of traffic lanes. Parking prices and tariffs for public transportation do not change. More people will use public transport. The amount of private cars will increase vastly from the current 7 million to 12 million in 2040. Passenger traffic by train will not increase during off-peak hours but an increase is expected in peak hours due to more commuter traffic. In the Randstad train traffic increases twice as much as in the Intermediate zone and Periphery. Freight transport by rail grows due to more international trade and replacement of production activities. The share of freight transport that is distributed by road doubles compared to 2002 at the cost of transport via waterways and pipelines. In all, the pressure on the road network will increase with 80% due to developments in passenger traffic, freight transport and infrastructure expansions. Congestion will increase and concentrates around the major cities of the Randstad. Emission of carbon dioxide will increase with 70% in relation to 2000.

Agriculture

Agriculture will face a continuing demand for land from housing, industry, infrastructure, recreation, water and nature. Competition will be high since the market value for these sectors is much higher than for agriculture. Also, European environmental policy plays a role in the limited growth in agriculture. Still, agriculture is expected to cover a substantial part of the Netherlands in 2040. The economic potential for greenhouse horticulture is promising. Dairy farming will grow only if milk quota regulations will be abolished. Arable farming as well as intensive livestock farming will be subject to high pressures on prices due to liberalization. Employment in the agricultural sector will decrease with 50-65% due to increased labour productivity. Arable farming will concentrate in the Periphery. In the Randstad and Intermediate Zone, the area under agriculture decreases due to the need for other land-use functions. The greenhouse horticulture area will increase in the province of Zuid-Holland to 4.5% of its surface area. Subsidies for the preservation of the characteristic values of the agricultural landscape related to, for example, biodiversity, cultural history are considered unlikely in this scenario.

Energy

This scenario does not anticipate global climate policy and expects the emission trade to be ceased by 2020. Current subsidies for renewable energy will cease by 2020 as well. Demand for energy will increase with 50% leading to an increase of carbon dioxide emission. In this scenario, natural gas will be the main supplier of energy. There will be room for new technologies only if costs are acceptable. Natural gas however will be nearly depleted by 2040 forcing the increase of imported energy. Small spatial reservations have to be made for safety zones around transport lines and storage facilities of imported natural gas. Wind parks also demand limited amounts of land since they cause visual and noise pollution.

Environment

The prospering economy in this scenario will lead to a doubling of the amount of waste, causing a strong increase of the waste volume that will be reused (+70%) and incinerated (+200%). This calls for investments in additional incineration capacity that will have adverse consequences for the living environment. An additional possibility would be to export waste, but this requires an ‘open market’ whose existence is not certain. This scenario foresees an increased accumulation of phosphor in the soil. The leaching of nitrogen to groundwater will diminish because of Dutch nitrogen regulations. Air quality will improve due to cleaner production methods and technological innovations.

Nature, biodiversity and outdoor recreation

A permanent pressure remains on nature, biodiversity and recreation, because of the continuing demand for land for various, mainly urban uses. At the same time, the demand for nature and recreation areas increases with the strongly growing population and prosperity. Biodiversity in surface waters like lakes and streams will improve due to better environmental conditions, but biodiversity in agricultural areas will decrease. No additional areas for nature development are expected besides the current plans for an ecological main structure (EHS). Due to diminishing governmental interference it is possible that some of the planned nature areas will be located on other than planned places. The current policy strives to realise 75m^2 green space for each newly built house. On top of that, the Government will develop about 20,000 hectares of recreational area outside the cities. Also, the demand for private recreation, such as sports fields and golf courses, will increase; the current trend of 15-20 m^2 per citizen will increase to 26 m^2 per citizen in this scenario.

3.2.3 Land-use simulations

The most striking land-use change in the W scenarios is the strong increase in urban land use (Figure 4 at right). Residential land use expands substantially around the larger cities in the Randstad, as well as around many smaller villages in the rural areas. Commercial land use also increases strongly. This increase takes place in the Randstad and bordering parts of the Intermediate Zone. The urbanisation causes a serious deterioration of the quality and openness of the landscape, also in the designated national landscapes.

The appearance of the rural areas will also change. Arable farming will, to a large extent, disappear and be replaced by grassland for dairy farming. Capital-intensive forms of farming will also demand more land. Greenhouse horticulture expands around the main ports of Rotterdam and Schiphol. New nature will mainly be developed along the major rivers, where strong constraints are imposed on the expansion of urban functions and capital-intensive forms of farming. Recreation also claims more space, especially in the attractive small-scale landscapes of, for example, the Achterhoek. A limited description of the land-use simulations for the W scenarios has also been published in the 6th National Environmental Outlook (MNP, 2006).

3.2.4 The climate dimension

The W scenarios are characterised by a 2 degrees Celsius temperature rise between 1990 and 2050. Due to a change in atmospheric circulation the winters will be mild and wet because of increased westerly winds in the W+ scenario. Summers will be warmer and dryer because of increased easterly winds in this scenario. More details are provided in Table 2.

4 Discussion

The current paper describes a combination of existing scenarios of climate and socio-economic change as a starting point for further research into the adaptation and mitigation measures that may be needed to face the future in the Netherlands. The selected scenarios are fed into the Land Use Scanner model that simulates future land-use patterns. The G scenarios with a moderate temperature rise are combined with a socio-economic scenario that combines an orientation on national sovereignty with clear public responsibilities. The related land-use simulation for 2040 depicts a limited amount of urban growth, predominantly in the central and western part of the country. The W scenarios with a higher temperature rise are combined with socio-economic conditions that favour international cooperation and private responsibilities. These simulations show a much stronger urban growth, especially of rural types of residences in attractive landscapes.

The study presented in this paper is carried out within the larger ‘Climate changes Spatial Planning’ research programme. As such the results are closely related to a number of projects within this programme. These are foremost two Climate Scenarios projects and the ‘Socio-economic scenarios for climate change assessments’ Integration project. The former projects have provided the climate scenarios described in this paper and continue to elaborate on specific climatologic variables. The latter project discusses possible combinations of socio-economic and climate scenarios in a similar fashion as the current papert. The project aims to provide researchers with a set of components to analyse possible adaptation and mitigation measures. The reader is referred to their upcoming publications for further information.

For the LANDS project, that initiated this study, the presented results are a first step towards the creation of an integrated outlook on a climate-proof future for the Netherlands. To achieve this ambitious objective the project relies on the integration of the results from many other projects in the ‘Climate changes Spatial Planning’ research programme that analyse and propose possible adaptation and mitigation measures for different societal sectors. The relation of the LANDS project and its current scenario study with these other projects is depicted in Figure 5. The figure shows that the integrated climate and socio-economic scenarios, described in this paper, are not only intended to feed into the Land Use Scanner model for the simulation of future land-use patterns. The scenarios also provide the starting point for the different sector-specific studies. The possible impact on water management and nature is studied as part of the LANDS project, as well as in several other climate-related projects focussing on flood risk, adaptation measures in the Rhine basin, the spatial distribution of vegetation, optimizing the nature conservation potential. Other projects dealing with possible climate-adaptation measures for, amongst others, agriculture (carried out by LEI), transport, specific local or regional circumstances and fen meadows can also use the scenario assumptions and simulated land-use patterns as a reference point for their analyses. Subsequently, the results of these projects will be fed into the Land Use Scanner to simulate adjusted land-use patterns that take the possible impact of climate change into account.

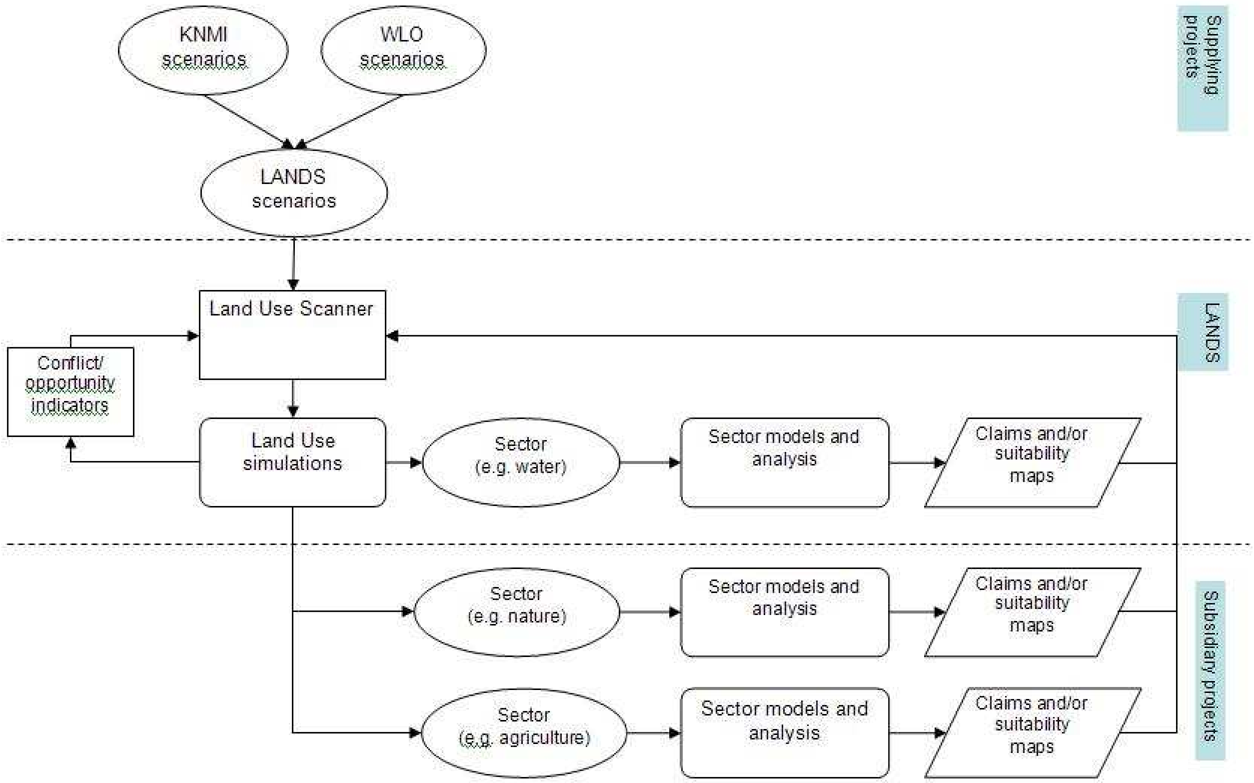

Figure 5. LANDS project scheme.

In order to integrate the outcomes of the different, sector-oriented projects into coherent maps of future land use, as is one of the ultimate goals of the 'Climate changes Spatial Planning' research programme, it is essential that they all start from the same assumptions regarding the possible future developments. To be able to actually use the output of the individual projects it is needed that they provide quantitative information related to the regional land-use demand (claim) and location preferences (suitability) for their specific sector. This information can then be included in the Land Use Scanner model to simulate new land-use projections.

The preliminary attempts to integrate results from the flood risk and agriculture project indicate the importance of actually starting from the same assumptions. The diverging character of their respective research results makes clear that substantial post-processing and intensive cooperation are essential to successfully integrate the various results.

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