Scenario-based projections of future land use in the Netherlands; a spatially-explicit knowledge base for the Knowledge for Climate programme

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TITLE

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Samenvatting

De ontwikkeling van effectieve regionale klimaatadaptatieperspectieven vereist niet alleen informatie over klimaatverandering maar vraagt ook om het rekening houden met veranderingen in economisch en sociaal opzicht. Landgebruikmodellen zijn geschikte tools om bestaande nationale sociaaleconomische scenario's door te vertalen naar veranderingen in lokaal landgebruik en voorzien zodoende in de benodigde relevante context voor de ontwikkeling en evaluatie van klimaatmitigatie en –adaptatiemaatregelen. Dit rapport beschrijft een basisset van scenariogebaseerde simulaties van toekomstig landgebruik in Nederland die de nodige context bieden voor de ontwikkeling van sectorspecifieke of regiospecifieke adaptatiestrategieën.

De landgebruiksimulaties die worden beschreven in dit rapport zijn ontwikkeld als onderdeel van het project ´Tools for Adaptation Strategies´ dat als doel heeft de verbetering van tools voor het ontwerp en de evaluatie van adaptatiestrategieën waarbij in het bijzonder de aandacht is gericht op ruimtelijk beleid en disciplineoverstijgende problematiek. Dit project is onderdeel van het kennisprogramma 'Kennis voor Klimaat'. De methoden en resultaten die worden beschreven in dit project komen voort uit een intensieve samenwerking met het Planbureau voor de Leefomgeving (PBL) en bouwen voort op vergelijkbaar werk dat is uitgevoerd in het kader van het 'Klimaat voor Ruimte' kennisprogramma. Sindsdien zijn belangrijke veranderingen in de modelopzet en in de ruimtelijke uitwerking van de sociaaleconomische scenario's geïmplementeerd. Deze aanpassingen worden besproken in dit rapport.

In Hoofdstuk 1 worden de twee sociaaleconomische scenario sets beschreven die de basis vormen voor onze landgebruiksimulaties. Daarnaast wordt een link voorgesteld met de beschikbare Nederlandse klimaatscenario's. Hoofdstuk 2 gaat dieper in op de totstandkoming van de ruimtevraag voor de verschillende sectoren en Hoofdstuk 3 bespreekt recente modelaanpassingen die in de huidige simulaties verwerkt zijn. Vervolgens behandelt Hoofdstuk 4 de resultaten van de nieuwe modelsimulaties voor de twee scenario's. Hoofdstuk 5 ten slotte bevat een discussie van het verrichte werk en blikt vooruit op het (modelleer)werk dat nog gedaan zal worden.

Summary

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 socio-economic 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. This report describes a basic set of scenario-based projections of future land use in the Netherlands that set the scene for the development of sector or region specific adaptation strategies.

The land-use simulations described in this report were developed as part of the 'Tools for Adaptation Strategies' project that aims at improving tools for design and evaluation of adaptation strategies with a special focus on spatial planning and cross cutting issues. This project is part of the Knowledge for Climate research programme. The methods and results described in this project are the result on intensive cooperation with PBL Netherlands Environmental Assessment Agency and build on similar work that was done as part of the Climate changes Spatial planning research programme. Since then important changes have been implemented in the model setup and the spatial simulations of the socio-economic scenarios. These changes are discussed in this report.

In Chapter 1 the two socio-economic scenarios are described that form the basis for our land-use simulations. In addition, a link to the currently available Dutch climate scenarios is proposed. Chapter 2 explores the derivation of the demand for land of the various sectors, while Chapter 3 discusses the recent model improvements that are incorporated in the presented simulations. Next, Chapter 4 contains the results for the new model simulations of the two scenarios. Finally, Chapter 5 discusses the work and describes the (modelling) work that will be done in the future.

Contents

1. Introduction

1.1 The need for scenario studies to help decision-making under uncertainty

Land-use planning is concerned with the future. By using scenarios, describing a bandwidth of possible future spatial developments, we can increase our strategic insight in what may happen in the future (De Waard, 2005) and policymakers can use the scenario outcomes to formulate appropriate responses (Dammers, 2000). Scenarios can be used to assess the effects of certain changes on the adaptive capacity of the system. One of the goals of Theme 8 is to develop tools for formulation of the adaptation task, based on climate scenarios and economic development. The Land Use Scanner tool is used to describe the socio-economic context for the Knowledge for Climate programme and to define possible climate adaptation strategies while taking into account possible socio-economic changes.

1.2 Two socio-economic scenarios: Global Economy and Regional Communities

We have chosen to base our scenarios on the 'Welfare, prosperity and quality of the living environment '(WLO) scenario study (CPB et al., 2006) that was carried out by the Central Planning Agency (CPB), the Netherlands Environmental Assessment Agency (MNP, now PBL) and the Spatial Planning Agency (RPB, now also PBL). In that study, four scenarios are introduced that describe different possible futures: *Strong Europe (SE), Global Economy (GE), Transatlantic Market (TM) and Regional Communities (RC)*. These images of the future are based on the well-known SRES-scenario's (respectively A1, A2, B1, B2) of the International Panel on Climate Change (IPCC, 2000) and differ in their emphasis on basic societal trends such as globalization versus regionalisation and economic development versus environmental protection.

To limit the amount of results, while maintaining the full bandwidth of uncertainty we have selected the two most diverging scenarios from the aforementioned study: Global Economy (GE) and Regional Communities (RC). Table 1.1 gives an overview of the most important trends for these scenarios until 2040. The Global Economy scenario shows a substantial population growth (up to 20 million inhabitants in 2040), a high economic growth and an expansion of the EU towards the east. A free trade agreement is operational without political integration and no initiatives for international co-operation are being taken with regard to environmental issues. In the Regional Communities scenario the population remains more or less stable (16 million in 2040), with a modest economic growth and a higher unemployment rate. Since the population in the Randstad area is still growing, this means a population decrease in certain peripheral areas. In terms of land use this effect hardly shows since the household size continues to decrease and it is not likely that houses will be demolished on a large scale. Next to that, trade barriers are implemented and taxes are levied in order to protect the environment; environmental policy receives a lot of attention and public awareness of the environment grows. These two scenarios thus describe very different future outlooks for the Netherlands with regard to demographics, economy, land use and spatial planning.

	1971-2001	Reg. Comm. 2002-2040	Glob. Econ. 2002-2040
Population (million persons)	16,1	15,8	19,7
Population growth (% per year)	0,7	0,0	0,5
Employment (% per year)	0,9	-0,5	0,4
Unemployment (avg. level in % of the labour force)	5,5	7,3	4,1
Labour productivity (% per year)	1,9	1,2	2,1
Volume GDP (market prices; % per year)	2,6	0,7	2,6
GDP per head (% per year)	1,9	0,7	2,1
GDP per head 2040 (2001=100)	(1971 = 57)	133	221

Table 1.1 Socio-economic characteristics of the selected scenarios.

1.3 Simulating land-use change with Land Use Scanner

Koomen and Borsboom-van Beurden (2011) describe the Land Use Scanner as a GIS-based model that simulates future land use through the integration of sector-specific inputs from other, dedicated models. The model is based on a demand-supply interaction for land, with sectors competing within suitability and policy constraints. It uses a comparatively static approach that simulates a future state in a limited number of time steps (in this project only one step). Unlike many other land-use models, the objective of the Land Use Scanner is not to forecast the amount of land-use change, but rather to integrate and allocate future demand for land provided by different, external sources, such as specialised sector-specific models or policy intentions. This is shown in Figure 1.1, which presents the basic structure of the Land Use Scanner model. The figure clearly shows that the sectoral *demand* for future land, in combination with the specification of local *suitability* for each sector, is the most important input for the allocation module.

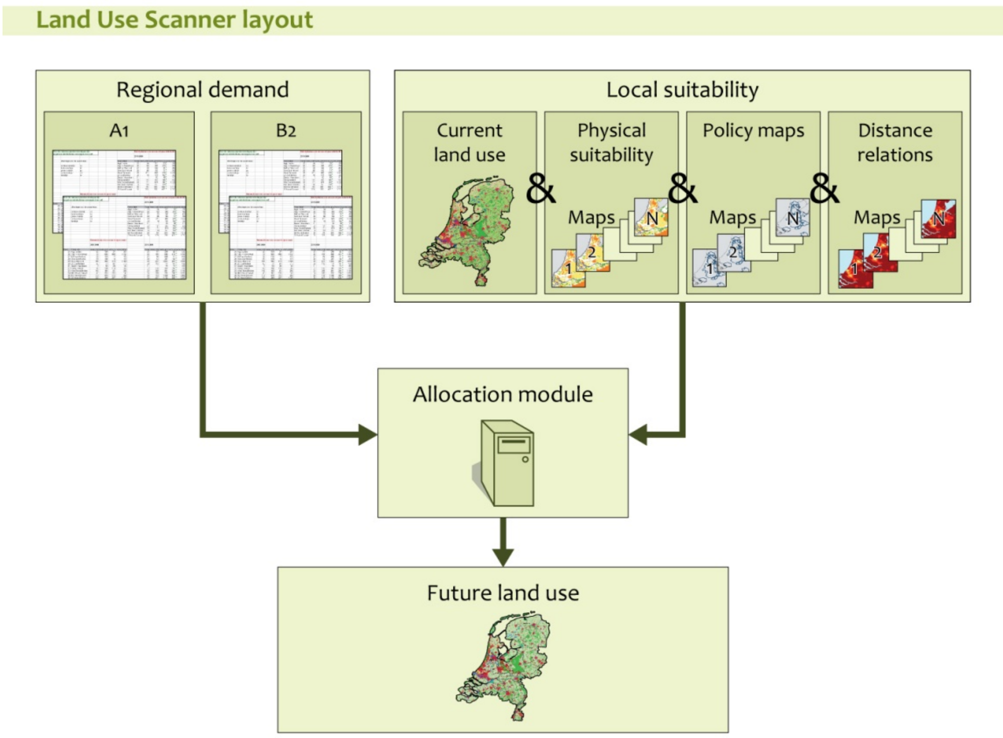


Figure 1.1 Basic layout of the Land Use Scanner model (Source: Loonen and Koomen, 2009).

The scenario assumptions have been translated into a regional demand for space for different land-use types using various sector-specific models. In doing so, the most recent available information has been used. For instance, the demand for urban area has been based on new calculations carried out by PBL in the period from 2010 to 2012 using its own new set of models (Zondag and Geurs, 2011). Chapter 2 discusses in more detail the origin of the regional demand for space for the various sectors.

During simulation, for each sector the demand for space is combined with local suitability and possible foreseen changes in land-use types that are not simulated such as water and infrastructure. These foreseen changes are based on determined spatial plans that are supplied exogenously. For the definition of local suitability, the assumptions used in the 'Welfare, prosperity and quality of the living environment' study have been used. Important elements are the 'hard' plans for among others housing and commercial land use, as depicted in the New Map of the Netherlands (NIROV, 2009). Further, spatial planning restrictions such as the Natura2000-plans, National Ecological Network (NEN), National landscapes, Bird- and Habitat Directives, Groundwater protection areas and areas related to the Space for the River programme ('Ruimte voor de Rivier') have been taken into account. Next to that, well-known location factors are taken from literature (Snellen et al., 2006) that, for instance, demonstrate the importance of the proximity of infrastructure and existing urban areas.

It is important to mention the link between our scenarios and the scenarios applied in the recent PBL studies 'Ruimtelijke Verkenningen' (Hilbers et al., 2011) and 'Ruimtelijke opgaven in beeld' (Kuijper et al., 2011). All these studies depart from the same two scenarios, yet in the two recent PBL studies, two additional variants are distinguished, i.e. a 'trend-variant' and a 'less restrictive' or 'liberal' variant. The result is a matrix of four different scenarios (two variants for two scenarios). Like the original scenarios, the trend-variants presume a continuation of current spatial and environmental policy. The less restrictive variants, on the other hand, presume less restrictive policies. It assumes urbanisation to be steered less by spatial policy restrictions and directions, implicating urban development to be directed more by autonomous market forces, rooted, for instance, in household preferences. Spatial directives are presumed to be maintained only when enforced in European agreements and/or aimed at preserving human safety. For our simulations, the liberal variant of Global Economy and the trend variant of Regional Communities have been chosen because they are most in line with the story lines of the original scenarios.

Another strong link that exists is the connection between our scenarios and the scenarios that PBL uses in the 'Delta'-programme. The strong commitment towards strengthening this connection, with all its advantages, both from a content- and modelling-perspective as well as from efficiency and economies of scale perspective, has led us to invest more time than anticipated in delivering this report. The greatest advantage of our strong cooperation with PBL is that our modelling efforts are also applied in the Delta-programme.

1.4 Linking land-use simulations with climate scenarios

In 2006, the Dutch Royal Meteorological Institute (KNMI) has developed four climate scenarios for 2050 that are ordered along two axes: (vertical) changed or unchanged air circulation patterns, and (horizontal) moderate or strong increase in average yearly temperature, see Figure 1.2.

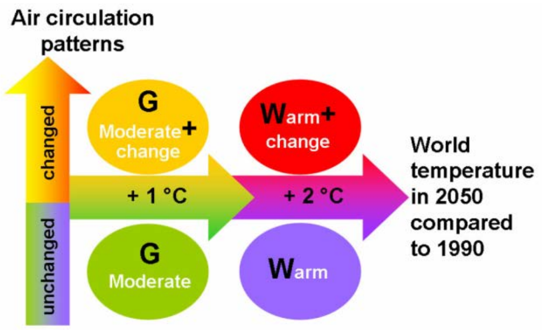


Figure 1.2 Overview of the four KNMI'06 climate scenarios (Van den Hurk et al., 2006).

The two socio-economic scenarios that we have selected do not have a direct link with the climate scenarios from KNMI, but in previous studies (e.g., Riedijk et al., 2007; Koomen et al., 2008a) it was proposed to link the moderate change in temperature scenarios (G and G+) to Regional Communities and the warm change in temperature scenarios (W and W+) to Global Economy. These links are based on the relation that can be established between the socio-economic factors that underlie the climate change scenarios: the higher temperatures are more closely linked to IPCC's A1 scenario family that are also the foundation for the Global Economy scenario, whereas the more moderate temperature increase can be associated with the B2 scenario family that underlies the Regional Community scenario. To researchers who want to combine socio-economic and climate scenarios we propose to apply this link. In the land-use simulations presented in this report climate change does not play an important role. Only for the future abiotic conditions that influence the suitability for dry and wet types of nature we distinguish between different climate scenarios. To reflect the fact that we are essentially representing socio-economic scenarios we will maintain the names of the 'Welfare, prosperity and quality of the living environment' scenario's.

2. Demand for land

2.1 From national to regional demand

The scenario assumptions and associated figures (see Table 1.1) all apply to the Netherlands as a whole. For our purposes future land-use patterns need to be simulated at the local level (in hectares). This means that the national figures have to be somehow translated to the local level. For this to work out, additional factors have to be included and further assumptions have to be made. For surely not every city within the Netherlands is expected to share equally in, for instance, the population increase projected for the Netherlands as a whole? Indeed the evidence points to the fact that there are many local factors at work that help shape the regional and local outcome of the assumptions and figures captured in national scenarios. Moreover, in this process sectoral dynamics (e.g., urban expansion) are often far from autonomous. Instead, sectoral dynamics like, for instance, the (re)location of firms proves to be narrowly associated with population dynamics.

In order to capture these complexities and simulate their combined effects on local land use, a number of computer models are used. These models are owned and developed by (consortia of) different specialised institutes. In terms of scope and complexity, these models range from sectoral (e.g., Agriculture) to multi-sectoral (e.g., integrated modelling of Residential area and Commerce/Industry). Step by step, these various models are becoming more integrated – at least as far as observed interdependencies of sectors and spatial levels warrant them to be. In any case, all associated models at least operate within the framework described by the consistent sets of assumptions and figures of the scenarios at hand. Figure 2.1 provides an overview of the model framework in which these assumptions and figures come together. As can be seen, the regional demand for land for each scenario that is used as input in the Land Use Scanner is based on information coming from more or less integrated, sector-specific models.

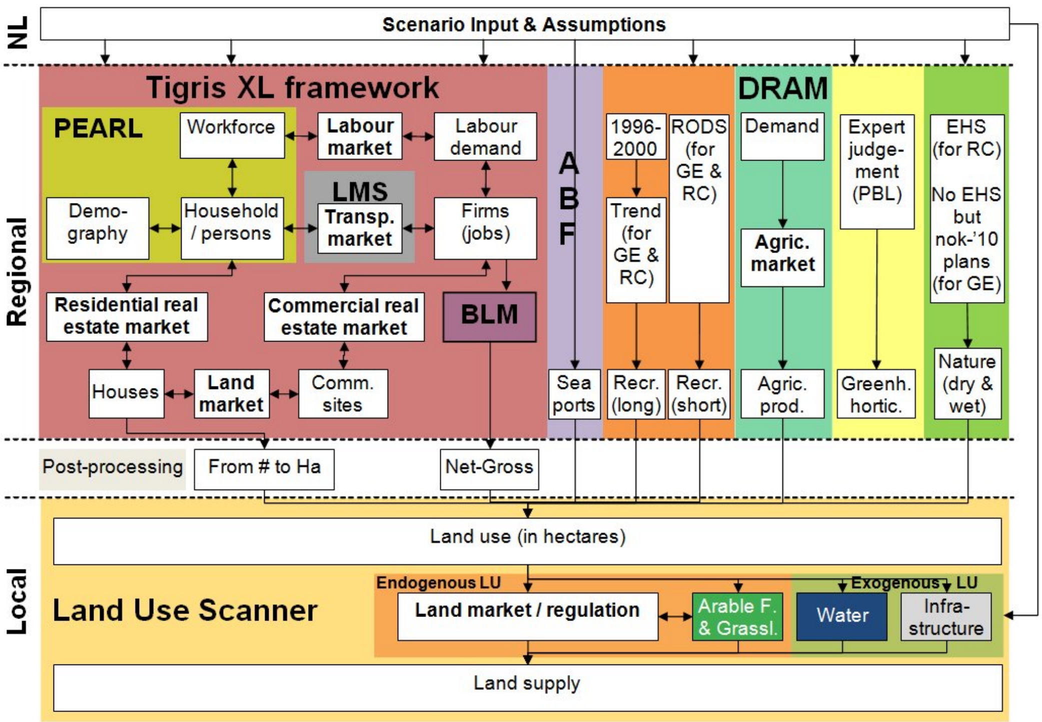


Figure 2.1 Overview of the relations between (sector-specific) models in the framework.

In the remainder of this chapter, Section 2.2 starts with a brief overview of how the demand for land for the two selected scenarios has been calculated and which sector-specific models were used in the process. The section then continues with more detailed explanations per sector of the calculations and, if applicable, translation steps. The section ends with an overview of the demand for land used for the two scenarios in the Land Use Scanner.

2.2 Origin of regional demand for land per sector

The demand for land for each scenario is based on information coming from sector-specific models developed by specialized institutes. Table 2.1 provides an overview of how the demand for space has been calculated and the sector-specific models used. Note that, as visualised in Figure 2.1, the simulated regional demand for land for the residential and commercial sectors is largely based on *integrated* model simulations. See Zondag and De Jong (2005), Willigers et al. (2010) and Appendix 1 for more information on how the sectors are integrated. More information on some of the other, more sectoral models can be found in Dekkers and Koomen (2006).

Sector	**Description of source(s) for the regional demand for land**
Urban area[1]	Essentially based on national demographic figures provided by the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006). These figures have been updated and transferred to regional figures by (Hilbers et al., 2011) for the scenario study 'Ruimtelijke Verkenningen'. In this step, the integrated *Tigris XL* model framework is used, including the demographic forecast model *PEARL*, and the transport model *LMS*.[2] In another update of the calculation procedure for the Delta study by Rijken et al. (2013), the above steps provide numbers of housing units per LMS-subzone (1,308 regions). In a final post-processing step, using differences in housing densities, the housing unit numbers are translated into a demand for space in hectares per NVM- region[3] for the different neighbourhood typologies.
Commerce/ Industry	Based on national, sectoral employment figures provided by the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006). Again, these figures are converted to regional figures by PBL for the 'Ruimtelijke Verkenningen' (Hilbers et al., 2011). Again, this conversion is performed in the integral Tigris XL model framework. The model output: numbers of jobs per sector, per region. The *BLM* model (Arts et al., 2005; Traa and Declerck, 2007) subsequently computes the net amount of industrial area per COROP region. In a post-processing step, the net demand for land is translated into a gross demand by adding a fixed percentage of land use to the original net claim.
Seaports	Based on the national, sectoral employment figures provided by the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006). Transferred to regional employment figures and land use demand by (Groenemeijer et al., 2008; Groenemeijer, 2009). Whereas the Tigris XL simulations referred to above are mainly based on estimated

[1] This sector is called Urban area since besides Residential area also public and socio-cultural amenities are included in the land use.

[2] For more detailed information on the modelling process within the Tigris XL framework, see Zondag and De Jong (2005), Willigers et al. (2010) and Appendix 1.

[3] NVM is the Dutch Association of Real Estate Brokers. The 76 NVM-regions are used to depict more-or-less homogenous housing market regions.

	coefficients (e.g., regarding location preferences of households typologies and firms), the figures provided by these ABF studies are derived mainly from extrapolations of observed trends.
Recreation	The demand for accommodation recreation is derived from a trend extrapolation based on the average growth in the number of square meter of recreational accommodation space per person during the period 1996-2008. So we calculated the growth in intensity for 1996-2008 and extrapolated this trend towards 2040. Multiplying the intensity in 2040 with the population in a scenario in 2040 results in the total amount of accommodation recreation. In these calculations, the division of the total demand for accommodation recreation in 2040 remains equal to the division in 2008 based on the assumption that this is a good representation of current recreation potential. For daytime recreation, the plans for new recreation around urban areas (RODS) have been taken to calculate an additional claim in hectares (DLG, 2010).
Agriculture	The figures for the Transatlantic Market-scenario (TM) from the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006) have been used for both scenarios for Arable Farming and Grassland. If necessary, Arable Farming and Grassland supply additional space for other land-use types. For the other agricultural land-use types, Greenhouse Horticulture and Perennial Crops, the demand has been calculated for the aforementioned study using the Dutch Regionalised Agricultural Model (*DRAM*) of the Agricultural Economic Institute (LEI; Wageningen University and Research Centre).
Greenhouse horticulture	The demand from the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006) has been taken. These claims were also used in Riedijk et al. (2007). The claims have been corrected for the new base year.
Nature	For the Regional Communities scenario: estimations by research institute Alterra (Wageningen University and Research Centre) based on the provincial ambitions for the National Ecological Network (NEN). Both the goals of the NEN and the extent to which these goals have already been realized, in terms of hectares, have been taken into account. For the Global Economy scenario, the additional claim has been calculated by taking an inventory of concrete plans for new nature ('Natuurmeting op Kaart 2010'; DLG, 2010), while subtracting the areas that already are nature. Future abiotic conditions in this scenario are used to distinguish between dry and wet nature.

Table 2.1 Description of the source of the demand for land per land-use type.

The results of the sector-specific models are used *directly* (when a demand in hectares is specified) or *indirectly* (when output is specified in another form, e.g. household numbers). In the latter case a post-processing translation is needed.

2.2.1 Urban area

The Urban area category in our model configuration consists of residential areas and related functions such as public facilities, retail areas, sports fields, allotment gardens, burial grounds local infrastructure et cetera. See Appendix 2 for more details on the definitions of land-use types we use in our model configuration. The land demand for this category is taken from the model-configuration of PBL Netherlands Environmental Assessment Agency for the Delta study (see

Rijken et al., 2013). The demand is based on the future demand for residences and the observed amount of urban area per residence as is described in this section. The regional demand for residences results from a complex interplay of numerous factors. These factors can be subdivided into two broad classes: *supply-side* factors and *demand-side* factors. On the supply side, these dynamics are basically steered by the availability of vacant houses, and – in the long term – the availability of suitable land. Other important supply-side factors are: accessibility, job availability, neighbourhood typology, amenities et cetera. On the demand side, the primary driving forces shaping regional residential land use dynamics are mainly demographical. Important indicators distinguished here are migration, birth- and death-rates and household composition. Together, these demographic indicators determine the total number of (different types of) households requiring accommodation. Household characteristics are also narrowly associated with housing and neighbourhood preferences.

As indicated in Chapter 1, the scenarios at hands differ in terms of supply as well as demand. Section 2.1 further indicated that it is the interplay between exactly these two basic sets of drivers that the integrated Tigris XL model framework tries to capture. When it comes to simulating future housing patterns, the demographic model PEARL has a major role to play. The remainder of this section provides an overview of how the main scenario assumptions derived from the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006) are implemented in this framework, and how, in the process, they are converted into the regional residential land use claims that ultimately feed the Land Use Scanner. See Zondag and De Jong (2005) and Willigers et al. (2010) for more information on these calculations.

Simulating demand with the Tigris XL-PEARL demography module

The ultimate, exogenous input for the regional demographic dynamics simulated by Tigris XL-PEARL are the national population figures (persons, households) provided by the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006). The next step is to specify the national demographic figures at a regional level. The information needed for this procedure is derived from empirical evidence, configured as regional demographic indices in Tigris XL-PEARL. Indices are specified on a municipality level for all relevant demographic variables, i.e.: birth- and death-rates, migration and household size. The simulation result: population dynamics (persons, households, potential labour supply) per scenario, per municipality and per time step (year).[4] The Tigris XL-PEARL demography module thus simulates scenario-specific regional demand for housing – both *quantitatively* (number of housing units) and *qualitatively* (type of dwelling preferred).

[4] In order for the totals of these regional figures to fit the total numbers provided for the Regional Communities and Global Economy scenarios in CPB et al. (2006), the indices are raised and lowered respectively. All indices are adapted to the same degree. This implies that the relative regional differences simulated for these scenarios remain equal. Note that the distinctive assumptions between the PBL scenario variants ('trend' versus 'less restrictive') have no bearing in this matter.

Simulating supply

As indicated above, future residential demand is guided by supply-side factors as well. This is especially true for the 'restrictive' trend variant discerned in the present study.[5] Like demand, supply can be subdivided in *quantitative* supply (e.g., numbers of vacant houses or available land) and *qualitative* supply (e.g., housing types or neighbourhood typologies). In the model framework introduced above, *quantitative* supply-side factors are mostly simulated in the Tigris XL housing, real estate and land market modules. In the former modules, home occupancy and number of housing units are administrated. The latter module manages available land. The spatial aggregation level employed in these modules is ultimately the LMS-subzone. Note that the distinction between the respective 'layers' (i.e. occupancy, object, land) is vital. The reason for this is that, by their nature, dynamics on these distinctive markets vary substantially. Compared to land use typologies, housing numbers (densities) change relatively fast. Dynamics in terms of home occupancy are higher still (Zondag and De Jong, 2005; Williger et al., 2010).

The *quantitative* supply-side factors discerned in these modules:

1 – Vacant homes
2 – Housing units
3 – Available land
4 – Spatial building restrictions
5 – Quotas for building within existing urban areas
6 – Residential development plans

The last three factors come in the form of scenario-input. See Table 2.2 below for the scenario assumptions made vis-à-vis these model parameters.

Factor	**Assumption in 'trend' (Reg. Comm.)**	**'Assumption in 'less-restrictive' (Glob. Econ.)**
Spatial building restrictions	Current, restrictive policies, rooted in the so called 'Nota Ruimte' (see Kuijper and Evers, 2011)	Less restrictive policies as stipulated by 'SVIR 2011' (see Kuijper and Evers, 2011)
Quotas: building within existing urban areas[6]	30 percent on average (see Kuijper and Evers, 2011)	20 percent on average (see Kuijper and Evers, 2011)
Residential development plans[7]	Existing plans for future expansion steer allocation of simulated demand	New residential development is for the most part driven by autonomous household preferences

Table 2.2 Scenario-assumptions quantitative supply-side factors future residential land use

[5] The demand-side factors vary according to the scenario distinguished here (i.e. Regional Communities vs. Global Economy, the supply-side factors diverge according to the variants discerned (i.e. 'trend' versus 'less-restrictive').

[6] Although the average for the Netherlands as a whole is set at 30 percent and 20 percent respectively, the quotas per region vary substantially. As for the trend variant, these regional differences are based on expert judgement founded on observed regional trends and (simulated) future possibilities (available space outside and inside existing urban areas. In the less-restrictive variant, the less restricted land and real estate markets are assumed to allow for indices that are, on average, 30 percent lower. See PBL (2010) for more details.

[7] Information on the size (acreage, number of houses) and location of these plans is derived from different sources, most notably: the so called VRM/TNO 'short term construction prognosis' ('bouwprognose'), 'regio-overleggen', the New Map of the Netherlands' 2010 ('Nieuwe Kaart van Nederland'), and prognoses carried out for the Dutch provinces and municipalities ('provinciale en gemeentelijke prognoses').

Initially, values for all six of the supply-side factors mentioned above are determined exogenously. Values for the first three factors are subsequently updated endogenously. Updates are performed for each time step (year). This is a very important element of the integrated model framework. Via endogenously calculated balance factors and prices, it allows tight land, real estate and housing markets to push additional demand to other, mostly neighbouring regions.

This brings us to the other type of supply factors distinguished here: the *qualitative* supply-side factors. As opposed to the quantitative factors, values for these variables are for the most part calculated endogenously. They are supplied by various modules, e.g., the transport market module, the labour market module, the demographic module. Relevant *qualitative* supply-side variables:

1 – Accessibility (between origin and destination zone)	5 – Household income
2 – Accessibility (for different modes and motives)	6 – Household density
3 – Employment	7 – Neighbourhood typology (3 types)
4 – Amenities	8 – Housing price (WOZ)

Source: Willigers et al. (2010)

Where demand and supply meet: the Tigris XL housing market module

Regional dynamics of housing units are calculated within the housing market module. For the most part, this is done in an iterative, two-step discrete choice model. This model is configured to optimize towards maximum household utility – given the strict *quantitative* supply restraints set in the modules discussed above, that is. The first step calculates whether or not household utilities are maximized by moving from their origin zones in the first place. If so, and if feasible, the second step subsequently simulates which destination zones are most favourable.

Subsequently, the *qualitative* supply-side parameters come into play as well. The estimations of the coefficients for these parameters are derived from housing surveys (Woning Behoefte onderzoek; WBO) from 2002. As already indicated above, the evidence shows that different household types have different preferences. Tigris XL-PEARL discerns six distinctive household types. This typology is based on combinations of the following household characteristics: Age class (head of household), Household size class, Employed (yes/no) and Income class. The values for these household characteristics are calculated and updated endogenously. The supplying Tigris XL-PEARL modules are the demography module and the labour market module. See Zondag and De Jong (2005), Willigers et al. (2010) and Appendix 1 for more information on these simulation steps.

The final step: determining regional land-use claims

The calculation steps discussed above yield regional, yearly figures on dynamics in housing stocks. See PBL (2011) for a detailed overview of these simulated dynamics. In a final post-processing step, these figures are converted into land-use claims per NVM-region (76 regions). These remaining calculation steps are performed outside Tigris XL. The calculation steps involved are:

1. Conversion: from housing numbers to land use in hectares;
2. Spatial aggregation: from NVM-subzones to provinces;
3. Temporal aggregation: from annual changes to the change per simulation period.

In step one, future land-use demand for urban area is calculated by taking the housing *numbers* simulated in Tigris XL, and multiplying them by indices of (observed) urban *densities*. The observed densities for these regions differ so much that separate regional density indices (at Socrates-region level) are required. These indices are calculated as the ratio of housing stock (2008) per Urban Area (2008). Different densities per scenario are obtained using densities from different neighborhood typologies. See Rijken et al. (2013) for a regional overview of the resulting land-use demand. Figure 2.1 shows the historical amount of urban area for the period 1977-2008 and the demand for future urban area for the two scenarios for 2040.

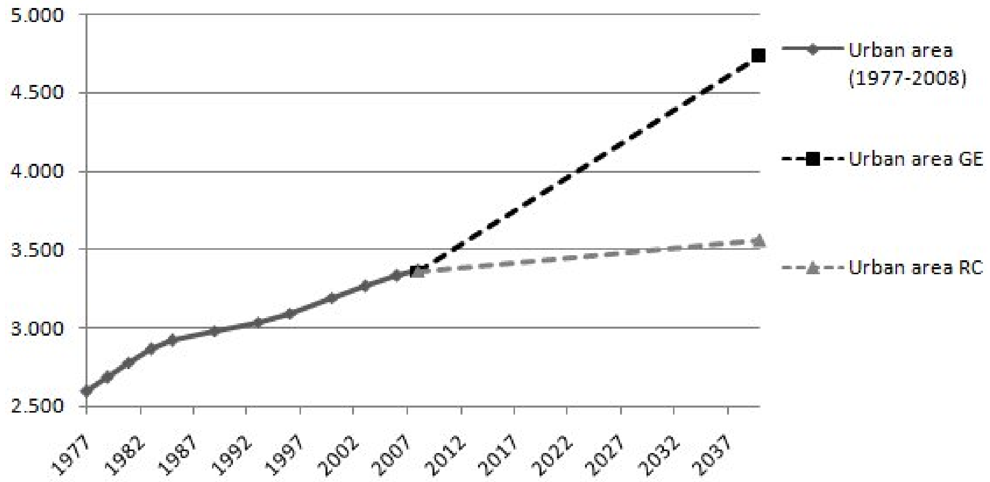


Figure 2.1 Amount of urban area: historic figures 1977-2008 (adapted from Soil Statistics of Statistics Netherlands) and 2008-2040 for the GE- and the RC-scenario.

2.2.2 Commerce and Industry

Commercial-office locations

Regional land use claims for office locations and industrial zones are ultimately based on national figures from the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006). For each scenario, this study gives a detailed account of national employment dynamics per economic sector. The two major steps taken in order to derive regional land use claims from these figures are:

1. distributing national employment totals per sector among the regions
2. converting the resulting regional employment dynamics per sector to land use claims for office locations and industrial sites.

The calculations associated with step 1 are performed by the integrated Tigris XL framework elaborated upon in Zondag and De Jong (2005), Willigers et al. (2010) and Appendix 1. The methodology is roughly similar to the one described in the previous section (regarding regional housing dynamics). The general idea is that regional employment dynamics are driven by interplay of various supply and demand factors. This time, the central modules in Tigris XL are: the labour market module (employment), commercial real estate module (office space) and the land market module (available land). Again, the demographic and transport-related drivers simulated in the demography module and transport module respectively, are important as well.

See Zondag and De Jong (2005), Willigers et al. (2010) and Appendix 1 for a more exhaustive overview of all this. See (Hilbers et al., 2011) for a detailed outline of the simulation results.

Step 2 is performed by the BLM model. The model starts by distributing the regional employment dynamics per sector among different *location types*.[8] This calculation step is based on estimated *location preferences* per sector, drawn from observed data for the period 1996-2003. The coefficients are obtained through regression analysis. In the next step *terrain coefficients* are used to convert the resulting figures on employment to land use claims. *Terrain coefficients* determine land use per combination of sector and location type. The coefficients are mainly derived from survey data (i.e., the so called 'Enquête Regionale Bedrijfsontwikkeling 1998'). Geographically, the coefficients are defined per 'landsdeel' ('Noordoosten', 'Randstad', 'Midden en Zuid'). These coefficients yield *net* land use claims, i.e., excluding space for water reservation, local infrastructure et cetera. The Land Use Scanner, however, simulates gross land use. Therefore, before introducing these claims into the Land Use Scanner, a post processing step adds an extra 30% (standard factor for net to gross office space) plus 10% (water reservation) of land use to the original net claims produced by the BLM. See Traa and Declerck (2007) and Arts et al. (2005) for more information on the BLM. See Kuijper et al. (2011) for a regional overview of the resultant land use claims.

Seaports

Like the urban sectors discussed above, future regional land use claims by commercial seaports are based on the national scenarios elaborated upon in (CPB et al., 2006). Whereas regional demand for land by the former sectors is derived from calculations by PBL ((Hilbers et al., 2011; Kuijper et al., 2011; Kuijper and Evers, 2011), the regional land use claims for seaports are based on studies performed by ABF (Groenemeijer et al., 2008; Groenemeijer, 2009). The reason for resorting to these ABF studies is simply that the aforementioned PBL studies do not go into detail on seaports.

First, Groenemeijer et al. (2008) translate the national employment figures from CPB et al. (2006) to figures on, employment per economic sector (agriculture, industry, retail et cetera) per region (municipality). The economic sectors distinguished are derived from the classification configured for the BLM model (see previous section). Indices on future regional shares are derived from observed sectoral employment trends for the period 1996-2007. Information on future building locations is taken into account as well.[9] Next, Groenemeijer (2009) goes on to convert the resultant employment figures to land use claims per location type (e.g., seaports). The spatial resolution is the so called COROP-plus region.

[8] Apart from office and industry locations, the BLM distinguishes seaports, and 'other locations' (residential areas etc.) where employment will concentrate. In our demand for Commerce and Industry we only consider employment on formal office and industry locations.

[9] As for the source of these plans, (Groenemeijer et al., 2008) refer to 'De Nieuwe Kaart van Nederland' (NIROV, 2008).

The conversion is based on two factors:

1) (future) share of employment per combination of sector and region situated at seaports (instead of office locations, residential areas etc.), i.e., *location type preferences per sector per region*;
2) (future) space occupied by employment per combination of sector and region situated at seaports: i.e., *terrain-quotients per sector per region.*

The values for these factors are derived from observed trends for the time period 1996-2003, regarding sectoral employment dynamics based on LISA statistics on the one hand, and land-use dynamics based on CBS Soil Statistics on the other hand. The result: future land-use dynamics per combination of economic sector, location type and region. The land-use demand for seaports that are thus calculated are all *gross* claims, including space for water reservation, local infrastructure et cetera.

2.2.3 Recreation

Recreation is divided into two sub-types: accommodation recreation and daytime recreation. Accommodation recreation, also referred to as short and long holiday recreation, consists of recreational facilities for overnight stay (including camping's, bungalow parks and second homes), while daytime or day trip recreation consists of the predominantly green recreational facilities for daytrips (including: theme parks, zoos and open air museums).

Accommodation recreation

For both the Regional Communities and the Global Economy scenario, the demand for accommodation recreation has been based on national trends in change in average intensity (the number of square meters of accommodation recreation available per person) over the eight-year period 1996 – 2008 provided by the Soil Statistics of the Central Bureau of Statistics (CBS). Based on a trend extrapolation of this data and in combination with the population figures for 2040 for the two scenarios, total demand in 2040 has been calculated for the Netherlands as a whole for both RC and GE. In these calculations, the division of the total demand for recreational accommodation land in 2040 remains equal to the division in 2008 based on the assumption that this is a good representation of current recreation potential.

Daytime recreation

We have calculated the demand for daytime recreation by taking the plans for new recreation around urban areas ('RODS 2010'; DLG, 2010) while subtracting the areas within these plan areas that are already daytime recreation. The procedure is applied on the Regional Communities scenario. For the Global Economy scenario, the demand is calculated per region by taking 50 percent of the demand in the Regional Communities scenario. The reasoning behind this is that in the GE-scenario, the government does not provide these public services anymore. Instead, private parties are supposed to take care of this, and they will do so to a lesser extent. Also in the Global Economy scenario, the urbanization pressure is considerably higher in the Randstad, which is the main area covered by the 'RODS 2010'-plans. Therefore, there is less space available for day trip tourism.

2.2.4 Agriculture and Greenhouse horticulture

The simulation process strives to allocate the exact demand for land per region as derived from the sectoral models. To allow for a feasible solution the total demand for land in a region should not exceed the available amount of land. As this is normally not the case, the model contains no strict demand for Arable farming and Grassland per region, thus allowing the allocation process to solve a regional lack of space by allocating less land to these two agricultural land-use types. The claims for the other agricultural land-use types are taken from the 'Welfare, prosperity and quality of the living environment' study (CPB et al., 2006) by PBL and are the same as the claims in Riedijk et al. (2007). A difference with these previous studies is that zero-grazing livestock is not modelled separately as there were serious doubts as to whether the presence of this type of agriculture was well-presented in current land use.

Greenhouse horticulture

The claims for Greenhouse horticulture are also taken from the aforementioned study and are also equal to the claims in Riedijk et al. (2007) for the simple reason that more recent claims with a thorough (computational and logical) foundation are lacking.

2.2.5 Nature

For the Regional Communities scenario, the demand for nature has been estimated by research institute Alterra (Wageningen University and Research Centre; see Van Eupen (2009) based on the provincial version of the national plan for a National Ecological Network (NEN). Both the goals of the NEN and the extent to which these goals have already been realized, in terms of hectares, have been taken into account in these calculations. The total demand in this scenario thus reflects the initial ambitions for the NEN that is supposed to be realised before 2018. Furthermore a distinction is made between wet and dry types of nature following the provincial ambitions in this respect.

For the Global Economy scenario we follow most recent national ambitions documented in the proposed new national spatial strategy (I&M, 2011; Elings et al., 2011). These revised plans foresee a more limited NEN in which the only new natural areas will consist of land that has already been acquired for the development of nature. In this case the additional demand has been calculated by taking the inventory of concrete plans for the creation of new nature ('Natuurmeting op Kaart 2010'; DLG, 2010), while subtracting the areas within these plans that have already been developed into nature. Subsequently, in a GIS-analysis using spatial information on future abiotic conditions (i.e. physical suitability) for dry and wet nature types, the additional demand is split between these two types.

2.3 Using regional land demand in Land Use Scanner

The preceding section has shown that the regional land demand for some sectors is computed using sector-specific models (Residential area, Commerce/Industry), while for other sectors more simple trend extrapolations or even basic, qualitative assumptions are used to define the future land-use demand per region.. Land Use Scanner uses this regional demand in combination with a local (grid-cell based) definition of suitability for each land-use type to simulate future land use per sector (Figure 2.1). In this process the following conditions apply:

1. All sectoral demand is met (by available land);
2. All available land is occupied (with exogenously, fixed, land use and with endogenously, simulated, land use)

This makes the Land Use Scanner an integrated, doubly-constrained, utility-maximising spatial equilibrium model Loonen and Koomen (2009).

Table 2.2 contains the demand for land per land-use type per region that is used as a starting point in the simulations for the two scenarios. The land-use types Infrastructure, Water, Building lot and Exterior are not modelled. Therefore, the demand for land for these types is fully granted before the modelling process starts.

As the table shows, the Urban area, Commerce/Industry, Recreation and Nature land-use types as well as Greenhouse Horticulture all have minimum and maximum claims that are equal to each other. This means that the model has a specific target to accomplish in terms of hectares. For Building lots, the model has the freedom to convert all currently available building lots into other types of land use should the regional demand and local suitability definition of these land-use types require so. Whether that happens, depends for a large part on the claim of other land-use types (i.e. Urban area, Commerce/Industry and Recreation).

		2040 Reg. Comm.		**2040 Glob. Econ.**	
Land-use type	**2008**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Urban area	336	355	355	473	473
Recreation – accommodation	21	23	23	29	29
Recreation – daytime	10	21	21	16	16
Commercial / Industrial area	76	71	71	93	93
Seaport	9	8	8	13	13
Nature - dry	489	475	475	518	518
Nature – wet	103	254	254	118	118
Agriculture – arable land	743	0	743	0	743
Agriculture – grassland	1,366	0	1,366	0	1,366
Agriculture – greenhouse horticulture	17	8	8	22	22
Agriculture – perennial crops	44	33	40	25	45
Building lot	37	0	37	0	37
Subtotal endogenous	*3,250*	*1,249*	*3,402*	*1,306*	*3,472*
Infrastructure	121	124	124	124	124
Water	2,855	2,856	2,856	2,856	2,856
Exterior	2,548	2,548	2,548	2,548	2,548
Subtotal exogenous	*5,525*	*5,527*	*5,527*	*5,527*	*5,527*
Total	8,775	*6,786*	*8,938*	*6,824*	*8,989*

Table 2.2 Land-use demand for the two scenarios in the Land Use Scanner (x 1 kHa)

3. Recent Land Use Scanner model development

3.1 Introduction

Since the publication of the previous set of land-use simulations (Riedijk et al., 2007) a number of improvements have been made in the model that are applied in the land-use simulations presented in this report . The most important changes are discussed in this chapter and concern: an update of the base land-use data and the computation and visualization of dominant land use, updates in exogenous developments for both scenarios, changes in defining local suitability and the possibility for modeling in time steps.

3.2 Base year land use

The Land Use Scanner-configuration that was documented in Riedijk et al. (2007) used land use data from the year 2000 as the base year for its calculations. In the new model configuration that is developed for the Knowledge for Climate research programme and that has been developed for the PBL studies ´Ruimtelijke Verkenningen´ and ´Ex Ante SVIR´ (Kuijper et al., 2011; Kuijper and Evers, 2011), the base year has been updated to 2008 using CBS Soil Statistics from 2008 in combination with land use data (LGN version 6) from research institute Alterra (Wageningen University and Research Centre) and the Top10Vector map of the Dutch Cadastre. LGN6 contains land use information from the years 2007 and 2008 and is used to refine the CBS Soil Statistics classes 51 (Agriculture), 60 (Forest), 61 (Dry nature areas) and 62 (Wet nature areas). See Appendix 2 for more information on the types of land use we discern. For more detailed information on the use of the different sources for calculation of the different land use classes in the base year map, see Appendix 3.

In previous configurations, residential land use was modelled in three up to a maximum of five different types based on neighbourhood typologies following a subdivision described by, for instance, Oskamp et al. (2002). In the new model, only one urban land-use type is modelled because we feel that the previously applied distinction was, to some extent, misleading: in the old model, in different parts of the country the same neighbourhood typologies contained very different residential densities, making the distinguished residential types not very homogenous and therefore more difficult to model. The new model setup ensures a more direct relationship between house numbers and densities. This revised treatment is a first step towards a clearer distinction between land use (urban area) and densities (number of houses) that is the topic of a new research project (Koomen et al., 2011b). Further, zero-grazing livestock is not any longer modelled separately because insufficient information is available to develop future scenarios for this type of land use.

The base year data is originally composed as a 25-metre raster and needs to be aggregated to a 100-metre raster before being applied in the model. In earlier model versions two separate aggregations of the base year data were produced. For the definition of land claims and suitability maps, the base year data were aggregated to rates of land use per 100-metre cell. For visualization and comparison homogenous 100-metre raster cells were applied. The model thus enforced inconsistencies between the continuously valued base year data and the discretely valued future land-use maps. The homogenous version of the base year data was compiled in a very straightforward manner: each raster cell was filled completely with the land-use type that occurred most frequently in that cell in the underlying base year data. This simple approach, however, can lead to discrepancies with regard to the total amount of land use per land-use type. For example when the amount of dominant land use for each type is summed for the whole study area, the total number of hectares can deviate from the summed allocated land use itself. This is problematic because it makes the homogenous base year data and the projected future land-use maps fundamentally incomparable.

To overcome inconsistencies between base year data and future land-use maps, the method to aggregate the base year data has been adapted. As a means of aggregation the base year data is now allocated to a 100-metre discrete grid version using the allocation procedure of Land Use Scanner. It does so by first separating the 100-metre cells that are fully covered by one land-use type from the cells that entail multiple land uses. For computational reasons the cells with a single land-use type are considered static (exogenous); the remaining cells are treated as endogenous land uses in simulation. The applied model defines the local suitability value for a land-use type in a cell as equal to the amount of land covered by that land use in that cell. The model is constrained to allocate quantities of a land use in a region equal to the quantities of that land use in that region in the original base year data. The resulting single base year data grid is used for the definition of land-use demand and suitability maps, as well as visualization and comparison purposes. The adapted method so ensures that the projected future land use maps are fully comparable with the base year maps and that the total amount of *dominant* land use is equal to the summed *allocated* land use.

3.3 Exogenous developments

For both the Global Economy and the Regional Communities scenario, some exogenous developments play a role. Most of these developments are captured within the exogenous (i.e. not-modelled) land-use types water and infrastructure. An exception is the development of the 'Tweede Maasvlakte', which is the addition of about 2,000 hectares of new land near Hoek van Holland. This land is available for claims from all endogenous land-use types.

3.4 Defining suitability

Scenario assumptions

In the Global Economy scenario, the car is more important than public transport as a means of transportation. Therefore, accessibility of highway ramps and motorways is given more weight and accessibility of public transport less weight, compared to the Regional Communities scenario. In the latter scenario, high-speed rail is more important, in the former scenario, the airports. In Global Economy, economic growth is higher than in Regional Communities, leading to a higher absolute level of suitability / land prices in general. In both scenarios, existing building lots for specifically Urban area, Commerce/Industry and Recreation are favoured when it comes to new developments.

With regard to urban land-use types, in both scenarios the attractivity of the surroundings and the New Map of the Netherlands-plans are equally important. In contrast, in Global Economy the regional strategic plans (the former 'streekplannen', now replaced by 'structuurvisies') have less weight since the government interferes less with market forces in this storyline.

For urban developments, in both scenarios policy restrictions with regard to nature apply. In Global Economy, these nature policy restrictions imply a tax or fine for any developments inside Bird Habitat Directive areas, Nature Protection areas ('Natuurbeschermingswet'), 'Natuurmeting op kaart 2010' areas and Natura 2000-areas and, to a lesser extent, national landscapes and two UNESCO-areas (the 'Beemster' and the 'Stelling van Amsterdam'. For Regional Communities, much larger areas are restricted. Again, developments inside Bird Habitat Directive areas and Nature Protection areas are heavily penalized, but now also the entire National Ecological Network (NEN) is protected.

For Commercial land use, in the Regional Communities scenario developments are steered more in the direction of the two mainports, Rotterdam and Schiphol.

In Global Economy, new nature developments are stimulated in the 'Natuurmeting-op-kaart 2010'- areas, at the expense of for instance Arable land and Grassland. These latter two land-use types are also discouraged in areas where dry and wet nature are already present. This discouragement also holds for the Regional Communities scenario. Further, in Regional Communities the National Ecological Network is important for realizing new nature areas, both dry and wet.

Scaling of suitability maps
Since Koomen et al. (2005), Borsboom-van Beurden et al. (2005) and Dekkers (2005), the basic principle with regard to the scaling of suitability maps has been to keep the suitability value close to realistic land prices per land-use type. This study uses the allocated mean suitability, in which allocated means that for any given land-use type, the mean suitability is calculated using only those grid cells in which that specific land-use type is allocated, is used to compare with realistic land prices.

3.5 Modelling in time steps

Since 2005, the Land Use Scanner has been extended with the possibility to model homogenous, discrete cells (describing only one type of land use) in addition to the heterogeneous cells that were available in the initial, coarser version of the model. See Loonen and Koomen (2009) for more details on and a comparison of the two model versions.

The discrete model version offers the possibility to calculate land-use change in time steps. This dynamic type of modelling is applied in the studies by PBL (Kuijper et al., 2011; Kuijper and Evers, 2011). Their simulations typically follow three time steps: from the base year (2008) to 2020, from 2020 to 2030 and then from 2030 to 2040. The interesting aspect of calculating in time-steps is, among others, that the selection and weighting of suitability factors can be varied in different time-steps. This allows, for example, for hard, already-decided-upon spatial plans to be executed in the first time-step, while more uncertain spatial plans that have a longer term view, can be entered in the second time-step. Another example is the addition of a new highway segment to the highway-network at the beginning of time-step 2, thus changing the accessibility and distance-relations between locations in the second time-step calculation.

For the Knowledge for Climate Theme 8 research programme, the optimization algorithm is used, without using time steps. We choose to do this because we do not expect that using time steps will make much difference for the long spatial planning horizon that is typical for the Netherlands. In the current simulations the new method for calculating the discrete base year 2008 is used as a starting point (see Section 3.2) and from this point onwards future land use is calculated in one step. So a discrete-static approach is adopted, keeping the comparability with the earlier configurations from the Climate changes Spatial Planning research programme intact. We have planned to test the added value of a dynamic simulation approach in the coming years.

4. Results

4.1 Base year 2008

Appendix 4 contains a map of land use for the base year 2008 as well as the simulation results for both the Regional Communities and the Global Economy scenario.

4.2 Suitabilities

Table 4.1 contains some basic statistics about the suitability maps per land-use type for both scenarios. As can be seen, the selective mean suitability follows the intended pattern: higher suitability / land prices for urban land-use types, lower for nature and agriculture. Also, in general the suitabilities / land prices are somewhat higher in the high-economic growth Global Economy scenario. Of course, suitabilities are partially composed from taxes and subsidies as well, so real market prices in the sense of not-being-disturbed-by-government-interference will not be present.

	2040 Reg. Comm.		2040 Glob. Econ.	
Land-use type	**Selective Mean Suit.**	**StdDev Mean Suit.**	**Selective Mean Suit.**	**StdDev Mean Suit.**
Urban area	26.4	7.2	33.0	7.3
Recreation – accommodation	10.9	2.0	11.3	3.1
Recreation – daytime	5.9	2.5	7.5	2.1
Commercial / Industrial area	26.2	6.5	27.0	7.1
Seaport	14.7	7.7	20.5	9.8
Nature – dry	6.1	1.9	6.3	2.4
Nature – wet	2.3	4.7	7.4	2.9
Agriculture – arable land	3.6	0.2	3.6	0.2
Agriculture – grassland	3.6	0.4	3.6	0.3
Agriculture – greenhouse horticulture	13.6	4.3	11.9	6.5
Agriculture – perennial crops	3.0	0.5	4.9	1.1
Building lot	3.3	2.2	5.8	2.9

Table 4.1 Suitability statistics for the two scenarios (Euro/m^2)

Table 4.2 contains the total amount of land use per function in 2008 and for the both scenarios in 2040. For the amount of land use per province, we refer to Appendix 2. The results of both scenarios are discussed in more detail in the next sections.

		Regional Communities		Global Economy	
	2008	2040		2040	
Land-use type	**kHa**	**kHa**	%	**kHa**	%
Urban area	336	355	+6	473	+41
Recreation – accommodation	21	23	+11	29	+35
Recreation – daytime	10	21	+101	16	+50
Commercial / Industrial area	76	71	-7	93	+22
Seaport	9	8	-9	13	+42
Nature – dry	489	475	-3	518	+6
Nature – wet	103	254	+148	118	+15
Agriculture – arable land	743	723	-3	688	-7
Agriculture – grassland	1,366	1,260	-8	1,234	-10
Agriculture – greenhouse horticulture	17	8	-54	22	+31
Agriculture – perennial crops	44	39	-11	41	-5
Building lot	37	10	-74	3	-93
Subtotal endogenous	3,250	*3,248*		*3,248*	
Infrastructure	121	124		124	
Water	2,855	2,856		2,856	
Exterior	2,548	2,548		2,548	
Subtotal exogenous	*5,525*	*5,527*		*5,527*	
Total	8,775	8,775		8,775	

Table 4.2 Resulting land use for the two scenarios, compared to current land use (x 1 kHa)

4.3 The Regional Communities scenario

4.3.1 Sector-specific developments

When looking at the map of dominant land use (see Figure 4.1 and Appendix 4), at first we do not observer much difference with current land use. A closer look, however, does reveal some interesting patterns. As the statistics in Table 4.2 also mention, we see some growth in urban land use, in particular in and near existing urban areas and according to existing plans. Residential development locations from the addition to the Fourth Memorandum of Spatial Planning (so-called VINEX-locations) like 'Leidsche Rijn' are developed, but virtually no new urban development outside areas that already are included in (municipal) plans are being developed. Connected to that, we also observe substantial growth in the recreation sector, in particular daytime recreation. Commercial/Industrial land use and Seaport do not grow at all, these sectors even shrink a little in terms of land used.

The amount of nature increases substantially since the NEN-policy will be fully completed in this scenario. We see a slight decrease of the amount of dry nature areas, while wet nature areas grow with 148 percent. The amounts of arable land and grassland decrease with 3 percent and 8 percent respectively. Also, the amount of greenhouse horticulture is halved. Finally, we observe that not all currently available building lots are being used. This is explainable because of the lack of economic growth and therefore the lack of growth in commercial land use.

A development that is not very likely is the replacement of greenhouse horticulture with grassland in 'het Westland' (southwest of The Hague). This development occurs because the greenhouse horticulture sector retreats in this scenario while residential and commercial/industrial demand does not grow sufficiently to need this space to meet its claims. The one sector that does grow substantially in this scenario, Nature, is focused on growth within the National Ecological Network areas and therefore is also not interested in 'het Westland'. As a consequence, the gap is filled by one of the two land-use types that retreat when there is a lack of space elsewhere (see also Section 2.2.4). These land-use types may thus be relocated somewhere else, in this case in 'het Westland'. In order to prevent this unlikely transition from occurring, the transition costs have to be adjusted in this scenario. A more realistic alternative would be a transition from Greenhouse horticulture into Building lot, since that would prevent the destruction of land value that occurs when this land would turn into Agriculture.

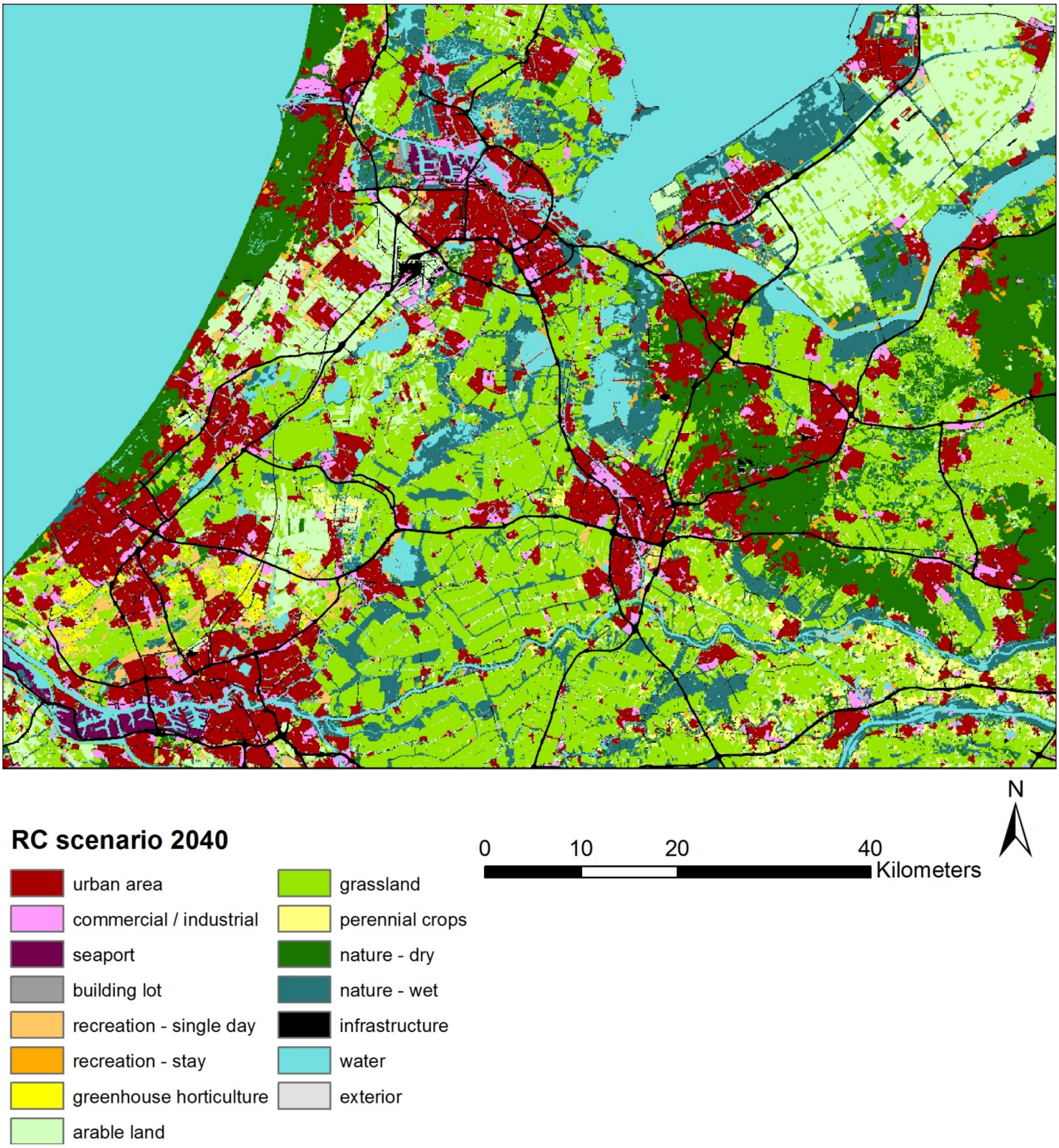


Figure 4.1 A closer look at the land use 2040 (Regional Communities scenario)

4.4 The Global Economy Scenario

4.4.1 Sector-specific developments

The Global Economy scenario assumes a higher economic growth than the Regional Communities scenario and as a result, a higher growth in the amount of urban land use is observed (see Figure 4.2). Urban land use grows 41 percent, in particular in the west of the country, in the area between Rotterdam and the Hague (where the buffer zone policy is abolished) and around Utrecht. Autonomous household preferences weigh heavy in the decision where to locate, and people like living on a location that easily accessible by car. They also like to live in an attractive environment with natural areas to relax in, so we also see urbanization in more rural, open areas. Almere, Eemnes/Huizen/Blaricum and Amersfoort also grow. Further, the amount of recreational land use grows substantially. The amount of accommodation recreation grows by 35 percent, and again daytime recreation grows the most, although in Global Economy less (50 percent growth) than in RC (101 percent growth) as people have less time for recreation. Commercial land use grows by 22 percent, which is much more than in Regional Communities, where there is a decrease in commercial land use. Also, seaports grow by 42 percent, of course for a large part explained by the extension of the Maashavens (the 'Tweede Maasvlakte').

With regard to nature, we see that only part of the current inventory of hard nature plans ('NOK 2010'; Dienst Landelijk Gebied, 2010) is realized. Both dry and wet nature grow a little bit, together almost 45,000 hectares, which is only about 8 percent. In contrast to the Regional Communities scenario, we see substantial growth in the greenhouse horticulture sector. Finally, 93 percent of all currently available building lots will be used up by 2040 in this scenario.

The greenhouse horticulture sector benefits from increased demand on the free trade global market and the use of new technologies that are more efficient in terms of energy use and labour. Therefore, this sector grows substantially in the Netherlands. As a result, the current locations for this land-use type are reinforced and extended, as can be observed in 'het Westland', the area southwest of The Hague.

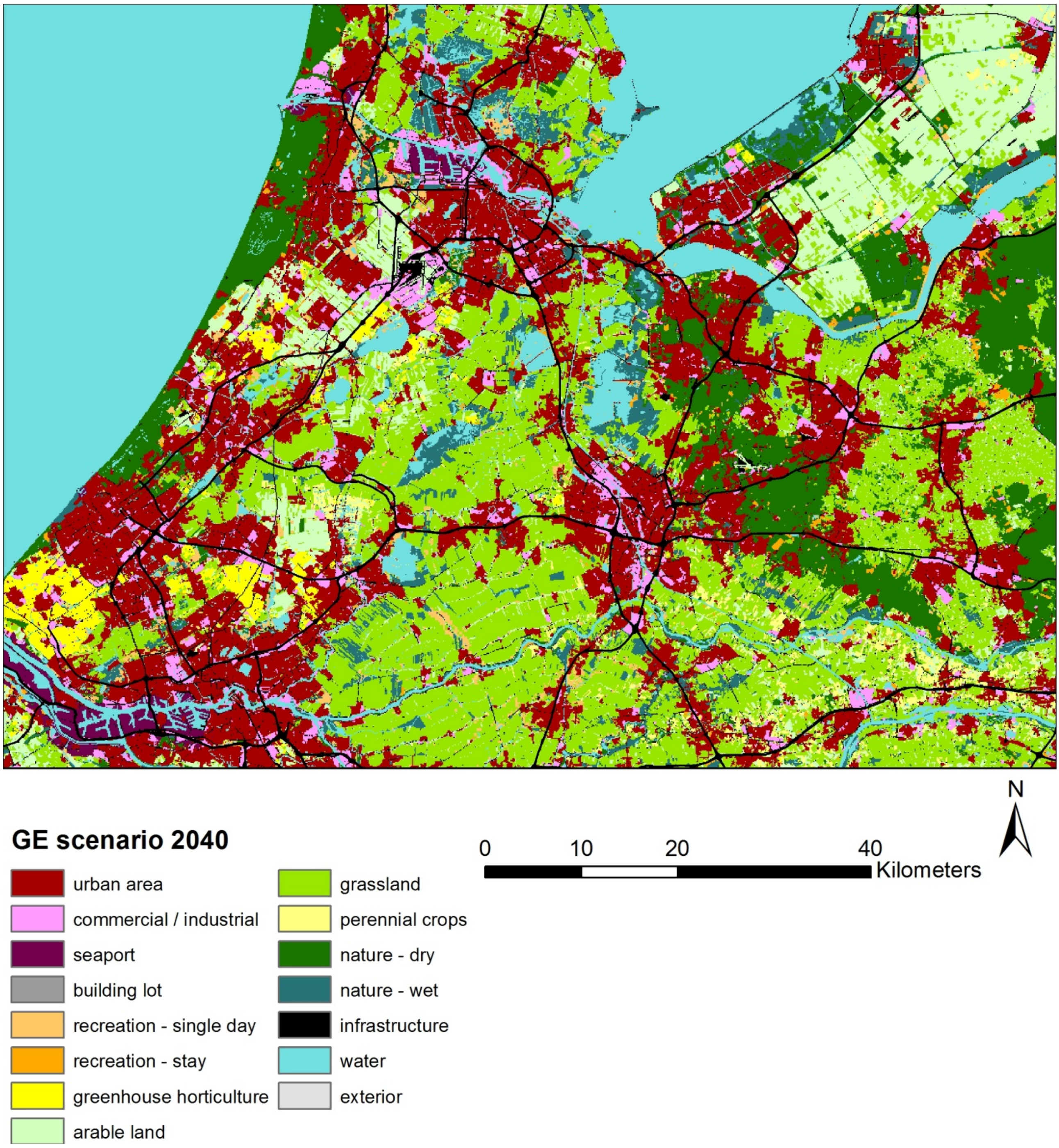


Figure 4.2 A closer look at the land use 2040 (Global Economy scenario)

4.5 Comparing the two scenarios

4.5.1 Urbanisation

We consider the following land-use types as built-up: urban area, commercial/industrial, seaport, and greenhouse horticulture (because of its distinct urban appearance). When taking a closer look at the urban development in both scenarios, we observe that almost all urbanisation that takes place in Regional Communities also occurs in Global Economy. In Global Economy, however, much more land becomes urbanised, while in Regional Communities the amount of new urban area is very limited. Apart from some isolated patches, only one location is urbanised only in Regional Communities: IJburg, east of Amsterdam. This reflects an urban development plan that is strongly promoted by national and/or regional Government. In Global Economy we observe that a lot of urbanisation takes place near highway entries, demonstrating the important role of the car in this scenario. Whether accessibility will actually play such an important role remains to be seen, but it demonstrates the models capability to translate this type of storylines into model output.

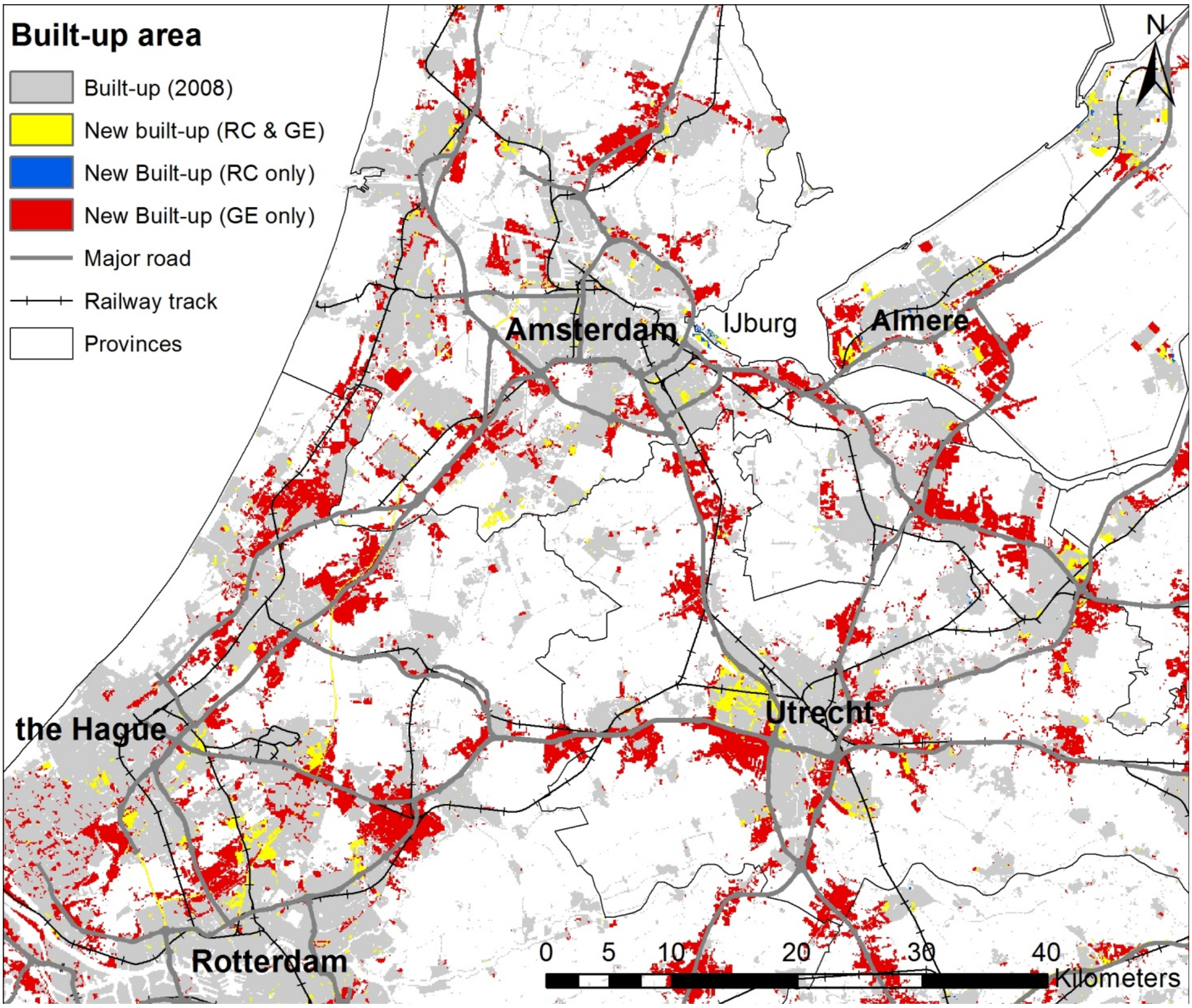


Figure 4.3 Comparing urbanization: land use (2008), and both scenarios

What Figure 4.3 does not show is that in the Regional Communities scenario, quite some built-up area disappears in the province of Zuid-Holland (Figure 4.4). That is caused by the decline of the greenhouse horticulture sector and the relocation of this type of activity from the Westland and from Aalsmeer to other locations.

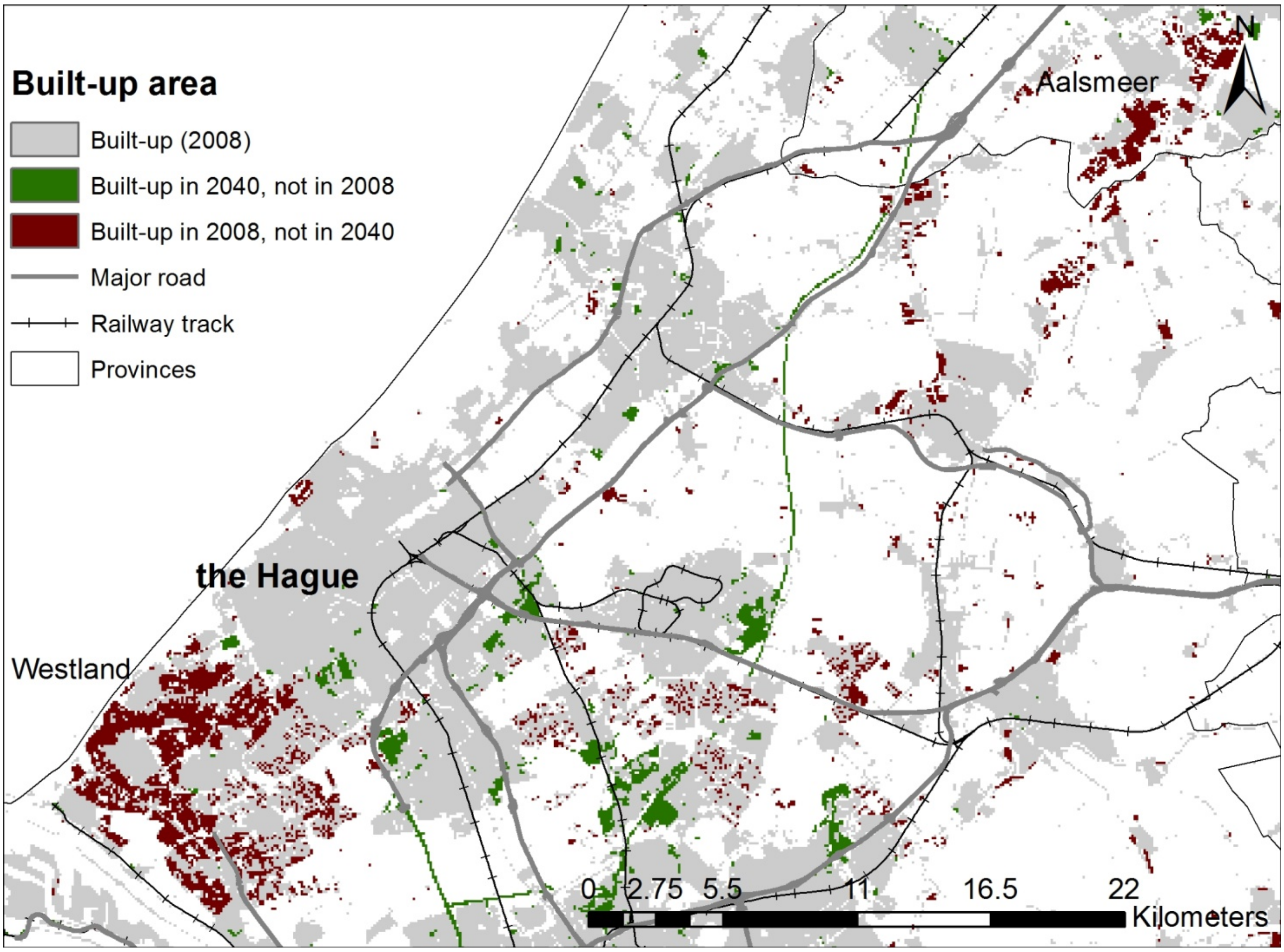


Figure 4.4 Built-up area in the Regional Communities scenario; greenhouse horticulture moving away from the Westland and from Aalsmeer.

4.5.2 Nature development

With regard to nature development, the differences between the scenario simulations is huge. Where GE only has a limited extension of nature, in RC much more nature development takes place. This is caused by a difference in policy ambitions. Furthermore, the simulations clearly show differences in the amount of wet and dry nature reflecting the fact that in RC Provinces have the ambition to develop more wet nature (according to the inventory of Alterra). This difference foremost illustrates the potential of the Land Use Scanner model to simulate the outcomes of such varying scenario conditions and policy ambitions. Which developments will become reality remains to be seen.

5. Discussion

5.1 Validity 'Welfare, prosperity and quality of the living environment' study

Hilbers and Snellen (2010) have examined the validity of the 'Welfare, prosperity and quality of the living environment' scenarios from 2006. One of the reasons to do this was the recent financial and economic crisis and the effect this may have on future developments. They conclude that, although large discrepancies in terms of mobility, demography and economic trends can be observed between empirical current trends and these scenarios, the bandwidth of possible futures offered by the set of scenario's still provides ample space to absorb these discrepancies. Schuur and Verkade (2011) reach a similar conclusion.

In their CPB-report 'The Netherlands of 2040', Ter Weel et al. (2010) present four new economic scenarios that diverge in terms of human capital (specialized versus generalized) and location type (spread versus concentration). Using these two axes, four different types of urban constellations (interpreted in the report in terms of their productive capacity) are described (see Figure 5.1). As Priemus (2011) also concludes, these simplified scenarios present a well-argumented interesting economic analysis. However, they are not complete as some sectors are not discussed and they mainly have an economic focus, lacking an explicit relation with spatial planning and policy. Since the scenario setup is very different from the one used in the 'Welfare, prosperity and quality of the living environment' study in 2006 and there is no explicit spatial component, these new scenarios cannot be used to assess the validity of the 2006 scenarios.

5.2 Relation to Delta Programme

We have aligned this scenario study as much as possible with the Delta scenarios project. In this multi-disciplinary subproject of the Delta Programme, a consortium of research institutes cooperates to provide a set of scenarios for the Netherlands in 2050 (Rijken et al., 2013). The land-use simulations presented in the current report differ in some aspects from the Delta scenario project. Apart from the fact that we maintain the initial time horizon of the 'Welfare, prosperity and quality of the living environment' study (i.e. 2040 and not 2050 as in the Delta scenarios) these differences are fairly technical and do not result in substantial differences in land-use patterns. For completeness sake we briefly mention the different model setting we apply in our simulations. First, our model application is less dynamic in the sense that we do not model in time-steps, see also Section 3.5. Second, we distinguish two types of nature: dry and wet. We use scenario-specific physical suitability maps to discern between the two types. Third, although we have aligned the components used in the suitability map specifications for all land-use types as much as possible, in general we use fewer components and avoid combining too much components with each other, thus making the suitability maps more pronounced. A difference related to calculating in time-steps is that in the Delta-simulations, suitability values are expressed in euros per square meter per year, whereas in our suitability maps we express suitability in euros per square meter only. Fourth, we have defined two scenarios, GE and RC, whereas the Delta Scenarios have more variants per scenario. Fifth, the Delta scenario-simulations take a two-step approach, first allocating urban land-use types and in a second model run allocation other functions, the argument being that urban and rural functions in reality do not really compete for scarce land.

Sixth and finally, the Delta scenario study discerns between more agricultural land-use types than we do.

5.3 Demand for agricultural land

The current model application does not specify a demand for land for Grassland and Arable farming, but rather uses these categories to provide land for other developments. This is in line with observed land-use changes in the past decades (see, for instance, Van Rij et al., 2008; Koomen et al., 2008b), but does not allow the scenarios to reflect potential changes in the relative importance of these types of agricultural land use. It is, for example, likely that changes in agricultural subsidies following the reform of EU's Common Agricultural Policy in 2013 will lead to considerable changes in the relative profitability of agricultural crops. As part of the Dutch Delta research program, the Netherlands Environmental Assessment Agency wants to develop new scenarios of future agricultural development. Such results can be used to update the land-use simulations presented in this study. When the new scenarios become available, we will use this information to update the current project configuration.

5.3 Next steps

As a follow-up on the land-use simulation improvements described in this report additional methodological advancements are currently being explored. Foremost, this relates to an alternative specification of the suitability map definitions for various land-use types. Until now, mainly expert judgement is used to weigh the different factors in suitability maps. We are currently testing other suitability map specifications (see, for instance, Koomen et al., 2011a; Koomen et al., 2012). For residential land use, the weights for the suitability map factors were determined using multinomial and binomial regression analyses of location values. These location values were determined using actual house transactions, thus bringing land market information into the land use model, albeit still in an indirect way. Next, the suitability maps for the land-use types Arable farming and Grassland were replaced with a Net Present Value (NPV) approach. Different combinations of using statistics for Residential area and NPV for two types of Agriculture were tested. The first results show that in particular a binomial statistic approach in which the probabilities are rescaled for the different land-use types using maximum bid prices for each land-use type, works well. With regard to the use of the utility functions, there is room for improvement. The first ideas to realize this are: 1) to make the functions more spatially explicit; 2) to increase the number of or to use other explanatory variables; and 3) to use other information in the suitability maps besides NPV, since the Net Present Value is but one factor in the decision-making process of actors. Further, the aim is to improve the spatial explanation of land prices, add utility-based frameworks for other land-use types (e.g., office rents for commercial land use).

During the tests with the aforementioned utility-based frameworks, 1996 land use was simulated starting with an empty map (so, without using any information on existing land use). The next step is then to focus on explaining and simulating land-use change. Therefore, transition analysis and conversion costs will be added to the new frameworks to assess their effect.

A final methodological improvement relates to the incorporation of functional units (e.g. residences, water storage quantity) rather than hectares of land use in the model. This will enable 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. Initial work on this topic has started (Koomen et al., 2011b). Eventually this would allow us to relax the supply-assumption in the land-use allocation algorithm, allowing more than 1 hectare of land use being allocated in a 100x100 meter grid cell.

Appendix 1 Modelling urban development and transport using Tigris XL[10]

The TIGRIS XL model is a system of sub-models that includes dynamic interactions between the sub-models. Its land-use model uses time steps of one year, which enables the user to analyse how the system evolves over time. The land-use model is fully integrated with the National Transport Model (LMS) of the Netherlands and the two models, land-use and transport, interact every five years.

TIGRIS XL is a linkage module model and it consists of five modules addressing specific markets. The advantage is that each module can be developed in a flexible way to address it specific characteristics, local policies and data availability. Core modules in TIGRIS XL are the housing market and labour market module; these modules include the effect of changes in transport on residential or firm location behaviour and in this way link changes in the transport system to changes in land-use. A land and real estate module simulates supply constraints arising from the amount of available land, land-use policies and construction. The module defines different levels of government influence, ranging from completely regulated towards free market, and various feedback loops between demand and supply are available. A demographic module is included to simulate demographic developments at the local level. At the regional or national level the model output is consistent with existing socio-economic forecasts.

Two spatial scale levels are distinguished, namely the regional level (COROP, consisting of 40 regions in the Netherlands, equal to NUTS-3 regions) and local transport zones of the National Model System (LMS sub-zones, 1,308 sub-zones covering the Netherlands). Figure A3.1 zooms in on the Tigris XL (TXL)-part of Figure 2.1 and presents an overview of the model and the main relationships between the modules, for a more extensive description we refer to Willigers et al. (2010).

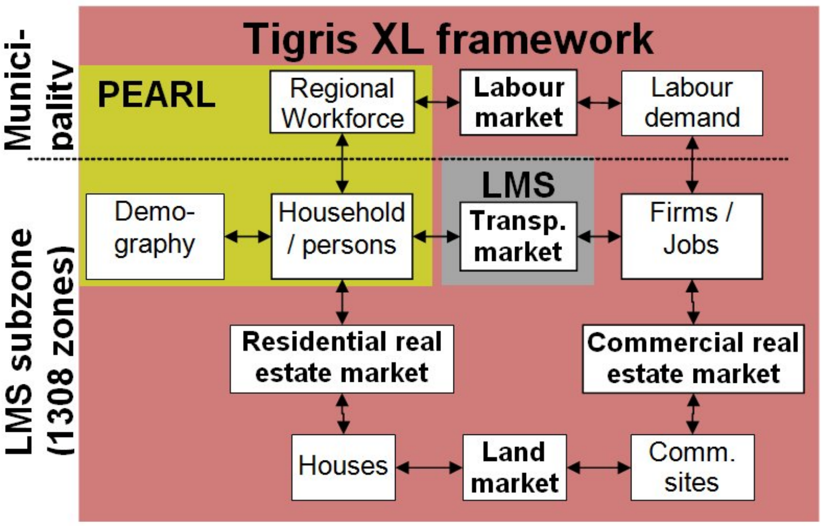


Figure A3.1 Functional design of the TIGRIS XL model

[10] This appendix is derived entirely from Zondag and De Jong (2005) .

Demography module

The demographic module addresses the transition processes of the population and households. It deals with persons by category (gender, age) as well as households by category (size, income, et cetera). The demographic module operates at the local zone level and processes, besides the transitions (e.g., ageing), the migration flows calculated in the housing market module. The demography module ensures consistency between households and persons categories for all the zones.

Housing market module

The aim of the housing market module is to simulate the annual moves (if any) of households. The module interacts with the demographic, land and real estate, labour and transport market module to account, for example, for demographic changes and changes in the supply of houses. The housing market module simulates two choices, namely the choice to move or stay and the residential location choice, conditional on a move. The residential location choice has a nested logit structure and contains a regional and local scale level: there is a choice of region and a choice of location within the region. At each level a wide set of explanatory variables have been tested in the model estimation to address differences in household characteristics, local amenities, prices and accessibility. Another important variable is the distance (travel time) related impedance, that was included to reflect the geographical dimension of the moves. The parameters of the move/stay and residential location choice function, for each household type, have been estimated on a large four-annual housing market survey in the Netherlands with over 100,000 households of 2002.

Labour market module

The labour market module in TIGRIS XL models the changes in number of jobs by sector and changes in workforce at a regional and zone level. Specific models have been estimated for seven economic sectors to account for the differences in location behaviour between sectors. For each sector the influence of accessibility on the spatial distribution has been modelled in combination with a set of other explanatory variables. The parameters have been estimated on a historical data set (1986 – 2000) including employment figures by sector at a local level. The labour market module interacts with the demographic, land and real estate, housing market and transport modules.

Transport market

The transport module calculates the changes in transport demand and accessibility. The National Transport Model (LMS) is integrated for this purpose within the TIGRIS XL framework. The land-use markets for the TIGRIS XL model generate socio–economic input data for the transport module and the transport module calculates accessibility indicators based on the changes in socio-economic data and/or transport policy measures. These accessibility indicators are input for the residential and firm location choice modules. The transport module interacts with the land-use modules every five years. The selection and statistical testing of accessibility indicators is crucial for the responsiveness and reliability of a Land Use & Transport Interaction (LUTI)-model.

Land and real estate market

The land and real estate market module processes the changes in land-use and buildings, office space and houses, and addresses both brown field and green field developments. The land and real estate market interacts with the housing market and labour market module. The modelling of the changes in land-use depends on the setting for the level of market regulation. This can vary from a regulated land-use planning system to a free market. In a regulated market, all supply changes are planned by the government. In a free market, supply changes are based on the preferences of the actors and only restricted by the availability of land.

Appendix 2 Regional land use (2008) and scenario results (2040)

2008	Urban area	Recreation – accommod.	Recreation – daytime	Commercial / Industrial area	Seaport	Nature – dry	Nature – wet	Agriculture – arable land	Agriculture – grassland	Agriculture – greenh. hortic.	Agriculture – perenn. crops	Building lot
Outside Provs.	31	4	2	13	0	29	253	313	479	1	8	4
Groningen	15598	447	442	3728	453	14421	5812	98890	83067	95	409	2513
Friesland	16355	1607	541	4059	71	34901	17042	36574	211211	181	383	1992
Drenthe	14849	2069	331	3250	0	52553	6186	74732	100181	389	736	1650
Overijssel	23867	2167	344	6357	0	45477	12468	30787	196866	192	1385	2064
Gelderland	43661	4256	1385	9815	0	120801	9837	45343	229523	937	10849	3735
Utrecht	22658	702	391	4058	0	19451	5575	6412	68477	235	2682	1897
Noord-Holland	45481	1793	1892	8502	1264	27607	10869	63093	85152	2044	1812	4336
Zuid-Holland	52485	1385	2026	10313	4982	15702	11594	58306	91186	8930	3121	6499
Zeeland	9749	2190	263	1902	1435	14491	2552	99420	29412	338	5500	2119
Noord-Brabant	54496	2466	1178	14175	828	90649	7061	95531	189991	1721	9148	5940
Limburg	27698	1512	752	7725	0	35646	6551	53193	64720	1263	5747	1437
Flevoland	9202	623	938	2054	0	16994	6930	80209	15817	448	1982	2600
Total	*336,130*	*21,221*	*10,485*	*75,951*	*9,033*	*488,722*	*102,730*	*742,803*	*1,366,082*	*16,774*	*43,762*	*36,786*
RC scenario 2040												
Outside Provs.	31	4	2	15	0	0	507	190	374	1	9	3
Groningen	16086	495	442	3752	456	10726	9197	98818	82956	36	398	2513
Friesland	16904	1779	539	4100	70	37653	21254	36285	204639	259	510	925
Drenthe	15751	2291	330	3204	0	35733	22528	74685	100277	336	1254	537
Overijssel	25723	2400	344	6083	0	39319	25994	30147	189554	108	1615	376
Gelderland	46923	4713	1397	9481	0	136705	40713	39526	190205	384	9033	247
Utrecht	24665	777	1515	4070	0	21807	14891	5185	57081	97	2324	126
Noord-Holland	47364	1985	4918	8332	1165	31936	24072	60881	69796	624	1599	837
Zuid-Holland	55210	1534	8437	8992	4691	17786	22769	55705	82494	4096	2262	1601
Zeeland	10208	2425	266	1477	1225	15588	4628	98795	29162	85	4964	548
Noord-Brabant	57295	2731	1178	12526	616	91929	31026	90836	174059	867	9166	618
Limburg	28314	1674	752	6800	0	31753	17766	51987	61236	571	4687	704
Flevoland	10683	690	935	2063	0	4228	19134	79917	18052	298	1113	496
Total	*355,157*	*23,498*	*21,055*	*70,895*	*8,223*	*475,163*	*254,479*	*722,957*	*1,259,885*	*7,762*	*38,934*	*9,531*
GE scenario 2040												
Outside Provs.	31	4	2	15	0	29	253	275	513	1	9	4
Groningen	19722	603	442	4623	730	15955	7289	96772	78690	114	400	535
Friesland	20821	2168	540	5328	113	36383	19741	35422	203489	426	380	106
Drenthe	20202	2791	331	4141	0	56428	7116	71218	92772	1025	712	190
Overijssel	34092	2923	344	8322	0	49993	14215	28040	182119	243	1312	60
Gelderland	64615	5740	1391	12489	0	123874	10947	39489	208501	1232	10913	136
Utrecht	37717	947	953	5324	0	19970	6620	4386	54073	262	2277	9
Noord-Holland	64478	2418	3405	10456	1482	28892	13800	55464	68816	2015	1844	439
Zuid-Holland	77305	1868	5232	11595	7602	18457	13528	47543	67891	11617	2872	67
Zeeland	12457	2954	265	2354	2034	16250	2756	97121	27471	222	5288	199
Noord-Brabant	73475	3326	1178	16394	836	94766	7771	88222	175827	2361	8162	529
Limburg	32814	2039	752	8632	0	38977	7311	49178	59448	1576	5367	150
Flevoland	15518	840	937	2993	0	17957	7113	75144	14095	945	1911	156
Total	*473,247*	*28,621*	*15,772*	*92,666*	*12,797*	*517,931*	*118,460*	*688,274*	*1,233,705*	*22,039*	*41.447*	*2.580*

The above table presents an overview of the land use per province in 2008 and the resulting land use for 2040 for both scenarios.

A short description of the land-use types used in the simulation is provided below.

1. Urban area - residential areas, including shops, restaurants, cafes, hotels and socio-cultural facilities such as schools, churches, hospitals and theatres, public facilities such as municipal offices, government buildings, police stations et cetera, burial grounds, parks, sports fields and allotment gardens.
2. Recreation – accommodation: recreational facilities for overnight stay (including camping's, bungalow parks and second homes). Also referred to as short or long holiday recreation
3. Recreation – daytime: the predominantly green recreational facilities for day trips (including: theme parks, zoos and open air museums).
4. Commercial / Industrial area: commercial areas on business estates, mining and dump sites.
5. Seaport: large coastal harbour areas.
6. Nature – dry: all types of dry natural vegetation (e.g., forest, heath land).
7. Nature – wet: all types of wet natural vegetation (e.g., swamps, marshes, forests in swamps, reed).
8. Agriculture – arable land: land used for potatoes, beets, cereals, flower bulbs and similar crops.
9. Agriculture – grassland: agricultural land for grazing livestock consisting of grassland and, to a lesser extent, fodder maize.
10. Agriculture – greenhouse horticulture: greenhouse horticulture.
11. Agriculture – perennial crops: orchards and tree nurseries.

The following land-use types are present in the maps of current and simulated land use, but are not allocated by the simulation algorithm:

1. Infrastructure – rail: railways and related buildings (e.g., stations).
2. Infrastructure – road: main roads and related buildings (e.g., bus and petrol stations)
3. Infrastructure – airport: runways and related buildings (e.g., hangars), unpaved grounds and buildings of service providing companies are not included here.
4. Exterior: land outside Dutch territory, i.e. Belgium or Germany
5. Water: including all types of water: large sweet-water bodies (IJsselmeer with the connecting lakes and water storage basins for drinking water and industry), the Rhine and Meuse river courses, water with a predominant recreational function, the North Sea and neighbouring salt water bodies (Waddenzee, Oosterschelde, Westerschelde and closed off estuaries) and the remaining inland water bodies wider than 6 meter such as canals, lakes, ditches and harbours. Also included here are the water bodies in use for the extraction of sand or gravel and the storage of industrial waste water.

In total the model distinguishes 17 types of land use. Apart from the 16 listed above it also includes a rest category that consists of building lots (where construction has started or will start in the future) and other partially paved terrains. The former category of construction sites is available for new land-use functions in the simulation, leading to a strong decrease in the surface area of this category.

Appendix 3 Procedure for creating land use 2008 base map

Calculation of ggLUMOS base map land use 2008 (25m raster cells)
The vector file CBS Soil Statistics 2008 is rasterized using the rasterize-tool from the Geospatial Data Abstraction Library (GDAL). The conversion is done using the center-point principle. The result is a grid-version of the CBS-vector file with a resolution of 25 meter and 38 classes, which is used as the basis for the analysis described below.

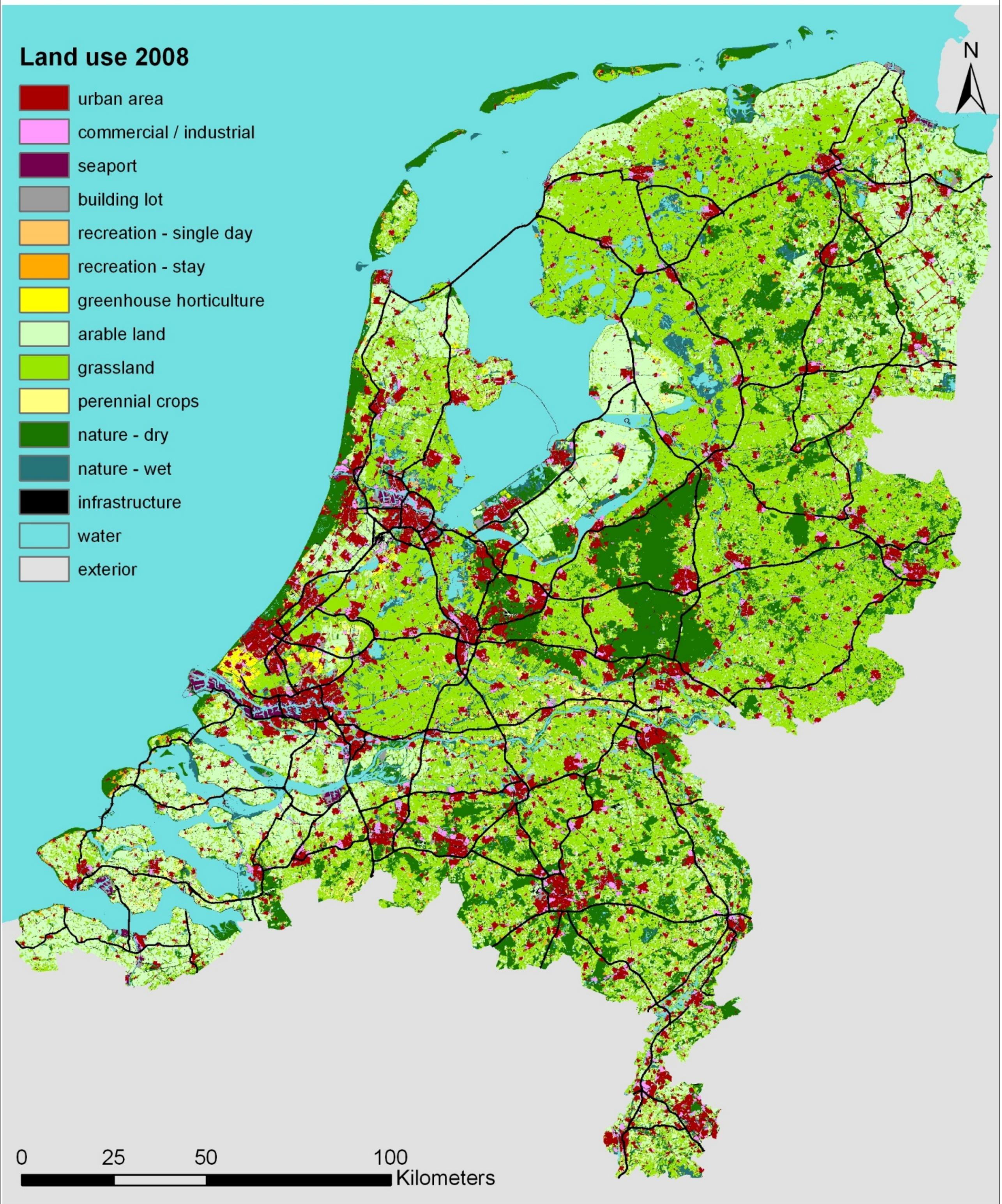
First, the CBS Soil Statistics classes 51 (agriculture), 60 (forest), 61 (dry natural areas) and 62 (wet natural areas) are enriched using information on crop types, nature and vegetation from the Dutch Land Use Data set LGN (version 6) from Alterra, Wageningen University and Research Centre. Information from the following LGN-classes is used: 1 through 6, 9 through 12, 26 (built-up in rural areas) and 28 (grass in secondary built-up area) and 30 through 43, classes 45, 61 and 62. When within the aforementioned CBS classes LGN would indicate another land use than agriculture, nature or forest, the CBS class is maintained, so in these cases the information from LGN is not used, with the exception of the two aforementioned classes 26 and 28.

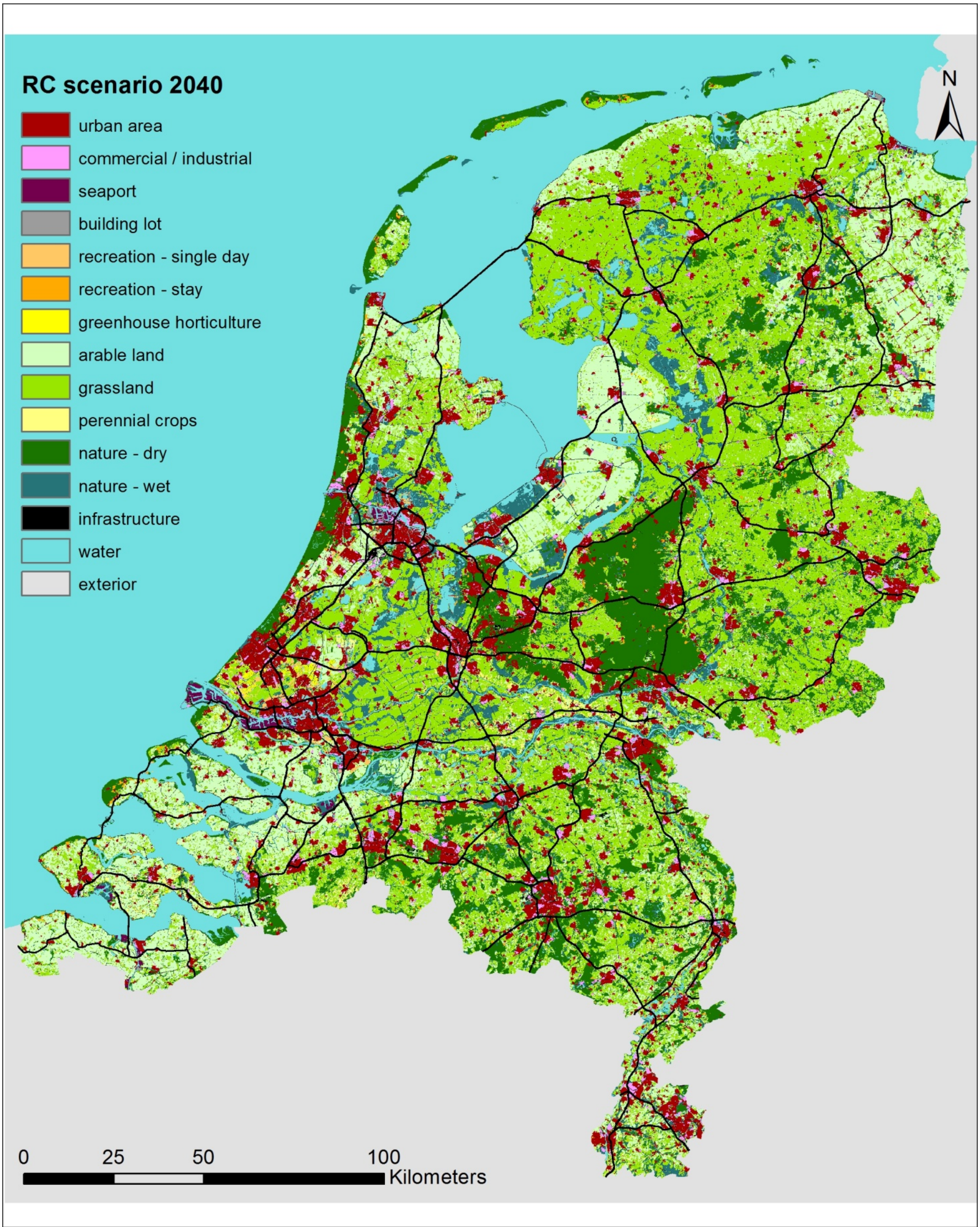
In step 2, the CBS class 20 (residential) is enriched by using the five housing environment types ('woonimilieutypen') from ABF-research (Technical University Delft):
1 – Residential area – High density (city centre)
2 – Residential area – High density (outside city centre)
3 – Residential area – Low density (green and urban)
4 – Residential area – Low density (villages)
5 – Residential area – Rural

After that, in step 3 the CBS classes 22 (public services) and 24 (commercial areas) is enriched by using information from a data set specialized in commercial and industrial sites (IBIS, 2011). Only class 2 (seaports) is used from this data set.

Appendix 4 Detailed land-use maps

This appendix presents the detailed land-use maps for 2008 and 2040 according to the Regional Communities and Global Economy scenario.




RC scenario 2040
urban area
commercial / industrial
seaport
building lot
recreation - single day
recreation - stay
greenhouse horticulture
arable land
grassland
perennial crops
nature - dry
nature - wet
infrastructure
water
exterior
N
0
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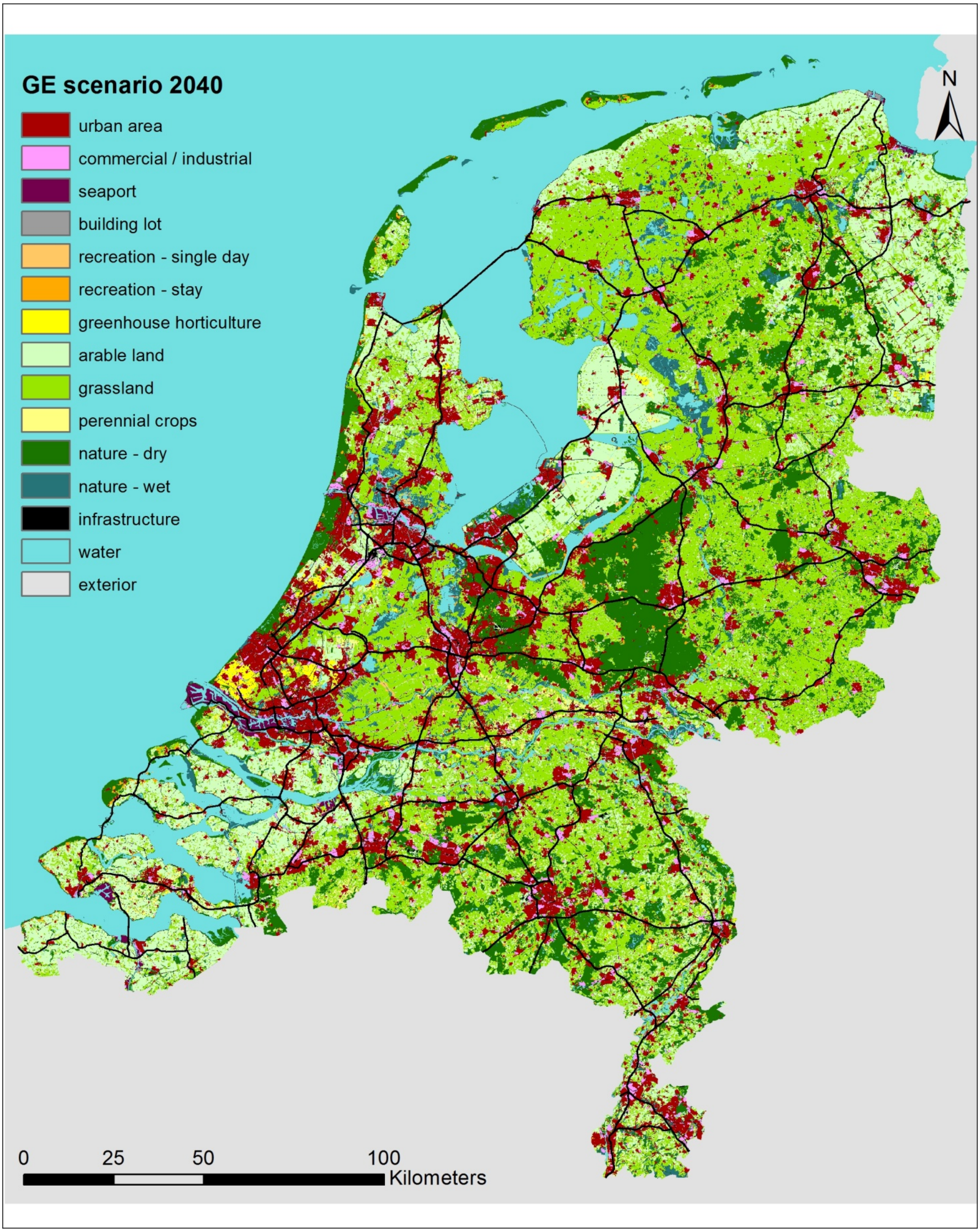
Kilometers


GE scenario 2040
urban area
commercial / industrial
seaport
building lot
recreation - single day
recreation - stay
greenhouse horticulture
arable land
grassland
perennial crops
nature - dry
nature - wet
infrastructure
water
exterior
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Kilometers

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