DRIVING FORCES OF LAND-USE CHANGE

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Abstract
This paper presents a multi-sectoral overview of the key driving forces of land-use change. As part of the design phase for a new land-use model for the Netherlands Environmental Assessment Agency, an overview was made of spatial processes and policies affecting land use. The overview was based on five sector-specific research efforts into the driving forces of land-use change, for each of the five largest land-occupying sectors (housing, employment, nature, water, and agriculture). Each research effort had a similar set-up and consisted of a leading expert, responsible for preparing a note on driving forces for a particular sector, and the input from leading experts, using workshops to collect views and insights from the field. In addition to the five largest land-using sectors, the research focused on the themes transport, energy, and recreation, which are related to nearly al other sectors as they have a large influence on spatial developments and evaluation indicators.

For this paper, underlying research was used for discussing main drivers for the different sectors. Based on insights into main and upcoming driving forces, the main challenges to be addressed in the development of a new land-use model were identified.

1. INTRODUCTION

The Netherlands Environmental Assessment Agency (PBL) actively applies land-use models to support their policy studies. PBL land-use models, the Land Use Scanner (Hilferink and Rietveld 1999) and the Environment Explorer (Nijs et al. 2001), since 1997, have contributed substantially to several large-scale studies to research findings and policy recommendations (see RIVM and Stichting DLO 2001 and 2002, MNP 2004a, MNP 2004b, MNP 2007, Deltacommissie 2008, VROM 2008). The PBL now has the ambition to build a new or second-generation land-use model. The new model will build on our experiences in this field, and on advice obtained from an external audit committee on land-use models, which evaluated the PBL models in 2007 (Timmermans et al. 2007). The main observation from the audit committee stated that the existing land-use models of PBL were among the best in their field, but the socio-economic activity perspective should be further embraced to adequately address environmental risk assessments involving population distribution data, as well as upcoming questions regarding prices and management. This implied either a substantial redesign of the model, or the development of a new land-use model.

The ambition to make a new model (or adapt an existing one) opened up a rare opportunity to look carefully at the building blocks of such modelling. What were the upcoming policy issues, which drivers and processes needed to be modelled, and what was state-of-the-art in land-use modelling? This paper by Borsboom and Zondag (2009) gives an overview of these different components and discusses how these components were integrated into the design of a new land-use model. The analysis or inventory of the driving forces behind land-use change, as presented in this paper, is one of the components of this model's design phase. The results from the analysis present the driving forces and the important processes which need to be included in the new land-use model.

The analysis of the driving forces focused on the five major land-occupying sectors in the Netherlands: agriculture, housing, water, nature and employment. For each sector, a comparable approach was used, consisting of a leading expert preparing a note on the driving forces behind land use for that sector. Such a note reflected the knowledge of the leading expert, and was supplemented – in one or two expert workshop – with the knowledge of an expert panel on relevant driving forces and the impact on the spatial distribution of activities and land use. Participants from different backgrounds, such as academic institutions, government agencies and consultancy, were invited to these workshops, to capture the differences in knowledge and opinions. Five sector-specific reports on the driving forces behind land use resulted from this activity.

In addition to these five sectors, three themes were identified: *transport*, *energy* and *recreation*, which interact strongly with the sectors and influence land-use predominantly indirectly. For each theme, separate notes were written internally at PBL, based on literature review and expert interviews. It should be noted that the sectors influence each other and the driving forces of a sector are influenced by developments in the other sectors. A sector-specific set-up was chosen for these notes to keep the scope manageable and to provide in-depth information. The sector-specific notes were then used in a multi-sectoral workshop, organised to discuss main interactions between the sectors.

This paper presents selected main driving forces which influence land use in these sectors. In Section 2, clusters of drivers affecting land use in most sectors are discussed briefly. These clusters consist of a set of driving forces which influence land use in different ways. In Section 3, particular effects of the driving forces on land use are discussed on sectoral level. Per sector, tables provide an overview of the impact of the driving forces on land use. Finally, Section 4 presents main challenges for the new land-use model, based on the analysis of the driving forces.

2. CLUSTERS OF DRIVING FORCES OF LAND-USE CHANGE

The clusters of interrelated driving forces represent either main societal changes or the natural system. Each cluster can be separated into many specific driving forces affecting specific elements of the spatial system. Figure 1 presents an overview of the mega drivers behind land-use change.

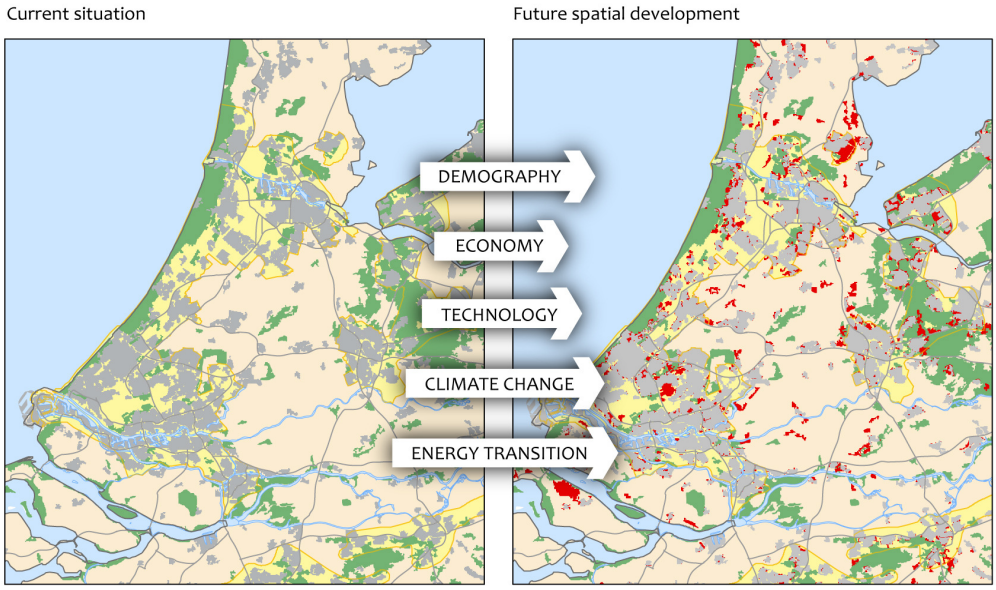

Figure 1: cluster of driving forces influencing future land use

Apart from these clusters of driving forces, future land use will be strongly affected by existing patterns of land use and by spatial and other policies. Policies can affect land use directly (e.g. spatial policies) or via driving forces (e.g. subsidies on new technologies); therefore, they have not been included as a separate arrow in the figure.

Existing spatial patterns of land use, objects and activities

Existing land-use patterns cannot be considered clusters of driving forces, but have a very dominant influence on future land use. The time dynamics of the changes in land-use are very slow and therefore the existing land use is a very important given for future land use. Further the likelihood that a land use change occurs at a location depends on the existing land use. It is, for example, rather unlikely that existing areas which are highly valued, either ecologically or economically (high sunk costs), will easily transform their functionality. This situation is often represented as geographical inertia. Secondly, existing ecological, cultural, water and transport networks strongly influence the choice of location for new developments, as do

residential and commercial activities. However, with the expanding stocks of residential and commercial buildings, over the years, dynamics increasingly take place in the way of changes or transformations within building stocks at existing locations.

Demography
'Demography' is a cluster of driving forces consisting of different components which affect size and composition of population and households. Demographic developments are especially influential, because the behaviour of actors is often related to demographic characteristics.

Economy
Under the heading 'economy', a wide set of economic developments and determinants were clustered. Examples of important economic developments affecting land use are: growth in income and trust funds, rise in double-income households, changes in economic structure, agglomeration forces, global and local market developments (e.g. agricultural products), and organisation of production processes. Furthermore, each of these economic components is also influenced by different factors; a description of these relationships can be found in the supporting notes, per sector.

Technology
Technological developments are an important driving force behind developments in many sectors and the organisation of society as a whole, which often results in land-use changes. Examples are technological developments which increase productivity in agriculture, technological options affecting underground storage or desalination of water, or internet enabling online shopping.

Societal values and trends
Societal values have an important impact on almost any type of land use. For example, changes in people's lifestyles can directly affect housing types and locational preferences, as well as consumption patterns, and with that the type and location of economic production. More indirectly, societal values regarding nature, landscape or agricultural production, for example, may affect governmental budgets, such as for nature development, and restrictions and regulations could affect the size and type of agricultural production.

Climate change and energy transition
Climate change influences land use in multiple ways; for example, via rising sea levels, periods of intensified rainfall or drought, changing temperatures and humidity affecting conditions for biotopes or agricultural production. Consequences of climate change changes policies, such as mitigation or adaptation strategies. The need for energy transition from fossil fuels towards more sustainable energy production is driven by mitigation policies addressing climate change, as well as by a growing scarcity of accessable fossil energy sources. The impact of such a transition is likely to differ from sector to sector, because of the varying complexities, possibilities and costs of such transitions. In transport, for example, such a change of energy source is complicated, because of on-board storage of energy sources (e.g., in cars and aircraft). If petroleum sources become scarce, and alternative fuels remain rather unsuccessful, large price increases could affect the transport market and, indirectly, the organisation of economic production and urban systems (processes such as globalisation and urban sprawl).

Policies

To realise governmennt ambitions, the various government levels have access to a large and diverse set of policies affecting land-use. These policies can be categorised by dimension:

- Scale: international, national or local;
- Sectoral level: spatial planning or sector specific;
- Type: juridical and financial, and communication/information instruments.

The list of relevant policies is too numerous to include in this paper. Within the LUMOS research project, a report has been prepared on 'Policy questions and indicators for a new land-use model' (GeodanNext 2009).

3 DRIVING FORCES OF LAND-USE CHANGE, PER SECTOR

Within the LUMOS research project, an overview of the drivers of land-use change, per sector, was presented in sector-specific notes written by leading experts in the field. The short descriptions in this section are based on these notes, for more detail we refer to the underlying notes (in Dutch):

- Driving forces behind housing demand and residential land use – Hugo Priemus and Joris Hoekstra (OTB – Delft University of Technology)
- Driving forces behind land-use for employment – Oedzge Atzema, Piet Korteweg, Jan Lambooy and Frank van Oort (University of Utrecht)
- Driving forces behind future land use for agriculture – Cees van Bruchem and Huib Silvis (Agricultural Economics Research Institute (LEI))
- Driving forces behind changes in land use for nature and use of land for water– Annemarie Groot, Eddy Moors and Claire Vos (Alterra – University of Wageningen)

The descriptions below reflect the interpretation and selection of the authors of the underlying notes.

3.1 Driving forces of land-use change in housing

Historically, housing market developments are largely explained in connection to demographic developments, such as birth rate, life expectancy, household formation and dissolution, and international migration. The variety in types of households is increasing due to factors, such as individualisation and an increasingly multi-ethnic society. A rather recent phenomenon in some Dutch regions is demographic shrinkage instead of growth as a driver of possible land-use change. These developments call for increased detailed information on the types of households, to address differences in their preferences, and increased regionalisation, to address the differences in the regional challenges (such as pressure on the housing market due to growth around Amsterdam, versus shrinkage in some areas in the periphery).

Another set of increasingly important driving factors are economic and financial drivers, such as income (including an increase in double-income households) and capital development. Many of the housing policy options of the government are also financial instruments, such as taxation on housing transfer, fiscal support (tax deductions) for house owners, liberalising rents, shift in housing subsidies for people on low incomes, from rental housing only, towards all housing. To create a model simulation of these drivers, the financial position of households, housing prices and financial interference of the government must all be explicitly entered into the model.

The supply side of the housing market (housing stock by type and location), is affected by other important policy drivers. For the supply side, the existing pattern of infrastructure, houses, employment and land use (e.g. ecological areas) are important givens, as changes happen slowly, and are strongly influenced by existing patterns. Changes within the existing housing stock are becoming increasingly important, such as urban renewal or gentrification, and urban facilities and qualities. In addition, the relationship between supply and demand is changing and becoming more complex, as a result of increased ownership of second homes, an unclear distinction between houses with a purely temporary, recreational function and regular houses, and a more short-term occupation of houses (for example, seasonal or short-term workers from Eastern Europe). Improving the inclusion of these aspects is hampered by data restrictions, definitions and omissions. This applies, for example, to lack of data on housing and substitute housing (holiday homes, caravans, boats, commercial buildings), or on unregistered international migration.

Table 1 presents a detailed overview of the driving forces behind the housing demand and residential land use. For an in-depth understanding of the relationship between driver and land-use changes, reference is made to the underlying report by Priemus and Hoekstra (2009).

Table 1: Driving forces behind housing demand and residential land use

	housing demand	**land use per household**
Demography		
Lower fertility	-	-
higher life expectancy	+	+
Increasing variation household types	+	+
life styles	±	±
diminishing household sizes	+	-
extramural care elderly	+	+
emigration developments	±	±
immigration developments	±	±
increasing multi-ethnicity	0	0
regional population decline	-	0
Economy		
Increasing income	+	+
increasing capital	+	+
Increasing number of double-income households	+	+
Increasing energy costs	-	-
Increasing regional differences	±	±
Policy changes		
abolishing conveyance tax	0	0
abolishing fiscal benefits house owners	-	-
transfering rental allowance to housing allowance	+	+
shifting public housing to private property	-	+
Liberalising rental prices	-	?
Less regulated spatial planning	+	+
Current spatial pattern of houses and land use	**housing demand**	**location of houses**
size, location and type of existing housing stock	0	+
size, location and type of holiday homes	+	+
current spatial distribution of households	+	+
land positions and spatial plans	0	+
natural areas	0	-
Location of employment	+	+
Railway station or slip roads	+	+
Noise or air pollution	-	-

3.2 Driving forces of land-use change in agriculture

The changes in agricultural land use can be distinguished as:

1. Conversions from agricultural land to urban land or nature areas;
2. Changes in type of agricultural production;
3. Changes towards multi-functional land use, such as agricultural land use for business or pleasure, combined with recreational or nature functions.

In general, conversions of agricultural land are driven by exogenous developments outside the agricultural sector, such as urbanisation or nature development. The changes in agricultural production are driven by worldwide developments on the market for agricultural products, environmental regulations and technological innovations. The change towards multi-functional agricultural land use varies per region, and is driven by regulations and subsidies for nature and landscape management, and by the attractiveness of different opportunities for farmers to increase their incomes.

Demographic and economic developments in the Netherlands result in a need for more urban land, which is won through the conversion of agricultural land, mainly affecting crop farming and cattle farms. Worldwide demographic and, especially, economic developments (for example, rising incomes in China and India) result in a growing demand for agricultural products, such as meat and milk. This will be beneficial to Dutch cattle farmers and could result in increased land use for this type of agriculture (leaving less land available for arable farming). It should be noted that environmental restrictions, such as on nutrients or ammonia, and technological opportunities will strongly influence this development. A worldwide increase in welfare may also result in an increasing demand for horticultural products. However, the amount of additional land needed in this sector will be modest, as horticultural productivity per hectare is very high, and is still increasing.

The effects of climate change could have an impact on agriculture via periods of intensified drought and rainfall, seepage of salt water and additional demands for water storage. Energy scarcity or energy taxation, as part of a mitigation policy, are likely to result in higher energy prices which may affect greenhouse farming. However, this sector may also benefit from these higher prices, because it also has potential as producer of energy. In addition, high energy prices may promote the production of agricultural biofuels. This is probably not going to be a voluminous sector within the Netherlands because of high land prices, but internationally much agricultural land is used in the production of biofuels, and this might offer potential for increasing the Dutch production of other agricultural products.

Technological developments have been, and are expected to remain, a dominant driver behind changes in agriculture. In general, technological developments have resulted in higher levels of productivity in terms of land and employment, and, therefore, it is possible to increase agricultural production while agricultural land areas are diminishing. Future important technological developments are expected in the fields of genetic modification, nanotechnology and robotics. The agricultural sector is influenced by a diverse set of policies from different tiers of government, including trade agreements (e.g. WTO discussions), EU policies regarding milk quotes; income support or environmental regulations; national subsidises and restrictions regarding landscape, ecological services and development of natural areas; and local policies and permits (e.g. development of greenhouse farming).

Table 2: Driving forces of agricultural land use per sector

	arable farming	**cattle farming**	**horticulture**
Demography and society			
Population growth NL	-/0	-/0	-/0
Population composition	0	0	0
Green land functions	-	-	0
Red land functions	-	-	0
Market developments			
Increasing welfare worldwide	-	+/++	+
Higher energy prices / biofuel prices	+	-	-/0
Second-generation biofuels	-/0	0	0
Technological developments	±	±	±
General policies			
Less regulated spatial planning	-	-	+/0
Stricter ammonia policy	0	0/-	0
Lower derogation	-	++	0
Agricultural policies			
WTO liberalisation	-/0	-/0	-/0
Increase milk quote	--	++	0
Increasing modulation	0	0	0
Change to flat rate	0/+	-	+/0
Change to income support, based on contribution for nature, environment and landscape	-/0	0	0

3.3 Driving forces of land-use change in employment

In the analyses, land use related employment was divided in two components which are influenced by driving forces differently, namely the spatial distribution of employment and the land use per worker. For the five economic sectors, the spatial distribution and density of employment differentiates strongly. Table 3 presents the differences in land use per economic sector. The agricultural sector is not included, as it has already been discussed in the previous section.

Table 3: Land-use characteristics per economic sector

Sector	**Employment density**	**Distribution**
Industry	Low	Regional dispersion Local (de)concentration
Transport & distribution	Very Low	Regional dispersion Local (de)concentration
Intermediate services	Very High	Regional dispersion Local (de)concentration
Final services	High	Regional dispersion Local (de)concentration
Public services	High	Regional dispersion Local concentration

The land-use characteristics of the sectors show that a change in economic structure, for example, from industry to final or public services, affects the density and location of employment. At the local level, many sectoral processes of concentration and de-concentration occur driven by different locational factors, such as accessibility and environmental regulations.

Important driving forces affecting land use in economic sectors are locational factors, organisation of companies, and the discussed economic structure per sector. Besides traditional locational factors, for example, transport cost, labour supply, and cost and agglomeration factors such as consumer market size, the so-called soft locational factors are becoming more important. Examples of these factors are the skills of employees (and training opportunities), access to knowledge, quality of residential amenities, environmental regulations, and image of a location.

Table 4: dominant locational factors per sector

Sector	**Locational factor**	**Distribution effect**
Industry	Transport costs Labour costs	Local dispersion Regional dispersion
Transport & distribution	Transport costs Land prices	Local dispersion Regional dispersion
Intermediate services	Accessibility Quality of labour ICT network/services	Local concentration Regional concentration Regional dispersion
Final services	Accessibility Quality of neighbourhood	Local dispersion Local concentration
Public services	Access Visible location	Local concentration Local concentration

Overall changes in the organisation of employment towards more knowledge-intensive and network organisations, generally, result in a higher density of employment and concentration (although the geographical scale of concentration differs per sector). At a micro-level, the life

cycle of companies has an important impact on their location and land use, as growth is an important factor, possibly resulting in relocation. For example, a region with a large share of starting companies will have a high level of employment at non-business locations (e.g. in residential areas), whereas regions with more established companies will have a higher demand for commercial sites and business parks.

Important underlying drivers of land-use change are developments in the labour market, real estate market, and in governmental policies. The demographic prognoses, affecting the supply side (labour force) of the labour market, generally, show a rather stable population size, but – due to an increasing number of elderly – a shrinking potential labour force. A direct impact of this change in labour force can be mitigated by changes in labour participation of especially woman and the elderly. The demographic developments differ strongly between regions, as several regions have a shrinking labour force along their periphery while, in the centre, the labour force is stable or even growing.

In the real estate market, a shift is expected from a quantitative growth in commercial sites (including office space), towards a qualitative focus on the renewal and restructuring of existing sites and buildings. In combination with the urban densification policies of the government, this might result in less additional land needed for employment, and more intensified use of existing sites and properties. Table 5 presents the demand and supply trends, affecting commercial buildings and offices; the overwhelming trend is towards densification and concentration.

Table 5: demand and supply drivers affecting the real estate market

Sector	**Distribution effect**	**Density**
Demand trends commercial buildings		
Intensified use of capital	-	Higher densities
Cost efficiency	Regional concentration	Higher densities
Increasing land prices	Local concentration	Higher densities
Rental market	Local dispersion	Higher densities
Increasing importance services	Regional concentration	Higher densities
Globalisation	Urban concentration	Higher densities
Supply trends commercial buildings		
Commercialisation	-	Higher densities
Standardising	-	Higher densities
Compensation	-	Higher densities
Restructuring	Local concentration	Higher densities
Trends affecting office space		
Quality increase	Urban concentration	Higher densities
Scale reduction	-	Lower densities
Owner - occupier	-	Higher densities
Part-time work	Urban concentration	Lower densities
Technological innovations	-	-
Organisational innovations	Urban concentration	Higher densities
Flexible use	-	Higher densities
Globalisation	Urban concentration	Higher densities
Risk management	Urban concentration	Higher densities

3.4 Driving forces of land-use change in nature

The driving forces behind changes in land use have been grouped into societal, economic and physical drivers, and policy drivers (see Table 6 for a detailed overview of the drivers). The demographic and societal changes affect the size, composition and behaviour of the population, from which the demand for nature areas stems. An important driving force is the increasing demand for nature areas to be used for outdoor leisure activities or for short stays (e.g. camping). This trend offers opportunities for nature, as more agricultural land may be converted into it. However, this increasing human activity may reduce the quality of nature land use, for example, through overcrowding or loss in biodiversity.

Changes in the agricultural sector have a large impact on the size and quality of nature areas. In this sector, economically driven scale increases negatively affect the size of nature areas, as small natural elements in the landscape disappear, and larger barriers are created between nature areas. Urbanisation, driven by economic and demographic developments (as economic growth and reduced household sizes), is contributing to further fragmentation of nature areas. Even stronger is the impact of infrastructural construction, as it confines and cuts off nature areas, which leads to further deterioriation of habitats. In addition, both urbanisation and transport contribute to noise, air and light pollution in these areas, which may affect biodiversity.

Climate change could become particularly important to nature in the Netherlands. Higher average temperatures, more periods of intensified drought and rainfall, and increasing problems with seepage of salt water in the west part of the country are expected. These changes affect the existing nature areas, but adaptation measures, such as additional water storage, provide opportunities for combining these with nature development. The water management approach is an important driver for nature areas. Water security, for example, can be achieved more technically via dikes and infrastructural measures, or more naturally via enlargement of river banks creating options for nature development. Another example is the regulation of water levels, influencing an area's ecological value while providing often needed balance with productivity needs in the agricultural sector.

EU policies and regulations affecting the size and quality of nature areas are the EU Water Framework Directive and the Natura 2000 network. At national level, the National Ecological Network (EHS) contributes to the size and quality of nature. This policy focuses especially on connecting the different nature areas within the country, thus, supporting biodiversity and robustness.

Table 6: driving force behind changes of land use in nature

	Land use for nature	**Effect on quality of land use for nature**	**Magnitude of impacts on land use**
Societal drivers			
Demography	+	-	Reasonable
Recreation (daily)	+/-	+/-	Reasonable
Recreation (accommodation)	-	-	Reasonable
Residential use of countryside housing	0	+/-	Small
Economic drivers			
Environmental agriculture	+	--	Very large
Scale increase agriculture	-	-/+	Very large
Urbanisation	0	-	Large
Infrastructure	0	-	Very large
Mobility	-	-	Large
Physical drivers			
Intensified drought	0	-	Reasonable
Seepage of salt water	0/+	-/+	Large
Intensified rainfall	0	-	Small
Adaptation measures	+	-/+	Small
Water management	-/+	-/+	Large
Water security	-/+	-/+	Large
Air pollution	0	-	Small
Areas with protected species	0	-	local
Policies			
EU Water Framework Directive	+	+	Large
Natura 2000 network	+	+	Large
National Ecological Network (EHS)	+	+	Large

3.5 Driving forces of land-use change for water

The underlying driving forces behind land use for water (namely societal, economic, physical and policy drivers) are similar to those for nature, see Table 7 for a detailed overview of the drivers. The interaction between land use and water consist of direct impacts on land use, such as areas reserved for rivers or water storage, and indirect impacts of water affecting land use via hydrological systems. Hydrological conditions support certain types of land use (ecological systems or agricultural production), and these downstream conditions can be protected by upstream regulations.

Appreciation of water for recreational purposes in residential environments and as landscape elements is increasing, which results in increasing use of land for water. For example, housing prices increase near the waterfront. Such trends can be combined with the demand for additional water storage from intensified local rainfall in and around urban areas. Economic and population growth in regions, increasing the potential flood damages, can result in stricter guidelines for water safety to protect these regions. The water safety measures can lead to additional land claims related to water.

Existing physical forces, such as land subsidence in the west of the Netherlands, in combination with changing forces due to climate change, such as rising sea levels and intensified rainfall and drought, have an important impact on the amount of land use for water and water quality. Most physical drivers indicate that additional water storage is needed, the consequences of land use for water are positive, but the amount of additional land needed for water is uncertain depending on the preferred solutions (e.g. new lakes/reservoirs, raising water levels or infrastructural measures).

EU policies and regulations consist mainly of supporting directives to reach water quality and security goals. The Water Framework Directive and the Implementation of nitrates Directive mainly affect the water quality. The Natura 2000 network and the Dutch National Ecological Network both also protect water areas.

Table 7: driving forces behind changes of land use for water

	land use for water	**Magnitude of impacts on land use**
Societal drivers		
Water-related recreation	+	+
Housing at the waterfront	+	++
Urbanisation	+	+
Cultural values	+	++
Economic drivers		
Welfare	+	++
Water safety incidents	+	++
Transport on water	+	0
Technology	-	--
Physical drivers		
Water security	+	++
Technology	-	--
Local water problems	+	++
Mitigation seepage of salt water and droughts	+	++
Policies		
EU Water Framework	+	+

Directive/nitrate guideline		
Natura 2000network/EHS	+	+
EU Floods Directive	+	+

4 MAIN CHALLENGES FOR THE NEW LAND-USE MODEL

So far, this paper has given an overview of the driving forces behind land-use change for the main land-consuming sectors. As was the research objective, this effort was part of a larger designing process resulting in the specifications for a new Dutch land-use model for the Netherlands Environmental Assessment Agency (PBL). This final section discusses the main challenges for a new land-use model, reflecting the main and upcoming driving forces and current state of practice in these models.

Based on a review of the driving forces, the list below summarises the main challenges for a new land-use model:

- Shifting focus from modelling quantity (houses, office space, etc) towards quality. Such a shift includes more attention for modelling of existing built-up areas and processes of transformations or renewal within these areas. Traditionally, land-use models at PBL focus on green field developments. In addition, more attributes will have to be modelled, for example, ownership;
- Increasing regional diversification, as it is expected that in the coming decades the Netherlands will face a pattern of growing and shrinking regions, in terms of population and employment. These processes will also have an impact on the functionality of areas, as they effect the potential for large-scale agriculture, nature development, recreation (day recreation, and holiday homes) and services. Traditionally, land-use models focus on growth, and diverse land-use claims are allocated to scarce land resources;
- Modelling land use (e.g. residential), objects (e.g. houses) and actors (e.g. households) in a much more integrated way. Especially, more attention for the modelling of actors is needed, as many driving forces mentioned in this paper influence the segments or behaviour of households, companies and farmers. For example, the composition of households and companies is influenced by (company) demographic processes and changes in economic structure, while their behaviour is influenced by income developments, financial incentives and taxes, and societal values. Changes in the segments or behaviour of the actors will be reflected in different land-use demands, densities of land use (e.g. number of households per hectare) and changes at different locations (e.g. suburban vs urban neighbourhoods);
- Climate changes affect physical conditions (e.g. rising sea levels, periods of intensified rainfall and drought, increasing seepage of salt water) in Netherlands, and, therewith, land use (quantity and quality) of nature water and agriculture and flood risks for urbanized regions along coasts and rivers. The water system plays a crucial role when calculating the impacts of climate change or addressing the effectiveness of adaptation strategies. Therefore, the interactions between water and land use should be included much more in a new land-use model;
- Energy transition, driven by climate change mitigation policies and high energy prices, is an important and sensitive scenario variable, affecting land use of different sectors in diverse ways. Land can be used directly to produce energy (windmills, biofuels, etc.) and to distribute it. The indirect impacts of changes in energy, for example through mobility or housing costs, can potentially be large, because it

affects the organisation of the production process and spatial developments, such as suburbanisation.

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