Simulation of Future Land Use for Water Management: Assessing the suitability of scenario-based modelling

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Abstract

The problem of water shortage is getting increased attention in the field of water management, even in the wet Netherlands. Good quality ground and surface water may become too scarce to allow for sustainable use for various functions. In order to assess the magnitude of this problem in the Netherlands, a water shortage study has been started in which the impact of land use change is an important issue. Land use models can help translate coherent sets of hypotheses regarding future developments, scenarios, storylines, into maps of a possible future. By developing scenarios that are clearly different from each other, especially on the factors that influence the problem of water shortage, divergent images of the future were generated for 2030. In this way, a first impression was developed for the bandwidth in which future developments can occur. The goal of this paper is to assess the applicability of scenario-based land use modelling in water shortage studies.

Keywords: land use, spatial planning, spatial dynamics, water management
JEL-codes: C53, R14, Q25

1. INTRODUCTION

Water management in the Netherlands is normally concerned with the prevention of flooding, but the opposite problem, water shortage, is increasingly getting attention. The idea of water shortage is not immediately combined with the wet appearance of the Netherlands. But there are indications for possible shortages of water at certain periods when the overall demand for water is high. Even in the wet Netherlands ground and surface water may become too scarce to allow for sustainable use for various functions as: transportation, irrigation, recreation and drinking water production. In order to assess the magnitude of this problem a water shortage study has been started in the Netherlands, in which the impact of land use change is an important issue.

Land use has a strong influence on the water balance of a given area: Groundwater recharge varies per land use type because of differences in infiltration and evaporation rates. Especially the increasing urbanisation and changes in agricultural areas influence problems of water shortage: An increase in built-up area causes higher peaks in the drainage systems and less infiltration, and crop choice in combination with soil type strongly influences evaporation and infiltration rates. Land use models can help translate hypotheses regarding future spatial developments into maps of a possible future.

Future land use is greatly influenced by current land use, autonomous socio-economic developments and spatial policies and in the long term climate changes and other changes in the physical environment. By using scenarios, hypotheses about developments in government policy, socio-economic factors, the climate and the physical environment can be combined. Various studies have already begun developing these scenarios, for example ICIS (2002), Koole *et al*. (2001) and CPB (1996, 2001). By combining existing future expectations into scenarios that are clearly different from each other, divergent images of the future were generated for 2030. These scenarios differed especially on the factors that influence the problem of water shortage. The resulting land use maps were used as input in specific hydrological instruments to assess the impact of land use change on water shortage. The predicted impact might lead to adjustment of current policies. The simulation of future land use was carried out using the information system Land Use Scanner.

This paper starts with a short explanation of the Land Use Scanner model and then describes the choices made in the design and composition of all aspects of the various scenarios. After that, the land use simulation results and their subsequent application in a hydrological model are discussed. Based on our experiences we then present some overall conclusions and recommendations.

2. THE LAND USE SCANNER[1]

The land use model that is used in this study is the Land Use Scanner. Inputs for the simulation of land use are the different scenarios in which expectations with regard to the future are included. Furthermore, the model uses maps of existing land use and distance decay functions in combination with attractivity maps for the various kinds of land uses in order to calculate future land use in the various scenarios.

The Land Use scanner is a GIS based model that simulates future land use. The model has been used for various physical planning projects including: the projection of land use for different planning perspectives (Schotten *et al*. 1997), the planning of a new national airport (Van de Velde *et al*. 1997), the preparation of the Fifth National Physical Planning Report (Schotten *et al*. 2001) and recently the simulation of future agricultural land use in the Netherlands (Koomen *et al*., 2005). A full description of the model is given in Hilferink and Rietveld (1999).

The Land Use Scanner offers an integrated view on all types of land use. It deals with urban, natural and agricultural functions, normally distinguishing 15 different land use categories. The model is grid based, covering the Netherlands in almost 200.000 cells of 500 by 500 meter. Each cell describes the relative proportion of all present land use types, thus presenting a highly disaggregated description of the whole country. Regional projections of land use change are used as input for the model. These projections are land use type specific and derived from sectoral models of specialised institutes. The various land use claims are allocated to individual grid cells based on their suitability. Unlike many other land use models the objective of the Land Use Scanner is not to forecast the dimension of land use change but rather to integrate and allocate future land use claims from different sectoral models. The outcomes of the model should not be interpreted as fixed predictions for particular locations but rather as probable spatial patterns.

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[1] This section uses material from Koomen & Buurman (2002)

Mathematical formulation

The Land Use Scanner uses an allocation model to match the spatial claims of the different land use types with the available land. The crucial variable for the allocation model is the suitability s_{cj} that represents the net benefits of land use type *j* in cell *c*. The higher the suitability for land use type *j*, the higher the probability that the cell will be used for this type. Suitability maps are generated for all different land use types based on location characteristics of the grid cells in terms of physical properties, operative policies and expected relations with nearby land use functions. In the simplest version of the model a logit type approach is used to determine this probability.

The model is constrained by two conditions: 1) the overall demand for the land use functions which is given in the initial claims and 2) the total amount of land which is available for each function. By imposing these conditions a doubly constrained logit model arises, which yields as a side-product the shadow prices of land in the cells.

In the doubly constrained model the expected amount of land in cell *c* that will be used for land use type *j* can be formulated as:

$$M_{cj} = a_j \cdot b_c \cdot \exp(\beta \cdot s_{cj}) \tag{1}$$

In which:

M_{cj} is the expected amount of land in cell *c* that will be used for land use type *j*.

a_j is the demand balancing factor (condition 1) that ensures that the total amount of allocated land for land use type *j* equals the sectoral claim.

b_c is the supply balancing factor (condition 2) that makes sure the total amount of allocated land in cell *c* does not exceed the amount of land that is available for that particular cell.

β is a parameter that allows for the tuning of the model. A high value for β makes the suitability more important in the allocation and will lead to a more mixed use land pattern, a low value will produce a more homogenous land use pattern.

s_{cj} is the suitability of cell *c* for land use type *j*, based on its physical properties, operative policies and neighbourhood relations.

Implementation in a geographical information system

The Land Use Scanner model is implemented in an information system using Data and Model Server (DMS) software. The resulting Geographical Information System (GIS) allows for storage, manipulation and presentation of the geographical data that are used in the model. It furthermore contains the necessary arithmetic functions to implement the logit functions of the allocation model. The actual simulation is done in the following ten steps that are also presented in figure 1.

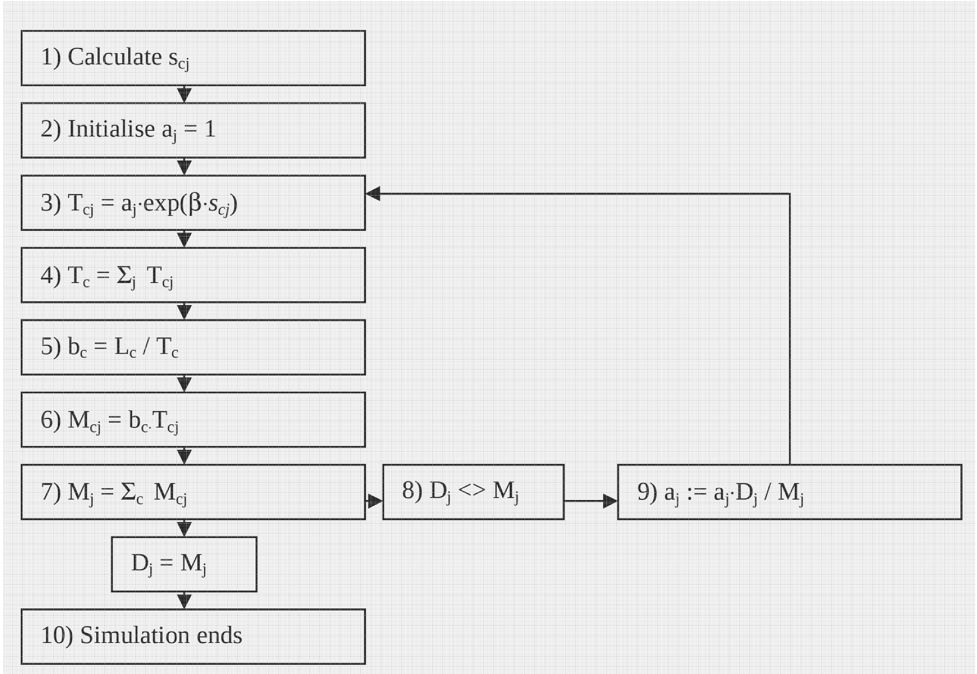

Figure 1. The Land Use Scanner simulation process

1. Calculate the suitability for every land use type and cell; s_{cj} = function of physical properties, operative policies and neighbourhood relations. The suitability of a cell may vary according to the simulation perspective and is calculated at the start of each simulation session. Perspectives differentiate for example in their assumption for the most probable location of residential land use. While one perspective may state that residential land use will be realised near existing cities, another may give preference to the proximity of natural areas.
2. Initialise the demand balancing factors for every land use type at value 1; $a_j = 1$
3. Calculate the expected demand for every cell and land use type; $T_{cj} = a_j * \exp(\beta * s_{cj})$, a_j and s_{cj} are already known, β is a parameter with a chosen value.
4. Summarise the total demand of all land use types for land for every cell; $T_c = \Sigma_j \; T_{cj}$
5. Calculate the supply balancing factor; $b_c = L_c / T_c$, L_c denotes the total amount of available land in a cell and is already known
6. Calculate for every cell and land use type the amount of allocated land; $M_{cj} = b_c * T_{cj}$.
7. Summarise the total amount of allocated land for every land use type; $M_j = \Sigma_c \; M_{cj}$.

8. Check for every land use type whether the allocated amount of land is within a predefined range of the sectoral claim; $D_j =? M_j$, D_j denotes the total of the future claim and the amount of land that is presently used for a function.
9. If the claim and allocated amount of land for a land use type are not within the predefined range, a new value for the demand balancing factor is calculated; $a_j = a_j * D_j / M_j$. A new iteration starts again at step 3. This adjustment of the demand balancing factor should theoretically lead to a fitting allocation after one iteration, but this is normally not the case because several land use types adjust their balancing factors simultaneously. It may take several iterations before an allocation is achieved that more or less fits for all land use types. This process leads to a continuing increase in the a_j factor and can be considered as a bidding process.
10. The simulation is finished when the allocated amount of land is near enough to the sectoral claim. Normally a map is produced with the dominant land use types for every cell to show the result of the simulation.

3. DESIGNING SCENARIOS AND DETERMINING LAND USE CLAIMS

The purpose of designing scenarios should not be to predict the future. Certainly in the long run, as Dammers (2000) also clearly states, models cannot possibly predict the future. They can only create a spectrum of possible futures and in doing so offer more insight in directions and sensitivity of developments. Policymakers can thus get an idea of what trends will lead approximately in what directions.

The scenario's that were developed for this study are based on three existing scenarios developed by the International Centre for Integrative Studies (ICIS) of the University of Maastricht (ICIS, 2002): 'Environment matters', 'Government controls' and 'Market rules'. Each scenario is based on different predictive economic scenarios for the next decennia that have been composed by the Netherlands Bureau for Economic Policy Analysis (CPB, 1996; 2001): 'Divided Europe' (DE), 'European Co-ordination' (EC) and 'Global Competition' (GC). Because the purpose of this study is to create three clearly different scenarios, we have adapted the scenarios according to our own wishes. The trends as we have defined them based on the three ICIS-scenarios are described in table 1[2].

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[2] A more elaborate description can be found in Koomen & Dekkers (2003, ch. 2).

	Environment matters	Government controls	Market rules
Economic situation	Industry: small-scale and clean Service-sector: ICT and eco-technology Agriculture: biological farming, eco-recreation	Industry and Services need more space	Technological breakthroughs Industry: large-scale Service-sector: growing rapidly
Government intervention	(Spatial) policies determines land use	(Spatial) policies determines land use	Maximum freedom inland market
Climate change	Extreme climate change (temperature rises) Higher chances of flooding.	Less extreme climate change.	No extreme climate change.
Spatial implications	More room for water, condensation of urban areas. More room for nature, no residential land use allowed in green and wet areas.	Interweaving of urban and rural areas. Free space in rural areas is developed into nature areas. Residential land use is planned around large existing urban areas. Commercial land use is facilitated near large infrastructure bottlenecks.	Free space in rural areas is developed into residential land use and offices. Nature is a remnant, especially meant for recreational purposes. Residential land use is possible in green areas.

Table 1. Base assumptions of the three ICIS-scenarios and following spatial implications

With regard to the quantitative completion of the spatial claims in the ICIS scenarios, several remarks can be made:

- ICIS argues that CPB makes a distinction for Nature in its three scenarios, but this is not entirely accurate. CPB (2001) does *not* treat Nature separately, only CPB (1996) does. Therefore, the reference in table 1 towards three different scenarios for nature is also not entirely accurate.
- The foundations of the ICIS-scenarios are not consistent. For example, ‘Environment matters’ is based on two different CPB-scenarios (DE and GC), which are based on entirely different socio-economic developments.
- Also, the ICIS-scenarios only distinguish three land use functions: urban area (only residential land use, commercial land is not included), agriculture and nature. This is of rather limited use for our study purpose.

Therefore, other scenarios were studied to see if they can substitute/replenish the ICIS-scenarios. For the Nature Balance 2002 (Natuurplanbureau, 2002), ‘NVK-2’ in Dutch, four scenarios of the future have been developed, based on the CPB-scenarios GC and EC. The quantitative completion of these scenarios is documented by Koole *et al*. (2001). These scenarios distinguish more land use functions which also adapt better to the arrangement of land use functions within the Land Use Scanner. A very useful aspect of these scenarios is the distinction of the land use functions horticulture and flower bulbs. These functions have very specific requirements with regard to ground water levels and irrigation.

Because the land use functions as described by Koole *et al*. (2001) are not available at a regional level, another background report for the same Nature Balance 2002 is used: De Nijs *et al*. (2002). Strangely enough, the claims for the various land use functions in these two publications differ, while both are background report for the same Nature Balance.

When comparing the land use functions of the Nature Balance according to De Nijs *et al*. (2002) with those of the Land Use Scanner in table 2, we notice that these two match relatively well. In order to give a complete overview, the land use functions that have a fixed spatial claim in the Land Use Scanner are added at the bottom of the table.

Land use functions (NVK-2)	**Comparison**	**Land use functions (Land Use Scanner)**
Residential	NVK-2 includes Recreation, which is supposed to be a separate function in the Land Use Scanner (LUS) (Scholten *et al* (2001, p. 145). Koomen (2002, pp. 19-20) corrects this: The largest part of Recreation is also included in Residential in the Land Use Scanner.	Residential
Commercial	Perfect match	Commercial
Meadow	Perfect match	Meadow
Other pasture plants	97% of this class is corn, which is present in the Land Use Scanner	Corn
Grains Sugar beets Potatoes Other arable land	Together comparable with Farming	Farming
Flower bulbs	Perfect match	Flower bulbs
Fruit	Comparable with Cultivation land	Cultivation land
Non-greenhouse vegetables Tree cultivation	Together comparable with Other Agricultural and Cultivation land (incl. land that lies fallow)	Other Agricultural and Cultivation land (incl. land that lies fallow)
Other cultivation land	Greenhouse vegetables are probably included in this NVK-2 function, whereas in the Land Use Scanner, this is a separate function. Therefore, we extract the function Greenhouse vegetables from the NVK-2 function Other cultivation land. CPB (2001) states that the Greenhouse vegetables sector occupies 10.000 hectares and that this sector will not grow in the future. The other part of this function is added to the Land Use Scanner function Other Agricultural land	Greenhouse vegetables
Nature + Forest		Nature + Forest
	Land uses with fixed spatial claims	Infrastructure, Water

Table 2. Assessment of the usability of land use claims from the nature balance (NVK-2) for our Land Use Scanner application.

The four scenarios of NVK-2 are compared on socio-economic, environmental and governmental aspects, after which three of the four are selected to match the ICIS-scenarios: ‘Environment matters’ matches with Co-operation Region (CR), ‘Government controls’ matches with Co-operation World (CW) and ‘Market rules’ matches with Individualistic Region (IR). Only for the residential and commercial land use functions, the relation is adjusted: for these two scenarios for the CW and CR claims are switched for residential and commercial land use because that better matched the expectations for future land use. The fourth NVK-2 scenario – Individualistic World (IW) is not used because its setup does not match at all with the three scenarios used in this study.

As both the land use typology and the general scenario assumptions of the Nature Balance study of De Nijs *et* al. (2002) matched well with out study, it was decided to use the prospected future land use demand from their study. This additional land use claim (see table 3) was added to the current land use in the Land Use Scanner to arrive at the expected total future area of the different land use types.

Land use function	**Environment matters (CR)**	**Government controls (CW)**	**Market rules (IR)**	**Source**
Residential, incl. Recreation	82296	86719	150306	NVK-2, CW, CR or IR
Commercial	58981	58981	68337	NVK-2, CW, CR or IR
Meadow	-434000	-368000	-345000	NVK-2, CR, CW or IR
Corn	15000	-15000	-26000	NVK-2, CR, CW or IR
Farming (Grains, Sugar beets, Potatoes and Other arable land)	-269000	-114000	-303000	NVK-2, CR, CW or IR
Greenhouse vegetables	0	0	0	NVK-2, CR, CW or IR
Flower bulbs	9132	199	5956	NVK-2, CR, CW or IR
Cultivation land	8118	176	5294	NVK-2, CR, CW or IR
Other Agricultural and Cultivation land (incl. land that lies fallow)	30750	625	18750	NVK-2, CR, CW or IR
Nature + Forest	500000	345000	400000	NVK-2, CR, CW or IR
Infrastructure	0	0	0	Fixed land use from Land Use Scanner
Water	0	0	0	Fixed land use from Land Use Scanner
Total of additional claims	**-723**	**-5300**	**-25357**	

Table 3. Overview of additional land use claims, summarized at the national level

4. IMPLEMENTATION OF THE SPATIAL IMPLICATIONS

In designing these scenarios, it is important to determine both the magnitude *and the location* of the spatial developments in the Netherlands. Therefore, the national additional land use claims from table 3 must be translated to a regional level. Data is available for two regional divisions: Residential, Commercial and Nature/Forest are available in COROP-format (this is comparable with NUTS-3), the other data is available in LEI14-format (a regional division) based on homogeneity of agricultural areas).

In the Land Use Scanner, the location of land use claims is defined using suitability maps. These maps define suitable locations for all types of land use based on the definition of the scenarios as described in table 1. Table 4 contains an overview of how the scenario-definitions are translated into attractivity maps.

Scenario	**Implementation Suitability maps**
Environment matters	Residential and Commercial: comparable with Compact City-scenario present in the Land Use Scanner (based on policy locations for residential land use plus the 10 cells around current residential land use are attractive locations for future residential land use). No residential land use in areas assigned to the Ecological Main Structure (EHS, Dutch policy for the creation of interconnected natural areas), no residential land use near large lakes and rivers an near wet areas (ground water levels I and II). Nature: stimulated in the EHS, existing nature areas and wet areas. Agriculture: based on suitability maps of the various crops.
Government controls	Residential: comparable with Compact City-scenario present in the Land Use Scanner (based on policy locations for residential land use plus the 20 cells around current residential land use are attractive locations for future residential land use). No residential land use in EHS-areas. Commercial: The 20 grid cells around current commercial locations are attractive locations for future commercial land use. Also the 20 grid cells around train stations and the 5 grid cells around highway entries & exits are attractive locations. Nature and Agriculture: Same as ‘Environment matters’.
Market rules	Residential: The 20 grid cells around current residential locations are attractive locations for future residential land use, as are the 10 grid cells around forest and the 2 grid cells around water. No explicit limitations for EHS, green and wet areas, no role for policy. Commercial: The 20 grid cells around current commercial locations are attractive locations for future commercial land use, as are the 2 grid cells around highways and the 5 grid cells around highway entries & exits. Nature: Based on EHS, existing nature areas and proximity of urban areas. Agriculture: Same as ‘Environment matters’.

Table 4. Translation from scenario-definition into attractivity maps

It is clear that the scenarios not only differ in the magnitude of the spatial claims, but also in the spatial preferences of the actors involved and the degree of government intervention.

5. LAND USE SIMULATIONS

For every land use type, maps were generated. Each map contained the expected number of hectares per grid cell in 2030. In order to gain more insight into the result, a set of dominant land use map was generated, indicating per grid cell which land use type takes up the largest number of hectares. In total, five different land use types are distinguished in these maps (figure 2).

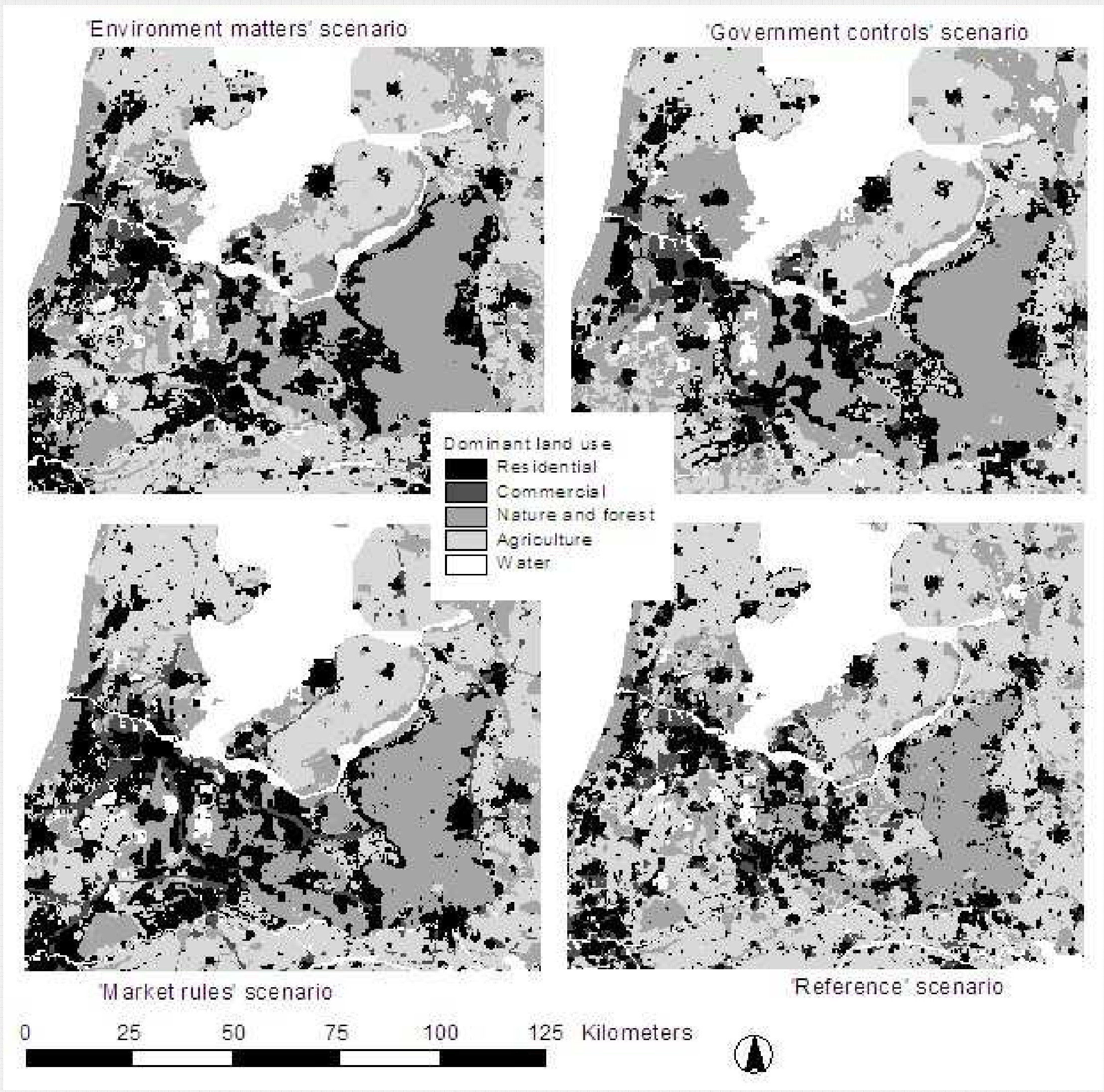

Figure 2. Result maps; dominant future land use for each scenario (source: Land Use Scanner; Water shortage study, VU/RIZA)

If we look at the results of the ‘Environment matters’ scenario, we can see that residential and natural land use grow at the cost of agriculture. The land use pattern with regard to residential land use remains the same: compact urban areas. The small villages in the large nature area on the right in the maps have disappeared. This is a consequence of restricting residential land use within the Ecological Main Structure (EHS) while the data representing this nature policy is too rough so the existing villages are included in the policy area. One obvious solution for this problem is to define the area more precise, so that the villages are located outside the EHS area. This scenario clearly favours Nature, which gives a good contrast with the other two scenarios.

The main difference of the ‘Government controls’ scenario with the ‘Environment matters’ scenario is the large growth of commercial land use near large urban areas in the west and south of the Netherlands. Clearly, the presence of a large number of train stations and highway entries & exits has an effect.

The ‘Market rules’ scenario differs most from the current situation. Residential land use has penetrated nature areas and commercial land use has spread itself alongside infrastructure corridors over large parts of the Randstad area and the province of Noord-Brabant.

A more in-depth analysis of the results on a larger scale reveals that in all three scenarios, some coastal villages in the province of north-Holland and Zeeland have disappeared from the map. In the ‘Environment matters’ and the ‘Government rules’ scenario’s, this is caused by the restrictions posed on residential land use within the EHS. For the ‘Market rules’ scenario, this is caused by the way in which the attractivity map is defined: the attractivity of a cell for residential land use is defined by the spatially weighted mean of the existing residential land use in a square of 5 or 10 kilometres. This means that the value for residential land use around isolated small villages, especially when these are located near the sea, is low. Nature has a higher attractivity value in these areas.

Also, in all scenarios, the land use class Greenhouse vegetables disappears from the Randstad area. This is largely due to the high level of competition of other land use types and the fact that spatial policy of the government assigns new and other locations outside the Randstad area for greenhouse vegetables in the Balance map 2010.

6. ASSESSING THE HYDROLOGICAL IMPACT

As mentioned before, land use has a strong influence on the water balance of a given area because of differences in infiltration and evaporation rates per land use type. Therefore, future land use was simulated using the Land Use Scanner. The results of these simulations were used as a starting point for further hydrological studies in two steps.

Firstly, the resulting scenarios from the Land Use Scanner simulation were discussed with representatives of parties involved with the regional water shortage study for the Mid-West of the Netherlands. They particularly opposed the results of the ‘Government controls’ scenario in particular. This scenario in their opinion should be an extrapolation of the current trends and the resulting dominant land use map did not confirm their views. Therefore, another scenario was build, the ‘Reference’ scenario (see figure 2). This scenario uses the land use claims (except for Nature) from the ‘Government controls’ scenario, but has different suitability maps. This scenario was used for further calculations in the water shortage study instead of the ‘Government controls’ scenario (Peereboom, 2003).

Secondly, for each scenario the resulting land use claims were converted in order to be used as input for MOZART (a hydrological model that covers the upper unsaturated soil zone). The hydrological situation for the future scenarios was simulated using the current water management guidelines. With this model, information on the nature, severity and size of the water shortage problem in the Netherlands can be obtained. MOZART was used to calculate damages caused by water shortages and the consequences for several important sectors. Using the chance on exceeding the precipitation deficit of characteristic years, expressed in repetition frequency (in years), the expected rainfall was calculated for 6 separate regions. The chances on water shortage for each region were then calculated. Consequently, policy measures can now be developed in order to decrease risk of damages caused by future water shortages. Also, estimations of water needed per region to avoid shortages can be computed, both in time and space (PDN, 2004).

The resulting land use maps were used as input in specific hydrological instruments to assess the impact of land use change on water shortage. According to hydrological experts of the Dutch Institute for Inland Water Management and Waste Water Treatment (RIZA), the land use maps resulting from this simulation can be used in combination with the hydrological instruments. However, for an optimal connection with the hydrological instruments, a smaller grid cell size (preferably 50 x 50 meters) is preferred over the current 500 x 500 meter cell size. Using 50 x 50 meter cells, homogeneous cells can be used instead of heterogeneous cells. This means that every cell contains only one land use type instead of percentages of several land use types. This would considerably improve the connection with the MOZART hydrological model, which requires discrete cell-values per land use type as an input.

Also, the current division of land use types is not optimal for being used in hydrological models. In particular the combined class Forest & Nature should be subdivided into Open nature areas and Deciduous and Coniferous wood, since these land use types differ a lot in water consumption. Since only the 500 x 500 meter heterogeneous model (Land Use Scanner 4.56) was available at the time, this model was used. In the newest version of the Land Use Scanner (4.70), allocation of land use for 2030 using homogeneous cells in a 100 x 100 meter grid has been made possible.

7. CONCLUSIONS AND RECOMMENDATIONS

The scenarios resulted in very diverse images of land use in the Netherlands in 2030. ‘Environment matters’ best resembles current land use, with compact urban areas and ample space available for nature. The ‘Government controls’ scenario in contrast shows a large growth of commercial land use functions near large urban areas in the west and south of the Netherlands, caused by the high density of train stations, highway entries and exits. The ‘Market rules’ scenario differs most from the current situation: Residential land use has penetrated nature areas and commercial land use has spread alongside infrastructure corridors over large parts of the Randstad area and the province of Noord-Brabant.

It can be concluded that the Land Use Scanner is very capable of generating diverse images of the future within a short time that are coherent with the scenario assumptions. The maps show the essence of the scenarios. Quantifying the mainly qualitative scenarios proved to be laborious, but in the end, good data was found and implemented. One can argue about the division of land use types and the exact size of spatial claims for the land use types.

In some cases small villages with low attractivity disappeared in the future, for example small coastal villages. On this point, the suitability maps could be improved. One possible solution was to model the inertia of existing land use by introducing transition costs between various land uses, in particular between the change from urban to rural land use. From an economical perspective this solution appeared interesting to explore further. This solution had been proposed previously by a.o. Koomen (2002) and has recently been successfully tested in Borsboom *et al*, 2005.

In order to evaluate results in a more structured way, quantitative measures and/or indicators for interpreting outcomes should be developed.

To facilitate a better integration of Land Use Scanner results with hydrological models, the level of detail should preferably be changed from 500 x 500 meters to 50 x 50 meter grid cells. This however calls for more precise and better founded assumptions regarding future land use demand and locational preferences. As a first step in this direction, a 100 metre grid has now been constructed that will be thoroughly calibrated and validated. Also, the division in land use types should be changed, in particular the combined class Forest & Nature should be subdivided into open nature areas and deciduous and coniferous wood as these land use types differ a lot in water consumption.

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