Chapter 3
Future Land-use in The Netherlands: Evaluation of the National Spatial Strategy

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3.1 Introduction

The Netherlands is a small but densely populated country with about 16 million people living in an area of 40,000 km^2. The 'Randstad' is a highly urbanized area of the country that comprises the major cities of Amsterdam, Rotterdam, Utrecht and The Hague, with a combined population of more than 5 million people. This conurbation is the economic heart of the Netherlands. Urban development threatens the natural and historical qualities of the landscape of the 'Green Heart', the central open area of this region. The first spatial plans for this area date from 1958 (RPD 1960; WWdL 1958), and these have been updated regularly since then (RPD 1966, 1977, 1988, 1994). New plans have been drawn up for the creation of about 2500 km^2 of forests and nature reserves by 2018 (LNV 2002; MNP 2002a). In addition, roughly 1500 km^2 of land will be needed for new residential and industrial areas by 2030 (ABF 2002). According to current policy, plans and trends, 10 per cent of the land use will change over the next 30 years. The National Spatial Strategy (VROM *et al.* 2005), drawn up by the present Dutch Government and prepared to provide a spatial policy framework to guide all of these developments, was adopted by Parliament at the end of 2005.

Roughly speaking, the National Spatial Strategy comprises three major categories of spatial planning policies. These concern:

- Restrictive areas, where further urbanisation will be curbed in the interests of a range of objectives; these areas include the nature reserves and protected areas and the risk zones around Schiphol Airport and other centres of hazardous activities;
- National Landscapes, where development is possible within these areas as long as the core qualities of the landscape are conserved or enhanced; within these

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landscapes, local authorities may only build new housing to meet the demand resulting from local population growth;
- Concentration areas, where new urban development will be clustered.

By order of the Dutch Ministry of Housing, Spatial Planning and Environment, the National Environmental Assessment Agency has evaluated the effects of this new National Spatial Strategy, giving particular attention to a number of questions. How will the National Spatial Strategy affect future land-use patterns in the Netherlands? Where, despite restrictions, is the pressure so high that new developments will ultimately be allowed to occur? What effect will the Strategy have on national landscapes? Will there be sufficient room in the concentration areas to accommodate all new developments? To answer these questions, future land-use developments have been simulated by the *Environment Explorer* in accordance with a ‘Trend’ scenario and a ‘Sprawl’ scenario (A. C. M. De Nijs *et al.* 2005; T. C. M. De Nijs *et al.* 2004). Limiting urban spatial sprawl is one of the main political topics in the Netherlands.

This chapter takes a closer look at the nature of the land-use model, at the Trend and Sprawl scenarios and at future land-use developments in general and restrictive areas, national landscapes and concentration areas in particular. The results of this study are discussed and conclusions are drawn that relate to the impacts of the policies, potential problems and the application of the land-use model itself. In closing, the effect of the study itself on the discussion of spatial developments in the Netherlands is discussed.

3.2 *Environment Explorer*

The *Environment Explorer* (A. C. M. De Nijs *et al.* 2001; T. C. M. De Nijs *et al.* 2004; Engelen *et al.* 2003; MNP 2005; White *et al.* 1997), a land-use simulation model, was used to simulate future land use in the Netherlands. This model attempts to plot regional spatial developments as accurately as possible on a land-use map with a grid size of 500 m. The model recognises 16 different land-use classes, including residential use, industrial use, offices, facilities, recreation, greenhouse horticulture, forest and nature conservation. The location of land-use change is determined by current land use, spatial policies, suitability, accessibility and the effect of current land uses in the neighbourhood (Fig. 3.1). The amount of land-use development is controlled in the scenarios. Zoning, suitability and accessibility maps have been compiled for each land-use category. The zoning map shows the areas where development is permitted and where it is prohibited. The suitability map shows how suitable each cell is for that particular land use. Accessibility by car and public transport is calculated by a dynamic traffic model in the *Environment Explorer*. This model computes changes in accessibility given the changes in land use, population, employment and infrastructure growth (RIKS 2002).

The neighbourhood potential is the influence exerted by the surrounding cells on the allocation of the various land uses. This neighbourhood potential is calculated

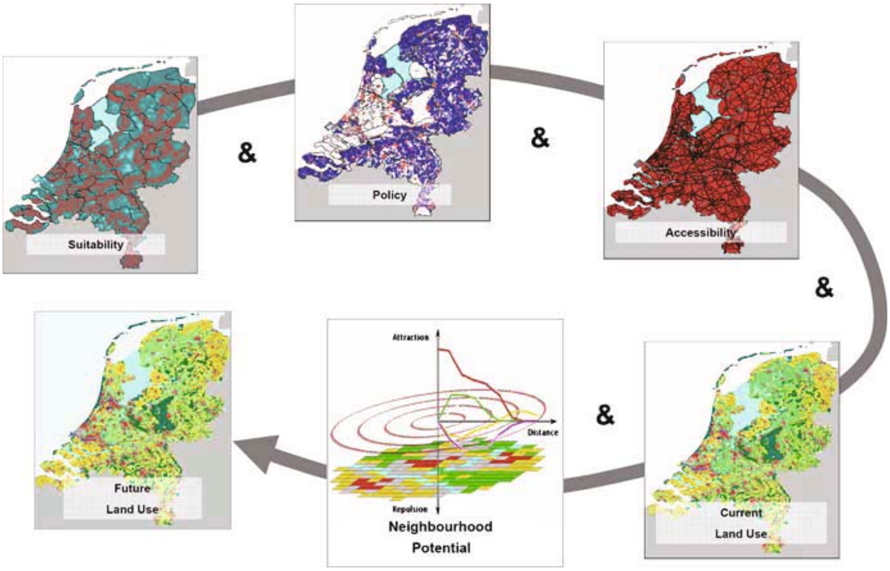

Fig. 3.1 The *Environment Explorer* simulates future land use as a function of the suitability of each area, the relevant spatial planning policies, accessibility, current land use and the influence of the neighbourhood

by a cellular automata (CA) model in which a set of transition rules describes how the various land uses interact – by either attracting or repelling each other. For example, over a short distance, airfields and industrial sites can have a negative impact on residential development, but the latter in turn is positively influenced by the proximity of greenspace. A set of transition rules determines the spatial interactions between each combination of land use over a number of distances. Where the various types of development will take place is relatively uncertain. This uncertainty is built into the allocation model in the form of a stochastic parameter, and it can be visualised in a probability map of future land use by running the model not once but 1,000 times in a Monte-Carlo simulation.

For the evaluation of the National Spatial Strategy, the spatial interactions between the various land uses in the *Environment Explorer* were calibrated according to the observed spatial developments over the period 1989–1996 (MNP 2005). Therefore, a semi-automatic calibration routine was added to the model with an 'error selection and correction' routine (Hagen-Zanker 2005b). The criterion to select the combination of land uses that gives the largest error is based on the Fuzzy Kappa statistic (Hagen 2003). The selected error is reduced by adjusting the transition rules, and errors that cannot be resolved are placed on a taboo list. This procedure iterates until the model error is minimised.

Analyses of the observed land-use changes in the period 1989–1996 revealed that 25 per cent of the changes can be considered to have been improbable. These unlikely land-use changes consist of changes from urban to agricultural uses or forest and nature conservation, and they can be attributed to changes in the defini-

Table 3.1 Results of the calibration and validation of the *Environment Explorer* based on the Fuzzy Kappa

	Environment Explorer	Random
Calibration 1989–1996	0.936	0.926
Validation 1996–2000	0.913	0.922

tions of the land-use classes over the years. For example, the grass bordering the roads is included in category roads in the map of 1989, while it is excluded from the map of 1996. In general, this is a major problem in the development of land-use models (Fang *et al.* 2006). The model was subsequently validated for the period 1996–2000, based on the Fuzzy Kappa. The results indicate that the *Environment Explorer* performed better during the calibration period than a random allocation model (Visser *et al.* 2006), whereas during the validation period it did not (Table 3.1). Two factors can mostly explain this performance: (1) the validation period was rather short; (2) further changes in the definitions of the land-use classes in the map of 2000. These latter changes have a number of effects, among which is a net decrease in residential area in the map of 2000 compared to the map of 1996, which can not be reproduced by the model.

The validation results over the short term are not so important; in contrast, the simulation results for the long term are very important. Nevertheless, it is impossible to verify these long-term simulations on observed land-use changes. These simulated land-use maps should be realistic, transparent and easy to explain, but it is not that easy to develop objective criteria to evaluate these characteristics. The first question that arises is just what are realistic land-use patterns. At the very least they should all have the same morphological characteristics. One very tight morphological constraint on models of urban growth is Zipf's law (Gabaix 1999; Gabaix *et al.* 2003; Zipf 1949). Zipf's law for cities is one of the most striking empirical facts in geography and economics. For most countries, the size distribution of cities strikingly fits a power law: the number of cities with populations greater than S is proportional to 1/S.

Therefore, we verified the long-term spatial developments of the model against the size distribution of urban clusters. The stochastic parameter in the *Environment Explorer*, which determines the number of new clusters over the long term, was used to accurately fine-tune this relation (Hagen-Zanker 2005a). The resulting size distributions for both the Trend and Sprawl scenarios in 2030 obey Zipf's Law (Fig. 3.2), and both approximately overlap with the city size distribution of observed land use in 1989 and 2000. The size distribution of the random allocation model does not obey Zipf's Law as a large number of small urban clusters have been allocated randomly on the map. The relative percentage of 50-ha clusters has increased from 60 per cent to nearly 80 per cent. In the long term, the *Environment Explorer* outperforms the random allocation model.

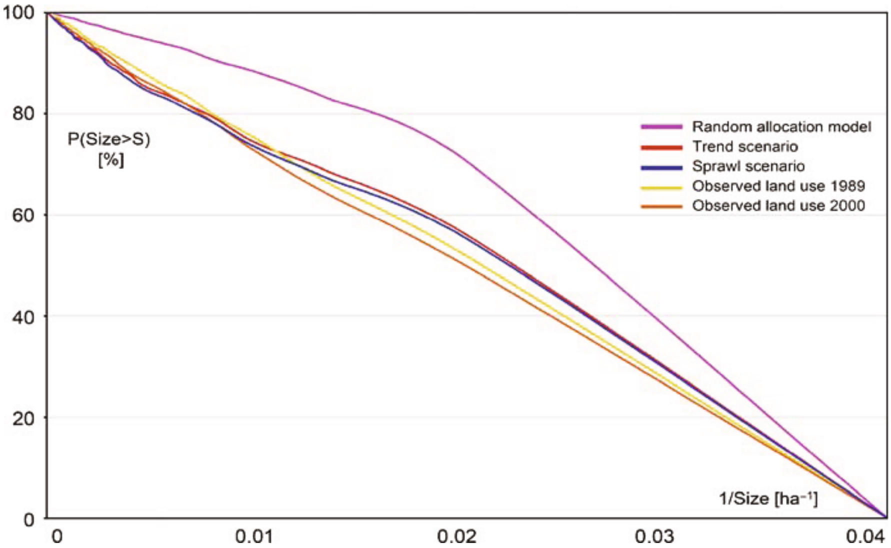

Fig. 3.2 Size distributions of urban clusters according to Zipf's Law for the observed land use in 1989 and 2000, the simulated land use according to the two scenarios and the random allocation model in 2030

3.3 The Trend and Sprawl Scenario

Although the names suggest otherwise, the Trend and Sprawl scenarios are almost identical. There is only one essential difference between both scenarios: smaller settlements will grow relatively faster in the Sprawl scenario than in the Trend scenario. Why and how this has been implemented will be described at the end of this section. Here, the common aspect will be discussed. Implementation of a scenario in the *Environment Explorer* includes the definition of:

- initial land use;
- amount of land-use developments;
- zoning, suitability and accessibility maps.

The spatial planning policies contained in the National Spatial Strategy have to be translated into either the input of these scenarios or the calibrated set of transition rules. In both scenarios, initial land use is based on the land-use/cover map from the *Bodemstatistiek 2000* (CBS 2003). Agricultural land use on this map is further broken down into 'grassland', 'arable' and 'other agricultural land' using a second land-cover map of the Netherlands, *Landgebruikskaart Nederland, 2000* (Alterra 2003). Residential land use is split into two categories based on the number of inhabitants: 'low-density population' and 'high-density population'.

The amount or quantity of land-use developments can be defined regionally in the scenarios of the *Environment Explorer*. For both scenarios, the growth of

Table 3.2 National targets per land-use category for the period 2000–2030

Land use	Target (ha)	Land use	Target (ha)
Residential	87,675		
Industrial	35,975	Recreation	17,625
Services	6,225	Forest	51,525
Social/Cultural	13,450	Natural grasslands	173,025
Greenhouse horticulture	5,425	Nature conservation	11,300

residential and employment uses is based on the so-called High Land-use Pressure Trend (HLPT) scenario (ABF 2002). The growth of recreational uses and greenhouse horticulture was derived by extrapolating the regional developments from 1989 to 2000. Regional developments in forest, nature and natural grassland areas are based on the ‘Nature Reference Map 2020’ (*Referentiebeeld Natuur 2020*) (Goetgeluk *et al.* 2000). Table 3.2 summarises the national targets for each land use for the period 2000–2030.

The same suitability maps have been used in both scenarios. These are based largely on a study (Verburg *et al.* 2004a, b) that shows that soil conditions are not important in determining residential, employment and recreational land uses. The suitability maps for forest and nature conservation were also taken from this study. The suitability for natural grassland is based equally on the suitability for nature conservation and the presence of grassland in the ‘Land-use Map’ of the Netherlands 2000. We assumed that suitability for agricultural uses is the highest in those areas where these uses are currently found. Areas under other agricultural uses are slightly less suitable, and areas under all other urban uses are not suitable at all for agricultural use. The suitability map for greenhouse horticulture was derived from a specific study ‘Potential options for greenhouse development’ (LEI-DLO 1997), which is based on the amount of light received per year and the proximity of distribution centres.

For each land use, the expansion locations and restrictions are defined in the zoning map. Expansion locations are locations where a specific land-use change has been planned in accordance with to local, regional or national policy plans. Restrictions are locations where a specific land use is not allowed to develop. The expansion locations for the various land uses are based on the plans contained in ‘Plans in the Netherlands’ (*Nederland in Plannen*) and the ‘New Map of the Netherlands’ (NIROV 2004). The expansion locations for forest, natural grassland and nature conservation marked on the zoning map were derived from the ‘net boundaries’ of the National Ecological Network 2003 (NEN). All of the restrictive policies in the National Spatial Strategy have been reproduced on the zoning map. The restrictions for each land use are listed in Table 3.3.

The policies for concentration areas and National Landscapes policies in the National Spatial Strategy, as described in the Introduction, are expected to have less effect on spatial development than the expansion locations and restricted

Table 3.3 Definition of restrictive areas per land use

Restrictive areas	Source	Residential, Services, Facilities	Industry, Greenhouse horticulture	Forest, Nature conservation
20-ke contour Schiphol 2004, noise disturbance contour	NR[1]: PKB 3	X		
Coastal Foundation Zone and Weak Spots	NR: PKB 4	X	X	
Net boundaries NEN 2003	NR: PKB 5	X	X	
Protected areas under the Birds and Habitats Directives and the Nature Conservancy Act	NR: PKB 6	X	X	
Existing and New Nature 2003	(MNP 2002b)	X	X	
Space for the rivers	(VenW 2005)	X	X	
National buffer zones/ Regional parks	(LNV 2002)	X	X	
Risk contours for companies requiring an external safety report	MNP (in preparation)	X		
Schiphol bird protection zone	(VenW 2004)			X

[1] NR: PKB, National Spatial Strategy: Spatial Planning Key Decision (VROM *et al.* 2005)

areas. In both scenarios, it is assumed that the impact of expansion locations and restrictive areas is 20-fold greater than that of the concentration areas and the National Landscapes policies. This figure is based on expert judgement. The road network, motorway entrances and exits and the locations of the stations are specified in the *Environment Explorer* to allow the Traffic module to calculate accessibility (RIKS 2002). Accessibility was calculated for the period 2000–2010 using the standard Dutch National Model System network of 1995 (HCG 1997). The assumption was made that after 2010 all extensions to the infrastructure will be completed, as planned in the Multiannual Programme for Infrastructure and Transport (VenW 2003), and that no further extensions will be made to the road network before 2030.

Up to this point, the Trend and Sprawl scenarios do not diverge. However, the policies in the National Spatial Strategy give the municipal and provincial councils more freedom to approve new developments in the National Landscapes than they had previously. Whereas the municipal councils in the Green Heart formerly had virtually no opportunities for expansion, they are now permitted to build new homes to meet demands resulting from local population growth. It is most likely that the smaller settlements in the Green Heart will grow relatively faster under this new policy than larger towns and cities outside this National Landscape. In time, this change in policy will affect the transition rule for housing development in the model. These rules have been calibrated on historical land-use changes. Therefore, to estimate the impact of this change in policy, we constructed a Sprawl scenario in which the transition rules for housing development were adjusted to allow the smaller settlements to grow slightly faster than they do in the Trend scenario. The effect of this change in policy and the size of the adjustment to the neighbourhood rules are difficult to determine. However, the actual difference between the rules should be minor. Therefore, the effect of this adjustment on urban clusters sizes in 2030 has been verified against Zipf's Law.

3.4 Results

3.4.1 Urbanisation Probabilities in 2030

Figure 3.3 depicts the urbanisation probabilities in 2030 according the Trend scenario. The urban area comprises the following land-use categories in the *Environment Explorer*: housing, employment, recreation, sports fields and greenhouse horticulture complexes. The map shows that a number of urban areas will probably expand towards each other and eventually merge. In the Randstad conurbation, the open spaces between The Hague and Rotterdam will close. The city of Utrecht will expand to the south, merging with several small towns. New development around Amsterdam will be more dispersed.

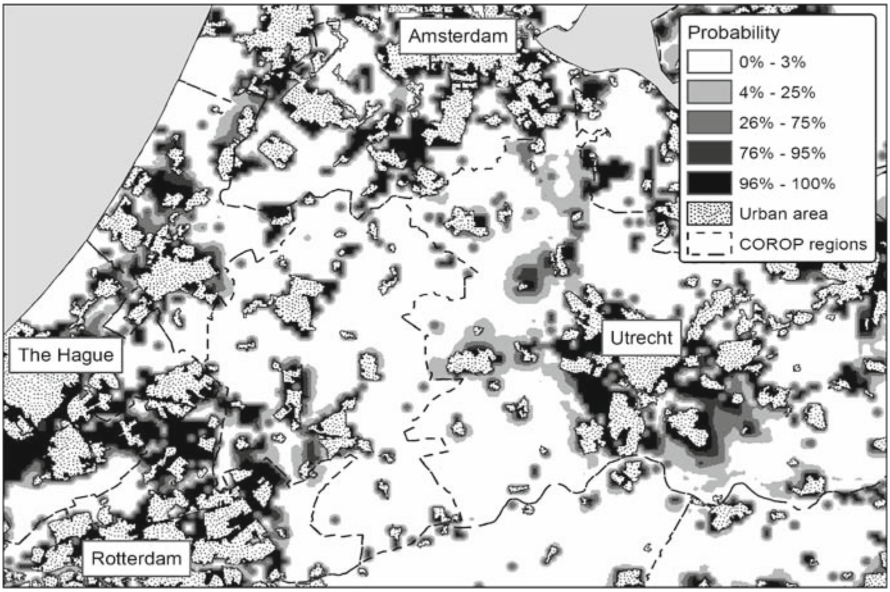

Fig. 3.3 Urbanisation probabilities in the Randstad conurbation in 2030 under the Trend scenario

In this scenario, the expansion of residential and employment land uses is heavily determined by the restrictive areas, including, among others, nature reserves and protected areas, regional parks and land in the floodplains reserved for flood control, water retention and habitat development. Developments in the concentration areas are given a preference over other areas. The National Landscapes are kept free of new housing and employment land as much as possible.

3.4.2 Pressures on Land in the Restrictive Areas

The Trend scenario was used to determine the relative pressure on land in the restrictive areas. These restrictive areas are only built on if all other available land within the COROP region has already been developed. COROP regions are the same as the NUTS Level 3 regions. The 40 regions are sub-divisions of the provinces in the Netherlands, each consisting of a central town or city and catchment area. Only if growth exceeds the amount of available land will these last open areas be developed. The probability of urban development in the restrictive areas was mapped for all urban restrictions, with the exception of the 20 km contour around Schiphol. This safety zone around Schiphol airport does not exclude industrial development and greenhouse horticulture.

There appears to be little pressure for urban development in the restrictive areas (Fig. 3.4), and only in the Randstad is the pressure on land so high that there is a chance of urbanisation in restrictive areas. New urban development may occur in the restrictive areas north of The Hague, around Amsterdam and in the vicinity of small towns in the nature conservation area to the north-east of Utrecht.

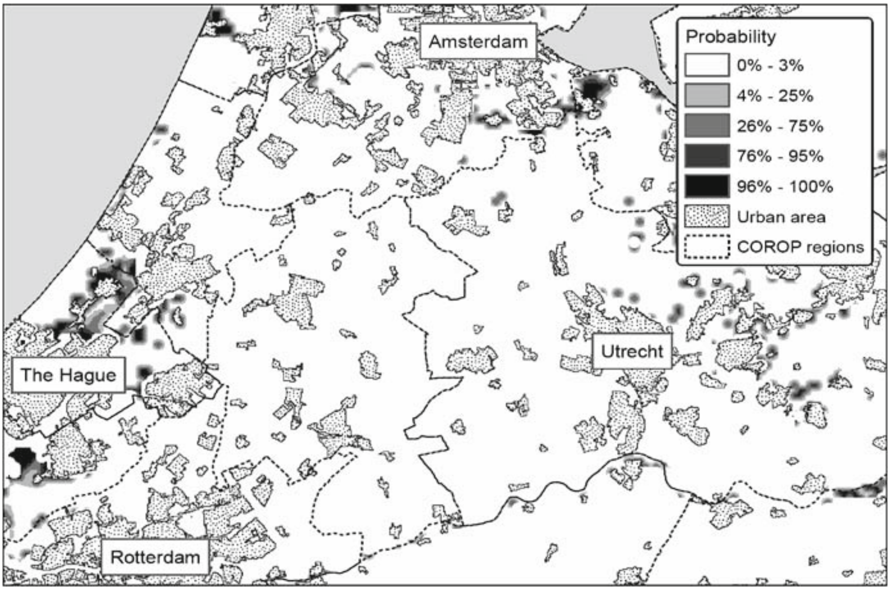

Fig. 3.4 Probability of housing development in the restrictive areas

3.4.3 Urban Development in the National Landscapes

Figure 3.5 shows the differences in urbanisation probabilities between the Trend and Sprawl scenarios in the Green Heart, one of the National Landscapes mostly threatened by urbanisation. Here, the probability of urbanisation is slightly higher under the Sprawl scenario, particularly in the eastern part of the Green Heart. The probability of urbanisation decreases in the area south-east of Utrecht and increases at the western side of the city. The areas of different grey shading indicate sites where the probability of urbanisation under the Trend scenario is higher; the black areas indicate where the urbanisation probability under the Sprawl scenario is higher. In the Sprawl scenario new residential development is less concentrated around the main cities, but it will be located more often near small villages in the Green Heart.

3.4.4 Space in the Concentration Areas

One of the main principles of the National Spatial Strategy is to locate new urban development in the concentration areas. The National Spatial Strategy states that the 'concentration percentage' in these areas should – at the very least – remain the same, but at the same time it does not clearly define concentration percentage. In addition, land also has to be reserved for water, nature and landscape conserva-

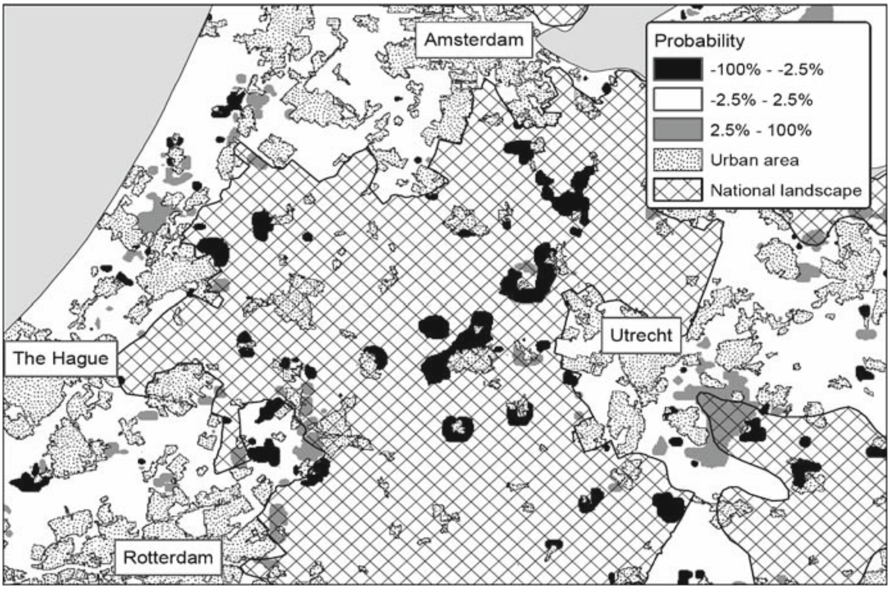

Fig. 3.5 Difference in urbanisation probabilities between the Trend and Sprawl scenarios

tion, recreation areas, sports fields and agriculture. In this analysis the concentration percentage (P) is taken to be the percentage of the urban area that is located in the concentration area ($A_{\text{Urban, Concentration Area}}$) relative to the total urban area in the province ($A_{\text{Urban, Province}}$):

$$P = \frac{A_{Urban,Concentration\,Area}}{A_{Urban,\text{Province}}} * 100 \tag{3.1}$$

Urban areas in this definition include residential and employment land, facilities, parks and greenspace, sports fields, recreation areas, roads, railways and greenhouse horticulture. It is questionable whether all spatial developments can be accommodated within these concentration areas. Therefore, for each province, the available, required and developed land has been determined for 2030. The available land is the land which will still be available for new urban developments; it is defined as the agricultural land and building sites in the land-use map of 2000, barring all physical and spatial restrictions. The required land in 2030 will be the land needed to maintain – at the very least – the same concentration percentage. It is estimated by multiplying the growth of urban land per province, in accordance with the scenario, by the concentration percentage in 2000; as such, it is the amount of land that will be needed in the concentration areas for the development of urban land uses. The developed land is the land which will most probably be developed in 2030. The developed land in 2030 was calculated from the urbanisation probability in 2030 according to the Trend scenario.

On the basis of this analysis, there is not enough land available in the concentration areas in the Randstad and in Limburg to accommodate all new developments (Table 3.4). Accordingly, the concentration percentage in these provinces will decline sharply in the future. The differences between the available, required and (probably) developed land provides some indication of the policy inputs needed to cluster new urban development in the concentration areas.

3.5 Conclusions and Future Directions

For the *ex ante* evaluation of the National Spatial Strategy, future land use was simulated by the *Environment Explorer*. Observed development trends were used to comprehensively calibrate and validate the *Environment Explorer* for short-term projections. The *Environment Explorer* outperformed a random allocation model in the calibration period, but not over the validation period. Land-use models generally perform poorly in validation studies when used for large-scale applications Pontius *et al.* (2008), while their performance in local-scale applications, such as at the city level, appears to be better (Hagoort 2006). The calibration and validation of land-use models are impeded by classification and aggregation errors in land-use maps (Fang *et al.* 2006; Pontius *et al.* 2004; Pontius and Spencer 2005). A novel methodology has been applied to verify long-term projections. The distribution of urban cluster sizes in future land-use maps was verified using Zipf's Law. The calibrated model was used to estimate the urbanisation probabilities in 2030 for a Trend and a Sprawl

Table 3.4 Available, required and developed land (ha) in the concentration areas, and the concentration percentages in 2000 and 2030 under the Trend scenario

	Available land	Required land	Developed land	Concentration per cent 2000	Concentration per cent 2030
Groningen	8,400	989	942	21.0	20.0
Drenthe	5,319	758	682	10.3	9.2
Overijssel	15,543	2,665	2,596	26.9	26.2
Gelderland	15,028	4,782	5,456	19.1	21.8
Utrecht	10,734	8,838	8,045	57.9	52.7
Noord-Holland	9,113	10,357	7,966	60.4	46.5
Zuid-Holland	24,931	17,195	16,202	73.0	68.8
Noord-Brabant	33,561	11,646	11,174	43.0	41.3
Limburg	5,634	6,491	4,444	36.2	24.8
Flevoland	6,012	2,255	2,991	28.8	38.2

There are no concentration areas in the provinces of Friesland and Zeeland

scenario using Monte-Carlo simulations. The effects of policy on the restrictive areas, the National Landscapes and the concentration areas were examined.

The probability of urbanisation in 2030 is highest near existing urban areas and is influenced by spatial planning policy. Urban development in restrictive areas is avoided as much as possible. Only in the Randstad is the pressure on land so high that it is likely that urban development will take place in the restrictive areas. Urbanisation in the National Landscapes will probably increase as a result, particularly in the Randstad and Limburg where development pressures are the highest. There is sufficient space in most of the concentration areas to accommodate all new developments. Given the scenario assumptions, there will be insufficient land in the provinces of Noord-Holland and Limburg to accommodate all new urban developments in the future while retaining enough land for water, nature and landscape conservation. This analysis identifies those provinces for which problems may be expected over the long term with implementing national spatial planning policies.

This evaluation of the National Spatial Strategy using the *Environment Explorer* provides detailed insights into the feasibility of the policy goals and potential problems. The study shows how land-use models can be used to determine the effects of spatial planning policies on future spatial development. Even so, the results of such modelling studies are inherently uncertain. The Monte-Carlo simulation enables the large uncertainties surrounding the location of developments to be visualized through the use of urbanisation probabilities. However, the uncertainty in the growth of land use and the effectiveness of current policies has not yet been incorporated in the simulated scenarios. These results provide policymakers with the opportunity to take potential problems into account beforehand. Monitoring programmes have been developed, especially those focussing on the simulated hot spots of urban developments in restricted areas. Additional measures can be defined to circumvent potential problems in the national landscapes and concentration areas. Moreover, the detailed spatial results have made it possible to determine various – potentially adverse – effects of these new policy plans; for example, to assess future noise levels and risk contours near airports in the Netherlands (Dassen 2005).

For this study, the *Environment Explorer* was calibrated for a relatively short period, given the slow pace of spatial development. Calibration on a consistent dataset over a longer time-span could improve simulation results. Moreover, a major part of the land-use changes in the calibration period was dubious: urban areas changing to forest, nature conservation or agricultural uses. Therefore, future research should be directed towards reducing the uncertainties in the results of the land-use model by taking advantage of better monitoring data. For example, to circumvent the classification problems in land-use maps, land-use models should utilise the primary remote sensing data instead of the interpreted results in the land-use maps. Moreover, all information available in subsequent remote sensing images (time-series) should be used to identify current land-use developments and develop algorithms to simulate future land-use developments. In terms of the allocation algorithm, the optimal spatial and temporal resolution needs to be determined. How well does the same model perform at different spatial or temporal scales? To what extent is it possible to aggregate land-use categories? How well does the same model distinguish two or twenty land-use categories. Finally, to measure these differences in model performance, it is of utmost importance to develop a set of sensitive and appropriate indicators.

As this study was first published in 2005 it is possible to look back on its impact in the Netherlands. Shortly after publication, the results of this study were presented to the relevant policymakers at the Ministry of Housing, Spatial Planning and Environment. The conclusions were quoted by various stakeholder groups in the Netherlands. One of these, the Netherlands Society for Nature and Environment (SNM 2005), published an article in its newsletter calling on the Dutch population to stop further urbanization. In general, the results of this study have been widely accepted. In *Revolutionary Future for Housing Construction*, Hugo Priemus (2005) explicitly supports the results of the study and states his opposition to the popular idea of a '*transformation of the Randstad*', as suggested by planners and administrators. The results of this study have been used in several regional scenario studies in the Netherlands (Dijk 2007; SafeCoast 2005; Witmond *et al.* 2006). It is difficult to determine whether this study influenced policy, but the results have been discussed widely among scientists, stakeholders and policymakers.

References

ABF (2002) Ruimtevraag wonen, werken en voorzieningen herberekend. Verkenning 2000–2030 voor deel 3 van de Vijfde Nota Ruimtelijke Ordening, *No. R 2001–0097LM,* ABF Onderzoek en Informatie, Delft.

Alterra (2003) *Landelijk Grondgebruiksbestand LGN4 2000,* Alterra, Wageningen.

CBS (2003) *Bodemstatistiek 2000,* Central Bureau of Statistics, The Hague.

Dassen, A.G. (2005) *Evaluatie Regelgeving Burgerluchthavens en Militaire Luchthavens, No. 500047002,* Milieu- en Natuurplanbureau, Bilthoven.

De Nijs, A.C.M., Engelen, G., White, R. and Delden, H.v. (2001) De LeefOmgevings Verkenner. Technische Documentatie, *No. RIVM-rapport 408505007,* Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven.

De Nijs, A.C.M., Kuiper, R. and Crommentuin, L.E.M. (2005) Het landgebruik in 2030: Een projectie van de Nota Ruimte, *No. Rapport 711931010,* Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven.

De Nijs, T.C.M., De Niet, R. and Crommentuijn, L. (2004) Constructing land-use maps of the Netherlands in 2030, *Journal of Environmental Management,* 72(1–2): 35–42.

Dijk, v.T. (2007) Scale dependent synergy between risk management and open space preservation, Paper presented at the AESOP 2007 International Conference 'Planning for the Risk Society'.

Engelen, G., White, R. and de Nijs, T.C.M. (2003) The Environment Explorer: spatial support system for integrated assessment of socio-economic and environmental Policies in the Netherlands, *Integrated Assessment,* 4(2): 97–105.

Fang, S.F., Gertner, G., Wang, G.X. and Anderson, A. (2006) The impact of misclassification in land use maps in the prediction of landscape dynamics, *Landscape Ecology,* 21(2), 233–242.

Gabaix, X. (1999) Zipf's law for cities: an explanation, *Quarterly Journal of Economics,* 114(3): 739–767.

Gabaix, X. and Ioannides, Y.M. (2003) The Evolution of city size distributions, In H. a. Thisse, H. (ed.) *Handbook of Urban and Regional Economics. Volume IV: Cities and Geography,* North-Holland Publishing Company, Amsterdam, pp. 2341–2378.

Goetgeluk, R.W., Louter, P.J., Beurden, J.A.M.B.-v., Waals, J.F.M.v.d. and Geurs, K.T. (2000) Wonen en werken ruimtelijk verkend. Waar wonen en werken we in 2020 volgens een compacte inrichtingsvariant voor de Vijfde Nota Ruimtelijke Ordening? *No. RIVM-rapport 711931001,* Rijksinstituut voor Volksgezondheid en Milieu, Bilthoven.

Hagen-Zanker, A., Straatman, B. and Uljee, I. (2005) Further developments of a fuzzy set map comparison approach. Further developments of a fuzzy set map comparison approach, *International Journal of Geographical Information Science,* 19(7): 769–785.

Hagen-Zanker, A., van Loon, J., Maas, A., Straatman, B., de Nijs, T.C.M. and Engelen, G. (2005) Measuring performance of land use models. An evaluation framework for the calibration and validation of integrated land use models featuring cellular automata, Paper presented at the European Colloquium on Theoretical and Quantitative Geography, Tomar, September 9–13.

Hagen, A. (2003) Fuzzy set approach to assessing similarity of categorical maps, *International Journal for Geographical Information Science,* 17(3): 235–249.

Hagoort, M.J. (2006) *The Neighborhood Rules: Land-use Interactions, Urban Dynamics, and Cellular Automata Modelling,* Utrecht.

HCG (1997) *LMS 5.0 Deel 1–7,* Hague Consulting Group, The Hague.

LEI-DLO (1997). *Kansen voor Kassen,* LEI-DLO, The Hague.

LNV (2002) *Structuurschema Groene Ruimte 2. Samen werken aan groen Nederland,* Ministerie van Landbouw, Natuurbeheer en Visserij, The Hague.

MNP (2002a) *Natuurverkenning 2,* RIVM, Bilthoven.

MNP (2002b) *Natuurverkenning 2,* Kluwer, Alphen aan den Rijn.

MNP (2005) Kalibratie en validatie van de LeefOmgevingsVerkenner, *No. Rapportnr. 550016006,* MNP, Bilthoven.

NIROV (2004) *De nieuwe Kaart van Nederland,* NIROV, The Hague.

Pontius, R.G., Boersma, W., Castella, J.C., Kok, K., Veldkamp, A. and Verburg, P.H. (2008) Comparing the input, output, and validation maps for several models of land change, *Annals of Regional Science,* 42(1): 11–37.

Pontius, R.G., Shusas, E. and Mceachern, M. (2004) Detecting important categorical land changes while accounting for persistence, *Agriculture Ecosystems and Environment,* 101(2–3): 251–268.

Pontius, R.G. and Spencer, J. (2005) Uncertainty in extrapolations of predictive land-change models, *Environment and Planning B,* 32(2): 211–230.

Priemus, H. (2005) Wat staat ons allemaal te wachten? Revolutionaire toekomst voor de woningbouw, *Building Business,* 7.

RIKS (2002) *Verkeer in de LeefOmgevingsVerkenner: Ontwikkeling en bouw van een verkeersmodule in de LOV,* RIKS, Maastricht.
RPD (1960) *Nota Inzake de Ruimtelijke Ordening in Nederland,* The Hague.
RPD (1966) *Tweede Nota over de Ruimtelijke Ordening in Nederland,* The Hague.
RPD (1977) *Derde Nota over de Ruimtelijke Ordening. Deel 2: Verstedelijkingsnota,* The Hague.
RPD (1988) *Vierde Nota over de Ruimtelijke Ordening. Eenheid in Verscheidenheid,* The Hague.
RPD (1994) *Vierde Nota over de Ruimtelijke Ordening Extra,* The Hague.
SafeCoast (2005) *Inventory of Spatial and Economical Scenarios Available in the North Sea Region:* WL | Delft Hydraulics & Grontmij.
SNM (2005) RUIMTE - Verstedelijking gaat steeds meer ten koste van natuur, recreatie en water, *Nieuwsbrief.*
VenW (2003) *Meerjarenprogramma Infrastruktuur en Transport,* VenW, The Hague.
VenW (2004) *Wijziging Luchthavenverkeerbesluit Schiphol en Wijziging Luchthavenindelingbesluit Schiphol,* Ministerie van Verkeer en Waterstaat - Luchtvaart, The Hague.
VenW (2005) *Planologische Kernbeslissing Ruimte voor de Rivier Deel 3, Kabinetsstandpunt,* Rijkswaterstaat, The Hague.
Verburg, P.H., de Nijs, T.C.M., Ritsema van Eck, J., Visser, H. and Jong, K.d. (2004) A method to analyse neighbourhood characteristics of land use patterns, *Computers*, *Environment and Urban Systems,* 28: 667–690.
Verburg, P.H., Van Eck, J.R.R., De Nijs, T.C.M., Dijst, M.J. and Schot, P. (2004). Determinants of land-use change patterns in the Netherlands, *Environment and Planning B,* 31(1): 125–150.
Visser, H. and De Nijs, A.C.M. (2006) The Map Comparison Kit, *Environmental Modelling and Software,* 21: 346–358.
VROM, LNV, VenW and EZ (2005) *Nota Ruimte,* The Hague.
White, R. and Engelen, G. (1997) Cellular automata as the basis of integrated dynamic regional modelling, *Environment and Planning B,* 24(2): 235–246.
Witmond, B., Vos, W., Voogt, S. and Vervoort, K. (2006) *Wetlands in het IJsselmeer,* Ecorys BV, Rotterdam.
WWdL (1958) *De ontwikkeling van het westen des lands,* Werkcommissie Westen de Lands van de Rijksdienst voor het Nationale Plan, The Hague.
Zipf, G.K. (1949) *Human Behaviour and the Principle of Least Effort,* Addison-Wesley, Cambridge, MA.

Additional Reading

Dendoncker, N., Rounsevell, M. and Bogaert, P. (2007) Spatial analysis and modelling of land use distributions in Belgium, *Computers, Environment and Urban Systems,* 31(2): 188–205.
Jantz, C.A., Goetz, S.J. and Shelley, M.K. (2004) Using the sleuth urban growth model to simulate the impacts of future policy scenarios on urban land use in the Baltimore-Washington metropolitan area, *Environment and Planning B,* 31(2): 251–271.
Koomen, E., Stillwell, J., Bakema, A. and Scholten, H.J. (2007) *Modelling Land-Use Change Progress and Applications,* Springer, Dordrecht.
Manson, S.M. (2007) Challenges in evaluating models of geographic complexity, *Environment and Planning B,* 34(2): 245–260.
Torrens, P.M. (2006) Simulating sprawl, *Annals of the Association of American Geographers,* 96(2): 248–275.