

## Simulating agricultural land use change in the Netherlands

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### Abstract

The agricultural sector in the Netherlands has changed dramatically over the last 50 years in terms of its relative importance in the Dutch economy, number of farms and productivity per hectare and per worker. As a consequence of these changes, even in the rural areas farmers and farm workers constitute only a small minority of the population. Yet, the area under agricultural use has changed relatively little: two thirds of the total land area in the Netherlands is still farmland. The big question for the future is how expected further changes in agriculture may affect agricultural land use: how much land will be taken out of production and to what use it will be put. This paper identifies the forces that drive these changes, and discusses the possible directions these might take under different scenarios. The Land-Use Scanner, an economics-based model for simulating future land use, is applied to show what possible land-use configurations may result from two of these scenarios.

### 1. The problem

Space is scarce in the Netherlands. Not only is it one of the most densely populated countries in the world, but economic growth has led to an ever-increasing demand for space for residence, business, recreation and infrastructure. In recent years the goal of establishing a coherent system of nature areas has been added to these demands. Yet a further addition is the need to allocate space for buffering water, to cope with the consequences of expected climate change.

Yet, in spite of these pressures, two thirds of the land area are still in agricultural use. Many changes have taken place in the agricultural sector. Land reclamation ceased decades ago, and all efforts have been put into raising the productivity both per area of land and per worker. This has been achieved by land consolidation, research and technology, specialization and economies of scale. The Netherlands with its small area is one of the world's largest exporters of agricultural products by value, and in those areas in which it has specialized (such as flowers, vegetables, dairy, pigs, poultry and potatoes) few countries can match the productivity of Dutch farmers.

However, recent developments and prospects for the future are less rosy. Farm incomes have remained behind those in other sectors, and at the same time the sector has come under increasing pressure from society to reduce its negative impact on the environment - through eutrophication of the water, nitrates in the air, use of energy in greenhouses, soil subsidence, and making the landscape more monotonous. There are pressures for removing or at least modifying the protective regime under which farming in the EU has been for so long. Further changes are undoubtedly in the making.

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The big question is whether such changes may or may not lead to a more substantial change in the amount of land in use by farmers over the next generation or so. In order to answer that question, we shall first examine the forces of change in agriculture and the external claims on agricultural land. These trends are included in two scenarios for long-term economic and environmental change which are commonly in vogue for projections in the Netherlands; they are based on scenarios used by IPCC. Next, the Land-Use Scanner is introduced as a suitable tool for simulating changes in land use. The final section describes the results of applying this model to the problem at hand and draws conclusions from the exercise.

The exercise, and this paper, is based on a joint research project of the four institutions to which the authors belong.

## **2. Driving forces in agricultural land use**

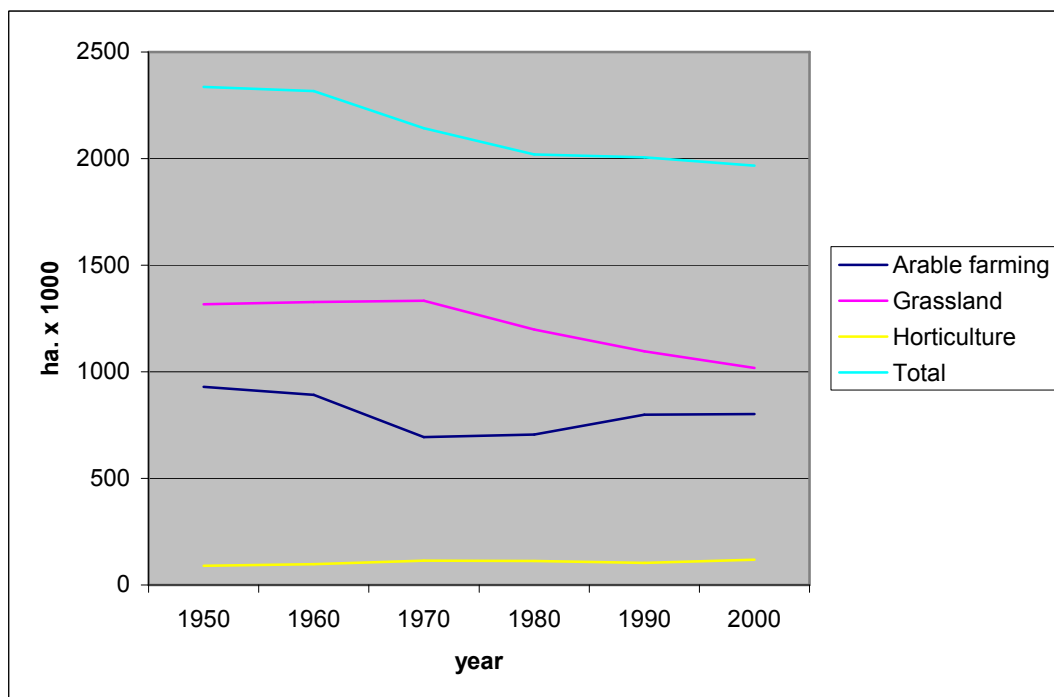
The most important trends in the agricultural sector in recent decades have been the following:

- Increase in farm size. The number of farms is in decline, from 410,000 in 1950 to 90,000 in 2002. The total area under cultivation has decreased by only 16% over that same period (cf. Figure 1), so the average farm is much larger today. This trend is still in full swing today: the number of farms has declined by 4% per year in recent years. As for the decrease in area under agricultural production, this is speeding up somewhat, to the tune of 2.5% decrease in total during the 1990s; but it is still far behind the decline in number of farms – in other words, most farmland coming onto the market is bought by other farms for expansion.
- Intensification: higher inputs of both capital and consumables per hectare, leading of course to higher yields. These inputs are now six times as high as in 1950. Intensification is now slowing down, however: during the interval 1980-2000 inputs per hectare rose by only 13%.
- As a result of these two trends, an increase in aggregate production: in the 1980s this was about 2.6% per year, but in the 1990s annual growth declined to 0.8%. however, this growth differs strongly by subsector, and in recent decades it has been higher for those activities that use land intensively: greenhouse horticulture and zero-grazing animal husbandry. Furthermore, whereas agricultural growth was higher than the national average in the 1970s and 80s, since then it has underperformed the national economy which during the 1990s grew by 3% per year.
- Reduction in agricultural employment, dramatic in earlier decades (there were 2.8 million workers in agriculture in 1900, as compared to 190,000 today) but continuing until the present – during the 1990s the decline was 0.8% per year.
- As a consequence of these and other changes, the role of agriculture in economy and society has been dramatically reduced: in terms of its share in employment (even in rural villages farmers are now a small minority); in GNP; the share of food in the household budget (food prices having declined by two thirds in real terms since 1950); and even the share of agriculture in the production cost of food has declined.
- Increasing dependence on the world market: three quarters of value added is exported, and a large part of the inputs is imported. This state of affairs makes it harder for Dutch farmers to introduce farming methods that are more environment-friendly but also more costly: even if Dutch customers would support such changes (admittedly a big if), importers are unlikely to care and will switch to cheaper suppliers.

- A recent trend is diversification: farmers provide tourism services; protect historical landscapes, wild plants and animals on their land in exchange for compensation; make land available for water storage (ditto); sell regionally typical produce at the farm or at an outlet they control; or provide care for patients who recuperate on farms. Apart from this, many farmers have also taken to other economic activities completely outside the farm. Not all of this diversification is new, of course, but it is receiving increased attention as a path for the future (Van der Ploeg in Boekema & Van Brussel 2003).
- Shifts in the structure of the agricultural sector:
  - the arable subsector has declined in relative importance, although not in area cultivated;
  - in the grazing-livestock subsector, the opposite has happened: dairy production is increasingly important, but it has been achieved entirely by intensification: more milk per cow and more cows per hectare, as a comparison of Figures 1 and 2 shows.<sup>5</sup>
  - zero-grazing grew rapidly in the 1960s and 70s, but is now in decline (cf. Figure 2);
  - in horticulture, greenhouses have become more and more important as compared to open-air market gardening; at the same time, ornamental cultures have gained at the expense of vegetables and fruit.

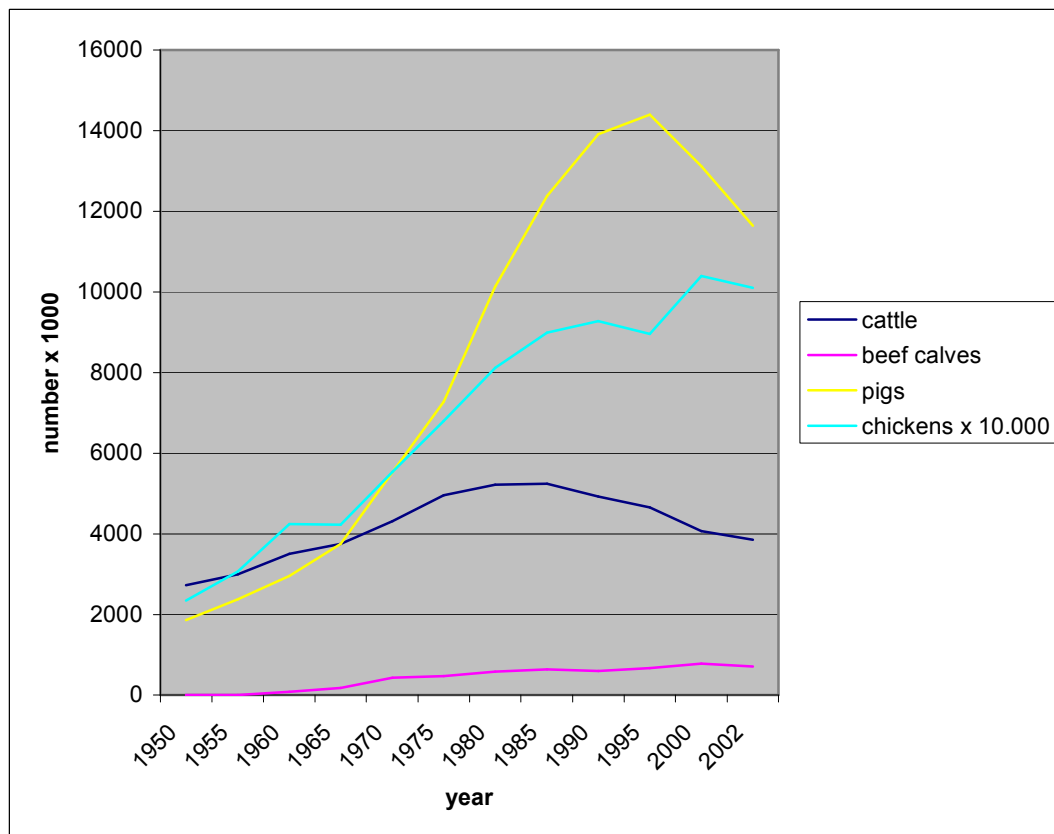
The consequences of these shifts for land use are visualized in Figure 1.

**Figure 1. Changes in agricultural land use in the Netherlands 1950-2000** (source: Central Bureau for Statistics, statline 2003)



<sup>5</sup> Although in recent years the trend has been fewer cows per hectare of grass, still with more and more milk per cow.

**Figure 2. Trends in livestock numbers 1950-2002** (source: Central Bureau for Statistics, statline 2003)



These trends are due to macro-economic and socio-cultural changes, of which the most important are:

1. Overall economic growth, leading to a tripling in agricultural wages over 50 years, and thus a necessity to introduce labour-saving innovations; this same factor has also led to a shift in demand from food towards ornamental products and other luxury items. This leads us to:
2. Shifts in consumer preferences. Within the food sector, quality aspects receive more emphasis, and this may lead to a greater demand for the products of biologically responsible agriculture. At present, 'biological' agriculture makes up only a tiny fraction of total production; its effect on land use is somewhat larger as it requires more space. Recent statistics indicate that about 1.5% of the total area under agriculture is used for this type of production which the government aims at expanding to 10% by 2010 – a highly ambitious target. In any case, the emphasis on quality and provenance of food may open up some new prospects for those sectors of Dutch agriculture which on pure quantity may in future become uncompetitive.
3. Technological progress, which made possible the gains in productivity in the past. Although it is in principle impossible to predict inventions, there appears to be scope for further gains: remotely controlled machines, increased application of electronic sensors in various biological processes, introduction of genetic technology, more ecologically responsible methods of pest control, and new ways of processing animal manure. Such innovations would lead to higher productivity, although not necessarily to a higher

demand for agricultural land – although it would strengthen the position of the sector in competing for space.

4. A very important socio-cultural factor is the shortage of suitable successors for existing farmers. This is partly a consequence of economic prosperity: increasing opportunities for farmers' sons to make an attractive living outside agriculture, but other trends play their part as well: demographic (smaller numbers of children), cultural (changing perspectives on the values of a farming lifestyle), as well as economic (not everyone is able to make the investments necessary to develop a farm into a viable modern business unit).
5. Government policy, at both the national and the European level. The opening up of the intra-European market and the many protectionist measures on a global scale have exercised an enormous influence on the vicissitudes of the sector. The national government has stimulated productivity by land consolidation and by subsidizing some subsectors – notably arable farming and dairying in the past, while facilitating the expansion of zero-grazing and promoting agricultural research. In recent decades, environmental policies have become increasingly important, as well as the promotion of animal welfare. Undoubtedly we are on the threshold of further major changes, with the proposed Fischler reforms in the Common Agricultural Policy of the EU, the expansion of the EU, and the increasing demands from parties outside the EU for liberalization of trade.

### **3. External pressures on agricultural land**

The most common cause of agricultural land being taken out of production is demand for land from other sectors. The past decades have shown a continuous demand for land for business, housing, recreation, nature and water. This demand is likely to continue, as will be argued in this section.

#### *Business and manufacturing*

Driving forces for the spatial development on industrial and business areas are technological innovations, an increasing shift in the economic structure from agriculture and manufacturing towards the tertiary sector, ICT and virtual accessibility, urban vitality, globalisation, changes in organisation of production, and an increase in prosperity and mobility. All these driving forces have different spatial effects. Their impact is mostly on urban areas, but some businesses are less dependent on cities and can thrive in rural areas where land prices are lower.

Companies do show an increasing interest in the image of the place of business. This includes the position in relation to mainports, the presence of other companies, the proximity of services and the vicinity of high-quality living environments. Especially this demand for high-quality living environments may have an effect on rural areas: employment can be generated where employees are to be found.

#### *Housing*

Rural spatial policies have been very restrictive on housing. The distinction between urban and rural areas has been strict. However, this may now be changing. Agricultural policies are being transformed into rural spatial policies. There will be more possibilities to build houses in the rural areas. 'Green for red' is an important issue. When developing red functions (e.g. housing)

in rural areas, green functions should be integrated in planning and financing. This is the case for rural estates and country housing. Furthermore, reforms in the zero-grazing sector offer scope for transforming former space for stables into housing units.

There are many perceptions, definitions of what a rural area is, hence the distinction between urban and rural is not clear. Living in rural environments is popular, but, as there are many perceptions on rural-urban, so there are many perceptions on rural living. A survey by Heins shows that especially morphological and socio-cultural aspects contribute to a positive perception on rural areas. Pull-factors (tranquillity, space and greenery) are more important than push-factors from the city in the wish to live in rural areas (Heins, 2002).

Rural living is not by definition living in the countryside. Many people find it attractive to live in a rural scene, but also want access to urban amenities. The wish to live 'rural' often means living in a green area rather than in the countryside. This can be realised in urban areas with a rural look.

### *Recreation*

There is an increasing demand for recreational space. The driving forces of this demand are:

- Economical. People have more time as well as more money to spend on leisure activities (some of them do, anyway). There is an increasing demand for tranquillity and space.
- Demographic. An ageing population combined with good health increases the demand for recreation.
- Cultural. There is an increasing interest in nature areas for recreation, as well as in regional history and culture. Rural areas are seen as recreational areas e.g. for biking, especially when these rural areas are easy to reach and attractive (Veer & Van Middelkoop, 2002).

The majority of people recreate in and around cities, but an increasing proportion of mostly older people recreate in rural areas. Families with children tend to make more use of theme parks and other planned recreational areas. Ethnic minorities mostly visit city parks.

Public authorities are the most important actors in the development of recreation facilities. They provide recreational areas through planning and act as wardens of recreational areas like forests. As we saw in the previous section, some farmers also offer recreational services; the feasibility of such activities depends on the suitability of the area and on the personality of the farmer concerned – not all farmers enjoy catering for tourists. Such services, by the way, tend to be on a small scale: the larger recreational centres such as holiday parks are operated by a small number of large companies.

### *Nature*

In nature and landscape policy, the use of green areas by people is becoming more and more important. This means that green areas, including rural areas, are opened up and developed for recreation (LNV 2000). The main actor in the nature and landscape sectors is government. There are a few private parties, but they act within the boundaries of governmental policies.

However, there are some external threats to conservation and (as the Dutch call it) development of nature. High land prices are one of the main reasons that the realisation of the ecological main structure, a plan for linking conservation areas into a coherent whole, is slowing down (MNP 2003). Furthermore, nature suffers from disturbance (e.g. noise), pollution and fragmentation. On

the other hand, the presence of valuable nature areas and landscapes, as well as the need to store water, impose restrictions on other types of land use.

There are high expectations of combining nature with other land uses. Since the early 1980s there are contracts with farmers to enhance natural values on their properties. Also for the ecological main structure, the current government has shown an interest to shift away from purchasing land towards management of nature by farmers and other private land-owners.

### *Water*

As is the case with nature, the main actors in the water sector are the governmental authorities at national and local level – including the independent water boards. In recent years, there has been some flooding, which has cast doubt on our continuing ability to control water levels. The new policy of integrated water control is based on three principles:

1. Anticipation instead of reaction to inundation.
2. Priority on retention first (in the area where rain falls), then storing (in an area reserved for the purpose), then evacuation (of the water, not the people) – rather than concentrating on getting the water out as quickly as possible
3. More spatial measures besides technical ones – i.e. reserve space for water rather than relying always on technical ingenuity to get the water out or in.

In future water management will become more and more a guiding principle rather than an afterthought in spatial planning. This means that water will demand more space. In this area, too, much is expected of multiple land use, e.g. combining agriculture with water storage through incidental inundation.

## **4. Two scenarios for future land use**

Enumerating the trends and driving forces in land-use change, as we have done in sections 2 and 3, provides useful insight into current trends and possibly into future development. However, this yields only a disconnected set of possibilities. Some trends may continue, others may stop and new ones may emerge. To provide a framework for integrating the various sectoral trends, two scenarios were selected from an existing study into future spatial development (RIVM 2002). In that study, four scenarios are developed, picturing fundamental directions of social and economic change along two axes: individualism vs cooperation and globalisation vs regionalism. This produces four different directions in which society may go, and one scenario was developed for each of these. The scenarios correspond with a selection out of the set formulated by the IPCC. From these four we have chosen two, which are diametrically opposed: global economy (i.e. globalisation combined with individualism) and regional community (i.e. regionalism combined with cooperation). In the first scenario economic efficiency and international cooperation are the dominant trends, whereas in the latter scenario equity and national sovereignty prevail. Table 1 gives an overview of the assumptions and spatial developments that were assigned to the two scenarios.

**Table 1. Basic assumptions and related spatial implications for the scenarios**

	<b>Scenario</b>	
<b>Assumptions</b>	<i>Global Economy (A1)</i>	<i>Regional community (B2)</i>
Common Agricultural Policy	World markets for agricultural products	Internal EU support under conditions, no export subsidies
Spatial Policy	Less restrictive policies	Restrictive policies for rural areas
Nature Policy	Only the most valuable natural areas are protected	Realization of the Ecological Main Structure
<b>Spatial implications</b>		
Total agricultural land use	Strong decline of agricultural land use	Decline of agricultural land use follows historic trend
Land prices	Increase/decrease	Slight increase
Agricultural Production	Large-scale, industrial farming	More extensive, small scale farming
Agriculture and Nature Conservation	Few chances for agriculture in combination with nature development	Diversified rural development
Agricultural sectors	Growth in industrial dairy farming and greenhouse horticulture. Arable farming considerably smaller	Less growth in dairy farming and greenhouses. Arable farming constant.
Urbanisation	urban sprawl in rural areas	Concentration near existing urban areas
Nature Conservation	Acquisitions through private persons and organisations	Acquisitions through the national government

The story-lines of the scenarios were subsequently fed into sector-specific regional models to quantify the expected demand for various types of land use, e.g. residential, commercial and natural. The demand for agricultural land was estimated by using the land-market model developed by the Agricultural Economics Research Institute (LEI). That model had been applied to the four scenarios mentioned above, in predicting agricultural land use in 2030 for 40 economic regions (Koole *et al.* 2001). For the present study the model has been applied again, but now with a different regionalization. The model uses an actor-oriented approach: predicting what may happen at each farm, given certain known characteristics of the farm, parameters on how it will react to pressures and opportunities, and assumptions derived from the scenarios on what these pressures and opportunities will be.

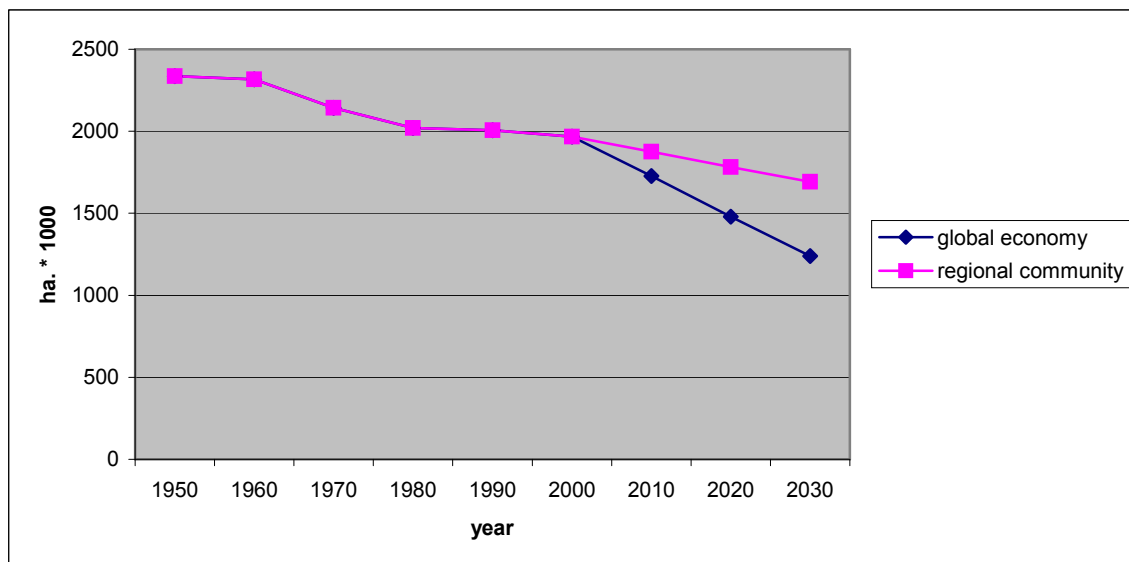
An actor-oriented approach means an analysis in terms of farm types, for which a typology of seven classes was used:

- arable farming
- market gardening (open-air annual crops)
- perennial crops (trees)
- greenhouse horticulture
- grassland livestock farming (mostly dairying)
- zero-grazing livestock (mostly pigs and poultry) and
- mixed types

However, such a typology does not immediately translate into land-use classes: each farm type may use different parcels in different ways; some land-use categories cannot be associated with one particular type of farm (e.g. woodlots or fallow); and some farm types cannot be linked directly to a particular type of land use: the category of mixed farms, or also zero-grazing – to which classifications of cultivated land do not apply. This problem was solved by statistically linking farm types to categories of land use, and then projecting land claims for the future.

The expected total agricultural area per scenario is shown in Figure 3. As compared to the historic trend, both scenarios predict an acceleration of the decline in agricultural land; but in the global economy scenario, this decline is much more dramatic; in the regional community scenario, it resembles the trend in the years 1960-1980, when land consolidation and other policies led to rationalization of farms and land being taken out of production – in spite of the land reclamation, which at that time was still going on.

**Figure 3. Total agricultural area in the 1950 -2030 period, according to two scenarios**



## 5. Modelling changes in land use: the Land-Use Scanner

The Land-Use Scanner is an information system for simulating future land use. It combines a model for allocating space to land use classes, a GIS-type computer programme, and a spatial database containing present land use and data on the suitability of land for various types of use. The system essentially balances claims on land from the various land-use categories with the amount of suitable available land. In this section, the system will be briefly described. For a fuller account the reader is referred to Hilferink and Rietveld (1999) and Scholten *et al.* 2001.

The Land-Use Scanner was developed in 1995/96 at the initiative of the National Institute for Public Health and Environment (RIVM), with the participation of the National Spatial Planning Agency (RPD), the Department of Regional Economics at the Vrije Universiteit Amsterdam, the Agricultural Economics Research Institute (LEI), and the Geodan company. Its purpose is to assist policy-makers in spatial planning by simulating the impact of policy decisions and of autonomous trends on future land use. By showing how competing claims from different sectors

can be reconciled, it can serve as a means of communication between planners representing different interests.

The model is grid-based, dividing the Netherlands into cells of 500 x 500 metres. Each cell contains information on which proportion of its area falls into what land-use class. The current application distinguishes in 14 types of land-use, including 4 kinds of agriculture, 2 residential classes, commercial, recreational and natural land use, water and various types of infrastructure. The model aims at allocating projections of claims on land derived from specialised sector models to the available space in the most efficient way. Efficiency is here defined as reconciling competing claims such that the user who can draw most benefit from realizing his claim at a particular location will get the land.

This means, of course, that we must distinguish between different dimensions of land suitability for different purposes: the quality of the land itself (e.g. in terms of soils where agricultural use is concerned); the existing use (which represents a cost if it is to be changed); infrastructure and accessibility; the proximity of other land use of the same type (i.e. residential areas are preferably not planned in the middle of an industrial area); and government policies pertaining to the area. The total suitability for a land-use type represents the net benefits to be obtained by using that cell for that purpose. The higher these benefits, the greater the probability that the land use in question will be realized.

This probability is determined by a logit equation, which is constrained by the total amount of land available and by the overall demand for each land-use type as given in the claims that are fed into the system. The central equation can be expressed as:

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

in which  $M_{cj}$  is the amount of land in cell  $c$  that is projected as used for  $j$ ;

$a_j$  is the demand-balancing factor which ensures that the total amount of land allocated to class  $j$  equals the claim from the sector concerned;

$b_c$  is the supply-balancing factor which ensures that the total amount of land allocated in cell  $c$  does not exceed 25 hectares (the total area of the cell);

$\beta$  is a parameter which expresses the strength of the suitability factor – a high value making for more mixed land use, closely following the suitability pattern, whereas a low value will lead to a more homogeneous land-use pattern;

and  $s_{cj}$  is the overall suitability of cell  $c$  for a land-use type  $j$ .

It is, thus, not certain that all claims can be realized, but it is certain that all land will be used – that is the nature of the logit approach. The logit model simulates a bidding process between competing land users (or, more precisely, land-use classes): each use will try to get its total claim satisfied, but may be outbid by another category that derives higher benefits from the land. Thus, it can be said that the model mimicks the land market.<sup>6</sup>

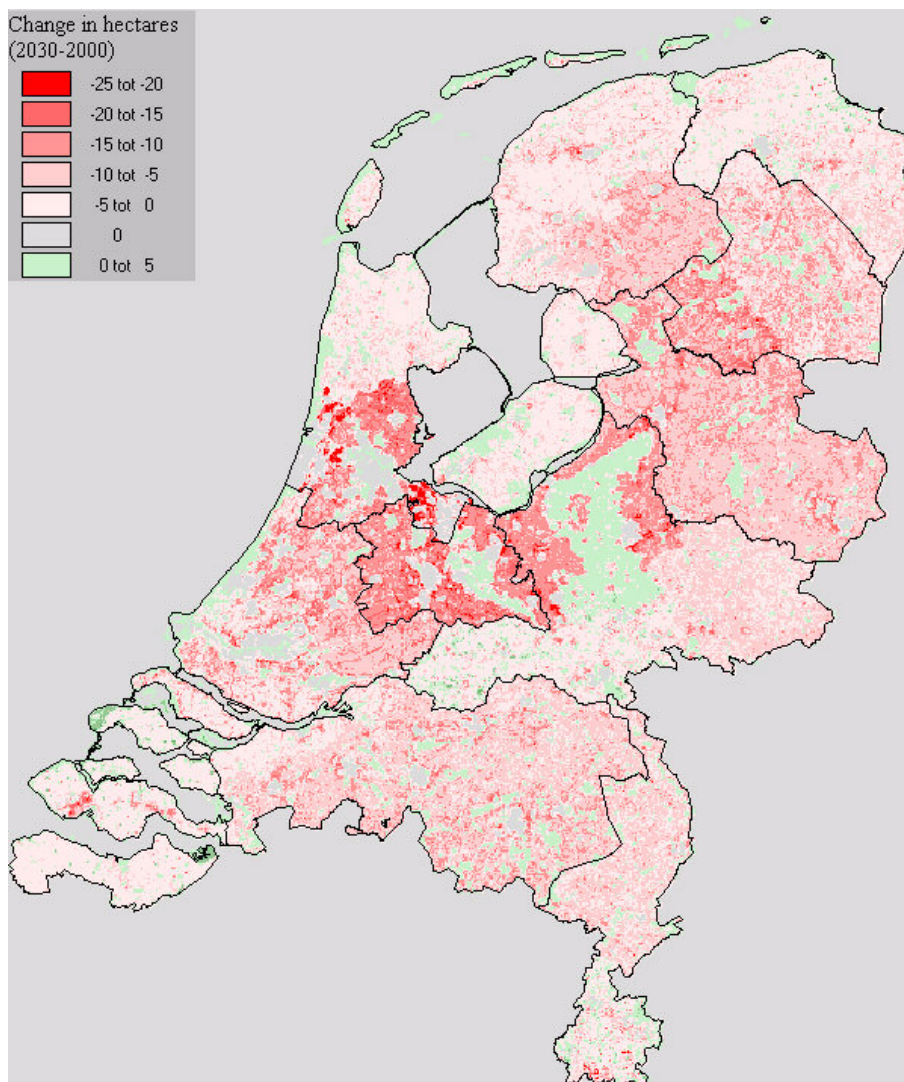
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<sup>6</sup> This means that comparison with the results of the LEI land market model (cf. section 4) could be an interesting line of research, which will help in validating both models. A preliminary comparison suggests that simulations with the two models lead to different results (Scholten *et al.* 2001).

## 6. Results

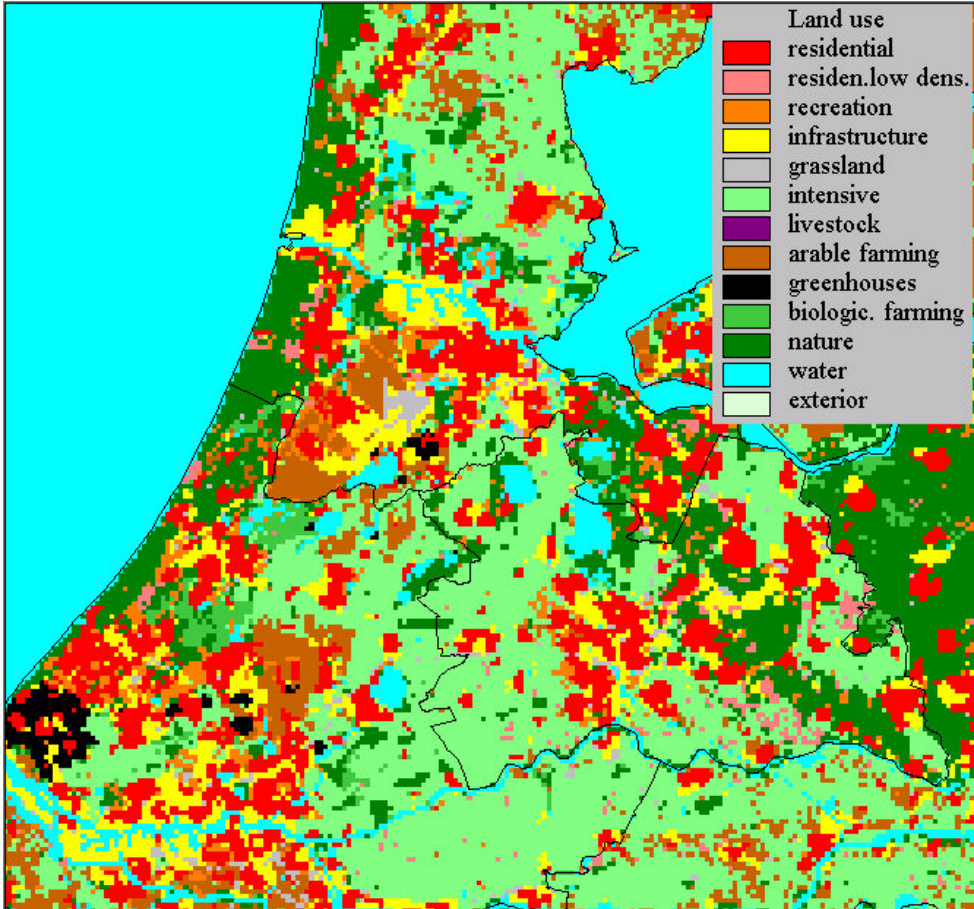
The global economy scenario leads to an accelerated decrease in agricultural land over the next generation or so, as we saw in section 4 (Figure 3). Running the Land-Use Scanner under this scenario presents the spatial distribution of this decrease, as visualized in Figure 4 below. It can be seen that the decrease is strongest in the regions surrounding Amsterdam and Utrecht. This is due partly to strong competition from non-agricultural users, but also because farming in this area – mostly dairying - will become increasingly marginal as soil conditions there are unfavourable. Urban pressure is intense also in the southern part of the Delta metropolis (around Rotterdam and The Hague), but in that region there is more horticulture, which is able to offer higher land prices because of its much higher revenue per hectare.

**Figure 4. Decline in agricultural land use for the global economy scenario as simulated by the Land-Use Scanner**



The regional community scenario presents a very different picture. Not only is the decrease in agricultural land less than under global economy, as we saw in Figure 3; but the importance attached to small-scale biological farming, the integration of agriculture and nature/landscape conservation, and to maintaining open areas for recreation near urban areas leads to new opportunities for the appropriate types of farms. This is exemplified for the Delta Metropole (Randstad) area of the Netherlands, in Figure 5. The Land-Use Scanner predicts, for instance, that nature conservation on farms will become common in the belt between The Hague and Amsterdam, at least in the southern part of that belt – not in the area just south of Amsterdam where the airport is situated; that area is a large-scale land reclamation project from the 19th century, which has little to offer in terms of natural or historical values. In other parts of the region, nature and recreation areas will increase in importance. In the highly appreciated woodland areas near the larger urban areas low-density residential areas are likely to develop.

**Figure 5. Simulated land use in 2030 for the regional community scenario**



Under neither scenario is agriculture likely to disappear. The high-intensity, highly productive, technically advanced subsectors are likely to flourish even under a economy scenario –albeit with further momentous changes that will undoubtedly affect the landscape. Certain products, such as sugar beets or cereals, may well disappear altogether. Intensive livestock-keeping (pigs and poultry) has an uncertain future, both as a result of environmental and animal-welfare legislation and in consequence of the accession of new EU members; bold innovations in waste disposal and in agro-industrial complexes may, however, cause it to flourish again. Greenhouse horticulture is likely to do well under global economy and even for certain arable products (such as potatoes) the outlook is not all bleak.

Under regional community, agriculture has a future too; but here intensive animal husbandry will be much smaller and less intensive, with a free-range component; the average farm will be smaller; and there will be more emphasis on the integration of agriculture with other functions, such as nature, recreation, and residence (hobby farming). There will be much emphasis on preserving an attractive environment around the cities.

How likely is it that either of these scenarios will actually come to pass? For one thing, whatever the reality value of the predictions regarding trends in agriculture, it must be borne in mind that the Land-Use Scanner does not claim to predict the use of a particular grid cell with any degree of accuracy – in fact, the colour code in Figures 4 and 5 represents a probability of a dominant land-use category. It does aim to show spatial patterns: what land-use changes are most likely in which regions – the regions themselves not being pre-defined but defining themselves by the patterns generated.

The probability of a projected pattern depends, apart from the exogenous variables contained in the scenarios, on the values given to constants in the model, such as those governing the importance of present land use, or of soil quality, or of proximity to other land-use types. Modifying these will alter the predictions made by the system, and the values actually used reflect the researchers' assumptions. The results presented here should, therefore, be regarded as answers to 'what if' questions rather than hard predictions. That is also the reason that the two scenarios representing relatively extreme cases were selected.

Still, we believe that such projections are useful as guidelines for spatial policy as well as for policy in general. Their strength is that they bring together the likely consequences of possible developments in many different fields for the use of space. One may then ponder whether such consequences are desirable. In that respect, the Land-Use Scanner can provide insights useful to policy-makers.

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