Linking models in land use simulation:
Application of the Land Use Scanner to changes in agricultural area

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abstract

When we model land use change, we utilize – consciously or unconsciously – other models as well. The variables we regard as exogenous in our model are often generated endogenously by a different model. We are not always fully aware of the implications of this for our modelling exercises. The model resulting in claims for agricultural land may have already taken competing claims into account – whereas our land use model may simulate this competition all over again. The data used for different models may not be compatible.

Conversely, our land use simulation exercises can also be used by others as input. A model for the agricultural sector, for instance, must consider the constraint of available land – especially whether the land required is available in a particular area which is regarded as optimal for a particular production line. Land use models can provide that input. Hence, linkages between models are important and at the same time easily being overlooked.

In order to examine both the possibilities and the problems inherent in these linkages, a research project on the linking of various models in use at the Agricultural Economics Research Institute in The Hague has been undertaken.This project has led to interesting insights into the problems of linking models. It is hoped that these insights will help to improve the models we use – including land use models. In this paper we focus on one of the model in the middle of the so-called 'model train', the Land use Scanner. We discuss the basic characteristics of the model, the input data and the results.

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1. *Introduction*

Any model, whether it is used to describe land use, world trade or the orbit of celestial bodies, uses assumptions. The model concentrates on the description or explanation of a particular aspect and takes some of the assumptions or data for granted. These data are considered as exogenous and their explanation lies beyond the scope of the model at study. These exogenous data themselves are the output of other models. Those models may have used different assumptions as well as different data. When we use models on a stand-alone basis, we are usually not aware of these problems.

However, in the case where several models are linked together, these problems can no longer be ignored. Are the assumptions of the principal model the same as those made by the models supplying 'exogenous' data? For example, an economic model for demand and supply of agricultural production could make certain assumptions about availability of land or land use claims. If it is unknown (or ignored) which competing sectors have been considered in calculating these claims, a land use model at another spatial scale may simulate this competition all over again, using probably different assumptions or mechanisms. Both the data and the underlying principles may not be compatible.

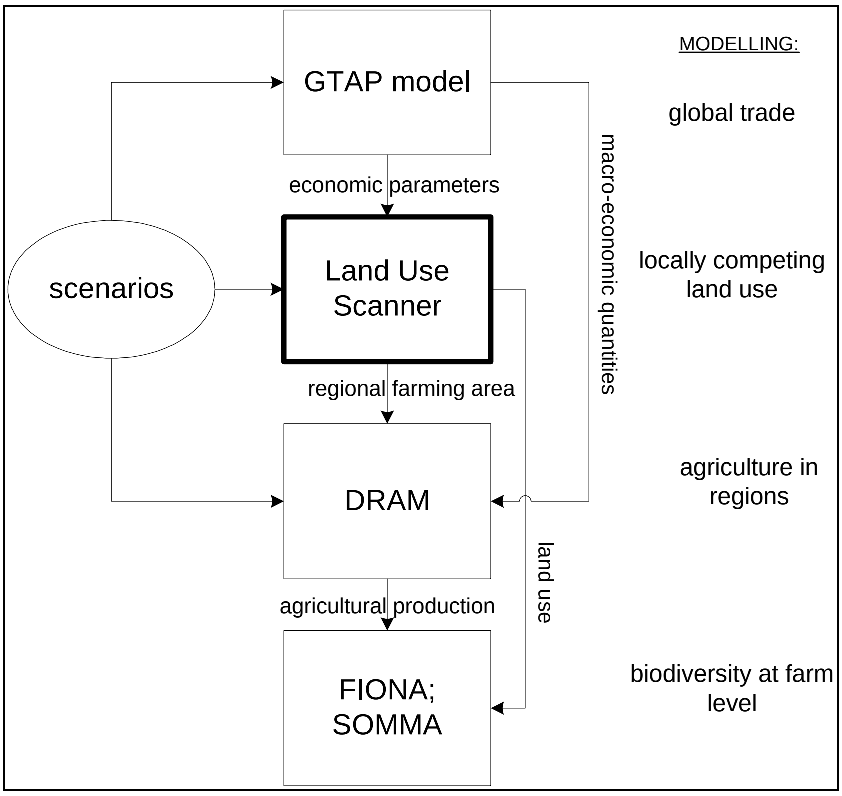
The Agricultural Economics Research Institute (LEI) in The Hague, (The Netherlands) uses a number of models at various spatial levels – from the individual farm to the global economy – and for different purposes. For example, global models can be used to estimate the effect of world wide trends of agreements on national economies of specific sectors, whereas models at the individual farm level give insight into the effect of agri-environmental schemes on biodiversity at a location as small as the plot. Recently, the linkages between these models have received more attention, which also lays bare the compatibility problems between them. Figure 1 shows a simplified scheme of a chain of linked models. In this case, the models are not only mutually dependent on data. They also use common assumptions in calculating the effect of scenarios.

In order to examine both the possibilities and the problems inherent in these linkages, a research project on this 'model train' has been undertaken. Based on two opposing scenarios prepared by the Netherlands Bureau for Economic Policy Analysis (CPB)[3], the study calculates the long-term consequences of these scenarios: beginning with a general equilibrium model at global level

[3] These scenarios are derived from the global IPCC Scenarios (IPCC, 2000).

(GTAP) through a sectoral model at national and regional scale - the Dutch Regionalized Agricultural Model (DRAM) – to models assessing ecological effects in a local area (FIONA and SOMMA). Central in this chain is the The Land Use Scanner, a land use information system and simulation model for the Netherlands. It has been used to predict changes in the agricultural area for the regions used in DRAM. The land claims, which are an exogenous variable in the Land Use Scanner, were generated from projections of future population and GDP, on the basis of their historical correlation with land use.

Figure 1. A simplified scheme of linked models[4]



We begin with a brief description of the Land Use Scanner, including a discussion of the concept of agricultural land use which as we shall see is problematic. The next section explains how historical data on land use were employed as a basis for generating claims on land. The final section provides the results of running the model under the conditions specified.

[4] GTAP=Global Trade Analysis Project;
DRAM= Dutch Regionalized Agricultural Model;
FIONA=Farm level Integrated Optimization of Nature and Agriculture
SOMMA=Spatial Optimisation Model of Metapopulations and Agriculture

2. *The Land Use Scanner*

Estimating the area available for agriculture is an important component in economic and ecological projections on the agricultural sector. This cannot be done with sectoral models, as these can only estimate the area *needed* by farmers. Whether the required amount of land will actually be available depends also on the claims made by other sectors. In the 'model chain' with which this project is concerned, models such as GTAP can generate the claim on land needed to ensure the volume of agricultural production predicted. A land-use simulation model is then needed to confront these claims with those made by other sectors of the economy. The results can be fed back to the earlier link in the chain for adjusting the predicted production volume.

The Land Use Scanner is such a model-cum-information system for the Netherlands. It is capable of regionalizing the output generated, so it can serve as input for the next link in the chain, the Dutch Regionalized Agriculture Model (DRAM), which distinguishes 14 agricultural regions. This paper describes how the Land Use Scanner was adapted and applied for this particular purpose. The resulting claims were fed into the Land Use Scanner. Three modifications were made to the model because of the specific needs of this particular project:

- firstly, previous claims were regionally specific, but in the present case the claims are country-wide; this, of course, provides the model with more freedom to allocate the claims to specific areas.
- Secondly, in previous versions several types of agricultural land use were modelled. Here, the agricultural claim is taken as a whole, leaving it to DRAM to assign the available agricultural land to particular agricultural products.
- Thirdly, the model has been adapted to reach its final result in three consecutive steps (for feeding into DRAM), whereas previously the final outcome was predicted directly.

The model was developed in the late 1990s by a consortium of several research institutes, in order to predict the likely consequences of expected economic developments and of government policies on the use of space. It has since been used in several major policy documents such as the 4th National Environment Study, the 2nd National Nature Study, and the 5th Spatial Policy Statement. In 2002, it was incorporated into the Land Use Modelling System (LUMOS), which intends to provide a common environment for several land-use modelling approaches.

Participants in the LUMOS consortium include a number of university institutes, government research bodies, and IT companies.

The Land Use Scanner is grounded in economic theory, the fundamental hypothesis being that land use is determined by the suitability of land for a particular purpose. Different land-use categories are pictured as actors competing for limited space, with each area of land going to the category that can derive the largest benefits from it – an approach based on the bid-rent theory for urban land use (Alonso 1964) and on Von Thünen's theory of agricultural land use (Von Thünen, 1842). This theory is cast into a logit format, following the method of discrete-choice analysis (McFadden 1981). The basic equation (Hilferink & Rietveld 1999) is:

$$x_{cj} = \frac{\exp(\beta . s_{cj})}{\sum_j \exp(\beta . s_{cj})}$$

where x_{cj} is the probability that cell *c* will be used for land use *j*;

s_{cj} is the suitability of cell *c* for that land use class;

and β is a parameter measuring the strength of the correlation between x_{cj} and s_{cj}.

Two constraints are added to this equation: one to ensure that the total area of land allocated to land use *j* does not exceed the total amount needed; that amount (the claim) is derived exogenously. The second constraint ensures that the total area for all land uses in cell *c* will be equal to the area of the cell – in other words, there is no land left unused.[5]

The central variable in the mode is suitability of land. This is based on the following factors (Schotten & Boersma 2001):

- Existing land use. There are costs attached to changing land use: firstly transaction costs since it usually also involves change of ownership, and since planning permission will often have to be sought; and secondly (particularly when the land has been built on) the demolition of structures. This means that there are strong incentives to maintain existing land use.
- Inherent land suitability. This refers to the qualities of a piece of land by itself, without reference to the wider environment. We can think here of soil types, the characteristics of

[5] This latter condition can, of course, be fulfilled only if the total claims for all land uses are not less than the total area of the country. If they are (which is not likely in the Netherlands), a category 'unused land' would need to be introduced. We may also note that total claims on land may exceed the total area available. The constraints in the model do require that the two quantities are equal, but they can be equalized by an iterative method which results in not all claims being met.

which are relevant not only to agriculture but also to the cost of building; of groundwater levels; of topography (even though this is rarely a factor in the Netherlands); or of landscape, which can be attractive to prospective residents or for recreation; finally, areas with unique ecosystems or rare species will carry a high value for protection as nature reserves.

- Spatial relations. Apart from the qualities of the land itself, proximity to other land use types influences its suitability for particular land uses. For instance, people will like to live near a railway station and a highway access point, but not near the highway itself and not near an airport or industrial area. For the latter, on the other hand, a location in the immediate vicinity of a highway or airport will usually be attractive.
- Policies pertaining to land use. The Netherlands has a strong tradition of government intervention in land use, and there are many restrictions on land use. These restrictions and spatial plans are incorporated into the database.

For all of these factors maps have been created and converted into grids with cells of 500x500 metres, so that various properties of the same cell can be analyzed. However, these data in themselves are not sufficient to determine suitability for particular uses: they need to be evaluated. A map will show, for instance, how far a particular cell is from the nearest highway; but how attractive or unattractive is such a location, and how does it measure against other factors? Given that people may like to live in attractive scenery, how strong is that effect? How do we deal with policy restrictions which make certain land uses more costly but not impossible? And how do we assess the cost of changing land use? The answers to these questions involve value judgments. They may be derived from empirical knowledge on preferences, but in research done so far a scenario approach has been used: different scenarios can be translated into different valuations of the various factors.

These valuations are made by modifying parameters included in the programming lines of the model. Combining the aforementioned maps with these scenario-driven parameters results in the so-called attractivity maps, which simulate the bid prices that land-use categories are willing to pay for using land within any given cell. These attractivity maps now show the values for s_{cj}. By simulating bid prices for land, the model generates shadow prices for land as a by-product.

The final requirement for running the model is the land claims for each land-use category, which are also scenario-dependent. In previous applications of the Land Use Scanner they were derived from sector models or from policy statements. For the original version, completed in 1998, three scenarios from the long-term vision of the Dutch Central Planning Bureau were used (CPB 1997).

In order to implement the model, an information system was developed in the C++ language, called the Data and Model Server (DMS); this system, provided with a user interface written in the Delphi language, has since been used also as a modelling environment for other research projects. The resulting maps in grid format can be exported as ASCII files and thus used in standard GIS applications. The DMS can also generate output in tabular form, although this, of course, lacks the spatial dimension of the grid maps.

The present application of the Land Use Scanner is aimed specifically at predicting the land area available for agriculture per DRAM region under two different scenarios, for 2010, 2020 and 2030. The version of the Land Use Scanner used (version 4.56) uses 1996 as a base year. Total agricultural land use in 1996 according to the Land Use Scanner was 2.37m hectares; however, DRAM uses an area of 1.98m hectares as a basis – a considerable difference, which is only partially explained by differences in definitions and observations techniques. Therefore, in order to make the data from the Land Use Statistics (and the Land Use Scanner) comparable to those used in DRAM, a correction factor had to be applied. Over the period 1970-2000, it was found that the total agricultural land use according to the agriculture census was on average 16.2% smaller than that of the Land Use Statistics, with a standard deviation of 0.7% (before 1970 the discrepancies are somewhat larger). The output from the Land Use Scanner has therefore been decreased by that average percentage to make it compatible with DRAM data.

3. The construction of land claims

In previous versions of the Land Use Scanner, spatial claims have been derived from different sectoral models as well as from coarse estimates and policy statements. This carries the risk that these claims may be incompatible: different assumptions may have been used to generate the claims for each category, or different interpretations of the same scenario. Claims for one sector may take the supply factor into account, while for another only the demand side may have been considered (as it should). For the present application, an attempt has been made to derive the claims for all categories by a uniform method. This is not necessarily better than what has been done in the past – the sectoral models may be based on better information and may follow a more refined method – but it has the obvious advantage of compatibility between categories, and it suits our purpose as we are fundamentally interested in only one sector.

The method chosen is to correlate historical data on land use with population and GDP figures, and then to apply the regression coefficients found to the projected population and real GDP figures of the two scenarios. A similar approach is used in the FAO World Food Model (see Balkhausen & Banse 2004). It predicts the total agricultural land using the GDP and population as the explanatory variables, which express the conversion of the agricultural land to non-agricultural uses of land.

Land Use Statistics data (culled partly from the Statline database and partly from printed reports) were collected for the period 1967-2000 (the latter being the year of the most recent version). A major problem with the use of these data is that the definitions of the various land-use classes vary from year to year. For instance, streets within a built-up area may be counted as infrastructure in one year, but as residential area in another. Road embankments may be included with the roads one time, another time with the surrounding area. Such changes can account for large variations in the areas measured – especially where the areas themselves are relatively small, as is the case for infrastructure. A major change of this kind was carried through between 1966 and 1967, which is why the latter year was chosen as a starting-point for this exercise. However, other major changes were made in 1976 and 1993, and various smaller changes in between.

Corrections for such changes have been made by comparing rates of change during the few years before and after they were implemented with the jump in the year when the definition was changed. These comparisons can yield correction factors. Since 1977, the land use statistic has no longer been made every year, whereas annual figures are needed for the time series. This can easily be achieved by computing average annual growth rates for the periods in between. Another problem is that the land use classification used by the Land Use Scanner does not match exactly with that of the Land Use Statistics; comparing areas for each class for 1996, however, shows such things as cemeteries being classified as residential areas in the Land Use Scanner - appropriately perhaps.

Five classes of variable land use were constructed in this way:

- Residential: areas of more than 1 hectare where residence is the main land use function. As mentioned, it includes cemeteries and also streets except main thoroughfares; it does not include parks, sports fields, shopping areas, hospitals, schools and the like, except where such functions occupy areas of less than 1 hectare.
- Business: industrial areas, retail zones, central business districts, social and public services, garbage dumps and vehicle demolition sites, mines, and building sites; unclassified areas (of which there are few) are also included here. All such areas must be larger than 1 hectare in order to be enumerated separately.
- Recreation: parks, sports fields, garden allotments, theme parks, campings, bungalow parks, landscaped recreation sites, and the like.
- Agriculture: cultivated areas, fallow land, and auxiliary lands used by farmers such as farmyards, buildings, hedgerows and ditches.
- Nature: forests, moors, dunes, wetlands and other areas set aside for nature protection.

There are three more classes in the Land Use Scanner, but these are treated as fixed and cannot be manipulated by the model in its present form. They are:

- Infrastructure: paved roads, railways, and airports (but not port areas, which are classified as industrial). The Land Use Scanner is not well equipped to forecast these, as they tend to be linear (at least the roads and railways) and the Land Use Scanner works with areas rather than lines. However, planned extensions to infrastructure can be fitted into the model as part of the forecast.
- Water: any watercourses more than 6 metres wide. Both reclaiming new land from the water and flooding existing land are rare at present. Still, in principle it would be possible to include an argument for converting water into land and vice versa under certain conditions.
- Abroad: land areas outside the Netherlands. This is a formal category, which exists only because the total area of the Land Use Scanner is a rectangle of grid cells; some of these necessarily fall outside the national territory.

The historical picture of changes in these land use classes for the period investigated, after all corrections were carried out, is shown in Figures 2-7; we include infrastructure here, because .it is after all subject to systematic change.

Figure 2. Change in residential area, 1967-2000; index base 1967=100, 1480km^2.

The area for residential space increased rapidly until the early 1980s, when the main post-war building boom came to an end. Since then, population increase has been small, although the demand for living space is still increasing due to the smaller size of households and due to economic growth. However, the impact of these trends on total residential area (measured at ground level) has been small.

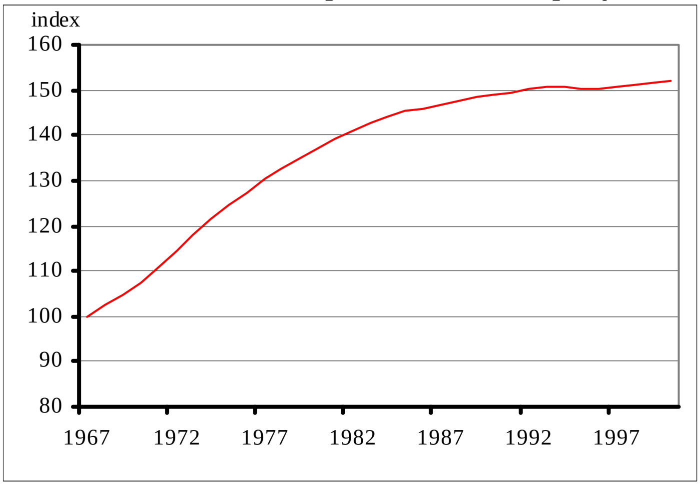


Figure 3. Change in business area, 1967-2000 ; index base 1967=100, 924 km^2

The growth of space for business has been more erratic, which is partly a consequence of the heterogeneous nature of this land-use class as described above. Yet, the effect of low economic growth during the period 1980-1993 is clearly visible. The expansion in business land since 1993 is due mostly to an increase in industrial areas and in building sites.

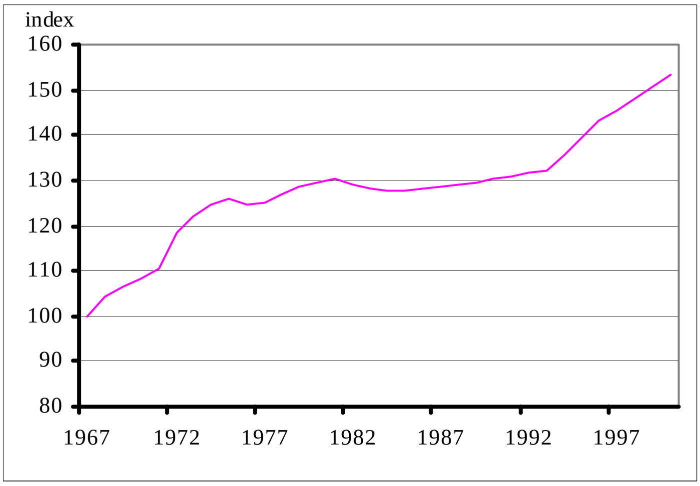
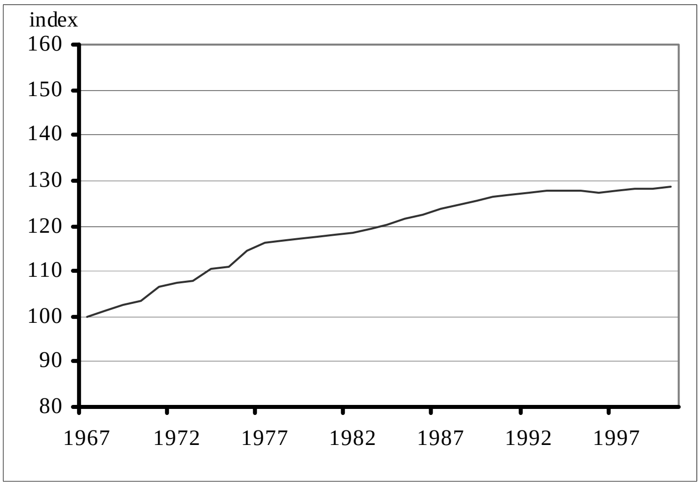
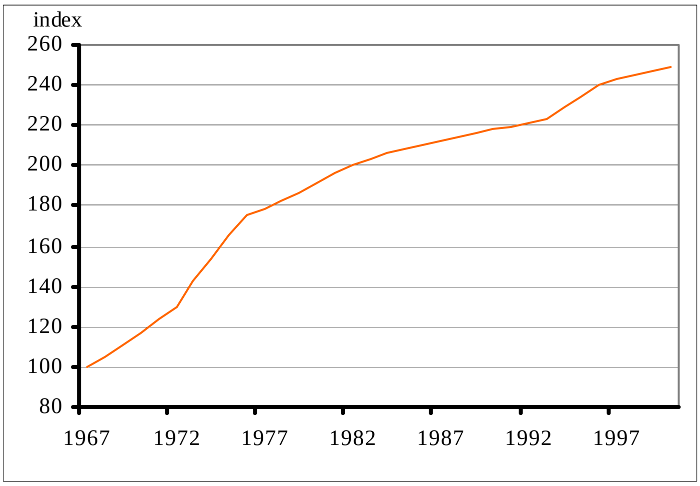


Figure 4. Change in infrastructure area, 1967-2000 ; index base 1967=100, 879 km²



The increase in the area required for infrastructure has been quite steep until the 1990s, but has since levelled off. During slack periods in the economy this growth was also slower, but the effect is less pronounced than in the case of industrial land use. It may be noted also that in spite of the enormous increase in mobility in recent decades, the claim of infrastructure on space remains relatively modest, at 3% of the total land area in the year 2000.

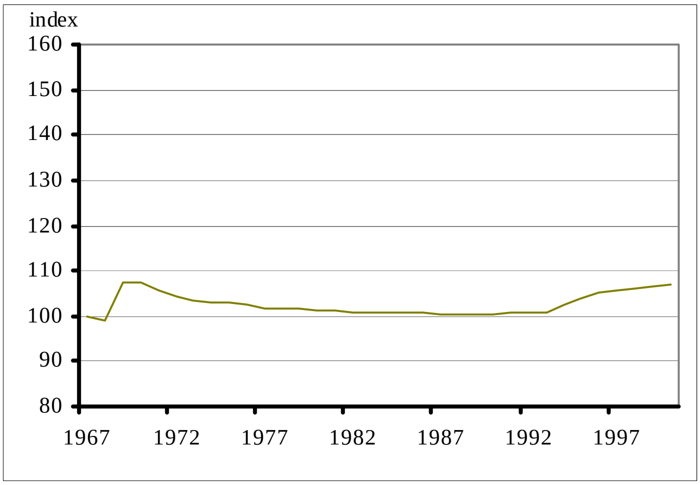
Figure 5. Change in recreation area, 1967-2000[6] ; index base 1967=100, 357 km²



The demands of land for recreation appear to follow those of infrastructure in their pattern over time. Remarkably, recreation, infrastructure and residential land use have all failed to expand since about 1994 in line with both demographic and economic growth. This is probably due mainly to government policy, which has encouraged more efficient use of existing space (e.g. compact cities) and discouraged the conversion of open space into built-up areas. This is not necessarily present policy: as the area of building sites has increased, we may expect larger areas for housing and infrastructure in the near future.

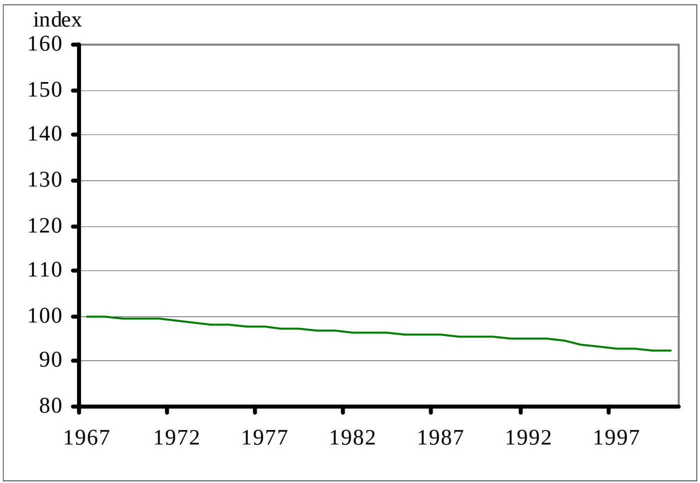
6 Notice the different scale for the index values in this figure

Figure 6. Change in nature area, 1967-2000 ; index base 1967=100, 4527 km²



The most curious pattern is exhibited by the land allocated to nature conservation (or, in the Netherlands, also the creation of new 'natural' areas). We see first of all a dramatic increase in the late 1960s. This happened when the last major land reclamation project was completed: the newly added land was not yet cultivated and classified as wasteland – which we now call nature. In the early 1970s it was allocated to farmers, leading to a decrease in nature area. The pattern of converting wasteland into cultivated or built-up areas – which has been going on for thousands of years - was thus resumed. However, the increasing scarcity of nature has increased its value; and for over a hundred years people have begun to regret the loss of their natural environment. Clearance of forest or moor for agriculture has ceased some time ago. Setting aside areas for nature conservation has now finally reached the point where it has exceeded the amount of nature which is being lost to urbanization, with the proclamation of the National Ecological Network in 1990 (LNV 1990). From that moment on the government has been buying land, and the result is clearly visible in Figure 6.

Figure 7. Change in agriculture area, 1967-2000; index base 1967=100, 33382 km²



All this means that the increase of urban functions now takes place entirely at the expense of space for agriculture, and Figure 7 indeed shows an acceleration in the decline of agricultural land in recent years. Most of this recent decline, however, is due to the expansion of nature reserves.

The decrease of land used for agriculture was going on even in the early 1970s, in spite of the allocation of new farm land in the reclaimed area going on at that time. Still, the decline during the period under consideration has been only 0.24% per year; but the vast area of agricultural land has been sufficient to accommodate a large increase in built-up area. At present, two thirds of the land area is still in farms.

For each of the above land use categories, regression equations were set up for estimating the relationship between the land area and population, and Real Gross Domestic Product (RGDP). We have assumed a double-log relationship between these categories. Moreover, we introduced dummy variables to the equations to explain changes in the pattern of the estimated relationships. They mostly cover the period from 1994, 1995 or 1996 to 2000. Such a dummy explains decrease of the agricultural land due to the McSharry reform land or government policy towards nature. For residential land, it covers the relatively slow residential area growth to compare with population changes after 1994.

The equations were estimated using 1973–2000 data. Overall, the estimation results are satisfactory. The goodness of fit varies between 89% and (almost) 100% and almost all parameters are significant on a higher than 1% significance level. The estimated coefficients are presented in Table 1 in terms of short- and long-term elasticities of land areas in respect of the population and RGDP.

Table 1. Estimated elasticities of land areas in respect of population and RGDP.

		agriculture	nature	recreation	infrastr.	residential	business
Population	short-term	1.58	-0.81	0.53	0.04	-9.48	
	long-term	0		1.83	0.31	1.70	
RGDP	short-term	-0.08	0.19				0.09
	long-term						0.39

As expected, population growth has had a positive and RGDP growth a negative impact on the agricultural land area. However, the long-term population impact is zero, which is caused by increasing yields and imports of agricultural products, which substitute for domestic production. The population growth generates demand for residential area and therefore has a negative impact on the nature area. On the other hand, growing RGDP creates resources the expansions of nature.

The estimation results confirm the positive impact of population on recreation, infrastructure and residential areas. They also confirm our observation made above that economic growth is not reflected in the development of these areas. Since the residential areas expansion is a rather long process, the short–term population changes are not reflected in residential areas changes, which explains the negative short-term population elasticity. Finally, as expected, the extent of business areas is strongly correlated with economic growth.

Since an increase of nature area is rather weakly explained by economic and population changes since 1995, we estimated the linear trend for this area for 1995 - 2000. The estimated equation shows that the nature area increases by 24 square kilometres on average per year since 1995.

Further discussion resulted in modifications. For one thing, we must remember that the object of these projections is not to serve as forecasts for future land use, but as probable claims exerted by different sectors. This implies that – in a country like the Netherlands – a total claim of less than the total land area is unlikely to be realistic. This occurs in the second scenario. To rectify this, it was decided to keep the claim for agricultural land constant in both scenarios. This is realistic, because up to now there have always been farmers willing to buy any farmland appearing on the market. Unless the revenue per unit product would drop below the variable costs, this situation is likely to continue as long as the land price is allowed to drop far enough. Of course the agricultural area actually realized would depend on the claims of other sectors, as well as on the price agriculture is able to pay for land. These will vary between the two scenarios.

A further modification was to make nature in the Regional Community scenario dependent not on population and GDP but on government policy. This is in accordance with the meaning of this scenario. The statement by the Minister of Agriculture, Nature and Food in the government budget for 2005 on the amount of nature reserves to be realized by 2018 has been used to predict the area for 2020; for the period 2020-2030 the extra area to be added remains as in version 1. Under the Global Economy scenario the claim for nature remains correlated with population and GDP.

Finally, it was decided to increase the claim for residential space under the first scenario, on the basis that there will be fewer restrictions on building. This will lower the price of residential land, therewith the cost of living space, allowing more space for the same amount of money. To accommodate this effect, the additional claim for residential land in this scenario was increased by 25% (i.e. not on the total residential area, but on the area added for each target year).
The resulting equations were used to project future claims on land under the demographic and economic growth rates of the Global Economy and the Regional Community Scenarios. These claims are shown in tables 2 and 3..

Table 2. Projection of land claims, Global Economy [7]

year	land area	agriculture	nature	recreation	residential	business	total
1996	33800	23510	4765	859	2223	1323	33799
2000	33784	23261	4835	889	2251	1418	33784
2010	33784	23261	4810	983	2832	1606	34599
2020	33784	23261	4820	1099	3182	1789	35258
2030	33784	23261	4840	1214	3544	1975	35941
change 2000-2030:		0%	0.1%	36.5%	57.4%	39.2%	

Table 3. Projection of land claims, Regional Community

year	land area	agriculture	nature	recreation	residential	business	total
1996	33800	23510	4765	859	2223	1323	33799
2000	33784	23261	4835	889	2251	1418	33784
2010	33784	23261	5753	950	2367	1548	34986
2020	33784	23261	6385	968	2272	1623	35616
2030	33784	23261	6705	955	2142	1671	35841
change 2000-2030:		0%	38.7%	7.4%	-4.8%	17.8%	

The claim for infrastructure has been excluded from these tables, as it is not used by the Land Use Scanner. The year 1996 is included because it is the base year for the Land Use Scanner. The total land area has been kept constant from 2000 onwards, but in the historical data it varies slightly from year to year, due to small areas being flooded or reclaimed, and probably also because of differences in accuracy of measurement. It may be noted that under the second scenario the residential area decreases after 2010; this is in line with the expectation under that scenario that the population also decreases, and that residential area per inhabitant has changed little in recent years.[8]

The claims are now higher than the total land area available in all future years, so the model has something to allocate. The claims of Tables 2 and 3 were entered into the Land Use Scanner.

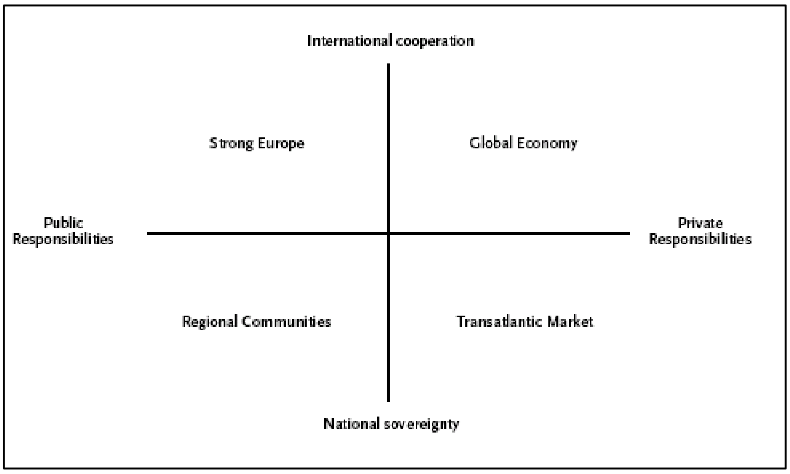
[7] The total claim includes the area for infrastructure in the base year, so it can be compared with the total land area.

[8] Although floor space per inhabitant has increased, so has the net amount of floor space per hectare of residential area. Thus, residential areas have generally become more compact.

4. Building scenarios

As mentioned in section 2, two opposing scenarios have been used as a basis for the calculations. These scenarios, which form a subset of the four scenarios derived form the well-known IPCC scenarios, are ‘Global Economy’ and ‘Regional Communities’ (see figure 8).

Figure 8. The set of four CPB scenarios (De Mooij and Tang, 2003)



The scenarios are used to adjust the Land Use Scanner in two different ways: one is the claims on land by different sectors, the other is by placing values on various spatial data such as land quality, policies, existing land use, and proximity to other land uses. These data are contained in maps which are part of the information system in the Land Use Scanner. The valuation is done by editing certain lines in the programme, which lines then control the so-called attractivity maps which show the scores per land-use class per grid cell. The tables on the next page give an overview of the values used in our two scenarios.

The variables in columns 3 and following in Tables 4 and 5 represent the factors which influence the suitability of land for particular uses, and the scores reflect the values attached to them in the two scenarios. The factors include intrinsic properties of the land (quality of soil and landscape); the current use of the land; policies relating to particular areas; and what happens in the vicinity of the cell concerned. For all these factors maps exist, and with the aid of the scores in the tables attractivity maps are constructed by the Land Use Scanner which assign the degree of suitability for each land use class to each cell. These values are adjusted by the average bid price for land assumed in the scenario, shown in column 2.

The average bid price for each land class differs between the two scenarios in that the difference between residential and industrial land is somewhat higher in Regional Community, reflecting the assumption that government subsidy for home ownership will be withdrawn under Global Economy but maintained under Regional Community – leading to higher house prices under the latter scenario; and also in that under Global Economy the bid price for agriculture is higher than for nature, whereas the reverse applies under Regional Community. Nature reserves and forests are usually the lowest-value areas, but under Regional Community the government will be committed to purchasing land in order to satisfy its commitment, forcing it to outbid farmers.

In the suitability factors for housing, a higher value is attached to existing land under Regional Community, because there will be a tendency to retain and redevelop existing residential areas rather than allow new construction. Under Global Economy, a high value is attached to easy access to motorways, but under Regional Community access to public transport is more valued while the use of cars is discouraged. Building in protected areas is discouraged under Global Economy and totally forbidden under Regional Community. In both scenarios, new residential and business areas are more likely to be developed near existing ones; but in Regional Community the preferred distance is smaller. Existing plans for developing residential, business and recreation areas are adhered to under Regional Community, but not necessarily under Global Economy where the application of spatial plans is more relaxed. Existing nature areas are more likely to remain so under Regional Community, and areas protected under the European Bird and Habitat Directives are compulsorily nature reserves. Areas earmarked for the National Ecological Network are likely to become nature reserves, but may also be used for agriculture – under certain restrictions. The same is true for areas earmarked for water storage, which will be either nature reserves or under extensive agriculture. Some nature areas must, under Regional Community, be made available in the vicinity of urban areas. Finally, dispersed development of residential or business areas is discouraged under this scenario.

All of these values are written into files read by the Land Use Scanner. Further adjustments to the model were made in reducing the number of land use classes to the five used for the present version (in addition to the three which are not affected by the model: infrastructure, water and land areas outside the national territory).

Table 4. Global Economy Scenario

Class	Average price (€/m²)	Value of cell characteristics (€/m²): existing land use	Suitable for agri-culture	areas of scenic beauty	high-noise areas	Bird/-Habitat Directive areas	existing resi-dential/ business area	Value of proximity to other cells (€/m², with distance in km): existing land use of the same type	motorway access point	railway station	area with 100,000 inhabitants	area with 100,000 jobs	main-port
Residential	30	5			-2	-4		5 (5km)	3 (5km)			3 (30km)	
Business	25	5				-4		5 (5km)	3 (5km)	3 (3km)	3 (30km)		1 (150 km)
Recreation	12	5		2		5	-5				2 (10km)		
Nature	2.5	4					-5						
Agriculture	3	5	5										

Table 5. Regional Community Scenario

Class	Aver-age price (€/m²)	Value of cell characteristics (€/m²): existing land use	planned for this class	Suitable for agri-culture	areas of scenic beauty	high-noise areas	Bird/-Habitat Directive areas	National Ecological Network	water storage areas	existing resi-dential/ business area	Value of proximity to other cells (€/m², with distance in km): existing land use of the same type	motor-way access point	railway station	area with 100,000 inhabit-ants	area with 100,000 jobs	main-port
Residential	35	6	5			-2	forbidden	forbidden	forbidden	forbidden if <1 ha	4 (1km)		3 (3km)		1 (30km)	
Business	25	5	5				forbidden	forbidden	forbidden	forbidden if <1 ha	5 (1km)	1 (5km)	3 (3km)	3 (30km)		1 (100 km)
Recreation	12	5	5		1		forbidden	forbidden	forbidden	forbidden if recreation <1 ha				1 (10km)		
Nature	5	8					compulsory	5	4	-5				1 (25km)		
Agriculture	3	5		5				-4								

Finally, the model was adjusted to make three runs: one of 14 years for the period 1996-2010, one of 24 years for the period 1996-2020, and one of 34 years for the period 1996-2030. Each run uses the same scenarios, but different claims. This setup is not ideal: it would have been more realistic to programme runs for 1996-2010, 2010-2020 and 2020-2030. In practice, however, this turned out to be very time-consuming. Programming the outcome of the first run as existing land use for the second one is simple, and this was performed. The outcome was very unsatisfactory, because of unrealistic rigidities in the model. In order to resolve these, it would be necessary to write entirely new scenarios for each run, i.e. six different scenarios instead of two. Moreover, each of these scenarios would need to be tested a number of times, until a realistic outcome is achieved. Such a 'dynamization' of the model has to be postponed for a later version, when more time will be available.

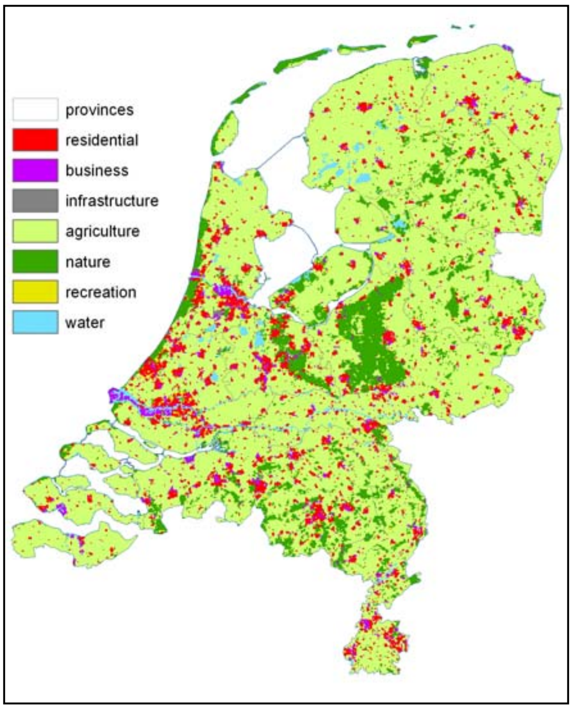
Undoubtedly, further refinement of the scenario parameters listed in tables 6 and 7 is also possible and indeed called for. This, too, will have to await future applications of the model, which remains a work in progress. Meanwhile, we shall proceed to a discussion of the results achieved under the present version.

5. *Results*

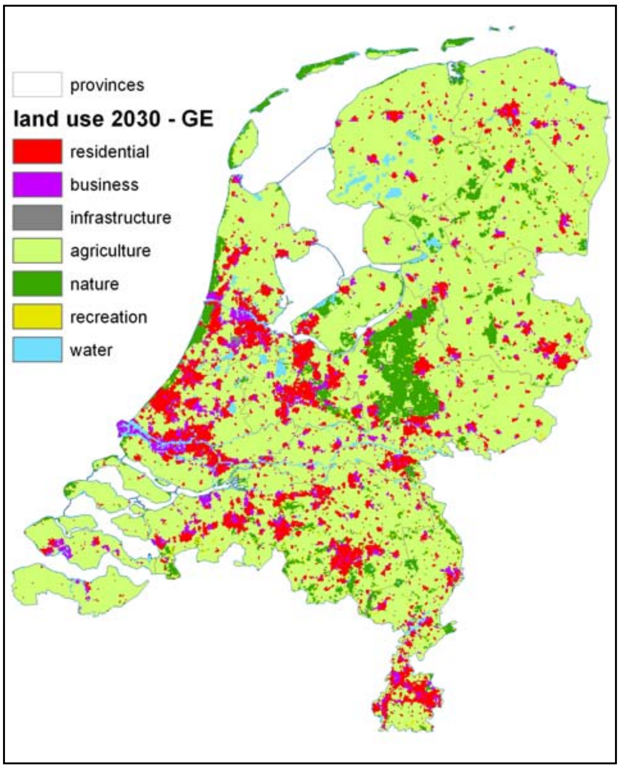
Maps 1-3 shows how land use changes use under the two scenarios until 2030, compared to the pattern in the base year 1996 (Map 1). The most striking change under the Global Economy scenario (Map 2) is the large increase in built-up area, concentrated in the metropolitan belt encompassing Amsterdam, The Hague, Rotterdam, Utrecht and a number of smaller cities. Part of the nature zone east of Utrecht (Gooi/Utrechtse Heuvelrug) has been swallowed up by urbanization. Other major urban expansion takes place in the province of Noord-Brabant and in southern Limburg.

Such urban expansion is less extensive and much more dispersed in the Regional Community scenario (Map 3), although even here the Green Heart of the central metropolitan area is significantly reduced. In compensation, nature areas in the northeastern part of the country are increased. In general, however, the differences between Maps 1 and 3 are quite small at least in the broad outline at the national level, which is another way of saying that change in spatial patterns is expected to be minor under the Regional Community scenario. Changes do occur, however, and they can be detected by zooming in on particular areas.

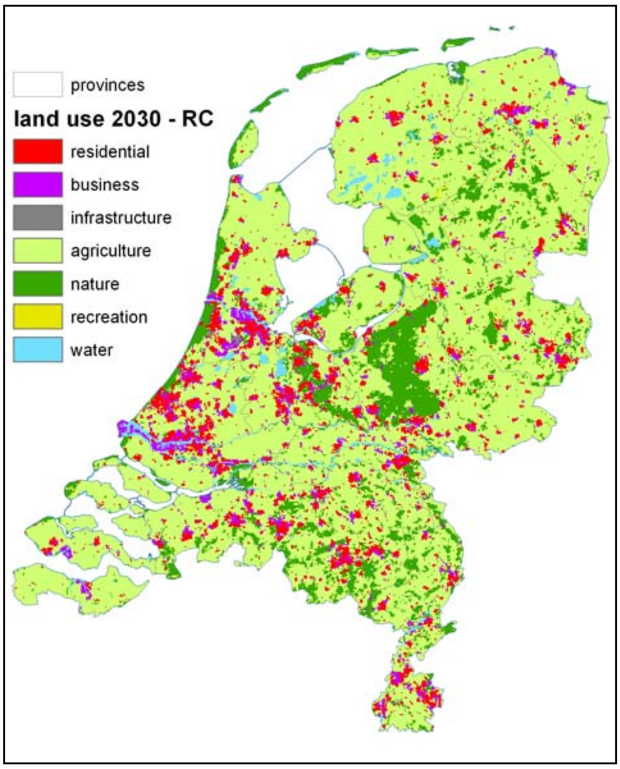
Map 1. Land use in 1996



Map 2. Land use in 2030: Global Economy



Map 3. Land use in 2030: Regional Community



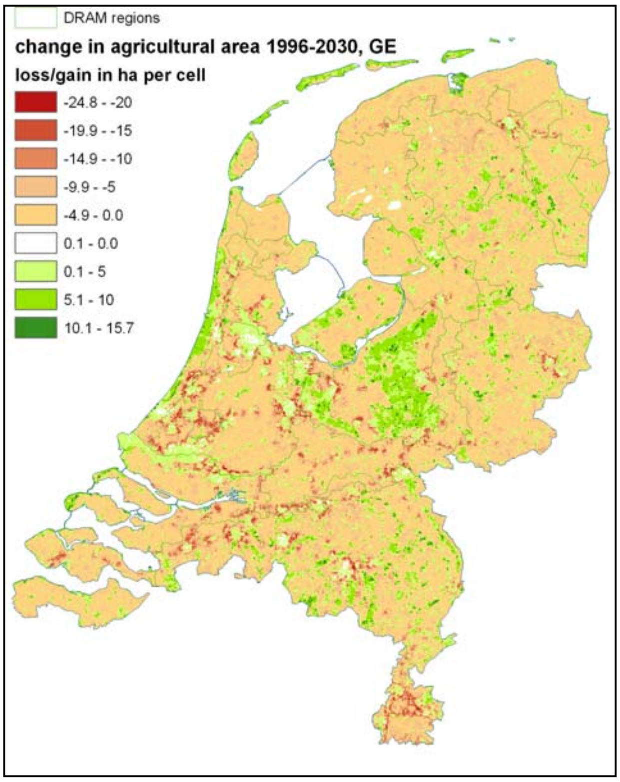
We may also look at the changes in land use in overall figures, rather than at spatial patterns. Table 6 shows the changes in area per land use class. It may be noted that the residential area actually decreases under the Regional Community scenario, a consequence of the decrease in population; this led us to state claims for residential land lower than the existing area (see Table 3). The area under agriculture decreases fairly sharply under both scenarios, considering that the decline over the period 1967-2000 was less than 8%. It is remarkable how little a map at country scale shows of the significant changes in, for instance, nature area under the Regional Community scenario.

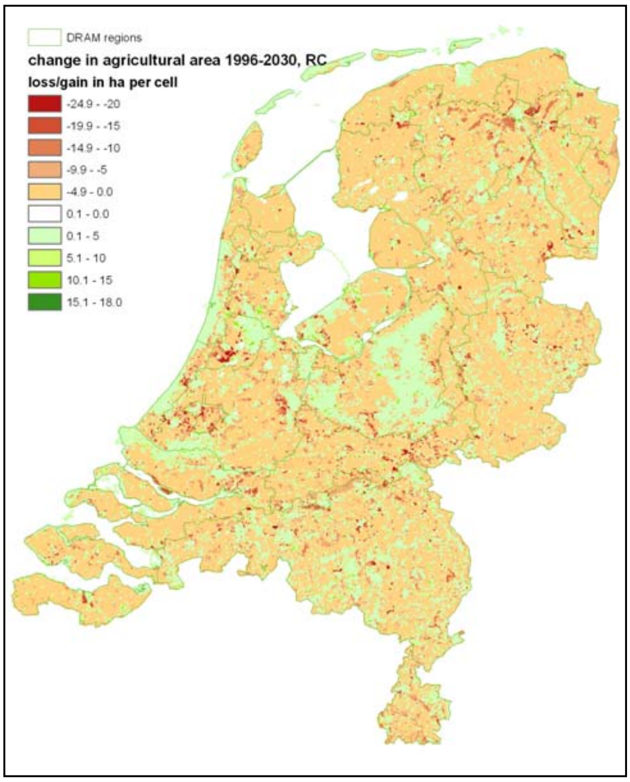
Table 6. Changes in area under two scenarios, 1996-2030

		Global Economy		Regional Community	
Land use class	Area in 1996 (hectares)	Area in 2030	% change	Area in 2030	% change
Residential	242,126	354,463	46.4%	234,255	-3.3%
Business	121,996	197,461	61.9%	167,137	37.0%
Infrastructure	110,656	110,656	0.0%	110,656	0.0%
Recreation	83,035	121,377	46.2%	95,484	15.0%
Nature	464,611	557,402	20.0%	670,491	44.3%
Agriculture	2,360,940	2,048,110	-13.3%	2,111,440	-10.6%

Maps 1-3 show only the dominant form of land use for each cell. A different picture is obtained when we look at what happens for a particular land use class under each scenario. For that, we choose agriculture, of course. Maps 4 and 5 show the number of hectares lost to (or gained by) agriculture per cell. We see that the agricultural sector has to give up land mostly near the larger cities and along axes of infrastructure; this is the case in both scenarios, but under Regional Community the loss is lower and less concentrated. Notably, there is more loss around the northern metropolis of Groningen than under the Global Economy scenario. There is also some gain of agricultural land under both scenarios, mostly in or near nature zones – and rather unrealistically also in large cities. This is an aspect of the model that will still need working on, although the changes are not dramatic: typically, the model allocates a few percentage points of land per cell to agriculture in these zones. The increase of agricultural land is more dramatic under the Global Economy scenario, where because of its higher bid price it is able to out-compete nature in some areas, notably the Veluwe, which is the largest forest area in the country. There and in the coastal dunes, up to 10 hectares per cell (i.e. 40% of the total area) can be allocated to agriculture. These are, one must assume, farmers pushed out of other areas as a result of urbanization.

Map 4. Change in agricultural area: GE *Map 5. Change in agricultural area: RC*





Finally, Table 7 presents represents the results that were requested of the Land Use Scanner under the present project: the total agricultural area under each of the two scenarios per agricultural region, for 2010, 2020 and 2030. The regions are those used by the Dutch Regionalized Agricultural Model (DRAM), also shown on Maps 4 and 5. The top part of the table shows the areas as calculated by the Land Use Scanner, the bottom part shows the adjusted areas, corrected for the differences between the agricultural area as measured in the Land Use Statistics (which serve as the basis for the Land Use Scanner) and as measured in the Agricultural Census; this correction is discussed in section 3. There is only one region which registers a small net increase of the agricultural area, and only under the Regional Community Scenario. This is the CZ (which stands for Central Sand) region – the Veluwe area discussed above.

Table 7. Agricultural area projected by the Land Use Scanner, per DRAM region

gross areas

region	area in ha	agriculture 1996	Global Economy 2010	Global Economy 2020	Global Economy 2030	Regional Community 2010	Regional Community 2020	Regional Community 2030
NW	282,550	199,802	189,720	184,384	178,808	186,404	181,663	179,837
NZK	196,650	164,136	149,833	146,142	142,231	151,357	148,172	146,965
NZ	389,325	299,919	283,127	274,554	265,643	276,769	269,220	266,451
VK	122,275	94,143	90,446	87,852	85,142	88,150	86,037	85,272
WW	367,350	239,957	210,519	200,583	190,437	215,091	209,330	207,415
ONH	67,950	34,838	35,138	33,248	31,377	32,612	31,685	31,422
OZ	329,825	242,719	228,552	220,392	212,020	226,102	219,762	217,437
CZ	259,425	99,098	119,476	111,924	104,639	101,667	96,641	94,928
RK	217,125	163,116	142,087	135,534	128,742	144,811	140,469	138,851
OZH	35,175	14,237	13,590	12,331	11,117	12,101	11,646	11,565
ZZK	353,375	249,922	229,218	221,387	213,346	232,643	226,632	224,343
ZZ	567,200	354,475	339,077	322,056	304,909	333,116	321,975	318,119
ZL	69,925	41,048	31,147	28,464	25,947	35,338	34,309	34,115
HYP	238,975	160,897	150,864	145,411	139,858	147,056	143,398	142,167
outside DRAM[9]	227,275	2,635	4,194	3,979	3,767	4,018	3,768	3,662
total	3,724,400	2,360,940	2,216,987	2,128,241	2,037,984	2,187,235	2,124,707	2,102,548

net areas (based on agricultural census)

correction factor 0.8377

regio	1996 (census)	1996 (calculated)	Global Economy 2010	Global Economy 2020	Global Economy 2030	Regional Community 2010	Regional Community 2020	Regional Community 2030
NW		167,365	158,920	154,450	149,779	156,142	152,171	150,641
NZK		137,489	125,508	122,417	119,140	126,785	124,117	123,106
NZ		251,229	237,163	229,981	222,517	231,837	225,513	223,194
VK		78,859	75,763	73,590	71,319	73,840	72,069	71,428
WW		201,001	176,342	168,019	159,520	180,172	175,346	173,742
ONH		29,182	29,433	27,850	26,283	27,317	26,541	26,321
OZ		203,315	191,448	184,612	177,600	189,395	184,085	182,137
CZ		83,010	100,080	93,754	87,651	85,162	80,952	79,517
RK		136,635	119,020	113,531	107,841	121,302	117,665	116,309
OZH		11,925	11,384	10,329	9,313	10,137	9,756	9,687
ZZK		209,348	192,006	185,446	178,710	194,874	189,839	187,922
ZZ		296,928	284,029	269,772	255,408	279,036	269,704	266,474
ZL		34,384	26,090	23,843	21,734	29,601	28,739	28,577
HYP		134,776	126,372	121,804	117,153	123,182	120,118	119,087
outside DRAM		2,207	3,683	3,513	3,333	3,156	3,366	3,156
total	1,981,000	1,977,653	1,857,070	1,782,731	1,707,126	1,832,147	1,779,770	1,761,209

[9] Due to the fact that the 500x500m cells do not exactly match with the regional boundaries, some cells with agricultural land fall outside the DRAM regions.

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