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Environment Explorer: Spatial Support System for the Integrated Assessment of Socio-Economic and Environmental Policies in the Netherlands

GUY ENGELEN[1], ROGER WHITE[2] AND TON DE NIJS[3]

[1]Research Institute for Knowledge Systems bv, Maastricht, The Netherlands, [2]Department of Geography, Memorial University of Newfoundland, St. John's, NF, Canada, and [3]National Institute for Public Health and the Environment, Bilthoven, The Netherlands

ABSTRACT

Environment Explorer is a system developed to support spatial scientists, planners and decision makers at the regional and national levels in the Netherlands to help them analyse a wide range of social, economic and environmental policies and their associated temporal and spatial dynamics. The core of this system consists of linked dynamic spatial models operating at both the macro- and the micro-geographical scales. At the macro scale, the modelling framework integrates several component sub-models, representing the natural, social, and economic sub-systems. At the micro level, cellular automata based models determine the fate of individual parcels of land, based on institutional, physical and environmental factors as well as on the type of activities in their immediate neighbourhoods. The approach chosen enables the straightforward integration of detailed physical, environmental, and institutional characteristics as well as the particulars of the transportation infrastructure, and permits a very detailed representation of the evolving spatial system. As part of the policy support system, the models are supplemented with dedicated tools for interactive design, analysis and evaluation of the policy interventions and scenarios to be tried out. The system covers the entire territory of the Netherlands and represents processes at the national, the regional (40 economic regions), and the cellular (25 ha cells) levels. It runs on top of detailed GIS information and generates future land use and land cover for the period 2000 till 2030. The quality of the policies tried out is expressed in some 40 economic, social and environmental indicators available in the model as dynamic maps. The application has been developed over the past 5 years. It has been used at the national and the provincial level for the preparation of spatial policy documents. Some conclusions relative to the development and the use of the system are presented.

Keywords: integrated assessment, spatial modelling, policy support system.

1. IF ONLY WE KNEW . . .

With a population of some 16 million living on 40,000 km^2 of land, the Netherlands is a small but densely populated country. It is primarily a large Delta shaped by the Rhine, Meuse, and Scheldt rivers. No less than 5 million people live on some 8,500 km^2 of land that is at or below sea level. Certainly, they live behind dikes, protected from the sea and the rivers, nonetheless; they live in a country that is troubled by on the one hand subsiding land due to tectonic movements and continued oxidation of the peat substrate, and on the other hand increasing amounts of water running down the main rivers. At the same time, the Netherlands is one of the Western European countries that still witness a growing population and consequently is faced with an ever-increasing demand for space to house its population and their economic activities. In some scenarios a growth of over 1.5 million people in the next 20 years is expected.

In the given circumstances strict policies and control on how the limited available land is used seconded by an alert and elaborate monitoring system and a set of state of the art instruments for exploring strategies and policies developed to tackle threats detected, are the best available options to keep the country afloat. With the increasing amount of stress exerted on the system and the complexities of the problems posed, the needs for appropriate planning instruments change rapidly too. In particular the need for instruments supporting a truly integrated approach to spatial planning problems is very urgent. Four aspects of planning problems and the systems in which they are set are of particular importance. First, and most importantly, these systems are *integrated wholes*. Thus, while a planner or policy maker

Address correspondence to: Guy Engelen, Research Institute for Knowledge Systems bv, P.O. Box 463, 6200 AL Maastricht, The Netherlands. Tel.: +31-43-388-33-22; Fax: +31-43-325-31-25; E-mail: gengelen@riks.nl

may intervene directly in only a limited part of the system, linkages will transmit consequences of the policy to many other parts of the system. Conversely, the problems the planner is dealing with may have had their origins in actions that were taken in other parts of the system in an attempt to resolve other problems. Second, human systems, and the natural systems in which they are imbedded, are *dynamic and evolving*; they are never in equilibrium. Policy makers thus intervene in a changing system, and at certain critical points, the consequences of even a small intervention may be of major importance yet may be entirely unanticipated. Third, these systems are *inherently spatial*. In space, human and natural processes occur in more or less defined clusters of high and low concentration and typified by periods of high and low activity. The consequences of planning policies depend on the spatial context within which they are implemented, as well as on the way they alter that context. Fourth, the world is one of *uncertainty*, and while increased knowledge and improved modelling tools may lessen that uncertainty, they cannot eliminate it. Policies therefore need to be designed to incorporate uncertainty, rather than assume that it does not exist.

This paper presents an integrated spatial planning instrument – named Environment Explorer – developed to accommodate the four characteristics of planning problems just described, and built to design, analyse, and evaluate long-term policies relative to the physical environment in the Netherlands in an economic, social and ecological context. The development of Environment Explorer started in 1997 [1]. Since then, it has evolved into a powerful Policy Support System for integrated spatial planning, supported by the National Institute for Public health and the Environment (RIVM), as well as the National Institute for Marine and Coastal Management (RIKZ), the National Institute for Inland Water Management and Waste Water Treatment (RIZA), and the Transport Research Centre (AVV) of the Ministry of Transport, Public Works and Water Management. It has become a highly interactive, transparent instrument currently used at the National and the Provincial levels. For example the province of Utrecht used Environment Explorer in its search for new residential and industrial locations as part of its new provincial master plan [2].

2. AN INTEGRATED SPATIAL MODEL OF THE NETHERLANDS

2.1. Autonomous Developments, Intended and Actual Policies

The primary goal of Environment Explorer is to explore the effects of (alternative) policy options on the quality of the socio-economic and physical environment and, with this information at hand, to stimulate and facilitate awareness building, learning, and discussion prior to the decision-making proper. To this end, the system combines autonomous developments with policy-induced changes to form integral pictures of possible futures for the Netherlands and evaluates their relative value on the basis of social, economic and ecological criteria. It does not seek to optimise the separate economic, ecological and social dimensions, rather to maximise the whole. Although this means losing some detail, the benefit of the approach is the strong integrative and interactive nature of the resulting system, in which highly dynamic, autonomous processes play a key role.

The motor driving the spatial changes in Environment Explorer is fuelled by economic and demographic developments: supply and demand in both qualitative and quantitative terms. These processes operate at different spatial scales and are thus represented in the models. In fact, these dynamics are very much represented as the competitive reality of 'survival of the fittest': it is the function that is most powerful and that generates the highest added value per unit of area that will be most successful in claiming parcels of land. Similarly, it is the region that offers the most attractive alternative for economic and residential activity that will attract most businesses and residents. Government, represented by the analyst using the system, has the task of safeguarding collective interests, including protection of the economically weak, the social values, the open space and the natural assets in general. The actual and the intended policy actions to counter the initiatives of the 'free market' players, can be entered into the Environment Explorer system by means of zoning maps and control parameters acting as constraints upon the autonomous dynamics of the system.

2.2. Models Coupled at 3 Geographical Levels

The core component of Environment Explorer is an explicitly dynamic land use-transportation model applied to the full territory of the Netherlands. In order to represent the processes that make and change the spatial configuration of the country, it features a layered model representing processes operating at three geographical levels: the National (1 region), the Regional (40 economic regions) and the Local (351000 cellular units of 25 ha each) (see Fig. 1) (For a detailed discussion of the model, including its mathematical description, the user is referred to [1]).

At the ***National level***, the scale of the entire country, the model integrates national figures taken from economic, demographic and environmental growth scenarios considering developments in the Netherlands in the context of Europe and the world beyond and prepared by the Dutch planning agencies or IPCC [3]. From these, growth figures for the national population, the activity per economic sector, and the expansion of particular natural land uses are derived and entered in the model as trend lines.

The economic activities are condensed into eight main sectors: crop farming, dairy farming, greenhouse farming, other farming, industry, services, socio-cultural activities,

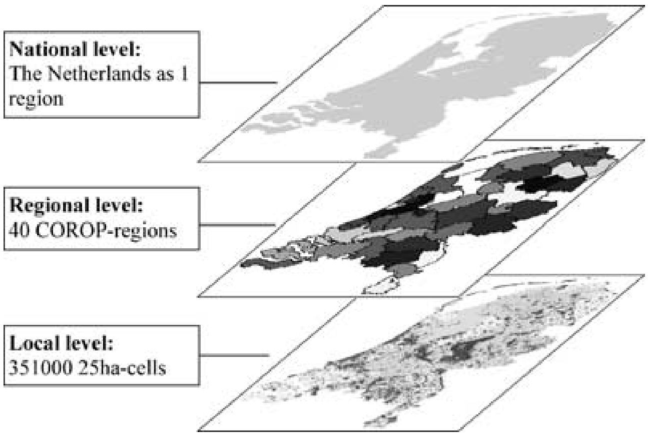

Fig. 1. The Environment Explorer model represents processes at three spatial levels: National, Regional and Local.

and recreation. The population is assigned to two residential categories: high and low-density residential. The natural land use categories are: wetlands, forests, and extensive grasslands. The choice of the categories is based on their distinct spatial requirements and specific spatial behaviour, the quality, match, and availability of data at the three geographical levels of the model, and last but not least the end-use requirements of the model: the particulars of spatial policies and spatial planning criteria.

The national growth figures entail changes in land use through changes in economic output and land required for carrying out the activities, through changes in land required for housing, and through the expansion of natural land uses. But they do not say where land use changes will occur, or whether the changes are possible given constraints on the amount and quality of land available. These locational aspects are modelled at the Regional level and at the Local level. In the first instance, the national growth figures are a constraint for the models at the regional level.

At the ***Regional level*** consisting of 40 large economic regions (called COROP regions), a dynamic spatial interaction based model (see for example: [4–8]) caters for the fact that the national growth will not evenly spread over the country, rather that regional inequalities will influence the location and relocation of new residents and new economic activity and thus drive regional development. The model arranges the allocation of national growth as well as the inter-regional migration of activities and residents based on the relative attractiveness of the regions. One of three principles is applied:

1. For the allocation and relocation of people, industrial, and socio-cultural activities, a standard potential based model is applied: each region competes with all the other regions for new residents and new activities in each of the eight economic sectors on the basis of its geographical position relative to the other regions, its employment level, the size of its population, the type and quantity of activity already present, and its location relative to the public and the private transportation systems. In addition to these, and novel in the context of interaction based models, summarized cellular measures obtained from the model at the Local level characterising the space within the regions are factors determining the relative regional attractiveness. The latter are: the abundance of good quality land, the zoning status of that land, and its accessibility relative to the waterways, roads and public transportation.
2. For other activities, such as services, for which economic considerations are more important, a relative profit criterion is applied. In this case, the relative costs of producing and shipping the goods as well as the buying power of the customers is an additional criterion in the determination of the attractiveness of a region.
3. Finally, for the natural and agricultural categories, only the abundance and the quality of the land for sustaining the particular ecosystem or activity are criteria in the determination of the attractiveness.

In the dynamic context of the model, the attractiveness of regions evolves with the changes in each component on which it is based. Conversely, changes in regional attractiveness result in changing numbers of people and levels of activity as well as altered pressure on the transportation infrastructure. Four sub-models can be distinguished:

1. A *regional economic module* calculates the amount of production and employment for each of the economic sectors, its allocation and re-allocation among the regions.
2. A *regional demographic module* deals with the growth of the regional population: its allocation and re-allocation among the regions and the demand for housing.
3. A *transportation module* deals with the changes in the characteristics of the transportation infrastructure, the flows of people and goods travelling over it, the congestion of the networks and its consequences on interregional distances and accessibility. The interregional distances are expressed in generalised transportation costs calculated on the basis of the costs per kilometre travelled, the costs per hour travelled and the parking costs. The transportation module is in fact a four-stage transportation model fully linked to the other modules at the regional, but also at the local level and solved at each simulation time-step. The transportation system consists of: the railways and railway stations, the navigable waterways, and the road network (the LMS-road network used by the Ministry of Transport, Public Works and Water Management) consisting of the motorways, main national, and regional roads. People choose to travel via the road or railway system, while goods are assumed to be transported over the roads only. The geographical layout of the networks, as well as the quality and capacity of the links determine the flows of goods and people. On the basis of different motives for

travelling, the production of traffic is calculated. The total volume of traffic between regions is split over the public and private transportation system in function of the generalised costs. Next, the volumes are allocated to the shortest routes linking the centres of the regions and the links constituting them. Thus the congestion can be calculated as well as its impact on the interregional distances. These affect the long-term migration of activities and residents as well as the short-term movement of goods and people between the different regions.

4. A *land-claim module* translates the regional growth numbers into spatial claims. The latter are passed on to the model at the local (cellular) level for a detailed allocation. Two principles are applied at this level: (1) A claim for land is fixed and passed on as a hard constraint. This principle reflects the fact that for particular activities policies determine the amount and location of land that is to be created or to be preserved in a region. It applies mostly for the natural land categories and recreational land. Or, (2) the principle of supply and demand is applied to regulate the densification of land use as well as its spatial allocation. This principle applies in particular to housing and most of the economic activities.

At the ***Local level*** the detailed allocation of economic activities and people is modelled by means of a Cellular Automata based land use model [9–13]. To that effect, the Netherlands is represented as a mosaic of 351000 grid cells of 25 ha each (500 m on the side). Each cell is modelled dynamically and together the cells constitute the changing land use pattern of the country. Land use is classified in 17 categories, 10 of which are so called land use ‘functions’ and modelled dynamically. The land use function categories are chosen with a view to guarantee a one-to-one relation with the economic and residential categories at the regional level. In principle, it is the relative attractiveness of a cell as viewed by a particular spatial agent, as well as the local constraints and opportunities, that cause cells to change from one type of land use to another. This model is driven by the demands for land per region generated at the regional level. In fact there are 40 identical cellular models running in parallel: one for each COROP region. Four elements determine whether a piece of land (each 25 ha cell) is taken in by a particular land use function or not (see Fig. 2):

1. The physical *suitability*. Suitability is represented in the model by one map per land use function modelled. The term suitability is used here to describe the degree to which a cell is fit to support a particular land use function and the associated economic or residential activity for a particular activity (see for example [14]). It is a composite measure, prepared in a Geographical Information System (GIS), on the basis of some 15 factor maps determining the physical, ecological and environmental appropriateness of cells. Factors used are among others: elevation, soil quality and stability, agricultural capacity, air quality, noise pollution, etc.
2. The *zoning* or institutional suitability. Zoning too is characterized by one map per land use function. It is another composite measure based on master plans and planning documents available from the national or regional planning authorities including among others ecologically valuable and protected areas, protected culturescapes, buffer areas, etc. For three planning

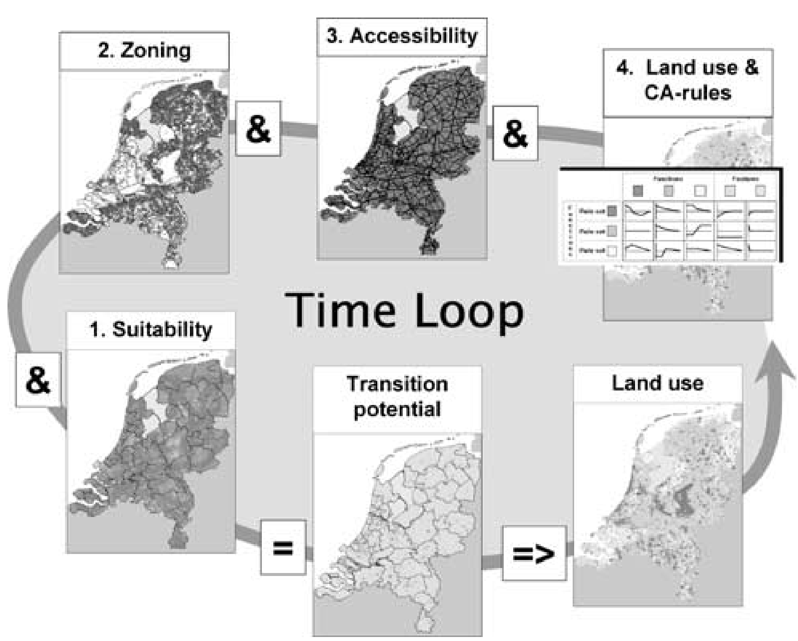

Fig. 2. 4 elements determine the dynamics at the local level.

periods, to be determined by the user (example: 2000–2005, 2005–2015, and 2015–2030), the map specifies which cells can and cannot be taken in by the particular land use. For the analysis of policy and planning alternatives, it is of paramount importance that suitability and zoning can be handled separately. Zoning is a man made instrument for imposing constraints or stimulating particular trends, while suitability is most often a fact of life and an intrinsic quality of the area. Changing suitability requires usually an engineering action in the physical environment, such as altering slopes, filling in land, building infrastructures, etc., while changing zoning requires first of all an intervention in the legal and institutional environment.

3. The *accessibility.* The accessibility for each land use function is calculated in the model relative to the transportation system consisting of the railways and railway stations, the navigable waterways, and the road network. It is an expression of the ease with which an activity can fulfil its needs for transportation and mobility in a particular cell. It accounts for the distance of the cell to the nearest link or node on each of the infrastructure elements, the importance and quality of that link or node, and the needs for transportation of the particular activity or land use function.
4. *Dynamics at the Local level.* While the above three elements are introduced in the model to determine the non-homogeneous nature of the physical space within which the land use dynamics unfold, there is a fourth and important aspect, namely the dynamic impact of land uses in the area immediately surrounding a location. This is no longer the domain of abstract planning, but rather that of the reality on the ground representing the fact that the presence of complementary or competing activities and desirable or repellent land uses is of great significance for the quality of that location and thus for its appeal to particular activities. For each location, each cell that is, the model assesses the quality of its neighbourhood: a circular area with a radius of 4 km containing the 196 nearest cells. For each land use function, a set of rules determines the degree to which it is attracted to, or repelled by, the other functions present in the neighbourhood. The strength of the interactions as a function of the distance separating the different functions within the neighbourhood is articulated in the rules. If the attractiveness is high enough, the function will try to occupy the location, if not, it will look for more attractive places. New activities and land uses invading a neighbourhood over time will thus change its attractiveness for activities already present and others searching for space. This process explains the decay of a residential neighbourhood due to the invasion by industrial or commercial activities, as well as the revival of decayed neighbourhoods initiated by the arrival of few high quality functions like parks, exclusive office buildings, high-end condominiums, etc. The rules determining the interactions between the different functions – the inertia, the push and pull forces, and economies of scale – are defined as part of the calibration of this cellular automata model.

On the basis of these four elements, the model calculates for every simulation step the *transition potential* for each cell and function. In the course of time and until regional demands are satisfied, cells will change to the land use function for which they have the highest potential. Consequently, the transition potentials reflect the pressures exerted on the land and thus constitute important information for those responsible for the design of sound spatial planning policies.

The linkage between the models at the National, Regional and Local levels is bi-directional and very intense: the national growth figures are imposed as constraints on the regional models, the regional models distribute and allocate the national growth to the 40 regions and impose the regional growth numbers on the cellular models. Finally, the cellular models determine at the highest level of detail where the growth is likely to take place. In this process, the cellular models return to the regional models information on the quality and the availability of space for further expansion of each type of economic or residential activity. This information is an input into the spatial interaction calculations at the regional level and it influences strongly the relative attractiveness of the individual regions. As regions in the course of time are gradually running out of space for one or the other activity, they will lose part of their competitive edge and will exert less attraction. Growth is consequently diverted to other, more attractive regions.

3. USING ENVIRONMENT EXPLORER FOR INTEGRATED PLANNING

3.1. State Variables and Indicators

From the model description, it is clear that Environment Explorer generates output at the Regional and the Local levels. Typically the model is run for the 30-year period between 2000 and 2030, but other time intervals are possible too. Results are calculated and visualized on a yearly basis. At the regional level, the population, as well as the employment and production figures in each economic sector are calculated. At the Local level the resulting new land use map is generated and presented for every simulated year. In addition to these, and based on the regional and local state variables, the model calculates some 40 spatial indicators expressing changes in the economic, social, or environmental status of the country, the regional and cellular entities. Together they constitute important information relative to the merits of one or the other project, policy or strategy tried out with Environment Explorer. Each indicator is in itself a more or less elaborate sub-model that may require specific additional information. Indicators include among others: access to employment (economic), cost of land (economic), built-up area (social), open space (social), recreational space per inhabitant (social), noise pollution and emissions due to traffic (environmental), congestion on the road system (economic), flooding risk (social), residential density (social), spatial fragmentation (environmental, see Fig. 3), etc. Like the other state variables, indicators are calculated on a yearly basis and are available in Environment Explorer in the form of dynamic maps, time charts and numeric output.

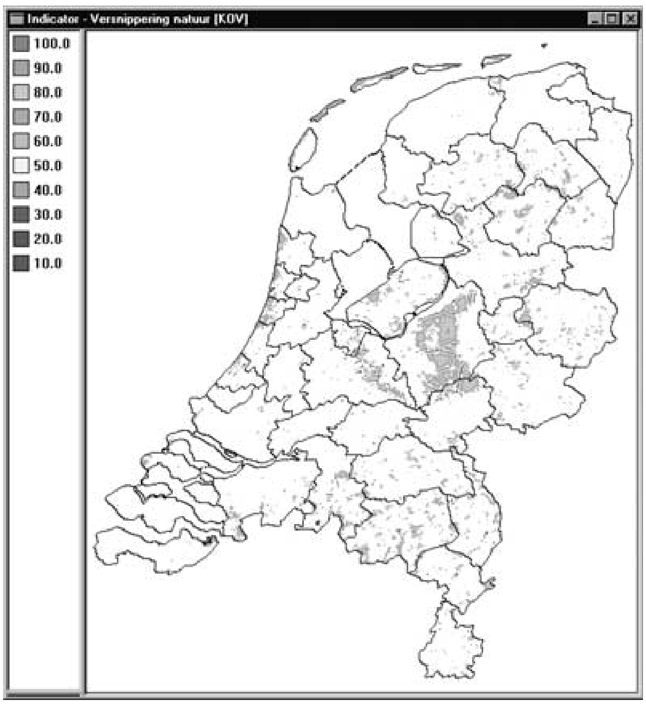

Fig. 3. The degree of spatial fragmentation of natural areas calculated as an indicator in Environment Explorer.

3.2. Scenarios, Strategies and Projects: Interventions in the Spatial Structure

Environment Explorer has been designed for use as an analytical tool: it offers analytic capabilities to policy makers in government departments ranging from the municipal to the national levels. But, it has an important role as a tool for communication too: it stimulates collaboration, discussion and consultation among the different planning institutions and departments. That is why the instrument has been equipped with a state of the art graphical user interface (Fig. 4), providing access to all the variables, parameters and maps used at every level of detail. It offers the users the ability to create and enter policy variants interactively by defining and adjusting values within a preset range of values and context. Over and above economic and demographic scenarios, which can be stated by means of dedicated dialogues, tables and graphs, the model can take into account spatial scenarios, such as those proposed by various government departments and entered in the form of alternative sets of numbers and maps. The suitability and zoning maps as well as the transportation networks are available in the model with the appropriate editors enabling interactive changes by the user so that infrastructure projects or particular policy decisions on opening or closing areas for development can be tried out experimentally. Thus the visions and strategies as options for future spatial, economic and social policies, proposed by the individual governmental

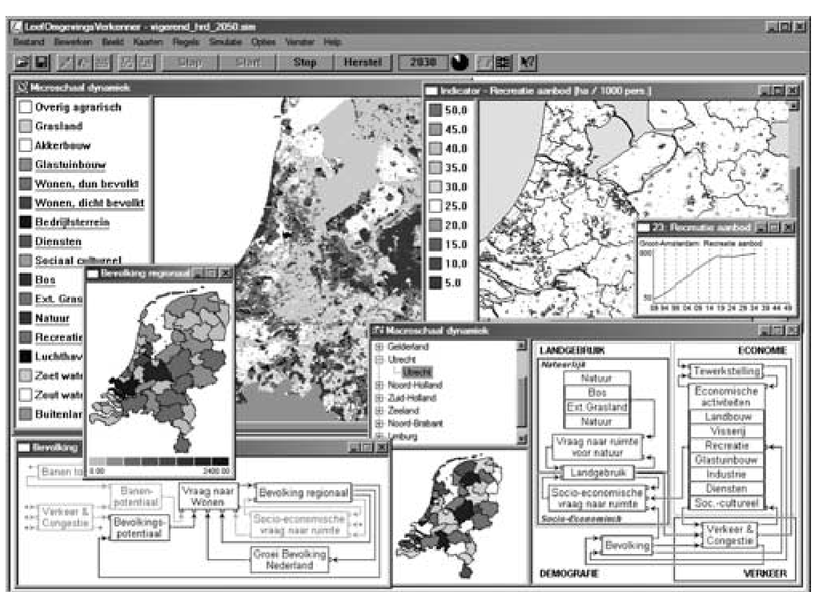

Fig. 4. Environment Explorer is equipped with a state of the art graphical user-interface.

institutions are pooled and presented as detailed spatial blueprints of the Netherlands and translated into relevant societal terms. Their impact and effectiveness in the short and long term future of the country is calculated, visualized, and available for further analysis and discussion.

In order to construct, amend and evaluate integrated spatial strategies and scenarios, a number of additional tools are available. In particular, for preparing input maps, Environment Explorer is equipped with an **OVERLAY-TOOL**, an instrument geared at the creation of the Suitability and Zoning maps used at the Local level of the model. It takes (factor) maps from a GIS as an input and combines them into a single composite map by weighing the relative importance of the information represented on the maps. The weights are set interactively through the manipulation of sliders on the screen. The composite map changes accordingly and instantly. The output can be exported straightforwardly into Environment Explorer or back into the GIS if desired. But, the **OVERLAY-TOOL** is equally used for carrying out multi-criteria analysis on the spatial outputs of Environment Explorer and in particular on sets of indicator maps. The result of this analysis is one composite indicator map, or a series of such maps: one per year simulated, reflecting the concerns expressed in the weights and criteria selected. It thus is instrumental in evaluating the particular merits of policy options tried out in terms of their multi-faceted impacts, the spatial patterns generated, and the precise timing of events and developments.

The **ANALYSE-TOOL** is an instrument enabling the pair-wise comparison of the many maps generated in typical runs of Environment Explorer, containing categorical data or data on a ratio or ordinal scale. It is an essential instrument for comparing and analysing the spatial effects of the alternatives generated. To that effect it is equipped with fuzzy set map comparison techniques capable of detecting qualitative similarities between maps [15, 16], as well as other comparison tools and statistics such as the Kappa statistic [17].

The **OVERLAY-TOOL** and the **ANALYSE-TOOL** are of particular use in interactive sessions with stakeholders and representatives of different planning departments as they focus the discussion on the importance of particular factors in the determination of the physical or institutional appropriateness of areas for one or the other use. Similarly, they enable a straightforward evaluation of alternatives designed and tried out in collaborative working sessions.

The **MONTE CARLO-TOOL** is geared at using the model in a stochastic mode. In particular it supports the execution of multiple runs with the model in which particular combinations of parameters are varied stochastically within predefined ranges representative of their inherent uncertainty. As a result, for each land use function modelled, a land use probability map is made available, summarizing the multiple run and computed as the proportion of runs in which the cells were taken in by the land use (Fig. 5). The particular value of such probability map is that it demonstrates to the planner the

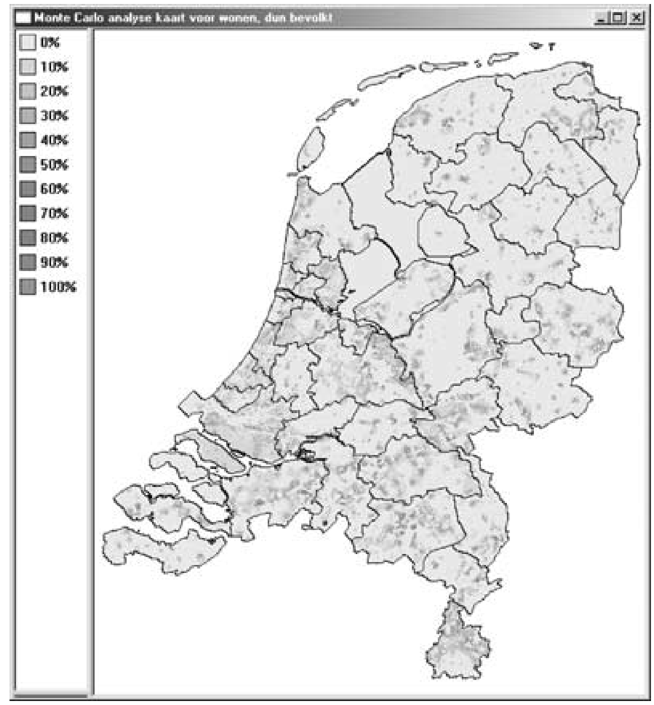

Fig. 5. Map representing the probability that a cell is taken in by the land use 'industry' as the result of the uncertainty in a population growth parameter.

existence of spatial bifurcations in the spatial system, appearing suddenly as one or more parameters pass a critical value [11]. Most important to the planner is the knowledge about bifurcations that cause important qualitative changes in the system due to variations in parameter values that are well within the uncertainty ranges. Another practical value of the land use probability maps is that they show the planner where in space certain risks may appear in more or less consistent manners and independent of the uncertainty in one or more parameters [18]. If activities appear consistently in areas where they cause environmental, social or economic stress, then the planner needs to work out additional restrictive measures. Similarly, if activities systematically avoid expanding into areas designated for growth, then new stimulating measures need to be tried out.

3.3. An Extensive Analysis

The prime purpose of Environment Explorer is to represent at a high level of abstraction the autonomous dynamics that change the face of the Netherlands. Actual and intended policies and plans are introduced. They constrain and steer this autonomous growth. Confronted with adverse trends and growth of the system in economic, social or environmental terms, the planner can intervene and change existing policies or define new ones in an effort to bring the system onto a more favourable path of development. The many features of Environment Explorer are specifically intended for this purpose and support the user in his search for a better or more acceptable evolution of the system. Its *integrated nature* enables analysing direct but also indirect consequences of interventions, its *dynamic nature* enables exploring immediate effects, but also those that become visible at later stages, its *spatial nature* enables evaluating impacts at the national, the regional and the local scale, and its *stochastic mode* enables studying the effectiveness of planning options under conditions of uncertainty.

4. AN EVALUATION

Now that the system is in its fifth year of existence, a number of conclusions can be drawn relative to its development and use.

Overall, the appropriateness of Environment Explorer as an analytical instrument for the design and evaluation of spatial plans as well as a tool for communication about such plans is granted by most users at the provincial and the national levels. All agree that it provides insight in the interconnected nature of different functions, processes and cause-effect relations. It makes the consequences of policy interventions explicit in the domain of the specialist user but also in that of colleagues and counterparts working in the other domains. Its availability enables the calculation of more alternatives than would normally be possible and hence permits more alternatives to be considered and it enables an objective evaluation of the results generated. Environment Explorer stimulates the creativity of technicians and policy-makers. With the tool at hand, they generally work more systematically and intensively on the definition of the set of evaluation criteria for the alternatives prior to their elaboration and develop more alternatives before they home in on ‘politically acceptable,’ ‘likely,’ ‘no-regret,’ or ‘easy to implement policies.’ However, Environment Explorer represents a complex and complicated system. Consequently it is difficult to keep the tool itself from being complicated, and despite the fact that major effort has gone into rendering it as transparent and user-friendly as possible, it only meets the expectations of part of its intended end-users in this respect. Technicians, familiar with GIS and models having worked their way trough the technical documentation, are happy with the system as it is. For occasional and non-technical users this is much less the case. They tend to get lost in the open nature of Environment Explorer and have suggested a number of additional tools to streamline policy analyses. Among others, the design and evaluation of alternative policies using terms and a language better understood by policy makers and planners has been advocated by many. That is also why hands-on training workshops have been organised, and sessions, involving groups of specialists working as a team on national or regional planning documents, have been facilitated or assisted by those already familiar with the system.

Instruments like Environment Explorer depend extensively on good quality data. In particular high-resolution land use maps are required for the base year of the model, but also for years in the past in order to determine trends, calibrate and validate the model. This is a problem because good land use maps are rare. Most often the detail, the number, and the set of land use categories mapped are insufficient to be useful. Moreover, the definitions and categories change over time. Thus, making the land use maps consistent between years becomes a laborious prerequisite. Next, the match between on the one hand the land use categories of the land use map (at the Local level) and on the other hand the activity classes (at the Regional and National levels) represented in economic and census tables, is not necessarily one to one. Very often it will be necessary to go back to the most fine-grained representation of the census data in order to establish a workable match.

The calibration and validation of this type of model is far from easy or fast. This is partly due to the limited availability of good quality data, but also to the integrated nature of the model: all linked processes need to be calibrated in isolation and in combination in order to generate reliable results. Moreover, it has been the experience of Environment Explorer that the model needs to be recalibrated regularly when additional processes are built-in or when better data become available. An automated or semi-automated calibration procedure is much wanted to take care of this problem. Such procedure is currently under development [19].

Finally, Environment Explorer is a data intensive system. This is true for the base data required to set-up the system but also for the definition of the scenarios, strategies and alternatives tried out. The system facilitates handling these with great ease, yet it is important to have a good (meta-) documentation method to keep track of the data used in the exercises carried out.

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