



Land Use Scanner exercise and assignment

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Looking into the future has fascinated mankind for ages. With the advent of computers we do not even need a crystal ball anymore to foresee how our country will look like in say 30 years time. Regular desk top PC's now have enough computing power to help simulate future land use. All that is needed is a set of spatial data, modelling software and some thoughts on which spatial developments you expect are going to happen in the coming decades. The latter is of course the tricky part. By looking at current developments we may distil trends that are likely to continue for the coming 5 years, but looking much further is risky at best. Many uncertainties prevail: Will population growth come to halt? Will economic development be slow? Will society prefer ecological sustainability or economic prosperity? What will be the role of the government in steering socio-economic developments?

A much favoured approach to deal with the uncertainties relating to future spatial developments is the use of scenarios. By describing several opposing views on the future we can simulate a broad range of spatial developments, thus offering a full overview on possible land-use alterations. Each individual outlook on the future will not necessarily contain the most likely prospects, but as a whole the simulations provide the bandwidth of possible land-use changes. The individual scenarios should in fact not strive to be as probable as possible, but should stir the imagination and broaden the view on the future. Important elements are: plausible unexpectedness and informational vividness (Xiang and Clarke, 2003).

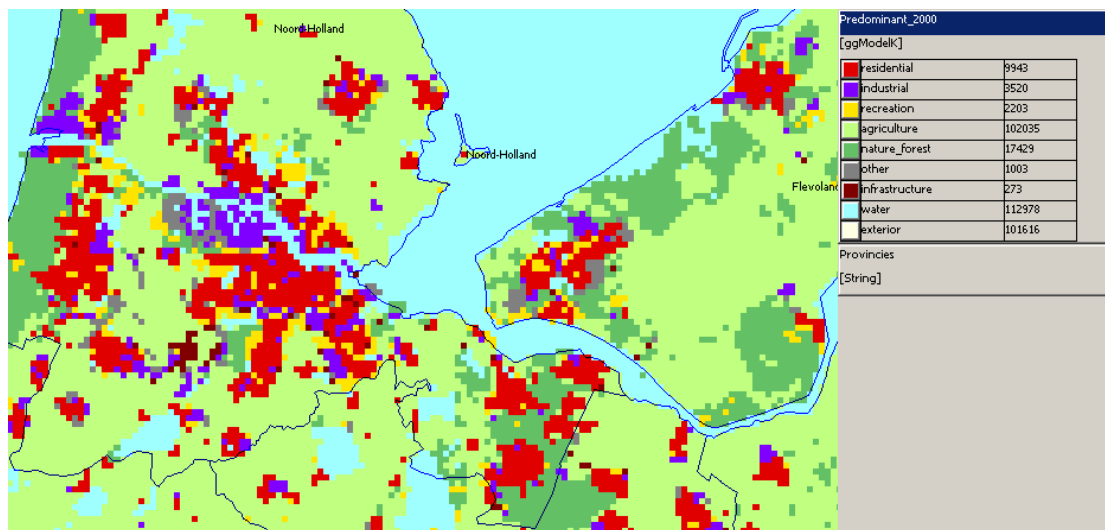


In this assignment you will be asked to simulate future land use in the Netherlands with an actual land-use model according to a specific scenario of socio-economic developments. First we will introduce the *Land Use Scanner* model that you are going to use. After this introduction you will explore the model in a hand-on exercise. When you are familiar with the model's main functions you will start the actual assignment.

Introducing the *Land Use Scanner*

In this assignment we will use the *Land Use Scanner*, an integrated land-use model that has been used for various policy related research projects. Early applications include, amongst others, the simulation of future land use following different scenarios (e.g. Borsboom-van Beurden et al., 2007) and the evaluation of alternatives for a new national airport (Scholten et al., 1999). The model has been used in many outlooks on the future relating to a range of planning themes, such as: water management (Dekkers and Koomen, 2007; De Moel et al., 2011); climate change (Koomen et al., 2008); the prospects of agricultural land use in the Netherlands (Koomen et al., 2005); and the development and evaluation of regional spatial strategies (Koomen et al., 2011). Apart from these Dutch applications, the model has also been applied in several European countries (Hoymann, 2010; Te Linde et al., 2011; Schotten et al., 2001). The GeoDMS framework underlying Land Use Scanner is also used in the recent EU-ClueScanner model that was developed for the European Commission and that now covers the 27 member states of the European Union at a 100meter resolution (Lavallo et al., 2011) A full account of the original model is provided by Hilferink and Rietveld (1999), whereas recent applications are documented in a book by Koomen and Borsboom-van Beurden (2011). For an extensive overview of all publications which are related to *Land Use Scanner*, the reader is referred to www.lumos.info and www.feweb.vu.nl/gis.

The *Land Use Scanner* is a GIS-based model that simulates future land use. Unlike many other land-use models its objective is not to forecast the dimension of land-use change but rather to integrate and allocate future land-use claims from different sector-specific models. The model offers an integrated view on all types of land use. It deals with urban, natural and agricultural functions, normally distinguishing 9 different land-use categories. The model is grid-based and uses 351,000 cells of 500 by 500 meter to cover the Netherlands. The full version of the model covers the country at a 100 by 100 meter resolution (8,775,000 cells), but that version cannot be freely distributed due to data restrictions.



Current dominant land use per cell, clearly showing the raster structure.

In the provided model version each cell describes the relative proportion of all land-use types present at a location. So a cell can contain more than one type of land use, presenting a highly disaggregated description of the whole country. The following image serves as an example:

	<i>Residential</i>	<i>11 ha</i>	<i>Other</i>	<i>3 ha</i>
	<i>Industrial</i>	<i>0 ha</i>	<i>Infrastructure</i>	<i>1 ha</i>
	<i>Recreation</i>	<i>2 ha</i>	<i>Water</i>	<i>3 ha</i>
	<i>Agriculture</i>	<i>5 ha</i>	<i>Exterior</i>	<i>0 ha</i>
	<i>Nature-forest</i>	<i>0 ha</i>	Total	= 25 ha

A cell of 25 hectares can contain many types of land use.

To provide a simple, single visualisation of this disaggregated description of land use maps of predominant land use are created. Keep in mind, however, that this representation may be a bit misleading. In the example-cell introduced above, residential land use is dominant with only 11 ha (less than half) of the total surface area of the cell (25 ha).

The model simulates future land use, based on the following main components:

1. the present situation;
2. estimates of future land use demand per sector per region and/or for the whole of the Netherlands (land-use claims); and
3. suitability for a certain land use per grid cell.

The following sections describe each of these elements.

Present situation

In the *Land Use Scanner* the present situation is described by:

- *current (i.e. 2000) land use*;
- *policy maps* showing operative (government) policies based on restrictions (yes or no);
- *thematic maps* showing location characteristics of the grid cells in terms, for example, attractiveness of the urban environment, physical characteristics (e.g. landscape quality or altitude), accessibility or safety issues;
- *distance decay maps* that describe the presence of specific land-use types and a policy map within different distance ranges (1, 5 and 50 km).

Regional demand

Sector-specific models of specialized institutes, such as housing and employment models, provide the regional projections of land-use change that are used as input for the *Land Use Scanner* model. These are called regional claims sets in the model.

Local suitability

Suitability is a crucial component in the allocation of future land use. This suitability of a location (grid cell) can be interpreted as the net benefits that a land-use function derives from that specific location and are expressed in Euros per square meter. A high suitability for a certain land-use type leads to a high probability that this land-use type gets allocated. The value of a grid cell in a suitability map can also be negative indicating that the cell is highly unsuitable for a certain land use. For every location the suitability or attractiveness for the different land-use types is described, based on a number of site specific characteristics. The factors influencing this suitability are divided in three groups:

1. present land use;
2. policy maps; and
3. thematic maps.

The importance of each contributing factor is dependent on the scenario and weighted in a script, as will be explained in the exercise.

Allocation of future land use

The demand for land is matched with the supply of suitable land, resulting in a simulated future land use for each grid cell. This process is called allocation. The *Land Use Scanner* is able to use two different descriptions of land use per cell in the allocation process:

1. a *continuous* description using heterogeneous cells to indicate the amount of land for each land-use type present at a specific location (as was explained on the preceding page).
2. a *discrete* description using homogenous to indicate the single dominant land use at a particular location.

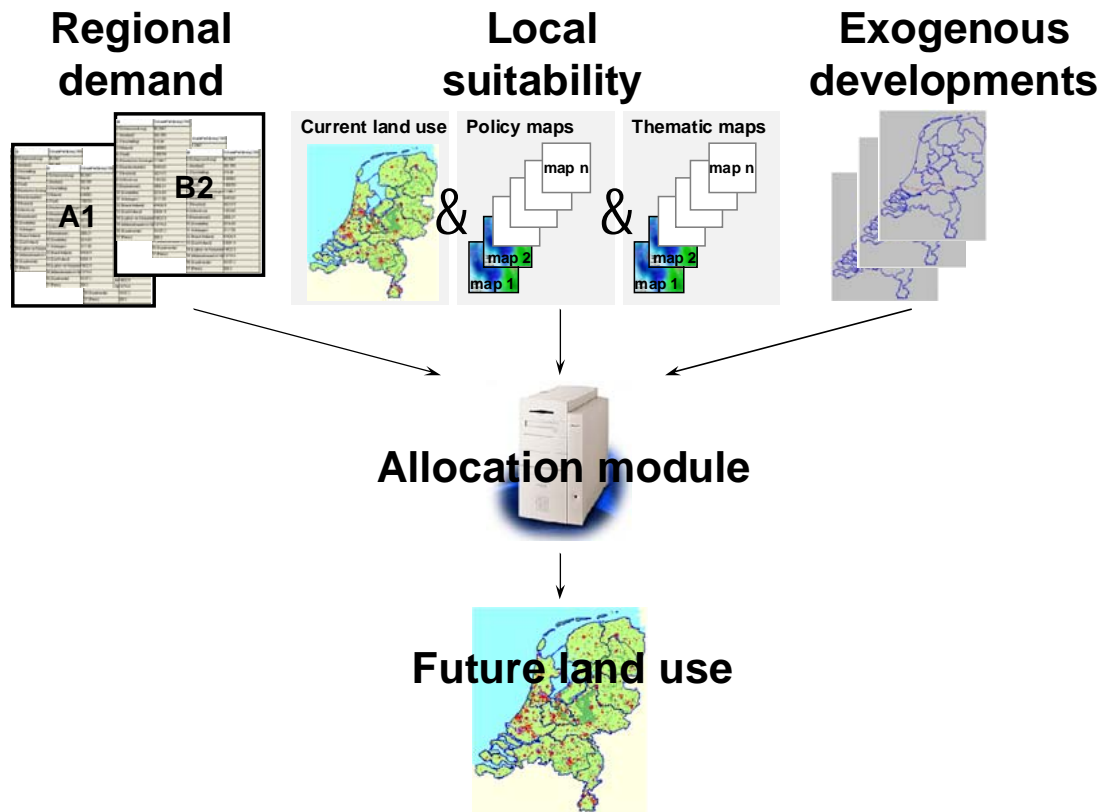
Each description of land use has its own allocation procedure. The continuous allocation uses a logit function to calculate the most probable land use at that location, whereas the discrete allocation uses a spatial optimisation procedure that is solved through a form of linear programming. Appendix 1 briefly explains these different allocation procedures.

This assignment uses the continuous allocation procedure, but the discrete allocation procedure is also included in the provided model version to provide the opportunity to compare the different approaches. The outcomes of the continuous model version can be

interpreted as the expected proportions of land to be used for the various types of land use. The predominant land-use maps depicting these results are similar to the outcomes of the discrete allocation process.

The spatial developments of a number of specific land-use types (Water, Infrastructure, Other land use and Exterior) are not simulated through the allocation module, because they are either absent or having a very confined, local appearance. These normally only constitute of planned additions to the infrastructure network, that are directly (exogenously) inserted in the simulation outcomes.


The functioning of the model is summarised below.




Basic layout Land Use Scanner model.

Exercise – Getting to know the *Land Use Scanner*

To familiarize yourself with the *Land Use Scanner* model we ask you to go through this simple exercise. **Read the exercise carefully!**

Each time an Action of your part is required during this exercise, the symbol  will be printed in the left margin of the page. After having completed all steps you should be able to use all basic functions of the model.

Getting started

 Start the *Land Use Scanner* model.



The model should now display the blank starting page entitled: Land Use Scanner - demo.dms. Beneath this title-bar you find:


- the menu bar with several pull down menus,
- a currently empty dark-grey tool-bar that can contain window-specific tools,
- on the left hand side a TreeView that allows you to navigate through the spatial data collection
- on the right hand side a currently empty light-grey data view area (for displaying tables and maps)
- at the bottom a status bar that can present hints and status information

We will concentrate on the TreeView, since that provides the easiest access to the model.

Viewing spatial data


The *Land Use Scanner* contains a number of spatial data sets. These can be viewed by browsing through the TreeView.

 1. Start by clicking on the + in front of the container (directory) called “Present” and again on the + in front of the subsequent “landuse” and “ggModel_2000” containers. This container includes 9 data-layers that describe the land use in the year 2000. The small globes  indicate that a map of the data-layers can now be drawn in the data-view area.

 2. View several land-use maps by trying out all three possible ways to draw a map view:





- by double-clicking on any of the data layer names. This option allows multiple data layers to be drawn in the same map view window.
- by activating (clicking on) the data layer and then simultaneously pressing the Ctrl-M key combination. This option will open a new map view window for every data layer.
- by giving a right mouse-click on the data layer and selecting the Map View > Default option from the appearing menu. This option will open a new map view window for every data layer.




Note that a legend appears on the right hand side that indicates that the units are hectares (Ha) and that values range from 0 to 25, the latter obviously being the maximum value for the 500x500-meter grid cells. A last column in this legend contains the count for each class.


 Right mouse-click on the legend area. This allows you to select the statistics function (one of the menu options of the pop-up menu). This option provides some basic statistics on the selected dataset, e.g. minimum and maximum value per gridcell and the total area (sum) covered by this land-use function.

The edit palette pop-up menu option allows you to change the classification and colour, but we will not spend time on that (all information about these options can be found in the user guide, also available on www.objectvision.nl).

3. The tool-bar now contains several standard GIS-functions like:

 zoom in,  zoom out,  pan,  get info,

 set to full extent,  copy visible area to clipboard,  toggle scalebar.

 Explore these functions to familiarize yourself with their possibilities. See for a description of all tools the user guide.

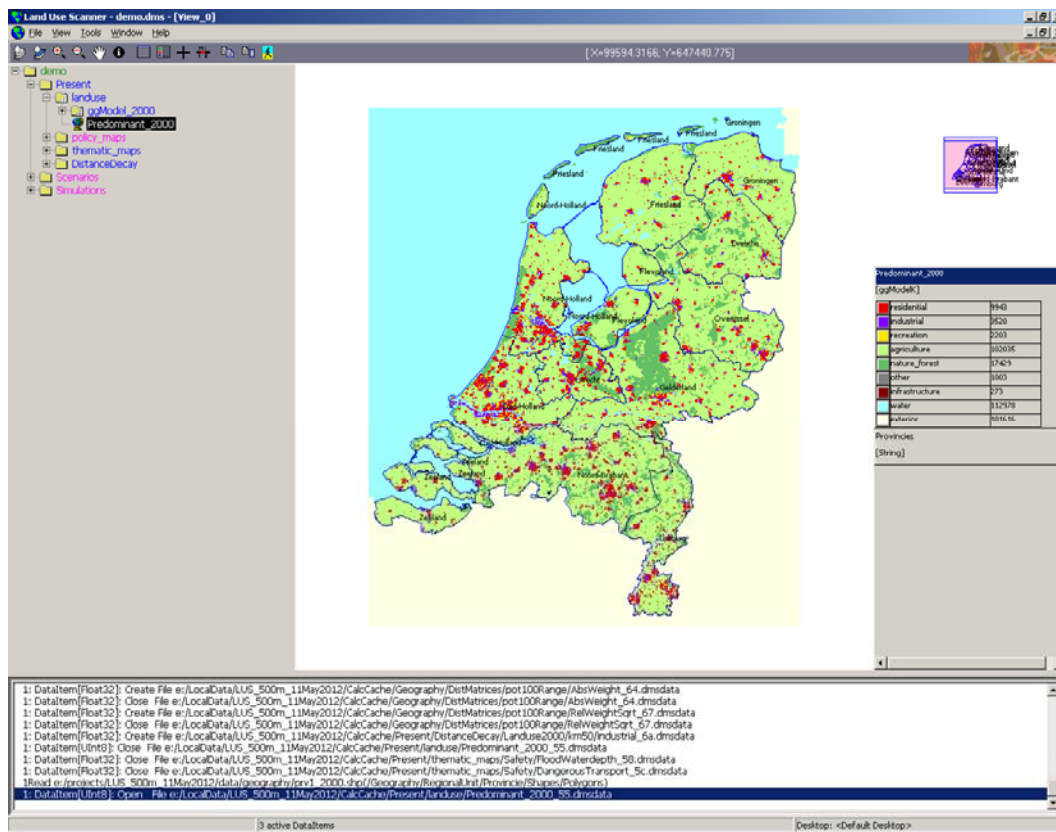
- The individual land-use maps do not offer a coherent view on land use in the country so we will try out a different way of looking at these data layers.



Close all opened map views (menu option Window > Close All) and then open the Predominant (per cell land use predominance) container and the Predominant_in_9_classes_2000 data layer.

You should now have a view similar to the figure below. This map shows for every grid-cell the land-use function that covers the most hectares. It clearly indicates the most notable features of the country: a network of big cities in the west of the country, a number of large nature areas along the coast and in the middle of the country, and lots (two thirds of the land surface!) of agricultural land in between.

Note that with 9 land-use classes the predominant land use may only cover 3 of the total of 25 hectares of the gridcell when all land-use function have a more or less similar share.



Dominant land use in the Netherlands for the year 2000.

- The *Land Use Scanner* also contains a collection of spatial data sets that are relevant for the simulation of future land use. These sets are considered when suitability is defined.



Take 10 minutes to browse through the containers containing policy maps and thematic maps. You will find policy maps related to e.g.: existing spatial plans for urban extensions, nature policy, water management, planned infrastructure. The thematic data are mainly related to the locational preferences of the various land-use functions and indicate among others: urban and rural attractiveness, accessibility, noise disturbance and landscape characteristics. A description of all available data layers is provided in appendix 3.

Defining suitability

Future scenarios are implemented in the *Land Use Scanner* through sets of maps that reflect suitability and exogenous developments and a table with land-use claims. In the assignment that follows this exercise these scenarios will be introduced. Now will first explore the model, starting with the way suitability is included in the model.

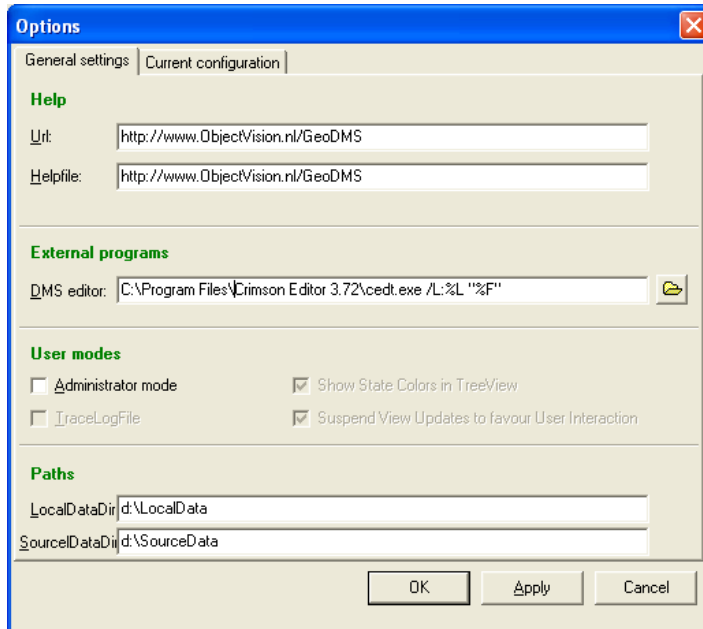


- Start by opening the A1_Best scenario in the Scenarios > Spatial container. Now open the Residential land-use suitability map and write down the minimum and

maximum value in the statistics. Zoom in at city level and save a bitmap of that particular situation.



- Inspect the definition of the suitability map that you opened by right-clicking on the appropriate data layer and selecting the edit config source option. You may also hit the Ctrl+E keys after selecting the data layer. This will open a text editor at the line of the script that defines the data layer you just opened. Note that this option will only work when you properly refer to the text editor of your choice. This reference is made in the General settings tab in the Options menu available from the pull down menu option Tools:



By default, the Crimson Editor (downloadable from: www.crimsoneditor.com) is configured in the geo-DMS. The appropriate line number and file name are provided to the editor by means of the parameters (/L:%L "%F"). Make sure that the correct pathname is used to refer to the location where the editor is installed.

- All suitability maps of a scenario are defined in a single compact text file that holds the scenario-name. The file looks like this:

```

24 container A1_Best:ur1 = "%projDir%/data/metadata/scenarios.htm#A1"
25 {
26
27 // ===== RESIDENTIAL
28
29
30 attribute <Eur_M2> residential(rdc_500lu):
31 //Current Landuse
32 Expr = "value(20.0, Eur_M2) * landuse/ggModel_2000/residential / value(25, ggHa)"
33 // - value( 0.0, Eur_M2) * landuse/ggModel_2000/nature_forest / value(25, ggHa) // in order to preserve current r
34 //Policy maps: Note that these maps are based on the principle Present (= Yes, value 1.0) or Not present (= Niet, value 0.
35 // + value( 0.0, Eur_M2) * float32( policy_maps/Spatial_plans/recreation == Yes)"
36 // + value( 0.0, Eur_M2) * float32( policy_maps/Spatial_plans/residential == Yes)"
37 // + value( 0.0, Eur_M2) * float32( policy_maps/Spatial_plans/industrial == Yes)"
38 // + value( 0.0, Eur_M2) * float32( policy_maps/NatureLandscape/birdHabitat == Yes)"
39 // + value( 0.0, Eur_M2) * float32( policy_maps/NatureLandscape/net_EHS03 == Yes)"
40 // + value( 0.0, Eur_M2) * float32( policy_maps/water/intake_reservoir == Yes)"
41 // + value( 0.0, Eur_M2) * float32( policy_maps/water/disaster_retention == Yes)"
42 //Thematic maps
43 // + value( 0.0, Eur_M2) * thematic_maps/residential/UrbanAttractivity / value(100, Percent)"
44 // + value( 0.0, Eur_M2) * thematic_maps/residential/AttractivitySurroundings / value(100, Percent)"
45 // + value( 0.0, Eur_M2) * (rescale(min_elem( thematic_maps/Accessibility/Dist_NSstation2001, value ( 5, km) ), flc
46 // + value( 0.0, Eur_M2) * (rescale(min_elem( thematic_maps/Accessibility/Dist_mainports, value (60, km) ), flc
47 // + value( 0.0, Eur_M2) * (rescale(min_elem( thematic_maps/Accessibility/Dist_opafrit, value (15, km) ), flc
48 // + value( 0.0, Eur_M2) * (rescale(min_elem( thematic_maps/Accessibility/Dist_100000inh, value (25, km) ), flc
49 // + value( 0.0, Eur_M2) * (rescale(min_elem( thematic_maps/Accessibility/Dist_100000jobs, value (25, km) ), flc
50 // - value( 0.0, Eur_M2) * thematic_maps/Noise/perc_opp_gt_50dba / value(100, Percent)"
51 // + value( 0.0, Eur_M2) * float32( thematic_maps/NatureLandscape/Landscape_experience / value( 5, BelevingRange))

```

Part of the A1.dms suitability script

It contains a header and a series of text lines relating to the actual suitability of the various land-use functions. See for example the suitability script of the residential land-use function in the figure above.

A function's suitability is distinguished in values related to:

- 1) **current land use;**
- 2) **policy maps;**
- 3) **thematic maps; and**
- 4) **distance decay maps.**

These four segments are separately indicated under each land-use function.

Note that most available spatial datasets are included in the script, but apart from the one that relates to current land use all **values** (the encircled numbers) are set to zero. This means that the suitability of a land-use function is currently only related to present land use. This is a good start because we normally want to preserve land-use functions on their current location. Remember that we will simulate the total of current land use and additional claims on a blank map. To include the preferred locations for the future development of specific land-use functions we will however need to add values to the relevant datasets. Doing this in a structured way that is coherent with the storyline of the scenario is the objective of the upcoming assignment. For now we will only practice adjusting the script.

Please only adjust the values in the encircled area, so do not for example change the km or Percent values at the end of the lines. You may however also change the signs of the values in front of the lines, indicating whether a map increases (“+ **value ...**”) or decreases (“- **value ...**”) the suitability of a land-use function.

As a guideline, you can use the following values for indicating the importance of the various datasets/policies/maps:

Importance	Value
Not important	0.0
Somewhat important	1.0
Important	3.0
Very important	5.0

Of course, you are free to choose values outside these guidelines. For example, if you really want to stress the importance, you could set the value to 15.0 and see what the effect is on your simulation result. Note, however, that the maximum total suitability value for each land-use type should stay below a certain threshold (around 80) to prevent computational errors during simulation.



Scroll down to the part of the A1.dms script that relates to the function Residential land use, which is indicated by a green heading with the word residential in capitals.



Change the values for residential spatial plans and AttractivitySurroundings (indicating the attractivity of the surrounding landscape) from 0 to 5. Make sure you save the changes you made.



Reopen the *Land Use Scanner* by hitting the ALT and R keys simultaneously or by going to the File dropdown menu, choose open configuration file, and select the demo.dms file. **DO NOT SAVE THE CHANGES MADE TO THE CURRENT DEMO.DMS FILE!**

Note Reopening the *Land Use Scanner* allows the model to take your update in the scenario-script into account. You can now redraw the changed suitability map for residential land use in the A1 scenario. This map should include the plans for residential extensions and an indication for attractive landscapes.



Compare the current minimum and maximum values with the original ones that you wrote down in step 1. Have the values changed as you expected them to? Also check whether the pattern reflects that of the underlying data-layers by adding these to the map view and compare it with the saved bitmap.

Other scenario components

Apart from suitability, scenarios are defined through their exogenous land-use developments and land-use claims.

1. The container Scenarios > ExogenousLanduse > A1 contains the expected exogenous developments. It contains the expected future land use for the functions that are not simulated by the allocation module. Most of these functions are not expected to change at all; the boundaries with the bordering countries are fixed and we aim to keep the water level constant. The future situation of these functions will thus be equal to the current situation. Only some planned additions to the rail network are included in the infrastructure layer. For sake of simplicity these are kept the same for all scenarios. We will not pay any further attention to this issue.
2. Each land-use function demands a certain surface area. For each scenario, the demand per land-use type may vary. For example, in a scenario with higher population growth, it is presumable that more space will be needed for residential areas, thus the land-use claim (in hectares) for residential will be higher. The container Scenarios > RegionalClaimSets > A1 contains the land-use claims for each land-use type. These claims are included per region.



For instance, doubleclick on the map Residential_claims. A table will be displayed in the DataView listing the land-use claims for 40 regions. Also, in the TreeView you can see that a map of the residential claims can also be drawn. Close (exit) the table in DataView and then doubleclick on the A1-mapitem in the TreeView to draw the map of the claims in the DataView.

Note that it is not necessary for all land-use claims to add up exactly to the amount of land available (the current land use), i.e. there can be over-demand or over-supply of land.

Simulating future land use


1. In the TreeView, click on Simulations > A1_Best. Within this container you will find a results container. Within this container open the sub-container labelled continuous. When you open this container. you will see two subcontainers: LandUse and evaluation. The container LandUse contains result maps of all nine land-use types for 2030 (subdivided in two subcontainers: Endogenous and Exogenous land use) and a map with the predominant land use per cell only (Predominant_in_9_classes). You can, for example, compare the maps of predominant land use in 2030 with the map of predominant land use in 2000.
2. The container evaluation contains a set of evaluation measures, which are described below:



- Two table-containers, CurrentLanduse and AllocatedLanduse.

Double-click on the container label AllocatedLanduse and a table listing allocated land use in hectares will be drawn in the DataView.



Copy-Paste the contents of this table to Excel by clicking on the Copy-Paste icon now visible in the Toolbar  and then selecting Edit > Paste (or CTRL+V) in Excel. Using both current and allocated land use, you can numerically see the differences between the endogenous land use in 2000 and in 2030 and calculate percentages et cetera.



- The container DifferenceMaps_ggEndogenous contains five difference maps of the endogenous land-use types. The maps indicate the difference between land use of a certain type in 2030 and 2000. The difference is scaled from -25 to + 25 hectares per cell.
- The container Urbanisation contains several evaluation measures that were developed specifically for analysing the effects of urbanisation (see Ritsema van Eck and Koomen, 2008, for more details). The indicators describe:
 - *urbanisation sec*, by creating maps of current and allocated built-up areas and calculating a difference map;
 - *urban pressure on nature and landscape*, distinguishing pressure on net Ecological Main Structure (netEHS), BirdHabitatareas and pressure on areas of high quality landscapes;
 - *urban area size*, capturing the size of individual urban areas (BuiltupAreaSizePerCel) in both the current and allocated situation, and an additional statistic for each situation describing the average size of the urban areas.



3. Familiarise yourself with these evaluation measures by opening several maps, see if you understand the interpretations of the maps you open.

As soon as you draw the map of predominant land use in 2030 or use one of the evaluation measures, the model will run the scenario and calculate the results. This may take several minutes. After the results have been calculated, they are kept in memory and therefore opening other evaluation measures or displaying other allocated land use will go fast.



Closing a session

In the menu-bar, click on File > Exit and choose No in the appearing question box:
DO NOT SAVE THE CHANGES MADE TO THE CURRENT DEMO.DMS FILE!

Assignments – Modelling the future of the Netherlands

Now you are familiar with the model it is time to bring this new-found knowledge into practice. You are provided with a fully functional copy of the *Land Use Scanner* that already contains a basic reference to four socio-economic scenarios. Scenario-specific land-use claims have been added to the model and all available spatial datasets are included in the suitability maps. No weights have been added to these maps however. The land-use claims and suitability maps are combined in the allocation module and results are available from the Simulations container.

It is your task to simulate the future of the Netherlands according to a specific scenario or policy alternative. For this assignment you are asked to *either*:

1. **simulate land-use patterns according to one of the four scenarios by *selecting and weighing* the various components of the suitability maps in order to match the storylines of the scenarios; *or***
2. **optimise land-use patterns according to specific policy objectives by adjusting the suitability maps and possibly also the demand for land.**

The two different assignments are described below.

Assignment 1 Simulate land use according to a scenario

To generate maps related to Dutch land use in 2030 we request you to do the following:

- 1) All group-members should take a look at the list with available spatial data as included in the table below. A more detailed description of each data layer is included in appendix 3.

Indicate individually which spatial data are relevant for your specific scenario *in general* (for all land-use types) based on the scenario descriptions included in Appendix 2. Specify the relevance of each relevant dataset on a scale from 1 (minor importance) to 5 (extremely important). Non-relevant datasets should keep the value 0.

			Values in script			
Main group	Theme	Data layer	A1	A2	B1	B2
policy_maps	Spatial_plans	Residential Industrial Recreation				
	NatureLandscape	BirdHabitat Net_EHS03				
	Water	Intake_reservoir Disaster_retention Space_for_rivers Groundwater_protection Groundwater_intrusion				
thematic_maps	Residential	UrbanAttractivity AttractivitySurroundings				
	Accessibility	Dist_mainports Dist_NSstation2001 Dist_highwayExits Dist_100000inh Dist_100000jobs				
	Noise	Perc_opp_gt_50dba				
	NatureLandscape	Landscape_quality4K Landscape_experience Altitude				
	Safety	FloodWaterDepth EarthQuakes				

		DangerousSites DangerousTransport	
DistanceDecay	LandUse2000	Amount of specific land-use types in range of 1, 5 or 50 km	
	PolicyMaps	Amount of BirdHabitat area within 1km Amount of net_EHS03 area within 1km	

Note that the policy maps related to infrastructure development that are also present in the container policy_maps are used to define future changes in the exogenous infrastructure class. We will not pay attention to these developments in this assignment.

- 2) Discuss the possibly conflicting views on the relevance of the spatial datasets in your group and decide upon a joint valuation of the components that make up your suitability maps.
- 3) The next step is to actually adjust the suitability maps for all *individual land-use types* in your scenario. You can do this by changing the appropriate values in the scenario-script (e.g. A1.dms) in the text editor. As a start you can use the values that you agreed upon in the previous step. Note that the data-layers that are important for a scenario in general are not necessarily relevant for all individual land-use types. Some data-layers will be important for urban functions others for nature etcetera.
Keep in mind that the suitability values reflect the net benefits of a certain location for a specific land-use type. This should provide a rationale (as well as limits) for your range of suitability values. Moreover, take care that for computational reasons there is a maximum value for the suitability of land-use types. Since the *Land Use Scanner* uses the Suitability in an exponential function, high values for this variable will cause a numerical overflow error and will stop the simulation. Therefore, try to keep the range of the suitability values of your land-use types between -20 and $+40$ Eur_m², as the legend of the suitability maps also indicates.
Finally, save the script and re-start the *Land Use Scanner* (re-opening the map window will not run the script).
- 4) Take a look at the resulting suitability maps per land-use function and discuss whether these are coherent with your initial thoughts on the scenario. Results can be analysed by comparing saved bitmaps and statistics of the situation before and after you change the script.
- 5) Simulate future land use by running the appropriate simulation (e.g. Simulations -> A1_Best). Check the resulting maps on consistency with the storylines of scenario, e.g. by making maps that depict dominant land use and the changes from the current land use. Discuss which adjustments are needed.
- 6) Adjust the suitability maps and rerun the model until the results correspond with your views on the scenario.
- 7) Summarize the results by making characteristic maps of future land use. Make use of the possibilities for creating evaluation maps that describe dominant land use, the changes as compared to the current situation and impacts on natural areas and landscape values. You can export result maps to, for example, ArcGIS, to create more elaborate impact assessments and/or more refined maps.
- 8) Prepare a Powerpoint-presentation of 5-10 minutes with your group in which you offer your selection of relevant maps. Discuss the results in terms of: the rationale for the weights you applied to the suitability data layers, their coherence with storylines, the validity of your results, possible shortcomings in the simulation process, and its general usefulness for policy-purposes.

Assignment 2 Optimise land use according to a set of policy objectives

The *Land Use Scanner* model is also able to optimise land-use patterns according to specific, spatially explicit policy objectives (see, for example, Koomen et al., 2011). In this assignment you are asked to consider one of the following three different objectives:

- a. water management (protecting the hydrological cycle, land use follows hydrological conditions etc.);
- b. safety and public health (limiting all kinds of risk to society); or
- c. nature conservation (preserving biodiversity and strengthening the nature network).

To optimise Dutch land use in 2030 according to one of these objectives you will start to work with the land demand following the A1 scenario. This is an arbitrary choice as the policy objectives are not directly related to the scenario assumptions, but selecting the A1 scenario has the advantage that a substantial amount of land-use change occurs making it easier to see the impact of your choices. One could argue that optimised land-use patterns according to this scenario prepare policy makers for worst case conditions: you try to meet specific objectives under conditions of substantial urban growth. We ask you to follow the steps below:

- 1) All group-members should take a look at the list with available spatial data as included in the table below. A more detailed description of each data layer is included in appendix 3.

Indicate individually which spatial data are relevant for your specific policy objective *in general* (for all land-use types) based on your interpretation of this policy theme. Note that it may be necessary to first define for yourself what you consider to be important spatially explicit policy measures to improve land-use patterns according to these rather general themes. Specify the relevance of each relevant dataset on a scale from 1 (minor importance) to 5 (extremely important). Non-relevant datasets should keep the value 0.

			Values in script		
Main group	Theme	Data layer	Water	Safety	Nature
policy_maps	Spatial_plans	Residential Industrial Recreation			
	NatureLandscape	BirdHabitat Net_EHS03			
	Water	Intake_reservoir Disaster_retention Space_for_rivers Groundwater_protection Groundwater_intrusion			
thematic_maps	Residential	UrbanAttractivity AttractivitySurroundings			
	Accessibility	Dist_mainports Dist_NSstation2001 Dist_highwayExits Dist_100000inh Dist_100000jobs			
	Noise	Perc_opp_gt_50dba			
	NatureLandscape	Landscape_quality4K Landscape_experience Altitude			
	Safety	FloodWaterDepth EarthQuakes DangerousSites DangerousTransport			

DistanceDecay	LandUse2000	Amount of specific land-use types in range of 1, 5 or 50 km	
	PolicyMaps	Amount of BirdHabitat area within 1km Amount of net_EHS03 area within 1km	

Note that the policy maps related to infrastructure development that are also present in the container *policy_maps* are used to define future changes in the exogenous infrastructure class. We will not pay attention to these developments in this assignment.

- 2) Discuss the possibly conflicting views on the relevance of the spatial datasets in your group and decide upon a joint valuation of the components that make up your suitability maps.
- 3) The next step is to actually adjust the suitability maps for all *individual land-use types* in your policy alternative. You can do this by changing the appropriate values in the scenario-script (in this case A1.dms) in the text editor. As a start you can use the values that you agreed upon in the previous step. Note that the data-layers that are important for a policy alternative in general are not necessarily relevant for all individual land-use types. Some data-layers will be important for urban functions others for nature etcetera.
Keep in mind that the suitability values reflect the net benefits of a certain location for a specific land-use type. This should provide a rationale (as well as limits) for your range of suitability values. Moreover, take care that for computational reasons there is a maximum value for the suitability of land-use types. Since the *Land Use Scanner* uses the Suitability in an exponential function, high values for this variable will cause a numerical overflow error and will stop the simulation. Therefore, try to keep the range of the suitability values of your land-use types between -20 and $+40$ Eur_m², as the legend of the suitability maps also indicates.
Finally, save the script and re-start the *Land Use Scanner* (re-opening the map window will not run the script).
- 4) Take a look at the resulting suitability maps per land-use function and discuss whether these are coherent with your initial thoughts on the policy objective. Results can be analysed by comparing saved bitmaps and statistics of the situation before and after you change the script.
- 5) Simulate future land use by running the appropriate simulation (i.e. Simulations -> A1_Best). Check the resulting maps on consistency with the policy objectives, e.g. by making maps that depict dominant land use and the changes from the current land use. Discuss which adjustments are needed.
- 6) Adjust the suitability maps and rerun the model until the results correspond with your views on the policy objective.
- 7) In order to meet your policy objectives you can also consider the implementation of policy measures that change the demand for land (e.g. limit the amount of urban land by prescribing higher building densities, or expand the demand for nature by launching a more ambitious nature development programme). Discuss such options in your group and decide upon a justifiable change in demand. You can implement the changed demand in the Microsoft access database in LUS_DEMO\data\Scenarios\RegionalClaimSets\RB_claims.mdb. Access may frighten you a bit at first, but it works quite intuitively. The database contains a table for each land-use type that specifies the amount of additional land that will be added to current (2000) land use per region and per scenario. Some land-use types have only one region (Nature_Forest), while others are specified at a more detailed regional level (Provinces, COROP-region or LEI14 -agricultural-regions). You can type the changed demand directly in the database table (after clicking on a field) or copy pre-calculated demand figures from, for example, excel and paste these over the table figures. Make sure you change figures in the A1 columns as this is the base-scenario you use in your optimisation.
- 8) Once you have changed the demand you can rerun the simulation (after re-opening *Land Use Scanner*) and discuss whether the results match your expectations.

- 9) When you are satisfied with your results, summarize the results by making characteristic maps of future land use. Make use of the possibilities for creating evaluation maps that describe dominant land use, the changes as compared to the current situation and impacts on natural areas and landscape values. You can export result maps to, for example, ArcGIS, to create more elaborate impact assessments and/or more refined maps.
- 10) Prepare a Powerpoint-presentation of 5-10 minutes with your group in which you offer your selection of relevant maps. Discuss the results in terms of: the rationale for the weights you applied to the suitability data layers, their coherence with the policy objectives, the validity of your results, possible shortcomings in the simulation process, and its general usefulness for policy-purposes.

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Please note that most of the listed references and additional information are available from: <http://www.feweb.vu.nl/gis>

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Appendix 1 *Land Use Scanner* Background

The *Land Use Scanner* employs two approaches to simulate the probability that a certain location is chosen for a specific land use. These two approaches, continuous and discrete, are described below in different paragraphs. An extensive discussion on both allocation approaches and a comparison of their performance is provided in a report by Loonen and Koomen (2009).

A crucial variable for both approaches is the suitability s_{cj} for land use of type j in grid cell c . This suitability can be interpreted to represent the net benefits (benefits minus costs) of land-use type j in cell c . The higher the benefits (suitability) for land-use type j , the higher the probability that the cell will be used for this type. The economic rationale that motivates this choice behaviour resembles the actual functioning of the land market. The model is furthermore constrained by two conditions: the overall demand for the land-use functions which is given in the initial claims and the total amount of land which is available for each function.

Continuous allocation

The original, continuous model employs a logit-type approach, derived from discrete choice theory. Nobel prize winner McFadden has made important contributions to this approach of modelling choices between mutually exclusive alternatives. In this theory, the probability that an individual selects a certain alternative is dependent on the utility of that specific alternative, in relation to the total utility of all alternatives. This probability is, given its definition, expressed as a value between 0 and 1, but it will never reach these extremes. When translated into land use, this approach explains the probability of a certain type of land use at a certain location, based on the utility of that location for that specific type of use, in relation to the total utility of all possible uses. The utility of a location is in our case expressed as the suitability for a certain use. In combination with the constraints related to demand for land and the amount of available land per cell the following doubly constrained logit-model can be formulated:

$$M_{cj} = a_j \cdot b_c \cdot e^{(\beta \cdot s_{cj})}$$

In which:

- M_{cj} is the expected amount of land in cell c that will be used for land-use type j .
- a_j is the demand balancing factor that ensures that the total amount of allocated land for land-use type j equals the sector-specific claim.
- b_c is the supply balancing factor that makes sure the total amount of allocated land in cell c does not exceed the amount of land that is available for that particular cell.
- β is a parameter that allows for the tuning of the model. A high value for β makes the suitability more important in the allocation and will lead to a more mixed use land pattern, strongly following the suitability pattern. A low value will produce a more homogenous land-use pattern.
- e is the base for natural logarithms (=2.71828)
- s_{cj} is the suitability of cell c for land-use type j , based on its physical properties, operative policies and neighbourhood relations.

The outcomes of the model are thus based on various external model results, a probability approach and many operational choices of the model user. The results should therefore not be interpreted as an exact prediction for a particular location but rather as a probable spatial pattern of land-use change.

Discrete allocation

The discrete allocation approach allocates equal units of land (cells) to those land-use types that have the highest suitability, taking into account the regional land-use demand. This discrete allocation problem is solved through a form of linear programming. The solution of

which is considered optimal when the sum of all suitability values corresponding to the allocated land use is maximal.

This allocation is subject to the following constraints:

- the amount of land allocated to a cell cannot be negative;
- in total only 1 hectare can be allocated to a cell;
- the total amount of land allocated to a specific land-use type in a region should be between the minimum and maximum claim for that region.

Mathematically, we can formulate the allocation problem as:

$$\max_X \sum_{cj} S_{cj} X_{cj}$$

subject to:

$$X_{cj} \geq 0 \text{ for each } c \text{ and } j;$$

$$\sum_j X_{cj} = 1 \text{ for each } c;$$

$$L_{jr} \leq \sum_c X_{cj} \leq H_{jr} \text{ for each } j \text{ and } r \text{ for which claims are specified};$$

in which:

X_{cj} is the amount of land allocated to cell c to be used for land-use type j ;

S_{cj} is the suitability of cell c for land-use type j ;

L_{jr} is the minimum claim for land-use type j in region r ; and

H_{jr} is the maximum claim for land-use type j in region r .

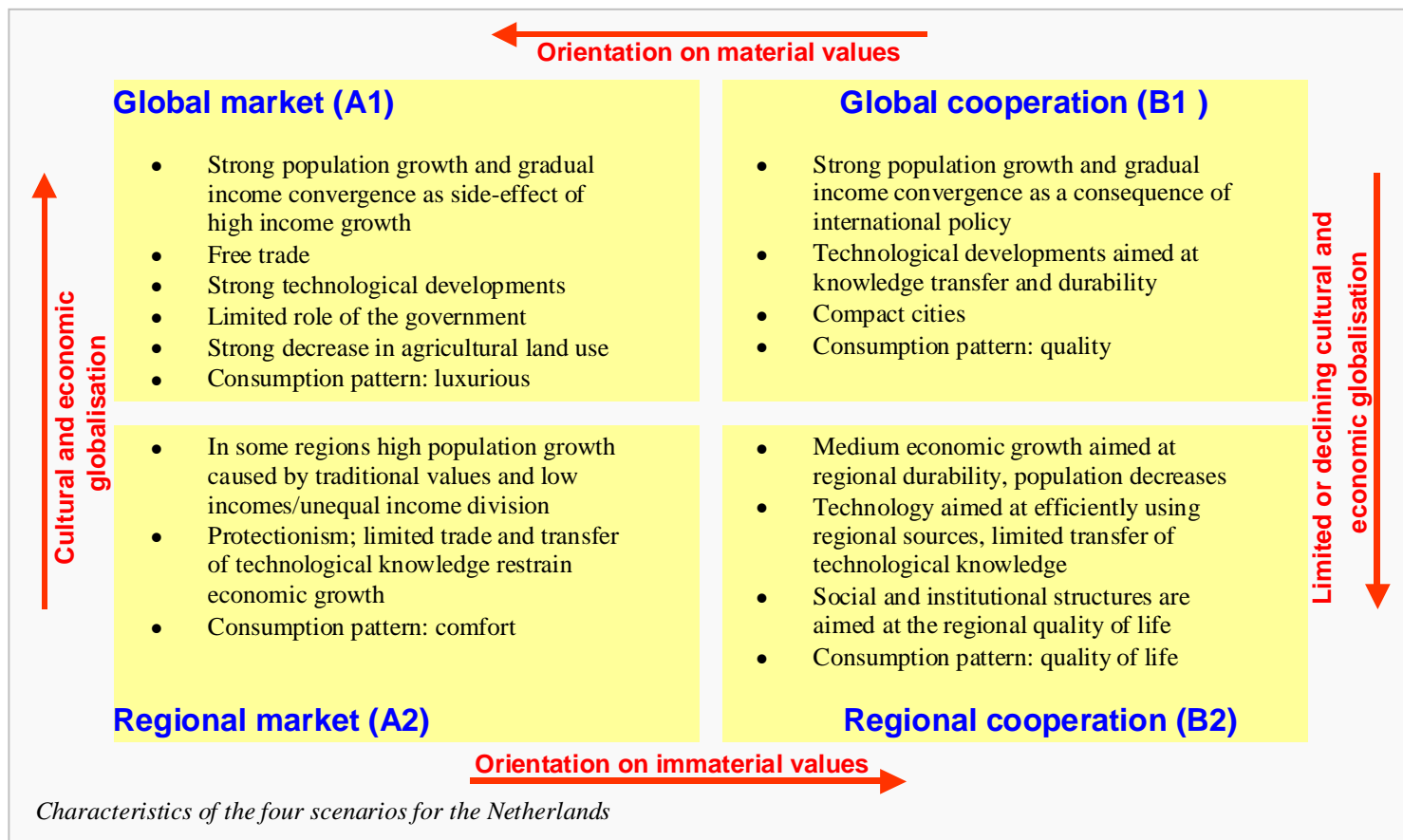
The regions for which the claims are specified may partially overlap, but for each land-use type j , a grid cell c can only be related to one pair of minimum and maximum claims. Since all of these constraints relate X_{cj} to one minimum claim, one maximum claim (which cannot both be binding) and one grid cell with a capacity of 1 hectare, it follows that if all minimum and maximum claims are integers and feasible solutions exist, the set of optimal solutions is not empty and cornered by basic solutions in which each X_{cj} is either 0 or 1 hectare.

Appendix 2 Description of the four scenarios

The assignment contains four scenarios for future spatial developments. They provide a coherent framework for studying the distinguished developments and are ordered following two opposing trends:

- global (1) vs. regional (2); and
- market economy (A) vs. cooperation (B).

The four resulting scenarios are depicted below:



Global market combines globalisation with individualism, whereas Regional cooperation connects regionalism with cooperation. In the A-type scenarios, people tend to focus more on material values, whereas in the B-type scenarios, they focus on immaterial values. Likewise, in a 1-type world cultural and economic globalisation is an important trend where in a 2-type world the opposite is the case. Each combination of trends (i.e. scenario) has specific characteristics, which are summarised below.

A1: The ‘**Global Market**’ scenario assumes a continuing globalisation and liberalisation, resulting in high economic growth and a fast introduction of new technologies. In this capitalized, market-oriented and individualistic world civilians are strongly focussed on the material aspects of life. The welfare state crumbles off.

A2: In the ‘**Regional Market**’ scenario the traditional bands between Western Europe and the United States is re-enforced and a strong cultural and trade block emerges. The differences between the Western world and other (less wealthy) regions increase. Traditions are important in this world, which shows itself in a society oriented towards self-sufficiency, an industry aimed at ‘improving the existing’ instead of radical changes and civilians aimed at family values, status and comfort.

B1: In the ‘**Global Cooperation**’ scenario globalisation continues, not only aimed at removing trade barriers but also on exchange of knowledge and technologies between industrialised and developing countries. There is a general concern for the division of wealth

and raw material between people and for the management of nature and the environment. Solidarity shows itself in the form of a strong welfare state.

B2: The ‘**Regional cooperation**’ scenario assumes an emphasis on the own identity and self-sufficiency within a region. Global developments are not the general concern and receive less attention. People are less materialistic and more focussed on the quality of their living environment. Solidarity is important and the national government plays an important role in the division of wealth and the protection of collective interests.

This appendix also contains the basic assumptions and related spatial implications for the four scenarios.

The scenarios are included in the land-use model in two ways:

1. they set regional or national land-use claims, by predicting a future surface area for every land-use type.
2. they influence the relative importance of the factors that describe the suitability.

The table below contains the expected total surface area of each land-use type for the four scenarios. These are included in the model-version that will be used for the assignment. The figures in this table are derived from different sector-specific models and are based on the trends and assumptions for each scenario. As can be seen from the claim table, three of the four scenarios have a total land-use demand that is greater than the current land use, indicating over-demand. We solve this problem in our model by taking additional land from agriculture assuming that this function will be the weakest (least spending power) in the competition for space.

A more extensive description of the related basic assumptions and spatial implications is listed in the large table on the following page.

Land-use type	A1 (Best)	A2 (West)	B1 (East)	B2 (Home)	Current land use (2000)
Residential	328536	341462	274001	282301	224793
Industrial	127962	127962	134107	134107	104043
Recreation	174608	182208	135116	136671	89642
Agriculture	2077050	2211180	2131394	2201843	2354560
Nature_Forest	530250	595250	647250	661250	485250
Other	42078	42078	42078	42078	42078
Infrastructure	87034	87034	87034	87034	82835
Water	2852990	2852990	2852990	2852990	2852990
Exterior	-	-	-	-	-
Total land-use claims	6220508	6440164	6303970	6398274	6236191

Expected land use (hectares) in 2030 following the four scenarios, compared to the current situation (2000), source: Nijs et al (2002).

	Global Market - A1 (Best)	Regional Market -A2 (West)	Global Cooperation - B1 (East)	Regional Cooperation - B2 (Home)
Socio-economic conditions				
<i>Economic growth</i>	Highest	High	Medium	Low
<i>Population</i>	20 million	18 million	19 million	15 million
<i>Societal focus</i>	Individual freedom	Individual freedom	Global cooperation	Regional cooperation
<i>Recreation</i>	Not much spare time, emphasis on active leisure, accessibility and proximity to residential areas are important	Much spare time (more than in A1 and B1, emphasis is on rest & relaxation	Valuable (more than in A1), people also like to go into nature areas, but some nature areas are restricted. Accessibility by road and by rail are important	Valuable, people also like to go into nature areas
General and sector-specific spatial policy				
<i>Economic orientation</i>	Free market prevails, globalisation	Free market prevails, protectionism	Government intervenes, strong international institutions	Government intervenes, strong local and regional institutions
<i>Spatial policy</i>	Less restrictive policies	Less restrictive policies	Restrictive policies for rural areas	Restrictive policies for rural areas
<i>Agricultural policy</i>	Free world markets for agricultural products	Internal EU support under conditions, no export subsidies	Regulated world markets for agricultural products	Internal EU support under conditions, no export subsidies
<i>Nature protection & development</i>	Only the most valuable natural areas are protected. International treaties are followed. Acquisition through private persons and organisations	Symbolic role of the government, general trend: nature serves humanity. International treaties are followed. Nature appears where agricultural land disappears. Nature is pushed aside by urbanisation processes	Global environmental policy, strong international institutions. International treaties are followed and acquisition by national government following Ecological main structure (EHS)	Larger areas protected, Ecological main structure realised. International treaties are followed and acquisition by national government following Ecological main structure (EHS)
<i>Agriculture and nature conservation</i>	Strong decline of agricultural land use. No chances for agriculture combined with natural values	Agricultural land use remains the same or decreases slightly. No chances for agriculture combined with natural values	Agricultural land use remains the same or decreases slightly. Room for agricultural nature management	Decline of agricultural land use follows historic trend. Diversified rural development, much room for agricultural nature management
<i>Water management</i>	Building near rivers is allowed	Building near rivers is allowed reluctantly	Restrictions on urbanisation in designated areas	Restrictions on urbanisation in designated areas
Expected spatial developments				
<i>Urbanisation</i>	Urban sprawl in rural areas. Accessibility by road to and from urban areas is important. Attractivity of the environment is important for residences.	Urban sprawl in rural areas. Accessibility by road to and from urban areas is very important. Proximity to an airport is important. Attractivity of the environment is not important	Concentration near existing urban areas, no new residential areas near airports	Concentration near existing urban areas, no new residential areas near airports and in low-lying rural areas
<i>Commercial functions</i>	Abundant growth, preference for highway locations	High growth, strong preference for highway locations	Medium growth, public transport accessibility promoted, also preference for highway locations	Limited growth, public transport accessibility strongly promoted

Basic assumptions and related spatial implications for the scenarios

Appendix 3 Overview of available spatial data

Spatial data <i>Land Use Scanner</i> - demo				
Main group	Theme	Data layer	Spatial data description	Units
landuse	ggModel_2000 (current land use in 9 classes)	Residential	Residences and connected activities, including: <ul style="list-style-type: none"> - primary facilities: shops, schools - small offices of a.o. banks - public parks < 1 hectare, streets and parking lots - small playing fields, barnyards, gardens 	[0 to 25 Ha]
		Industrial	Commercial and industrial land use, including: <ul style="list-style-type: none"> - shopping malls, hotels and restaurants incl. parking lots - social-cultural facilities such as high schools, hospitals, museums, churches, cinemas, conference facilities - industrial or commercial areas, such as harbours, wholesale trade market, office buildings incl. parking lots, auction site, factory outlets - dump sites, extractive industries, distribution centres, seaports, wreck storage zone 	[0 to 25 Ha]
		Recreation	Green and stay recreation, including: <ul style="list-style-type: none"> - parks, public gardens and playing (sports) fields - allotment gardens - short and long stay facilities (bungalows etc.) 	[0 to 25 Ha]
		Agriculture	Agricultural land use, including: <ul style="list-style-type: none"> - arable land and horticulture (a.o. potatoes, beets, cereals, flower bulbs and greenhouses - grassland, (zero-)grazing livestock and orchards 	[0 to 25 Ha]
		Nature_forest	Nature and forest areas, including: <ul style="list-style-type: none"> - broad-leaved and coniferous forest - salt grassland, beach, dunes, heath land - peat, moors, swamp, bare soil 	[0 to 25 Ha]
		Other	Other land use, including: <ul style="list-style-type: none"> - half-built constructions (construction sites) - burial sites 	[0 to 25 Ha]
		Infrastructure	Railway, roads and airports	[0 to 25 Ha]
		Water	Fresh and salt water, including: <ul style="list-style-type: none"> - water storage basins, lakes, rivers, sea - recreational water - reservoirs and water for extractive industries 	[0 to 25 Ha]
		Exterior	Land use outside the Netherlands; the exterior is not simulated in the <i>Land Use Scanner</i>	-
		Predominant		Predominant land use in 9 classes
Policy_maps	Spatial_plans	Residential	Spatial development plans for new residential areas	[Present: 1 or 0]
		Industrial	Spatial development plans for new commercial areas	[Present: 1 or 0]
		Recreation	Spatial development plans for new recreational areas	[Present: 1 or 0]
	NatureLandscape	BirdHabitat	BirdHabitat - International (European) treaty protecting the natural habitat of birds and endangered species	[Present: 1 or 0]

		Net_EHS03	Ecological Main Structure - Dutch spatial policy protecting particular nature areas, existing or still to be acquired	[Present: 1 or 0]
	Water	Intake_reservoir	Water intake polder - for water storage in case of prolonged local rainfall	[Present: 1 or 0]
		Disaster_retention	River water retention areas - for water storage in case of anticipated river flooding	[Ratio: 0 to 1]
		Space_for_rivers	Space reserved by National Government for widening of river flood plains, expressed in fraction of cell that falls within the contours of this spatial plan	[Ratio: 0 to 1]
		Groundwater_protection	Ground water protections zone designated by regional authorities, expressed as fraction of cell that falls within this policy zone	[Ratio: 0 to 1]
		Groundwater_intrusion	Ground water intrusion area not currently protected, expressed as fraction of cell that belongs to this area	[Ratio: 0 to 1]
	Infra	schiphol5b	Schiphol - the national airport Schiphol near Amsterdam with five runways	[Present: 1 or 0]
		HSL_Zuid	Spatial plan for the High Speed Train track to Brussels and Paris	[Present: 1 or 0]
		HSL_Oost	Spatial plan for the High Speed Train track to Germany	[Present: 1 or 0]
		Betuwelijn	Spatial plan for a freight train track from Rotterdam harbour to Germany	[Present: 1 or 0]
thematic_maps	residential	UrbanAttractivity	Attractivity measure of the urban environment, calculated using a.o. number of cultural facilities, number of hotel and catering outlets, number of shops etc.	[%]
		AttractivitySurroundings	Attractivity measure of surroundings for residents	[%]
	Accessibility	Dist_mainports	Distance to mainports Schiphol airport and Rotterdam Harbour	[km]
		Dist_NSstation2001	Distance to nearest railway station	[km]
		Dist_highwayExits	Distance to nearest highways exit	[km]
		Dist_100000inh	Distance to nearest 100.000 inhabitants	[km]
		Dist_100000jobs	Distance to nearest 100.000 jobs	[km]
	Noise	Perc_opp_gt_50dba	Area per cell [%] with a noise level of more than 50 dB(A)	[%]
	NatureLandscape	Landscape_quality4K	Landscape values [low, medium, high, very high]	[0 .. 3 classes]
		Landscape_experience	Perceived attractivity of landscape [strongly negative, .. highly positive]	[-4 .. 5 classes]
		Altitude	Altitude	[m]
	Safety	FloodWaterDepth	Average water depth resulting from worst possible flooding	[m]
		EarthQuakes	Location prone to earth quakes with an intensity of VII on Mercalli scale	[Present: 1 or 0]
		DangerousSites	Fraction of the surface area in a cell that is within a risk zone or immediate vicinity (100m) of a dangerous facility (e.g. chemical factory, storage facility for explosive material)	[Ratio: 0 to 1]
DangerousTransport		Fraction of the surface area in a cell that is in the immediate vicinity (100m) of a pipeline transporting dangerous goods	[Ratio: 0 to 1]	
DistanceDecay	LandUse2000	Land-use types in range of 1, 5 or 50 km	Relative amounts of specific land-use types that can be found within different distance ranges. Calculated by applying a square root distance decay function that gives less weight to larger distances from the observed cell. Similar to moving window filters in GIS	[Ratio: 0 to 1]
	PolicyMaps	BirdHabitat area within 1km	Relative amount of BirdHabitat area within 1 km range calculated by applying a square root distance decay function.	[Ratio: 0 to 1]
		net_EHS03 area within 1km	Relative amount of area classified as Ecological Main Structure within 1 km range calculated by applying a square root distance decay function.	[Ratio: 0 to 1]

Overview of available spatial data