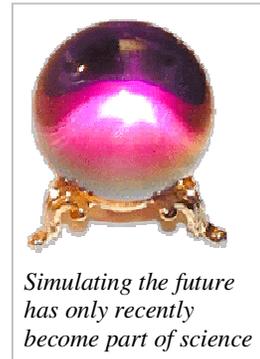# *Land Use Scanner* exercise and assignment

prepared by Dr. Jasper Dekkers & Dr. Eric Koomen
SPIN*lab* - Vrije Universiteit Amsterdam

[version April 2016]

Looking into the future has fascinated mankind for ages. With the advent of sufficiently powerful personal computers we do not need a crystal ball anymore to foresee what our country will look like in, say, 30 years from now. All that is needed not to simulate future spatial developments 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 to 10 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).

Simulating the future has only recently become part of science

In this assignment you are asked to simulate future land use for 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 hands-on exercise. When you are familiar with the model's main functions you will start the actual assignment.

For more information about *Land Use Scanner*, the full model and its applications, or for information about how to obtain the 100m version of the Student Edition, you can visit the website (spinlab.vu.nl) or contact Dr. Jasper Dekkers (j.dekkers@vu.nl) or Dr. Eric Koomen (e.koomen@vu.nl).

Introducing *Land Use Scanner*

In this assignment we will use *Land Use Scanner*, an integrated land-use model that has been used for various policy related research projects. Early applications include, among 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 a modelling framework that was developed for the European Commission and that now covers the 27 member states of the European Union at a 100-meter resolution (Lavalle 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*, visit spinlab.vu.nl.

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 10 or more different land-use categories. The model is grid-based and the Student Edition comes in two versions: the version that is recommended for slower (e.g. 32-bit) computers uses 351,000 cells of 500 by 500 meter to cover the Netherlands. The second version of the model covers the country at a 100 by 100 meter resolution (8,775,000 cells). Because this version has much more spatial detail, calculation times take longer, so we recommend to only use it on faster (e.g. 64-bit) computers.
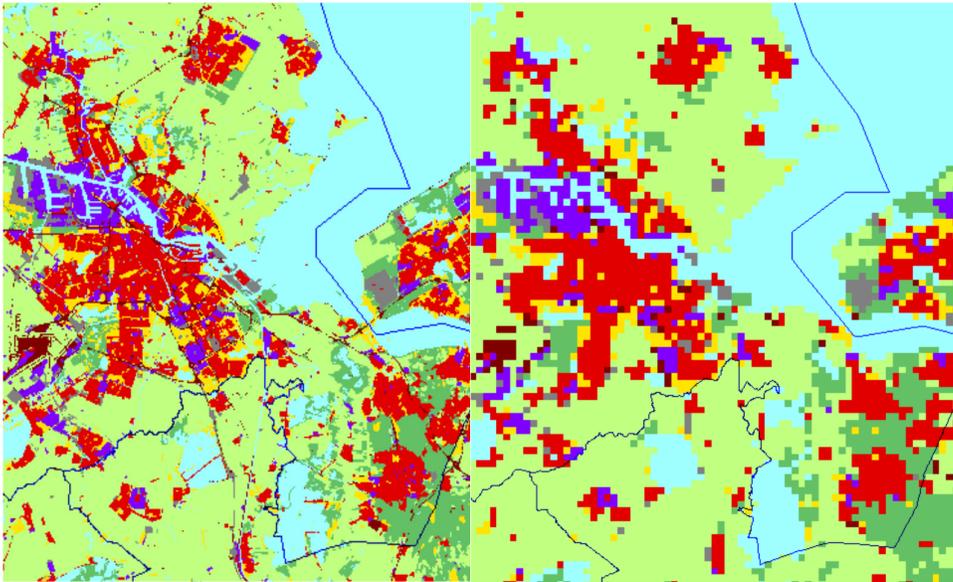

Figure 1 - Current dominant land use per cell at the 100m (left) and 500m raster resolution.

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. An individual cell with a 500m-resolution can, for example, have the following composition:

residential	*11 ha*	*building lot*	*3 ha*
industrial	*0 ha*	*infrastructure*	*1 ha*
recreation	*2 ha*	*water*	*3 ha*
agriculture	*5 ha*	*exterior*	*0 ha*
nature	*0 ha*	***Total =***	***25 ha***

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 hectares (less than half) of the total surface area of the cell (25 hectares). With nine land-use classes the predominant land use may cover as little as 3 hectares in a cell.

In addition to land-use data the model contains many different spatial data sets that are organised in three main folders:
1. *Current situation*: a collection of spatial data sets that describe the current situation;
2. *Scenario components*: the definition of the future scenarios that will be simulated;
3. *Simulations:* the land-use maps and other outcomes that result from simulation.

The following sections describe content and relevance of these elements.

Current situation
In *Land Use Scanner* the current situation refers to current land use and other data sets describe the current situation of important drivers of land-use change. These data sources can be used to define local suitability. They are grouped in the following subfolders :
- *Current land use* describing nine aggregate land-use classes for 2010;
- *Policy maps* showing operative (government) policies based on restrictions (yes or no);
- *Thematic maps* showing location characteristics of the grid cells in terms of, 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 two nature policy areas within different distance ranges.

Scenario components
In the model scenarios of possible future developments can be constructed using the following components: 1) local suitability; 2) regional demand; and 3) exogenous developments. These aspects are further introduced below.

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 at a particular location leads to a high probability that this land-use type gets allocated there. 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 the aforementioned four groups:
a) Current land use;
b) Policy maps;
c) Thematic maps; and
d) Distance decay maps.

Reference to current land use is added because the allocation process does not automatically retain this. In contrast to many other land use models, *Land Use Scanner* starts simulation with an empty map. To account for the fact that land use has a certain inertia (e.g. due to the cost of converting land from one use to another) we include reference to current land use in the definition of suitable locations. The importance of each contributing factor is dependent on the scenario and weighted in a script, as will be explained in the exercise.

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 demand or claim sets in the model.

Exogenous land use

The spatial developments of a number of specific land-use types (infrastructure, water 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 remaining land-use types are simulated within the model and are referred to as *endogenous* land-use types.

Simulations 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 (Figure 2). *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 previously).
2. a *discrete* description using homogenous cells 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 optimization procedure that is solved though 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 a single dominant land use per cell from these calculation results are visually similar to the outcomes of the discrete allocation process that - by definition - results in one land use type per grid cell.
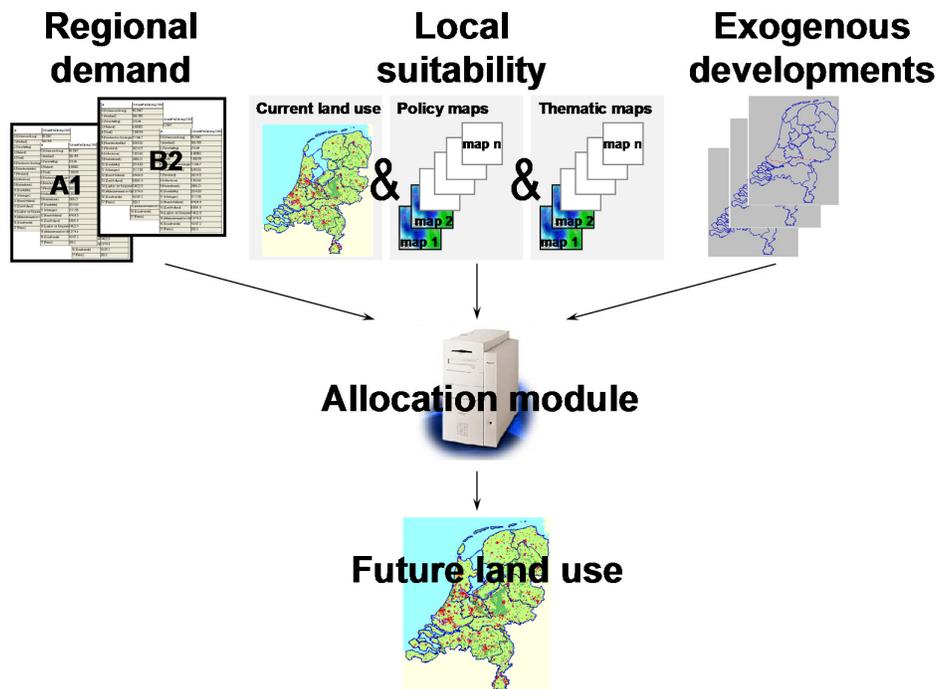

Figure 2 - Basic layout Land Use Scanner model.

Exercise – Getting to know *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!**

Note Each time you are required to perform an action during this exercise, the symbol (A) is 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

(A) Start the *Land Use Scanner* model. The model should now display a 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); and
- 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

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

(A) 1. Start by clicking on the + in front of the container (directory) called "Current_situation" and again on the + in front of the subsequent "Current_landuse" and "LU_2010" containers. This container includes nine data-layers that describe the land use in the year 2010. The small globes [🌏] indicate that a map of the data-layers can now be drawn in the data-view area.

(A) 2. View several land-use maps by trying out all two 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 or by giving a right mouse-click on the data layer and selecting the Map View-option from the appearing menu. This option will open a *new* map view window for every data layer;

Note that when you view a current land use layer, a legend appears on the right hand side which indicates the amount of hectares (ha) and that values range from 0 to 25, the maximum value for the 500x500-meter grid cells. A last column in this legend contains the count (i.e. number of cells) for each class.

(A) Right mouse-click on the legend area. This allows you to select the statistics function in the appearing menu, providing you with some basic statistics on the selected land-use function.

3. The tool-bar now contains several standard GIS-functions like:
   🔍 zoom in, 🔍 zoom out, ✋ pan, ℹ get info,
   🖐 full extent, 📋 copy visible area to clipboard, 📏 toggle scalebar

(A) Explore these functions to familiarize yourself with their possibilities.

4. 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.

(A) Close all opened map views (menu option Window > Close All) and then click on the data layer "Predominant_2010". This layer describes predominant land use per cell (Figure 3). 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.
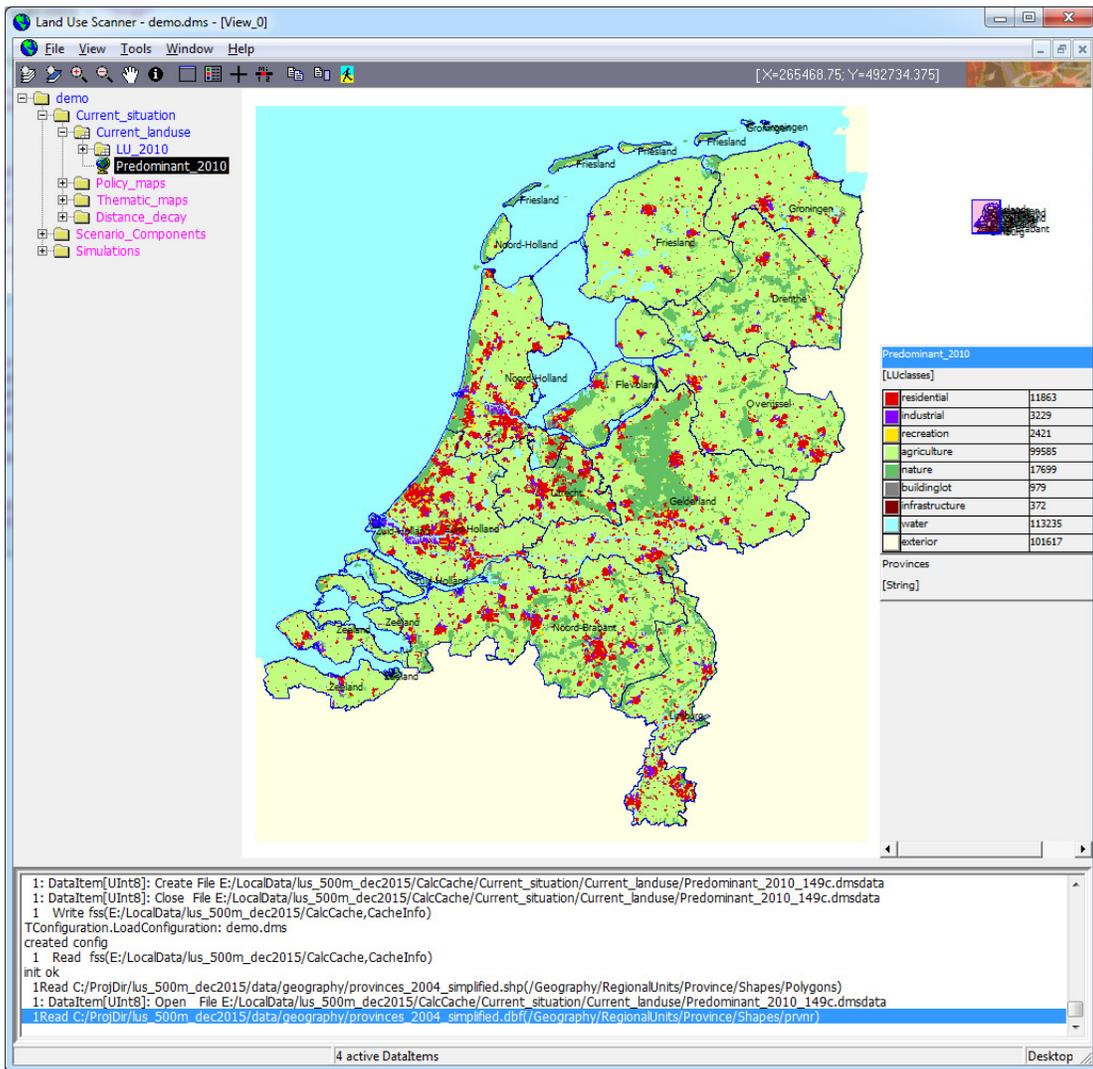
Figure 3 - Dominant land use in the Netherlands for the year 2010 as shown in the Land Use Scanner demo user interface.

5. *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, thematic maps and distance decay maps. See the description of all available data layers in appendix 3 for information about what the available data sets represent.

Defining suitability

We will now explore the way suitability is included in the model.

1. Start by opening the A1_GE scenario in the Scenario_Components > Local_Suitability 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 Crtl+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 (Figure 4). By default, reference to the Crimson Editor (downloadable from www.crimsoneditor.com) is included in the GeoDMS. The appropriate line number and file name are provided by the GeoDMS to the editor by means of the parameters (/L:%L "%F"). Make sure that the correct pathname (and name of .exe file) is used to refer to the location where the editor is installed. You can also

refer to another text editor. The following line may help you to refer to a standard windows text editor: c:\windows\system32\notepad.exe "%F" . But this reference may be different on your specific computer.
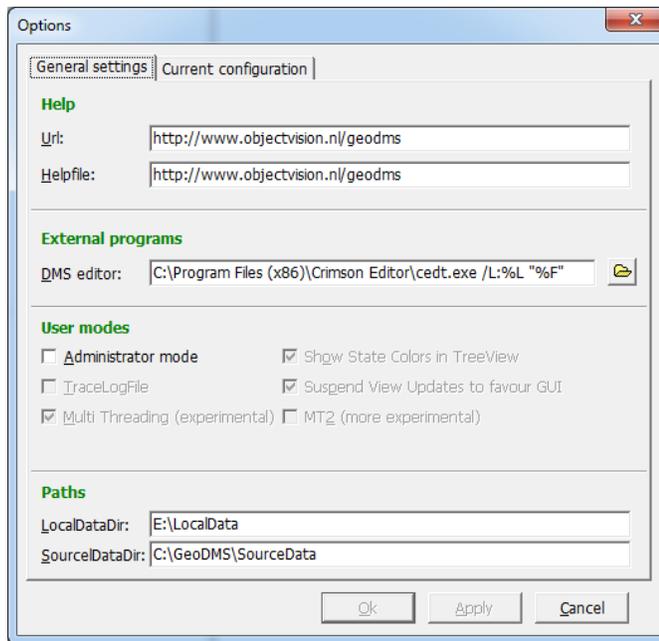

Figure 4 - Options Menu.

2. All suitability maps of a scenario are defined in a single compact text file that holds the scenario-name. 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 (Figure 5).

Figure 5 - Part of the A1.dms suitability script.

A function's suitability is clearly distinguished in values related to:
a) **current land use**;
b) **policy maps;**
c) **thematic maps, and**
d) **distance decay maps**.

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. Since *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 Euro per m^2, as the legend of the suitability maps also indicates.

Scroll down to the part of the A1.dms script that relates to the function Residential land use, which is indicated by the green heading with the word RESIDENTIAL in capitals. Change the values for residential spatial plans and attractiveness surroundings (indicating the public appreciation of the surrounding landscape) from 0 to 5. Make sure you save the changes you made.

Reopen *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! Saving will create a complete copy of the configuration including all data sources and thus lead to unwanted consumption of disk space.

Note Reopening *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 > Exogenous_Landuse > A1_GE contains the expected exogenous developments, i.e. the expected future land use for the functions that are not simulated. Most of these functions are not expected to change at all. 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 Scenario_Components > Regional_Demand > A1_GE > Additional_Claims lists for each land-use type the area that is expected to added be between 2010 and 2040 based on the scenario assumptions.

Rightclick on the map residential and select Table View (shortcut: press Ctrl-D). A table will be displayed in the DataView listing the land-use claims for 3 regions. Close (exit) the table in DataView and then doubleclick on the item in the TreeView to view the map of the claims. It is not necessary for all land-use claims to balance out (add up to exactly 0). The model is able to cope with over-demand or over-supply of land.

Simulating future land use

1. In the TreeView, click on Simulations > A1_GE > results > continuous (i.e. the continuous allocation algorithm). 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 2040 (subdivided in two subcontainers: Endogenous and Exogenous land use) and a map with the predominant land use per cell only. You can, for example, compare the maps of predominant land use in 2040 with the map of predominant land use in 2010.

2. The container evaluation contains a set of evaluation measures for different spatial scale levels, which are described below:
   - *Total*: Four table-containers describing national totals in current land use, total demand, allocated land use and the fraction of demand that was realised.
   - *Regional*: 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 in the Toolbar ![icon] 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 2010 and in 2040, calculate percentages et cetera.
   - *Local*: The container DifferenceMaps_ggEndogenous contains difference maps of the 6 endogenous land-use types. The maps indicate the local (i.e. per grid cell) difference between land use of a certain type in 2040 and 2010.
   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:
     - *urban development,* 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), BirdHabitat areas 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.
   - *Floodrisk*: This set of indicators describes the potential damage that arises from flooding. These calculations build upon land-use specific damage functions that link land use and expected water depth to potential damage in Euros per hectare. Damage is calculated for individual grid cells based on predominant land use and aggregated to flood risk management zones (dike rings). By comparing current and simulated land use based damage per region an indication is obtained of the potential increase in damage due to land-use change. This change ratio is applied to expert-based damage assessments for the current situation to obtain a more accurate estimate of potential future damage. Similar calculations are applied in many research projects and policy evaluation studies (e.g. de Moel et al, 2011). A more detailed description of the calculation process is provided elsewhere (Bubeck and Koomen, 2008).

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 2040 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 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 *Land Use Scanner* that already contains a basic reference to four socio-economic scenarios (see Appendix 2 for a description). 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.

The final result of the is assignment is a group presentation in which you will discuss the land-use simulation results you created. The presentation will be evaluated based on the criteria listed in the table below.

Table 1 - Evaluation criteria for the presentation you will deliver to finalise the assignment

Criteria	Weight	Explanation
1 – Content	40	Content of your presentation; do you present the right maps, do you show understanding of specific model components, the simulation process and the way results should be interpreted?
2 – Originality	10	Do you come up with original results in your analysis, include original evaluation measures/indicators, or apply an innovative viewpoint from which you have developed your scenario
3 – Presentation	10	General presentation skills: eye contact with your audience, using your voice properly, et cetera
4 – Reflection	40	Do you include critical reflection on the modelling approach, model aspects and the assignment in general in your presentation? Does your reflection make sense?
	100	

Assignment 1. Simulate land use according to a scenario

To generate maps related to Dutch land use in 2040 in a specific scenario, 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 Table 2 on page 13. A more detailed description of each data layer is included in Appendix 3. In this table, indicate individually which themes are relevant for your specific scenario *in general* (for all land-use types) based on the scenario descriptions included in Appendix 2. Then select what spatial data sets can be used to represent a theme and specify the relevance of each dataset *for each individual land-use type* on a scale from 1 (minor importance) to 5 (extremely important). Non-relevant datasets should keep the value 0.

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.
Keep in mind that the total suitability value of a land-use type reflects the net benefits of a certain location for that specific land-use type. This should provide a rationale (as well as limits) for your range of suitability values. Keep the range between -20 and +40.
Finally, save the script and re-start *Land Use Scanner*.

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_GE). 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 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 maps by right-clicking a layer to, for example, ArcGIS, to create more elaborate impact assessments and/or more refined maps.

8) Prepare a Powerpoint-presentation of 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 et cetera);
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 2040 according to one of these objectives you will start to work with the land demand following the A1_GE-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 Table 2 on page 13. A more detailed description of each data layer is included in Appendix 3. Define for yourself what you consider to be important *spatially explicit* policy measures to improve land-use patterns according to the general objective of your choice. Then select what spatial data sets can be used to put your specific policy objective interpretation into practice. In Table 2, specify the relevance of each dataset *for each individual land-use type* on a scale from 1 (minor importance) to 5 (extremely important). 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. Non-relevant datasets should keep the value 0.
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 (i.e. A1.dms) in the text editor. As a start you can use the values that you agreed upon in the previous step. Keep the range of your total suitability value between -20 and +40.
    Finally, save the script and re-start *Land Use Scanner*.
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_GE). 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 csv-files in ..\ProjDir\LUS_500m_dec2015\data\Scenarioclaims\. For each land-use type the amount of additional land that will be added to 2010 land use per region and per scenario is specified here.
    Note You may ignore the Current-scenario. You can type the changed demand directly in the file in a text editor, or open the csv-file in Excel and make your changes there.
    Note 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. 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 maps to, for example, ArcGIS, to create more elaborate impact assessments and/or more refined maps.
10. Prepare a Powerpoint-presentation of 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.

Table 2 - List of suitability factors

Main group / Theme	**Data layer**	**Values in scenario script**				
		Residential	**Industrial**	**Recreation**	**Nature**	**Agricult.**
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	UrbanAttractiveness					
	AttractiveSurroundings					
Accessibility	Dist_mainports					
	Dist_TrainStation					
	Dist_HighwayEntry					
	Dist_100000inh					
	Dist_100000jobs					
Noise	Perc_opp_gt_50dba					
NatureLandscape	Landscape_quality4K					
	Landscape_experience					
	Altitude					
Safety	Flood water depth					
	Earthquakes					
	Dangerous sites					
	Dangerous transport					
Distance_decay						
LandUse2000	Amount of specific land-use types in range of 1, 5, 25 or 50 km					
PolicyMaps	Amount of BirdHabitat area within 1km					
	Amount of net_EHS03 area within 1km					

Note Building lots supply ready-to-build land to urban types of use. Since it only supplies land and no new building lots are created in simulation, the total area of this land-use type will decrease to around 0 hectares in most scenarios. In scenarios with limited demand for new developments building lots may remain vacant at their current locations. Therefore, you do not need to fill in suitability values for building lots.

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Please note that most of the listed references and additional information are available from spinlab.vu.nl

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Appendix 1 *Land Use Scanner* Background

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. Normally β is set at 1.

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; and
- 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:

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

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

$L_{jr} \leq \sum_{c} X_{cj} \leq H_{jr}$ for each j and r 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 refers to four scenarios for future spatial developments, taken from the 'Welfare, prosperity and quality of the living environment' (WLO) scenario study (CPB et al., 2006). 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:

Orientation on material values

Global Economy (A1)

- Strong population growth and gradual income convergence as side-effect of high income growth
- Free trade
- Strong technological developments
- Limited role of the government
- Strong decrease in agricultural land use
- Consumption pattern: luxurious

Strong Europe (B1)

- Strong population growth and gradual income convergence as a consequence of international policy
- Technological developments aimed at knowledge transfer and durability
- Compact cities
- Consumption pattern: quality

- In some regions high population growth caused by traditional values and low incomes/unequal income division
- Protectionism; limited trade and transfer of technological knowledge restrain economic growth
- Consumption pattern: comfort

- Medium economic growth aimed at regional durability, population decreases
- Technology aimed at efficiently using regional sources, limited transfer of technological knowledge
- Social and institutional structures are aimed at the regional quality of life
- Consumption pattern: quality of life

Transatlantic Market (A2)

Regional Communities (B2)

Orientation on immaterial values

Cultural and economic globalisation

Limited or declining cultural and economic globalisation

Main characteristics of the four scenarios for the Netherlands

Global Economy combines globalisation with individualism, whereas Regional Communities 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 Economy** 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 **'Transatlantic 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 **'Strong Europe'** 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 Communities** scenario assumes an emphasis on the own identity and self-sufficiency within a region. Global developments are not the general concern an 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; and
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 (GE)	A2 (TM)	B1 (SE)	B2 (RC)	Current land use (2010)
Residential	362963	318748	321098	278558	273110
Industrial	116087	96556	93161	73778	87470
Recreation	142504	115438	124934	106245	98829
Agriculture	2026500	2134310	2081980	2136390	2264360
Nature	599113	582113	624112	607113	486551
Building lot	39	39	1919	40977	36882
Infrastructure	121461	121461	121461	121461	121461
Water	785629	785629	785629	785629	785629
Exterior	-	-	-	-	-
Total demand	**4154296**	**4154294**	**4154294**	**4150151**	**4154292**

Expected land use (hectares) in 2040 following the four scenarios, compared to the current situation (2010), source: WLO (2006), adapted by SPINlab - Vrije Universiteit Amsterdam

	Global Economy A1_GE	Transatlantic Market A2_TM	Strong Europe B1_SE	Regional Communities B2_RC
Socio-economic conditions				
Economic growth	Highest	High	Medium	Low
Population (2040)	20 million	17 million	19 million	16 million
Societal focus	Individual freedom	Individual freedom	Global cooperation	Regional cooperation
Recreation	Not much spare time, emphasis on active leisure, accessibility and proximity to residential areas are important	More spare time 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				
Economic orientation	Free market prevails, globalisation	Free market prevails, protectionism	Government intervenes, strong international institutions	Government intervenes, strong local and regional institutions
Spatial policy	Less restrictive policies	Less restrictive policies	Restrictive policies for rural areas	Restrictive policies for rural areas
Agricultural policy	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
Nature protection & development	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)
Agriculture and nature conservation	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
Water management	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				
Urbanisation	Urban sprawl in rural areas. Accessibility by road to and from urban areas is important. Attractive surroundings are 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. Attractiveness of the surroundings 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
Commercial functions	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 - *Land Use Scanner* Student Edition

Spatial data *Land Use Scanner* – demo			
Main group / Theme	**Data layer**	**Spatial data description**	**Units**
Current_landuse			
LU_2010 (current land use in nine classes)	residential	Residences and related activities, including: - primary facilities: shops, schools - small offices of a.o. banks - public parks < 1 hectare, streets and parking lots - small playing fields, children's farms, gardens - cemeteries	[0 to 25 Ha]
	industrial	Commercial and industrial land use, including: - 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	Recreational areas, including: - parks, public gardens and playing (sports) fields - allotment gardens - day trip locations (amusement parks, zoos etc.) - short and long stay facilities (campsites, caravan parks, holiday parks etc.)	[0 to 25 Ha]
	agriculture	Agricultural land use, including: - arable farmland and horticulture (a.o. potatoes, beets, cereals, flower bulbs and greenhouses) - grassland, (zero-)grazing livestock and orchards	[0 to 25 Ha]
	nature	Nature and forest areas, including: - broad-leaved and coniferous forest - salt grassland, beach, dunes, heath land - peat, moors, swamp, bare soil	[0 to 25 Ha]
	building lot	Grounds prepared for new buildings or other developments	[0 to 25 Ha]
	infrastructure	Railway, roads, airports and semi-paved terrain	[0 to 25 Ha]
	water	Fresh and salt water, including: - water storage basins, lakes, rivers, sea - recreational water - reservoirs and water for extractive industries	[0 to 25 Ha]
	exterior	Land use outside the Netherlands that is not simulated in *Land Use Scanner*	-
Predominant_2010		Representation of predominant land use per grid cell in any of nine classes described above	[0 .. 8 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	Land protected under European directive for the natural habitats of birds and endangered species	[Present: 1 or 0]
	net_EHS03	National Ecological Network; protected network of Natural areas that in part has yet to be acquired	[Present: 1 or 0]
Water	intake_reservoir	Areas designated for water storage in case of prolonged local rainfall	[Present: 1 or 0]
	disaster_retention	Areas designated to store river water in case of anticipated floods to protect areas downstream	[Present: 1 or 0]
	space_for_rivers	Areas reserved by National Government for widening of river flood plains	[Present: 1 or 0]
	groundwater_protection	Ground water protection zone designated by regional authorities (fraction of cell within policy zone)	[Ratio: 0 to 1]
	groundwater_intrusion	Ground water intrusion areas that currently are not fully protected (fraction of cell belonging to this area)	[Ratio: 0 to 1]

Thematic_maps

Residential_locat.	urban_attractiveness	Index expressing relative richness in: cultural facilities; hotels & catering outlets; and shops	[%]
	attractive_surroundings	Indicator of landscape attractiveness as perceived by general public	[%]
Accessibility	dist_mainports	Average Euclidean distance to mainports Schiphol airport and Rotterdam Harbour	[km]
	dist_trainstation	Euclidean distance to nearest railway station (passenger stations in use in 2010)	[km]
	dist_highwayentry	Euclidean distance to nearest highway entry (National Road Database, 2012)	[km]
	dist_100000inh	Euclidean distance to nearest 100,000 inhabitants, aggregated to 4-digit zip code level (2009)	[km]
	dist_100000jobs	Euclidean distance to nearest 100,000 jobs, aggregated to 4-digit zip code level (2009). Source for employment figures: ABR Regiobase (Statistics Netherlands, 2009)	[km]
Noise	perc_opp_gt_50dba	Fraction per cell with a noise level exceeding 50 dB(A)	[%]
NatureLandscape	landscape_quality4K	Landscape values as perceived by experts in 4 classes [low, medium, high, very high]	[0 .. 3 classes]
	landscape_experience	Attractiveness of landscape as perceived by general public [strongly negative, .. highly positive]	[-4 .. 5 classes]
	altitude	Elevation at ground level	[m]
Safety	floodWaterDepth	Average water depth resulting from the worst possible flood (www.risicokaart.nl)	[m]
	earthquakes	Location prone to earth quakes with different intensities (6.0, 6.5 or 7.0) on the Mercalli scale	[0 .. 3 classes]
	dangerous_sites	Fraction of cell area 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]
	dangerous_transport	Fraction of cell area within the immediate vicinity (100m) of a pipeline transporting dangerous goods	[Ratio: 0 to 1]

Distance_Decay

LandUse2010	Land-use types in range of 1, 5, 25 and 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	Fraction of the area within a 1-km range that is designated as part of the BirdHabitat directive area (calculated by applying a square root distance decay function)	[Ratio: 0 to 1]
	net_EHS03 area within 1km	Fraction of the area within a 1-km range that is designated as part of the National Ecological Network (calculated by applying a square root distance decay function)	[Ratio: 0 to 1]