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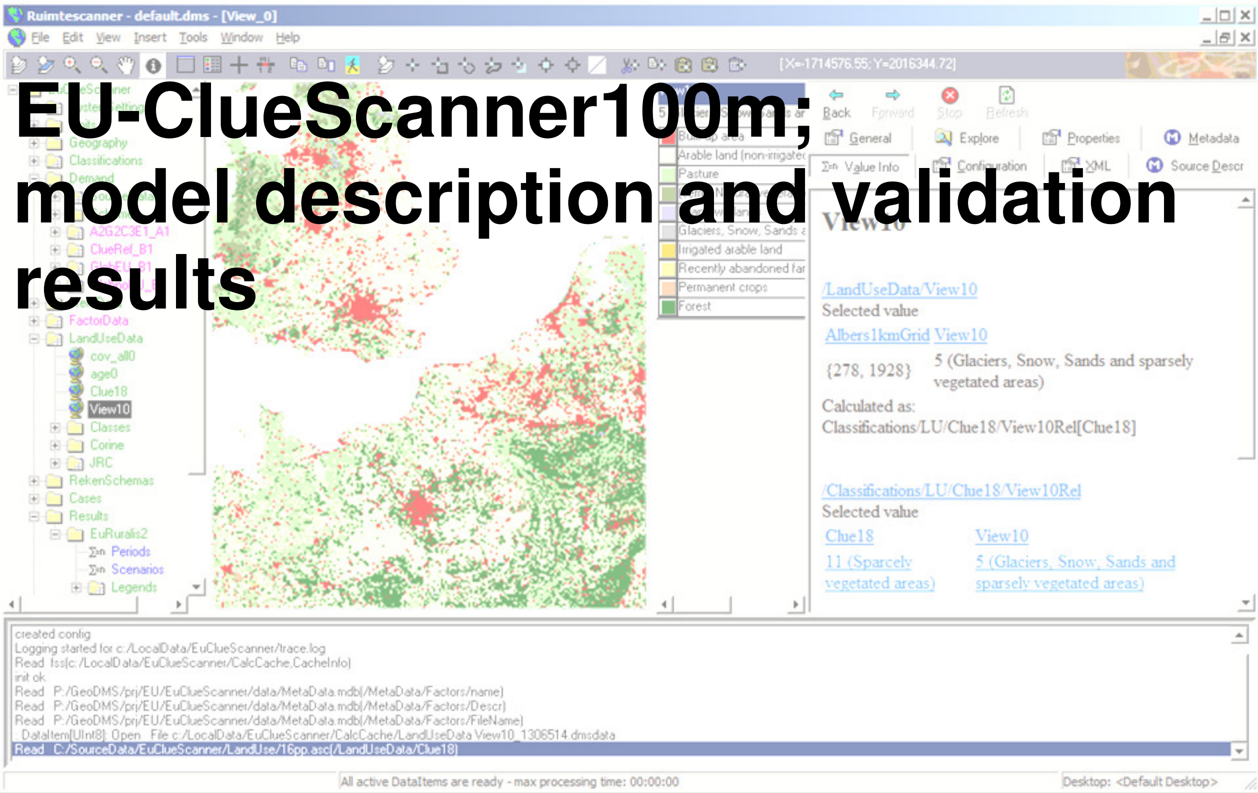
Object Vision

EU-ClueScanner100m; model description and validation results



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Object Vision

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1 Introduction

The EU-ClueScanner model is part of a multi-model framework that aims to produce policy-relevant information related to land-use change. It can support the creation of ex-ante assessments of policies that impact spatial developments. The framework is thus relevant to many different DGs of the Commission to help answer questions such as: what spatial developments are likely to occur in the coming decades? what possible impacts would a foreseen policy have on land-use patterns in Europe and how will these affect issues such as biodiversity for instance? how will specific environmental protection policies and/or climate change adaptation measures influence spatial patterns? The final report documenting the development of the EU-ClueScanner model discusses the initial applications of the model for DG Environment to answer this type of questions (Perez-Soba et al., 2010).

The purpose of this report is to help those who will operate the EU-ClueScanner get started with the model. In addition it will explain the basic functionalities of the model and specify how specific components of the model can be adjusted to define new policy alternatives. The tutorial also points at relevant documents for background information and more advanced manipulation of the model.

This first chapter provides an initial introduction to the model in general and the applications for DG Environment and Joint Research Centre (JRC) in particular. It helps users getting started with the model and describes the most important model components. Chapter 2 describes how existing policy alternatives can be viewed and explains the main elements of the graphical user interface (GUI). It discusses how various types of data can be viewed, how the calculation process can be traced and how land-use results and indicator values can be retrieved. Chapter 3 helps the user to define new policy alternatives. First through describing relative simple operations, such as the replacing of spatial data sets and the editing of the current demand specification, and then by highlighting more complex modelling tasks such as the manipulation of basic simulation settings. Chapter 4 briefly discusses how possible improvements can be made to the EU-ClueScanner model. Chapter 5 describes the validation of the 100m version of the model that was performed especially for EC-JRC. The appendices at the end of this tutorial contain in-depth information on various model elements and include amongst others, an overview of the basic land-use classes and included spatial data sets.

1.1 The EU-ClueScanner in a multi-model framework

The EU-ClueScanner is a land allocation model positioned at the heart of a multi-scale, multi-model, framework. It bridges sector models and indicator models and connects Global and European scale analysis to the local level of environmental impacts, see Figure 1.

External, global models account for interactions between Europe and other world regions. The dynamics of the global economy are typically described by GTAP or derived LEITAP model, whereas global climate-land use interactions are incorporated in an integrated assessment model (IMAGE). This configuration was used in the EURURALIS project (Eickhout et al., 2007; Van Meijl et al., 2006) and the applications created for the DG Environment.

Results from the global level models relate to the demand for goods and commodities and are, in Europe, delivered at Member State level. The output of the global-level models is translated into a land demand in km^2 for the specific land-use types distinguished in the EU-ClueScanner model. This translation is performed in a newly developed demand module that is implemented in the GeoDMS model script and thus part of the EU-ClueScanner model.

Land allocation in the EU-ClueScanner model is based on the approach taken in the well-known Dyna-CLUE model (Verburg et al., 2006; Verburg and Overmars, 2009). Especially for DG Environment this approach has now been programmed in the GeoDMS environment using the numerical algorithm of the Land Use Scanner model to optimize its performance for use on desktop computers. The Land Use Scanner is another well-established land use model with many applications within Europe (Dekkers and Koomen, 2007; Koomen et al., 2008). Combining the strengths of both models ensures a consistent, state-of-the-art and flexible modelling core.

In addition, a series of indicator models corresponding to the demands of the policy alternatives are implemented. Indicator models use information derived from economic models (e.g. LEITAP) and the land allocation models to arrive at a balanced set of indicators focussing on the land-use and environmental domains. To assess specific issues (such as, for example, flood risk) additional detailed spatial data sets are used in the implemented indicators. Another interesting option for many ex-ante assessments is the possibility to link the pan-European analysis at 1 km^2 resolution to more detailed models for specific case studies that either focus on specific regions or on specific policy domains.

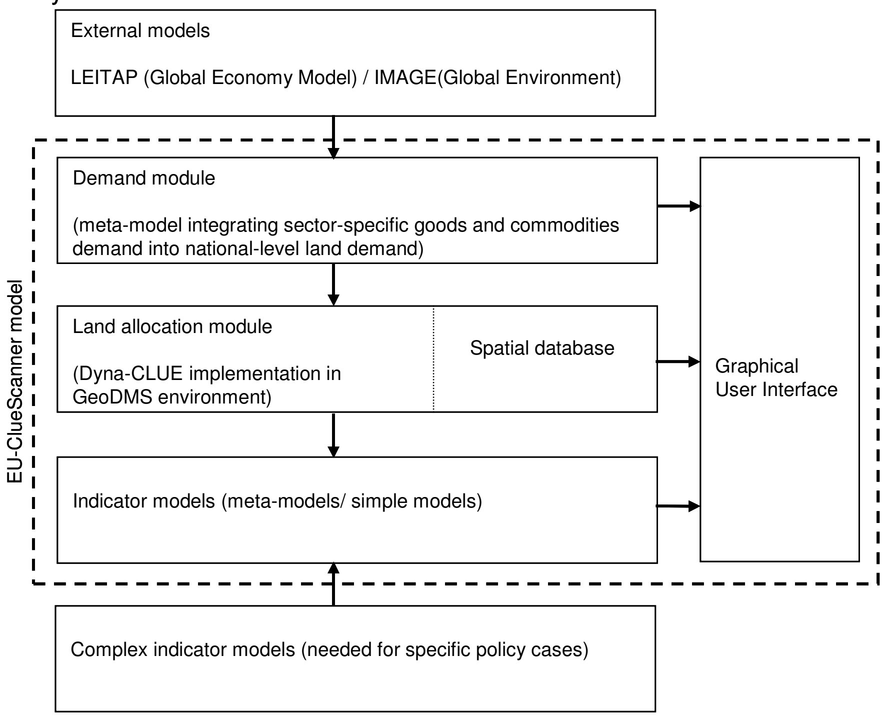


Figure 1 The EU-ClueScanner as the the core of a multi model framework.

1.2 Main model components

The EU-ClueScanner model has the following main components:

- a *demand module* that specifies the amount of land that has to be allocated per land-use type, normally following scenario conditions;
- *location specific characteristics* (locspecs) that influence the suitability of a location for a land-use type, typically reflecting scenario-specific restrictions or stimulating policies that are added to the statistically derived suitability definition;
- *conversion settings* that specify which land-use conversions are allowed and, optionally,

where these conversions may take place;
- weights for *suitability factors* (SF) and *Neighbourhood enrichment* (NE) that together comprise the statistically derived suitability map for each land-use type;
- a *dynamic transition potential* that specifies the conversion elasticity (ease of conversion) for each land-use type; and
- an *output generator* specifying how the above-mentioned components are combined into a simulation run.

The relation between these model components is depicted graphically in the figure below, whereas Appendix 4 describes their characteristics in more detail. The main components of the model are also present in the Dyna-CLUE model and have been introduced in previous publications (e.g. Verburg et al., 2006; Verburg and Overmars, 2009). Based on the settings specified for these components and the current land use, the model simulates land-use changes for each year in the simulation period (e.g. 30 years). Based on projected land-use patterns a number of indicators can be calculated related to land use and specific themes (e.g. soil sealing). The next chapters will describe how these model components can be viewed and edited to inspect existing scenarios and create new ones.

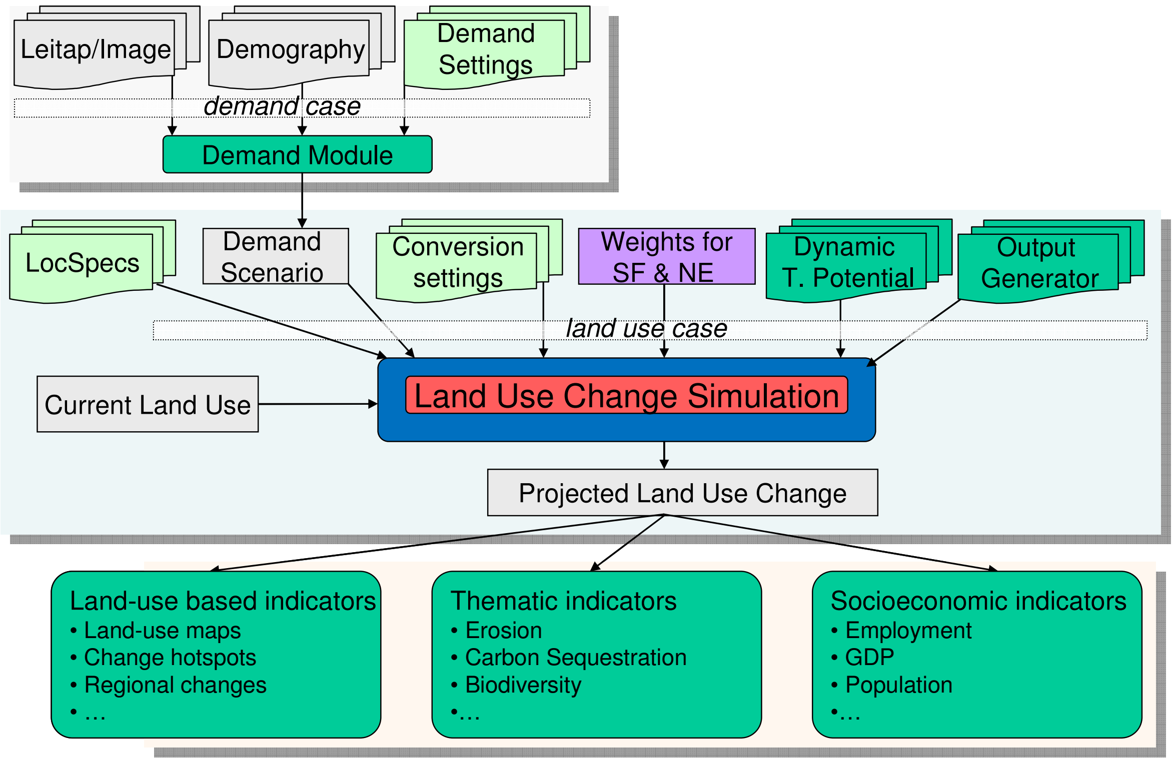


Figure 2 Main model components.

The main model components are an integral part of the EU-ClueScanner model. Their policy alternative specific settings can be edited in various in Microsoft Access databases or small parameter files as is described in Chapter 3. For convenience sake the location of these editable settings files is provided in the table below.

Table 1 Location of main model components in the EU-ClueScanner 100m version. Appendix 4 describes most of the files mentioned below in more detail.

Component	Editable settings files and their storage location[1]
Demand module	Demand.mdb in projects\EuClueScanner\data\demand normally specifies how the demand should be calculated per land per year; the results of these calculations are stored in demand.in1 files in the \projects\EuClueScanner\Demand\ *PolicyAlternativeName* (e.g. Validation2000MNL)*CountryName* folder
Locspecs	LocspecX.asc (when present) in \projects\EuClueScanner\Paramsets\ *PolicyAlternativeName.* Note that these are currently not used in the100m version.
Conversion settings	Main.1 in \projects\EuClueScanner\Paramsets*PolicyAlternativeName*[2] *(e.g. ReferenceJRC)* specifies, amongst other basic model settings, a land-use type specific conversion elasticity (resistance to transition). Allow.txt in \projects\EuClueScanner\Paramsets*PolicyAlternativeName*[2] defines which transitions are allowed; this definition can be location specific by referring to spatially-explicit allow driver maps (e.g. X1.tif) stored in \SourceData\ EuClueScanner\Drivers
Weights for suitability factors (SF) and neighbourhood enrichment (NE)	Alloc1.reg and alloc2.reg in \projects\EuClueScanner\Paramsets\ *PolicyAlternativeName**CountryName* specify the results of the statistical calibration of the model. The relative weight of each of these components in defining local suitability is specified in the neighmat.txt file in \projects\EuClueScanner\Paramsets*PolicyAlternativeName*
Dynamic transition potential	Main.1 in \projects\EuClueScanner\Paramsets*PolicyAlternativeName*[2], this file may refer to spatially explicit dynamic driver maps (e.g. sc1gr33.1) that describe changing conditions over time. These maps are stored in \SourceData\EuClueScanner\DynamicDrivers
Output generator	Part of a crucial land-use allocation GeoDMS script (\Projects\EuClueScanner\cfg\ Default\JrcClueWrap.dms) that determines which intermediate results of the simulation should be processed and how this should be done..

Notes:
[1]Please note the JRC-model model version still contains reference to elements of the 1km version. So for specific elements of that model version (e.g. the location of model components) it may be wise to also consult the tutorial related to the 1km application developed for DG Environment.
[2]The main.1 and other parameters files are normally stored in the policy-alternative folder, but when country-specific conditions apply they can also be placed in country-specific folders. The model will first look in these folder and the country-specific settings will then apply.

1.3 DG environment application with 1km resolution

The EU-ClueScanner model is a very flexible environment that allows the construction of many different applications. These applications can differ on the initial land use that is used as starting point for simulation, the land-use types that are simulated, the demand that is specified for each type of land use, the location characteristics that are included and other model-specific setting relating to, for example, the possible conversions of specific land-use types. This section lists the most important characteristics of the EU-ClueScanner application developed for DG Environment. It specifies the included land-use typology and included policy alternatives.

Thematic resolution

The Corine Land Cover database for the year 2000 (CLC2000) was selected as base data for the DG Environment application as it is the most recent, consistently developed and available pan-European source of land-use related information. The CLC2000 data was aggregated to a 1km^2 spatial resolution representing 18 main land-use types for inclusion in the land-use model. Table 2 describes the thematic integration of the initial land-cover classes in CLC2000 to this set of 18 main classes. The table, furthermore, lists for which land-use types future patterns are simulated. For the remaining land-use types the location is kept stable.

Although the CLC data technically refer to land cover we use the more common term 'land use' in this report as it better corresponds to phenomena such as abandoned farmland that are simulated by the model. The latter type of land use, for example, allows for the simulation of forest regeneration and is not based on the CLC data. It arises from simulation when agricultural demand is insufficient to maintain agricultural use. Based on the conversion settings specific locations may develop into semi-natural vegetation (3) or forest (10).

Table 2 Thematic resolution of the model and their relation with the Corine Land Cover types.

Nr.[1]	CLC (main) class[2]	Description	Simulated[3]
0	1.1/1.2/1.3/1.4	Built-up area	Yes (0)
1	2.1.1/2.4.2p(50%)/ 2.4.3p(25%)	Arable land (non-irrigated)	Yes (1)
2	2.3/ 2.4.2p(50%)/ 2.4.3p (45%)	Pasture	Yes (2)
3	3.2.1/3.2.3/ 3.2.4/2.4.3p (30%)	(semi-) Natural vegetation (including natural grasslands, scrublands, regenerating forest below 2 m, and small forest patches within agricultural landscapes)	Yes (3)
4	4.1	Inland wetlands	No (9)
5	3.3.5	Glaciers and snow	No (9)
6	2.1.2/2.1.3	Irrigated arable land	No (4)
7	New	Recently abandoned arable land (i.e. "long fallow"; includes very extensive farmland not reported in agricultural statistics, herbaceous vegetation, grasses and shrubs below 30 cm)	Yes (5)
8	2.2/2.4.1/2.4.4	Permanent crops	Yes (6)
10	3.1	Forest	Yes (7)
11	3.3.2/ 3.3.3/3.3.4	Sparsely vegetated areas	No (9)
12	3.3.1	Beaches, dunes and sands	No (9)
13	4.2.2	Salines	No (9)
14	4.1/4.2.1/4.2.3/ 5.1/5.2	Water and coastal flats	No (9)
15	3.2.2	Heather and moorlands	No (9)
16	New	Recently abandoned pasture land (includes very extensive pasture land not reported in agricultural statistics, grasses and shrubs below 30cm)	Yes (8)

Notes:
[1]This column shows the individual land-use types distinguished in the DG Environment application. Please note that the model can contain up to 18 classes depending on its application, but in this case 16 land-use types are distinguished (the numbers 9 and 17 are not present in this model version).
[2]For reference purposes the corresponding (main) land-cover classes from the CLC2000 dataset are shown. See Appendix 1 for a complete overview of these land cover classes.
The 'p' after certain CLC-classes denotes that only part of it is assigned to the DG Environment class. This partial assignment has been done randomly according to the mentioned probabilities. So each cell with CLC type 2.4.2 (representing complex cultivation patterns) has a probability of 50% to be classified as arable land and a probability of 50% to be classified as pasture. A random selection was chosen as that corresponds well with actual land-use patterns that can be observed from aerial photographs.
[3]The numbers between brackets refer to the coding generally used within the model (referred to as Clue10).

Policy alternatives

European policies can be relevant for land use change in two ways. First, there is a group of policies that influences the *demand for land*, e.g. stimulation of different types of agriculture through the Common Agricultural Policy. A second group of policies influence *land-use configurations*, for example by excluding or favouring some regions for a specific type of land use. For the development of these policy alternatives one future scenario is selected as reference: the Global Co-operation (B1) scenario. This well-known scenario originating from the IPCC-SRES framework sketches the climatic and socio-economic boundary conditions within which the policy alternatives are developed.

Within the DG Environment application seven policy alternatives are included next to a baseline (see the summary in Table 3). The first set of policy alternatives deals with different implementation options of the proposed Renewable Energy Directive (Directive 2009/28/EC) and considers potential changes in the demand of land (through biofuel production) that can be associated with this policy. In addition, several spatial policy alternatives are defined that influence land-use configuration, each focusing on a separate important policy theme relevant for the environment:

- Biodiversity alternative: strengthening the green environment (i.e. nature and landscape);
- Soil and climate change alternative: protecting soil and adapting to climate change.

The chosen policy packages fit within the proposed modelling framework and are able to illustrate key policy issues and trade-offs for the EU. The policy options selected are not necessarily likely to be implemented in reality. Their inclusion in the land-use simulations merely aims to show the potential of the modelling framework to assess the impact of such explicit policies. Thus answering *what-if?* type of questions. An extensive description of the reference scenario and policy alternatives can be found in the final report of that project (Perez-Soba et al., 2010).

Table 3 Overview of the included land-use simulations following the reference scenario and supplemented policy alternatives and their short names used in the model.

Nr.	Characteristic	Short name
1	Reference scenario: Global Co-operation (B1)	ReferenceB1
2	Biofuel mandate in OECD countries without EU (unrestricted land conversion of forests into agricultural land)	BFP5nonEU
3	same as 2) with EU	BFP5nonEUandEU
4	same as 3) with full protection of all existing forests	BFP5nonEUandEU_noF
5	Biodiversity alternative	BiodiversityB1
6	Biodiversity alternative with alternative 3 as reference	BiodiversityB1_high
7	Soil and climate change alternative	SoilCCB1
8	Soil and climate change alternative with alternative 3 as reference	SoilCCB1_high

1.4 JRC application with 100m resolution

Specifically for the JRC application a new set of land-use base data was constructed based on the original Corine Land Cover database for the years 1990 and 2000. These data originate from the European Environment Agency (EEA) and were provided by EC-JRC as grid versions at a 100 metre resolution and contained the complete set of Corine land-cover classes (see Appendix 1). Initial attempts to use a more extensive land-use data set covering 'some of the 'white spots' enclosed in the CLC2000 territory such as Switzerland and Norway failed due to problems with projections and inconsistencies between the subsequent years. This process has been described in the interim technical report related to this project (Koomen and Hilferink, 2009). To prevent the introduction of inaccuracies it was decided to use the CLC data in the original Lambert equal area projection that is also prescribed by the INSPIRE guidelines. To allow the use of this projection the EU-ClueScanner model was extended with a specification of this projection and the definition of a lookup matrix that relates the cells of the 100m grid on Lambert coordinates to the cells of the 1km grid on Albers coordinates. This matrix is used to reproject 1km factor data for use in the model application at a 100m grid (see Appendix 3 for more details on this issue).

In addition to 100m resolution land-use data, the JRC application also contains thematic datasets at this fine resolution to enhance the calibration of the model and allow the calculation of specific indicators. These data relate to elevation, slope, Natura-2000 areas and water depths for the 100-year return period floods under current climate conditions. Appendix 2 lists the 100m resolution data sets that are used in the calibration of the JRC model version.

Thematic resolution

As thematic resolution (land-use typology) the set of land-use types indicated in the table below is selected. JRC has expressed the wish that as much urban land-use types are simulated as possible. The model will have the flexibility to introduce new or more refined land-use types should this be deemed necessary in future especially when higher resolution data (e.g. from the MOLAND database or acquired from regional institutions) are available. The land-use typology has, furthermore, been harmonized with the land-use model that will be developed for EC-DG Environment. This has led to the inclusion of several natural land-use types that allow for more specific allocation rules and the assessment of changes in biodiversity.

In addition to this typology based on Corine Land Cover (CLC) it is possible to include additional land-use types in model simulation to account for anticipated developments related to, for example, land for biofuels or recently abandoned pasture land. The latter land-use type allows the simulation forest regeneration.

It is apparent from Table 2 that the land-use typologies in the JRC and DG Environment projects are different. For clarity's sake these differences are shortly discussed below:

- The JRC-model has a finer resolution (100m versus 1km) and potentially also slightly different origin (more recent version of CLC). The coarser resolution may lead to a structural underestimate of some classes and an overestimate of others.
- The JRC application uses the Lambert equal area projection whereas the DG environment application uses the WGS-1972 Albers projection
- The random reassignment of the CLC-classes 2.4.2 and 2.4.3 will cause local differences. The initial reassignment for EURURALIS was also done randomly, but the randomness of this process and the difference in spatial resolution will obviously lead to a different spatial representation.
- The JRC application is calibrated to simulate changes in six land-use types (those JRC9 types that are indicated to be simulated in the table below), whereas the DG Environment application is calibrated to simulate seven types of land use. The JRC version distinguishes two urban classes (DG Environment: one) and two agricultural classes (DG Environment: four). It does not (yet) distinguish the additional abandoned farmland classes that are used in the DG Environment application and that are governed fully by transition rules that are applied in subsequent modelling step. These land-use types can be, however, be added by including the appropriate conversion settings.
- The JRC application contains the extensive JRC22 typology to represent specific spatial phenomena (e.g. specific types of infrastructure or water). These land-use types are not simulated, but allow for more visualisation and analysis options. They can, for example, be used to add extra thematic detail to simulation results with types of land use that are not likely to change (such as glaciers or wetlands). This type of information may be valuable for ecological impact assessments. The DG Environment application has a similar approach with a more limited set of land-use types. Figure 3 and Figure 4 provide examples of the representation of the CLC data in the DMS environment. The former shows the land-use typology of the JRC-project at a 100m resolution, the latter that of the DG Environment project at a 1 km resolution.

Table 4 Thematic resolution of the JRC model and its relation with the DG Environment model and initial Corine Land Cover types.

JRC22[1]	JRC9[1]	DG.Env[2]	CLC-class	CLC-code	Name	Simulated
0	0	0	1.1.1	1	Continuous_Urban_fabric	Yes
1	0	0	1.1.2	2	Discontinuous_Urban_fabric	Yes
2	1	0	1.2.1	3	Industrial_or_commercial_units	Yes
3	7	0	1.2.2	4	Road_and_rail_networks	No
4	7	0	1.2.3	5	Port_areas	No
5	7	0	1.2.4	6	Airports	No
6	1	0	1.3	7/8/9	Mine_dump_and_construction_sites	Yes
7	0	0	1.4	10/11	Artificial_non_agricultural_vegetated_areas	Yes
8	2	1	2.1.1/ 2.4.2p(50%)/ 2.4.3p(25%)	12/20p/21p	Arable_land (non-irrigated)	Yes
9	2	6	2.1.2/2.1.3	13/14	Arable_land (irrigated)	Yes
10	2	8	2.2/2.4.1/2.4.4	15/16/17/ 19/22	Permanent_crops	Yes
11	3	2	2.3/ 2.4.2p(50%)/ 2.4.3p (45%)	18/20p/21p	Pastures	Yes
12	4	10	3.1	23/24/25	Forests	Yes
13	5	3	3.2.1/3.2.3/ 3.2.4/2.4.3p (30%)	26/28/29/ 21p	Semi natural vegetation	Yes
14	6	15	3.2.2	27	Heather and moorlands	No
15	6	12	3.3.1	30	Beaches, dunes and sands	No
16	6	11	3.3.2/ 3.3.3/3.3.4	31/32/33	Sparsely vegetated areas	No
17	6	5	3.3.5	34	Glaciers and snow	No
18	6	4	4.1	35/36	Inland_wetlands	No
19	6	13/ 14[3]	4.2	37/38/39	Coastal_wetlands	No
20	8	14	5.1	40/41	Inland_waters	No
21	8	14	5.2	42/43/44/ 50	Marine_waters	No

Notes:
[1]The JRC columns show the individual land-use types distinguished in the model developed for JRC. JRC22 denotes the basic classification available in the land-use maps for 1990 and 2000; JRC9 the classification used for the calibration.
[2]For reference purposes the land-use types of the model developed for DG Environment are included in the third column. These correspond to the EURURALIS application.
The ‘p’ after certain Corine Land Cover classes and codes denotes that only part of this type is to the mentioned class. This partial assignment has been done randomly within the quantitative constraints mentioned here. So a random selection of 50% of the grid cells belonging to CLC-class 2.4.2 has been assigned to arable land, the other half has been assigned to pastures. A random selection was chosen as that corresponded well with the actual land-use patterns that can be observed from aerial photographs (verbal comment Peter Verburg, 2009). As this artificial reclassification is not considered to be realistic at a 100 metre resolution JRC is considering to change this approach for future applications.
[3]The DG Environment application separates Salines (13) from the other coastal wetlands (salt marshes and intertidal flats). The latter are combined with all sweet and salt water classes (14).

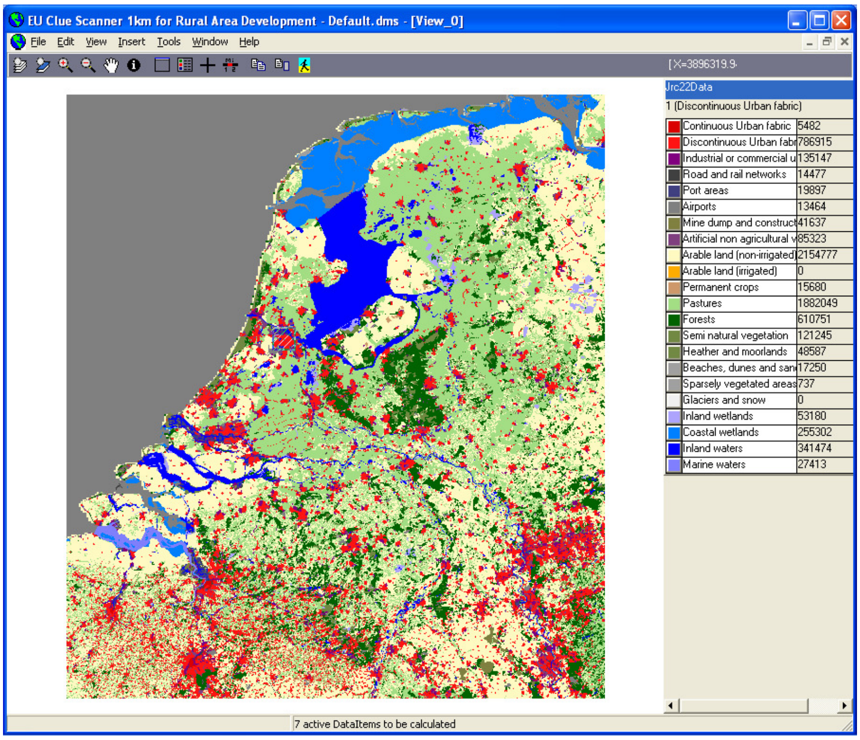


Figure 3 The 100m CLC grid data inserted in the GeoDMS environment shown as the 22 basic land-use types defined for current land use in the JRC application.

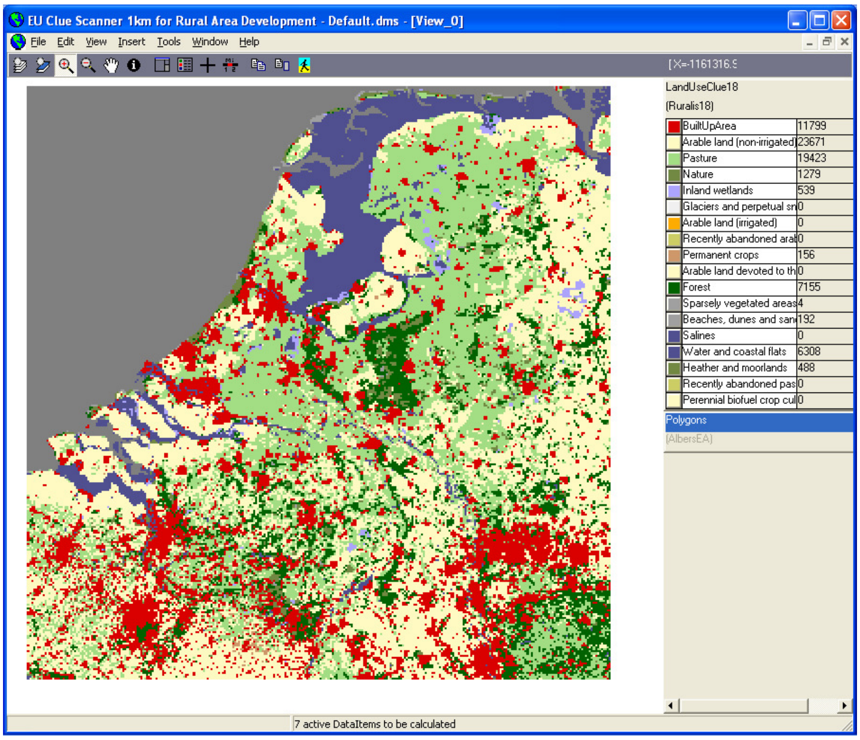


Figure 4 The 1km CLC grid data inserted in the GeoDMS environment shown as the 18 land-use types defined for the DG Environment application.

Model runs

To demonstrate the potential of the 100m version of the EU-ClueScanner several model runs are included. These do not relate to policy alternatives as is the case with the DG Environment, but reflect the results of the calibration of this new model version. The model runs make use of the new JRC9 typology and follow the results of the multinomial logistic regression that was applied to estimate the probability of occurrence of each simulated land-use type. This analysis was performed separately for each individual country, based on a set of explanatory variables representing different driving forces. The current statistical calibration used Corine Land Cover data for 1990 and thus describes the importance of various driving forces in explaining the land-use patterns of that year. We assume, however, that the observed relations also hold true for the simulation of future land use. It should, furthermore, be noted that the importance of the factor data was estimated separately from the importance of the neighbourhood-related variables. Appendix 5 lists the mains steps of the applied calibration methodology.

The results of the statistical analysis are used to describe the importance of different driving forces and are stored in files called alloc1.reg (for factor data) and alloc2.reg (for neighbourhood-related data) in the \Projects\EuClueScanner\Paramsets\ReferenceJRC directory. See Appendix 4 for a more extensive description of the layout and content of these files. All these model specification files will normally be the same for different scenarios, but they are stored in scenario specific folders to allow for the inclusion of different calibration values per scenario.

The model contains one set of validation runs and several sets of reference alternatives (see Table 5). The validation runs are intended to show how well the model is able to simulate the year 2000 based on 1990 land use and the statistical calibration. In fact, a very informative quantitative validation has been performed by comparing these simulation results with observed land use in 2000 (see Chapter 5). The reference alternatives use the same specification of local suitability as the validation runs, but apply this to the period 2000-2030 using a different base year (2000) and different demands for future land use. The available reference alternatives have the following characteristics:

- the basic Reference alternatives allow the simulation of future land use in 2030 based on an extrapolation of past (1990-2000) land-use developments. Appendix 6 describes how this demand is obtained.
- the Nuts2 alternatives are created especially for JRC to allow them to run the model at NUTS2 level. At this moment these runs do not contain a demand for land and thus use the current amounts of land in simulation. The results will therefore only show a shift in land-use patterns based on the underlying definition of local suitability. JRC will add a demand to specific NUTS2 regions in the future as part of upcoming regional studies.
- the RefernceB1OrgClue alternative uses the same land-use typology and specification of demand and suitability as the reference alternative in the DG environment application. It is included here to allow a comparison between the different resolutions, although especially the definition of neighbourhood relations is known to be unsuitable.

For all validation and reference alternatives (except ReferenceB1OrgClue) three different methods to define local suitability (called: 'Suitability traits') are included to analyse their performance:

- The split100 trait uses the original local suitability definition used in the Dyna-Clue model and DG Environment application. This option is meant to incorporate a binomial logistic regression of suitability factors and neighbourhood enrichment. In this case the associated alloc1.reg and alloc2.reg files are rescaled separately for each individual land-use type using the standard logistic expression: exp(x)/(1+exp(x)). By definition this function results in a value between 0 and 1, expressing the probability a location will be allocated to a specific type of land use. Please note that the rescaled local suitability based suitability factors (following alloc1.reg) and neighbourhood enrichment (following alloc2.reg) is subsequently combined into one value using the relative weight of neighbourhood enrichment specified in the neighbourhood settings file (neighmat.txt).

- The mnl100 trait uses multinominal logit functions for calculating the two components of the local suitability definition and thus estimates the probability of occurrence of one land-use type at a certain location in relation to the total probability of occurrence of all land-use types at that location. This approach has the basic expression: exp(x) / sum exp(s) and best resembles the performed multinomial logistic regression. After applying the logit function the two components (based on alloc1 and alloc2) are then combined using the using the relative weight of neighbourhood enrichment specified in the neighbourhood settings file.
- The linear100 trait first combines the local suitability definitions following the suitability factors and neighbourhood enrichment linearly (without rescaling) and then applies a multinominal logit function on the combined result. This linear specification is still subject to investigation and validation, as especially the impact of combining the logit-based rescaling with the discrete allocation is fairly novel.

Table 5 Overview of model runs available in JRC model version

Model run[1]	SuitabilityTrait[2]	ParamName[3]	DemandName[4]	PeriodSet[5]
Validation2000Clue	Split100	ReferenceJRC	Validation2000	P1990_2000
Validation2000MNL	Mnl100	ReferenceJRC	Validation2000	P1990_2000
Validation2000Linear	Linear100	ReferenceJRC	Validation2000	P1990_2000
ReferenceClue	Split100	ReferenceJRC	JrcRegion2030	P2000_2030
ReferenceMNL	Mnl100	ReferenceJRC	JrcRegion2030	P2000_2030
ReferenceLinear	Linear100	ReferenceJRC	JrcRegion2030	P2000_2030
Nuts2Clue	Split100	ReferenceJRC	To be created	P2000_2030
Nuts2MNL	Mnl100	ReferenceJRC	To be created	P2000_2030
Nuts2Linear	Linear100	ReferenceJRC	To be created	P2000_2030
ReferenceB1OrgClue	Split100	B1	ReferenceB1	P2000_2030

Notes:
[1]Name of the model run in the tree view, under runs -> EuClueScanner100m.
[2]Describes the way in which local suitability is defined from the combination of suitability factors and neighbourhood enrichment; see discussion in text below.
[3]Name of the parameter set (stored in Projects/EuClueScanner/Paramsets) that contains the main allocation settings (main.1, alloc1.reg etc). As the Nuts2 model runs currently do not have specific parameter sets, the appropriate NUTS0 parameter sets are selected from ReferenceJRC. The original parameter set related to the B1 scenario of DG Environment project is stored in SourceData/EuClueScanner/B1.
[4]The demand set that is used; these are normally stored in the Projects/EuClueScanner/Demand directory. Only the original demand files related to the DG Environment project are stored in a different directory (LocalData/EuClueScanner/Demand). Please note that no demand has yet been specified for the NUTS2 model runs.
[5]The simulation period. For the validation runs this is the 1990-2000 period. The other reference alternatives cover the 2000-2030 period.

1.5 Getting started

Before installing first please check the system requirements. The following hard- and software components are needed to successfully install and run the model. You need to have local administrator rights to be able to do the installation yourself. If you do not have these rights you should ask your system administrators to assist with the installation procedure.

Hardware requirements

1. Processor: Intel Pentium or Pentium compatible;
2. Internal RAM: 1GB (4 GB recommended) for 1km version; 4GB (24 GB recommended) for 100m version;

3. Internal hard disk with at least 20 GB (30 GB for 100m version) free for the GeoDMS Program Files and data files;
4. Screen: High resolution with supporting video card (dual-screen recommended)

Software requirements

1. Win32 Operating System: XP or Vista; Windows 7 (64 bit) recommended for 100m version;
2. To edit meta info and claim data: GUI for working with Microsoft Access database files (*.mdb, version 2003 or later);
3. To edit configuration (*.DMS) files: an ASCII text editor (the Crimson Editor 3.70 is recommended).

Downloading and installing the four components

To install the software and project data, you need to download and install 4 folders:

1. **GeoDms585 or recent update** (by default C:\Program Files\ObjectVision\GeoDms586) contains the compiled GeoDMS software. The software can be installed by running the file: http://svn.objectvision.hosting.it-rex.nl/public/geodms/trunk/distr/GeoDms586-SetupW32.exe This can be done directly from this web location, or after downloading the file to a temporary location on your PC. Info on this installation can be found at http://www.objectvision.nl/geodms/ under the menu item Software -> Installation Instructions. To check for more recent updates of the GeoDMS (that are provided frequently): http://svn.objectvision.hosting.it-rex.nl/public/geodms/trunk/distr/
2. **SourceData** (by default assumed to be located in C:\SourceData\EuClueScanner) contains external data that is read-only in the context of the EuClueScanner project. Download http://www.objectvision.nl/OutGoing/EuClueScanner/SD-EUCS-2010-07-16.rar and extract its contents in C:\SourceData or any other read-only location. Additional Sourcedata for JRC should be located in C:\SourceData\EUCS_100m (next to C:\SourceData\EuClueScanner) and can be downloaded from: http://www.objectvision.nl/OutGoing/EuClueScanner/SD-EUCS_100m-2010-05-26.rar Enable file compression to save disk space before extracting. See the Getting started section below for more information on extracting files and enabling file compression. Without file compression, the SourceData takes 10 GB. File compression reduces this size to 1.4 GB on disk.
3. **ProjectData** (choose any location, for example C:\Users\XXX\projects\EuClueScanner, further referred at by '%projdir%) contains data and model scripts that are created and changed within the context of the project. Download this from: http://www.objectvision.nl/OutGoing/EuClueScanner/PRJ-EUCS-2010-07-16.rar and extract its contents in your project base folder (in this example: in C:\Users\XXX\projects).
4. **LocalData** (by default assumed to be located in C:\LocalData\EuClueScanner) contains intermediate and final results of the calculations, including the 'CalcCache' storage location that the GeoDMS creates. Precalculated results for all configured scenarios are provided here to enable you to request Indicator values without having to (re)calculate a scenario. Also the precalculated results of the demand model runs are provided. Download http://www.objectvision.nl/OutGoing/EuClueScanner/V1/LD-EUCS-v1.rar and extract its contents in C:\LocalData or any other read-only location.

As the model is continuously being improved new versions of especially the ProjectData may be available. These will normally be provided by email, but users can look for available updates with a subversion (svn) client at http://svn.objectvision.hosting.it-rex.nl/public/EuClueScanner/trunk The software tool TortoiseSvn (http://tortoisesvn.tigris.org/) is recommended for this purpose.

Folder sizes and their advised management

The system components have been classified into these four groups on the basis of advised management policies in order to minimize the tasks of version control, exchange and synchronization.

Table 6 Main folder characteristics

Folder	**Approximate size on disc (compressed)**	**Required rights**	**Advised Management**
ProgramFiles	18 MB	Read/Execute	Secure installation procedure
SourceData		ReadOnly	Secure installation procedure. Compression on.
\EuClueScanner	1.2 GB (1km data)		
\EUCS_100m	4.5 GB (100m data)		
ProjectData	8.8 MB	ReadWriteCreate	Incremental Backup / version control
LocalData and \CalcCache	350 MB and several GB depending on model operations	ReadWriteCreate	Compression on. Remove old files during disk cleanup. Manage CalcCache like a Downloads Cache folder

Additional tips and tricks

1. In order to save disk space it is **strongly recommended** to enable file compression in the LocalData and SourceData folders before extracting the .rar files. This can be done in the Windows Explorer by right-clicking on the created (and still empty) folder, selecting ‘Properties’, clicking the ‘Advanced’ options on the ‘General’ tab and then ticking the ‘Compress contents to save disk space’ box. For additional instructions on how to enable FileCompression, see ‘Keep files Compressed’ at http://www.objectvision.nl/geodms/docs/CalcCache.htm#h6
2. You can extract .rar files with WinRar (WinRar 3.80 was used for compressing the data).
3. You can start the GeoDMS software from the Start button or execute %ProgramFiles%/ObjectVision/GeoDms<<version number>>/GeoDmsGui.exe. The first time you start this, the program doesn’t know which configuration to load and will present a File Open Dialog (also accessible from the MainMenu->File->Open Configuration File). You’ll have to select %projdir%/cfg/default.dms to open the default model configuration. When you close a modelling session you normally should **not save** any changes into the current default.dms unless you are absolutely sure you have added valuable new elements to the model. Otherwise you create barely changed copies of the original model and loose disk space.
4. If you choose to extract the SourceData or the LocalData in a different folder than C:\SourceData resp. C:\LocalData, you have to tell the GeoDMS where to look in the general settings. These and other more complex settings are managed from the ‘Tools’ option in the main EU-ClueScanner menu by selecting ‘Options’ and then the ‘General Settings’ tab (see below). Here you can provide the chosen location in the Paths section. Close and restart the GeoDmsGui.exe to make the changed values effective.
   These settings are stored in a config ini file, which is part of the project configuration.
5. General information on how to use the GeoDMS user interface can be found at http://www.objectvision.nl/geodms/ under the menu item User Guide -> GeoDMS GUI. For details on the Declarative Model Script (the .dms files) look at the menu item Modelling.

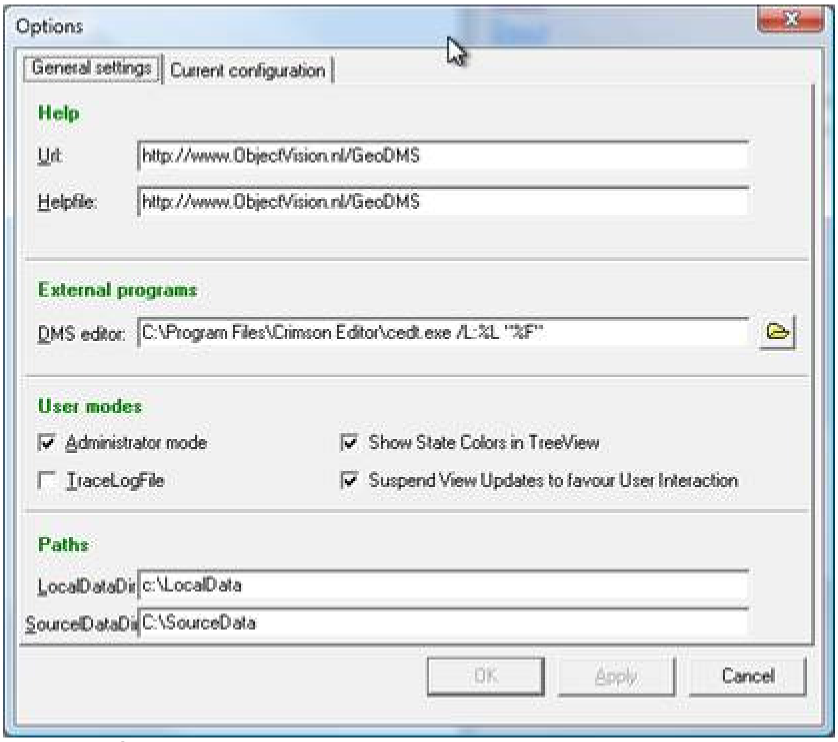


Figure 5 General settings tab in the Main menu.

Advanced options

The GeoDms executes a configurable external editor when you double-click on messages that refer to model scripts or press Ctrl-E. By default, the Crimson Editor is configured. The appropriate line number and file name are provided to the editor by means of the parameters added to the reference to the editor in general setting tab in the Main menu (/L:%L "%F"). The Crimson Editor is downloadable from http://www.crimsoneditor.com/; please check whether the pathname included in the 'General Settings' tab corresponds to the location where the editor is installed). You can download and install. DMS syntax highlight files for this editor from: https://geodms.svn.sourceforge.net/svnroot/geodms/dev/res/Crimson Editor with subversion, or from http://geodms.svn.sourceforge.net/viewvc/geodms/dev/res/Crimson%20Editor/ You can also configure your own favourite editor as an external program under the 'General Settings' tab.

2 Viewing existing policy alternatives

This chapter helps the modeller to get familiar with the main components of the EU-ClueScanner model. First the main elements of the Graphical User Interface (GUI) are explained. Subsequently the main components of the model are described. These relate to the available spatial data (land-use and factor data) and policy alternatives (claim data, runs, results, tracing calculation process and indicators). Note that this chapter is partially based on an adaptation of the first two chapters of the GeoDMS GUI user guide (van der Beek, 2009), which can be found at http://www.objectvision.nl/GeoDMS/ under User Guide -> GeoDMS GUI. More in-depth information on the concepts and the syntax of the GeoDMS configuration language is available at the same website under Modelling- > Modeller's guide.

2.1 Tree view and main GUI elements

The graphical user interface (GUI) provides the modeller with a range of windows to view data layers, look-up background information, inspect simulation results and follow the simulation process. Figure 6 presents an overview of the many different windows in a typical application. Which windows are shown in a session depends on the options that are selected (ticked) in the main menu under View.

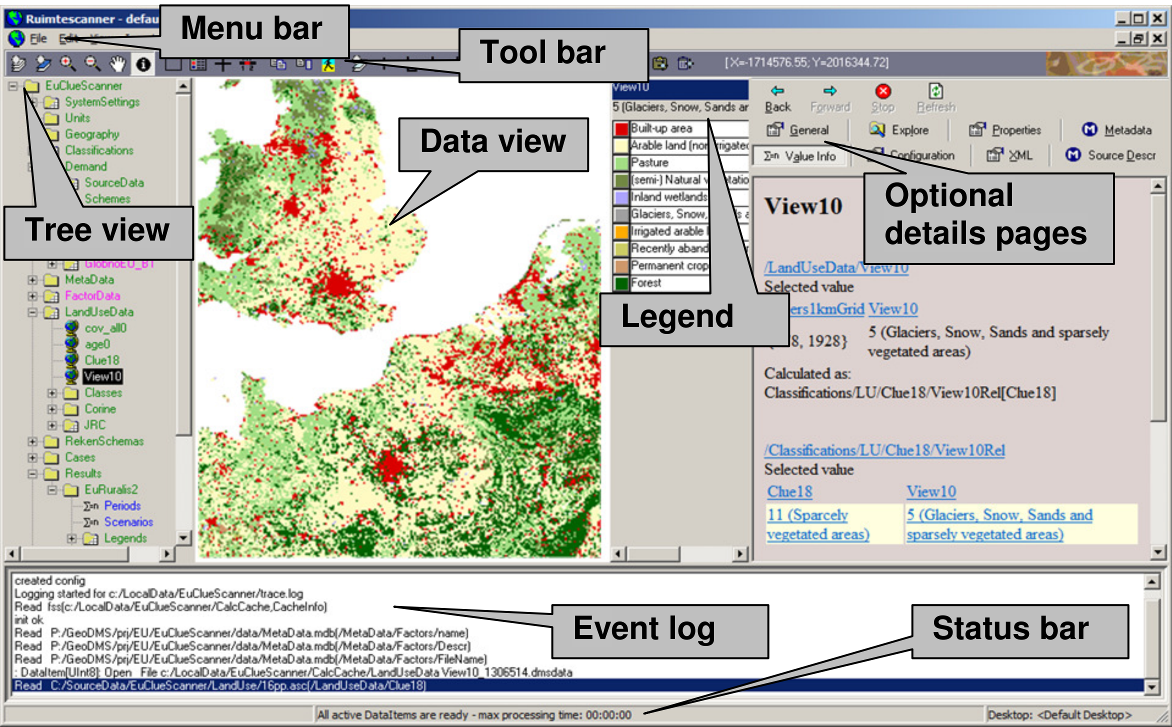


Figure 6 Tree view and main components of the GeoDMS interface.

The GUI contains the following elements:

- the Menu bar with several pull down menus;
- an initially empty dark-grey Tool bar that contains window-specific tools;
- on the left hand side a Tree view that allows navigation through the available data sets and model result;

- a Data view that displays data as tables or maps;
- a map Legend that appears with map in the Data views;
- various Details pages containing technical and background information that appear or disappear by simultaneously clicking the ALT and 1 keys
- an Event log that presents information on the processed steps. This event log appears/disappears by simultaneously clicking the ALT and 2 keys
- a Status bar that presents hints and status information about ongoing processes.

The Tree view is the main navigation component within the application. It is comparable to the Windows Explorer in Windows and allows easy access to the huge collection of data and model result items that are available in the model. The Tree view presents the hierarchical structure of the EU-ClueScanner configuration. By default the root and the first level items are shown (the root item is expanded). Each item in the tree (called a tree item) is presented with a name and an icon. The icons are related to the default viewer for the corresponding tree item. In section 2.2.1 these icons are explained.

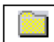
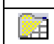
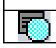
The selected item in the Tree view is the active item in the application. This is an important concept, as many functions of the application work on the active tree item. By clicking the right mouse button a pop-up menu can be activated, with a set of menu options that work on this active tree item. This also applies to most main menu options and to the Detail pages. The pop-up menu options, most main menu options and the details pages are described in Chapter 4 and 5 of the GeoDMS user guide.

Icons used in the Tree view

The main purpose of the icons is to show which default viewer is used for an item. Double clicking or pressing the enter key on a selected tree item activates this viewer. The following icons are used to indicate this default viewer:

	Data item that can be viewed in a map. This implies the domain of the data item has a geographic relation (see GeoDMS modeller's guide for how to configure a geographic domain unit). Dependent on the geographic domain, the data is visualized in a grid, point, arc or polygon layer.
	Data item that cannot be visualized in map (has no geographic relation) but can be viewed in a Datagrid.
	Data item that contains a classification (a set of classes). A classification can be made or edited with the classification and palette composer, see GeoDMS user guide Chapter 10

Not all tree items are data items. For the non-data items (these items cannot be viewed with a primary data viewer), the following icons are in use:

	A tree item with no data item and subitems that also have no data items. The icon is used for containers grouping other containers or units.
	A tree item with no data item, but with data items as subitems. All subitems of this item with the same domain unit can be viewed in a Datagrid.
	A tree item with no data item and no subitems, e.g. a unit

The next sections explore the five main components of the tree view: land-use data, other spatial (factor) data sets, the demand specification, models runs and indicators.

2.2 Land-use data

The land-use data can be viewed by browsing through the Tree view. Start by clicking on the + in front of the container (directory) called “LandUseData”. For the DG Environment version 1km resolution, the 2000 land use is shown in two different thematic aggregations: one using 18 classes and one using 10 classes (see Section 1,2,1). The container ‘Çorine’ includes the Corine Land Cover (CLC) data-layers that describe the land use at a 100m resolution in the years 1990 and 2000. A more detailed account on the different land-use typologies can be found by browsing to EuCluescanner->Classifications->LU in the Tree view. The small globes indicate that the data item can be visualised in a map view.

Maps can be drawn in the data view area in three different ways:

1. 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.
2. 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.
3. by giving a right mouse-click on the data layer and selecting the Map View or the Default option from the appearing menu. The other options allow showing the data as a table (which does not make sense here) or histogram. The latter option shows the frequency distribution of the different land-use types.

The included classes are described in the legend that appears on the right hand side of the map. The last column in this legend contains the count for each class. As the application has a 100x100 m resolution the count values can be read as surface areas in hectares. More background information on the data is available in a meta-data sheet that can be retrieved as one of the Details pages.

Right mouse-clicking on the legend area allows the user to select, amongst others, the statistics function. This option provides some basic statistics on the selected dataset, e.g. minimum and maximum value per grid cell and the total area (sum) covered by this land-use type. The edit palette pop-up menu option allows you to change the classification and colour as is explained in more detail in the GeoDMS user guide.

The tool-bar now contains several standard GIS-functions such as:
 zoom in,  zoom out,  pan,  get info,  zoom to full extent,
 copy visible area to clipboard,  toggle scale bar.

The objective of these and other functions is indicated with a mouse-over text. For a full description of all tools, including options to export specific views and datasets as bitmaps or other data formats, see the GeoDMS user guide.

Please note that the Corine data sets are stored as tif files in the EUCS_100m\landuse folder in the SourceData directory. This data set can be copied from here to be used in, for example, a GIS environment. Alternatively all data items that can be viewed in a map, such as the land-use data sets, can be exported by right-clicking on the attribute in the tree view and selecting the option export primary data. The user can then choose to export data in various formats, such as ascii grid or bitmap (bmp) with world file (reference to a coordinate system). It is necessary to first draw the map in the map window before this option is selected. These export options will create a copy of the whole data set, using its full extent. When the user only wants to export the part of the map that is visible in the map window, the tool bar option ‘copy visible area to clipboard’ should be selected.

2.3 Factor data

The EU-ClueScanner also contains a wide range of spatial data sets that describe specific themes such as accessibility, geomorphology, climate and land use in neighbouring cells. These datasets were collected for the EURURALIS project (Eickhout et al., 2007; Van Meijl et al., 2006) and are used as independent factors in the statistical calibration of the model. The factor data are stored as tif files in the 'Drivers' folder in the SourceData directory.

The data can be requested in the EU-ClueScanner from the FactorData container and can be shown as indicated above. They are shown with a corresponding legend file and meta data (a standardised description) in the details pages. In addition, datasets at a 100 metre resolution are also included. These datasets are related to features such as elevation, slope, south slope and Natura2000 areas. These are stored as tif files in the folder EUCS_100m in the Source data container and can be visualized by browsing to the container JrcFactorData in the Tree view.

Appendix 2 provides an overview of the included datasets.

2.4 Demand

The container *Demand* normally specifies the total amount of land (in hectares for the model version at 100m resolution, in km^2 for the 1km resolution version) that has to be allocated per year, per land-use type, per region. These land-use claims or demands can be calculated in the demand module based on the information from external sources such as the LEITAP model and can be viewed in the Demand container. Demands are calculated per demand scenario and specified for each of the claim regions. These regions normally consist of individual countries, only the Belgium and Luxemburg are aggregated in the JRC application. The functioning of the demand module is explained in Section 3.2. Please note that different from previous model versions it is no longer needed to specify the exact demand per land-use type per year for each region needs to be specified. The model is now able to allocate land when more (or less) land is claimed than is available in a region. When no land is claimed at all (i.e. when a demand specification is lacking) the allocation is unconstrained and fully governed by the conversion settings, transition potential and other model parameters.

In the initial 100 metre version of the model the Demand module is not directly used. The demand for the Reference (B1) alternative from the DG Environment application is used by way of example in the 100 metre model runs. This application thus also uses the Clue10 typology applied for DG Environment. In addition a demand for the year 2000 is calculated to allow for a validation of the model. This demand is obtained by comparing the total amounts of land the JRC9 land-use classes that are simulated by the model and thus prescribes the actual (observed) amounts of land for 2000. Appendix 6 lists how this demand is derived for each country. These demand data are stored as text files (with a .in1 extension) in the folder projects\EuClueScanner\Demand\Validation2000\ *Country name.* Appendix 4 explains the layout of these files. The demand files related to the original 1km model can be found in the Demand folder in the LocalData directory. This folder contains a subfolder per demand scenario (e.g. ReferenceB1) that in turn contains subfolders per demand region.

2.5 Runs

The term *runs* refers to individual simulation runs. These represent a unique combination of claims (demand) and local suitability settings and in our case correspond to the eight policy alternatives that are included in the model. The definition of the runs can be inspected in runs ->

EuClueScanner100m -> runs -> *PolicyAlternativeName* (e.g. Validation2000MNL) -> *CountryName* (e.g. Austria). This is a reflection of all possible model settings and may be a bit confusing at first. The most important components of the case definition are described in Chapter 3. It is clear from these folders that the model is essentially specified at the level of individual countries.

To actually produce and view intermediate and final simulation results several options exist in the country-specific policy alternative folder:

- DynaClue -> TimeSteps -> *Year* (e.g. P2000) -> ResultingState -> LandUse starts the simulation of land use in a specific year. Obviously this simulation process takes longer when a longer period is selected. This TimeSteps folder contains also many other important dynamic model settings per individual simulation year.
- simulation_results -> LandUse shows land use in the final year and all preceding years (in the PerYear container). The visual representation is explained in the legend file and meta data in the details pages. Once this item is activated the allocation process starts. Upon completion the resulting land use is stored as a .TIFF file in the LocalData\EuClueScanner*PolicyAlternativeName folder.* Please note that the second time an item is calculated, the old version will not directly be overwritten. The new version will receive a .tmp extension instead. When model is opened again the old version will get a .old extension and the new version will takes its place. This procedure allows the user to rename and store previous simulation results for a policy alternative.
- The simulation_results -> Indicators folder allows the user to inspect the results with different land-use based and thematic indicators. This folder contains several indicators that help interpret the (impacts of) simulated land-use patterns at a 100m resolution. Especially soil sealing and river flood risk indicators are interesting as these use highly detailed additional data sets. The individual indicators are described in more detail the factsheets that can be viewed in the model by opening the details pages.
- The endstate folder shows the final-year simulation result (discr_result) and allows the inspection of locations that have changed since the initial year: changed_to shows the new land use of changed locations, changed_from shows their intial land use.

The Event log shows the progress of calculations during simulation. It lists, amongst others, the amount of data items that still have to be calculated and thus gives an indication of the additional time needed to complete a calculation.

Pre-processed results from model runs that have already been stored can be viewed in the *indicators* folder in the tree view. Please note that this has only been done for the policy alternatives of the 1km application for DG Environment. The indicators in this folder are designed specifically for the land-use types and resolution of this application and can not readily be applied to results from the JRC version of the model. The tutorial for the 1km version of the model describes how these simulation results can be made available for indicator calculations.

Temporary results that are produced by updating data items during a modelling session are stored in the LocalData\EuClueScanner\CalcCache directory. This is the storage facility for all (intermediate) results that are produced during simulation. The results stored here will automatically be retrieved when an attribute is called upon from the tree view. Please note that this directory can become extremely voluminous, so it is advisable to delete files not recently used in the CalcCache when the model becomes too slow or after the model has crashed.

2.6 Indicators

The *indicators* folder contains, for each pre-calculated policy alternative of the 1km application for DG environment, the land-use results in various representations, derived thematic indicator maps (related to specific policy themes) and a set of socio-economic indicators that originate from the LEITAP and demographic models that feed into the EU-ClueScanner. The latter type of indicators is derived from the LEITAP model and only available at the National level. This extensive set of indicators helps the user interpret simulation results. A full overview of the available indicators is presented in the final report of this project (Perez-Soba et al., 2010) and can be obtained by opening the indicators subfolders for a policy alternative.

Indicators can either be viewed as maps and tables. Regional aggregations usually exist at the national level and lower Nuts2 and Nuts3 statistical regions. The indicators can be viewed by selecting them in the tree view. Background information on the origin, input data and applied methodology can be found in the associated meta-data sheets that can be viewed by clicking Alt+1 and selecting the MetaData tab in the Details pages. Figure 7 shows an example of an indicator map retrieved within the user interface.

The simulated land-use patterns for the different policy alternatives are essential input for the calculation of the various indicators. This input is read from the pre-calculated results folder (Results.use) in the the LocalData\EuClueScanner\ EuClueScanner1km directory. It is thus a prerequisite for indicator calculation to first perform the land-use simulation for any new policy alternatives and copy the results to the Results.use folder.

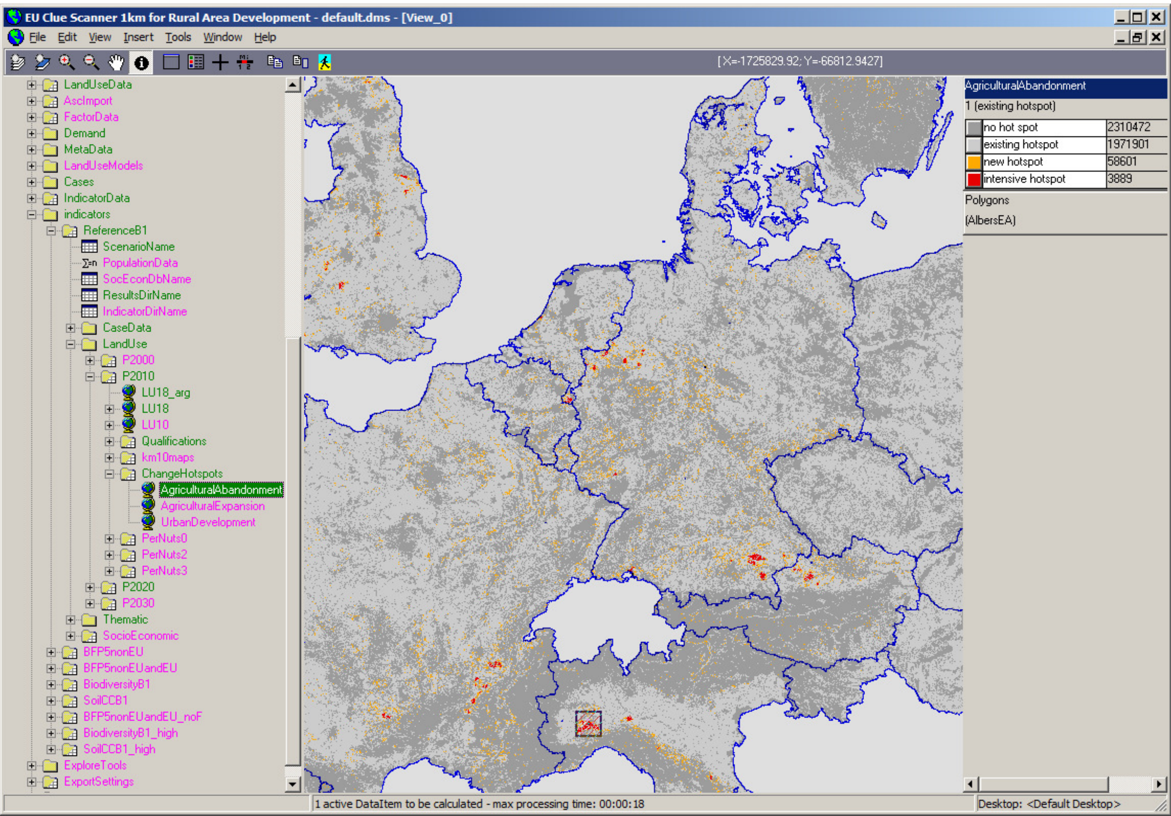


Figure 7 Example of a land-use based indicator (hot-spot of agricultural abandonment).

A comparison of land-use maps can be created with the ExploreTools/CompareLanduse template. It allows the user to compare two individual land-use maps that can be selected from pull-down lists. The ExploreTools can be activated by clicking Ctrl+A when the administrator mode is switched on. A so-called case generator window appears that first asks the user to specify a name for this map comparison and then (after clicking next) to select two land-use maps from two pull-down menus that will be compared on a pixel-by-pixel basis. The resulting maps are available in a new folder in the tree view under runs -> CompareLandUse that contains four maps:

- map1 is the land-use map that was selected first
- map2 is the land-use map that was selected subsequently
- diff1 is a map showing the initial (map1) land use for those locations where land use changed between the two years.
- diff2 is a map showing the final (map2) land use for those locations where land use changed between the two years.

Please note that the created difference maps are created temporarily within a modelling session. They are not stored when the model is closed. Should you wish to store specific maps you created you can do so by exporting them through the various options in the Tool bar. If you have specific map comparison you want to evaluate in each session it may be wise to define that comparison option as an indicator in the appropriate GeoDMS script file (see Section 4.3).

3 Defining new policy alternatives

Creating a new model application to simulate land use according to, for example, a new reference scenario or policy alternative normally requires the following steps:

1. specification of the application in terms of land-use related themes, thus answering the question how the proposed policy alternative may influence land-use patterns;
2. specification of the application in terms of model inputs, thus define which model components should be used to simulate the anticipated spatial processes;
3. implementation of the new settings and data in the model and simulation;
4. visualisation and interpretation of the model results.

The development of a new policy alternative is an iterative process that requires intensive cooperation between policy makers and scientists with a good overview of data and model potentials (i.e. land-use modelling experts). This is especially important in the specification of the application (step 1 and 2), but also for the evaluation of initial simulation outcomes (step 4); policy makers should evaluate whether or not the results are in line with their expectations. They may request alternative model specifications when the simulated land-use patterns conflict their anticipations or other policy objectives.

The implementation of a proposed new policy alternative should start with obtaining a clear understanding of its land-use related impacts. Initial discussions between policy makers and modellers/scientists should thus focus on clarifying the intentions and likely consequences of proposed policy alternatives in terms of land-use change. When these cause-effect relations are clear, specification in terms of model inputs can be proposed by the modeller. A basic question in this respect is: will the policy influence the demand for land (e.g. through intervention in the macro-economic processes as is the case with a reform of the Common Agricultural Policy) or will it mainly affect the locations of future developments. The former case will normally require the application of a regional economic model such as LEITAP, whereas the latter types of spatial policy can be represented in spatial data sets (e.g. maps of areas where specific land-use restrictions will apply). The policy alternatives that were developed for DG Environment also resulted from several discussion sessions that focussed on the objectives of specific policies and the potential of the land-use modelling framework to accommodate their likely consequences. The actual implementation of the final set of policy alternatives has been extensively documented in an appendix to the final report (Perez-Soba et al., 2010). This description is essential reading for those who consider developing a new policy alternative.

New applications request a modification of the modelling set-up in some form or other. Roughly ranging from simple to complex, these may include:

- adding new thematic data (e.g. policy maps, revised accessibility);
- adding new land-use datasets, e.g. CLC 2006 when it becomes available;
- developing and adding new indicators;
- extending the study area with, for example, Switzerland, Balkan or Turkey;
- link the land-use model with other models (transport, hydrology, economics);
- changing the resolution (e.g. 100m grid);
- revise the calibration based on the new land-use data or other additional data sets;

The table below organises the main tasks related to the implementation of new model applications under two main headings: 1) defining and running new policy alternatives; and 2) more extensive improvements of the modelling framework required for specific new applications. It indicates the complexity of these tasks and lists the model components that should be edited and the profile of the user that is likely to be involved. Most of the basic tasks needed to modify or implement a new scenario are feasible by an experienced user within reasonable time (depending on the type of scenario between 1 hour and 10 days). It is important to note that new and more complex applications may involve additional relevant partners (e.g. to run hydrological or global agro-economic models).

Please note that the complexity of the tasks only refers to the work involved in adjusting the EU-ClueScanner model. **In many cases the most substantial part of the work will have to be performed outside the actual model.** Collection and preparation of pan-European datasets is, for example, an extremely time consuming issue. Even the collection of base data for a single new member state and harmonising it with the currently available datasets can easily take several months for a GIS-expert.

Table 7 Indication of complexity (=simple, ** = advanced, *** = complex) of various tasks related to the application of the EU-ClueScanner framework.*

Tasks	Complexity	Model component	User profile
1. Defining and running new policy alternatives			
Replacing spatial data sets (adding pre-processed data relating to e.g. policy, accessibility)	*	file manager	programmer
Editing current demand specification	*	Dbase	programmer
Combining existing scenario components (demands, transition potential definitions, etc.) into new policy alternative	*	Dbase/ DMS-script	policy maker
Adding new demand specification (e.g. adding new external LEITAP or demographic projections)	*	Dbase/ DMS-script	programmer
Adding new spatial data sets (adding pre-processed data and referring to it in policy alternatives)	*	DMS-script/ DMS-script	programmer
Edit basic simulation settings (e.g. Conversion Settings Matrices)	*	DMS-script/ parameter files	programmer/ scientist
2. Improving the EU-ClueScanner model			
Replacing land-use base data (e.g. inserting CLC2006) and adjusting demand settings	*	DMS-script	scientist
Revise calibration, renew specification of weights of suitability factors and neighbourhood enrichment, based on pre-processed data for one country	**	e.g. SPSS/ DMS-script	scientist (with expertise in statistics)
Add/edit indicator definitions including graphic representation (strongly dependent on the type of indicator)	**	DMS-script	programmer
Link model to other models e.g. to assess specific impacts (strongly dependent on type of linking)	**		programmer
Edit allocation process: - change Transition Potential definitions - change rules of Neighbourhood enrichment - adjust post-processing rules (succession) - edit Output Generation Definition	***	DMS-script	programmer/ scientist
Change set of land use classes, including revision of demand and other simulation settings	***	DMS-script	programmer/ scientist
Extend study area (e.g. include Switzerland or Balkan), including adding of demand and other model settings	***	DMS-script	programmer/ scientist
Change resolution including respecification of model settings	***	DMS-script	programmer/ scientist

This chapter aims to introduce the relatively simple tasks related to the defining and running of new policy alternatives, whereas the subsequent chapter discusses some of the advanced tasks involved in improving the modelling framework. The complex tasks listed in the table are beyond the scope of this tutorial as they require a thorough knowledge of the modelling environment. The same goes for adaptations to the modelling shell (GeoDMS) such as: adding new spatial analytical or other functionality, supporting new file formats or updating the model to a new windows version. Such changes will normally have to be programmed in the GeoDMS-source code (in C++) and are thus the domain of software programmers.

To define new policy alternatives a relatively small set of files can be manipulated relating to:
- the spatial data sets describing policy maps or driving forces;
- the regional land demand associated with the policy alternatives; and
- model settings (including the statistically calibrated suitability factors, transition potential and location specific characteristics).

This chapter first explains how existing spatial data sets can be replaced. Subsequently the editing and adding of new elements (demand specifications, data sets) is explained. Finally more complex issues such as the changing of the basic model settings and the creation of completely new policy options are discussed.

3.1 Replacing spatial data sets

The simplest way to include new information in the existing policy alternatives is through replacing existing spatial data sets. This may be necessary to include revised policy maps or updated accessibility maps. To replace an existing dataset, a number of actions have to be taken as is described below.

First the to-be replaced data set needs to be identified and located. Appendix 2 provides an overview of the included factor data sets. These are stored as TIFF files in the SourceData\EuClueScanner\DRIVERS folder on your computer. The exact location of the Sourcedata folder can be found by in the 'General setting' tab (see Section 1.5). Alternatively the location (Source description) of a specific file can be retrieved by opening the details pages (by selecting this option from the 'View' menu or by pressing the 'alt' and the '1' buttons), while viewing the dataset. In the viewer on the right you can read the source of the dataset.

It is necessary that the new data set has the same grid specifications (extent, location, and cell size) and is created in the same projection (see Appendix 3) as the old data set it is replacing. It should also have the same values units (e.g. kilometres or per cent) as the old file to make sure that it has an equivalent impact. When the units are, for example, accidentally specified as meters instead of kilometres the data set will have 1000 times stronger impact. When the replacing data set has exactly the same name as the original file it will be directly used in calculation. The adding of new data sets is discussed in Section 3.5.

3.2 Editing current demand specification

The demand for land is calculated in the model with the demand module. This module translates base data related to demographic development and the demand for agricultural commodities into a demand for land in hectares or km^2 per land-use type. The base data comes from external sources and is stored in a Microsoft Access database (demand.mdb) located in projects\EuClueScanner\data\ demand. This database consists of collection of different tables related to *demographic data*, a*gricultural commodities*, and additional *demand settings*.

The *demographic data* is derived from scenario-based projections of the PHOENIX model (Hilderink, 2004) and stored in four scenario-specific tables in the database (demography_A1, demography_A2, demography_B1, demography_B2). The demand for *agricultural commodities* is taken from the LEITAP/IMAGE combination (Van Meijl et al., 2006) and stored in several scenario-specific tables (using the original names of the files coming from the LEITAP modellers, e.g. GTAP_CLUE_090615_DGEnv_Ref). The demand database also contains scenario-specific *demand settings* (e.g. the amount of land in m^2 per inhabitant) that are used to translate the base data into land demand. These settings may differ for different scenarios and the DG Environment application contains 7 different variants that are included as separate tables in (with the prefix demand_settings) in the demand.mdb. Table 8 briefly explains the demand setting parameters. The demographic and agricultural demand base data and demand settings are stored at the national level.

The current demand settings can be edited fairly easily in Microsoft Access to, for example, test the impact of changes in agricultural policy. This should, however, be done with great caution as the current settings have been made by a wide range of experts in the EURURALIS project. Note also that changes in Microsoft Access cannot be undone. It is thus advisable to save a copy of the original database. Ideally, revised demand settings should be stored in a new table with a meaningful new name within the demand.mdb. A new policy alternative can then be created that makes use of this new demand specification (see Section 3.4).

Table 8 Demand setting parameters

Demand setting	Explanation
isEU15	Parameter indicating whether or not the other demand settings parameters apply to EU15 countries. The demand settings for the new accession states are specified in the second row of the column and may differ on all of the following demand settings.
RatioPermanentRotationalCrop	Ratio of permanent crops to arable land, used to calculate the demand for permanent crops
CeasingSubsSetAside	Starting year of decrease in set aside subsidies (or 0 when decrease is absent)
PeriodSubsSetAsideDiminishing	Period in years over which set-aside subsidies are diminishing
IncreasingSubsSetAside	Starting year of increase (or 0 when decrease is absent)
PeriodIncreaseSpread	Period in years over which increase is spread
MaxPercentSetAside	Maximum percentage of land set aside
PercentIncrease	Percentage of the increase
MaxFallowPastures	Percentage of maximum fallow for pastures
MinFallowPastures	Percentage of minimum fallow for pastures
BiofuelSetAside_2000_2010	Percentage of biofuel allowed on set-aside land in 2000-2010
BiofuelSetAside_2010_2020	Percentage of biofuel allowed on set-aside land in 2010-2020
BiofuelSetAside_2020_2030	Percentage of biofuel allowed on set-aside land in 2020-2030
TrendDensity	Yearly increase in the amount of urban land in m^2 used per inhabitant
corrPasture	Minimum percentage used to define a lower limit to the area including fallow (areaInclFallow)

3.3 Combining existing scenario components

Individual simulation runs consist of a socio-economic scenario and superimposed policy alternatives. These are defined in the table Scenarios that is stored as part of a Microsoft Access database (metadata.mdb) located in \projects\EUClueScanner\data. This table can be viewed and edited with Microsoft Access (see the example in Figure 8). You can add runs (new simulation alternatives) by inserting new rows into the Scenarios table. Changes to the contents of this table become effective after reloading the model configuration from the GeoDmsGUI (File->Open). A case definition consists of several components that are discussed below.

The column *ItemName* contains a name given by the user to characterise the new alternative. This is the name that will appear in the tree view of the model.

The *IsActive* and *IsActive100m* columns denote whether the new case is part of the DG

Environment application (with a 1km grid) or the JRC application (with a 100m resolution) and should be ticked accordingly.

The *IsCalculated* and *IsCalculated100m* columns indicate whether pre-calculated results already exist. These should be stored in the LocalData\EuClueScanner\ EuClueScanner1km\Results.use folder when available. Please note that this folder name should correspond exactly to the ItemName in the Scenarios table to be found. Section 2.5 describes how results for a new case can be obtained and stored.

The column *SuitabilityTraits* indicates which method will be used to combine the different components related to local suitability. Three different options exist that differ in the way the statistical calibration results from the alloc1.reg and alloc2.reg files are used in the definition of local suitability. These methods were developed and tested for the 100m version of the model and consist of the following options:

- Split100 contains a method that fits best with binomial logistic regression results, this method was part of the original dyna-Clue model;
- Mnl100 contains a method that fits best with multinomial logistic regression results;
- Linear100 contains a first attempt at a method to combine the results of alloc1 and alloc2 files first before rescaling them with a multinominal logit function. This method is included here for test purposes.

Section 1.4 shortly describes the application of these methods in the model runs developed for JRC.

The column *ParamName* links to the separate ParamSets table in the metadata.mdb (see also Figure 9) that specifies which parameter sets are chosen (e.g. ReferenceJRC), which land-use typology is used (Clue10 for 1km applications of DG Environment or JRC9 for 100m version of JRC), which regional division is selected (e.g. Country or Nuts2) and which basic land-use data set is used as starting point. The parameters sets of the 100m version of the model are stored in the projects/EuClueScanner/Paramsets folder and contain the scenario specific parameter files are read. These files include:

- alloc1.reg, which relates Suitability Factors to land-use types;
- alloc2.reg, which relates Neighbourhood Enrichment factors to land-use types;
- neighmat.txt, which defines the size and shape of the neighbourhoods and the weight assigned to the neighbourhood function;
- allow.txt, which specifies succession and/or refers to succession maps;
- locspecX.asc, which refer to location-specific characteristics (e.g. spatial policies) per land-use type when applicable (only in specific policy alternatives).

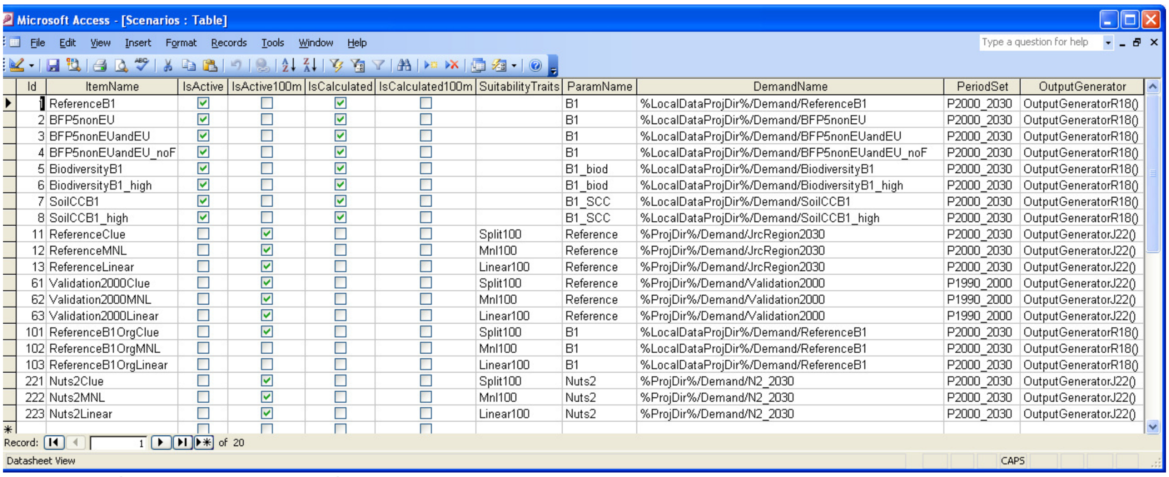
See Appendix 4 for descriptions of these file formats. The files may differ per country and policy alternatives to reflect local conditions or specific policies or anticipated spatial developments.

The Column *DemandName* in the Scenario table identifies for each case which demand set to use. The DemandName is read from the separate DemandSets table in the metadata.mdb. This link has been defined with the relationships option in Microsoft Access.

The *PeriodSet* item in the table specifies the period of simulation, this is normally 2000 to 2030, but in case of the validation refers to the 1990 to 2000 period.

Finally the *OutputGenerator* specifies the way output is generated based on the simulation results. This refers back to the inclusion of the non-simulated (static) land-use types in maps with future land use that was discussed in Section 1.4. Currently options exist to create maps in the Clue18 typology (for simulations using the Clue10 typology, see Table 2) or the JRC22 typology (for simulations using the JRC9 classification, see Table 4).

New runs can be created by combining the above components. It is, for example, possible to combine the spatial policy alternatives (e.g. the parameter sets related to Biodiversity and Climate Change) with a different demand scenario than is currently implemented (e.g. by selecting the BFP5nonEU demand scenario).



Microsoft Access - [Scenarios : Table]

Id	ItemName	IsActive	IsActive100m	IsCalculated	IsCalculated100m	SuitabilityTraits	ParamName	DemandName	PeriodSet	OutputGenerator
1	ReferenceB1	☑	☐	☑	☐		B1	%LocalDataProjDir%/Demand/ReferenceB1	P2000_2030	OutputGeneratorR18()
2	BFP5nonEU	☑	☐	☑	☐		B1	%LocalDataProjDir%/Demand/BFP5nonEU	P2000_2030	OutputGeneratorR18()
3	BFP5nonEUandEU	☑	☐	☑	☐		B1	%LocalDataProjDir%/Demand/BFP5nonEUandEU	P2000_2030	OutputGeneratorR18()
4	BFP5nonEUandEU_noF	☑	☐	☑	☐		B1	%LocalDataProjDir%/Demand/BFP5nonEUandEU_noF	P2000_2030	OutputGeneratorR18()
5	BiodiversityB1	☑	☐	☑	☐		B1_biod	%LocalDataProjDir%/Demand/BiodiversityB1	P2000_2030	OutputGeneratorR18()
6	BiodiversityB1_high	☑	☐	☑	☐		B1_biod	%LocalDataProjDir%/Demand/BiodiversityB1_high	P2000_2030	OutputGeneratorR18()
7	SoilCCB1	☑	☐	☑	☐		B1_SCC	%LocalDataProjDir%/Demand/SoilCCB1	P2000_2030	OutputGeneratorR18()
8	SoilCCB1_high	☑	☐	☑	☐		B1_SCC	%LocalDataProjDir%/Demand/SoilCCB1_high	P2000_2030	OutputGeneratorR18()
11	ReferenceClue	☐	☑	☐	☐	Split100	Reference	%ProjDir%/Demand/JrcRegion2030	P2000_2030	OutputGeneratorJ22()
12	ReferenceMNL	☐	☑	☐	☐	Mnl100	Reference	%ProjDir%/Demand/JrcRegion2030	P2000_2030	OutputGeneratorJ22()
13	ReferenceLinear	☐	☑	☐	☐	Linear100	Reference	%ProjDir%/Demand/JrcRegion2030	P2000_2030	OutputGeneratorJ22()
61	Validation2000Clue	☐	☑	☐	☐	Split100	Reference	%ProjDir%/Demand/Validation2000	P1990_2000	OutputGeneratorJ22()
62	Validation2000MNL	☐	☑	☐	☐	Mnl100	Reference	%ProjDir%/Demand/Validation2000	P1990_2000	OutputGeneratorJ22()
63	Validation2000Linear	☐	☑	☐	☐	Linear100	Reference	%ProjDir%/Demand/Validation2000	P1990_2000	OutputGeneratorJ22()
101	ReferenceB1OrgClue	☐	☑	☐	☐	Split100	B1	%LocalDataProjDir%/Demand/ReferenceB1	P2000_2030	OutputGeneratorR18()
102	ReferenceB1OrgMNL	☐	☐	☐	☐	Mnl100	B1	%LocalDataProjDir%/Demand/ReferenceB1	P2000_2030	OutputGeneratorR18()
103	ReferenceB1OrgLinear	☐	☐	☐	☐	Linear100	B1	%LocalDataProjDir%/Demand/ReferenceB1	P2000_2030	OutputGeneratorR18()
221	Nuts2Clue	☐	☑	☐	☐	Split100	Nuts2	%ProjDir%/Demand/N2_2030	P2000_2030	OutputGeneratorJ22()
222	Nuts2MNL	☐	☑	☐	☐	Mnl100	Nuts2	%ProjDir%/Demand/N2_2030	P2000_2030	OutputGeneratorJ22()
223	Nuts2Linear	☐	☑	☐	☐	Linear100	Nuts2	%ProjDir%/Demand/N2_2030	P2000_2030	OutputGeneratorJ22()

Record: 1 of 20

Datasheet View

Figure 8 Screenshot of the Scenarios table in the metadata.mdb.

3.4 Adding a new demand specification

To be able to understand how a new demand specification can be added it is important to understand the way the relations between the different tables in the metadata.mdb are defined. Figure 9 provides an overview of these relations that can be shown and edited in Microsoft Access with the option tools -> relationships. The figure makes clear that policy alternatives (called Scenarios in the metadata.mdb) rely on demand sets that combine information from both the GTapSets and DemandSettingSets tables. This section describes different ways to make new demand specifications: add new demand sets, add new demand settings sets or add new demand base data (such as the LEITAP demand sets stored in the GTapSets table).

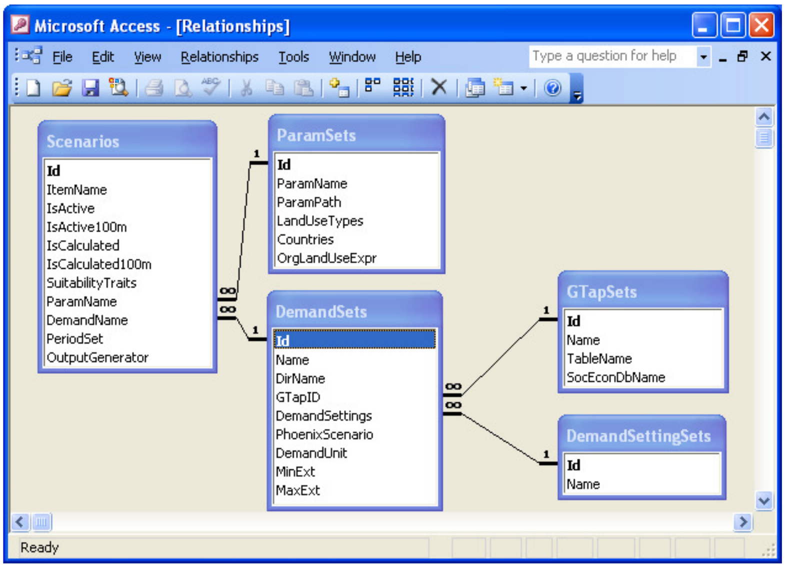


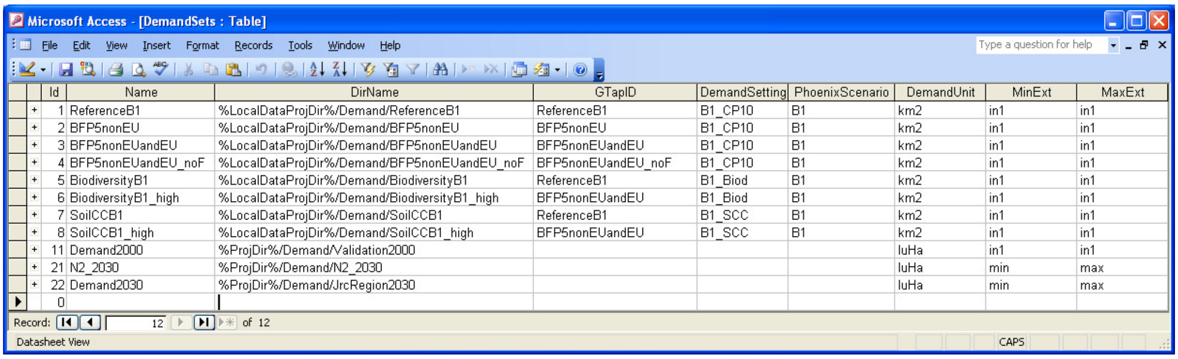
Figure 9 Relationships in the metadata.mdb.

Add new demand sets

It is possible to add a new demand sets to the model by adding an extra record (with a new unique ID) to the DemandSets table in the metadata.mdb (see Figure 10). In this record the following components should be defined:

- Name, a short name for the new demand set that will show up in the tree view;
- DirName, the name of the directory where the demand data will be stored when the demand module is run;
- GTapID, the name of the LEITAP model run that contains the base data for the demand for agricultural commodities. This name is read from the separate GTapSets table in the metadata.mdb through a link that has been defined with the relationships option in Microsoft Access. The actual LEITAP results are stored as separate tables in the demand.mdb (see Section 3.2).
- DemandSettings, the name of the appropriate DemandSettingsSet. This name is read from the separate DemandSettingsSet table through a link has been defined with the relationships option in Microsoft Access. The actual demand settings are stored as separate tables in the demand.mdb (see Section 3.2).
- PhoenixScenario, referring to the name of the required demographic scenario (stored as separate table in demand.mdb with the prefix demography).
- DemandUnit describing whether the demand is specified in either km2 or ha.
- MinExt and MaxExt describing whether the demand is specified in a single demand.in1 file (indicated by the value ‘in1’ in both columns) or is specified between a minimum and maximum boundary (denoted by ‘min’ and ‘max’). In the latter case the model expects two demand files per country having a .min and .max extension respectively. When no demand files are present (as is the case now for Nuts2 regions) the model will allocate land based on current totals per land use and parameters such as transition potential and local suitability (based suitability factors and neighbourhood enrichment). When the total of all demands is not exactly equal to the available amount of land, the model will ensure that all demands are adjusted (increased or decreased) with the same ratio to such an extent that the all available land is used in allocation. If the amount of available land is larger than the sum of the maximum claims (only) the max claims are increased; if the sum of the minimum claims is larger than the available land (only) the minimum claims are decreased. This applies anyway whether the claims come from the same file (i.e. demand.in1) or from separate .min and .max files.

The addition of a new demand set is fairly easy when existing components are used as is shown in the figure below for a new demand set called *test*. When new demand settings or demand base data related to agriculture or demography are to be included, more actions are required as is described in the next subsection.



Id	Name	DirName	GTapID	DemandSetting	PhoenixScenario	DemandUnit	MinExt	MaxExt
1	ReferenceB1	%LocalDataProjDir%/Demand/ReferenceB1	ReferenceB1	B1_CP10	B1	km2	in1	in1
2	BFP5nonEU	%LocalDataProjDir%/Demand/BFP5nonEU	BFP5nonEU	B1_CP10	B1	km2	in1	in1
3	BFP5nonEUandEU	%LocalDataProjDir%/Demand/BFP5nonEUandEU	BFP5nonEUandEU	B1_CP10	B1	km2	in1	in1
4	BFP5nonEUandEU_noF	%LocalDataProjDir%/Demand/BFP5nonEUandEU_noF	BFP5nonEUandEU_noF	B1_CP10	B1	km2	in1	in1
5	BiodiversityB1	%LocalDataProjDir%/Demand/BiodiversityB1	ReferenceB1	B1_Biod	B1	km2	in1	in1
6	BiodiversityB1_high	%LocalDataProjDir%/Demand/BiodiversityB1_high	BFP5nonEUandEU	B1_Biod	B1	km2	in1	in1
7	SoilCCB1	%LocalDataProjDir%/Demand/SoilCCB1	ReferenceB1	B1_SCC	B1	km2	in1	in1
8	SoilCCB1_high	%LocalDataProjDir%/Demand/SoilCCB1_high	BFP5nonEUandEU	B1_SCC	B1	km2	in1	in1
11	Demand2000	%ProjDir%/Demand/Validation2000				luHa	in1	in1
21	N2_2030	%ProjDir%/Demand/N2_2030				luHa	min	max
22	Demand2030	%ProjDir%/Demand/JrcRegion2030				luHa	min	max
0								

Figure 10 Screenshot of the DemandSets table in the metadata.mdb.

To apply the new demand sets in land-use simulation, the following steps are necessary:

1. A (new) policy alternative (model run) should be defined in the Scenarios table that refers to the new demand set (see Section 3.3);
2. The new or revised policy alternative should be applied in the demand module in the EU-ClueScanner to calculate the demand per land-use type, per year for each country following the changed settings and existing demand base data. This calculation starts after activating the Result data item in the Tree view under Demand -> runs -> *PolicyAlternativeName* -> FileGenerator. A demand file for an individual country can be created by activating the data item demandFile in Demand -> runs -> *PolicyAlternativeName* -> per_country -> *CountryName* -> Results.

The demand specification resulting from running the demand module is stored as a Demand.in1 text file in the folder \LocalData\EuClueScanner\Demand*PolicyAlternativeName**CountryName*. Please note that existing demand specification files are not directly replaced when the demand for an already existing policy alternative is calculated anew. In this case a new Demand.in1.tmp file is created, that will only replace the initial file when the EU-ClueScanner model is closed. Upon closing the model, the initial files are renamed to Demand.in1.old to allow the user to recover the initial demand settings when necessary. Appendix 4 provides a short description of the format of the demand files.

When the demand files have been generated for a new policy alternative, the simulation of future land use can be started as was described in Section 2.5.

Adding new demand settings

New demand settings can be added by creating a new table in the demand.mdb. To make sure that the right structure is used, it is best to copy an existing demand settings table and paste it (with structure and data) as new table within the demand.mdb. The copied table should be given a sensible short name with the prefix demand_settings. Please note that certain characters (e.g. spaces, slashes are not allowed as tree item names in the GeoDMS and should thus be avoided. The demand settings of the new table can then be adjusted to, for example, change the amount of urban land per inhabitant (see also Section 3.2).

To be able to use the new demand settings created in the demand.mdb in the specification of a new demand set the following steps are necessary:

1. First it is necessary to create a reference to the new demand settings in the metadata.mdb. This should be done by adding a new record to the DemandSettingsSet table in the metadata.mdb with the exact name of the new demand settings table excluding its demand_settings prefix. When these names do not match the demand module in the EU-ClueScanner will not be able to combine data from the two databases and produce an error.
2. The new settings can then be combined with the other demand base data sets (e.g. a demographic scenario from Phoenix model) in the DemandSets table to create a (new) demand set. Please note that the DemandSets table has to be reopened in order to read the newly defined DemandSettingsSet. The new or revised demand sets can then be used to define a new policy alternative as was explained above.

Adding new demand base data

New base data referring to demographic developments or the demand for agricultural commodities can be added to the demand.mdb. Such new demographic or agricultural projections can be created with the PHOENIX or LEITAP/IMAGE runs or be inferred from other sources. To be able to directly use the new demand input it is necessary that exactly the same table format is used as in the current demand base data. This means that, for example, the same regional division (mostly countries) and units (inhabitants) are used.

For the LEITAP/IMAGE model a structured file format is agreed upon. The results of a LEITAP/IMAGE run are delivered as .csv files (comma separated value files commonly used for data export that in this case use a semicolon as separator) with the following attributes:

- Country;
- Year;
- PermanentPasture;
- AreaArableLand;
- AreaArableBiofuels;
- AreaPerennialBiofuels.

New LEITAP model run results should be stored as .csv files in the \projects\EUClueScanner\data\Demand folder. They can be imported in the demand.mdb (through the options external data -> textfile) as one table for each .csv file. The .csv filename should correspond with the name of the table. In the GtapSets table in the metadata.mdb a record is then added for each imported csv table in the demand.mdb. In this GtapSets table, each Gtap set has an ID (autonumber), a name, a tablename (which needs to match with the name of the table in the demand.mdb) and a SocEconDbName. This last attribute refers to additional databases for these LEITAP results with economic indicators, stored in the \projects\EUClueScanner\data\indicator_econ folder. In the DemandSets table the name of the GtapSet is selected to specify which LEITAP model run results are used.

After the .csv files are imported in the existing structure in the demand.mdb database they can be used to calculate new demand specification files when they are referred to in a new demand set specification (i.e. a new record in the DemandSets table as was described above). In this version of the EU-ClueScanner the demands are calculated at the national level. The module could also function at sub- or supra-national level. This implies the data used in the module is available or can be (des)aggregated to the requested level. Technically it is possible to calculate the demands at other regional levels (as long as the number of regions does not become too large). But some adaptations to the basic model configuration are needed for which some technical support may be required for non-expert users.

3.5 Adding new spatial data sets

New spatial data sets (with a new name) referring to, for example, accessibility or spatial policy can be added to the model. Typically, these will be created in a GIS environment. They should have the same grid specifications (extent, location, and cell size) and be created in the same projection (see Appendix 3) as the other data sets available in the model. They can be stored together with all other datasets in SourceData\EuClueScanner\Drivers. After placing data in this location, references have to be made to it in the EU-ClueScanner. In the Microsoft Access-database 'Metadata.mdb', which can be found in the Projects\EuClueScanner\data directory, a row can be added to the FactorData table specifying the correct FileName and other characteristics. The data set can now be included in the definition of simulation runs (e.g. as factor in the calibration of the model, see Section 4.2, or as a new allow driver map, see Appendix 4) or be used in indicator calculations. Note that spatial datasets that are used to increase or decrease the local suitability values for a land-use type in the context of a policy alternative are applied in simulation as part of a single locspec file (see Appendix 4).

4 Adjusting the EU-ClueScanner model

Before discussing possible adjustments to the existing EU-ClueScanner model configuration, it is good to highlight two specific model characteristics: the *administrator mode* and the GeoDMS *script files* that comprise the model.

For more advanced users a specific *administrator mode* exists that allows the inspection of basic model settings (e.g. units, standard regional divisions, classification schemes for the visualisation of data), many in-between steps in simulation, auxiliary data files and templates used for the creation of indicator values etcetera. This mode is active when the administrator mode tick box is clicked in the General Settings tab in the Options window that appears by clicking Ctrl+Alt+O (see Figure 5). By now you may be expert enough to use this mode.

Most of EU-ClueScanner components are programmed in the GeoDMS *script files* that can be edited with any text editor. The user interface only offers limited functionality to edit these files, as previous experience has learnt that direct editing of the underlying script files offers more flexibility, a more compact and robust programming environment and a better overview of the context of these files and their relation with other model components. The GeoDMS files define the actual modelling application and offer an open and flexible environment to manipulate its many components. The definition of indicator calculations, the inclusion of new spatial datasets and model run characteristics are also defined in the GeoDMS files. For a complete description of the naming conventions, available operators and functions, potential configuration errors and many other aspects of GeoDMS scripting, see the modellers guide at http://www.objectvision.nl/GeoDMS/ under modelling.

4.1 Replacing land-use base data

The current EU-ClueScanner model uses the CLC2000 data to represent current land use. In the near future a revised version (CLC2006) is expected to be released, that would allow the incorporation of a more recent starting year for simulation. To replace the current land use data set a few steps are necessary.

First a reclassified version of the new land-use dataset must be created that uses the same land-use classification and has exactly extent and projection as the current land-use base data set. Table 2 specifies how the current, extensive set of CLC types is reclassified to the classification used in the model. It is important that this reclassification scheme is followed closely to prevent the introduction of inconsistencies with previous simulation results. The reclassified data should then be stored in the SourceData folder, closely following the projection and data file format specifications listed in Appendix 3. This new data set can then replace the current version stored in \SourceData\EUCS_100m\landuse.

A second, more complex step is adjusting the demand settings (see also Section 3.2). This calls for a thorough analysis of the current specification and a revision of those settings that are not appropriate anymore in the demand_settings tables in the demand.mdb. This may, for example, relate to the year set aside subsidies cease. Exactly which settings should be changed and how this should be done, depends on the year the new base data refer to and the scenario and policy alternative under consideration.

Then, the the simulation period (start and end year of simulation) have to be specified in the PeriodSet column in the Scenarios table of the metadata.mdb. A new period may have to be referred to with a new name in this column. When this is done, the characteristics of this new period have to be specified in the default.dms script file in the folder \Projects\EuClueScanner\cfg\default. This new specification can be based on already existing examples. In fact, copying the lines of script relating to an existing period and editing these may the most efficient strategy.

Finally, the spatial data sets related to the age of land use and dynamic simulation should be considered carefully. The age of land use is stored in the age0.asc file in the folder \SourceData\EuClueScanner\LandUse and may have to be updated. Ideally this calls for a detailed transition analysis comparing land use in the initial base year (2000) and the new base year. Based on this, locations where land use remained the same will increase in age (with the difference in years between the two observation moments), whereas changed locations will receive a new age of 0 years. Also the dynamic driver files (stored in \SourceData\EuClueScanner\DynamicDrivers) contain explicit mentioning of specific years and may have to be adjusted. Again this depends on the new period of simulation and the characteristics of the policy alternative under consideration.

When new land-use base data become available, the user can also to consider updating the calibration. However, as the driving forces that influence land-use patterns are considered to be relatively stable over time this is not essential.

4.2 Revise calibration

Calibration is the process of tuning a model in such a way that sensible results can be obtained. This is normally done through a statistical (logistic regression) analysis that describes the relation between a number of spatially explicit explanatory variables (e.g. accessibility, soil type and climatic variables) and an observed (to be explained) land-use pattern (Pontius Jr. et al., 2008). These explanatory variables are called factor data in the model.

In case of the EU-ClueScanner a separate calibration was performed for each individual country, to reflect the fact that driving forces behind land-use change may differ between countries in specification and explanatory power. This means that different factors are used to explain land-use patterns per country; in general about 10 different factors are used for a country from the total list of over 60 factors described in Appendix 2. In addition, explanatory variables are used that describe land use in the direct environment (or neighbourhood) of a grid cell.

A revision of the calibration becomes necessary when new land-use or factor data are added to the model, or when a land-use type is introduced. In this case a new statistical analysis should be performed that uses an observed land-use (e.g. of the new base year) as to be explained variable and a set of explanatory variables. Standard statistical software such as SPSS can be used to do this type of analysis. To keep calculation times within reasonable bounds it is advised to limit the number of observations, depending on the calculation power and available internal memory in the computer. The sample should preferably be structured with a minimum distance between the observations to limit spatial autocorrelation. In addition it is suggested to limit the number of to be explained variable values (land-use types) to about 9 and to make sure that all land-use types have sufficient observations (at least 2% of the total amount of observations) to prevent the creation of statistically insignificant results. A thorough statistical background is required to perform such analyses and assess the value of their outcomes.

For the JRC version of the EU-ClueScanner multinomial logistic regression was applied using SPSS. Appendix 5 lists the main steps in this approach. In multinomial regression the probability of occurrence of a certain land-use types is estimated in relation to the probability that other land-use types will occur. This implies that when a single new land-use type is added to the model the statistical analysis should be performed for the complete set of land-use types. It is not sound to only analyse the occurrence of a single land-use type using, for example, binomial logistic regression and use that in combination with previous multinomial regression results.

4.3 Edit or add indicator definitions

The indicators are defined in a set of GeoDMS script files that are stored in the folder \projects\EuClueScanner\cfg\Default. Initial reference to the indicators is made in the IndicatorData.dms file. This file also defines some of the units and legends that are used in their calculation and representation. Their actual calculations are defined in the indicator-specific GeoDMS files in the IndicatorData subfolder. Additional spatial data sets that are needed for the calculation of the indicator values are stored in the \SourceData\EuClueScanner\Indicators folder. These data sets are independent of the policy alternatives and are thus stored in this general folder that also contains the factsheets describing, for example, the origin and methodology of the indicators.

The definition of the indicators can be edited by manipulating the corresponding GeoDMS files. Obviously this requires a thorough understanding of the current indicator definitions and the basics of the GeoDMS scripting language. Straightforward changes can, however, already be made by relatively novel users of the GeoDMS language.

New indicators can be added by defining them in separate GeoDMS files and referring to them in the IndicatorData.dms file through an include statement (e.g. #include <NewIndicator.dms>, see similar references in IndicatorData.dms). The GeoDMS language offers a large set of operators that allow the user to define new quantitative evaluation measures. The operators include more complex spatial analysis options generally found in more advanced GIS-packages that relate to, for example, combining, comparing and overlaying individual data layers, defining contiguous areas with the same raster values, calculating distances or network analysis. A full list of these operators is available in the GeoDMS Modeller's guide that can be found under modelling on: http://www.objectvision.nl/GeoDMS/. Examples of other indicators developed within the same modelling environment are described elsewhere (Bubeck and Koomen, 2008).

4.4 Link EU-ClueScanner to other models

The EU-ClueScanner model can be linked with other spatial models related to either derive more specific input for simulation (e.g. changed regional agricultural demand from CAPRI, or revised accessibility maps from TRANSTOOLS) or provide additional impact assessments (e.g. through coupling with a hydrologic model). These model couplings require a clear vision on the anticipated level of integration and a careful consideration of the thematic, temporal and spatial resolution of the involved models. A model coupling can be a straightforward exchange of output and input data when the considered land-use types (thematic resolution), time period (temporal resolution) and regional divisions or grid cell size (spatial resolution) are aligned. Substantial efforts are, however, required when the models need to be adjusted. This would, for example, be the case when additional agricultural land-use types have to be inserted in the land-use model to allow the input from an agro-economic model such as CAPRI.

Although coupling of the modelling framework to alternative detailed indicator models is possible it may not always be recommended. Many indicator models are based on detailed understanding of processes at the micro-level (e.g. causing greenhouse gas emissions) and are therefore subject to scaling errors when applied to a 1 km spatial resolution. It is thus important to choose indicator models that are suited for and sensitive to the information provided by the EU-ClueScanner framework at the spatial and temporal scale of analysis. Also a good fit with the thematic content of the different land-use classes is necessary. For example, due to the limited differentiation currently possible in land-use intensity, no specific indicator on the agricultural biodiversity is included in the modelling system given the dependence of this indicator on detailed changes in land-use intensity.

4.5 Adjust land-use typology

Adjusting the land-use typology to, for example, include new types of land use is a complex task that involves several of the activities described above. It involves the steps mentioned below.

First the new land-use types have to be defined spatially. This will most likely be a refinement of the existing types of land use (e.g. a distinction in high and low density urban fabric). In that case it is necessary that the land-use base data will be updated (see Section 4.1). Care should be taken the new land-use types completely overlap the existing land-use types it replaces. This type of data preparation will typically take place in an ArcGIS environment.

A next step consists of the definition of the most suitable locations for the new land-use types. This implies a revision of the statistical calibration that defines the most likely locations for land-use types according to suitability factors (alloc1.reg) and neighbourhood enrichment (alloc2.reg). See Section 4.2 for this step. In some cases it may be possible to skip the statistical calibration, for example when a new land-use type is expected to have the same basic spatial behaviour as another type of land use.

Subsequently, it is important to consider which other factors influence the future location of the new land-use type and how this relates to the main model parameters. Will it be strongly related to neighbouring land use (in which case the weight for the neighbourhood enrichment should be set at a high value in neighmat.txt)? Will it have a strong resistance to change (specified in main.1)? Are specific transition allowed or impossible (specified in allow.txt)? Will certain location characteristics (e.g. spatial policies) influence the location of the land use type (to be included in locspecx.asc)? Please note that it is essential that reference to the new land-use type is made in the main.1 file. This file specifies amongst others the total amount of land-use types that are simulated and their internal codes. Especially the main.1, neighmat.txt and allow.txt files should be checked on their proper treatment of the new land-use types. As usual Appendix 4 provides info on the exact characteristics of these files.

Finally a future demand for land for the new type of use should be specified in the demand.in1 files. These list the expected total amount of land per year and can be created with the demand module or other tools.

5 Validating the JRC version at 100m resolution

This section describes the way the 100m version of the EU-ClueScanner was validated by comparing simulated land use for 2000 with observed land use in CLC2000. Firstly, an account on the applied methodology is provided, followed by the validation results. Based on that, the ability of the model to produce sensible land-use patterns will be discussed.

5.1 Validation methodology

The method applied to evaluate the model's performance was a pixel-by-pixel comparison between simulated land use for 2000 and observed land use in CLC1990 and CLC2000. The simulated land use maps for 2000 resulted from the model runs described in Section 1.4 that follow the calibration method documented in Appendix 5. In these model runs suitability for each land-use class is defined according to the statistical analysis of the observed land-use patterns in CLC1990. More specifically we chose to use the validation2000MNL model runs that follow closely the multinomial logit specification that was also used in the statistical analysis. In this validation effort, the claims per land-use type for 2000 were specified by assigning the exact quantities corresponding to the observed amount of land for these land-use types in CLC2000.

For the validation we followed a similar approach to that carried out in a previous assessment of contemporary land-use change models (Pontius Jr. et al, 2008). That study distinguished three possible two-map comparisons:

- CLC1900-CLC2000, which characterises the observed land-use change (Appendix 6);
- CLC1990-MNL2000, which refers to the land-use change predicted by the model;
- CLC2000-MNL2000, which permits to determine the accuracy of the prediction.

Based on the available maps it is also possible to perform a three-map comparison that allows distinguishing the correct prediction due to persistence of land use from well-predicted changes in land use. This is an important distinction as the amount of change is normally limited. Comparison methods that compare the complete simulation map with the complete observation map are strongly influenced by the static patterns and tend to overestimate the predictive power of land-use models. Therefore it is more meaningful to focus on the amount of correctly predicted change.

Based on the comparisons of the three available maps we can determine both quantity and location agreement between observed and simulated land use patterns. Quantity agreement is obtained by comparing the aggregate totals of all land-use classes in the simulated and observerd land use. To describe location agreement we first create the following maps:

- well-predicted change (A);
- observed change predicted, but as a wrong gaining class (B)
- observed change predicted as persistence (C)
- observed persistence predicted as change (D)

Based on that, location agreement was quantified using the following three statistic measurements:

- figure of merit = A / (A+B+C+D), which measures the accuracy of the model in predicting land-use change;
- producer accuracy = A / (A+B+C), which gives the proportion of pixels that the model predicts accurately as change, given the observed change;
- user accuracy = A / (A+B+D), which calculates the proportion of pixels predicted accurately as change, given the model predicted change,

5.2 Validation results

By way of example, the results of the validation method introduced above are described here for the simulation of land use for 2000 in the Netherlands. From Table 9, it can be concluded that there is a strong agreement between the quantities of observed and predicted land-use change. This is exactly what we expect since the simulated amounts of land per land-use class were derived from the CLC2000. There is a small disagreement, however, that can be explained by the fact that the classes that we consider static in the model (Infrastructures, Other Nature and Water) did change between the observed years. The approximately 7000 hectares increase in the classes that we do not simulate is therefore added to the classes that are simulated. This correction, that was already applied in the demand.in1 files that were used as input for these model runs, will cause an overestimate of the amount of change for these classes and thus a somewhat poorer performance in the validation.

Table 9 Observed and predicted land use change per land use type for 1990-2000 in the Netherlands

Aggregated land use classes	Observed Change		Predicted Change		Difference between predicted and observed change	
Urban Fabric	55565	18,9%	56308	19,1%	743	0,2%
Industry and related uses	24611	46,2%	24773	46,5%	162	0,2%
Arable land and permanent crops	-27755	-2,5%	-25411	-2,3%	2344	0,2%
Pastures	-75033	-5,1%	-72004	-4,9%	3029	0,2%
Forests	8195	2,7%	8871	2,9%	676	0,2%
Semi natural vegetation	7325	12,7%	7463	12,9%	138	0,2%
Infrastructures	2842	13,1%	0	0,0%	-2842	-11,6%
Other Nature	777	0,2%	0	0,0%	-777	-0,2%
Water	3473	1,0%	0	0,0%	-3473	-1,0%

Note: the percentages relate the amount of change to the total amount of land for a land-use class in 1990.

Figure 11 shows that location agreement between the simulated and observed land use in 2000 is mostly related to well-predicted persistence of land use. Indeed, well-predicted change occurs so infrequently that it can be hardly perceived in the map. This becomes even clearer from Table 10. This table further indicates that almost all (94%) of the change predicted by the model was observed persistence.

The enormous overestimate of change essentially results from the way the model deals with the locations classified as Heterogeneous Agriculture Areas in the original Corine typology and that were subsequently randomly assigned to Arable Land and Pastures. As a matter of fact, this outcome could be almost entirely explained by interchanges between these two classes: while a transition of 23,572 ha from Pastures to Arable land and an opposite transition of 3,108 ha was observed in 1990-2000, the model simulated for the same period 151,481 ha and 146,616 ha respectively (see the transition matrices for CLC1990-CLC2000 and CLC1990-MNL2000 in Appendix 6 and 7 for more detailed results).

The overestimation of change is exemplified in Figure 12 and Figure 13. These figures show that in some regions where 'chess-board' patterns exist (that reflect the random assignment), many land-changes are simulated where the observed patterns remain the same. Nevertheless, it should be noted that the landscape structure is maintained, even though land-use change is overestimated.

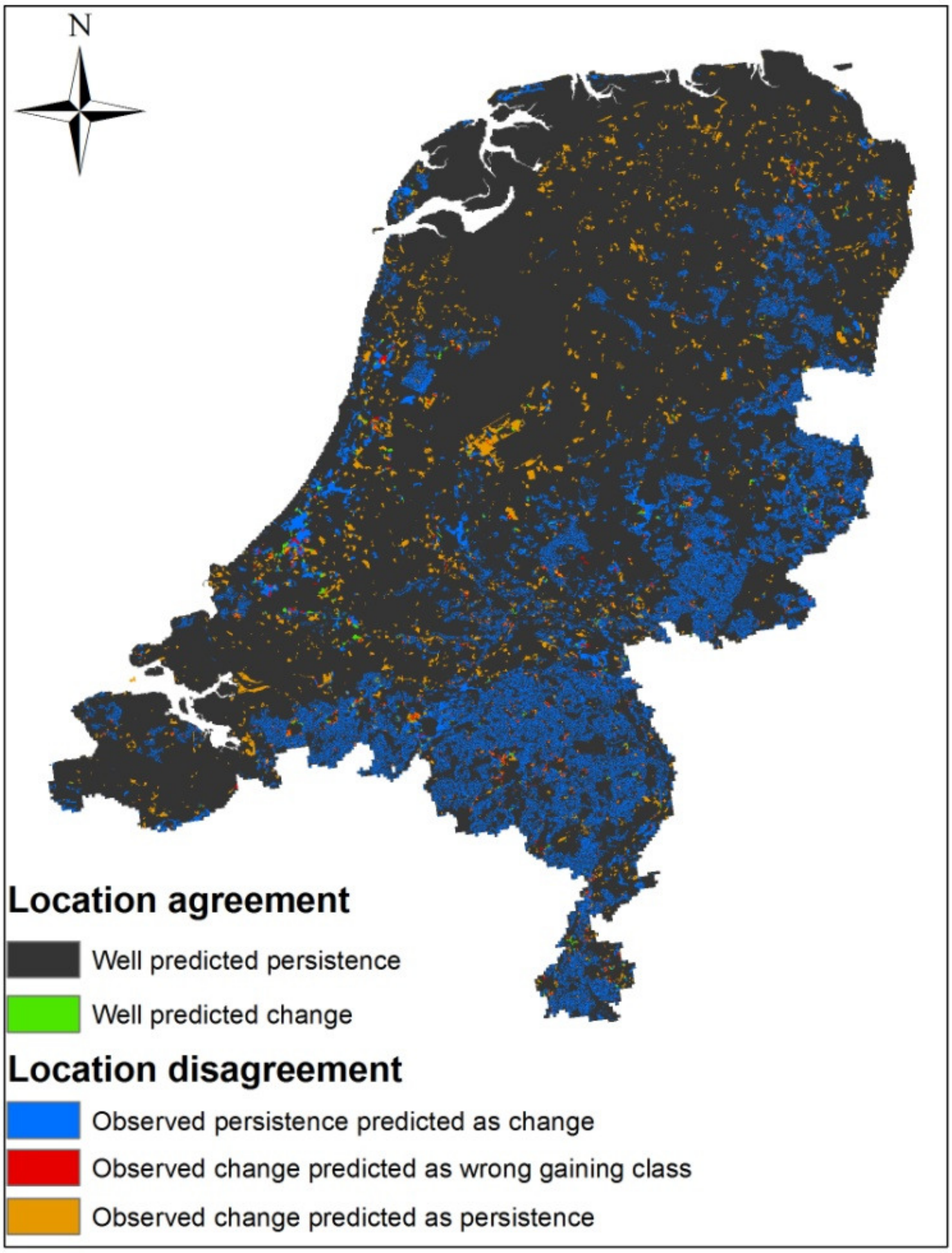


Figure 11 Three-map comparison for simulated and observed land use change in 1990-2000 in the Netherlands.

Table 10 Pixel-by-pixel comparison between simulated and observed land use change in 1990-2000 in the Netherlands

Persistance well predicted	Observed persistance predicted as change	Well predicted change	Observed change predicted as wrong gaining class	Observed change predicted as persistance
2726474	422752	9933	18131	116653

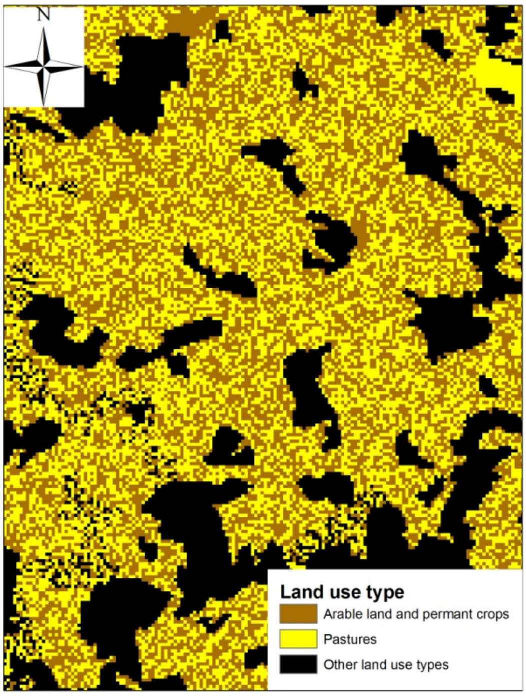


Figure 12 Detail of an area previously classified as Heterogenous Agricultural Land in the original Corine typology in CLC2000.

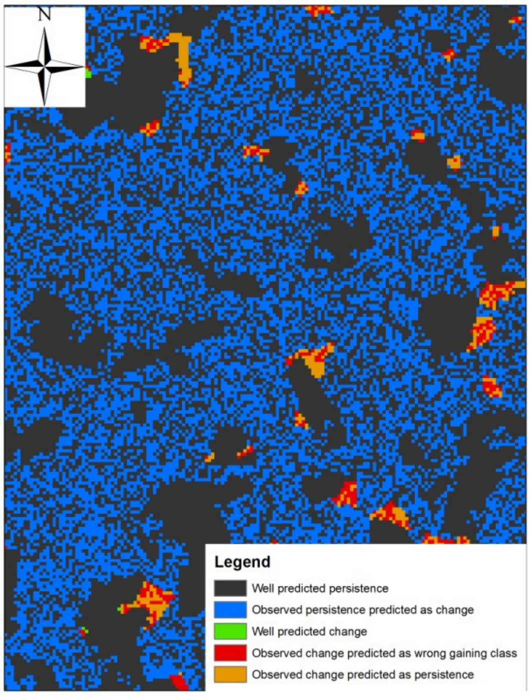


Figure 13 Outcome of the model simulation for 2000 in the same area.

Hence, it can be concluded that the model predicts much more land-use change than is desirable. This is confirmed by the statistical measurements of the models performance (Table 11). Both the Figure of Merit, that measures the overall accuracy of the model in predicting land-use change, and User Accuracy, that relates the well-predicted change to the total amount of change predicted by the model, are extremely low. The Producer Accuracy that relates well-predicted change to the observed amount of change is slightly higher.

Table 11 Statistical measurements of the model's performance for simulation of land-use change in 1990-2000 in the Netherlands

Figure of Merit	Producer Accuracy	User Accuracy
1,75%	6,86%	2,20%

It must be mentioned, however, that these statistical indices can be misleading in assessing the ability of model in predicting sensible land use patterns. Actually, they provide an indication of the location agreement between observed and simulated land-use change, which can prove to be a deceptive issue while dealing with a model using such a fine resolution for a large area. Pontius Jr. et al (2008) state that Figures of Merit tend to be larger when the amount of net change in the reference maps is higher. Since the total amount of net observed change accounts for less than 4% of the Netherlands total area, it is not surprising that a small value for the Figure of Merit was obtained. It is more difficult to correctly predict such a rare feature than a more common phenomenon.

In fact, for countries such as Austria where land-use change accounted for only 0.3% the total area, a Figure of Merit as low as 0.12% was obtained (see Appendix 7). Similar patterns have been encountered while simulating land-use change in other countries, showing that the model performs consistently for different regions. Therefore, it is recommendable for future research to carry on additional validation steps, making a distinction between near-location and far-location disagreement by converting the maps to a coarser resolution (Pontius Jr. et al, 2008), to better understand the performance of the model.

5.3 Conclusion

Calibration and validation are continuous processes that aim to improve the performance of land-use change models. It is very hard, if not impossible, to define the ultimate calibration for a model. Proper model settings depend on the type of application and associated time period and objective of the study. For shorter time period it is normally wise to create an application that shows little change (limited conversion elasticity, strong importance of neighbouring cells), whereas scenario-based studies for longer time periods may call for more freedom in the allocation process.

Based on the calibration and validation efforts undertaken for this study we have several suggestions for further improvement. These are introduced with reference to some general observations that were made while validating the EU-ClueScanner model. Figure 14 depicts these observations for a small part of the Netherlands.

The blocky appearance that sometimes appears in simulated land-use patterns indicates the coarseness of part of the underlying datasets. Not only are these data available at a 1km resolution, but most of these pan-European maps (related to for example soil characteristics or climatic variables) typically describe the landscape in large homogenous areas of hundreds of square kilometres. The performance of the model would greatly improve with more detailed spatial data. Especially for distance relation maps it is not so difficult to create these for European territory.

The scattered pattern related to the reclassification of heterogeneous CLC classes was discussed extensively above. This can be solved simply by assigning these classes to one aggregated class (e.g. arable land) only. Alternatively, the reclassification can be followed by a post-processing step to generate larger spatial units. Ideally the model should be recalibrated after this, since the spatial relations will change. But as these classes only take up a small proportion of the pastures and arable farming classes this may be necessary.

The spatial mismatch between the relatively coarse NUTS2 delineations and the 100m resolution can be solved by creating a more refined spatial data set describing NUTS2 regions. The initial simulation problems at the very edges of the countries have, however, been solved through a different way of dealing with no-data areas. Any no-data location in the land-use base map is now excluded from the allocation process.

The strong link with initial land use in the simulation process can either be caused by land-use specific conversion elasticities or by the demand. In the figure below it is especially the strong decrease in pastures that causes the new urban areas to follow former pastures. These may indeed very well be preferable locations for development. To correctly simulate these processes it is important to distinguish between profitable and marginal agricultural areas. In addition spatial policy constraints should be added to incorporate local regulations. Inclusion of such data sets, in addition to predominantly biophysical data sets included now, would enhance model performance.

The strong influence of neighbourhood relations may also reflect actual spatial processes, but for longer simulation periods other location factors may become more important. Here again inclusion of more detailed spatial data related to the full range of potential biophysical, economic and planning-related driving forces should help the model to better capture the most important spatial processes.

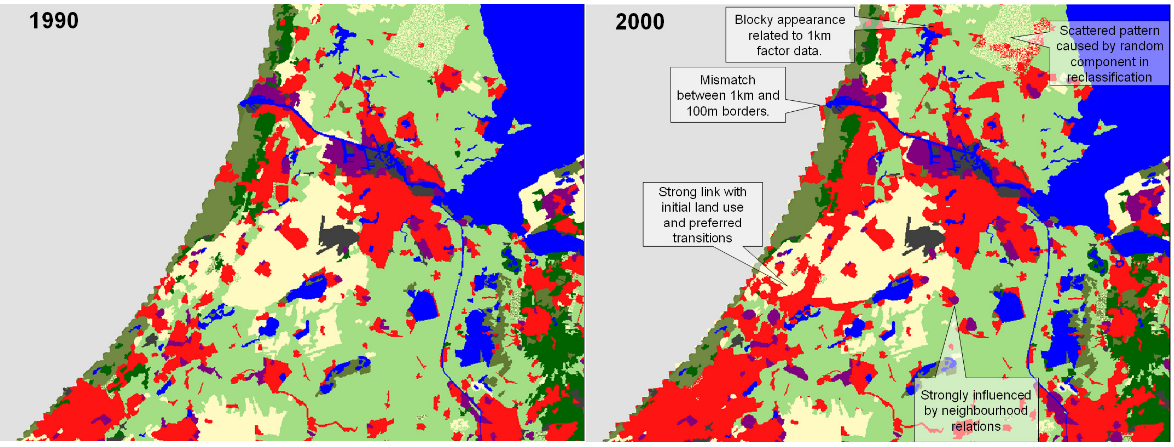


Figure 14 General Observations made while validating the EU-ClueScanner model.

Appendix 1 Overview of original CLC2000 classes

Corine land cover classes

1. Artificial surfaces

1.1 Urban fabric

- 1.1.1. Continuous urban fabric
- 1.1.2. Discontinuous urban fabric

1.2 Industrial, commercial and transport units

- 1.2.1. Industrial or commercial units
- 1.2.2. Road and rail networks and associated land
- 1.2.3. Port areas
- 1.2.4. Airports

1.3 Mine, dump and construction sites

- 1.3.1. Mineral extraction sites
- 1.3.2. Dump sites
- 1.3.3. Construction sites

1.4 Artificial, non-agricultural vegetated areas

- 1.4.1. Green urban areas
- 1.4.2. Sport and leisure facilities

2. Agricultural areas

2.1 Arable land

- 2.1.1. Non-irrigated arable land
- 2.1.2. Permanently irrigated land
- 2.1.3. Rice fields

2.2 Permanent crops

- 2.2.1. Vineyards
- 2.2.2. Fruit trees and berry plantations
- 2.2.3. Olive groves

2.3 Pastures

- 2.3.1. Pastures

2.4 Heterogeneous agricultural areas

- 2.4.1. Annual crops associated with permanent crops
- 2.4.2. Complex cultivation patterns
- 2.4.3. Land principally occupied by agriculture
- 2.4.4. Agro-forestry areas

3. Forest and seminatural areas

3.1 Forests

- 3.1.1. Broad-leaved forest
- 3.1.2. Coniferous forest
- 3.1.3. Mixed forest

3.2 Shrub and/or herbaceous vegetation associations

- 3.2.1. Natural grassland
- 3.2.2. Moors and heathland
- 3.2.3. Sclerophyllous vegetation
- 3.2.4. Transitional woodland shrub

3.3 Open spaces with little or no vegetation

- 3.3.1. Beaches, dunes, and sand plains
- 3.3.2. Bare rock
- 3.3.3. Sparsely vegetated areas
- 3.3.4. Burnt areas
- 3.3.5. Glaciers and perpetual snow

4. Wetlands

4.1 Inland wetlands

- 4.1.1. Inland marshes
- 4.1.2. Peat bogs

4.2 Coastal wetlands

- 4.2.1. Salt marshes
- 4.2.2. Salines
- 4.2.3. Intertidal flats

5. Water bodies

5.1 Inland waters

- 5.1.1. Water courses
- 5.1.2. Water bodies

5.2 Marine waters

- 5.2.1. Coastal lagoons
- 5.2.2. Estuaries
- 5.2.3. Sea and ocean

Appendix 2 Overview of spatial data sets

This appendix provides an overview of two types of spatial data sets:

- the 52 factor data sets that are used as independent factors in the statistical calibration of the model. These are called upon in the alloc1.reg and alloc2.reg files. The datasets are made available from the EURURALIS 2.0 project and are described in more detail in the meta data sheets (adapted from: Overmars et al., 2006) that are included as part of the details pages in the model.
- the 13 allow driver maps (X1-X13) that specify the spatially explicit settings for the conversion matrix. These maps are called upon in the allow.txt files. The meta data sheets that are included as part of the details pages in the model describe these maps in more detail.
- the 100m resolution factor data sets that are used in the calibration of the JRC model version.

ID	Name	Description	Coverage
Factor data sets used in calibration of the model (1km resolution)			
1	ACCESS1_06M	Timecost to cities > 100.000 (seconds)	missing Turkey (Cyprus and Malta are reasonably ok)
2	ACCESS2_06M	Timecost to cities > 500.000 (seconds)	missing Turkey and Cyprus and Malta
3	ACCESS3_06M	Timecost to ports > 15.000 kTon/year (seconds)	missing Turkey and Cyprus and Malta
4	ACCESS4_06M	Timecost to cities > 650.000 (seconds)	missing Turkey and Cyprus and Malta
5	ACCESS5_06M	Euclidean distance to nearest road of level 0 or 1 (metres)	missing Turkey and Cyprus and Malta
6	ACCESS6_06M	Timecost to major airports (seconds)	missing Turkey and Cyprus and Malta
7	ACCESS7_06M	Timecost to airports & ports (seconds)	missing Turkey and Cyprus and Malta
8	claycont_06pc	Soil clay content (%)	missing Iceland, Turkey, Cyprus and Malta
9	ddw_shortage	Water deficit growing season (mm)	ALL
10	dem_final	Elevation based on SRTM3 NASA-data (m)	ALL
11	envmap01	ALN: Alpine north (0/1)	missing Iceland, Turkey, Cyprus
12	envmap02	BOR: Boreal (0/1)	missing Iceland, Turkey, Cyprus
13	envmap03	NEM: Nemoral (0/1)	missing Iceland, Turkey, Cyprus
14	envmap04	ATN: Atlantic north (0/1)	missing Iceland, Turkey, Cyprus
15	envmap05	ALS: Alpine south (0/1)	missing Iceland, Turkey, Cyprus
16	envmap06	CON: Continental (0/1)	missing Iceland, Turkey, Cyprus
17	envmap07	ATC: Atlantic central (0/1)	missing Iceland, Turkey, Cyprus
18	envmap08	PAN: Pannonian (0/1)	missing Iceland, Turkey, Cyprus
19	envmap09	LUS: Lusitanian (0/1)	missing Iceland, Turkey, Cyprus
20	envmap10	ANO: Anotolian (0/1)	missing Iceland, Turkey, Cyprus
21	envmap11	MDM: Mediterranean mountains (0/1)	missing Iceland, Turkey, Cyprus
22	envmap12	MDN: Mediterranean north (0/1)	missing Iceland, Turkey, Cyprus
23	envmap13	MDS: Mediterranean south (0/1)	missing Iceland, Turkey, Cyprus
24	EUAC120_2006	# of people that reach a location from their home within 120 minutes (persons)	EU15
25	EUAC30_2006	# of people that reach a location from their home within 30 minutes (persons)	EU15
26	EUAC60_2006	# of people that reach a location from their home within 60 minutes (persons)	EU15
27	Geomorf01	Average height difference of 0-20 m: flat (0/1)	missing Turkey
28	Geomorf02	Average height difference of 20-80 m: rolling	missing Turkey

ID	Name	Description	Coverage
		(0/1)	
29	Geomorf03	Average height difference of 80-200 m: hilly (0/1)	missing Turkey
30	Geomorf04	Average height difference of 200-400 m: mountainous (0/1)	missing Turkey
31	Geomorf05	Average height difference of > 400 m: very mountainous (0/1)	missing Turkey
32	IL_2006	Presence of an impermeable layer within the soil profile (0/1)	missing Iceland, Turkey, Cyprus, former Yugoslavia
33	landsc_06	ORN- LandScan population, maximum set to 4000 (persons)	ALL
34	mean_temp_06	Mean yearly temperature	ALL
35	Peat_06	Presence of peat in European soil database of JRC (0/1)	missing Iceland, Turkey, Cyprus
36	poppot_1mi06	Population potential with 12.5 km inflection point, max set to 1 million (persons)	missing Iceland, Turkey
37	poppot_log06	Log (population potential with 12.5 km inflection point)	missing Iceland, Turkey
38	poppot_sum06	Gaussian population potential with 12.5 km inflection point (persons)	missing Iceland, Turkey
39	rain_wc_5m	Accumulated rainfall March-July (mm)	ALL
40	rain_wc_yr	Accumulated rainfall per year (mm)	ALL
41	Salinity	Presence of saline soils according to European Soil Database of JRC (0/1)	missing Iceland, Turkey, Cyprus and Malta
42	slope_final	Slope based on NASA's SRTM3 elevation data (degrees)	ALL
43	soildepth_06	Soil depth based on European soil database of JRC (cm)	missing Iceland, Turkey, Cyprus, Malta, Switzerland, Yugoslavia
44	stoniness100	Stoniness based on European soil database of JRC (0/1)	missing Iceland, Turkey, Cyprus and Malta
45	Swap	Soil water available to plants based on European soil database of JRC (mm)	EU25+2 MINUS nor/swe/fin and Cyprus and Malta
46	sz_landsc_rur	ORN- LandScan population, maximum set to 100 (persons)	EU25+2 MINUS nor/swe/fin and Cyprus and Malta
47	t_min0_1000	Count of months a year with average temperature < 0 degrees C (months)	missing Iceland, Turkey, Cyprus
48	t_plus15_1000	Count of months a year with average temperature > 15 degrees C (months)	missing Iceland, Turkey, Cyprus
49	wr_06	Soil with water restriction (too much water) based on JRC European soil database (0/1)	missing Iceland, Turkey, Cyprus AND and Malta
50	ac_cst_c_m06	Distance to coast for Malta and Cyprus (m)	only Cyprus and Malta
51	ac_pnts_c_m06	Distance to city/airport/port for Malta an Cyprus (m)	only Cyprus and Malta
Allow driver maps used in specification of land-use succession (1km resolution)			
52	X1	Natura2000 (0 or outside = 1; transition will only be allowed outside protected areas)	EU27 for other countries incomplete/ unreliable depending on base data
53	X2	Erosion sensitive areas (0/1)	idem
54	X3	Natura2000 and erosion sensitive areas (0/1)	idem
55	X4	Natura2000, erosion sensitive areas and peat (0/1)	idem
56	X5	Erosion sensitive and peat areas (0/1)	idem
57	X6	Natura2000 and peat areas (0/1)	idem
58	X7	Natura2000 and river flood prone areas	idem

ID	Name	Description	Coverage
		(0/1)	
59	X8	Succession abandoned arable to semi-natural (succession code denoting that this transition is enforced after a specified number of years; coded as 1000+number of years).	idem
60	X9	Succession abandoned pasture to semi-natural (succession code)	idem
61	X10	Succession semi-natural to forest (succession code)	idem
62	X11	Succession abandoned arable to semi-natural for Biodiversity scenario (succession code)	idem
63	X12	Succession abandoned pasture to semi-natural for Biodiversity scenario (succession code)	idem
64	X13	Succession semi-natural to forest for Biodiversity scenario (succession code)	idem
Factor data sets used in calibration of the model (100m resolution)			
65	Slope_100	Slope in 6 classes: - Flat to gently sloping (0-3^{o}) - Gently sloping (3-8^{o}) - Sloping (8-15^{o}) - Moderately steep (15-30^{o}) - Steep (30-60^{o}) - Very steep (60^{o}) Based on Elevation_100	EU-27
66	Sosl_100	Presence of south-facing slope (0/1)	EU-27
67	Natura2000_100	Presence of Natura_2000 areas (0/1)	EU-27
68	Elevation_100	Elevation (m) based on	EU-27

Appendix 3 Spatial data set format details

The EU-ClueScanner uses data of different resolutions (1km and 100m), different projections (Albers and Lambert) and different data file formats (ascii grid and tiff). This appendix specifies these aspects of the data. The EU-ClueScanner 1km (the version for DG Environment) uses data related to a 1km grid defined in the Albers projection. The EU-ClueScanner 100m also contains data related to a 100m grid defined in the currently more common Lambert projection. The specifications of the latter data are also provided to help with potential data exchanges between the different model versions. The EU-ClueScanner 100m contains a lookup matrix that relates the cells of the 100m grid on Lambert coordinates to the cells of the 1km grid on Albers coordinates. This matrix is used to reproject 1km factor data for use in the model application at a 100m grid.

EU-ClueScanner 1km

Projection

The initial data sets in the 1km version of EU-ClueScanner use the WGS-1972 Albers projection with the following specifications:

PROJCS["WGS_1972_Albers",
GEOGCS["GCS_WGS_1972",
DATUM["D_WGS_1972",
SPHEROID["WGS_1972",6378135.0,298.26]],
PRIMEM["Greenwich",0.0],
UNIT["Degree",0.0174532925199433]],
PROJECTION["Albers"],
PARAMETER["False_Easting",0.0],
PARAMETER["False_Northing",0.0],
PARAMETER["Central_Meridian",22.65],
PARAMETER["Standard_Parallel_1",32.5],
PARAMETER["Standard_Parallel_2",54.5],
PARAMETER["Latitude_Of_Origin",51.4],
UNIT["Meter",1.0]]

Ascii format specification

Most spatial data sets in the model are stored as TIFF, but also grids in ascii file format can be read. This file format is supported by, for example, ArcGIS. These files have a header that describes the main characteristics. The standard values for the EU-ClueScanner application for DG Environment are:

ncols	5856
nrows	4092
xllcorner	-3,932,373.5
yllcorner	-1,869,965.125
cellsize	1000
NODATA_value	-9999

In which:
ncols represents the number of columns;
nrows represents the numbers of rows;
xllcorner represents the x-lower left coordinate;
yllcorner represents the y-lower left coordinate;
cellsize represents the cellsize in meters; and

NODATA_value represents the value that the model interprets as a cell with no value.

EU-ClueScanner 100m

Projection

In the 100m model, all datasets use the ETRS 1989 Lambert projection with the following specifications:

PROJCS["ETRS_1989_LAEA_L52_M10",
GEOGCS["GCS_ETRS_1989",
DATUM["D_ETRS_1989",
SPHEROID["GRS_1980",6378137.0,298.257222101]],
PRIMEM["Greenwich",0.0],
UNIT["Degree",0.0174532925199433]],
PROJECTION["Lambert_Azimuthal_Equal_Area"],
PARAMETER["False_Easting",4321000.0],
PARAMETER["False_Northing",3210000.0],
PARAMETER["Central_Meridian",10.0],
PARAMETER["Latitude_Of_Origin",52.0],
UNIT["Meter",1.0]]

Data format specifications

Due to size constraints, the 100m model only supports TIFF files stored with smallest possible bit size (i.e. 1 bit for binary data, 8 bits for other types) and LZW compressed, with the following specifications:

Cell size: 100 m
Size: 60,000 columns * 45,300 rows
Pixel Size = (100;-100)
Corner Coordinates:
Upper Left (1,500,000; 5,430,000)
Lower Left (1,500,000; 900,000)
Upper Right (7,500,000; 5,430,000)
Lower Right (7,500,000; 900,000)

It is possible to store grid data as TIFF with ArcGIS software package, using ArcToolbox™ *Data Management Tools -> Raster -> Raster Dataset -> Copy Raster.* The file extension (.tif) must be specified while naming the file. The projection and format specifications referred above can be defined using the *Environments* options, namely *General Settings (Output coordinate system* and *Extent*) and *Raster Analysis Settings* (*Cell size*). The most straightforward way to define the projection is using the file ETRS_1989_LAEA_L52_M10.prj, which can be found e.g. in the folder SourceData/JRC/landuse. After this, the created TIFF file has to be exported using File -> Export map, in order to define the bit size and compression mode. To export from ArcGIS as TIFF in a compressed (LZW) format may turn out to be difficult. We solved this by specifying LZW as the default option in the ArcGIS preference definition file for TIFF files (C:\Program Files\Common Files\ESRI\Raster\defaults\tiffs.pdf). Notwithstanding its name this is a plain text file that can be edited in any text editor.

When importing the dataset to the model, be sure to include a copy of the projection file in the folder.

Appendix 4 Model specification files

This appendix explains the contents of the most important model specification files. For the DG Environment application at 1km resolution most of these files are stored in country-specific folders in the policy-alternative folders (e.g. ReferenceB1) in the SourceData directory. Only the demand data that are calculated by the demand module are stored in the Demand folder of the LocalData directory.

For the JRC version of the model at 100m resolution most parameter files are stored in the policy-alternative folders (e.g. ReferenceJrc) in the projects/EuClueScanner/ParamSets. The parameter files will usually be stored in the policy alternative folder itself. Only when country-specific conditions apply, these files should be placed in the country-specific directory. This is the case with the alloc files that contain the results of the calibration that was performed on a country-by-country basis. The demand is stored in country-specific directories in the projects/EuClueScanner/Demand/ *PolicyAlternativeName* folder.

The model specification files of the EU-ClueScanner are based on the well-known CLUE model. For people that want to get familiar with the basic elements (including the specification files) of this land-use model, reference is made to the tutorial available for the CLUE model. This can be downloaded from the website www.cluemodel.nl under the download caption. The original Clue help file is included in the Projects\EuClueScanner\doc folder. This extensive set of hyperlinked HTML pages is a valuable source of background information on the basics of this model.

main.1

The main.1 file contains the parameters that determine the configuration of the simulation. All main.1 files contain the following parameters:

Line	Description	Format	Used
1	Number of land-use types	Integer	No
2	Number of regions	Integer	No
3	Max. number of independent variables in a regression equation	Integer	No
4	Total number of driving factors	Integer	No
5	Number of rows	Integer	No
6	Number of columns	Integer	No
7	Cell area	Float	No
8	X-lower left coordinate	Float	No
9	Y-lower left coordinate	Float	No
10	Number coding of the land-use types	Integers	Yes (1km)
11	Codes for conversion elasticities	Float	Yes
12	Iteration variables	Float	No
13	Start and end year of simulation	Integers	No
14	Number and coding of explanatory factors that change every year (dynamic factors)	Integers	Yes (1km)
15	Output file choice	1, 0, -2 or 2	No
16	Region-specific regression choice	0, 1 or 2	No
17	Initialization of land-use history	0, 1 or 2	No
18	Neighbourhood calculation choice	0, 1 or 2	No
19	Location-specific preference addition	Integers	Yes (1km)

With the recoding of the original Clue model to the GeoDMS environment most parameters of the main.1 file have lost their importance as they are defined in other parts of the model or read directly from other input files. This last column in the table above lists which parameters are actually used in the allocation process. With the exception of the conversion elasticity these parameters are only used in the 1km application for DG Environment. It is possible, however, to also apply these parameters in applications at a 100m resolution. If possible, the parameters that are not used are set to 0 in the main.1 file for the current 100m application. However, for some parameters (e.g. number of land-use types) the model checks the values in the main.1 file. In these cases sensible values were maintained.

A more extensive description of the original use of the parameters is provided below:

1. The number of land-use types that are distinguished in simulation. A maximum of 12 different land-use types can be identified.
2. The number of regions, default is 1 and the maximum number of regions is 3. Normally a study area consists of only one region, but for study areas that are divided in parts with a very different behaviour of land-use types, more regions can be used. Please note that in the EU-ClueScanner separate models are specified for individual countries that are not subdivided in smaller regions.
3. The maximum number of independent variables in a regression equation. This is the number of driving factors of the regression equation with most variables.
4. The total number of driving factors that are addressed, this means the number of driving factor files per year.
5. Number of rows of the input grids.
6. Number of columns of the input grids.
7. The cell area of the grid cells, this should be in the same units as in the demand file. In our case this is 1 km^2.
8. X-coordinate of the lower left corner, this is also indicated in the header of the ArcView and ArcGIS ASCII files.
9. Y-coordinate of the lower left corner, this is also indicated in the header of the ArcView and ArcGIS ASCII files.
10. The internal number coding of the land-use types used in the simulation process. This should start with 0 for the first land-use type (= Clue10-type 0 introduced in Table 2), 1 for the second land-use type, etc. This line of script is also used to state which land-use types are simulated together (i.e. have the same demand for land). This is the case with the recently abandoned arable land (Clue10-type 5), forest (Clue10-type 7) and recently abandoned pasture land (Clue10-type 8) in the example below that are all treated as natural vegetation (Clue10-type 3).
11. The codes for the allowed changes and behaviour of the land-use types (conversion elasticities) have to be indicated for each land-use type, following the order of line 10. This must be a value between 0 and 1.
    0: Means that all changes for that land-use type are allowed, independent from the current land use of a location. This means that a certain land-use type can be removed at one place and allocated at another place at the same time, e.g. shifting cultivation.
    >0...<1: Means that changes are allowed, however, the higher the value, the higher the preference that will be given to locations that are already under this land-use type. This setting is relevant for land-use types with high conversion costs.
    1: Means that grid cells with one land-use type can never be added and removed at the same time. This is relevant for land-use types that are difficult to convert, e.g., urban settlements and primary forests. A value of one stabilizes the system and should thus be used with care.
12. Iteration variables: three numbers should be specified:
    Iteration mode: with the options: 0, which means that convergence criteria are expressed as a percentage of the demand; or 1, meaning that these criteria are expressed as

absolute values (units of demand)
First convergence criterium: average deviation between demanded changes and actually allocated changes (default for %: 0.35; otherwise minimal 1 grid cell divided by the number of land-use types).
Second convergence criterium: maximum deviation between demanded changes and actually allocated changes (default for %: 3; otherwise should minimally be the percentage of 1 cell change of the land-use type with the smallest demand, e.g. for a land-use type with a demand of 200 ha and a cell area of 4 ha, the value should be minimally 4/(200/100) = 2).

13. Start year and end year of the simulation.
14. Number of dynamic driving factors (e.g. population density or climate related variables). This number should be followed by the coding of these explanatory factors. The example below mentions 5 dynamic factors (numbers: 33 34 39 40 46) that thus should have input files for each year in simulation. These file codes correspond to the numbers listed in the FactorData table in the metadata.mdb. Appendix 2 also lists these numbers. Note that these files are currently ascii grids at a 1km resolution in Albers projection. When no dynamic drivers are used a '0' should be paced on this line.
15. Choice for the type of output file:
    1. ArcView-ArcGIS headers will be printed in output files;
    0. No headers in output files (suited for e.g., Idrisi).
    -2. No headers in output files, suppress information in log-file on iteration procedure.
    2. ArcView-ArcGIS headers will be printed in output files, suppress information in log-file on iteration procedure.
    Note: If the ArcView-ArcGIS file type is chosen, all input grid files should contain an ArcView-ArcGIS header.
16. Choice for a region specific regression:
    0. No different regressions for different regions
    1. Different regressions for different regions; demands for each region specifically defined
    2. Different regressions for different regions; demand for all regions aggregated.
    The default is value 0.
17. When temporal dynamics are taken into account it is necessary to know the land-use history. Often this is not known and a random number has to be assigned. One can choose between three options:
    0. The initial land-use history will be read from file age.0, which should contain a grid with, for every pixel, the number of years that the pixel is used for the current land-use type.
    1. A random number will be assigned to all pixels to represent the number of years that the current land use is already found at that location according to the standard seed for the random number generator. With this option two runs will result in the same random number, which is useful for comparison.
    2. A random number will be assigned to all pixels to represent the number of years that the current land use is already found at that location with a different random number generator. Two consecutive runs will start with different land-use histories.
    For option 1 or 2 an additional number should be added that indicates the maximum number of years that can be generated by the randomizer.
18. Choice for using the neighbourhood function:
    0. Neighbourhood function is not used.
    1. Neighbourhood function is used in simulation.
    2. Only the influences are calculated, the influence files are saved directly, no simulation.
19. Variables for location specific preference addition. The first number is a switch: activate the function (1) or not (0). If the switch is set to 1, it should be followed by, for each land-use type, the fraction of the preference addition that is added to the probability as calculated in the regression.

Below is an example of a main.1 file used in the 100m version of the EU-ClueScanner model.

```
line 1    6
line 2    1
line 3    0
line 4    0
line 5    0
line 6    0
line 7    0
line 8    0.0
line 9    0.0
line 10   0 1 2 3 4 5
line 11   1 0.8 0.5 0.5 0.5 0.5
line 12   1 0 0
line 13   0 0
line 14   0
line 15   2
line 16   0
line 17   0
line 18   1
line 19   0
```

demand.in1

The required amount of land (demand) per year, per land-use type, per region is stored in demand.in1 text files. These files contain for each year that needs to be simulated the demand in either km^2 for the version with a 1km resolution (see example below), or hectares for the version at a 100m resolution. The first line specifies the number of years for which demand is included in this file. In our case this is 31 (the initial year and 30 subsequent simulation years). After that, every line contains the demands for the respective land-use types for one year. The order of the land-use types should be the same as in the main parameter file (main.1) and the second line of the file contains the demands for year 0. Note: the total demand for all land-use types together should be equal to the total land area from the region file and should remain constant for each year.

Below is an example of the first 7 lines of a demand.in1 file for one demand region (normally country) in the 100m version of the model. The demand for land-use type 0, for example, increases, every year with about 800 ha.

```
11
317581.0    17137.0     1520974.0   1196644.0   3758362.0   586994.0
318363.1    17352.8     1520186.9   1196330.6   3758386.2   587072.5
319145.2    17568.6     1519399.7   1196017.2   3758410.4   587150.9
319927.3    17784.5     1518612.5   1195703.8   3758434.6   587229.4
320709.4    18000.3     1517825.3   1195390.3   3758458.8   587307.8
321491.6    18216.1     1517038.1   1195076.9   3758483.0   587386.3
322273.8    18432.0     1516250.9   1194763.5   3758507.2   587464.8
323056.0    18647.8     1515463.6   1194450.0   3758531.4   587543.2
323838.2    18863.7     1514676.3   1194136.5   3758555.6   587621.7
324620.4    19079.5     1513889.0   1193823.1   3758579.8   587700.2
325402.7    19295.4     1513101.7   1193509.6   3758604.0   587778.6
```

Remember, these files are calculated within the EU-ClueScanner by the demand module. The files are not intended to be edited by the user. Instead the input parameters of the Microsoft Access demand database (demand.mdb) located in projects\EuClueScanner\data\demand should be edited.

alloc1.reg

The alloc1.reg file contains the part of logistic regression results that relate to the importance of the suitability factors in explaining observed land-use patterns. This file has the following format (see also the example below):

Line 1: Number code for land-use type (here 0 = urban land use).
Line 2: Constant of regression equation for this land-use type.
Line 3: Number of explanatory factors in the regression equation for that land-use type.
Line 4 and further: On each line the beta coefficients (-0.00043 etc.) for the explanatory factor and the number code of the explanatory factor. The number codes of these factors can be found in the FactorData table in the metadata.mdb. Appendix 2 also lists these numbers. In the example below, line 4 refers to ACCESS1_06M: the timecost to cities > 100.000 (seconds).

```
0
  5.964
8
  -0.00043 1
  -0.00007 3
  -0.004 39
  0.001 45
  -1.482 65
  -0.333 32
  -1.599 67
  0.490 66

1
  6.303
8
  -0.00073 1
  -0.00010 3
  -0.007 39

etc.
```

alloc2.reg

The alloc2.reg file contains the part of logistic regression results that relate to the importance of the neighbourhood enrichment factors in explaining observed land-use patterns. This file has the same format as alloc1.reg:

Line 1: Number code for land-use type.
Line 2: Constant of neighbourhood regression equation for land-use type (ß0).
Line 3: Number of explanatory factors (land-use types) in the regression equation for that land-use type. For example the presence of urban area and arable land in the neighbourhood are explanatory factors for the land-use type urban area, so the number of explanatory factors is 2.
Line 4 and further: On each line the beta coefficients (ß1, ß2, etc.) for the explanatory factors and the number code of the explanatory factor. In using the neighbourhood function, the explanatory factors are the land-use types and therefore the number codes are the number codes for the land-use types.

Land-use conversions can be explained partly by the occurrence of land uses in the neighbourhood. For example, new urban area is more likely to develop at the fringe of existing urban area than elsewhere. Especially in the context of urban growth, it is useful to include neighbourhood interactions as a driving factor (Verburg et al., 2004). To characterise the neighbourhood of a location the enrichment factor is often used. This measure is defined by the occurrence of a land-use type in the neighbourhood of a location relative to the occurrence of this land-use type in the study area. The weight that is assigned to the neighbourhood characteristics is assigned in the neighbourhood settings file (neighmat.txt).

neighmat.txt

In this file the size and shape of the neighbourhoods and the weight assigned to the neighbourhood function is indicated for each land-use type individually. The file has the following format:

Line 1 Weight (0-1) assigned to the neighbourhood function for each land-use type.
Line 2 and further. For each land-use type:
- The radius of the neighbourhood (1 = 1 grid cell on each side of the central cell).
- Followed by the shape of the neighbourhood (with weights (0-1) for individual cells).

Below is an example of the first part of such a file for the 1km version of the EU-ClueScanner model. It shows that for the first land-use type only the first ring of cells surrounding the central cell is selected as neighbourhood. The second reference to this first land-use type indicates that each cell receives an equal weight.

```
0.3 0.3 0.3 0.3 0.3 0.3

3
1 1 1 1 1 1 1
1 2 2 2 2 2 1
1 2 4 4 4 2 1
1 2 4 0 4 2 1
1 2 4 4 4 2 1
1 2 2 2 2 2 1
1 1 1 1 1 1 1

etc.
```

allow.txt

The allow.txt file specifies how succession of land-use types takes place. It may refer to succession maps that specify locations where certain successions may take place. It is a Y x Y matrix where Y equals the number of land-use types. So when 10 land-use types are simulated by the model it will be a 10x10 matrix. Rows denote the present land-use type and columns the potential future land-use type. A value of 1 indicates that the conversion is allowed, a value of 0 indicates that the conversion is not allowed. Other codes refer to maps that specify whether succession is allowed for individual (1x1 km) locations.

The example below shows a typical allow.txt file used in the DG environment application. For clarity's sake the related Clue10 land-use type codes (0-9) are included next to the file. The value 52 in row 1 on line 2 in this example denotes that the conversion of the second land-use type (arable land) into the first (urban) is conditional on allow driver map 52. This map represents the Natura2000 areas with a value of 0, indicating that urbanisation is not allowed here (see the FactorData table in the metadata.mdb or Appendix 2 for a complete list of all allow driver maps). The remaining areas contain a value of 1 indicating that conversion is allowed. The conversion settings for the different policy alternatives in the DG-Environment application of the EU-ClueScanner are provided in a separate annex to the final report.

to: / from land use	0	1	2	3	4	5	6	7	8	9
0	1	0	0	0	0	0	0	0	0	0
1	52	1	1	0	0	1	52	0	0	0
2	52	61	1	0	0	0	52	0	1	0
3	0	61	52	1	0	0	52	60	0	0
4	0	0	0	0	1	0	0	0	0	0
5	52	61	52	58	0	1	52	0	0	0
6	52	61	52	0	0	1	1	0	0	0
7	0	61	52	0	0	0	52	1	0	0
8	52	61	52	59	0	0	52	0	1	0
9	0	0	0	0	0	0	0	0	0	1

Please note that this option has not yet been used in 100m version of the model, although this is technically possible. Take care, however, that the allow driver maps should be stored as ascii grids in the Albers projection at 1km resolution. A lookup matrix ensures that these dataset are used properly. When needed the allow driver definition can also be implemented at the level of countries, or be adjusted to ingest 100m resolution data in Lambert projection.

locspecX.asc

The implementation of policy themes is, to some extent, done by location specific modification of the suitability of the land for a specific land-use type. The suitabilities reflect an index of the potential land rent that can be attained at a specific location for a specific land-use type. Scenario settings (subsidies and taxes) influence these suitabilities. Financial support may, for example, be considered for maintaining agriculture in mountainous areas. This leads to a higher probability that agricultural land use is conserved in these areas than could be expected from the statistical regression between land use and (biophysical and socio-economic) driving factors that apply for the study area as a whole. Such modifications are reflected in the location-specific addition factors (locspec). These location-specific addition factors for different policies are combined in one map for each land-use type. See the appendix to the final report for an overview of the way various policies are combined in the current application.

When this option is used, for each land-use type a file named locspec#.asc (# indicates the land-use type number) should be supplied in the relevant policy-alternative folders (e.g. ReferenceJRC) in the Projects/EuClueScanner/ParamSets directory. These additions are stored in maps that provide a value in each grid cell that should preferably lie between 0-1 in order to fit the range of the regression results. Note that the switch on line 19 in the main.1 file should be set to 1 and weight factors should be specified. The function is not active when the switch in main.1 has the value 0.

Please note that this option has not yet been used in 100m version of the model, although this is technically possible. Take care, however, that the locspec files should be stored as ascii grids in the Albers projection at 1km resolution. A lookup matrix ensures that these dataset are used properly. As opposed to the previous 1km version the locspec files are now expected to be stored in the Projects/ EuClueScanner/Paramsets directory at the policy-alternative level and not in SourceData/EuClueScanner/*PolicyAlternativeName* at the country level. When needed the locspec definition can also be implemented at the level of countries, or be adjusted to ingest 100m resolution data in Lambert projection.

Appendix 5 Calibration steps

This appendix describes the main steps in the calibration of the JRC version of the EU-ClueScanner. It is basically an internal working document that is included to provide JRC with some background information on how to calibrate the model using mulitinomial logistic regression. The main idea is to calibrate the suitability map definition for the new JRC-land use model based on observed land-use patterns in 1990 (thus a static approach). This is based on the actual amount of change from 1990-2000 from our own CLC comparison and the calibrated suitability maps to simulate land-use in 2000 and validate the thus obtained simulation results with observed 2000 land use. A first introduction to Multinomial Logistics can be found at the following informative website: http://www.ats.ucla.edu/stat/Spss/output/mlogit.htm

Main steps

1. Collect the relevant data per country (a NUTS-0 region that normally consists of one country, but, in case of very small ones, more. See further on in document) in ArcGIS: 1990-land use in 9 classes, neighbourhood-land use, additional explanatory variables at 1km (selection of 52 datasets from WUR, based on their statistical results in alloc1.reg files) and several own 100m data sets.
2. The land-use types are reclassified in the JRC-9 typology.
3. Export data to x,y,z-text file. First a mask is applied on the land-use raster to make sure that only the country itself is analysed (and not the neighbouring countries in the NUTS0-rectangle). Then, through the SAMPLE command (using the Multi Output Map Algebra feature), the explanatory and neighbourhood variables are exported as z variables with the land-use data as mask and source of the x,y coordinates. The resulting file gets the name of the country and a .sav extension.
4. import data in SPSS
   - note that the file contains a header
   - specify the types of the variables in Variable view as being either scale (continuous), ordinal (range) or nominal (for categorical or binary dummy variables). Almost all variables are scale, except for natura2000 regions, southslope, Geomorf etc.
   - check the dataset descriptive statistics (Analyze -> Descriptive Statistics-> Descriptive) and then set the width (number of decimal cases) of each variable in Variable view, according to the maximum value (e.g. maximum value 1000, thus set width as 4).
   - apply a filter on the static land-use types (water, infrastructures and other nature – thus classes 7, 8 and 9) that are not simulated by the model (data -> select cases –> if: jrc9_1990 ne 7 and jrc9_1990 ne 8 and jrc9_1990 ne 9)
5. run multinomial regression (analyse -> regression -> MNL) taking into account:
   - dependent is land use (jrc9)
   - increase the stephalving from 5 to 10 for better results (under criteria)
   - specify as reference category a land-use type according to the name of the dataset file, e.g. Netherlands_refclass4 –means that class 4 should be specified as reference category.
   - factors are dummy and other categorical (nominal) variables
   - co-variates are continuous variables (scale)
   - Basically we try three separate regression models:
     - one using all factors from the WUR;
     - one using the WUR-factors and the relevant new 100metre grid data (not population);
     - one using the rings (neighbourhood variables);

   Each step is refined based on an analysis of the correlation between the independent (explanatory) variables as is discussed below. Eventually we end up with about 15 independent variables as is documented in files such as: summary JRC9Belgium.rtf in the G:/0301.../calibration directory. Such neat output files are generated by giving File -> Export in the spss outputfile (.spo).

- Check correlation between factors with Pearson test (Analyze -> Correlate -> BiVariate). This is done for the following groups of similar and potentially correlated variables:
    - population and accesses variables (e.g. access1_06min, access6_06min, euac60_1000, landsc_06, poppot_1000 and population density);
    - geophysical variables (e.g. geomorf0, mean_temp_06, rain_wc_5m , t_plus15_1000, slope, elev and sosl)
    - soil variables (e.g. claycont_06pc, soildepth_06 and swap)
    - neighbourhood variables

  There is strong correlation if correlation coefficient > 0.5 or < -0.5. In this case one of the correlated variables should be dropped. We prefer to keep the 100metre versions and strive to maintain at least one accessibility measure, one climate and one soil variable.
- Consider also dropping some of the neighbourhood variables based on the average value in the Descriptives (drop when this is very close to 0) or the significance in the statistical regression.
- Labels can be added to the output in spss by adding this bit of script to the syntax: VALUE LABELS jrc9_1990 1 'Urban fabric' 2 'Industry and related uses' 3 'Arable land and permanent crops' 4 'Pastures' 5 'Forests' 6 'Semi natural vegetation' 7 'Other nature' 8 'Infrastructure' 9 'Water'.

Appendix 6 Observed land-use change

This appendix list the observed land-use change between CLC1990 and CLC2000 for all 27 member states based on the reclassified Corine Land Cover data. The changes are described as aggregate changes (relating to the total amounts of land taken be each type of use) and land-use transitions based on a pixel-by-pixel comparison of the two data sets performed in GIS. Such transitions are helpful in highlighting the ongoing land-use change processes (see for example: Diogo and Koomen, 2010; Pena et al., 2007).

The observed aggregate changes were used to define the demand for the land-use types that were simulated in the validation2000 runs of the 100m version of the model. The amount of change observed was also used to estimate the amount of change between 2000 and 2030 for the Reference alternatives in the JRC application. In this case the observed amount of change between CLC1990 and CLC2000 was divided by the observation period to obtain a yearly increase per land-use type. This was then used as additional demand per land-use type for each year until 2030. This calculation corrected for the fact that the actual time period between CLC1990 and CLC2000 differs per country, as is shown below.

Country	CLC1990		CLC2000		Comments
	start	end	start	end	
Austria	1985	1986	1999	2001	
Belgium	1989	1990	1999	2000	
Bulgaria	1989	1992	2000	2001	
Cyprus[1]	x	x	2000	2000	no CLC1990 available
Czech Republic	1989	1992	1999	2001	
Denmark	1989	1990	1999	2001	
Estonia	1993	1995	1999	2001	
Finland[1]	1986	1994	1999	2002	no CLC1990 version 9/2007 available
France (Incl. Monaco)	1987	1994	1999	2001	
Germany	1989	1992	1999	2001	
Greece	1987	1991	2000	2001	
Hungary	1990	1992	2000	2000	
Ireland	1989	1990	2000	2001	
Italy (Incl. San Marino & the Vatican)	1990	1993	1999	2002	
Latvia	1994	1995	1999	2001	
Lithuania	1994	1995	1999	2001	
Luxembourg	1991	1991	2000	2000	
Malta[1]	x	x	2001	2001	no CLC1990 available
The Netherlands	1986	1988	1999	2000	
Poland	1989	1992	1999	2001	
Portugal	1985	1987	1999	2002	
Romania	1989	1992	2000	2001	
Slovak Republic	1989	1992	2000	2001	
Slovenia	1995	1996	1999	2000	
Spain	1984	1990	1999	2002	
Sweden[1]	x	x	1999	2002	no CLC1990 available
United Kingdom	1989	1990	1999	2002	no CLC1990 version 9/2007 available; a 1990 version was constructed based on the CLC-change data set

Note: [1]For the countries that lack CLC1990 data no change analysis could be performed.

Austria

Aggregated land use classes	1990	2000	Change
Urban fabric	317581	325362	7781
Industry and related uses	17137	19293	2156
Arable land and permanent crops	1520974	1512912	-8062
Pastures	1196644	1193360	-3284
Forests	3758362	3758133	-229
Semi natural vegetation	586994	587705	711
Infrastructures	5567	6172	605
Other Nature	921253	921030	-223
Water	69744	70289	545
Total	8394256	8394256	0

Observed land-use change in Austria based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	317455	78	2	8	6	0	32	0	0
	Industry and related uses	234	15239	184	345	590	67	156	0	322
	Arable land and permanent crops	4148	2635	1512278	842	522	163	312	0	74
	Pastures	2881	301	250	1191703	1311	143	12	0	43
	Forests	440	878	178	431	3751930	4322	11	117	55
	Semi natural vegetation	185	162	0	15	3669	582875	82	6	0
	Infrastructures	0	0	0	0	0	0	5567	0	0
	Other Nature	19	0	11	0	105	129	0	920907	82
	Water	0	0	9	16	0	6	0	0	69713

Transition matrix for observed land-use change in Austria based on CLC1990 and CLC2000.

Belgium and Luxemburg

Aggregated land use classes	1990	2000	Change
Urban fabric	550378	557787	7409
Industry and related uses	55115	64633	9518
Arable land and permanent crops	1068440	1060361	-8079
Pastures	792989	782356	-10633
Forests	697322	701456	4134
Semi natural vegetation	89938	84712	-5226
Infrastructures	20789	23490	2701
Other Nature	29938	29253	-685
Water	19917	20778	861
Total	3324826	3324826	0

Observed land-use change in Belgium and Luxemburg based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	549389	819	23	49	8	0	81	0	9
	Industry and related uses	183	51999	125	114	22	426	799	1110	337
	Arable land and permanent crops	3963	5785	1054515	1940	505	168	1140	142	282
	Pastures	3250	3266	5331	779813	633	192	228	189	87
	Forests	353	843	146	243	687819	7481	95	223	119
	Semi natural vegetation	476	685	131	156	11867	76411	28	103	81
	Infrastructures	0	13	31	0	0	0	20712	21	12
	Other Nature	173	1121	55	30	602	34	357	27465	101
	Water	0	102	4	11	0	0	50	0	19750

Transition matrix for observed land-use change in Belgium and Luxemburg based on CLC1990 and CLC2000.

Please note that these two countries have been combined into one demand region in the model.

Bulgaria

Aggregated land use class	1990	2000	Change
Urban fabric	424612	424782	170
Industry and related uses	108237	111140	2903
Arable land and permanent crops	4479194	4477440	-1754
Pastures	960400	959106	-1294
Forests	3481200	3491133	9933
Semi natural vegetation	1438023	1429267	-8756
Infrastructures	8424	8424	0
Other Nature	101837	100576	-1261
Water	95548	95607	59
Total	11097475	11097475	0

Observed land-use change in Bulgaria based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	424603	6	2	1	0	0	0	0	0
	Industry and related uses	0	107788	394	10	0	0	0	0	45
	Arable land and permanent crops	88	1798	4468566	7796	383	474	0	60	29
	Pastures	66	721	7910	950629	417	614	0	0	43
	Forests	0	315	112	157	3450575	29026	0	967	48
	Semi natural vegetation	25	511	324	229	37640	1399132	0	89	73
	Infrastructures	0	0	0	0	0	0	8424	0	0
	Other Nature	0	0	45	284	2051	0	0	99146	311
	Water	0	1	87	0	67	21	0	314	95058

Transition matrix for observed land-use change in Bulgaria based on CLC1990 and CLC2000.

Czech Republic

Aggregated land use classes	1990	2000	Change
Urban fabric	377511	383191	5680
Industry and related uses	87841	86755	-1086
Arable land and permanent crops	3789061	3499380	-289681
Pastures	578213	857937	279724
Forests	2490003	2555103	65100
Semi natural vegetation	490126	428316	-61810
Infrastructures	10596	11062	466
Other Nature	11972	11889	-83
Water	53784	55474	1690
Total	7889107	7889107	0

Observed land-use change in Czech Republic based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	377220	246	12	33	0	0	0	0	0
	Industry and related uses	1422	80056	760	1020	180	4144	82	0	177
	Arable land and permanent crops	3764	4065	3492084	286068	136	1993	270	0	681
	Pastures	448	538	6117	569656	210	729	89	0	426
	Forests	21	355	18	89	2434586	54816	0	20	98
	Semi natural vegetation	316	1491	367	1054	119947	366452	25	71	403
	Infrastructures	0	0	0	0	0	0	10596	0	0
	Other Nature	0	0	5	11	44	153	0	11672	87
	Water	0	4	17	6	0	29	0	126	53602

Transition matrix for observed land-use change in Czech Republic based on CLC1990 and CLC20000.

Denmark

Aggregated land use classes	1990	2000	Change
Urban fabric	251804	259532	7728
Industry and related uses	26065	30954	4889
Arable land and permanent crops	2939050	2918121	-20929
Pastures	270048	270218	170
Forests	408803	383133	-25670
Semi natural vegetation	178644	209381	30737
Infrastructures	11738	11883	145
Other Nature	191420	193930	2510
Water	82454	82874	420
Total	4360026	4360026	0

Observed land-use change in Denmark based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	251444	356	0	0	0	0	4	0	0
	Industry and related uses	33	25513	164	52	5	151	59	88	0
	Arable land and permanent crops	6918	4217	2917725	1872	473	6441	82	1272	50
	Pastures	520	296	225	268254	23	303	0	180	247
	Forests	144	202	7	5	382161	26188	0	96	0
	Semi natural vegetation	436	288	0	35	465	176138	0	1198	84
	Infrastructures	0	0	0	0	0	0	11738	0	0
	Other Nature	37	75	0	0	6	160	0	191096	46
	Water	0	7	0	0	0	0	0	0	82447

Transition matrix for observed land-use change in Denmark based on CLC1990 and CLC2000.

Estonia

Aggregated land use classes	1990	2000	Change
Urban fabric	53148	54532	1384
Industry and related uses	29315	29797	482
Arable land and permanent crops	837389	847642	10253
Pastures	524832	513048	-11784
Forests	2133239	2093230	-40009
Semi natural vegetation	509576	548202	38626
Infrastructures	6358	6393	35
Other Nature	217630	218735	1105
Water	221327	221235	-92
Total	4532814	4532814	0

Observed land-use change in Estonia based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	53142	0	2	3	1	0	0	0	0
	Industry and related uses	39	28692	1	0	8	69	0	506	0
	Arable land and permanent crops	384	33	814212	22572	41	142	4	1	0
	Pastures	662	75	33225	490219	63	581	0	7	0
	Forests	50	242	149	161	2088786	43499	25	322	5
	Semi natural vegetation	246	664	53	93	4326	503667	6	521	0
	Infrastructures	0	0	0	0	0	0	6358	0	0
	Other Nature	9	91	0	0	5	244	0	217281	0
	Water	0	0	0	0	0	0	0	97	221230

Transition matrix for observed land-use change in Estonia based on CLC1990 and CLC2000.

France

Aggregated land use classes	1990	2000	Change
Urban fabric	2080408	2144434	64026
Industry and related uses	372058	419105	47047
Arable land and permanent crops	20131305	20119019	-12286
Pastures	12433222	12341987	-91235
Forests	14491461	14510117	18656
Semi natural vegetation	3347396	3321298	-26098
Infrastructures	78866	90462	11596
Other Nature	1779079	1754752	-24327
Water	445554	458175	12621
Total	55159349	55159349	0

Observed land-use change in France based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	2078629	1574	38	18	5	0	95	6	43
	Industry and related uses	5110	347613	3334	2711	758	3610	3602	1589	3731
	Arable land and permanent crops	30065	36164	20006139	44969	3049	2137	4922	511	3349
	Pastures	22620	18896	93165	12284187	4971	3526	1580	445	3832
	Forests	4513	8118	6319	4413	14146448	314891	1430	3889	1440
	Semi natural vegetation	2722	4313	8533	4490	350145	2971129	276	5294	494
	Infrastructures	0	327	8	0	0	0	78451	0	80
	Other Nature	760	1564	1406	1071	4714	25954	66	1742595	949
	Water	15	536	77	128	27	51	40	423	444257

Transition matrix for observed land-use change in France based on CLC1990 and CLC2000.

Germany

Aggregated land use classes	1990	2000	Change
Urban fabric	2267868	2381891	114023
Industry and related uses	393661	436651	42990
Arable land and permanent crops	15473094	15172992	-300102
Pastures	5862762	5958103	95341
Forests	10408672	10392037	-16635
Semi natural vegetation	603582	647304	43722
Infrastructures	74632	76167	1535
Other Nature	542947	543265	318
Water	495971	514779	18808
Total	36123189	36123189	0

Observed land-use change in Germany based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	2263858	3265	250	47	259	87	38	38	26
	Industry and related uses	1758	344672	5742	1847	1408	12391	320	15178	10345
	Arable land and permanent crops	90801	65789	15086815	205596	12328	3071	1929	1396	5369
	Pastures	22914	8182	76767	5746968	3360	1330	130	1068	2043
	Forests	1175	9170	1189	996	10326173	68121	162	944	742
	Semi natural vegetation	1088	3307	548	829	47031	547928	116	2003	732
	Infrastructures	121	699	103	17	53	110	73426	0	103
	Other Nature	176	1409	1470	1663	1425	14048	0	522045	711
	Water	0	158	108	140	0	218	46	593	494708

Transition matrix for observed land-use change in Germany based on CLC1990 and CLC2000.

Greece

Aggregated land use classes	1990	2000	Change
Urban fabric	178291	184186	5895
Industry and related uses	52059	74711	22652
Arable land and permanent crops	3751335	3740097	-11238
Pastures	1084759	1080460	-4299
Forests	2430740	2374598	-56142
Semi natural vegetation	5097256	5128075	30819
Infrastructures	11009	20020	9011
Other Nature	349425	353832	4407
Water	127821	126716	-1105
Total	13082695	13082695	0

Observed land-use change in Greece based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	178179	57	16	1	0	2	36	0	0
	Industry and related uses	221	49293	13	123	0	421	1842	15	131
	Arable land and permanent crops	2931	12631	3725628	4052	203	825	4507	81	477
	Pastures	2236	3436	5616	1071163	201	952	897	41	217
	Forests	16	1272	639	744	2339743	85912	210	1427	777
	Semi natural vegetation	569	7540	6207	4048	34344	5033453	1588	8237	1270
	Infrastructures	0	24	7	9	0	40	10929	0	0
	Other Nature	34	263	409	171	99	6380	10	341239	820
	Water	0	195	1562	149	8	90	1	2792	123024

Transition matrix for observed land-use change in Greece based on CLC1990 and CLC2000.

Hungary

Aggregated land use classes	1990	2000	Change
Urban fabric	452082	454466	2384
Industry and related uses	59069	63043	3974
Arable land and permanent crops	5392710	5368266	-24444
Pastures	918365	899530	-18835
Forests	1682445	1737428	54983
Semi natural vegetation	518191	494449	-23742
Infrastructures	9912	11309	1397
Other Nature	106393	107265	872
Water	169848	173259	3411
Total	9309015	9309015	0

Observed land-use change in Hungary based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	451352	473	16	67	116	35	23	0	0
	Industry and related uses	305	56642	271	1180	190	414	6	0	61
	Arable land and permanent crops	2020	3803	5301719	54207	12237	15632	1237	325	1530
	Pastures	588	1615	62539	842078	2410	7293	47	1043	752
	Forests	98	271	891	749	1623701	56492	65	108	70
	Semi natural vegetation	53	208	2760	1002	98626	414307	31	947	257
	Infrastructures	0	0	0	0	0	0	9900	0	12
	Other Nature	22	31	0	118	56	243	0	104469	1454
	Water	28	0	70	129	92	33	0	373	169123

Transition matrix for observed land-use change in Hungary based on CLC1990 and CLC2000.

Ireland

Aggregated land use classes	1990	2000	Change
Urban fabric	87500	110565	23065
Industry and related uses	10671	17317	6646
Arable land and permanent crops	563677	706032	142355
Pastures	4052274	3869195	-183079
Forests	302365	293324	-9041
Semi natural vegetation	432882	554818	121936
Infrastructures	3280	5187	1907
Other Nature	1407977	1305281	-102696
Water	166129	165036	-1093
Total	7026755	7026755	0

Observed land-use change in Ireland based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	87154	278	0	29	0	1	35	0	3
	Industry and related uses	372	9805	0	0	0	0	493	0	1
	Arable land and permanent crops	3681	2320	487352	67853	716	1447	283	5	20
	Pastures	18437	4690	217821	3798691	4238	7207	1067	40	83
	Forests	98	21	20	100	232505	69524	0	45	52
	Semi natural vegetation	582	89	562	959	31359	399195	29	63	44
	Infrastructures	0	0	0	0	0	0	3280	0	0
	Other Nature	241	114	271	1524	24506	76111	0	1305081	129
	Water	0	0	6	39	0	1333	0	47	164704

Transition matrix for observed land-use change in Ireland based on CLC1990 and CLC2000.

Italy

Aggregated land use classes	1990	2000	Change
Urban fabric	1042963	1094501	51538
Industry and related uses	244088	273140	29052
Arable land and permanent crops	12726080	12626151	-99929
Pastures	2442015	2410878	-31137
Forests	7813500	7897245	83745
Semi natural vegetation	4001361	3961629	-39732
Infrastructures	42196	43309	1113
Other Nature	1442126	1446562	4436
Water	311517	312431	914
Total	30065846	30065846	0

Observed land-use change in Italy based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	1042854	61	22	0	26	0	0	0	0
	Industry and related uses	599	241958	54	4	48	924	239	0	262
	Arable land and permanent crops	34344	24286	12612498	17263	3568	31649	770	399	1303
	Pastures	12742	4145	7821	2392549	3545	20881	90	127	115
	Forests	716	772	1644	372	7792490	12914	7	4474	111
	Semi natural vegetation	3107	1412	3840	556	96329	3892976	15	3035	91
	Infrastructures	0	43	0	0	0	0	42153	0	0
	Other Nature	139	283	173	98	1087	2119	35	1437574	618
	Water	0	180	99	36	152	166	0	953	309931

Transition matrix for observed land-use change in Italy based on CLC1990 and CLC2000.

Latvia

Aggregated land use classes	1990	2000	Change
Urban fabric	61263	61263	0
Industry and related uses	18773	18894	121
Arable land and permanent crops	1298552	1303584	5032
Pastures	1404276	1399193	-5083
Forests	2840781	2712137	-128644
Semi natural vegetation	557944	686517	128573
Infrastructures	4599	4599	0
Other Nature	160163	159938	-225
Water	120848	121074	226
Total	6467199	6467199	0

Observed land-use change in Latvia based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	61263	0	0	0	0	0	0	0	0
	Industry and related uses	0	18773	0	0	0	0	0	0	0
	Arable land and permanent crops	0	4	1238535	59993	9	10	0	0	1
	Pastures	0	0	65041	1339199	10	26	0	0	0
	Forests	0	111	7	1	2711945	128717	0	0	0
	Semi natural vegetation	0	6	1	0	173	557764	0	0	0
	Infrastructures	0	0	0	0	0	0	4599	0	0
	Other Nature	0	0	0	0	0	0	0	159938	225
	Water	0	0	0	0	0	0	0	0	120848

Transition matrix for observed land-use change in Latvia based on CLC1990 and CLC2000.

Lithuania

Aggregated land use classes	1990	2000	Change
Urban fabric	157865	158653	788
Industry and related uses	47040	46805	-235
Arable land and permanent crops	2733488	2784118	50630
Pastures	1127691	1076231	-51460
Forests	1953242	1896182	-57060
Semi natural vegetation	325058	382059	57001
Infrastructures	9360	9376	16
Other Nature	67816	67880	64
Water	171218	171474	256
Total	6592778	6592778	0

Observed land-use change in Lithuania based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	157852	0	11	1	1	0	0	0	0
	Industry and related uses	646	46258	7	38	0	11	0	23	57
	Arable land and permanent crops	70	236	2717501	15349	5	246	0	0	81
	Pastures	70	129	66357	1060624	11	331	0	3	166
	Forests	0	77	102	68	1894608	58361	16	10	0
	Semi natural vegetation	15	105	140	85	1557	323004	0	123	29
	Infrastructures	0	0	0	0	0	0	9360	0	0
	Other Nature	0	0	0	0	0	106	0	67694	16
	Water	0	0	0	66	0	0	0	27	171125

Transition matrix for observed land-use change in Lithuania based on CLC1990 and CLC2000.

The Netherlands

Aggregated land use classes	1990	2000	Change
Urban fabric	294516	350081	55565
Industry and related uses	53234	77845	24611
Arable land and permanent crops	1111501	1083746	-27755
Pastures	1471212	1396179	-75033
Forests	305688	313883	8195
Semi natural vegetation	57792	65117	7325
Infrastructures	21701	24543	2842
Other Nature	320665	321442	777
Water	332539	336012	3473
Total	3968848	3968848	0

Observed land-use change in the Netherlands based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	293521	880	13	17	43	0	0	1	41
	Industry and related uses	3959	45206	292	27	207	725	2162	225	431
	Arable land and permanent crops	21798	13705	1059088	3108	6397	4329	336	1502	1238
	Pastures	28679	15793	23572	1392705	2926	1824	405	3275	2033
	Forests	1154	609	135	167	302477	241	33	765	107
	Semi natural vegetation	583	286	65	3	571	56229	7	3	45
	Infrastructures	1	221	1	1	0	0	21370	95	12
	Other Nature	322	515	332	108	1247	1744	57	314897	1443
	Water	64	630	248	43	15	25	173	679	330662

Transition matrix for observed land-use change in the Netherlands based on CLC1990 and CLC2000.

Poland

Aggregated land use classes	**1990**	**2000**	**Change**
Urban fabric	839544	847598	8054
Industry and related uses	150470	156579	6109
Arable land and permanent crops	15341257	15324205	-17052
Pastures	4330953	4315648	-15305
Forests	9261319	9229603	-31716
Semi natural vegetation	690466	743213	52747
Infrastructures	35635	36342	707
Other Nature	156511	144794	-11717
Water	517886	526059	8173
Total	31324041	31324041	0

Observed land-use change in Poland based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	839184	237	0	0	0	0	123	0	0
	Industry and related uses	3982	141319	922	1048	17	790	112	1482	798
	Arable land and permanent crops	3127	10424	15300541	15738	4986	5165	264	26	986
	Pastures	1059	1807	22025	4296072	2380	2831	45	1206	3528
	Forests	155	1284	533	283	9173595	84766	163	255	285
	Semi natural vegetation	91	1041	120	160	48498	638891	0	1568	97
	Infrastructures	0	0	0	0	0	0	35635	0	0
	Other Nature	0	341	46	2282	127	10749	0	140003	2963
	Water	0	126	18	65	0	21	0	254	517402

Transition matrix for observed land-use change in Poland based on CLC1990 and CLC2000.

Portugal

Aggregated land use classes	1990	2000	Change
Urban fabric	138459	183258	44799
Industry and related uses	24442	46759	22317
Arable land and permanent crops	3434149	3403476	-30673
Pastures	694219	655523	-38696
Forests	2471391	2435603	-35788
Semi natural vegetation	1470493	1548403	77910
Infrastructures	5721	8165	2444
Other Nature	573420	525745	-47675
Water	102831	108193	5362
Total	8915125	8915125	0

Observed land-use change in Portugal based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	137792	560	0	0	11	0	96	0	0
	Industry and related uses	1091	22186	4	8	106	331	504	161	51
	Arable land and permanent crops	23180	6111	3336786	14966	18291	29712	531	1319	3253
	Pastures	8822	2160	32675	632031	4619	11376	269	1470	797
	Forests	5607	8500	14103	3550	2152638	278307	595	7614	477
	Semi natural vegetation	5655	5915	16052	3964	238767	1183738	342	14560	1500
	Infrastructures	51	0	0	0	0	0	5670	0	0
	Other Nature	1049	1294	3663	1004	21159	44186	57	500191	817
	Water	11	33	193	0	12	753	101	430	101298

Transition matrix for observed land-use change in Portugal based on CLC1990 and CLC2000.

Romania

Aggregated land use classes	1990	2000	Change
Urban fabric	1313507	1316926	3419
Industry and related uses	167247	170414	3167
Arable land and permanent crops	9669809	9661981	-7828
Pastures	3480609	3482395	1786
Forests	6992116	7013968	21852
Semi natural vegetation	1333989	1312473	-21516
Infrastructures	12564	12615	51
Other Nature	517167	516050	-1117
Water	395475	395661	186
Total	23882483	23882483	0

Observed land-use change in Romania based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	1313296	0	95	63	1	25	0	12	15
	Industry and related uses	571	165379	39	96	13	86	51	757	255
	Arable land and permanent crops	2207	2018	9633341	28694	100	2980	0	223	246
	Pastures	723	1506	24519	3448982	95	4381	0	21	382
	Forests	9	987	224	1005	6923545	66158	0	22	166
	Semi natural vegetation	35	470	1597	2587	90179	1238701	0	127	293
	Infrastructures	0	0	0	0	0	0	12564	0	0
	Other Nature	59	42	1746	305	35	107	0	513614	1259
	Water	26	12	420	663	0	35	0	1274	393045

Transition matrix for observed land-use change in Romania based on CLC1990 and CLC2000.

Slovakia

Aggregated land use classes	1990	2000	Change
Urban fabric	234554	237862	3308
Industry and related uses	37636	34380	-3256
Arable land and permanent crops	1828892	1823741	-5151
Pastures	511353	496433	-14920
Forests	1940184	1939070	-1114
Semi natural vegetation	299445	316160	16715
Infrastructures	4270	4482	212
Other Nature	31899	29866	-2033
Water	22860	29099	6239
Total	4911093	4911093	0

Observed land-use change in Slovakia based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	234424	48	8	8	0	6	0	0	60
	Industry and related uses	221	32322	47	109	10	907	60	0	3960
	Arable land and permanent crops	2223	1138	1808712	13607	750	2062	146	3	251
	Pastures	490	324	13438	480756	1909	14040	3	0	393
	Forests	188	440	94	213	1883464	55679	0	0	106
	Semi natural vegetation	307	97	1409	1596	52930	242889	3	0	214
	Infrastructures	0	0	0	0	0	0	4270	0	0
	Other Nature	2	0	33	125	0	566	0	29741	1432
	Water	7	11	0	19	7	11	0	122	22683

Transition matrix for observed land-use change in Slovakia based on CLC1990 and CLC2000.

Slovenia

Aggregated land use classes	1990	2000	Change
Urban fabric	43361	43392	31
Industry and related uses	8584	8347	-237
Arable land and permanent crops	315969	315632	-337
Pastures	336947	337149	202
Forests	1139460	1138807	-653
Semi natural vegetation	118675	119708	1033
Infrastructures	2138	2606	468
Other Nature	54811	54394	-417
Water	8105	8015	-90
Total	2028050	2028050	0

Observed land-use change in Slovenia based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	43361	0	0	0	0	0	0	0	0
	Industry and related uses	0	8161	4	6	0	0	382	0	31
	Arable land and permanent crops	20	30	315553	208	44	61	15	0	38
	Pastures	7	55	41	336705	80	53	4	0	2
	Forests	0	97	30	71	1138623	549	62	0	28
	Semi natural vegetation	4	4	4	9	60	118583	5	0	6
	Infrastructures	0	0	0	0	0	0	2138	0	0
	Other Nature	0	0	0	150	0	462	0	54199	0
	Water	0	0	0	0	0	0	0	195	7910

Transition matrix for observed land-use change in Slovenia based on CLC1990 and CLC2000.

Spain

Aggregated land use classes	1990	2000	Change
Urban fabric	463771	545784	82013
Industry and related uses	139160	217361	78201
Arable land and permanent crops	20800930	20845017	44087
Pastures	3673127	3663243	-9884
Forests	9182476	9197008	14532
Semi natural vegetation	13051135	12835093	-216042
Infrastructures	23276	27960	4684
Other Nature	2216945	2182426	-34519
Water	284105	321033	36928
Total	49834925	49834925	0

Observed land-use change in Spain based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	461417	1486	395	183	0	41	241	0	8
	Industry and related uses	6860	126411	1693	611	153	2247	261	584	340
	Arable land and permanent crops	43225	48455	20537574	66721	9249	78514	2147	1494	13551
	Pastures	10324	10379	68309	3564183	4404	12216	861	977	1474
	Forests	4927	5211	21245	2866	8815490	293890	170	34484	4193
	Semi natural vegetation	18273	21888	203180	25368	353462	12364924	835	45871	17334
	Infrastructures	9	40	0	0	0	0	23227	0	0
	Other Nature	737	3210	12013	3305	14151	83099	170	2098836	1424
	Water	12	281	608	6	99	162	48	180	282709

Transition matrix for observed land-use change in Spain based on CLC1990 and CLC2000.

United Kingdom

Aggregated land use classes	1990	2000	Change
Urban fabric	1508230	1533966	25736
Industry and related uses	201153	208028	6875
Arable land and permanent crops	6723304	6701866	-21438
Pastures	7466254	7449206	-17048
Forests	1812058	1982571	170513
Semi natural vegetation	2419810	2317115	-102695
Infrastructures	64464	65116	652
Other Nature	4180787	4117765	-63022
Water	319418	319845	427
Total	24695478	24695478	0

Observed land-use change in the United Kingdom based on CLC1990 and CLC2000.

		CLC2000								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	1507637	582	0	2	0	0	9	0	0
	Industry and related uses	1854	196021	429	1390	106	964	235	41	113
	Arable land and permanent crops	14748	5926	6700906	9	864	248	240	1	362
	Pastures	9002	4248	3	7445800	6283	742	112	7	57
	Forests	329	657	517	1867	1742099	62005	17	4566	1
	Semi natural vegetation	316	529	8	48	169646	2248618	0	635	10
	Infrastructures	36	43	0	75	0	0	64310	0	0
	Other Nature	11	22	1	7	63573	4538	118	4112515	2
	Water	33	0	2	8	0	0	75	0	319300

Transition matrix for observed land-use change in the United Kingdom based on CLC1990 and CLC2000.

Appendix 7 Validation results

By way of example this appendix contains the validation results for two countries. Other results are available on request. Note that when the CLC1990 data set is lacking it is not possible properly validate the model. In that case the statistical analysis for the calibration is performed on the 2000 land-use data and no attempt was made to validate the resulting simulation outcomes.

Austria

		Validation_MNL								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	317326	75	0	162	18	0	0	0	0
	Industry and related uses	715	16422	0	0	0	0	0	0	0
	Arable land and permanent crops	1545	37	1323715	171189	16261	8227	0	0	0
	Pastures	436	63	160786	1006062	14397	14900	0	0	0
	Forests	5079	1656	21222	88	3724721	5596	0	0	0
	Semi natural vegetation	301	1042	7379	16008	3208	559056	0	0	0
	Infrastructures	0	0	0	0	0	0	5567	0	0
	Other Nature	0	0	0	0	0	0	0	921253	0
	Water	0	0	0	0	0	0	0	0	69744

Transition matrix for simulated land-use change in Austria based on CLC1990 and Validation2000.

Land use class	Persistance well predicted	Observed persistance predicted as change	Well predicted change	Observed change predicted as wrong gaining class	Observed change predicted as persistance
Urban Fabric	317200	7844	68	164	126
Industry and related uses	14542	2643	180	50	1880
Arable land and permanent crops	1315800	188715	32	640	7915
Pastures	1001767	186683	147	617	4295
Forests	3718645	33686	152	46	6076
Semi natural vegetation	555389	28566	0	157	3667
Total	6923343	448137	579	1674	23959

Three-map comparison per simulated land-use type in Austria.

Netherlands

		Validation_MNL								
		Urban fabric	Industry and related uses	Arable land and permanent crops	Pastures	Forests	Semi natural vegetation	Infrastructures	Other Nature	Water
CLC1990	Urban fabric	294516	0	0	0	0	0	0	0	0
	Industry and related uses	0	53234	0	0	0	0	0	0	0
	Arable land and permanent crops	12749	7967	926778	146616	8049	9342	0	0	0
	Pastures	36833	13129	151481	1239424	12319	18026	0	0	0
	Forests	5954	3577	118	433	293447	2159	0	0	0
	Semi natural vegetation	772	100	7713	12735	744	35728	0	0	0
	Infrastructures	0	0	0	0	0	0	21701	0	0
	Other Nature	0	0	0	0	0	0	0	321038	0
	Water	0	0	0	0	0	0	0	0	332539

Transition matrix for simulated land-use change in the Netherlands based on CLC1990 and Validation2000.

Land use class	Persistance well predicted	Observed persistance predicted as change	Well predicted change	Observed change predicted as wrong gaining class	Observed change predicted as persistance
Urban Fabric	293521	47224	4827	4257	995
Industry and related uses	45206	17865	4337	2571	8028
Arable land and permanent crops	884674	153736	445	5131	42104
Pastures	1177614	155112	25	4647	61810
Forests	290751	20155	94	863	2696
Semi natural vegetation	34708	28660	205	662	1020
Total	2726474	422752	9933	18131	116653

Three-map comparison per simulated land-use type in the Netherlands.

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