Land use modelling - implementation; Preserving and enhancing the environmental benefits of land-user services

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Preserving and enhancing the environmental benefits of "land-use services"

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CONSORTIUM

Coordination:

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In cooperation with:

Geodan next | Object Vision | bio Intelligence Service

Affiliated partners: LEI and PBL

Administrative summary

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Geodan Next, the Netherlands
Object Vision, the Netherlands
BIO Intelligence Service, France

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Contents

Executive summary

In the next 20 years the EU is anticipated to face new challenges with respect to land use change and its related impacts, which mainly involve the agricultural, forestry, energy, transport, tourism and nature conservation policy sectors. Environment is a transversal policy field across these sectors and therefore, the European Commission is currently involved in several discussions in which land use and its environmental impacts play a key role. Those are for example the further implementation of measures for adaptation to climate change, the role that the new Common Agricultural Policy might have to maintain the 'green' services, the assessment and management of flood risks, etc.

In order to find out the potential that a European land-use modelling framework could have to support environmental policy making within the European Commission, the Environment Directorate-General of the European Commission commissioned a project from December 2008 to February 2010. This study is a second phase that builds upon a scoping study reported in June 2008, which analysed the options for a quantitative modelling at EU scale of trade-off and impact of land use, and defined a roadmap for the preferred option.

The Final Report describes the methodology and work developed from December 2008 to December 2009. It reflects the discussions and agreements achieved in seven meetings between the officers of the European Commission (mainly from DG Environment), and the researchers in charge of the project implementation. These meetings have strongly contributed to an encouraging and engaged policy-science interaction, which has become a key feature of the project. The integrated land-use modelling framework, the reference scenario and policy alternatives used as example to test the implementation of the model, the main results, policy-oriented conclusions and final evaluation of the limitations and uncertainties are summarised below.

The integrated land use model and its implementation in eight policy scenarios

- 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.
- The core of the modeling framework is formed by the land use model Dyna-CLUE (Verburg et al., 2002; Verburg and Overmars, 2009). In addition, the global multi-sectoral models LEITAP and IMAGE (van Meijl et al., 2006; Eickhout et al., 2007) are used to define demand for different types of land use, which are based on predictions on world-wide economic drivers.
- Indicator models either consist of well-established models or targeted, simplified indicator models such as used in EURURALIS projects (WUR/MNP, 2008).
- The framework is designed in such a way that it is flexible in including other models and indicators if needed for a specific policy scenario application. The framework is based on the Data & Model Server (DMS) software which is a flexible system for linking specialised models and data within a consistent workflow. The model framework and its base implementation with a land use model and a series of indicator models is provided as documented, open source software including a short

user tutorial instruction and access to the modellers-reference of the declarative DMS scripting language and set of operators (http://www.objectvision.nl/dms).

- In all scenarios considered in this study, the global influence is accounted for through changes in climate and global demand for goods and commodities based on outcomes of the LEITAP and IMAGE models. Results from these simulations relate to the demand for various types of land use and are, in Europe, delivered at Member State level. The output of the global-level models is translated into a land demand in km2 for the specific land-use types distinguished in the Dyna-Clue land allocation model.
- Two reference scenarios were used in order to explore future trends as realistically as possible, i.e. the B1 (Global Co-operation) from IPCC-SRES reference scenarios, and Policy promoting biofuel use in five non-European countries (USA, Canada and Japan, Brazil, South Africa) and EU27 with unrestricted land conversion of forests into agricultural land (second option of the Biofuel policy alternatives), which is to some extent comparable to the IPCC A2 scenario (Continental markets) since it involves a high demand for land.
- Eight policy alternatives are used as examples, which are only intended to illustrate the possibilities and deliverables of the model but are not an actual impact assessment of envisaged policies. 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, two policy alternatives are defined. The biodiversity alternative introduces a number of ambitious policies to increase the protection of specific ecological and landscape related values, including policy options for the following policy themes: fragmentation control and promotion of clustering of nature, controlling urban growth, natural corridors, Natura 2000, high Nature Value protection, Less Favoured Areas and protection of peat land. The Soil and Climate Change alternative focuses on adaptation and mitigation measures related to water management and soil protection, including the following policy themes: flood damage reduction, restoring water balance, protection of permanent pastures, protection of peat land, soil protection and erosion prevention.
- The implementation of the modelling framework shows that it is successful in simulating different spatial land use policy options. The main policy-oriented considerations are presented below for the three policy alternatives, keeping in mind that the policy alternatives are only intended as illustration. The conclusions focus on those scenarios and results showing major differences compared to the reference scenario:
    - Policies promoting biofuel use have large impact on land use, although impacts within Europe are relatively small as compared to impacts outside Europe. The protection of forest in the tropics will increase land use pressure in Europe. The scenario assessing the impact of Biofuel policies in five non-European countries (USA, Canada and Japan, Brazil, South Africa) and EU27 with unrestricted land conversion of forests into agricultural land predicts the strongest impact in EU27, i.e. the demand for agricultural land is the largest, which results in a striking decrease of 50% in abandoned agricultural land compared to the reference scenario. In addition, an increase of 15% of arable

land and 4% decrease of forest total area are calculated. The agricultural expansion is mainly observed in Central Europe, which happens at the expense of agricultural land that would become abandoned according to the reference scenario. This increase in arable land results in a net loss of carbon sequestration rate, which is approx. 20% lower in 2030 compared to the reference scenario, where more forest is maintained and more agricultural land is abandoned.

- The hypothetical policies considered in this study aiming at protecting biodiversity have as main effect an increase of 6% in total arable land area in 2030 compared to the reference scenario. This increase is mainly based on (i) the increase in set-aside land (since high set-aside with the same cropping area means more agricultural land), especially in those countries where the demand for agricultural land remains the same, e.g. Poland and other Central European member states and (ii) a decrease of agricultural abandoned land in Western Europe. The arable land expansion is at the cost of forest area, whereas semi-natural vegetation increases due to incentives to protect semi-natural grasslands that slow down the succession to forest. The conversion to nature is occurring mainly within the ecological corridors. The impact on biodiversity measured by changes in the Mean Species Abundance (MSA) is rather limited since the MSA index is for a great part determined by the total areas of the different land cover classes, and to lesser extent by the distribution of these classes. The difference with the reference scenario is therefore are not large, since the spatial policies to promote and protect biodiversity are mainly affecting the location of certain land use and not so much their total area. It is however a clear difference between the biodiversity scenario without the increase in set-aside and the biodiversity scenario with the high demand for agricultural land. This shows that spatial policies do have a positive impact on biodiversity, but that the demand for land has a larger effect that cannot be compensated by the spatial policies that promote the protection of biodiversity, i.e. a high land use pressure will outweigh the effect of subsidies to convert arable land to nature.
- Policies aiming at mitigating and adapting to climate change related to water management and soil protection mainly result in different land use patterns at local scale which are reflected in some improvements in biodiversity as a result of the protection of permanent grassland and peat soils. At hotspots erosion is decreasing compared to the reference scenario, due to additional incentives for soil conservation.
- When comparing main land cover changes in 2030 compared to 2000 a general increase in built-up area is observed. This increase is lower in the Soil and Climate change scenario because of policies stimulating compact forms of urbanisation. Arable land shows the largest differences between scenarios: it increases substantially in the EU Biofuel policy options to accomodate for the increased demand for biofuel crops, and decreases under the Biodiversity and Soil and Climate Change alternatives where set-aside policies are maintained or even increased. Pasture area increases slightly and permanent crops area decreases for all scenarios.

  - All results can also be shown at local level and hotspots of change can be identified.

Limitations and uncertainties of the EU-CLUE scanner modelling tool

- The modelling framework is very flexible and can be adapted to various needs for specific assessments and scenarios. However, modifications of the modelling framework are to some extent limited by the available data and the state of understanding the land system.
- Modelling changes in land use intensity is in principle possible in the modelling framework. However, this is hampered by the low current availability of spatially explicit data on land use intensity, which would allow to properly model the integrated environmental impacts of policies e.g. difference between extensive and rotational grasslands. As alternative, a coupling with more detailed sector models capable of simulating changes in land management could be used.
- Increasing the spatial resolution from 1 km^2 to 1 ha, for example, is in principle possible since CORINE Land Cover data support such a higher resolution. However, many of the data used to identify the location factors that determine the competitive advantage of the different land use types do not support such a lot of spatial detail and would require consistent and harmonised spatial data available at national level.
- The current model implementation is limited in its capacity to address feedbacks between the environmental impacts and the driving factors of land change and needs further research.
- The current model implementation addresses a restricted set of relevant indicators. Some of these indicators are proxies for ecosystem services provided by the land. Further research should focus on quantifying the ecosystem service trade-offs for the different scenarios.
- Although coupling of the modelling framework to many alternative detailed indicator models is possible it may not be always recommended. Many indicator models are based on detailed understanding of processes at the micro-level and therefore be subject to scaling errors when applied at a 1 km spatial resolution. It is therefore important to choose indicator models that are suited and sensitive to the information provided by the EU-CLUEScanner framework at the thematic, spatial and temporal scale of analysis. Also a good fit with the thematic content of the different land use classes is requested.

1. Introduction

1.1 Background

In the next 20 years the EU is anticipated to face new challenges with respect to land use change and its related impacts, which mainly involve the agricultural, forestry, energy, transport, tourism and nature conservation policy sectors. Environment is a transversal policy field across these sectors and therefore, the European Commission is currently involved in several discussions in which land use and its environmental impacts play a key role. For example, the proposal for a Soil Framework Directive, the further implementation of measures for adaptation to climate change, the role that the new Common Agricultural Policy might have to maintain the 'green' services, the assessment and management of flood risks, how to achieve the sustainability criteria for biofuels and bioliquids in the recently approved Renewables Directive, etc.

Since policies function in a complex setting of many competing claims on land-use and parallel developments in multiple sectors, it is difficult to get a clear view on the impact of policy measures with respect to the provision of land services. Consequently, the involved parties generally make use of models or ex-ante assessment studies that simulate possible spatial developments, to support the analysis of the causes and consequences of land-use change.

Many scenario studies have been conducted to assess environmental impact at the global level, e.g. the climate change related studies of the Intergovernmental Panel on Climate Change (IPCC, 2000; Arnell et al., 2004), the Global Environmental Outlook (UNEP, 2002) and the Millennium Ecosystem Assessment (MEA, 2005) which have studied the global effects of environmental change on the provision of ecosystem services. For an assessment of the developments at the European level these global studies do not provide sufficient detail and exclude European specific policies and developments. A coarse resolution makes an assessment of impacts on issues like biodiversity and carbon stock changes difficult since most impacts are location specific. Recent scenario studies for Europe at high spatial resolution as conducted within the SENSOR FP6 project, the FARO FP6 and EURURALIS projects, have indicated that impact assessment studies focusing on Europe as an entity is not always sufficient. Changes in Europe are affected by global developments while European changes and policies may affect environmental sustainability outside Europe. Especially in case of possible implementation of biofuel directives feedbacks with international markets and sustainability are important. Therefore, recent impact assessment frameworks have included multi-scale assessment methods that include linkages with global models in order to account for such changes (Helming et al., 2008; Verburg et al., 2008). Comprehensive land use impact assessment studies should therefore use a multi-scale approach capable of dealing with impacts and interactions over the full range of scales.

A scoping study was undertaken by DG Environment from Dec 2007 to July 2008 to (i) identify the key trade-offs over land use; (ii) identify how policy (environmental) policy) may affect these trade-offs and what would be the likely environmental impacts; (iii) perform an detailed inventory of on-going and forthcoming research and how it could contribute to the building of a modelling framework: and (iv) perform an analysis of the options for a quantitative modelling at EU scale of trade-off and impact of land use and define a roadmap for the preferred option. The current study builds upon the findings of the scoping study, which indicated that methodologies, tools and databases were already available to address the assessment of environmental, economical and social impacts of a broad range of policy options affecting large scale land use changes in EU-27.

1.2 Objective and boundaries of the contract

The main aim of the 'Land use modelling- implementation' study is to show the potential of a European land-use modelling framework to support environmental policy making within the European Commission, using existing methodologies, modelling tools and databases.

The modelling framework will simulate potential spatial developments according to a reference (or baseline) scenario and show, on top of this reference point, the possible spatial impacts of a number of policy alternatives affecting land use in EU-27. Quoting the Specifications to invitation to tender: "…although not directly linked to specific impact assessment of policy proposals, these scenarios will serve as basis for the definition of policy options in the context of the work on Climate Change Adaptation and Mitigation, Water Framework Directive, Biodiversity and Nature protection, Land use and Soils, etc…". It is important to stress that the policy options envisaged will be only examples to test and demonstrate the performance of the modelling framework and will by no means represent the official position of the European Commission. The project has duration of 14 months and ends in February 2010.

1.3 Content of the Final Report

This report describes the methodology and work developed in from December 2008 to December 2009. It reflects the discussions and agreements achieved in seven meetings between the officers of the European Commission (mainly from DG Environment), and the researchers in charge of the project implementation. These meetings have strongly contributed to an encouraging and engaged policy-science interaction, which has become a key feature of the project.

The work performed in the different tasks of the project is described in the following chapters:

- Definition of the modelling framework and model components
- Definition of reference scenario
- Description of Policy alternatives
- Description of selected indicators
- Summary of main results of the different scenarios
- Short description of the user interface
- Limitations and uncertainties of the EU-CLUscanner modelling tool
- Future possible developments of the current modelling framework
- References

2. Description of modelling framework and model components

2.1 Objectives

One of the main objectives is to define an integrated land use modelling framework that can support policy needs of different DGs of the Commission, such as ex-ante analysis of potential policies and measures and more specific impact assessments. The framework should be able to capture the economic, ecological and social domains and cover a range of geographical scales and incorporate the impact of global driving forces. This modelling framework should be as generic and flexible as possible.

2.2 Framework overview

The requirements of this modelling framework are as follows:

- The modelling framework should be able to capture multiple geographical scales, time slices, topics and sectors, in order to be capable of implementing and assessing the impact of multiple scenario types and compare the outcomes.
- The land use change impacts should be quantified via indicators showing changes in land use and environmental domains specifically. The framework should also allow exploring changes and tradeoffs in the social and economic domains. Hence, the framework should be flexible in handling different sector models, indicator models and even in the selection of the land use model and allocation algorithm.
- Input data and scenario conditions have to be easily updatable without high-level programming knowledge by the end-users.
- The results should allow the explicit and straightforward analysis of trade-offs between scales, between locations, between indicators and between policy options.
- Finally the results of calculations for implemented scenarios should be presented in a clear and appealing way for different types of end-users.

In order to fulfil these requirements, use is made of existing land use modelling tools and an existing software framework for integration of these tools. The framework is based on the Data & Model Server (DMS) software which is a flexible system for linking specialized models and data within a consistent workflow. Main advantage of using this framework is that, in contrast to many other frameworks, DMS is available as an open source product (GNU-GPL)[1] as requested in the technical specification of this project. This framework has been successfully applied in various projects linking land use models, databases and indicator models. The model components used in the implementation of this framework use existing, well-established models.

[1] The GNU operating system is a complete free software system, upward-compatible with Unix. GNU stands for "GNU's Not Unix". GNU-GPL (General Public License) is a free, copyleft license for software and other kinds of works. The licenses for most software and other practical works are designed to take away freedom to share and change the works. By contrast, the GNU General Public License is intended to guarantee freedom to share and change all versions of a program--to make sure it remains free software for all its users.

The core of the framework is formed by the land use model Dyna-CLUE (Verburg et al., 2002; Verburg et al., 2006; Verburg and Overmars, 2009), bridging sector models and indicator models and connecting European scale analysis to the level of environmental impacts. In addition, the global multi-sectoral models LEITAP and IMAGE (van Meijl et al., 2006; Eickhout et al., 2007) are used to define demand for different types of land use, which are based on predictions on world-wide economic drivers. Indicator models either consist of well-established models or targeted, simplified indicator models such as used in the SENSOR (Helming et al., 2008) and EURURALIS projects (WUR/MNP, 2008). For all models, quality assurance is provided by extensive documentation, validation and publication in peer-reviewed journals (e.g., Verboom et al., 2006; Schulp et al, 2008). The use of these well-established models, which are all available within the consortium, ensures the feasibility and quality of the approach. However, the framework is designed in such a way that it is flexible in including other models and indicators if needed for a specific policy scenario application.

The proposed modelling framework takes stock of methods and specific tools developed in previous EU projects, e.g. EURURALIS, SENSOR, NITRO-EUROPE, FARO-EU, EFORWOOD, PLUREL and RUFUS projects, in which much experience was gathered with different elements of the framework and its application in policy relevant scenario analysis.

The modelling framework allows simulation on simple computers without specific licences. The model framework and its base implementation with a land use model and a series of indicator models will be provided as documented, open source, software including a short user tutorial instruction and access to the modellers-reference of the declarative DMS scripting language and set of operators (http://www.objectvision.nl/dms).
The proposed model characteristics are specified in Table 1.

Table 1 Model characteristics proposed

Model characteristics	Current proposal
Spatial resolution	1000m grid cells
Thematic resolution	Full range of urban, agricultural land-use types based on CORINE simulating a maximum of 17 types per application
Geographical extent	Full EU-27 territory
Time horizon	2030 with possibility to extent to 2040/2050.
Degree of dynamics	Yearly time steps (aggregations possible)
Allocation principle	Dynamic allocation based on econometric estimation of suitability + process knowledge (e.g. growth processes); neighbourhood processes included for urban growth. Dyna-CLUE mechanism (Verburg and Overmars, 2009, see Annex 2)
Regional divisions for aggregation	All simulations are made at pixel level (1 km2). Results can be aggregated to NUTS2/3
Reliability	Validation of Dyna-CLUE model core on multiple cases available (Pontius et al., 2008); validation for CLC 1990-2000 evaluated (Verburg et al., 2009).

Performance	Depending on policy scenario and requirements in terms of sector-specific models. Core configuration (most scenarios) will run within a number of hours on a single fast PC
Interoperability	Open Source for all core-modelling components and the modelling framework
Flexibility	Maximum flexibility as result of framework that allows alternative model configuration.

2.3 Model components and methodology

Although this project is not directly linked to impact assessment of specific policy proposals, it is vital that the modelling framework is developed in such a way that it can easily serve as a basis for the definition of policy options at a later stage. Future applications are likely in the context of the work on Climate Change Adaptation and Mitigation, Water Framework Directive and in particular Water Scarcity and Droughts, Biodiversity and Nature protection, Land use and soils, etc. Therefore the involvement of relevant policy makers at the different DG's is an essential feature of the project.

The structure of the modelling framework allows the inclusion of different modelling components related to the drivers of change, the land allocation and impact indicator models. The framework is flexible in using and selecting these model components. The modelling components have been chosen based on the specific purpose of the project, scientific quality, possibility to deliver as open source software (land allocation module) and availability within the consortium.
In principle the same modelling framework could be used consisting of different sets of models combined. Especially the indicator models and the economic models may vary due to the specific requirements for a specific scenario. In case of the assessment of specific agricultural policy changes models like CAPRI may be a better choice. A description of the coupling of CAPRI to the Dyna-CLUE land allocation module is described in Britz et al. (submitted). Similarly, the land allocation output can be used as input for more detailed assessments. In Hurkmans et al. (2009) an example is provided of using the Dyna-CLUE output in an assessment of river discharge by coupling to a detailed hydrological model.

Figure 1 illustrates the multi-scale structure of the model components.

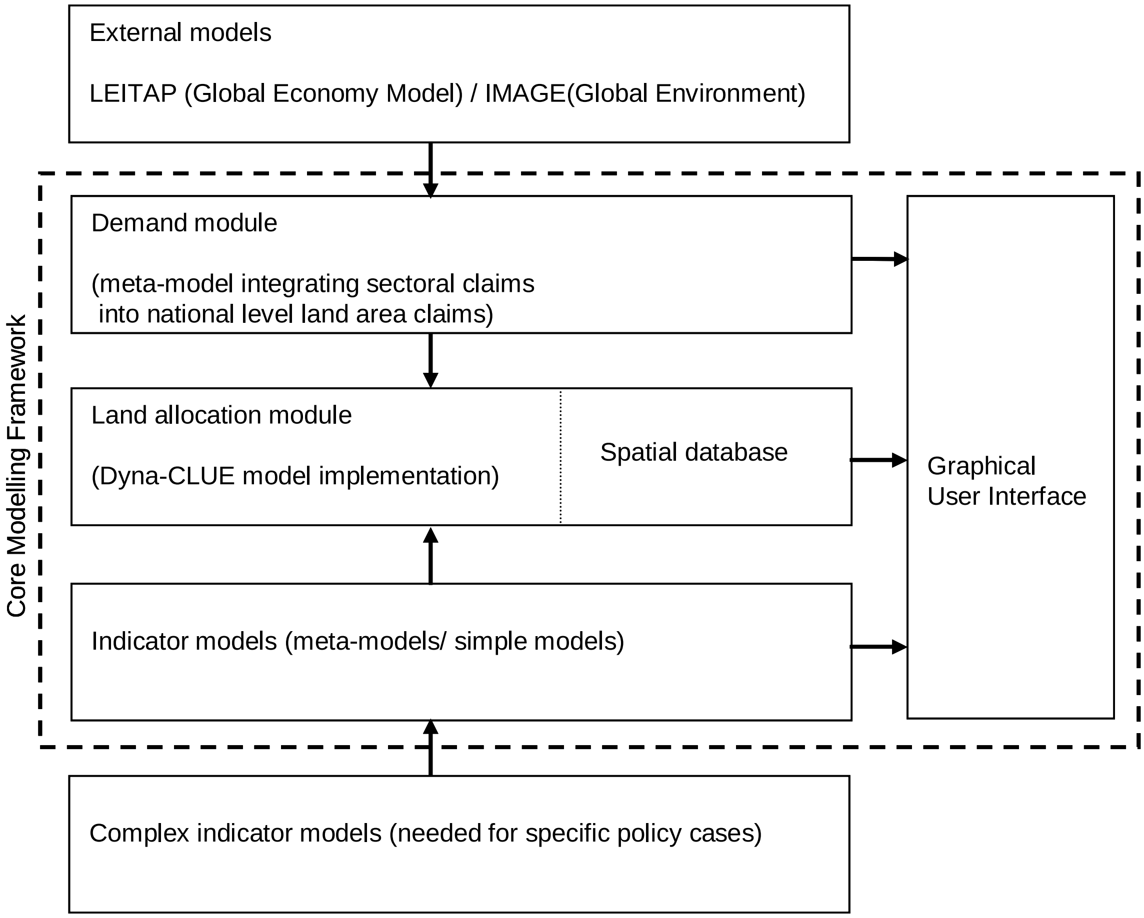


Figure 1 Modelling framework for multi-scale analysis linking the different model components across scales in this project

External, global models: LEITAP and IMAGE:

Global models account for interactions between Europe and other world regions as determined by the global economy and climate change. For the European Biofuel policy alternatives, the combination of a global economy (LEITAP) and integrated assessment model (IMAGE) following the configuration as used in the EURURALIS project (Van Meijl et al., 2006; Eickhout et al., 2007) is being used. These external models are only used for the European Biofuel policy alternative and not for the Biodiversity and Climate & Soil alternatives, in which the global context remains the same as in the reference, and the variation is only in the European policies.

The LEITAP model builds on a modified version of the GTAP multi-sector multi-region CGE model (Hertel, 1997). Its multi-region specification allows the inter-country effects expected from the Renewable Energy Directive (that affects demand and supply in the EU) to be captured. Due to the fact that prices and trade flows are modeled endogenously, LEITAP also illustrates the impact of the Renewable Energy Directive on prices and trade flows on global markets. The multi-sector dimension makes it possible to study the link between energy, transport and agricultural markets. The current version of LEITAP is extended by introducing energy-capital substitution as described in the GTAP-E model (Burniaux and

Truong, 2002). To introduce the demand for biofuels, the nested Constant Elasticity of Substitution (CES) function of the GTAP-E model have been adjusted and extended to model the substitution between different categories of oil (oil from biofuel crops and crude oil), ethanol and petroleum products in the value-added nest of the biomass using sectors. The nested CES structure implies that biofuel demand is determined by the relative prices of crude oil versus agricultural products, including taxes and subsidies, (Banse et al. 2008).

To analyze the impact of increasing demand for bioenergy production on land use changes, LEITAP presents the land demand for agricultural purposes in a nested structure considering different degrees of substitutability between types of land use, e.g. for arable, pasture, fodder etc. On the land supply side, LEITAP presents total agricultural land supply in land supply function, specifying the relationship between land supply and a land rental rate in each region (van Meijl et al., 2006). Land supply to agriculture can be adjusted by idling agricultural land keeping agricultural land in ‘good agricultural condition’, converting non-agricultural land to agriculture, converting agricultural land to urban use, and agricultural land abandonment, which will not be used in agricultural in the long-term.

Figure 2 gives the general idea behind the land supply curve. When agricultural land use approaches potential land use ($\overline{L}$), farmers are forced to use less productive land with higher production costs (strongly increasing part of the supply curve). As a consequence, in land-abundant regions like South America and for members of NAFTA, an increase in demand from D_1 to D_1^* (left-hand side of figure 2) results in a large increase in land use (from l_1 to l_2) and a modest increase in rental rates (from r_1 to r_2), while land scarce regions like Japan, Korea and Europe experience a small increase in land use and a large increase in the rental rate (right-hand side of figure 2; shift from D_2 to D_2^*). These land price differences will influence competitiveness of biofuel production. The empirical implementation of this land supply curve for non-European regions is based on data from IMAGE, while CLUE with a more detailed spatial presentation provides data on land availability in LEITAP for the European regions.

The modelling framework uses the IMAGE 2.4 version, in which LEITAP provides the agricultural economy model (e.g. food and feed demand) and IMAGE the necessary bio-physical information. IMAGE brings the restriction of land into the economic model. LEITAP and IMAGE are linked by agricultural production, technological changes, land allocation, and climate change. IMAGE considers 24 world regions, and a zoom version distinguishes the EU27 at Member State level. For land cover/land use change the spatial scale is 0.5 x 0.5 degrees grid at global level. Land allocation at this scale is only indicative and not sufficiently detailed to allow detailed impact assessment or further downscaling.

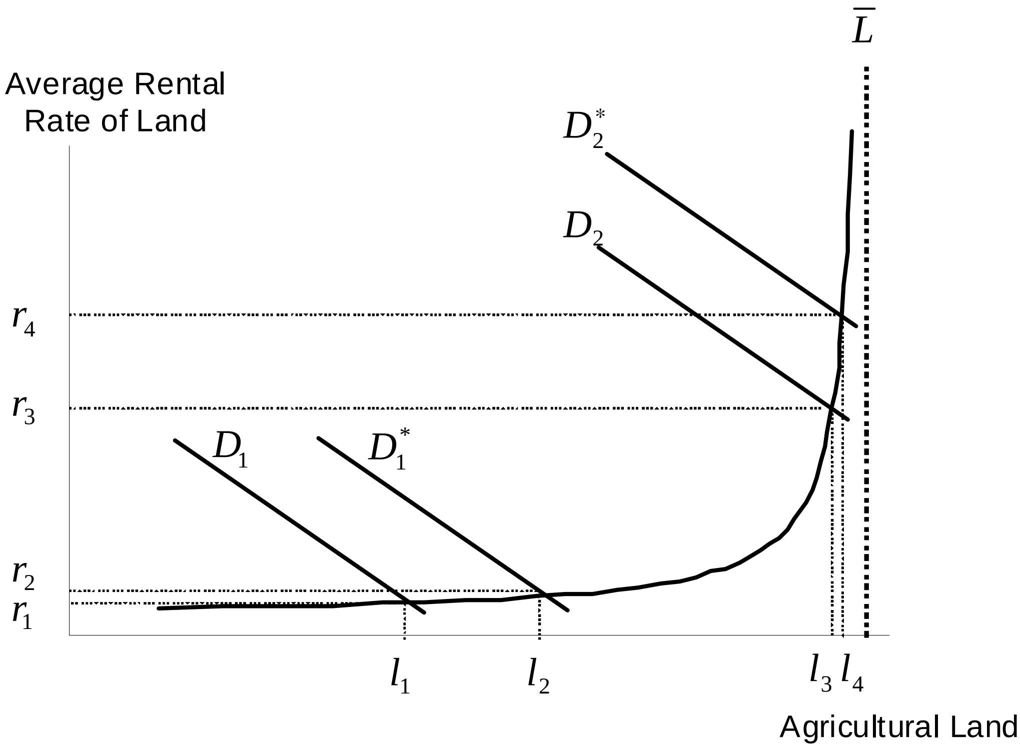


Figure 2 Impact of increased land demand for biofuel crops on land markets

European land use allocation model: Dyna-CLUE

Core to the model implementation is the Land Use Allocation model. This model translates the driving factors and policy specifications into spatially explicit assessments of land use change at high spatial and temporal resolution (EU-27 wide yearly results at 1 km^2 resolution). This model bases its assessment on a wide range of different land cover classes as far as it is allowed by the databases on land cover (CLC/CORINE) and supplementary sources on biofuel crops.

The land cover representation for this application includes 17 classes, i.e. built-up area, arable land (non-irrigated), pasture, (semi-) natural vegetation, inland wetlands, glaciers and snow, irrigated arable land, recently abandoned arable land, permanent crops, biofuel cultivation, forest, sparsely vegetated areas, beaches, dunes and sands, salines, water and coastal flats, heather and moorlands, recently abandoned pasture.

Results from the macro-economic model LEITAP (or any other economic model capable of simulating land area changes) are used as input indicating changes in area of agricultural land at the national scale. It is considered that economic processes are dominant explaining changes in land use between countries. Within countries other processes, including the variation in biophysical conditions, will together determine the spatial patterns of change. In addition to changes in agricultural area also changes in urban area are calculated. For this project a simple projection based on population growth, immigration projections and changes in urban area per person is made. Alternatively more advanced urban projection models could be used. The remaining land area is corrected for changes in the agricultural

and urban areas while its subdivision in individual classes of (semi-) natural vegetation is done in the Dyna-CLUE model as part of its allocation methodology.
The translation of aggregate changes in agricultural area to input of the Dyna-CLUE model requires a number of corrections to ensure consistency between the models. While LEITAP is based on agricultural statistics the Dyna-CLUE simulations are based on land cover data derived from CLC2000. Large differences in agricultural areas between the two data sources are the result of differences in definition, observation technique, data inventory bias etc. (Verburg et al., 2009). To some extent these differences are structural and can be corrected. Absolute changes in agricultural area in LEITAP are corrected for some of these differences and then serve as input to the Dyna-CLUE model.
From the IMAGE model climate change data are used as one of the location factors considered in the Dyna-CLUE model. The simulated changes in climate at coarse spatial resolution (50x50 km) are downscales to 1x1 km and superimposed on the more detailed Worldclim data used in the simulations.

For the land use allocation module, use is made of the CLUE model. CLUE is one of the most used land allocation models globally and is highly applicable for scenario analysis. The use of the model in many case studies at local and continental scale by different institutions worldwide (including FAO, CGIAR and many international institutes and universities) has proven its capacity to model a wide range of scenarios and provide adequate information for indicator models. The current version of the model is Dyna-CLUE, which includes newest advances, and considers world-wide and local processes. Figure 3 shows the land use change allocation procedure. There are 'four boxes' that provide the information to run the model:

- Spatial policies and restrictions (e.g. N2000);
- Land use demand (i.e. agriculture, urban and nature);
- Location characteristics, maps that define the suitable location for each Land Use type based on empirical analysis; for example, the European soil map is translated into functional properties such as soil fertility, water retention capacity. In addition to the soil map there is a set of 100 factors that range from accessibility to bio-physical properties; the factors can be dynamic in time (e.g. in case of population which is based on a downscaling of EUROSTAT NUTS level projections). A full list of factors considered can be found in Verburg et al., 2006;
- Set of rules for possible conversions (conversion elasticity, Land Use transition sequences). A detailed description of the functioning of the Dyna-CLUE land allocation procedure is provided in Annex 2.

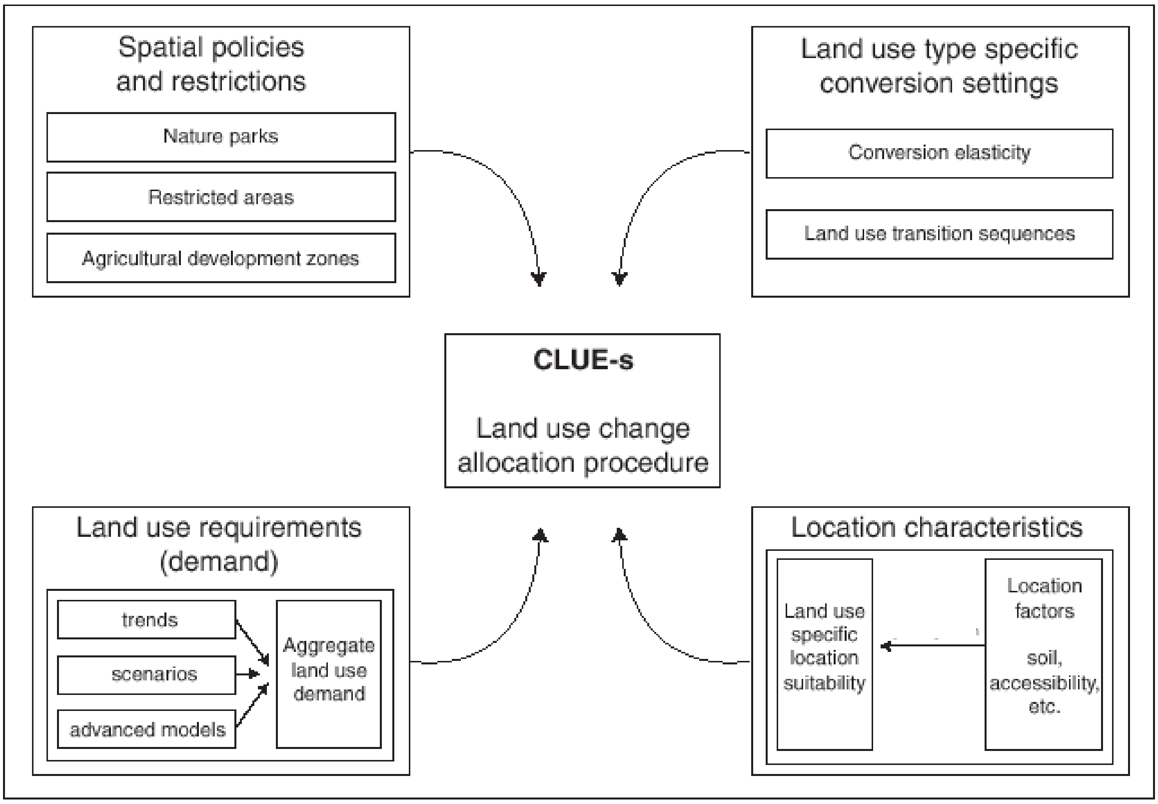


Figure 3 Land use allocation procedure in Dyna-CLUE

Data & Model Server (DMS)

The land allocation module of Dyna-CLUE is combined with the numerical algorithm of the Land Use Scanner model to optimize its performance for use on desktop computers within the Data & Model Server (DMS). Land Use Scanner is another well-established land use model with many applications within Europe with similar model assumptions as Dyna-CLUE but with fewer options for short-term dynamic changes which are needed for adequate analysis of the policy implementation cycle.
Combining the strengths of both models ensures a consistent, state-of-the-art and flexible modelling core.

Application of the DMS software environment allows the use of a flexible generic framework for a multi-scale and multi-sectoral model. Based on the selection of model components made, these model components will be implemented in the DMS. Implementation takes place through embedding the model components in the DMS and linking the input and output of models through simple, straightforward scripts. These linkages are essential and should ensure the consistency of the data flow through the model framework.

2.4 Technical setup

The various components and calculation steps are defined in the DMS model script language in a modular organisation to enable expert users to add suitability factors, policy options, dynamic processing steps, output generation definitions, and indicator definitions. The framework uses tables that define the basic set of land use types, suitability factors and land use conversion characteristics.

Indicator models

Finally, a series of indicator models corresponding to the demands of the policy cases are implemented. Indicator models use information both derived from the economic models and the land allocation models to arrive at a balanced set of indicators focussing on the land-use and environmental domains.
Most of the indicator models envisioned comprise relatively simple (open-source) algorithms that are making best use of knowledge in the field and are targeted at the application in combination with the outputs of the proposed land allocation algorithm.

Geographical scales

In all cases, the global influence is accounted for through changes in climate and global demand for goods and commodities based on outcomes of the LEITAP and IMAGE models. Results from these simulations relate to the demand for various types of land use 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 Dyna-Clue land allocation model. This translation is performed in a newly developed demand module that is implemented in the DMS model script.

An additional 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 are better capable to address specific landscape structures such as parcel boundaries (Gaucherel et al., 2006) and the behaviour of individual actors (e.g. through multi-agent models; Matthews et al., 2007). The modelling framework will provide the opportunity to link through to this type of case-study models. However, this coupling has hardly ever been used for assessment for scenario analysis. One example of using coarse scale land allocation results for more detailed assessment of regional scenarios with a multi-agent modelling system is provided by Valbuena et al. (submitted).

3. Description of reference scenario

3.1 Rationale

The reference scenario must describe foreseen future developments of European urban and rural areas affecting land use. These European futures are situated in the context of exogenous global drivers like

- increasing food and feed demand in emerging countries, i.e. the BRIC countries (Brazil, Russia, India and China);
- changing trade regimes because of increasing competitiveness of Asian and Latin-American regions;
- changing environmental constraints because of resource scarcity and climate change.

Moreover, the European future development is closely related to expected demographic changes within the European Union.

Potential policy options within the reference scenario should be based on these contextual developments, take account of approved (sector-specific) policies, and incorporate new policies that fit within the world view of the reference. From this perspective, past trends (in land use) and patterns of spatial development are translated into maps of future potential spatial structures. Since some socio- economic developments are uncertain and therefore difficult to project (e.g. migration flows in relation to economic growth) the scenario approach is used.

An obvious choice for the reference scenario is the well-known IPCC-SRES[2] framework. The scenarios in this framework are well-accepted by the policy and scientific communities and cover both climatic and socio-economic changes. They, furthermore, offer intuitive comparison material as the scenarios are known to most stakeholders and they have been elaborated in existing pan-European studies, such as ATEAM and Eururalis (see, for example, PIK, 2004; Verburg et al., 2006, EEA Report 4/2008; JRC report 47756; Verburg et al., 2008; Westhoek et al., 2006). They combine autonomous development and policy. Out of the four IPCC-SRES reference scenarios, the *B1 – Global Co-operation* and the *A2 – Continental markets* were initially proposed as two reference scenarios. The *B1 scenario* includes many policy developments that correspond to ongoing changes in policy context and discussions. As such it presents a business-as-usual type of scenario. Regarding Climate Change (CC), the *A2 scenario* is interesting because more GHG emissions are predicted; the impact on CC is higher and therefore will help to identify high vulnerable areas. However, considering that in 2030 (the target year of the scenario modelling) the CC impacts will not be significant, it was finally decided to keep only the B1 scenario. Nevertheless, having two reference scenarios will be more realistic than having only one, considering that CC has large uncertainty. Therefore, instead of having A2 as reference, it was agreed to consider the second option of the Biofuel policy alternatives, which includes biofuel policy in OECD

[2] The Special Report on Emissions Scenarios (SRES) was a report prepared by the Intergovernmental Panel on Climate Change (IPCC) for the Third Assessment Report (TAR) in 2001, on future emission scenarios to be used for driving global circulation models to develop climate change scenarios.

and EU, as second reference scenario. Given its larger demand for land, this scenario is expected to show the effectiveness of the policy options under conditions of stronger land pressure that are comparable to the ones in the A2 scenario.

The following sections describe the main storylines, related assumptions and resulting spatial developments for the B1 reference scenario based on the elaboration of the IPCC SRES scenarios for Europe as performed in the EURURALIS project and described in more detail elsewhere (Westhoek et al., 2006; Eickhout and Prins, 2008). The description below is partly taken from these sources, and adds which specific assumptions regarding the policies are considered in this project.

3.2 Global Co-operation (B1) scenario

The Global Co-operation scenario combines a global orientation with a preference for social, environmental and more broadly defined economic values. Economic profit is not the only objective. Governments are actively regulating, ambitiously pursuing goals related to, for example, equity, environmental sustainability and biodiversity. It is defined by the following assumptions per theme:

- Intensive multilateral international co-operation on many issues:
    - Globally, the high economic growth stimulates the global demographic transition, leading to a sooner stabilization of global population at around 8 billion inhabitants around 2030. Economic growth will be especially high in the new member states (3.4% per year in the EU-12), partly at the cost of the original EU-15;
    - Tariff barriers restricting market access are gradually removed, e.g. the current CAP export subsidies are abolished, since these are understood to hamper developing countries in their development. Border support is also phased out;
    - On the other hand international food safety standards are raised and new mechanisms are introduced to ensure high social and environmental production standards of traded goods. Developing regions are supported so as to comply with these standards;
    - There is a flexible policy with respect to the international mobility of individuals from outside the EU, leading to 2.1 net migrants per 1000 inhabitants in 2030, and no limitation for migration between member states. In combination with a relatively high fertility rate this leads to an increased population of almost 500 million inhabitants in 2030 in the EU and a corresponding high urbanisation pressure.
- Ensure environmental sustainability and biodiversity:
    - Environmental Agricultural income support is reduced to 33%, mainly aiming at maintaining environmental services;
    - Animal welfare and health considerations are assumed to lead to relatively less meat consumption (-5% in 2020 and -10% in 2030 of endogenous outcome based on GDP developments);
    - Less Favoured Areas are maintained, except for arable agriculture in locations with high erosion risk;
    - The government is expected to guide urbanization processes through spatial planning aimed at restricting urban sprawl. These restrictions lead to relatively compact urban growth; therefore, pressure on agricultural land is relatively low

leading to agricultural abandonment at a substantial scale, which offers opportunities for new spatial developments in rural areas;
- Successful climate mitigation strategies are assumed as well. The EU climate stabilization target of 2°C is implemented globally and therefore, global greenhouse gas concentration level is stabilized at 450 ppm CO2-equivalents;
- The maintenance (and acquisition) of natural and cultural heritage are mainly publicly funded.

Therefore, important driving forces in the 'global' assumptions are demographic, macro-economic and technological developments as well as policy assumptions. The demographic and macro-economic assumptions implemented in the LEITAP model are based on studies that implement the SRES. The population numbers are taken directly from SRES scenarios (Nakicenovic and Swart, 2000). Yearly GDP growth (between 0.9% per year in Japan and Korea and 5.2% in East Asia) and consistent employment and capital growth per scenario are taken from CPB (2003), which used the CPB macro-economic Worldscan model. The scenarios are constructed through recursive updating of the database for consecutive time periods such that exogenous GDP targets are met given the exogenous estimates on factor endowments (skilled labour, unskilled labour, capital and natural resources) and population. The procedure implies that technological change is endogenously determined within the model. In line with Netherlands Bureau for Economic Policy Analysis (CPB), we assume common trends for relative sectoral total factor productivity (TFP) growth. We deviate slightly from the CPB assumptions that all inputs achieve the same level of technical progress within a sector, i.e. hick's neutral technical change, by allowing land productivity to be determined by additional information on yields from FAO and the IMAGE model.

An overview of the most important socio-economic assumptions and key characteristics for the EU is provided in Table 2.

Table 2 Reference scenario socio-economic assumptions and key characteristics for the EU (source: Westhoek et al., 2006 and www.eururalis.eu)

Aspect	Global Co-operation (B1)
Population EU-27 in 2030	500 million
Population change since 2000	4%
EU-15 GDP yearly growth	1.3%
EU-12 GDP yearly growth	3.4%
EU enlargement	Turkey enters EU
Trade of agricultural products	Export subsidies and import tariffs phased out. Slight increase in non-tariff barriers
Product quota	Phased out; abolished by 2020
Farm payments	Fully decoupled and gradually reduced (by 50% in 2030)
Intervention prices	Phased out; abolished by 2030
Compulsory set-aside of arable land (excl. organic farms)	Set-aside target remains at 10% level

The B1 reference scenario is useful as reference point for the assessment of the specific potential impacts of future spatial EU-polices, as it already contains many current spatially explicit EU policies. This refers especially to the *Less Favoured Areas* support, which is maintained, and current protected nature areas (including Natura2000 areas, forests and other natural areas), that remain protected from development. In this way the reference scenario offers business-as-usual baseline conditions that allow a proper assessment of the impacts of new policy alternatives.

4. Description of Policy alternatives

This section describes the rationale of the policy alternatives and the manner in which they will be incorporated in the modelling framework. It lists explicitly how these proposed alternatives differ from the current policies and the way these are included in the reference scenario. It discusses, where applicable, the models that are used to create demand for land, or the datasets that will be used to define suitable or non-suitable locations for specific land-use types. The final documentation of the scenario-results will describe the exact implementation of the mentioned data sources.

4.1 Types of policies regarding their impact on land use

European policies can be relevant for land use change in two ways. Firstly, there is a group of *policies that influences the demand for land*, e.g. stimulation of agriculture through the Common Agricultural Policy. This policy influences the amount of land in use for different agricultural commodities within the EU. And secondly, a group of *policies that influence land-use configurations*, e.g. excluding or favouring some regions for a specific type of land use. This can be done through site-specific spatial planning policies or by theme-specific policies that relate to, for example, the general protection of nature areas or watersheds.

4.2 Policy alternatives in this study

Within this project we will evaluate eight policy scenarios. i.e. the two reference scenarios described in chapter 3, and the six policy alternatives described in this section (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 bio-fuel production) that can be associated with this policy. In addition, two other sets of spatial policy alternatives are defined, 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 policy alternatives will be addressed in a coherent way and applied to the reference scenario to provide a total of eight different land-use simulations. The chosen policy packages fit within the proposed modelling framework and are able to illustrate key policy issues and trade-offs for the EU. These policy alternatives are only taken to illustrate the possibilities and deliverables of the model but by no means are an actual impact assessment of envisaged policies. 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.

Table 3 Overview of the proposed land-use simulations following the two reference scenarios (shading in orange) and supplemented policy alternatives

Nr.	Characteristic
1	*First reference scenario: Global Co-operation (B1)*
2	Policy promoting biofuel use in five non-European countries (USA, Canada, Japan, Brazil and South Africa) with unrestricted land conversion of forests into agricultural land (i.e. no protection of forests)
3	*Same as 2) with the same policy also implemented in EU. This scenario is also used as a 2nd reference*
4	Same as 2) with full protection of all existing forests
5	Biodiversity alternative: policy aiming at preserving biodiversity
6	Biodiversity alternative with alternative 3 as reference
7	Soil and climate change alternative: policy aiming at mitigating and adapting to climate change, incl. via soil preservation actions
8	Soil and climate change alternative with alternative 3 as reference

4.3 European Bio-fuel policy alternatives

Current policy background

The European Union has set a target for an obligatory share of 10% for energy from renewable sources in transport, to be reached in 2020 (Directive 2009/28/EC). This applies to final energy consumption in transport within each Member State. This target for the transport sector is set for renewables in general, but it is expected to be mainly met by using bio-fuels.

A Biofuel policy (BFP) is chiefly promoted from a climate perspective, since bio-fuels are expected to deliver greenhouse gas savings compared to the use of fossil fuels in the transport sector. However, in its communication "An EU strategy for biofuels"[3], the European Commission pays much attention to tackling the oil dependence of the transport sector as one of the most serious issues affecting the security of the energy supply in the EU. Therefore, the 10% renewable energy target for the transport sector is intended not only for climate considerations, but also to improve energy security.

BFP alternatives

In order to analyse the possible impact of a BFP three alternatives are explored:

1. Policy promoting bio-fuel use in five non-European countries (USA, Canada, Japan, Brazil and South Africa) with unrestricted land conversion of forests into agricultural land (i.e. no protection of forests);
2. Same as 1) with the same policy also implemented in EU. This scenario is also used as a 2nd reference;
3. Same as 2) with full protection of all existing forests.

[3] COM 2006(34)

These alternatives mainly provide different demands for bio-fuel crops in Europe. The subsequent land-use allocation step then indicates the spatial patterns that will arise from these changes in the agricultural sector.

Model assumptions and characteristics

- In this study it is assumed that the entire 10% renewable energy target for the transport sector will come from bio-fuels for analytical reasons. In the rest of the study, it is referred to as Bio-fuel policy (BFP) alternatives.
- In earlier analyses, it is concluded that a BFP will not be met by EU-domestically grown bio-fuels alone (Banse et al., 2008; Eickhout et al., 2008). Hence, a comprehensive analysis of a BFP requires having good insights in the *inter-linkages between European policies and global impacts* in order to rightly assess the consequences for land use. Bio-fuel crops will (in)directly impact the amount of land available for other land uses and, in particular, diminish chances for nature development on abandoned land (with both positive and negative consequences for biodiversity, fire risk, employment, etc.). Previous studies have indicated that, in general, higher targets for the BFP will lead to a higher demand for agricultural land (Rajagopal and Zilberman, 2007; Reilly and Paltsev, 2007; Rosegrant et al. 2007; Banse et al. 2008).
- The impact of a BFP on the demand for agricultural land will be determined by including in the modelling framework a *'global' component*, consisting in the combination of the *computable general equilibrium (CGE) model LEITAP* and the global integrated assessment model IMAGE. By using a global, multi-region, multi-sector CGE model, the understanding of the international trade aspects of bio-fuels and bio-fuel policies can be better explained. Hence, the LEITAP model optimizes the use of bio-fuels per region in the world on the basis of costs by input factors like land, capital and labour. Trade restrictions are also considered, leading to higher costs for imports of ethanol from, for example, Brazil.
- The *land availability per world region* is a very important driver of costs for bio-fuel production. A distinguishing feature of the LEITAP-IMAGE-method is the introduction of a land supply curve to represent the process of land conversion and land abandonment endogenously (Eickhout et al., 2009; Van Meijl et al., 2006). As a consequence, in land-abundant regions like South America, an increase in demand results in a large increase in land use and a modest increase in rental rates, while land scarce regions like Japan, Korea and Europe experience a small increase in land use and a large increase in the rental rate. This approach determines how much land will be used for biofuels outside Europe as a result of EU BFP and how much land is needed within the EU, per Member State. Consequences for European land-use patterns will be elaborated upon by CLUE.
- Forests are defined in this modelling framework as all biomes with 90% or more closed canopy cover (tropical forests, tropical woodlands, boreal forest and all temperate forests). Savannah, shrub-land and wooded tundra are not included. The canopy cover used in IMAGE cannot directly be compared with the conditions set under the Renewable Energy Directive Art. 17.4(b) (EC, 2009). The canopy cover in IMAGE is used at a grid level of 0.5 x 0.5 degree, which is 50 by 50 km at the equator. In the RES

Directive[4] the condition is set at 30% canopy cover for one hectare. The canopy cover of savannah is set in IMAGE at more than 30%. However, increasing the spatial resolution will probably show hectares with a canopy cover below 30% and hectares with a canopy cover higher than 30%. Thus excluding savannah, shrub-land and wooded tundra classes in IMAGE exceeds probably the exclusion as defined in the RES Directive.

Modelling constraints

In the proposed Renewable Energy Directive (Directive 2009/28/EC), much attention is paid to sustainability criteria for bio-fuels and bio-liquids, following the debate on whether the negative aspects of bio-fuels outweight their benefits as a renewable energy source. The focus of sustainability criteria is on greenhouse gas balance (excluding inefficient bio-fuel production chains like ethanol from maize) and undesired land-use changes.

By using LEITAP and IMAGE, the extent of indirect effects of bio-fuels can be assessed, since differences between the B1 reference and the scenarios with a BFP provide insights in direct and indirect impacts on land use changes in all world regions.

However, the implementation of sustainability criteria is not straightforward. Land input is calculated for individual crops and only at the end of the modelling chain it is known if the use of those crops will be for food or bio-fuels. In the land supply curves, specific land use types can be excluded, following the sustainability criteria (for example, highly bio-diverse natural grasslands). Since land supply curves apply for all agricultural purposes, this means that these land use types are also excluded for food production. A model set-up to exclude land-use types for the use of bio-fuels alone is not straightforward. Therefore, the analysis is done with several land supply curves to assess the impact of excluding land use types entirely on prices and land use impacts. This analysis provides some insight in the impact of the proposed sustainability criteria. A full assessment of the impact of all sustainability criteria has not been envisaged under the current contract.

[4] The Directive on Electricity Production from Renewable Energy Sources is a European Union directive for promoting renewable energy use in electricity generation. It is officially named 2001/77/EC and popularly known as the RES Directive.

4.4 Biodiversity alternative

The biodiversity alternative introduces a number of ambitious policies to increase the protection of specific ecological and landscape related values. It builds on existing policy options that are currently being discussed (Table 4).

Table 4 Overview of the current spatial policy ambition level incorporated in the reference scenarios and the more ambitious policies in the biodiversity protection alternative

Policy theme	Current ambition level	Policy alternative
Controlling urban growth	No European-wide policy	Spatial planning to promote more compact forms of urbanisation; prevention of urbanisation in semi-natural and forest areas
Fragmentation control and promotion of clustering of nature	Current fragmentation control following EIA legislation, no active promotion of clustering	Policy targeted at clustering natural land-use types towards large robust natural areas
Natural corridors	No European-wide policy (except what is done in Natura 2000)	Create a coherent European-wide approach to give space to ecosystems; as an example we use the main Pan–European Ecological Network (PEEN) corridors (incentives to convert land in specified corridor areas to nature)
Natura 2000	Some incentives to continue extensive land use in NATURA2000 areas (2nd pillar funds)	More funds through 2nd pillar payments to continue extensive land use in Nature 2000 areas (incentive approx. three times as strong)
High Nature Value (HNV) protection	No specific protection	Compensation of extensive farming (especially permanent pastures) in HNV areas to prevent abandonment or intensification (compensation for pasture similar to current LFA support, for arable land 50% of current LFA support)
Less Favoured Areas (LFA)	Current LFA support	Targeted LFA support to HNV within LFA, increased level of 2nd pillar payments
Protection peat land	No policies	Land conversion in peaty areas are not allowed

In the following subsections, the relevance of some of the included policy measures is discussed.

<u>Controlling urban growth</u>
Urban growth is a threat to biodiversity and controlling this growth is an important policy issue in many Member States. Although this issue is currently not managed at the EU level, some urban growth control measures are included in this policy alternative to demonstrate their potential impact, i.e. what could be the consequences of more active policies controlling urban growth.

Fragmentation control and natural corridors

Fragmentation of natural habitats is a serious concern in Europe. This issue has become even more pressing in view of climate change as studies using the LARCH model indicate (BRANCH partnership, 2007). These studies suggest that climatic changes are likely to cause many plant and animal species to migrate, in general from south-west to north-east Europe. To allow this migration to actually take place and help create robust habitats where key-species have a larger chance of surviving the more extreme future conditions, strategies dealing with natural corridors have been suggested. In this study the following alternatives will be considered: enlarging current nature areas and creating networks of interconnected nature areas. Although there is no binding European-wide policy on natural corridors, there are initiatives and obligations regarding ecological coherence. Art. 10 of the Habitats Directive stipulates the creation of functional and spatial links between protected sites and DG ENV has started an initiative on Green infrastructure[5]. These strategies can be implemented in the model by using currently available datasets, that are suitable for enhancing the current suitability maps for nature, for example, through upgrading the suitability of the areas surrounding current larger nature areas (by applying spatial filters) and by including nature networks such as PEEN. Such substantial investments in the green infrastructure (acquisition of corridor areas, enlargement of Natura 2000 areas, active afforestation policies etc.) could ensure a rapid conversion (short succession time) of agricultural in nature areas.

Natura 2000

Currently, only a few NUTS2 regions in EU27 have more than 50% share of targeted agricultural habitats within their Natura 2000 sites. In particular the UK, the western part of the Iberian peninsula, most of Italy, the southeast of France as well as the northern part of Scandinavia have high proportions of extensive agricultural habitat types protected under Annex of the Habitat Directive in their Natura 2000 sites (EEA, 2006). Therefore, it is important to recognise the differences between EU27 countries regarding the needs for natural corridors and potential use of funding, which in some MS is restricted to areas within Natura 2000 areas. For example, UK agricultural areas in Natura 2000 sites are mostly all habitats according to the Habitats Directive (thus core areas, and green infrastructure/ecological corridors would be needed outside the Natura 2000 site, to link them to each other), whilst Natura 2000 sites in Spain and Sweden could have vast agricultural buffer zones around the core agricultural habitats, which act as corridors/linkages within the Natura 2000 sites. Under the new Rural Development Regulation (Reg. 1698/2005), measures are envisaged to support indirectly or directly extensive land use. The more relevant RDR axes for Natura 2000 are Axis 2 and 3. Axis 2 includes “Sustainable use of agricultural land and forestry land including Natura2000 areas”. In Axis 3, under the measure “Conservation and upgrading of the rural heritage”, there is support for drawing-up of protection and management plans related to Natura 2000 sites and to other places of high natural value. Our policy alternative considers the increase of current funding to promote the sustainable land use in these protected areas.

[5] http://ec.europa.eu/environment/nature/ecosystems/index_en.htm

High Nature Value (HNV) protection

"Natura 2000 and the conservation of threatened species will not be viable in the long–term without a wider terrestrial, freshwater and marine environment favourable to biodiversity. Key actions include: optimising the use of available measures under the reformed CAP, notably to prevent intensification or abandonment of high nature value farmland…" (COM/2006/0216). The policy alternative aims to stimulate extensive farming with associated high nature values in specified areas.

Less Favoured Areas (LFA)

Per January 1st 2010 Member States need to introduce new LFA schemes. At this moment DG AGRI is preparing new regulation that will be more targeted towards the environment and less to socio-economic objectives. Four directions have been considered for reviewing the LFA scheme that were subject to public consultation:

- 'Improved Status Quo', empowering the Member States to delimit LFAs according to national criteria;
- 'Common Criteria' focused on a targeted delimitation of the areas;
- 'Eligibility Rules', placing special emphasis on the eligibility rules to be applied at farm level;
- 'High Nature Value', joining the support to agriculture in areas affected by natural handicaps and the preservation of high nature value farming systems.

In this policy alternative, the fourth – more demanding option – is included, considering the communication on the redesigned LFAs (COM/2009/161). As with the other alternatives, attention will be paid to the possible risk of unintentional double-counting of the included policy options. In Annex 2 is explained how the overlapping of the many different policy zones has been accounted for.

Protection peat land

Peatlands are (former) wetlands that contain an accumulation of partially decayed vegetation matter. Such areas contain specific biodiversity values and are thus protected from conversion to agricultural or urban use in this alternative. This also limits the emission of greenhouses gasses that is associated with such conversions. Therefore, this policy issue is also included in soil and climate change alternative. The emphasis on the protection of peatlands differs between the scenarios as is discussed in a technical annex to this report.

4.5 Soil and climate change alternative

Climatic changes are expected to have important implications for land-use patterns. The spatial implications of climate change will, however, differ per type of land use and per region in Europe, making their inclusion in a pan-European land-use model a topic of extensive research. Many research projects and policy initiatives on this topic have now started[6]. But, up to now, very few spatially explicit indications of future land-use planning are available that can be readily inserted in the land-use model. Drawing from ongoing research we can, however, indicate some potential climate-related impacts, mitigation and adaptation measures. Especially relevant in this respect is the substantial Dutch research

[6] For example: the inventory by Massey and Bergsma, and the white paper on adapting to climate change (COM/2009/0147).

program 'Climate changes spatial planning'[7] that aims to develop an adequate and timely set of policies for mitigation and adaptation to cope with the impacts of climate change. This is done in an extensive series of related research projects dealing with, for example, climate scenarios, water management and adaptations in agriculture, nature and inland navigation.

Below is the short list of initial research findings that may be relevant for our European land-use model. We have chosen to limit this alternative to adaptation and mitigation measures related to water management and soil protection as EC-legislation is being prepared for these themes. Other, more local climate issues such as agricultural crop choice or heat stress in urban areas are discarded as they would require extensive additional research. Inclusion of these themes would also make this alternative a highly complex compilation of different policy themes that obscures the impact of individual policy measures. The modelling framework is, however, well-suited to address such adaptation issues in the future. The soil and climate change alternative introduces the policies mentioned below focusing on water management and soil protection and it builds on existing policy options that are currently being discussed (Table 5).

Table 5 Overview of the current spatial policy ambition level incorporated in the reference scenario and the more ambitious policies in the soil and climate change alternative

Policy theme	Current ambition level	Policy alternative
Flood damage reduction	Current national and EC (Flood directive) policies based on current flooding statistics	Discouraging urbanisation in areas that are likely to become more flood prone due to climate change (map provided by JRC). Promotion of extensive agriculture and nature in these areas
Restore water balance (limits probability on floods and droughts)	Water framework directive	Discourage urbanisation and promote forest, nature and extensive forms of agriculture in upstream parts of catchment areas
Protection permanent pasture	Some incentives to avoid conversion of permanent pasture; maximum decrease in total permanent pasture area	Strict protection of permanent pasture areas.
Protection peatland	No policies	Land conversion in peaty areas are not allowed
Soil protection	Thematic Strategy for Soil Protection Communication	Spatial planning to promote more compact forms of urbanisation
Erosion prevention	Limited incentive to convert arable land on erosion sensitive places to grassland and forestry (1st pillar measure)	Strong incentive to convert arable land on erosion sensitive places to grassland and forestry

Water management

Increased precipitation and winter temperatures are likely to cause higher discharge volumes in the larger rivers leading to higher chances on flooding. The recently adopted Directive 2007/60/EC on the assessment and management of flood risks (EC 2007) requires

[7] http://www.klimaatvoorruimte.nl/pro3/general/start.asp?i=1&j=1&k=0&p=0&itemid=113

member states to assess if water courses and coast lines are at risk from flooding, to map the flood extent, assets and humans at risk in these areas, and to take adequate and coordinated measures to reduce this flood risk. It also requires member states to take into consideration long-term developments, including climate change, as well as sustainable land-use practices in the flood risk management cycle addressed in this Directive. An initial strategy to limit the impacts of such flooding is to discourage urbanisation in areas that are likely to become more flood prone due to climate change. Extensive agriculture and nature may be promoted in these areas.

Increased variability in precipitation and higher summer temperatures will, most likely, also lead to more pronounced water shortages in summer time. This is likely to impact, for example, agricultural practices and shipping on the major rivers. In recognition of the acuteness of the water scarcity and drought challenges in Europe, the European Commission adopted a Communication addressing the challenge of water scarcity and droughts in the European Union (COM/2007/414). The Communication provides a fundamental and well-developed first set of policy options for future action, within the framework of EU water management principles, policies, and objectives. It recognises land-use planning as one of the main drivers of water use and highlights that inadequate water allocation between economic sectors results in imbalances between water needs and existing water resources. The anticipated restoration of the water balance requests a pragmatic shift in order to change policy-making and to move forward to effective land-use planning at appropriate levels. To implement such notions in the land-use model it is suggested to promote the storage of rainwater in the hydrological system in upstream areas to secure a longer delivery of groundwater to aquifer and river systems. This policy has the additional potential of reducing the peeks in river discharge and thus limits the chance on flooding. The policy objective of increasing the amount of rainwater storage can be effectuated in the model through the increased suitability of nature, forest and extensive forms of agriculture in upstream areas. Those upstream parts then need to be defined through additional spatial analysis that, for example, defines the upper 10% of the of the height range in each delineated catchment area.

Soil protection

Soil-related policy measures can serve various policy objectives. From a climate-change mitigation perspective it is important to stop the conversion of permanent grasslands and peaty areas to prevent the emission of greenhouse gasses. Soil-related measures may also help combat erosion and limit the impacts on hydrological systems as is discussed below.

Permanent grassland covers 32 % of the European Utilised Agricultural Area (UAA) with important differences between the Member States (Louwagie et al., 2009). Protection of these areas has several benefits: limiting carbon emissions, maintaining biodiversity stabilising soils and thus limiting erosion. Within this policy alternative we, therefore, introduce a strict protection of permanent grassland areas using CLC-data.
Likewise, we prevent land conversion in peaty areas that could also result in the emission of greenhouse gasses. Those areas under natural vegetation are not allowed to be converted to agricultural use. Peaty areas under grassland cultivation are not allowed to change in

arable farming. The spatial representation of these peaty areas will be based on the European soil map[8].

An additional soil-related concern is the growth of built-up areas at the expense of agricultural land. This often concerned prime agricultural land that, historically, is located close to the urban areas. Unfortunately, neither the economical nor the ecological or the social effects of such irreplaceable soil losses have been considered adequately so far by current spatial policies. In the meantime, the necessity to include environmental concerns and objectives in spatial planning, in order to reduce the effects of uncontrolled urban expansion, is widely recognised in the EU: “a rational land-use planning to enable the sustainable management of soil resources and the limiting of sealing of open space is demanded” (source: eusoils.jrc.it). Such a call for action relates to the protection of agricultural land for farming purposes and the prevention of soil sealing that has adverse impacts on hydrological conditions. The latter impacts relate to a decrease in groundwater recharge and an increase in superficial water discharge with possible consequences for (flash) flooding. Climate change, in the form of rising temperatures and extreme weather events, is exacerbating both greenhouse gas emissions from soil and threats such as erosion, landslides, salinisation and organic matter decline. Therefore the European Commission adopted the Thematic Strategy for Soil Protection (COM/2006/231), including proposals for a Framework Directive for Soils, in September 2006. The proposed Directive lays down a framework for the protection and sustainable use of soil. The broad framework of the Directive offers flexibility, but also leads to uncertainty about its possible effect in concrete situations in practice involving soil sealing. In this policy alternative, the Directive is understood to limit the impact of urban development through incentives to promote compact forms of urbanisation thus lowering the demand for urban areas.

In addition, this policy alternative will assume strong incentive to convert arable land on erosion sensitive places to grassland and forestry. This policy option builds upon the current more limited incentives as part of the 1st pillar CAP-measures. The spatial representation of erosion sensitive locations will initially be based on a simple calculation of current erosion risk given slope, climate and soil conditions. In future, the Pan-European Soil Erosion Risk Assessment database (PESERA, (see Kirkby et al, 2004) available from EC-JRC may be an appropriate alternative.

4.6 Implementation of the Biodiversity and Soil & Climate change scenarios

The Biodiversity and Soil & Climate policy alternatives described in the preceding section were translated into model input in a policy-science iterative process, which involved the model operators at Alterra and the policy developers at DG Environment. Initial implementation suggestions were offered by the modelers and adjusted after consultation with the relevant experts in Brussels. Several steps were also discussed during project meetings in Brussels (see Annex 5 for the minutes of these meetings). A detailed description of all model settings per policy issue is available in Annex 1.

[8] http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDB/index.htm

The policy alternatives are implemented in the EU-ClueScanner model through the changing of several input parameters. More specifically these relate to:

1. specification of location-specific preference additions, indicating where the suitability of a location is enhanced (e.g. through a subsidy) or restricted;
2. conversion matrices that specify which land-use transitions are allowed at specified locations;
3. conversion elasticities that regulate the ease of land-use transitions;
4. neighbourhood settings specifying the importance of the surrounding land use for simulation;
5. demand related parameters that influence the total amount of land for each land-use type.

Annex 2 explains these model parameters in more detail, presents several included spatial data sets and discusses related implementation issues.

5. Indicators

Land-use simulations result in attractive and very detailed maps, indicating possible future land-use patterns. These maps offer a wealth of information and are highly interesting themselves, but they are often difficult to interpret in terms of, for example, the exact differences between alternatives or their different impact on specific policy themes. To compare and interpret results in a systematic way the EU-ClueScanner model is equipped with an extensive set of quantitative indicators that apply spatial evaluation methods that are underpinned and documented in recent academic research. Quantitative spatial evaluation methods can help to answer questions such as: In which locations do the maps exactly differ from each other? What do these differences say about policy issues such as biodiversity or carbon sequestration? What are the impacts on a specific land-use type or policy theme in a certain region?

This section presents an overview of the indicators that are included in the model (Table 6). The list of indicators has been discussed extensively with representatives from the DG Environment and adjusted according to their wishes, data availability and technical possibilities of the modelling environment. All indicators are provided for the years 2000 (when possible), 2010, 2020 and 2030.

The indicators are newly implemented in the GeoDMS environment as none of them existed in the original land-allocation model. This process has several advantages: the indicators are directly available in the land-allocation model; their calculation is automated; and additional post-processing efforts are not needed anymore. The indicator's methodology, included data sets and implementation in the GeoDMS environment is documented in separate factsheets that are included as meta-data sheets in the modelling framework and as Annex 3 to this report.

The indicators can be grouped in three main categories:

1) the *land-use related indicators* are based on the primary (land-use) output of the land-allocation model.

2) the *thematic indicators* represent more complex policy-relevant issues that rely on land use and additional information.
3) the *economic and social indicators* are produced by the LEITAP model and therefore only available at national level. The values for these agro-economic indicators will differ for the B1 scenario and BFP alternatives. The values for the spatial policy alternatives (biodiversity, and soil and climate change) will not differ from the reference scenarios they are based on as they draw from the same base information provided by the LEITAP model. The population indicator is based on the Phoenix model and relates to the same B1-scenario for all alternatives. It will thus deliver the same information for all alternatives.

The list of indicators can be extended in the future when appropriate quantitative methods and related spatial data sets become available. The tutorial (included as appendix) briefly describes how new indicator calculations can be added to model. During the course of the project the feasibility of including a land price indicator was discussed that should capture the relative scarcity of locations. Such indicators are available in economics-based land-use models such as the Land Use Scanner that is also programmed in the GeoDMS environment. However the current EU-ClueScanner model is different, e.g. scaling of the suitability values and dynamic specification. To be able to create a meaningful land price or land scarcity indicator it is necessary to study the implications of these differences and probably change the specification of the suitability values. Likewise a landscape quality indicator was considered but not implemented, due to the current lack of appropriate spatial datasets and quantitative methods.

Table 6 Overview of indicators available to analyse simulation results. Numbers denote the amount of individual maps resulting from this indicator for an individual year.

Indicator	Spatial visualisation scale			Nr.
Land use related indicators	local [km^2]	regional [NUTS2 regions]	national [27 MS]	
1. land use (overview in 10 classes, changed to and changed from)	3			3
2. change hotspots (agricultural abandonment, agricultural expansion, urban development)	3			3
3. shares of agricultural land uses (total agricultural use, arable land, irrigated land, permanent pastures, permanent crops) and changed shares for these land-use types since reference year (2000)		5+5	5+5	20
4. shares of natural land uses (total natural area, forest, (semi-) natural vegetation, recently abandoned farmland and other nature) and changed shares for these land-use types since reference year (2000)		5+5	5+5	20
Thematic indicators				
5. carbon sequestration (in specific years and cumulative)		1	1	2
6. soil sealing (based on EEA-data provided by JRC, see Kahabka and Lucera, 2008)	1	1	1	3
7. biodiversity index (Mean species abundance index, based on the GLOBIO3 approach)		1	1	2

8. land cover connectivity potential		1	1	2
9. soil erosion risk (based on the USLE[9] approach)	1	1	1	3
10. increased river flood risk (expressed as new urbanisation in risk-prone areas, based on the data provided by JRC)	1	1	1	3
11. five sprawl-related indicators based on urban patterns (urban area, urban population density, urbanisation degree, number of urban areas, average urban area size)		5	5	10
Economic and social indicators				
12. Employment (index)			1	1
13. Agricultural employment (index)			1	1
14. Value added per farmer			1	1
15. Gross Domestic Production (index)			1	1
16. Agri share in GDP (%)			1	1
17. Real farm income (index)			1	1
18. Crop production			1	1
19. Total population from Phoenix (same for all B1-based alternatives)		1	1	1

6. Results

6.1 European Biofuel Policy alternative – three options (LEITAP + IMAGE + CLUE)

6.1.1 Additional information on the three BFP alternatives

Under the reference scenario, it is assumed that no country implements a mandatory blending obligation for biofuel. It should be mentioned that, even without a mandatory blending, the use of biofuel crops changes due to changes in relative prices (biofuel crops vs. fossil fuel).

1. First land simulation for the BFP alternative (Short name: **'BFP Five Non-EU'):** unrestricted land conversion of forests into agricultural land and a mandatory blending is implemented in five non European countries (USA, Canada and Japan, Brazil and South Africa).

The mandatory blending is implemented in two steps as follows:

- In 2010: the target is 5.75% biofuels in total final transport fuels;
- In 2020: a 10% target for biofuels in total final transport fuels.

Based on IEA (2008), we assume a 10% blending target for the USA, Canada, Japan and South Africa. In IEA (2008), a 25% blending target for Brazil is also indicated. Due to the fact that in the initial period the blending rate in Brazil exceeds already this target, mandatory blending is modelled as a complementarity condition.

2. Second land simulation for the BFP alternative (Short name: **'BFP Five Non-EU & EU'):** unrestricted land conversion of forests into agricultural land. The mandatory

[9] Soil erosion is calculated using the Universal Soil Loss Equation (USLE). This straightforward, well-established empirical model is based on regression analyses of observed soil loss rates on erosion plots.

blending is implemented in two steps (as above) in five non European countries (USA, Canada and Japan, Brazil and South Africa) **AND** in the EU member states as defined in the first land simulation.

3. Third land simulation of the BPF alternative (Short name: **"BFP Five Non-EU & EU no Forest'):** land conversion towards agriculture is restricted: only land cover types different from forest (which are defined as tropical forests, tropical woodlands, boreal forest and all temperate forests) can be converted to agriculture. A mandatory blending is implemented in two steps as defined in the first land simulation in five non European countries (USA, Canada and Japan, Brazil and South Africa) **AND** in the EU member states as in the second land simulation.

6.1.2 Results of LEITAP

The results of the LEITAP model for the reference scenario and the BFP scenarios are presented in this section. Note that the only change under the two BFP options are the mandatory blending obligations and all other policy instruments remain those of the reference scenario.

With enhanced biofuel consumption due to the EU BFP (5.75% in 2010 and 10% in 2020), real prices of agricultural products, especially biofuel crops, tend to increase compared to the reference scenario (Figure 4). Under the reference scenario, real world prices for agricultural products tend to decline and conform to their long-term trend. This is because of inelastic food demand together with a high rate of productivity growth (Schmidhuber, 2007). The oilseed sector has the highest price difference, because biofuels in EU transport are dominated by biodiesel from oilseeds. It should be mentioned that this analysis might overstate the price effect for oilseeds, because the LEITAP version applied here does not explicitly consider the impact on the protein feed part of oil meal. The EU biodiesel production has oil cakes as a co-product, and therefore this additional production results in reduction of the feed demand for oil cakes from other sources, which in turn results in a reduction of the price of oil seeds compared with the situation without co-products. ON theother hand, in USA ethanol production has DDGS[10] as co-product, which competes mainly with maize in USA, whereas is more used as a substitute for oil meals in Europe. If biofuel co-products would have been modelled, then an increase in ethanol or biodiesel production would increase the production of DDGS and oil cake, and therefore less oil meals and grains from other sources would be needed to feed livestock. The prices of animal feed therefore would go down compared with the situation without co-products. First results of a preliminary LEITAP version which includes also co-products of biofuel production indicates that the changes in land use are around 25% per cent smaller.

[10] Distiller's Dried Grains with Solubles (DDGS) is a co-product of the distillery industries.

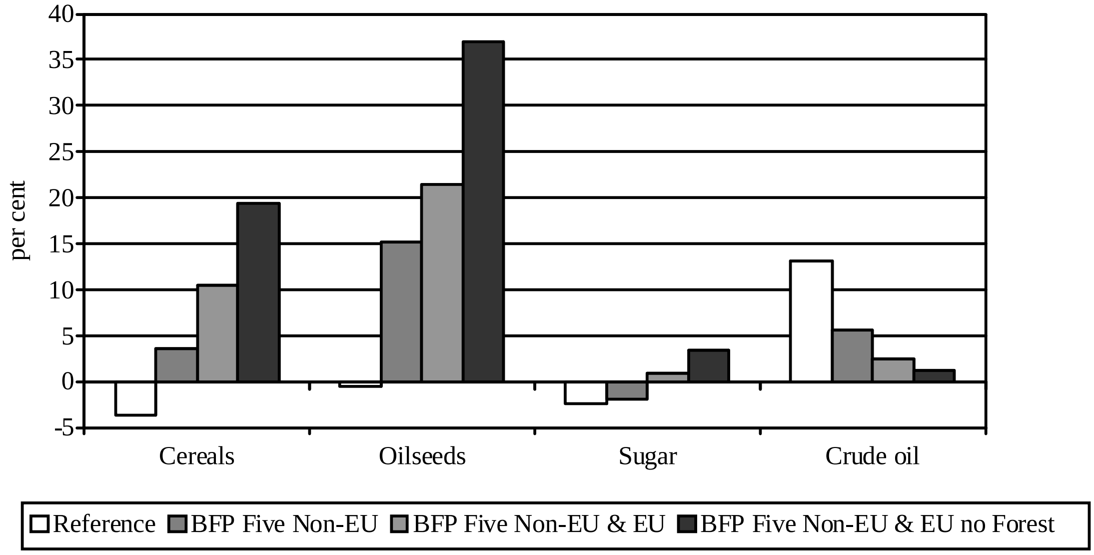


Figure 4 Percentage change in real world prices for agricultural products, 2020 relative to 2007

The increase in world prices is less than in some other global studies (e.g., Msangi et al., 2007) where oilseed and sugar prices are projected to rise 18% and 10%, respectively. These studies exclude the effect that a higher biofuel demand generates extra land supply through land price increases and therefore mitigates parts of these land price increases. The crude oil price declines slightly (6%) as demand for crude oil diminishes due to the introduction of the BFP. Similarly, Dixon et al. (2007) showed a decline in the world crude oil price of 4.5% due to US biofuel policies.

Even without mandatory blending, the share of biofuels in fuel consumption for transportation purposes increases slightly (Figure 5). This is because the ratio between the crude oil price and prices for biofuel crops changes in favour of biofuel crops (Figure 4). However, the endogenous growth under the reference scenario is low. Nevertheless, the results reveal that, without mandatory blending, the 5.75% and 10% biofuel targets will not be reached in EU member states.

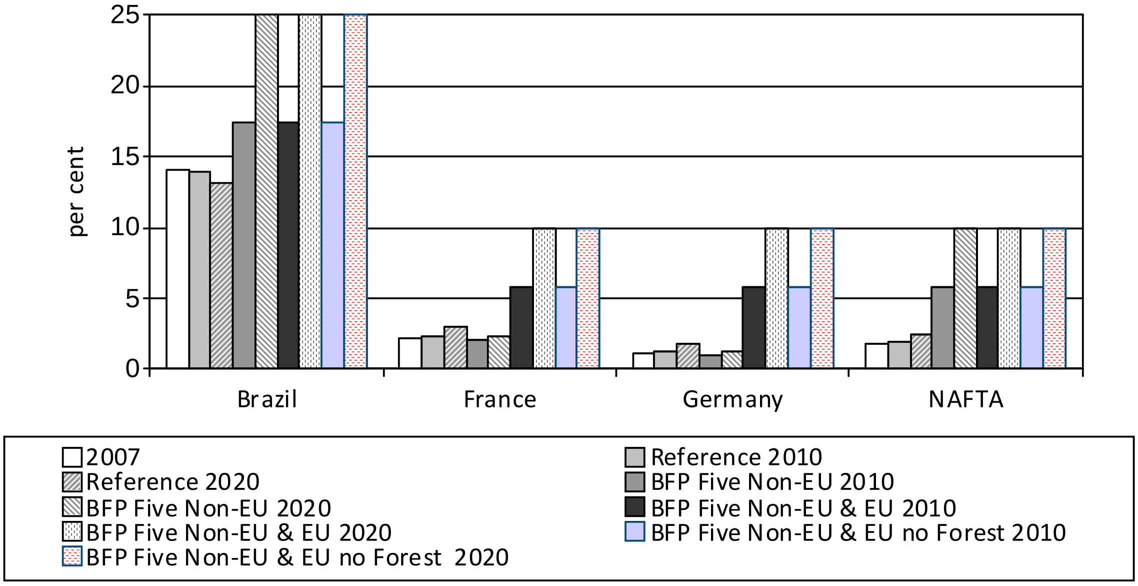


Figure 5 Percentage share of biofuels in transport fuel consumption for selected regions, 2007, 2010 and 2020

Fulfilling the required blending rates occurs at the expense of biofuel consumption in non-European countries. The BFP reduces crude oil demand in the EU and therefore also in the world. This generates a decrease in crude oil price in thr world and as a consequence other countries decrease their biofuel use. But in this case, the other countries have also a blending requirement that is binding and forces them to use more biofuels than they would do without this enforcement. Therefore, the other countries are not allowed to reduce their demand for biofuels.

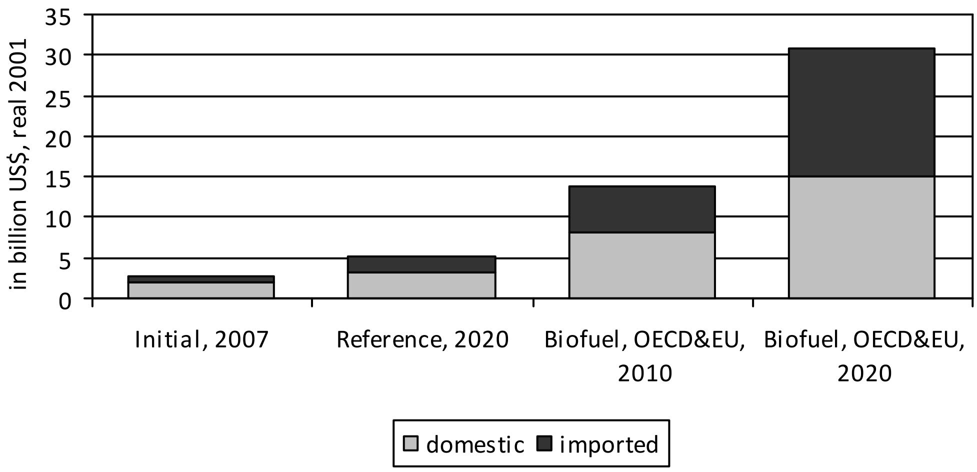


Figure 6 Origin of biofuel crops used in the EU-27 (in billion US$, real 2001), situation in 2007 and in 2020

In the BFP scenario, the demand for biofuel crops used by the petrol sector is USD $31 billion (in 2001 dollars) under the minimum blending requirement of 10% in 2020 (Figure 6). The import share increases from 36% in the reference scenario to 51% in the BFP case. The increased demand for biofuel products in the EU leads to higher land and product prices in the EU relative to land-abundant countries, which are often exporters to the EU market.

Our finding that a large part of the bio-fuels will be imported is in agreement with Von Lampe (2007) statement "… a European biofuel industry [based] on biodiesel is likely to require substantial additional imports of vegetable oils.' Banse and Grethe (2008) estimated the import share of biofuels at 35% without second generation bio-fuels. These two publications are based on models that do not take endogenous land supply into account.

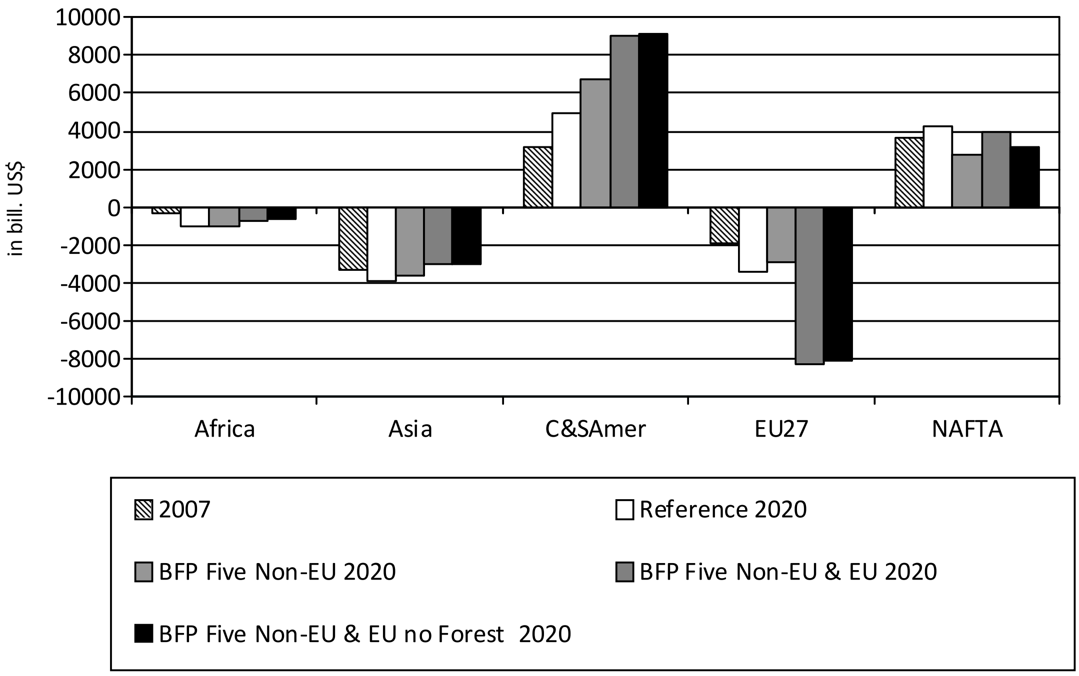


Figure 7 Net exports of biofuel crops (US$ billion, real 2001) by region, initial situation and by scenario

Consistent with the argument above, Figure 7 shows that the BFP will increase the EU trade deficit for biofuel crops, and increase the trade surplus in land-abundant groups of countries like South and Central America and NAFTA. If biofuel demand increases, the EU and NAFTA will need more biofuels and consequently will increase their imports and respectively reduce net exports. Southern and Central America, and to a lesser extent Africa, have both abundant land and a smaller substitution elasticity between crude oil and biofuels, leading to increasing net exports.

6.1.3 Results of IMAGE

The production and land management changes calculated by LEITAP for grass, food and energy crops are used as an input to the IMAGE model to derive changes in land use and related emissions. Global land use changes as calculated for the land simulations are presented below.

Land use and land use related emissions

Biofuel policies have an effect on agricultural land use. Allocation of extra agricultural land depends on trade and the nature of the biofuel policies implemented. The implementation of OECD biofuel mandates affects especially land use in the US, China, South East Asia and Sub Saharan Africa (Figure 10). Agricultural production in Brazil is largely affected by the implementation of the European BFP. Therefore Brazil is chosen as example. Oil-crops, maize and sugarcane are produced in this country to fulfill the demand for biofuel. This causes an additional use of land for agriculture, of which expansion of oil crops, maize and sugarcane for biofuels count for respectively 40%, 16% and 6% (Fig. 8).

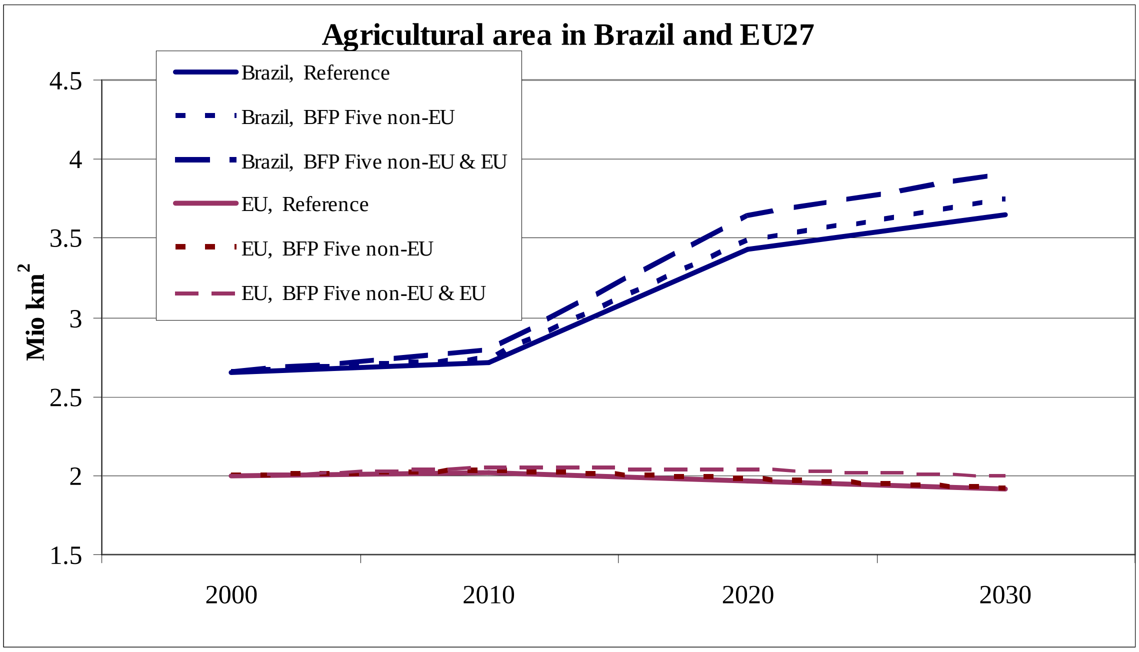


Figure 8 Impact of Biofuel Policies (BFP) on developments of agricultural area

Globally, the implementation of biofuel policies (in the five non-EU countries and the EU) causes an increase of 5% in the expansion of agricultural area towards 2030. This expansion of agricultural area in the BFP scenarios is especially at the cost of tropical woodland and warm mixed forest areas. The cumulative land use emissions occurring increases in the BFP scenarios due to the expansion of agricultural area and clearing of forest (Figure 9). Globally, land use emissions count for 20% of total emissions in the Reference scenario. Most land use emissions do occur in the regions where agricultural expansion has been projected to be large in the coming decades. Although the largest part of the land use emissions are due to the expansion of agricultural land for food production, the expansion for biofuel crops does increase the land related emissions especially in North and South America. To prevent the emissions occurring from forest clearing, sustainability criteria are included in the Directive on the promotion of the use of energy from renewable resources. Therefore, the third land simulation of the BFP alternative (‘BFP Five Non-EU&EU no Forest’) analyses a policy promoting biofuel crops when forests are globally fully protected from conversion to agricultural use.

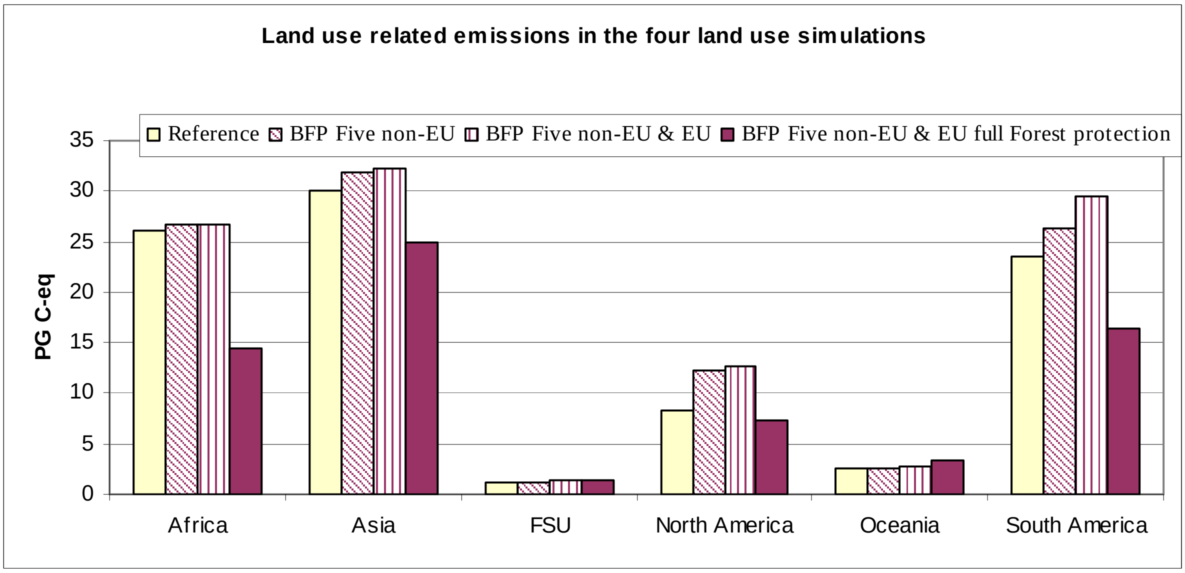


Figure 9 Land use emissions in the reference and three BFP options

In this case, if all the forests existing in the year 2000 would be fully protected, the potential agricultural area would be reduced by more than 60%. This reduction in the potential agricultural area in 2000 results in a reduction of its expansion by 2030 for most of the countries, when compared with a scenario in which forests are not protected (Figure 10), and therefore a decrease of 34% land use related emissions globally. The European Union and Oceania have less forest area than the other regions in 2000, and therefore the impact of forest protection in these regions is lower, showing even some expansion in agricultural area in 2030. Another impact observed is a much higher land use conversion pressure for those land covers potentially suitable for agriculture and not protected, e.g. savannah in Brazil. The lower land availability will result in an increase of land prices, which in turn will lead to higher prices of agricultural commodities.

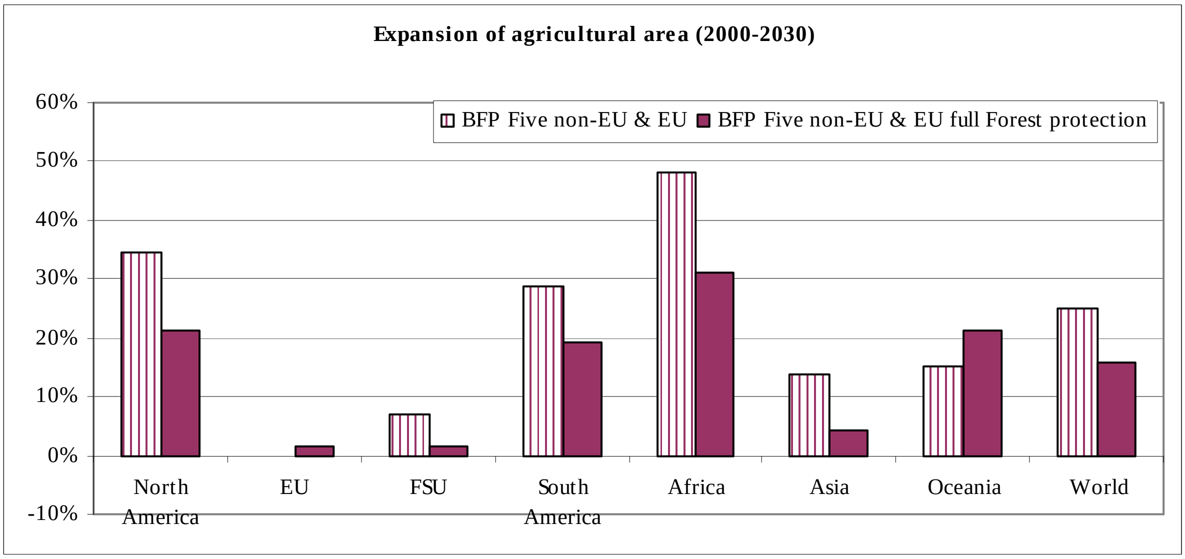


Figure 10 Growth in agricultural area between 2000 and 2030 in the world regions 'five non-EU & EU' (five non-European countries, i.e. USA, Canada and Japan, Brazil, South Africa, and the 27 EU Member States) without and with full protection of current forests.

6.1. 4 Results of CLUE

In the figures below the resulting land use changes are shown for the reference and the three BFP options. In addition, the impact of these land use changes on some selected indicators is presented.

Land Use changes

Figure 11 shows a simplified picture of the main land use change processes, i.e. urbanization, agricultural expansion and agricultural land abandonment. Urbanization is taking place at the same locations and same rate in all scenarios. Especially in the United Kingdom around London, Liverpool and Manchester strong urbanization is predicted, but also around other major cities in Europe, e.g. Paris, Barcelona, Rotterdam and the Katowice agglomeration, urbanization is taken place. The other two land use change processes do differ significantly between the four scenarios. In the reference scenario quite a strong abandonment is predicted in Western Europe, which will occur mainly in the more marginal mountainous areas, e.g. Massif Central in France and the Apennines in Italy. In contrary in Eastern Europe expansion of agriculture is predicted, e.g. Poland, Lithuania and Hungary. The patterns for the BFP scenario for five non-EU countries without the EU is very similar to the reference scenario, i.e. biofuel policies outside the EU hardly have any impact on land use change within Europe.

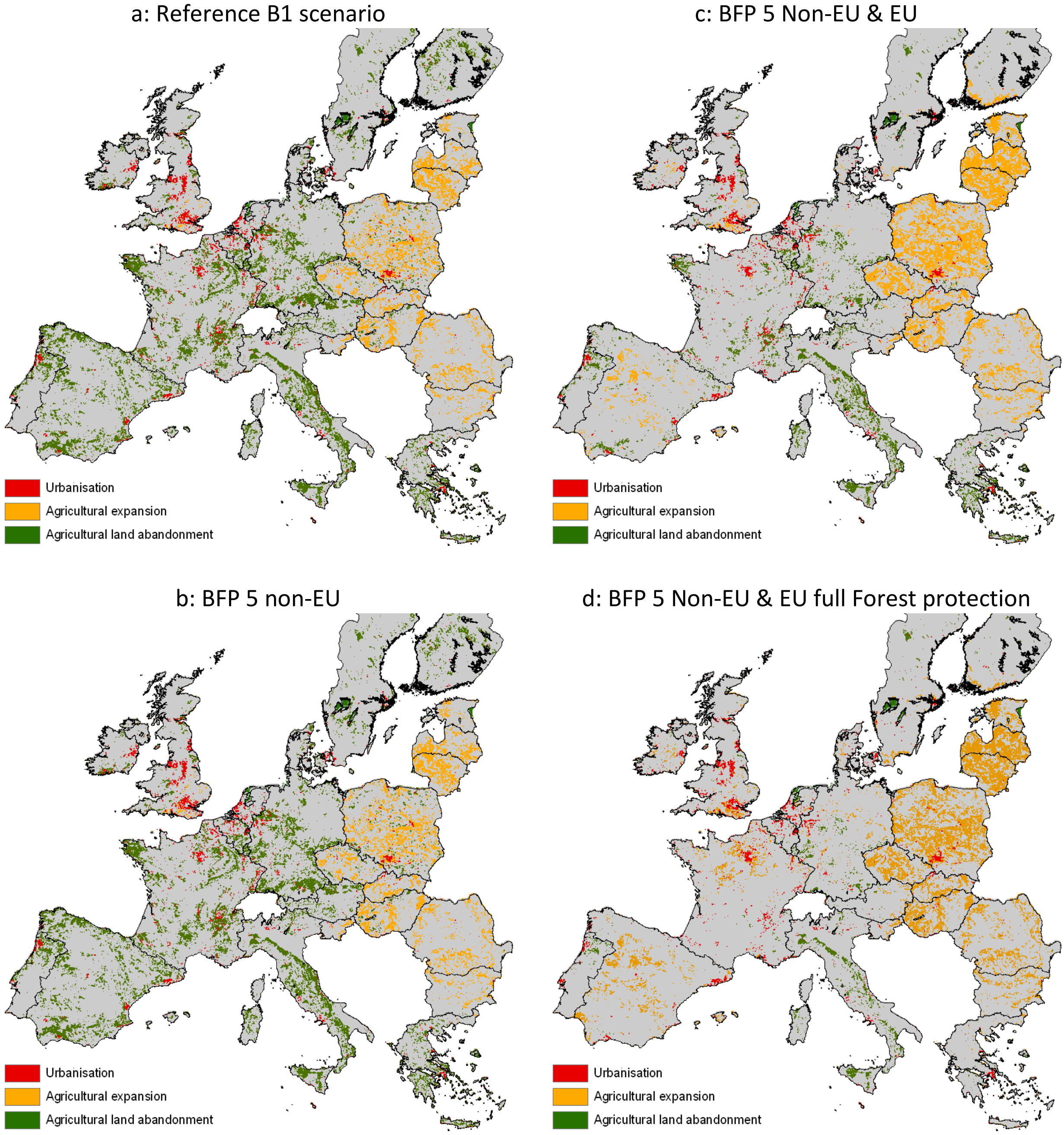


Figure 11 Main land use change processes for the (a) Reference scenario, (b) Biofuel Policies - Five non-European countries, (c) Biofuel Policies - Five non-European countries and EU, and (d) Biofuel Policies - Five non-European countries and EU and full protection of forests. For visualization purposes the areas of the land use change processes are somewhat exaggerated[11]

[11] At a 1km-grid scale the resolution is too small to see changes without zooming in. Therefore we applied a generalization of the main land use change processes using a 5x5 km moving window. A location is classified as 'agricultural land abandonment' if at least 10% of the land in the surrounding 25 km^2 is facing agricultural abandonment, the same holds for 'agricultural expansion' and for urbanization, i.e. a threshold of 5% of the land area in the surrounding 25 km^2 is used given the large impact of urban areas on landscapes and the relatively small areas of urban land use.

However, for the scenario with biofuel mandate for the five non-EU and EU countries the patterns are quite different, first of all abandonment is occurring at much smaller scale and only in the most marginal areas, whereas agriculture is expanding in many locations, especially in Eastern Europe, but also in Spain several areas will have an increase in agriculture. This expansion of agriculture is at the cost of semi-natural vegetation and forest in Eastern Europe, especially in the Baltic countries and Poland, where deforestation is occurring at large scale. In the BFP 5 Non-EU & EU with full forest protection, this pattern is even expressed stronger, with even less agricultural land abandonment and more agricultural expansion, also in Western Europe. The results on deforestation are questionable for some countries, e.g. in Poland 85% of the forest is State-owned. Deforestation may be more an issue for countries that have experienced expropriation in the 1950’s and where the forest has been transferred back to the initial owners in the 1990’s, leading to very small, fragmented ownership structures which favour deforestation.

To assess the impact of the biofuel mandate in EU, we combined the main land use change processes from both the reference scenario and the biofuel mandate with EU scenario (figure 12). This map shows where agricultural abandonment and agricultural expansion is taking place in both scenarios, i.e. autonomous development irrespective of the biofuel mandate (green an orange in the map). More interesting is to see where agriculture will expand due to the biofuel mandate (the red areas), this is mainly in Eastern Europe, but also in areas in Spain and Ireland, agriculture will expand. Besides the expansion, the biofuel mandate also prevents land abandonment to occur in large parts of Europe (the blue areas). Due to the higher demand of agricultural products many areas still remain in production, e.g. in France, Spain, Finland and Germany.

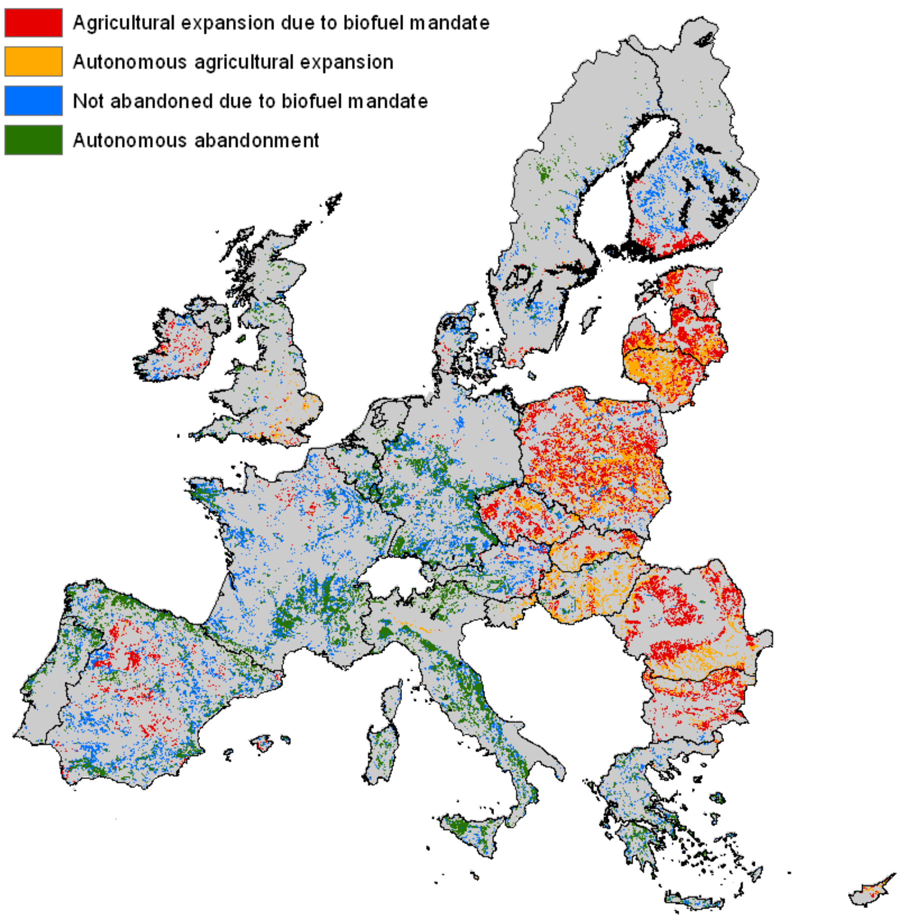


Figure 12 Comparison of the reference scenario with the second BFP option (biofuel mandate 5 non-EU & EU). The red colour indicates where agricultural expansion is taking place in the second BFP option only, orange indicates agricultural expansion in second BFP option *and* in the reference scenario, blue indicates areas that are not abandoned due to the second BFP option and green indicates the areas that are abandoned in both scenarios

In Figure 13, some more detail is given about the land use change that is predicted in the different scenarios for an area in Western Spain. In the reference scenario, and also in the scenario with the biofuel mandate for five non-EU countries, large parts of the permanent crops are abandoned or converted to extensive pastures. However, in the BFP 5 non-EU & EU option agricultural abandonment is not occurring and the arable land area is even expanding at the cost of permanent crops and semi-natural vegetation.

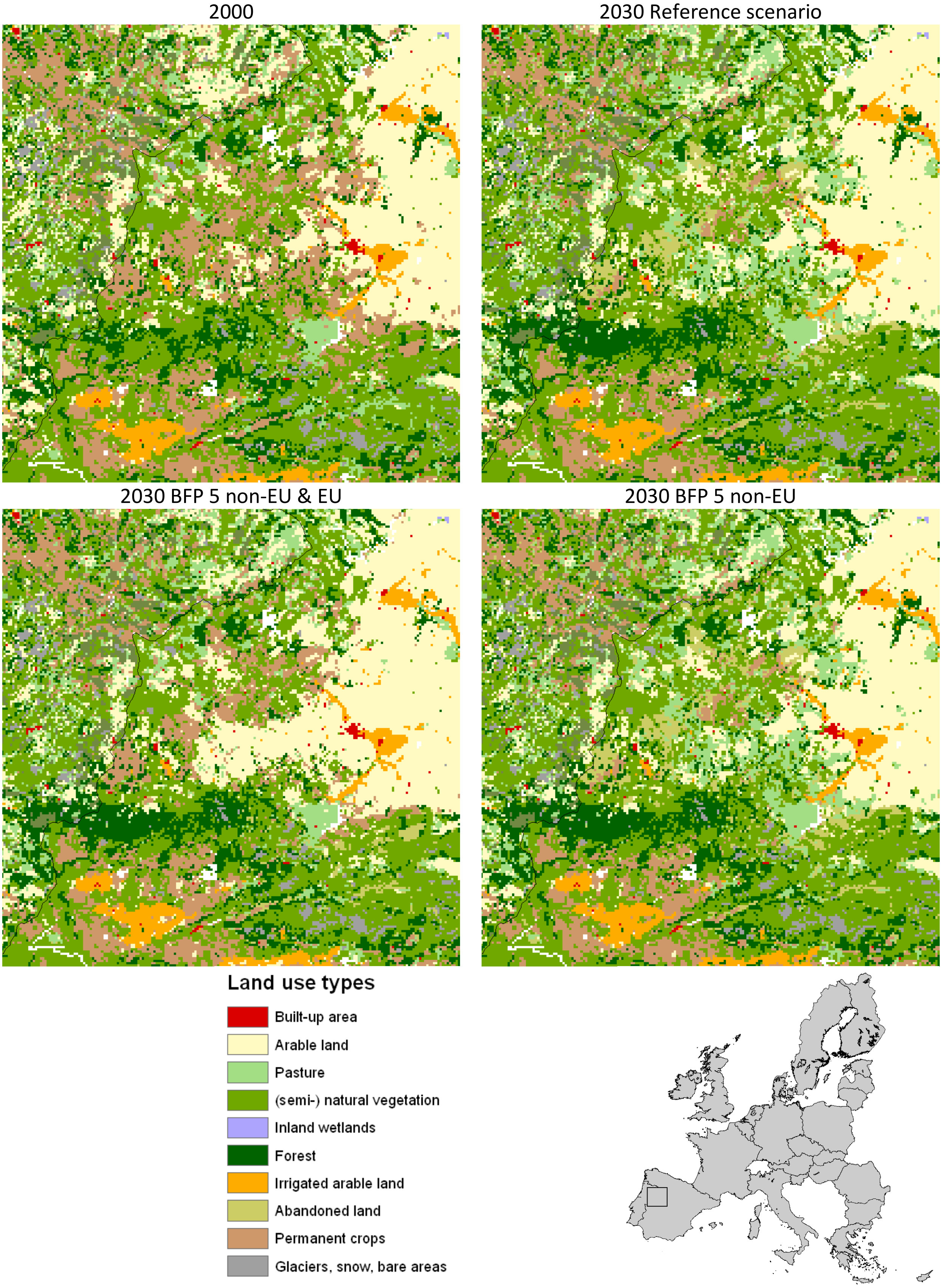


Figure 13 Changes in land use for three scenarios for an area in Western Spain, west of Salamanca province

Impacts of land use changes

Within the modelling framework a whole set of indicators is included to assess the impact of land use change on these indicators (as listed in section 5). The first indicators are simple land use related indicators such as the acreage of agricultural land per region (Figure 14). These kinds of indicators give a quick overview of the distribution of the main land uses in Europe and changes between scenarios can easily be compared. Figure 14 shows the higher share of agriculture in Central Europe due to the biofuel mandate with EU.

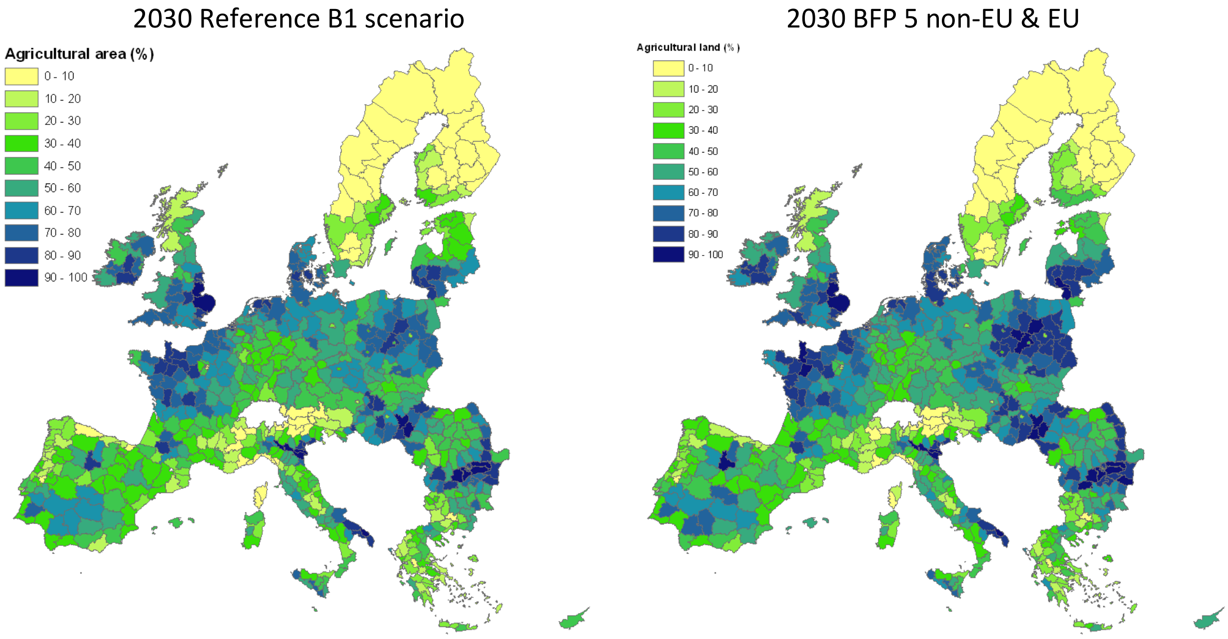


Figure 14 Fraction of agricultural land per NUTS2 region in 2030 for the reference and the BFP 5 non-EU & EU option

Also more complex environmental indicators are included in the framework, e.g. erosion, carbon sequestration and biodiversity. In relation to the BFP alternatives, the carbon sequestration indicator is most interesting, since the prevented emissions by using biofuels should not be off-set by greenhouse gas emissions that occur during cultivation and conversion of land use. Figure 15 shows the rate of carbon sequestration within the EU27 over time for the three scenarios for the period 2000-2030. In 2000, carbon sequestration is occurring at a rate of almost 100 Tg carbon per year. In the reference scenario a decrease in carbon sequestration is predicted for the period 2000-2010 and afterwards it is stabilizing at a rate of about 80 Tg Carbon per year. The increase in carbon sequestration due to land abandonment in Western Europe is off-set by the expansion of agriculture in Central Europe. In the biofuel mandate with EU scenario the decrease in carbon sequestration is much stronger, reaching a minimum of 50 Tg Carbon per year around 2015 and afterwards it is increasing again. This is due to the large amount of forest and nature land in Central Europe that is taken into production for arable land.

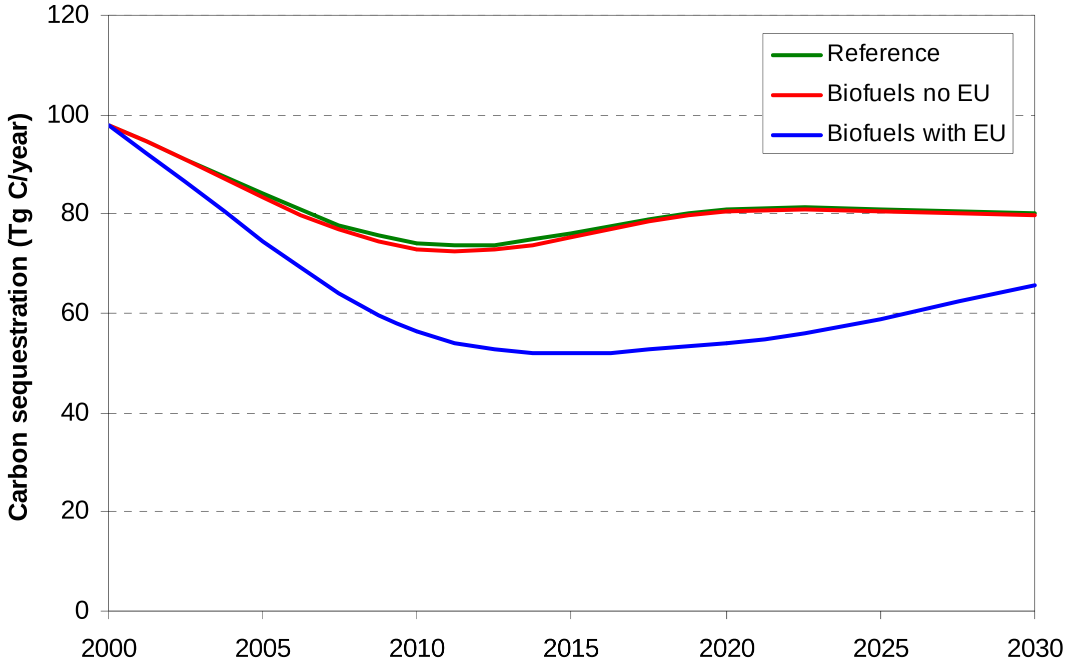


Figure 15 Change in carbon sequestration in the EU27 for the three scenarios for the period 2000-2030

The spatial pattern of carbon sequestration is shown in Figure 16, which clearly shows that in several regions in Central Europe negative carbon sequestration rates are predicted, especially for the scenario with a biofuel mandate including the EU.

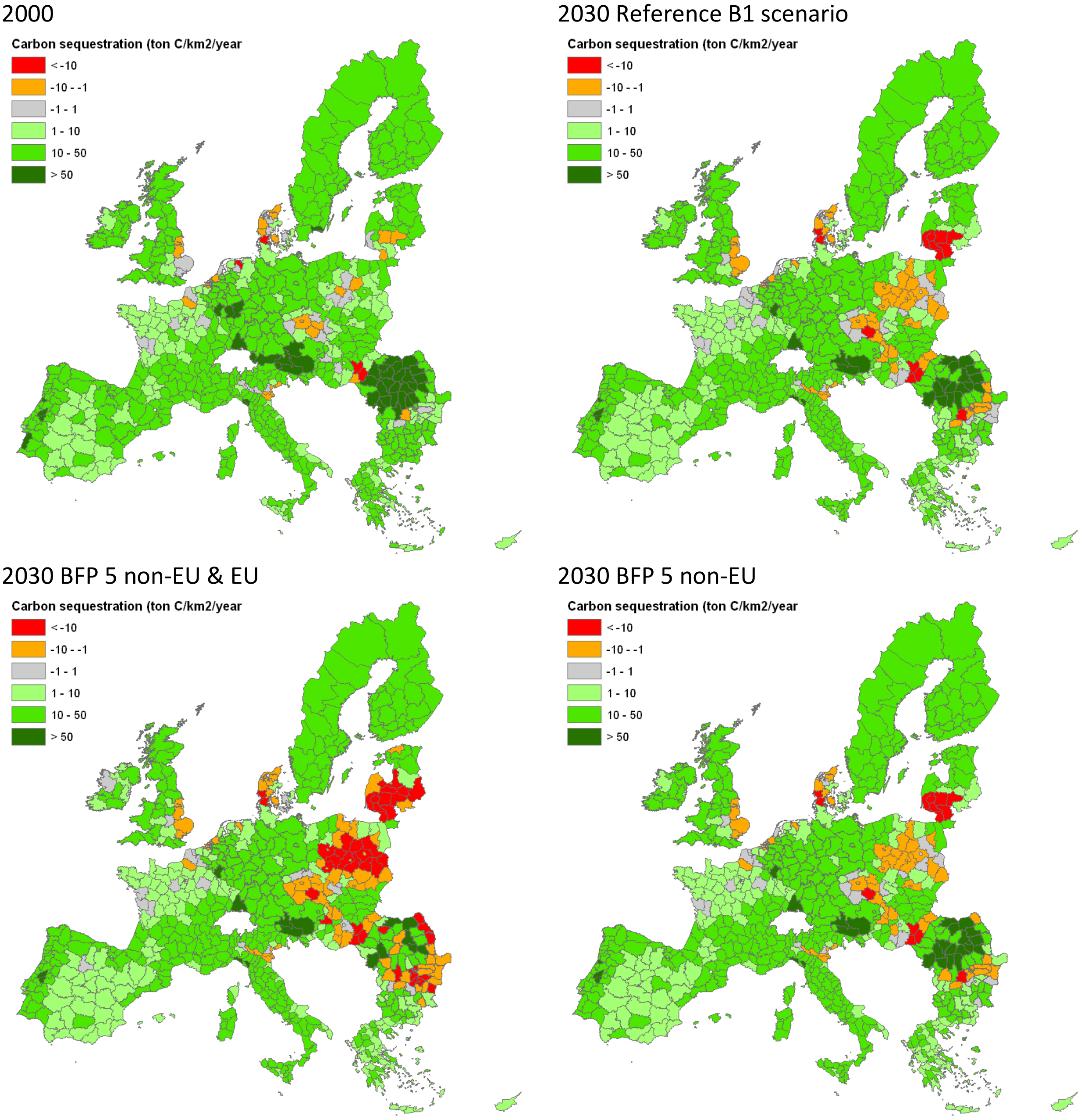


Figure 16 Rate of carbon sequestration per NUTS2 region in 2000 and in 2030 for the three scenarios

Conclusions

- Biofuel policies have large impact on land use
- European impacts are relatively small as compared to impacts outside Europe, however, we can observe, due to biofuel policies:
  - less agricultural land abandonment in Western Europe
  - more agricultural land in Eastern Europe
- Strong impact on carbon sequestration
- Global policies impact on European land use are small
- European policies impact on global land use are huge
- Protection of forest in the tropics increases land use pressure in Europe

6.2 Biodiversity alternative (CLUE)

The biodiversity alternative introduces a number of ambitious policies to increase the protection of specific ecological and landscape related values. It includes policy options for the following policy themes: fragmentation control and promotion of clustering of nature, controlling urban growth, natural corridors, Natura 2000, high Nature Value protection, Less Favoured Areas and protection of peat land. Annex 1 describes how these policy themes were exactly included and parameterised in the EU-ClueScanner framework.

At the request of DG Environment, we analysed three biodiversity alternatives:
(i) the plain one presented in Annex 1;
(ii) the same as (i) but without the increase in set-aside, since it appeared that the increased set-aside lead to increased land use pressure, with also negative consequences for biodiversity;
(iii) the same as (i) but with a higher demand for agricultural land, i.e. the demand settings from the third biofuel scenario (BFP 5 non-EU & EU).

Figure 17 shows the main land use change processes for the different scenarios. The main patterns are similar for the reference scenario and the biodiversity alternative (Figures 17a and 17b). However, there are also some differences, as agricultural land abandonment is lower and agricultural expansion is higher in the biodiversity alternative, which is caused by the increased set-aside level. Set-aside is part of the agricultural land cover, and therefore the agricultural area will expand since the land demand is still the same. For the biodiversity alternative without set-aside (Fig. 17c) the picture is rather similar to the reference scenario. Finally, for the biodiversity with high land use pressure (Fig. 17d), the picture is similar to the one from the BFP 5 non-EU & EU scenario, but even with some more agricultural expansion due to the increased set-aside.

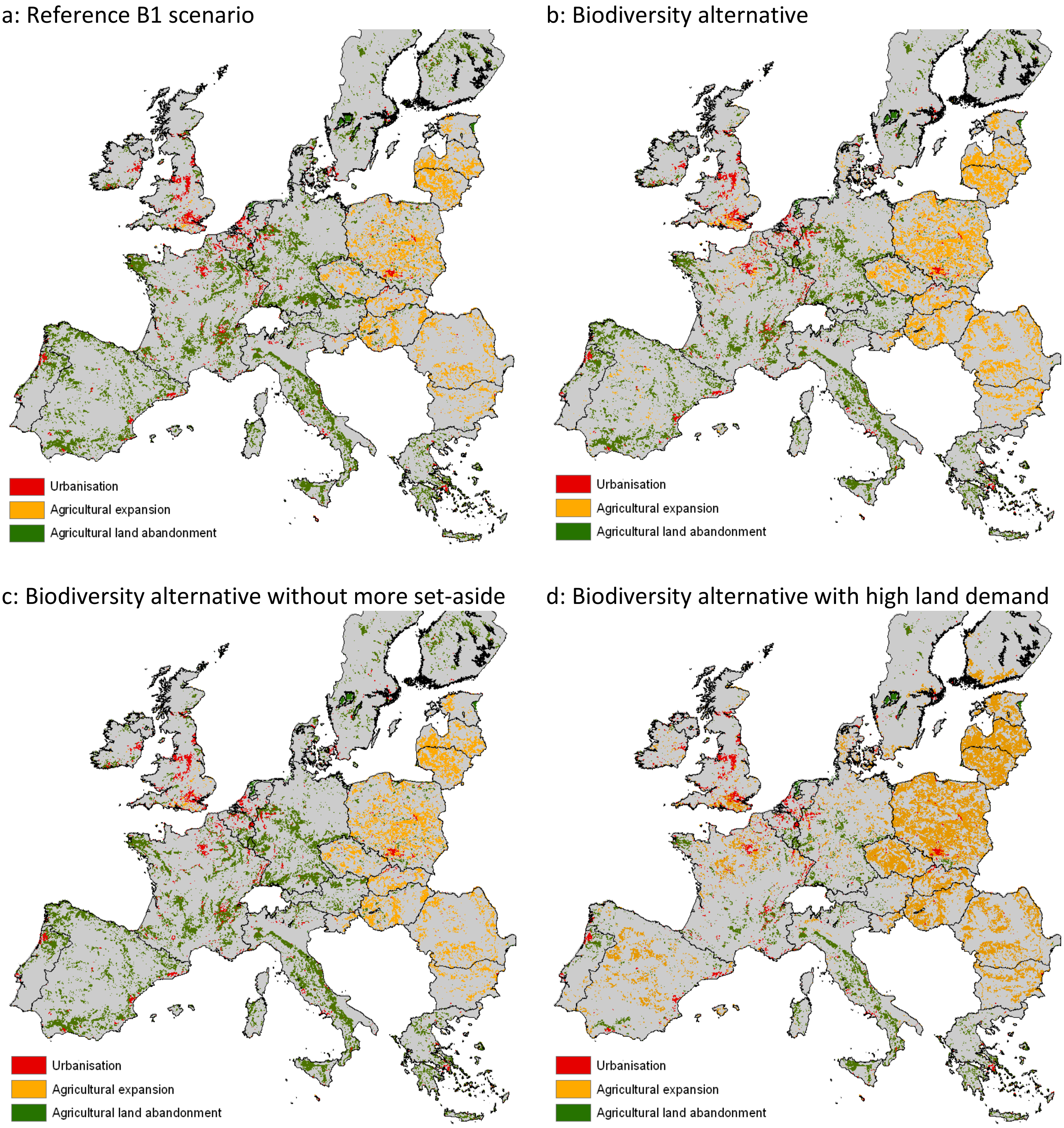


Figure 17 Main land use change processes for the (a) Reference scenario, (b) Biodiversity alternative, (c) Biodiversity alternative, without increase in set-aside, and (d) Biodiversity alternative with high demand for agricultural land (as BFP 5 Non-EU & EU). For visualization purposes the areas of the land use change processes are somewhat exaggerated[12]

[12] At a 1km-grid scale the resolution is too small to see changes without zooming in. Therefore we applied a generalization of the main land use change processes using a 5x5 km moving window. A location is classified as 'agricultural land abandonment' if at least 10% of the land in the surrounding 25 km^2 is facing agricultural abandonment, the same holds for 'agricultural expansion' and for urbanization, i.e. a threshold of 5% of the

To see the effects of the spatial policies for the Biodiversity alternative, one has to zoom in to certain regions, where clear impacts of the spatial policies can be observed. Figure 18 shows this for an area at the frontier of Austria, Czech Republic and Slovakia. Here several ecological corridors are located, where incentives are provided to convert arable land to nature. In the biodiversity scenario, conversion to nature is indeed occurring mainly within the ecological corridors. However, in the biodiversity scenario with the high land demand, the abandonment of agriculture does not occur, simply because land use pressure is too high, which will outweigh the effect of subsidies to converted arable land to nature.

Reference scenario | Biodiversity alternative | Biodiversity alt. high demand

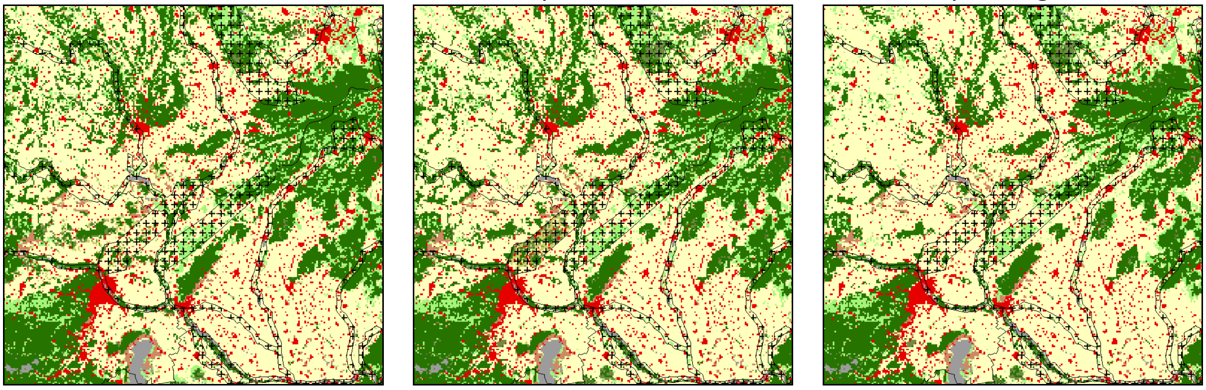


Figure 18 Land use patterns in 2030 for the different scenarios for an area at the frontier of Austria and Slovakia and Czech Republic. The marked areas indicate the ecological corridors. Within these ecological corridors it is visible that abandonment is occurring in the biodiversity alternative, but with a high demand for land not anymore.

An important indicator to assess the impact of the different scenarios on biodiversity is the Mean Species Abundance (MSA) index. This index ranges from 0 to 100, and represents the species abundance compared to species abundance in the natural system without any human disturbances. In Figure 19 the MSA index is given per country for the different biodiversity scenarios. For countries with many forests, e.g. Sweden and Finland, the index is highest since these systems are less disturbed, whereas highly populated countries, e.g. Belgium have the lowest index. The graph shows that the differences between the scenarios are small, since the MSA index is for a great part determined by the total areas of the different land uses, and to lesser extent by the distribution of the land uses. The changes between the scenario's therefore have not a very large effect, since the spatial policies to promote and protect biodiversity are mainly affecting the location of certain land use and not so much the total area of a land use.

Figure 19 shows that the MSA index in the biodiversity scenario without the increase in set-aside is higher or equal than in the reference scenario, whereas in the biodiversity scenario with the high demand for agricultural land, the MSA index is on average lower compared to the reference scenario. This shows that the spatial policies do have a positive impact on biodiversity, but that the demand for land has a larger effect that cannot be compensated by the spatial policies that promote the protection of biodiversity. Especially for some

land area in the surrounding 25 km^2 is used given the large impact of urban areas on landscapes and the relatively small areas of urban land use.

countries in Central Europe, e.g. Poland, Hungary, a negative effect on the MSA was observed in the Biodiversity scenario compared to the reference, which can be explained by the increase in agricultural land due to the increased set-aside requirement.

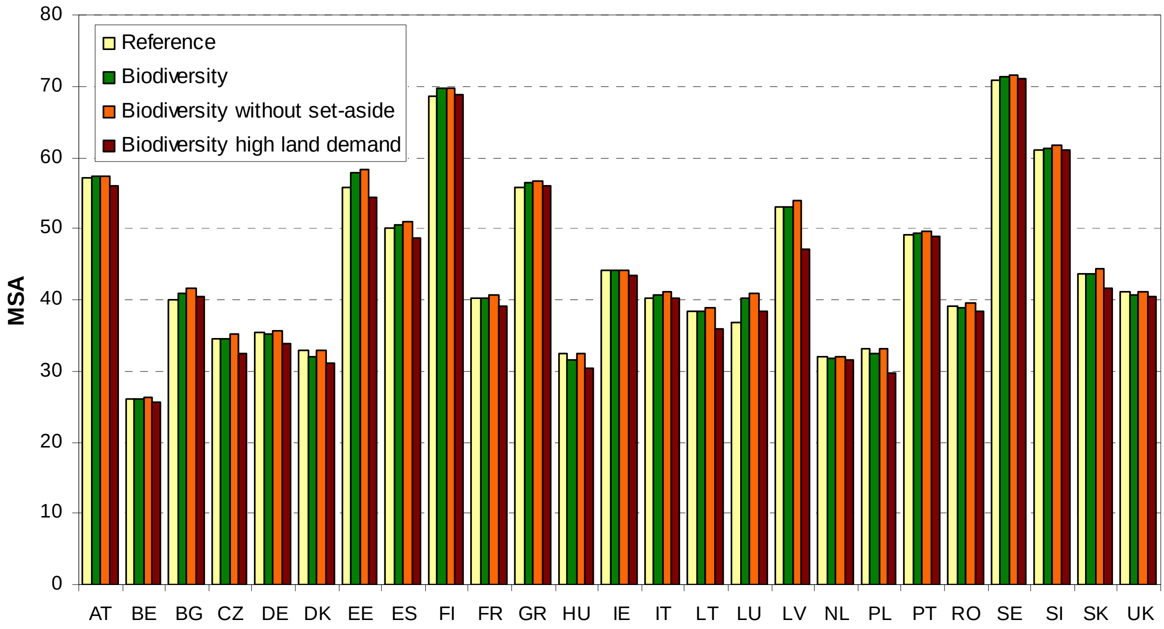


Figure 19 Mean Species Abundance index per country for the different Biodiversity scenarios

The EU-ClueScanner framework can also calculate the MSA index at km resolution (Figure 20). This map shows that there is a large variation within countries, and therefore this resolution also should be analysed to see the effect of the spatial policies. The right map shows the differences in MSA between the biodiversity and reference scenario. This shows that there are areas with increases in MSA index, especially the areas where the ecological corridors are located, but also a lot of areas with decreases in MSA. Since the spatial policies are focusing on ecological corridors and larger patches of nature, at other locations nature is less protected and thus a decrease can occur at those locations, particularly due to the increase of arable land which is caused by the obligatory increase in set-aside.

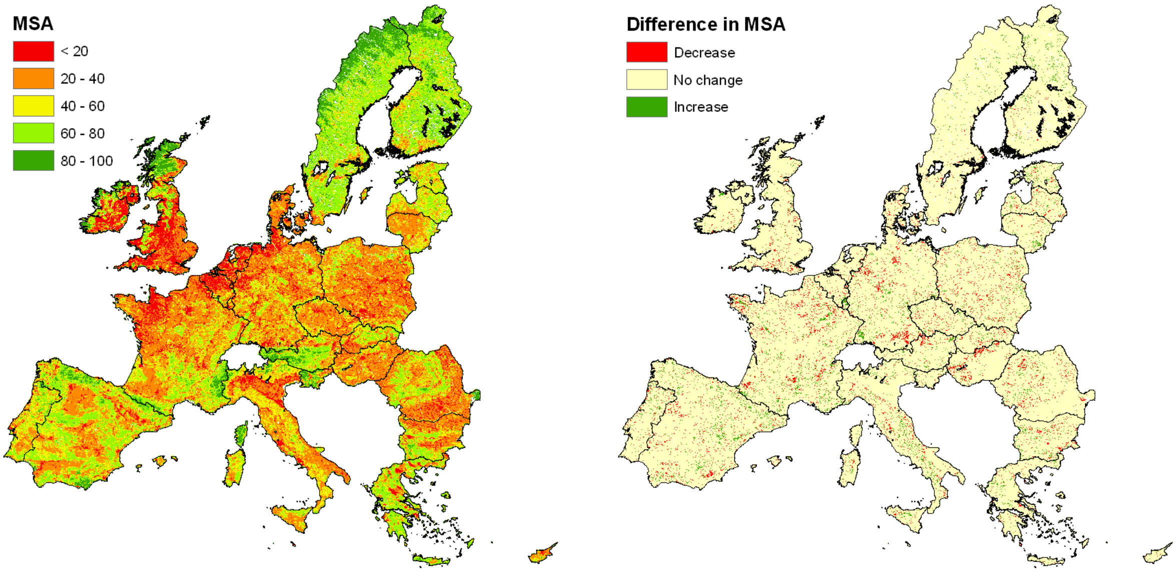


Figure 20 Mean Species Abundance index for the reference scenario (left) and the difference in MSA between the biodiversity scenario and reference scenario (right)

Conclusions

- Most of the policies to enhance biodiversity have a clear effect on land use changes, however, they are context dependent;
- In general the policies have a positive effect on biodiversity;
- Individual policies may have both positive and negative effects. For example, set-aside policy may have negative aspects due to the increase in agricultural expansion in countries where the demand for agricultural land remains the same since set-aside land is considered as agricultural land cover.

6.3 Soil and Climate Change alternative (CLUE)

The Soil and Climate Change alternative focuses on adaptation and mitigation measures related to water management and soil protection, since EC-legislation is being prepared for these themes. It introduces policies focusing on water management and soil protection and it builds on existing policy options that are currently being discussed. The following policy themes are included: flood damage reduction, restoring water balance, protection of permanent pastures, protection of peat land, soil protection and erosion prevention. Annex 1 describes how these policy themes were exactly included and parameterised in the EU-ClueScanner framework.

In Figure 21 the main land use change processes are shown for the reference scenario and the soil and climate change alternative. Both pictures show the same patterns with only minor differences, e.g. in the soil and climate change alternative less urbanisation occurs, due to spatial planning that promotes more compact forms of urbanisation. Furthermore we can see more agricultural abandonment in Eastern Germany, as result of the protection of permanent pastures and peatland conservation. For the high demand (not shown) the picture is again similar to the scenario BFP 5 non-EU & EU. This means that the main land use patterns in Europe are mainly determined by the land demand, whereas the effects of the spatial policies become pronounced at finer scales.

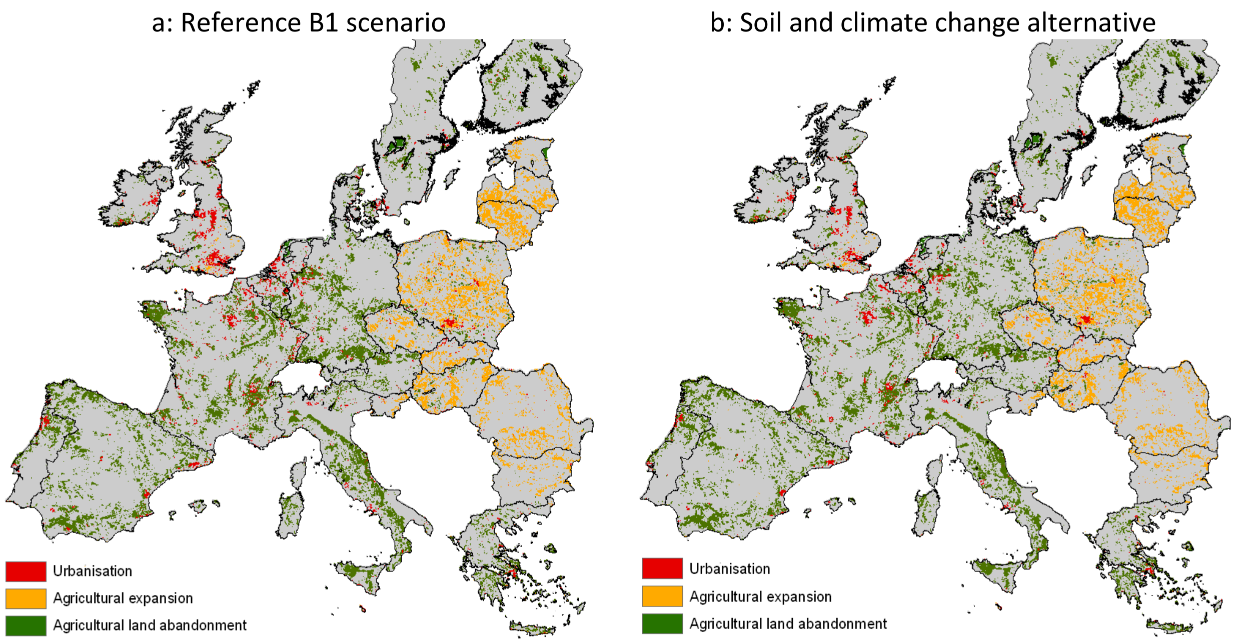


Figure 21 Main land use change processes for the (a) Reference scenario, and (b) Soil and Climate Change alternative

In Figure 22 and 23 two examples of the local impacts of the spatial policies are illustrated. Figure 22 shows the effect of peatland protection in northern Poland. For the marked areas, which indicate the peatland areas, no conversion to arable land is allowed, and pasture and nature are favoured in these areas (see Annex 1). This spatial policy indeed leads to the disappearance of arable land on peat, as shown in the right figure. In Figure 23 an example is shown for another spatial policy, the reduction of flood damage, in The Netherlands. The marked areas indicate the river flood plone areas, which were derived from a scenario study by JRC. Within these areas no conversion to built-up is allowed and extensive agriculture and nature is promoted in these areas. The right map shows that this is indeed happening, no new built-up areas within the flood prone areas and more nature. However, also outside the flood prone areas differences are visible, partly because the planned built-up areas are now allocated to other parts that are not within the river flood prone areas, but also because of the other policies that are simulated in the soil and climate change scenario, e.g. promoting more compact forms of urbansisation to reduce soil sealing.

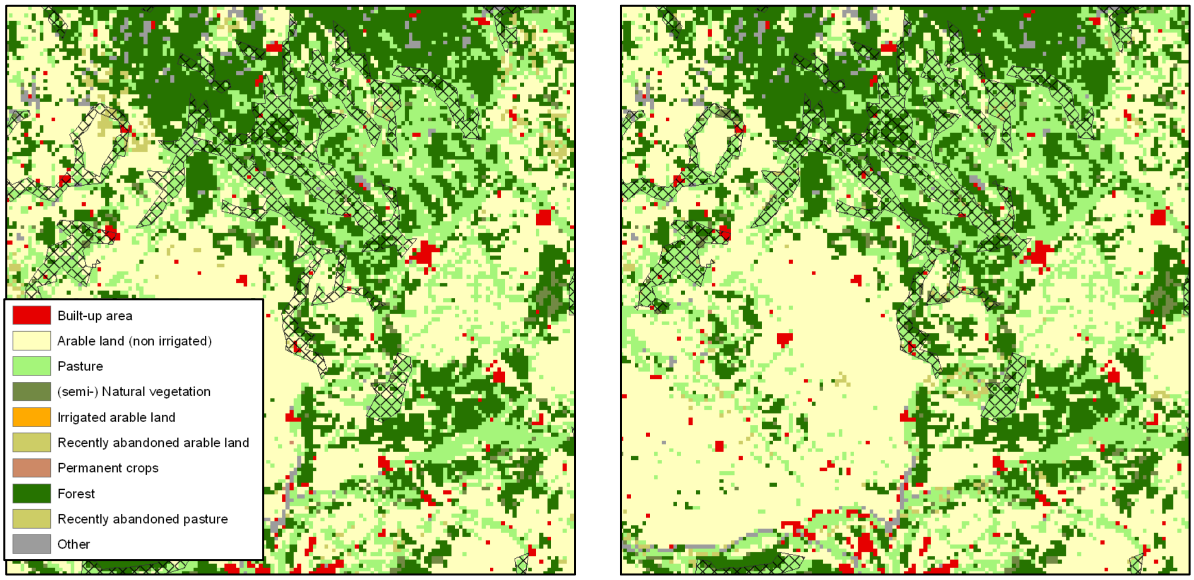


Figure 22 Example for the impact of peatland protection for an area in northern Poland. Left for the Reference scenario and right for the soil and climate change alternative with peatland protection. The marked areas indicate the peatland locations.

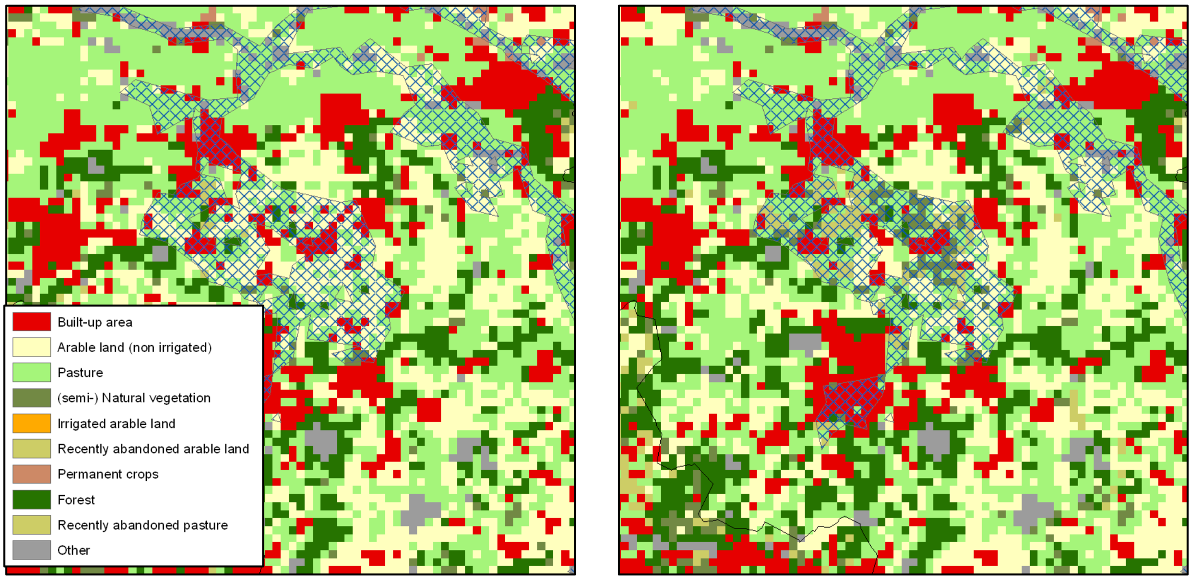


Figure 23 Example for the impact of the river flood damage reduction policy for an area in The Netherlands (north of Eindhoven). Left the figure for the Reference scenario and right for the soil and climate change alternative with flood damage reduction policies. The areas marked in blue indicate the river flood prone areas. In the soil and climate change alternative no new built-up areas are constructed in the river flood prone areas and part of agriculture is abandoned.

Conclusions

- Most spatial policies have clear effects on land use change, however, they are context dependent;
- Resulting land use changes are a composite of multiple interacting processes;
- The modelling framework is well capable to simulate different spatial land use policy options.

6.4 Comparison of main land use changes in all scenarios

In the previous sections examples were presented for a selection of the most interesting results. A full calculation and analysis of all indicators for the different scenarios can be further implemented and presented in several ways in the EU-Cluescanner tool. However, it should be considered that not for all indicators an EU-wide figure is meaningful, as discussed in section 8. In this section an overview of the main land use changes for the different scenarios is given (see Figure 24) and the main results are described below.

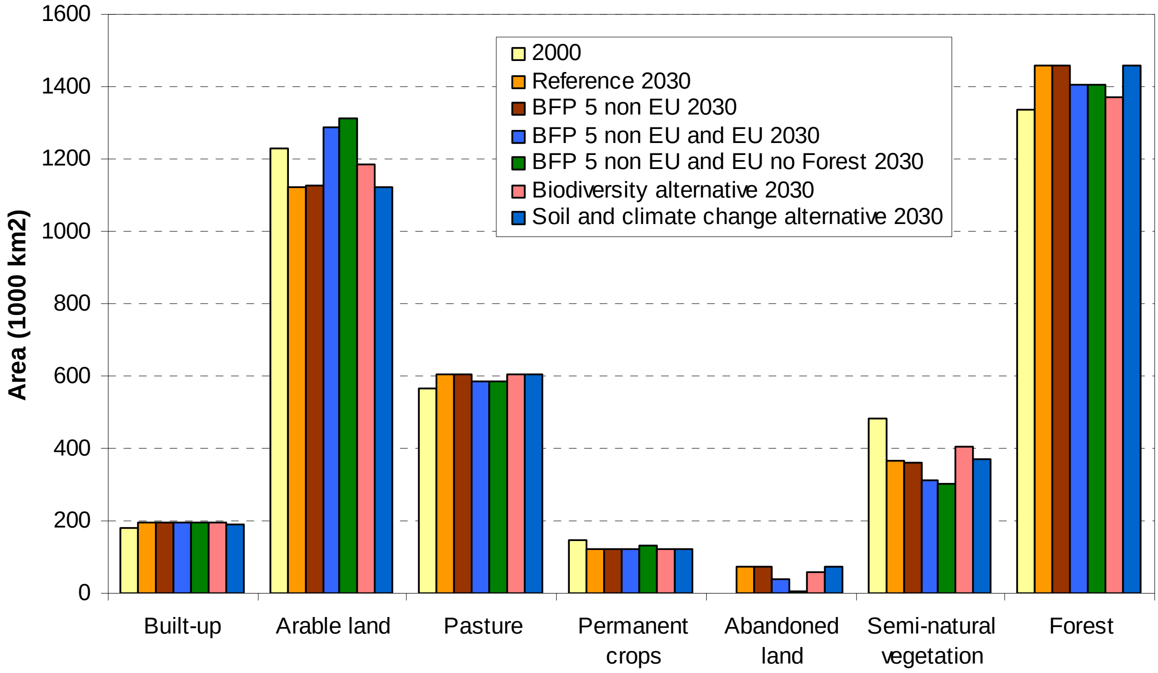


Figure 24. Occurrence of land uses in the EU-27 for the different scenarios

Built-up area increases in 2030 compared to the year 2000, and only in the Soil and Climate change scenario the increase is less, because of policies stimulating compact forms of urbanisation. Arable land shows the largest differences between scenarios, being remarkable the increase in 2030 compared to 2000 under *EU BFP for non EU and EU* with and without restricted forest land conversion into agricultural land, and decrease under the Biodiversity and Soil and Climate Change alternatives. In 2030, arable land area is higher for the Biodiversity scenario compared to the reference scenario, due to additional set-aside increase. Compared to 2000, pasture increases slightly in all scenarios and permanent crops decreases for all scenarios in 2030. For abandoned land in 2000 there is no value, since CORINE Land Cover does not distinguish this class. For 2030 most scenarios have a significant amount of abandoned land, however, in the *BFP 5 non-EU and EU no Forest* scenario the demand for arable land is so high that abandoned land does not occur anymore. Semi-natural vegetation decreases for all scenarios; however, it should be considered that a large part of abandoned land may be included in this class for 2000 for the reasons explained before. Compared to the 2030 reference scenario, The Biodiversity alternative results in higher semi-natural vegetation but less forest, which indicates a lower succession rate. This is mainly due to the incentives to protect semi-natural grassland, which retards the succession to forest (see Annex 1).

7. Short description of the user interface[13]

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. The figure below 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.

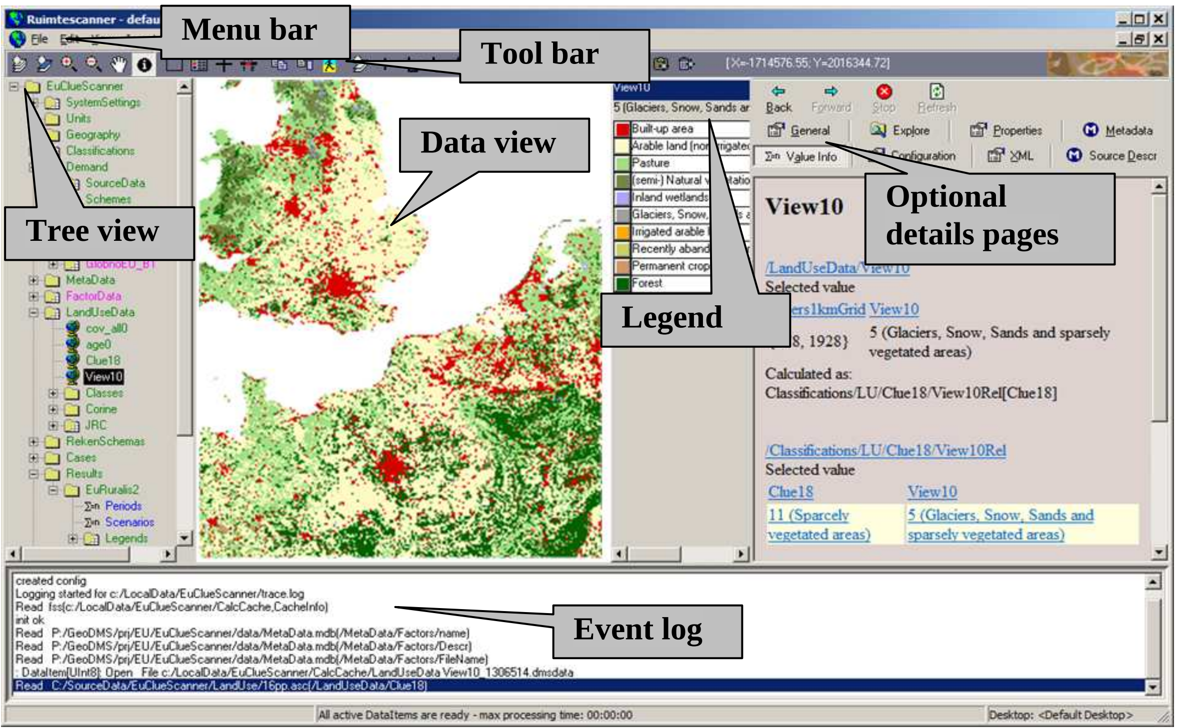


Figure 25 Tree view and main components of the GeoDMS user interface.

The GUI contains the following elements:

- the menu bar with several pull down menus;
- a tool-bar that contains window-specific tools;
- on the left hand side a TreeView that allows navigation through available spatial data sets and results;
- a data view area (for displaying tables and maps);
- a map legend that appears with map views;
- at the bottom an event log that can present hints and status information;
- various details pages that contain technical and background information; and
- a status bars that presents hints and status information about the ongoing processes.

The Tree view is the main navigation option through the available data sets. It is comparable to the Windows Explorer © in Windows and allows easy access to the huge collection of

[13] A complete description is available in Annex 4: Tutorial, available in an independent document

spatial data sets that is available in the model. The tutorial that is included as an annex to this document discusses the user interface in more detail.

The user interface is meant for relatively inexpert users to inspect the data sets related to land-use simulation and browse though the simulation results. The basic information related to simulation consists of:

- the initial land-use data sets derived from CORINE Land Cover 2000;
- a wide range of spatial data sets describing specific themes, such as accessibility, geomorphology, climate and land use in neighbouring cells, that are used as independent factors in the statistical calibration of the model;
- the land demand data that specify, for each scenario, the total amount of land (in km2) that has to be allocated per year, per land-use type, per region;
- the definition of individual simulation runs.

All results of the land-use simulation can also be viewed with the Tree view in the user interface. These results are included as land-use maps and a wide range of indicators as was described in Chapter 5. The interface, furthermore, helps users trace the calculation process and call upon intermediate results.

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. These options should only be explored by expert users.

The GeoDMS script files that comprise the model can be edited with any text editor. The user interface only offers limited functionality to edit these files, as previous experience has shown 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. To edit existing or define new policy alternatives, a relatively small set of files needs to be manipulated as is described in the tutorial. The regional land demand associated with the policy alternatives is stored in a Microsoft Access database and can be edited to change demand definitions or add new ones. Another Access database is used to manage the references to all available spatial datasets, including those that are used in the definition of policy alternatives. The definition of indicator calculations, the inclusion of new spatial datasets and model run characteristics are also defined in the GeoDMS files.

8. Limitations and uncertainties of the modelling tool

This chapter describes the current boundaries of the modelling tool and therefore the degree of uncertainty that is linked to the results presented. The modelling framework is very flexible and can be adapted to various needs for specific assessments and scenarios. However, to some extent the modifications of the modelling framework are limited by the available data and the state of understanding of the land system. A number of issues are discussed below in more detail.

Land use intensity is very important to consider given the large impacts of the intensity of land use on the environment. Land use intensity is, to some extent, intrinsic to the land cover classes considered in the model. However, within the land cover classes considered there are large differences in land use intensity. Forest can be either managed forest or largely natural, agricultural areas face large differences in management intensity having enormous consequences for agro-biodiversity and the high nature value farmland conditions. Similar considerations apply to urban area which includes dense urban areas, low-density urban areas as well as sports and (certain) recreational facilities. Although the modelling framework is in principle capable of allocating a further differentiation of land use classes according to intensity, this is hampered by the low availability of spatially explicit data on land use intensity. Since land use intensity usually varies over short distances (e.g., valley and slope), statistical data at NUTS level are insufficient while FADN data on the location of individual farms are not publicly available because of privacy issues. Furthermore, such an assessment of changes in land intensity would further require a coupling with more detailed sector models capable of simulating changes in land management. The currently used GTAP model can not disaggregate beyond the national level. Examples of such models are CAPRI for the agricultural sector and EFISCEN for the forestry sector. A scoping study by Verburg and Temme has indicated that modelling land use intensity changes in a spatially explicit manner is feasible, but needs a further investment to guarantee scientific quality. This has been included as part of a recently submitted proposal to DG Research (FP7).

Forestry and forest management. In the current modelling framework set-up, changes in forest (and semi-natural land use) area are a result of the interplay between changes in agricultural and urban areas and the re-growth of vegetation on abandoned agricultural lands. Potentially this could include explicit policies on reforestation (which in fact just shorten the re-growth time of the vegetation through planting or favourable management). However, this would require a specific elaboration of scenarios on that point, as well as an inventory of policies and ways of implementation of different member states. Linking to the EFISCEN forest management model could be an important asset in achieving this objective.

Similar considerations hold for many other possible improvements of the modelling system. Increasing the *spatial resolution* from 1 km^2 to 1 ha, for example, is now being undertaken for EC-JRC. The CORINE Land Cover data support such a higher resolution and this seems a promising pathway for the simulation of, for example, urban development in relation to flood risk. However, many of the data sets used to identify the location factors that determine the competitive advantage of specific land use types (such as various forms of agriculture) do not support this amount of spatial detail. As an example, the European Soil map has a much coarser spatial scale and cannot distinguish between differences in soil type at a spatial resolution of 1 hectare, even if these are critical for the choice of an agricultural land use type. If such a higher spatial resolution needs be achieved it may be important to implement spatial data available within the different member states which often have a higher spatial detail. The consistency between these data sets originating from different member states remains a challenge however. The limited availability of high-resolution data related to different biophysical phenomena, such as erosion, carbon sequestration and biodiversity, is furthermore hampering the calculation of many indicators at this higher resolution.

The current model implementation is limited in its capacity to address *feedbacks between the environmental impacts and the driving factors of land change*. In reality, such feedbacks can play an important role, e.g. intensive agriculture may increase soil erosion and salinization and these processes may, in turn, decrease the suitability of the land for agricultural use in the future. Other feedbacks operate between different locations. For example, increases in intensive, irrigated agriculture upstream may limit the expansion possibilities of agriculture in downstream areas through reduced water availability. Feedbacks are considered an important aspect of land change (Verburg, 2006). Previous studies have shown that such feedbacks can be implemented in the CLUE modelling system because of its temporal discrete calculations and open structure (Claessens et al., 2009). However, the quantification of the importance of such feedbacks and possible time lags is still difficult and an issue that needs further research. Therefore, it is considered of ultimate importance to further improve our capacity for impact assessment at medium to long time scales.

The current model implementation includes a *restricted set of indicators*. These indicators reflect the best available methods to interpret land-use simulation results in terms of different policy issues, such as erosion, biodiversity and carbon sequestration. The calculation of these indicator values could be enhanced through the inclusion of more reliable or more detailed data sets, related to, for example, the processes that influence biodiversity. More detailed assessments of this issue would, however, also call for a much more detailed simulation of relevant habitat conditions (hydrology, land-use intensity, atmospheric deposition etc.). An alternative option is offered by the concept of ecosystem services that are provided by land. This concept is powerful in negotiating the change in different benefits derived from land systems upon changing climate, policies and other factors. It would be beneficial to quantify the ecosystem service trade-offs for the different scenarios instead of focussing on a limited set of indicators. Quantification and mapping of ecosystem services is however very challenging but novel methods are emerging (Willemen et al., 2008; 2009). Based on results of the CLUE model for Europe in an earlier project a simple method towards quantification of ecosystem services is made by Kienast et al. (2009).

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 at a 1 km spatial resolution. It is thus important to choose indicator models that are suited 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.

9. Potential improvements of the current modelling framework

The current project develops a European land-use integrated modelling framework and shows its potential to support environmental policy. The EU-ClueScanner land-use allocation model is at the heart of the modelling framework. It is implemented in the geo-DMS environment for this project, using only open source components which make it possible for third parties to apply it. A short tutorial for using the modelling system and the user interface is included as Annex 4[14] to this report.

After this project is finished, the model is intended to be used in additional planning-related applications. These applications may deal with the inclusion of new reference scenarios, or definition of new policy options (e.g. related to transport). These applications may be implemented by DG Environment or by research institutions, depending on the wishes of DG Environment. 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).

Different options exits to adjust and improve the current EU-ClueScanner model. The options regarding the potential improvements related to the basic Geo-DMS software and the actual land-use model that is implemented in the software are shortly described as follows.

A first set of potential model adjustments relates to *Geo-DMS software* in which the model is programmed. Options include:

- updating the model to a newer Windows version should that be deemed necessary;
- addition of the technical functionality that is developed in other project (e.g. new spatial analysis functions);
- adding bug fixes in the Geo-DMS software.

The software is provided as open source environment. However, changes to the software that relate to the overall mechanisms of land allocation and the functioning of the software, cannot be made without a change in the name of the software in order to avoid multiple and inconsistent named versions of the software. A license will be provided with the software, with indication on the adequate referencing to the software upon use and other indications regarding Agreement for the Transfer of Materials.

To improve the *implemented land-use modelling framework*, a number of issues can be considered. These are listed below, ranging from simple to complex:

- 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;
- increasing the spatial resolution;

[14] Provided as independent document

- revise the calibration based on the new land-use data or other additional data sets;
- link the land-use model with other models (transport, hydrology, economics).

The simpler issues in this list can be implemented by DG Environment or EC-JRC. The more complex issues might be subcontracted or even be the topic of new tenders or EC research projects. The included tutorial discusses these issues in more detail. It provides technical guidance for the more basic additions to the modelling framework and a discussion on important issues that need to be considered for more complex issues, such as the revision of the calibration or the linking with other models.

It is important to notice that the above changes will only partly involve the adaptation of the actual modelling environment. To a large extent model improvements will rely on efforts outside the model itself. The replacement of an existing data set, for example, is a simple and straightforward activity from a modelling perspective, but creating new coherent spatial data sets that are consistent across the whole European territory is very demanding task. This involves the tackling of many technical (e.g. projections, semantics, etc.) and organisational efforts. Luckily institutes as the JRC and EEA are continuously expanding their data collections.

New data sets that are used to update the land-use allocation process have to be included in the appropriate modelling scripts to be effective, as it is described in the tutorial. A revised calibration of the model is necessary, either when substantial additions are made to the data sets that describe the most important allocation factors (e.g. additional accessibility or policy maps), or when the basic land use is changed. This calibration implies an extensive statistical analysis and the use of appropriate software (e.g. SPSS) that needs to be done by land use research experts. The tutorial discusses some aspects of the appropriate techniques (e.g. logistic regression) and other methodological considerations.

The land-use model can be linked with other spatial models to either (i) derive a more specific input for simulation, e.g. changed regional agricultural demand from CAPRI, revised accessibility maps from TRANSTOOLS; or (ii) 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 crop types have to be inserted in the land-use model to allow the input from an agro-economic model such as CAPRI. In any change in the framework regarding coupling of new models , it is advisable that the model experts will be involved to ensure a consistent coupling of the models.

Finally, based on the current modelling experience, the following considerations can be derived for data collection that could be used to improve the assessment of land use related policies impact:

- Regarding the land cover classes (LC class), an assessment could be done on the relevance of LC classes for the indicator at stake. For example, concerning the indicator

Carbon sequestration the relevant LC types are those with high Carbon stocks, i.e. permanent grassland, forest and nature. Once these classes are identified, it is crucial to have more information about the land use linked to the LC class. Especially relevant are the data on the intensity of agricultural use when assessing the impacts of agricultural policies on the environment. In this regard the differentiation between intensive and extensive grassland is crucial for nutrient and biodiversity issues. If information on agricultural intensity would be available then also abandoned land (and fallow/set-aside) could be classified, which is relevant for habitat succession and biodiversity, i.e. if fallow land is land really abandoned, the carbon will be sequestrated, however if it is a short-time fallow land, then the carbon will be again lost upon cultivation. Therefore, monitoring grasslands and agricultural abandonment is very important.

- Regarding the spatial resolution, the 1 km grid size seems an efficient level to make assessments at European scale. A higher resolution, e.g. 100 meter grid, could be interesting for some assessments. However, it will create problems for data processing with current software, and the results would probably not be significantly different from the 1 km grid at European scale;
- Regarding the update frequency, in general five years seems a good time interval for those land cover classes showing the largest rate of change, e.g. urban, nature and agricultural classes. Longer time periods might cause problems with monitoring purposes and reporting obligations (e.g. for the UNFCCC). Frequency of land cover data collection is very important to monitor vegetation changes and their impact on C sequestration. In this regard, other state-of-the-art measurements based on satellite imagery could complement the current land cover data.

10. References

Banse, M. and Grethe, H. (2008). Effects of the New Biofuel Directive on EU Land Use and Agricultural Markets. Paper presented on the 107th EAAE Seminar ‘Modeling Agricultural and Rural Development Policies’, 30 January – 1 February 2008, Seville

Banse, M., Van Meijl, H., Tabeau, A. and Woltjer, G. (2008) Will EU Biofuel Policies affect Global Agricultural Markets? European Review of Agricultural Economics 35(2): 117-141

BRANCH partnership (2007) Planning for biodiversity in a changing climate; BRANCH project Final Report. Natural England, UK.

Britz, W., Leip, A., Verburg, P.H. (submitted to Ecological Modelling). Modelling of land cover and agricultural change in Europe: combining the CLUE and CAPRI-Spat approaches

Burniaux, J.M. and Truong, T.P. (2002). GTAP-E: An Energy-Environmental Version of the GTAP Model. GTAP Technical Paper, No. 16. Revised Version. Center for Global Trade Analysis, Purdue University.

Claessens, L., Verburg, P.H., Schoorl, J.M., Geraedts, L. and Veldkamp, A. (2009). Modelling feedback mechanisms between land use change and landscape processes. Agriculture, Ecosystems & Environment 129, 157-170.

COM/2006/0216 final: Communication from the Commission - Halting the loss of biodiversity by 2010 - and beyond - Sustaining ecosystem services for human well-being

COM/2006/231 final: Thematic strategy for soil protection. Communication from the Commission to the Council, the European parliament, the European economic and social committee and the committee of the regions

COM/2007/414 final: Communication from the Commission to the European Parliament and the Council Addressing the challenge of water scarcity and droughts in the European Union

COM/ 2008/19 final. Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources.

COM/2009/0147 final White paper - Adapting to climate change: towards a European framework for action

COM/2009/161 final: Communication from the Commission - Towards a better targeting of the aid to farmers in areas with natural handicaps

CPB (2003) Four Futures of Europe. Netherlands Bureau for Economic Policy Analysis

Dixon, P. B., Osborne, S. and Rimmer, M. T. (2007). The Economy-Wide Effects in the United States of Replacing Crude Petroleum with Biomass. Paper presented at the 10th Annual Conference on Global Economic Analysis, 7-9 June 2007, Purdue University, Indiana

EC (2007a) The Impact of a Minimum 10% Obligation for Biofuel Use in the EU 27 in 2020 on Agricultural Markets. Impact Assessment of the Renewable Energy Roadmap - March 2007. DG AGRI. Directorate G. Economic Analysis, Perspectives and Evaluations. G.2. Economic Analysis of EU Agriculture. European Commission: Brussels.

EC (2007b) Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks.

Eickhout B., van Meijl H., Tabeau A., van Rheenen R. (2007) Economic and ecological consequences of four European land use scenarios. Land Use Policy 24:562–575

Eickhout, B., Notenboom, J., Ros, J.P.M., Van den Born, G.J., Van Oorschot, M., Van Vuuren, D.P. and Westhoek, H.J. (2008) Local and global consequences of the EU renewable directive for biofuels. MNP-report 500143001. Bilthoven, Netherlands.

Eickhout, B. and A.G. Prins (eds) (2008) Eururalis 2.0 technical background and indicator documtentation. Wageningen University and Research and the Netherlands Environmental Assessment Agency (MNP), Bilthoven, Netherlands

Eickhout, B., Van Meijl, H., Tabeau, A. and Stehfest, E. (2009) The impact of environmental and climate constraints on global food supply. In: Hertel, T., Rose, S. and Tol, R. (eds.), Economic Analysis of Land Use in Global Climate Change Policy. Routledge, New York

IEA (2008) Key World Energy Statistics. International Energy Agency Publication

Hertel, T. (1997). Global Trade Analysis. Modelling and Applications. Cambridge: University Press

Hurkmans, R.T.W.L., Terink, W., Uijlenhoet, R., Moors, E.J., Troch, P.A. and Verburg, P.H. (2009). Effects of land use changes on streamflow generation in the Rhine basin. Water Resources Research, 45:doi:10.1029/2008WR007574

Kahabka, H. and Lucera, L. (2008) Delivery report European Mosaic, EEA-FTSP-Sealing-DeliveryReport-EuropeanMosaic, Issue 1.0. European Environment Agency, Copenhagen.

Kienast, F., Bolliger, J., De Groot, R.S., Potschin, M., Haynes-Young, R., Verburg, P.H. and Heller, I., 2009. A methodological framework for integrated impact assessment of land use change on landscape functions and sustainability. Environ Manag 44:1099–1120.

Kirkby, M.J., Jones, R.J.A., Irvine, B., Gobin, A, Govers, G., Cerdan, O., Van Rompaey, A.J.J., Le Bissonnais, Y., Daroussin, J., King, D., Montanarella, L., Grimm, M., Vieillefont, V., Puigdefabregas, J., Boer, M., Kosmas, C., Yassoglou, N., Tsara, M., Mantel, S., Van Lynden, G.J. and Huting, J. (2004). Pan-European Soil Erosion Risk Assessment: The PESERA Map, Version 1 October 2003. Explanation of Special Publication Ispra 2004 No.73 (S.P.I.04.73). European Soil Bureau Research Report No.16, EUR 21176, 18pp. and 1 map in ISO B1 format. Office for Official Publications of the European Communities, Luxembourg.

Louwagie, G., Gay, S.H. and Burrell, A. (2009) Addressing Soil Degradation in EU Agriculture: Relevant Processes, Practices and Policies; Report on the project 'Sustainable Agriculture and Soil Conservation (SoCo)'. European Commission, Joint Research Centre, Institute for Prospective Technological Studies (JRC-IPTS), Sevilla, Spain.

Massey, E. and Bergsma, E. (2008) Assessing adaptation in 29 European countries. Institute for Environmental Studies Report W-08/20. Vrije Universiteit Amsterdam

PIK (2004) ATEAM Final Report 2004. Advanced Terrestrial Ecosystem Analysis and Modelling. Potsdam Institute for Climate Research, Potsdam.

Pontius R, Boersma W, Castella J-C, Clarke K, de Nijs T, Dietzel C, Duan Z, Fotsing E, Goldstein N, Kok K, Koomen E, Lippitt C, McConnell W, Mohd Sood A, Pijanowski B, Pithadia S, Sweeney S, Trung T, Veldkamp A, Verburg P (2008) Comparing the input, output, and validation maps for several models of land change. The Annals of Regional Science 42:11-37

Schmidhuber, J. (2007). Biofuels: An Emerging Threat to Europe’s Food Security? Impact of an Increased Biomass Use on Agricultural Markets, Prices and Food Security: A Longer-term Perspective. Notre-Europe. www.notre-europe.eu. Accessed 20/07/2007

Rajagopal, D and Zilberman, D. (2007). Review of Environmental, Economic and Policy Aspects of Biofuels. Policy Research Working Paper 4341. World Bank: Washington.

Reilly, J. and Paltsev, S. (2007). Biomass Energy and Competition for Land, Report of MIT. Joint Program on the Science and Policy of Global Change, No. 145. MIT: Cambridge.

Rosegrant, M.W., Zhu, T., Msangi, S. and Sulser, T. (2007). Global Scenarios for Biofuels: Impacts and Implications. Washington: IFPRI.

Schulp CJE, Nabuurs G-J, Verburg PH (2008) Future carbon sequestration in Europe--Effects of land use change. Agriculture, Ecosystems & Environment 127:251-264.

Valbuena, D., Verburg, P.H., Veldkamp, A., Bregt, A.K. and Ligtenberg, A. (submitted). Effects of farmers' decisions on the landscape structure of a Dutch rural region.

Van Meijl, H., Van Rheenen, T., Tabeau, A. and Eickhout, B. (2006) The impact of different policy environments on agricultural land use in Europe. Agriculture, Ecosystems & Environment 114(1): 21-38.

Verboom J, Alkemade R, Klijn J, Metzger MJ, Reijnen R (2007) Combining biodiversity modeling with political and economic development scenarios for 25 EU countries. Ecological Economics 62:267-276

Verburg, P. (2006). Simulating feedbacks in land use and land cover change models. Landsc Ecol, 21:1171-1183.

Verburg, P.H., Schulp, C.J.E., Witte, N. and Veldkamp, A. (2006). Downscaling of land use change scenarios to assess the dynamics of European landscapes. Agriculture, Ecosystems & Environment, 114:39-56.

Verburg, P.H., Rounsevell, M.D.A. and Veldkamp, A. (2006) Scenario-based studies of future land use in Europe. Agriculture, Ecosystems & Environment 114(1): 1-6.

Verburg, P.H., Eickhout, B. and Van Meijl, H. (2008) A multi-scale, multi-model approach for analyzing the future dynamics of European land use. Annals of Regional Science 42(1): 57-77.

Verburg P, Overmars K (2009) Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model. Landsc Ecol http://dx.doi.org/10.1007/s10980-009-9355-7.

Verburg, P.H., van de Steeg, J., Veldkamp, A. and Willemen, L. (2009). From land cover change to land function dynamics: A major challenge to improve land characterization. J Environ Manag, 90:1327-1335.

Von Lampe, M. (2007). Economics and agricultural market impacts of growing biofuel production. Agrarwirtschaft 55: 232-237.

Westhoek, H.J., Van den Berg, M. and Bakkes, J.A. (2006) Scenario development to explore the future of Europe's rural areas. Agriculture, Ecosystems & Environment 114(1): 7-20.

Wiesenthal, T., Leduc, G., Christidis, P., Pelkmans, L. and Georgopo, P. (2007). Assessment of Biofuel Policies in Europe – Lessons Learnt and Future Policy Options. Policy-Synthesis of the Premia Project: http://www.premia-eu.org. Accessed 04/02/2008.

Willemen, L., Verburg, P.H., Hein, L. and van Mensvoort, M.E.F. (2008). Spatial characterization of landscape functions. Landsc Urban Plann, 88:34-43.

Willemen, L., Hein, L., van Mensvoort, M.E.F. and Verburg, P.H. (2009). Space for people, plants, and livestock? Quantifying interactions among multiple landscape functions in a Dutch rural region. Ecological Indicators, 10:62-73.

WUR/MNP (2008) EURURALIS 2.0 CD-ROM. Wageningen University/ Netherlands Environmental Assessment Agency, Wageningen.

Annex 1. Detailed settings of model parameters according to main themes and scenarios

Model parameters are included in italic; these are for model implementation purposes only and represent the descriptions given

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
1. BUILT-UP AREA Change in built-up area per person per year (including all built-up area: residential / services / recreation / industry / infrastructure)	+0.75 m^2 per person per year due to the effect of strong economic growth but restrictive spatial planning policies (compact urbanization; about half of the average value of the trend during 1990-2000 over all EU countries; economic growth rates are about half of those over the 1990-2000 period, therefore area per person is expected to show a smaller increase as well). The increase of space per person is added to MS specific per person use of space derived by empirical analysis. There is no empirical base to differentiate growth rates by country	As reference	Overall attention for climate change and incentives to adapt spatial planning accordingly leads to implementation at MS level and local level of measures that favour more compact cities. More compact, less built-up area per person as compared to reference scenario (+0.4 m^2 per person per year)
2. PROTECTED AREAS 2.1 Natura 2000	Some incentives to continue extensive land use in Natura 2000 areas Forest, semi-natural, recently abandoned > all other uses not allowed in Natura 2000 locations (except succession); Other restrictions in Natura 2000 areas: Agricultural uses > urban: not allowed Arable > grass: allowed Grass > arable allowed Arable & grass > permanent allowed Permanent > grass & arable: allowed Agriculture > recently abandoned: allowed but incentives to prevent this by compensation to farmers (agri-env schemes)	More funds through 2nd pillar payments to continue extensive land use in Nature 2000 areas (incentive approx. 3 times as strong). Constraints for conversions are more strict in Natura2000 areas, differences from reference: Grass > arable not allowed Arable & grass > permanent not allowed Permanent > grass & arable: not allowed	As reference

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
	locspec weight for arable/grass/permanents resp: 0.1; 0.1; 0.1 for areas currently under arable/grass/permentnes areas within NATURA2000. In addition the elasticity for nature is set higher than recently abandoned	The locspec weights are set for arable/grass/permanents at resp: 0.3; 0.3; 0.3	
2.2 High Nature Value (HNV) farmland protection	No specific protection	Compensation of extensive farming (especially permanent pastures) in HNV areas to prevent abandonment or intensification (compensation for pasture similar to current LFA support, for arable land 50% of current LFA support) The HNV areas are selected from the JRC HNV map as those with a >50% likelihood. In these areas the locspec for permanent pasture will be +0.2 and for arable land and permanent crops +0.1 only for current arable and pasture areas. In case of overlap with NATURA2000 area no double subsidies	As reference
2.3 Policy measures to control fragmentation	Incentives aimed at limiting fragmentation of natural areas, no active promotion of clustering.	Policy targeted at clustering natural land use types towards large robust natural areas.	As reference

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
	Semi-natural and forest have a positive neighbourhood relation with all natural land use types; this prevents conversion of these types to agricultural use near large natural areas. In the neighbourhood settings the weight for nature is set at 0.2 to limit fragmentation.	In the neighbourhood settings the weight for semi-natural and forest will be increased from 0.2 to 0.4 to limit fragmentation	
2.4 Efforts to establish ecological corridors at national and international level	No European-wide policy (except what is done in Natura 2000)	Incentives to convert agricultural land into nature within the defined natural corridors (incentives to buy agricultural land (arable/permanent crops) by nature management organisations in corridor areas). The PEEN (Pan-European Ecological Network) corridor map will be used as an example. locspec weight is set at -0.2 for all arable/permanent crops within the defined ecological corridors and -0.2 for arable/permanent crops along major and medium sized rivers (2 km wide).When corridors intersect N2000 areas no locspec for the corridor is added. When corridors intersect HNV or LFA areas no incentives are provided to convert agricultural land to nature, neither compensation	As reference

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
		for continuing farming is provided (locspec of current arable land 0; outside currently cropped area locspec is -0.2 for arable and permanent crops	
3. LESS FAVOURED AREAS	Current LFA support including implementation in the EU12, except for arable agriculture in locations with high erosion risk. locspec 0.2 for all agricultural land use types at locations within LFA that are currently under agricultural use (arable, grass, permanents). In case of overlap N2000 and LFA the highest compensation counts (0.2)	Targeted LFA support to HNV areas within LFA areas, by increasing the level of 2nd pillar payments. locspec of 0.1 for all agricultural land use types at LFA areas and 0.3 for HNV areas within LFA that are currently under agricultural use. In case of overlap with N2000 highest compensation counts (0.3). In case of overlap with corridor the corridor value is subtracted from the value inside the LFA)	As reference
4. PERMANENT PASTURE	If permanent pasture area decreases by more than 10% over a relative to the average area over 2000-2007 at Member state level, the area is not allowed to further decrease. Implemented through calculation at the level of member states Some incentives to prevent the conversion of permanent pasture to arable land. Implemented by increasing the ‘conversion costs’ through changing the elasticity (elas perm	As reference	If permanent pasture area decreases by more than 5% as compared to the average area over 2000-2007 at Member state level, the area is not allowed to further decrease. Implemented through calculation at the level of member states Strict protection of permanent grassland areas.

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
	grasslands 0.5). Value is calibrated based on observed trend over 1990-2000		Implemented by increasing the 'conversion costs' through changing the elasticity (elas perm grassland 0.8) Value is increased as compared to 1990-2000 situation based on expert judgment
5. ABONDONED LAND Constraints and management influencing succession of natural vegetation on abandoned land	The settings are based on assumed overall land management attitude and nature management conditions, not on specific EU-wide policies. Moderate pressure in densely populated areas due to recreational uses/hobby farming etc. Conversion of recently abandoned to semi-natural takes longer (years added to 'natural' succession time per population pressure class 1: 100 years (no succession) 2: 20 years 3: 10 years 4: 2 years 5: 0 years Population pressure classes are based on a 'population potential' map with the following classes: 5: 0-45000 (index of population pressure) 4: 45000-165000 3: 165000-375000 2: 375000-725000 1: >725000 For documentation of the population potential map	Same as reference, only succession from recently abandoned farmland to semi-natural vegetation in Nature 2000 locations AND the surrounding 2 km is not retarded due to favourable management in the buffer areas of NATURA2000 location. However, since most often semi-natural grassland vegetations are favoured as vegetation in these areas the succession of current agricultural land from semi-natural to forest land is retarded instead by 7 to 20 years (randomly allocated) due to active management of the semi-natural vegetation by grazing/mowing.	As reference

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
	see factsheet poppot_sumtot Due to grazing it is assumed that succession is retarded by 5 to 10 years depending on livestock density in neighbourhood. If the mean density of land-based systems in the neighbourhood (circle radius 3 km) exceeds 75 LSU/km2 it is assumed that succession (both stages) is retarded by 10 years; if livestock density is between 30 LSU/km2 it is assumed that succession (both stages) is retarded by 5 years. Succession in Nature 2000 locations is not retarded due to assumed lower grazing pressure after abandonment.		
6. EROSION RISK	Limited incentive to convert arable land on erosion sensitive places to grassland and forestry. In addition conversion to arable land and permanent crops is not allowed in these erosion sensitive areas. This is implemented by assuming a lowering of the suitability for arable land in these areas (locspec weight -0.1) which represents the compensation if this land is no longer used for arable agriculture. No LFA support for arable land in erosion sensitive areas, no N2000 compensation for arable land in erosion sensitive areas	Incentives to convert arable land on erosion sensitive places to grassland and forestry. In addition conversion to arable land and permanent crops is not allowed in these erosion sensitive areas., Also no HNV support in erosion sensitive areas; when corridor intersects erosion sensitive area the discouragement is additive. This is implemented by assuming a lowering of the suitability for arable land in these areas (locspec weight -0.15)*, if corridor intersects with erosion sensitive area locspec -0.35 for arable land.*	Strong incentive to convert arable land on erosion sensitive places to grassland and forestry. The suitability for non-irrigated arable land in these areas is further lowered compared to the reference. In addition conversion to arable land and permanent crops is not allowed in these erosion sensitive areas Lowering the suitability of arable land for arable uses: locspec weight -0.3 for arable land which represents the compensation if this land is no longer used for arable agriculture. No LFA and N2000 support for arable land in

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
			erosion sensitive areas.
7 URBAN SPATIAL POLICIES 7.1 Focus of growth	Some restrictions in urban spatial planning resulting in compact urban growth; growth both in large cities and provincial towns. This is implemented via the neighbourhood settings by setting the weight for built-up at 0.2	Restrictions in urban spatial planning resulting in compact urban growth; growth both in large cities and provincial towns. This is implemented via the neighbourhood settings by setting the weight for built-up at 0.3	To prevent soil sealing the restrictions in urban spatial planning are stronger. In the neighbourhood settings the weight for built-up is set at 0.5
7.2 Nature and urbanization	No additional restrictions (see protected areas)	Semi-natural and forest may not change into built-up areas	As reference
8. PROTECTION PEATLAND	No policy	Conversion to arable land or permanent crops and changes from (semi-) natural land (incl. recently abandoned land) to other land uses are not allowed on peatland (following the EUROPEAN soil map). In the conversion matrix the above mentioned changes will not be allowed in peatlands	Conversion to arable land or permanent crops and permanent crops and changes from (semi-) natural land (incl. recently abandoned land) to other land uses are not allowed on peatland (following the EUROPEAN soil map); incentives are provided to convert arable land and permanent crops to nature or permanent grassland (restoration). In the conversion matrix the above mentioned changes will not be allowed in peatlands and additionally the locspec for arable land and permanent crops is lowered with 0.2 in

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
			peatlands. If peatlands overlap with N2000 or LFA no compensation for arable agriculture is provided (locspec still -0.2 for arable. If peatlands overlap with erosion sensitive area locspec remains -0.3
9. RIVER FLOOD DAMAGE REDUCTION	No policy	As reference; no additional measures because many river valleys are already identified as possible ecological corridors in which incentives for conversion of agricultural land into grassland/nature are implemented	Discourage urbanisation in areas that are likely to become more flood prone due to climate change. Promotion of extensive agriculture and nature in these areas. The river flood prone areas are defined as the areas in which at least 25% of the 1 km2 cell will be flooded with a water-depth of >0.5 m, which are derived from the scenario map provided by JRC*. In these areas the conversion to built-up is not allowed. Locspec for arable land is -0.2 except when interested with N2000 area, then compensation is maintained. In flood-prone peatlands locspec -0.3 for arable land. LFA compensations are excluded in flood prone areas.*
10. WATER BALANCE RESTORATION	No policy	As reference. Measures are focused on sensitive areas for biodiversity. Where these	Discourage urbanisation and promote forest, nature and extensive forms of agriculture

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
		overlap with upstream areas measures are already implemented through HNV, LFA or N2000 related measures	in upstream parts of catchment areas. Upstream parts of catchment areas area defined by: -Slope should be more than 10%; -Altitude should be more than 500 m; -Distance to river should be less than 10 km; -Soil Water Storage Capacity (obtained from the PESERA project) should be less than 100 mm. Implemented by lowering the suitability for built-up and arable land in these areas. The locspec for built-up -0.4 and for arable land -0.1 in these upstream parts of the catchment. For arable land this only holds for upstream parts not designated under any other spatial policy
11. COMPULSARY SET-ASIDE Change in policies with respect to set-aside	Set-aside is not abolished in 2008 and the 10% target remains, set-aside will remain at level similar to 2000-2006 period. In case of conflict with land demands the following alternative will be used: From 2008 onward set-aside is abolished. It is assumed that in a 5 year period (2008-2013) the actual level of set-aside decreases to half the area set-aside reported at MS level in 2000-2006. The other half of the set-aside area is assumed to be in marginal areas and not taken into agriculture again	Set-aside is maintained. From 2015 onward the set-aside is increased over a 5 year period to a maximum level of 15%. This is implemented as a 5% increase of set-aside land as compared to the 2000-2006 period over the period 2015-2020 (1% increase a year)	As reference

Issues related to model settings	B1 reference scenario	Biodiversity alternative	Soil and climate change alternative
11b. BIOFUEL ON SET-ASIDE % of set-aside land used for biofuel cultivation	2000-2010 5% 2010-2020 15% 2020-2030 20%	No biofuel on set aside and on forest	As reference

Annex 2. Technical specification of model settings for the scenarios

The following sections document the settings of different categories of model settings for the scenarios simulated in this study. The settings follow the specifications of the detailed scenario specification presented in Annex 1.

1. Specification of location specific preference additions

For the scenarios simulated in this project, the implementation of the 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. These 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. Table 1 shows which spatial zonings are included in the different scenarios. In the Figures 1 to 8 these maps are shown.

Table 1. The use of location specific preference additions for the different scenarios

Location specific drivers	Reference	Biodiversity	Soil and climate change
Natura 2000 areas currently cropped*	x	x	x
HNV farmland currently cropped		x	
LFA areas currently cropped	x	x	x
Erosion sensitive locations	x	x	x
Ecological corridor areas		x	
Peatland areas			x
River flood prone areas			x
Upstream areas			x

**currently cropped areas include land cover types: arable land, permanent grassland and permanent crops*

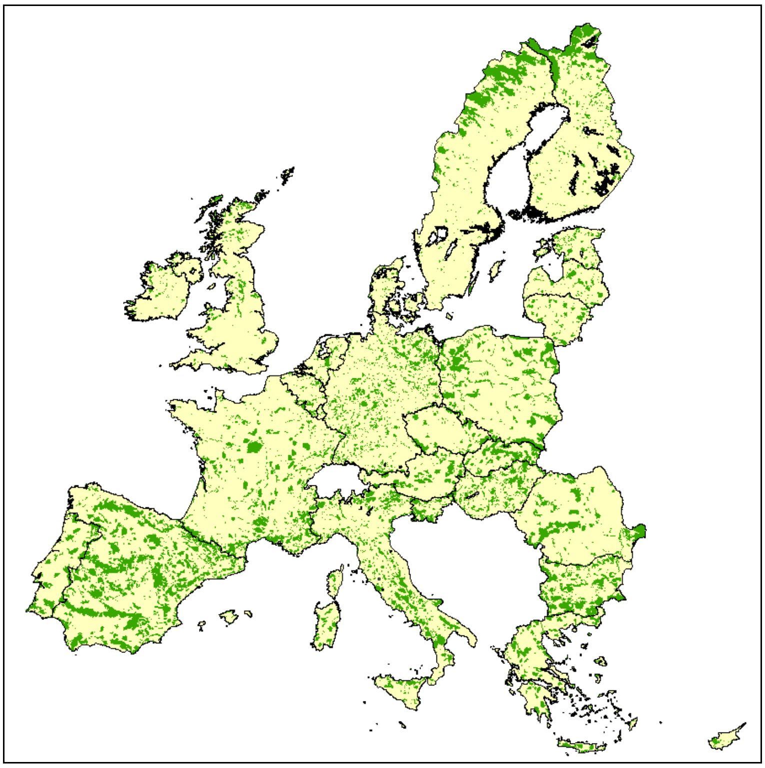


Figure 1. Natura 2000 areas

Natura 2000 areas

The GIS map for Natura 2000 is still an ongoing project, which has not yet been completed, but a preliminary version was used for this project. The European Natura 2000 database holds information about sites designated by EU Member States under the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC). It is Specially Protected Areas (SPAs) for birds and adopted Sites of Community Importance (SCIs) for habitats and other species.

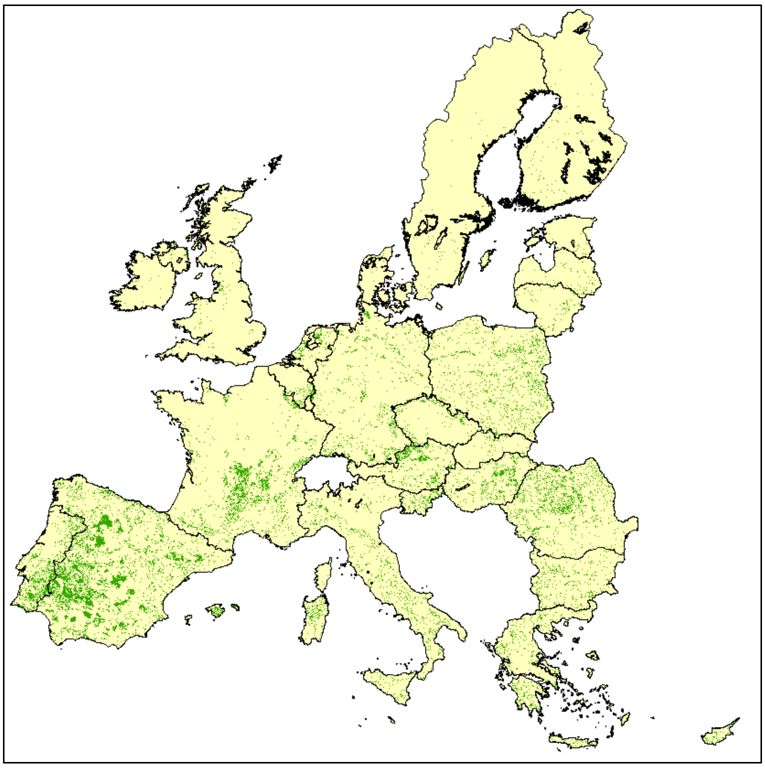


Figure 2. High Nature Value farmland

High Nature Value farmland

Derived from the HNV map with a threshold of 50% and filtered for the agricultural areas of the land use map of 2000

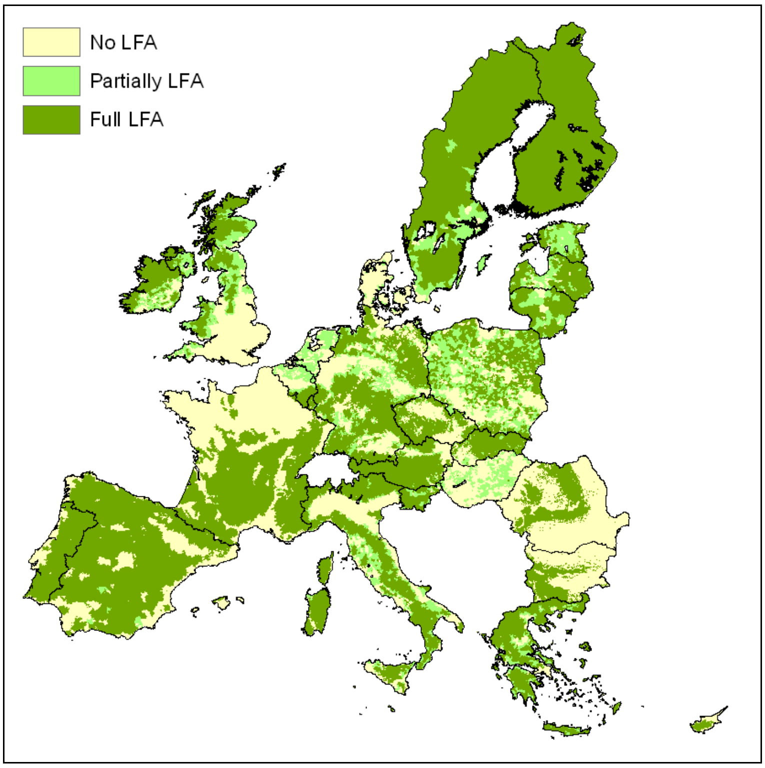


Figure 3. LFA areas

LFA areas

The LFA map is derived from the spatial dataset Less-Favoured Areas 2000-2006 based on GISCO Communes version 2.3. Areas that are fully eligible to one of the LFA articles are classified as 1, whereas areas that are only partially eligible to one LFA article are classified as 0.5. The non-LFA areas are classified as 0.

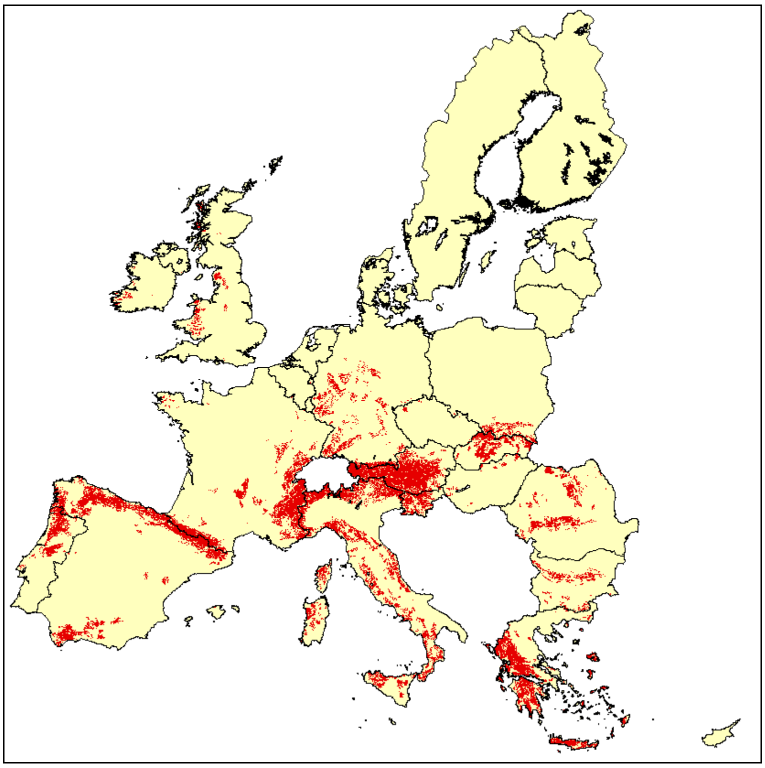


Figure 4. Erosion sensitive areas

Erosion sensitive areas

Delineation of areas with a high potential for soil erosion. Derived from a potential soil erosion map that was computed as the product of slope, soil erodibility and rain erosivity. A threshold was found by making an overlay with current arable, whereby it was aimed that approximately 8% of current arable would be eligible for receiving subsidies to prevent soil erosion.

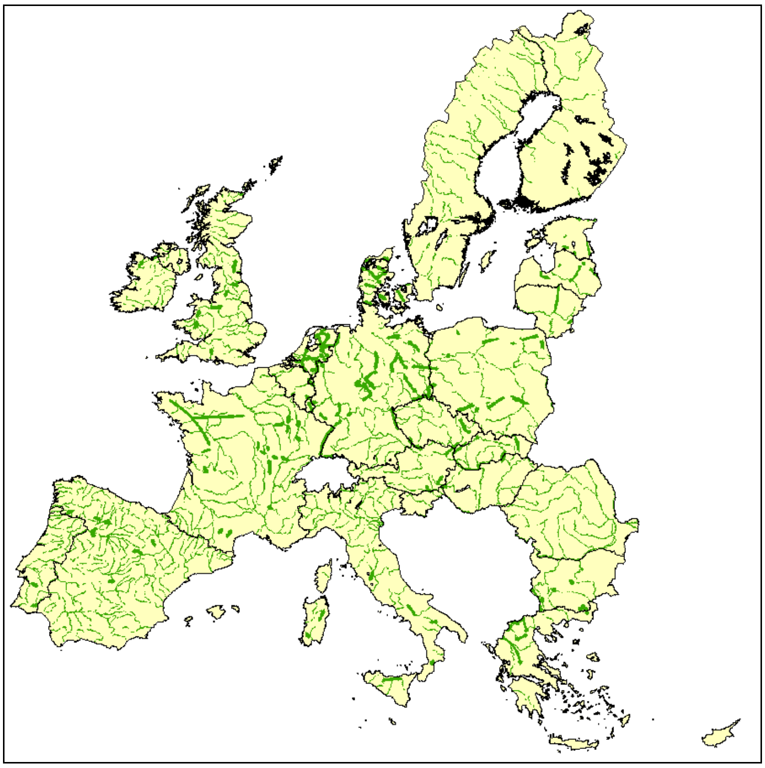


Figure 5. Ecological corridors

Ecological corridors

This map was created by combining three maps that indicate ecological corridors from different PEEN projects with the GISCO river map. The ecological corridors were derived from the PEEN project, and for Greece and Bulgaria the results of the PEEN South-East Europe project were used. Depending on their shapes, the corridors were directly converted to grids or a buffer function was used. Due to the different source data the width of the corridors is not everywhere the same, but on average it was set at 15 km. Along the large and medium sized rivers a buffer zone of 1 km at each side was used.

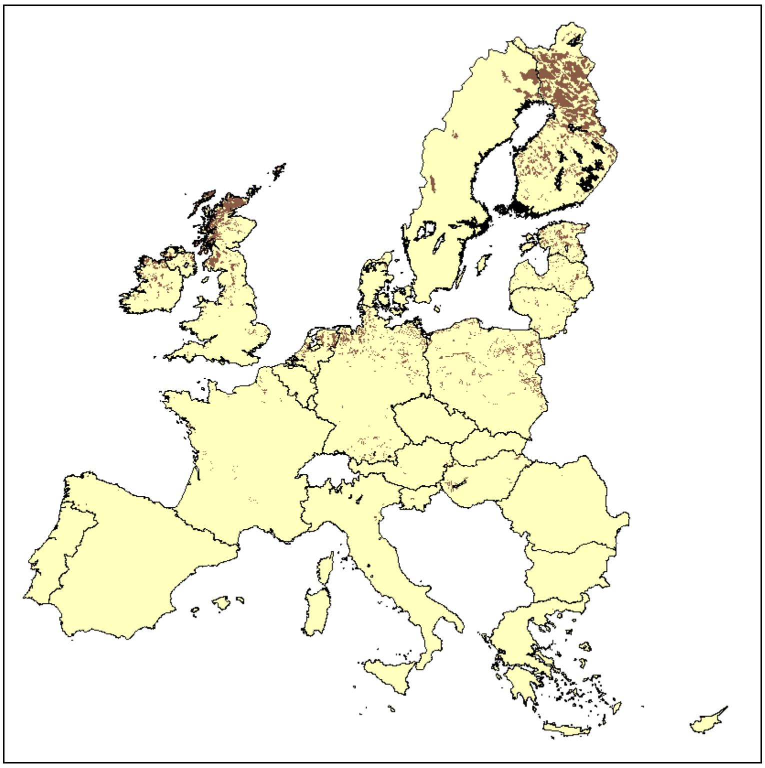


Figure 6. Peatland areas

Peat land areas

Derived from the European soil database of the JRC. All soils classified as Histosols were selected. Since the ESDB is a harmonised compilation of national soil maps, there are some border effects due to different classification systems, e.g. between Sweden and Finland.

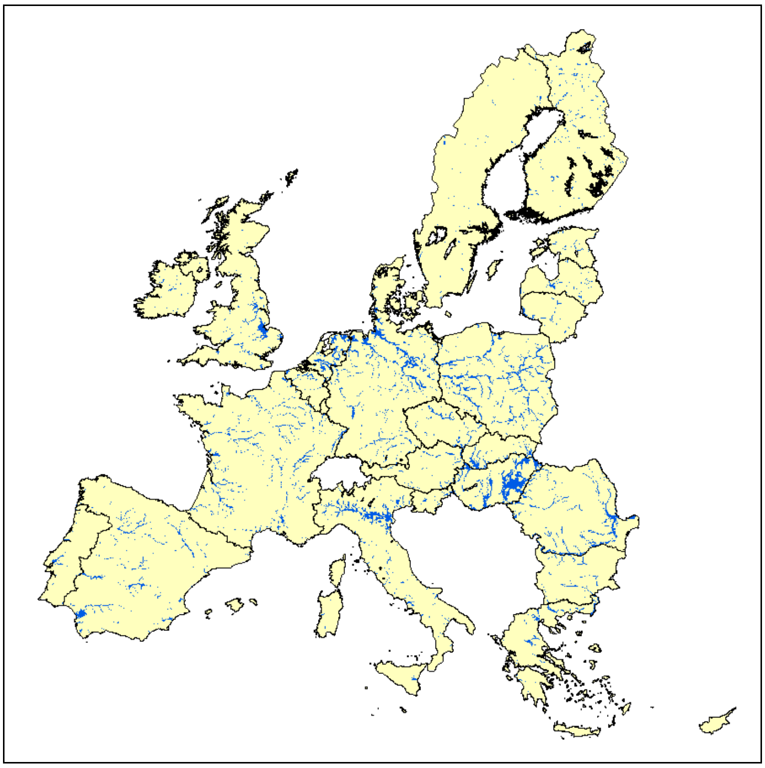


Figure 7. River flood prone areas

River flood prone areas

These areas are derived from the scenario river flood risk map provided by the JRC. The areas are defined as the areas in which at least 25% of the 1 km^2 grid cell will be flooded with a water depth of >0.5 m.

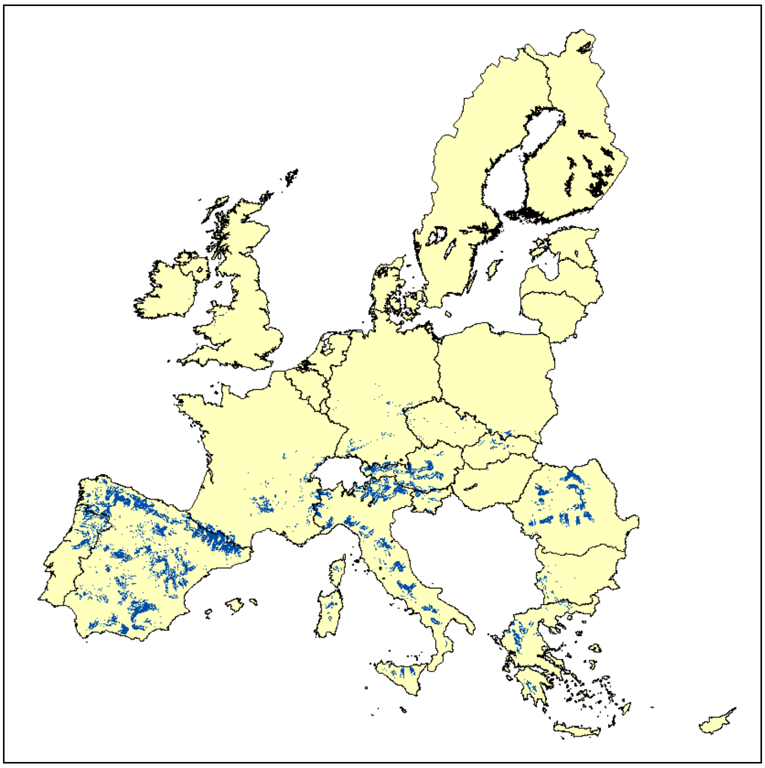


Figure 8. Upstream parts of catchment areas

Upstream parts of catchments

Upstream parts of catchment areas area defined by: slope should be more than 5 degrees, altitude should be more than 500 m; distance to river (based on the large and medium sized rivers from the GISCO river map) should be less than 10 km and soil water storage capacity (obtained from the PESERA project) should be less than 100 mm.

The change in suitability for a certain land use and a certain location is different depending on the type of spatial policy and the possible overlap of different policies. Many of these location specific drivers can coincide, e.g. Natura 2000 areas within LFA areas. The values for the changes in suitability due to the location specific preference additions (representing the spatial policies) have been defined for each scenario in line with the scenario descriptions and after consultation with DG

Environment. In Figure 9 two examples are shown of the visual schematisation of these locspec values for two scenarios. For the reference scenario this picture is relatively simple, but for the biodiversity scenario the picture is becoming already very complicated with five different location specific addition factors that may overlap in some places. All possible overlaps are documented in matrices as shown below. In supplement 1 of this annex it is described how these locspec maps are exactly calculated with ArcGIS.

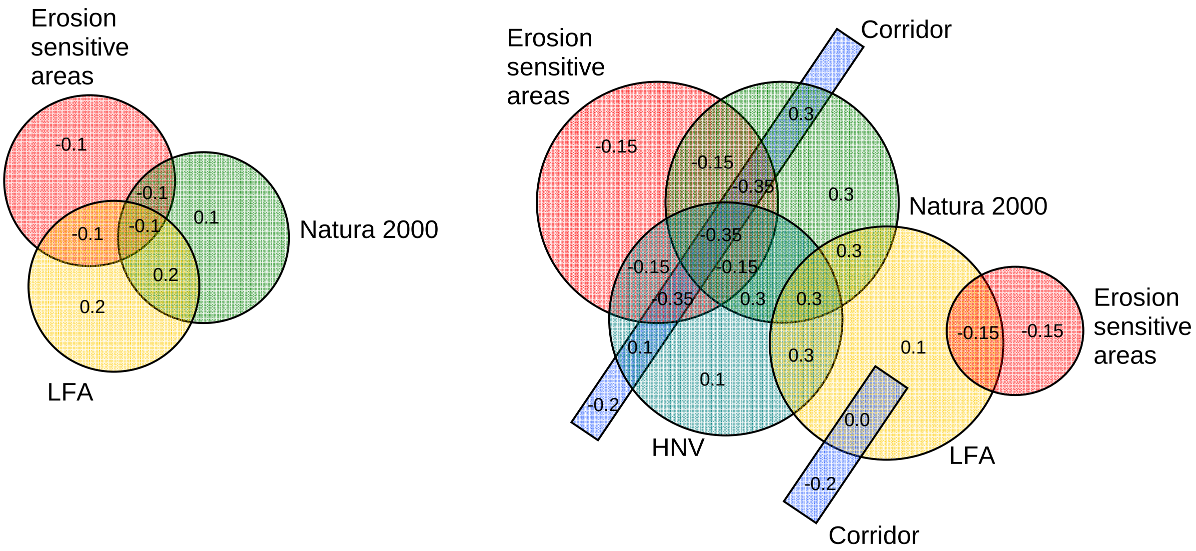


Figure 9. Schematisation of the location specific settings for the reference scenario (left) and for the biodiversity scenario (right) for arable land. Values indicate the change in suitability (which is defined at a scale between 0 (not suitable) and 1 (very suitable)) as result of the location specific settings.

Reference scenario

Arable / Permanent crops	Natura 2000	LFA	Erosion sens.
Natura 2000 currently cropped	0.1		
LFA currently cropped	0.2	0.2	
Erosion sensitive areas	-0.1	-0.1	-0.1

The values in the green cells indicate the change in suitability from a single location specific preference addition and the values in the yellow cells indicate the change in suitability for the combination of two location specific drivers. In case all three location specific drivers are overlapping, the erosion sensitive areas overrule the compensation from the LFA and Natura 2000, i.e. the value becomes -0.1. This means that the policy to reduce erosion, by discouraging arable and permanent crops on erosion sensitive areas, overrules the Natura 2000 and LFA subsidies that would encourage these land uses on these locations. The same reason of thought is used for the other scenarios and land uses as presented below. These settings may be seen as arbitrarily chosen but they are based on existing policy implementation and, if information on implementation was absent, simple rules will be applied e.g. such as erosion sensitive overrules other policies. These may easily be modified for other scenarios.

Pasture	Natura 2000	LFA
Natura 2000 currently cropped	0.1	
LFA currently cropped	0.2	0.2

Biodiversity alternative scenario

Arable / Permanent crops	Natura 2000	HNV	LFA	Erosion sens.	Corridors
Natura 2000	0.3				
HNV	0.3	0.1			
LFA	0.3	0.3	0.1		
Erosion sens.	-0.15	-0.15	-0.15	-0.15	
Corridors	0.3	0.1	0	-0.35	-0.2

In case more than two location specific drivers are overlapping, the following hierarchy is assumed for this scenario. Erosion sensitive areas always lower the suitability (i.e. locspec value of -0.15), Besides, the value is never higher than the maximum of the combinations indicated above, i.e., it is assumed that there is no additive effect of N2000, HNV and LFA compensations. This assumption is based on the scenario specification by the authors.

Pasture	Natura 2000	HNV	LFA
Natura 2000 currently cropped	0.3		
HNV currently cropped	0.3	0.2	
LFA currently cropped	0.3	0.3	0.1

In case all three location specific drivers are overlapping, the subsidies for Natura 2000 are the highest and will not be increased for HNV and LFA, i.e. the maximum locspec value remains 0.3.

Soil and climate change alternative scenario

Arable	Natura 2000	LFA	Erosion sens.	Peat land	Flood prone	Upstream areas
Natura 2000 currently cropped	0.1					
LFA currently cropped	0.2	0.2				
Erosion sens.	-0.3	-0.3	-0.3			
Peat land	-0.2	-0.2	-0.3	-0.2		
Flood prone	-0.2	-0.2	-0.3	-0.3	-0.2	
Upstream areas	0.1	0.2	-0.4	N.A.	N.A.	-0.1

Permanent crops	Natura 2000	LFA	Erosion sens.	Peat land	Flood prone
Natura 2000 currently cropped	0.1				
LFA currently cropped	0.2	0.2			
Erosion sens.	-0.3	-0.3	-0.3		
Peat land	-0.2	-0.2	-0.3	-0.2	
Flood prone	-0.2	-0.2	-0.3	-0.3	-0.2

In case more than two location specific drivers are overlapping, the following hierarchy is used. Erosion sensitive areas always lower the suitability similarly (i.e. locspec value of -0.3 except for the combination of erosion sensitive and upstream areas in which a value of -0.4 is assumed). Peat land and flood prone areas overrule the subsidies for Natura 2000 and LFA (i.e. locspec value of -0.2 or -0.3 when for combination of peat land and flood prone areas).

Pasture	Natura 2000	LFA
Natura 2000 currently cropped	0.1	
LFA currently cropped	0.2	0.2

Built up	Upstream areas
Upstream areas	-0.4

2. Conversion matrices

Allow drivers

These allow driver maps specify the spatially explicit settings for the conversion matrix. Values of 1 indicate that the conversion is allowed, values of 0 indicate that the conversion is not allowed. A full coding scheme can be found in the EU-ClueScanner documentation. The X numbers refer to the specific allow driver maps in the framework and the numbers are used in the below presented conversion matrices.

X1	52	Natura2000 (0, outside 1)
X2	53	Erosion sensitive areas (0, outside 1)
X3	54	Natura2000 and erosion sensitive areas (0, outside 1)
X4	55	Natura2000, erosion sensitive areas and peat (0, outside 1)
X5	56	Erosion sensitive and peat areas (0, outside 1)
X6	57	Natura2000 and peat areas (0, outside 1)
X7	58	Natura2000 and river flood prone areas (0, outside 1)
X8	59	Succession abandoned arable to semi-natural
X9	60	Succession abandoned pasture to semi-natural
X10	61	Succession semi-natural to forest
X11	62	Succession abandoned arable to semi-natural for Biodiversity scenario
X12	63	Succession abandoned pasture to semi-natural for Biodiversity scenario
X13	64	Succession semi-natural to forest for Biodiversity scenario

Succession allow files

The time for succession from abandoned arable and pasture land to (semi)-natural vegetation and from (semi)-natural vegetation to forest is different over Europe, depending on climate and local conditions. In addition the population pressure, livestock density and presence of Natura2000 areas affect the succession time. The succession is constrained by *allow drivers* in the conversion matrix (X8-X13). In supplement 2 to this annex (p.97), it is described how these different *succession allow drivers* were calculated. In the conversion matrices 0 means that the conversion is not allowed, and 1 means that the conversion is allowed. The other numbers refer to the *allow driver* maps, which indicate were that conversion is allowed.

Conversion matrix for reference scenario

Conversion to

Current land use	Built-up	Arable	Pasture	Semi-natural	Irrigated arable land	Abandoned arable	Permanent crops	Forest	Abandoned pasture	Other
Built-up	1	0	0	0	0	0	0	0	0	0
Arable	52	1	1	0	0	1	1	0	0	0
Pasture	52	53	1	0	0	0	1	0	1	0
Semi-natural	52	54	52	1	0	0	54	61	0	0
Irrigated arable land	0	0	0	0	1	0	0	0	0	0
Abandoned arable	52	54	52	59	0	1	54	0	0	0
Permanent crops	52	53	1	0	0	1	1	0	0	0
Forest	52	54	52	0	0	0	54	1	0	0
Abandoned pasture	52	54	52	60	0	0	54	0	1	0
Other	0	0	0	0	0	0	0	0	0	1

Conversion matrix for biodiversity scenario

Conversion to

Current land use	Built-up	Arable	Pasture	Semi-natural	Irrigated arable land	Abandoned arable	Permanent crops	Forest	Abandoned pasture	Other
Built-up	1	0	0	0	0	0	0	0	0	0
Arable	52	1	1	0	0	1	57	0	0	0
Pasture	52	55	1	0	0	0	57	0	1	0
Semi-natural	0	55	57	1	0	0	55	64	0	0
Irrigated arable land	0	0	0	0	1	0	0	0	0	0
Abandoned arable	52	55	57	62	0	1	57	0	0	0
Permanent crops	52	55	52	0	0	1	1	0	0	0
Forest	0	55	57	0	0	0	57	1	0	0
Abandoned pasture	52	55	57	63	0	0	57	0	1	0
Other	0	0	0	0	0	0	0	0	0	1

Conversion matrix for soil and climate change scenario

Conversion to

Current land use	Built-up	Arable	Pasture	Semi-natural	Irrigated arable land	Abandoned arable	Permanent crops	Forest	Abandoned pasture	Other
Built-up	1	0	0	0	0	0	0	0	0	0
Arable	58	1	1	0	0	1	56	0	0	0
Pasture	58	56	1	0	0	0	56	0	1	0
Semi-natural	58	55	57	1	0	0	55	61	0	0
Irrigated arable land	0	0	0	0	1	0	0	0	0	0
Abandoned arable	58	55	57	59	0	1	55	0	0	0
Permanent crops	58	56	1	0	0	1	1	0	0	0
Forest	58	55	57	0	0	0	55	1	0	0
Abandoned pasture	58	55	57	60	0	0	55	0	1	0
Other	0	0	0	0	0	0	0	0	0	1

3. Conversion elasticity's

The conversion elasticity's determine how easy or difficult a certain land use can be converted into another land use and are therefore a proxy for the conversion costs (0 = very easy to convert and 1 is very difficult to convert). These values are based on expert knowledge and calibration of earlier applications of this modeling framework (Verburg and Overmars, 2009).

	Reference	**Biodiversity**	**Soil and climate change**
Built-up	1	1	1
Arable	0.5	0.5	0.5
Pasture	0.5	0.5	0.8
Semi-natural	0.8	0.8	0.8
Irrigated arable land	1	1	1
Abandoned arable	0.3	0.3	0.3
Permanent crops	0.9	0.9	0.9
Forest	0.8	0.8	0.8
Abandoned pasture	0.3	0.3	0.3
Other	1	1	1

4. Neighbourhood settings

These neighbourhood settings determine the fragmentation patterns, i.e. higher neighbourhood settings will result in lower fragmentation patterns. For example, the built-up class has a higher neighbourhood setting value (0.5) in the Soild and climate change scenario than in the Reference scenario (0.2) because urban areas will be built more compact and therefore the fragmentation will be lower. The values are chosen based on the scenario specifications and calibrated based on earlier model application (Verburg and Overmars, 2009).

	Reference	Biodiversity	Soil and climate change
Built-up	0.2	0.3	0.5
Arable	0	0	0
Pasture	0	0	0
Semi-natural	0.2	0.4	0.2
Irrigated arable land	0	0	0
Abandoned arable	0	0	0
Permanent crops	0	0	0
Forest	0.2	0.4	0.2
Abandoned pasture	0	0	0
Other	0	0	0

The settings of the neighbourhood function are given below. These are the same for each scenario, but, for alternative scenarios they may differ. For example for built-up the neighbourhood function only affects the neighboring grid cells, whereas for pasture the neighbourhood is larger.

Built-up
1 1 1
1 0 1
1 1 1

Arable
1 1 1
1 0 1
1 1 1

Pasture
1 1 1 1 1
1 1 1 1 1
1 1 0 1 1
1 1 1 1 1
1 1 1 1 1

Semi-natural
1 1 1 1 1
1 1 1 1 1
1 1 0 1 1
1 1 1 1 1
1 1 1 1 1

Irrigated arable land
1 1 1
1 0 1
1 1 1

Abandoned arable land
1 1 1
1 0 1
1 1 1

Permanent crops
1 1 1
1 0 1
1 1 1

Forest
1 1 1 1 1
1 1 1 1 1
1 1 0 1 1
1 1 1 1 1
1 1 1 1 1

Abandoned pasture
1 1 1
1 0 1
1 1 1

Other
1 1 1 1 1
1 1 1 1 1
1 1 0 1 1
1 1 1 1 1
1 1 1 1 1

5. Demand related parameters

These parameters relate to the conversions made between the output of the macro-economic model LEITAP and the input of the EU-CLUEScanner model. A number of European-wide policies and conditions influence the overall areas to be allocated by the EU-CLUEScanner model. The parameters for these conversions are provided here.

Change in built-up area per person per year

In the reference and biodiversity scenario this value is set at +0.75 m^2 per person per year, whereas in the soil and climate change scenario a value of +0.4 m^2 per person per year is used, which assumes more compact building and therefore less built-up area increase per person.

The reference value is based on the trend between 1990-2000 period, because economic growth rates assumed for the reference scenario are lower than for the 1990-2000 period about half of the growth in area per person is assumed to be a reasonable estimate.

Permanent pasture

In the reference and biodiversity scenario the permanent pasture area cannot further decrease when the decrease was more than 10% at member state level as compared to the average permanent grassland area over the 2000-2007 period. For the soil and climate change scenario this threshold is set at 5%, i.e. more permanent pasture will remain upon a decrease in demand for permanent grassland from an economic/production point of view.

These settings are based on an interpretation of the current policies related to permanent pasture in relation to the specific requests for this scenario by DG ENV.

Set-aside

For the reference and soil and climate change scenario it is assumed that set-aside is not abolished in 2008 and the 10% target remains which is implemented by keeping set-aside at a level similar to the 2000-2006 period. For the biodiversity scenario from 2015 onwards the set-aside is increased to a maximum level of 15%. This is implemented as a 5% increase of set-aside land as compared to the 2000-2006 period over the period 2015-2020 (1% increase a year)

These settings are not based on a current policy proposal but based on the explicit request of DG ENV to evaluate these settings in the scenario.

Biofuel on set-aside

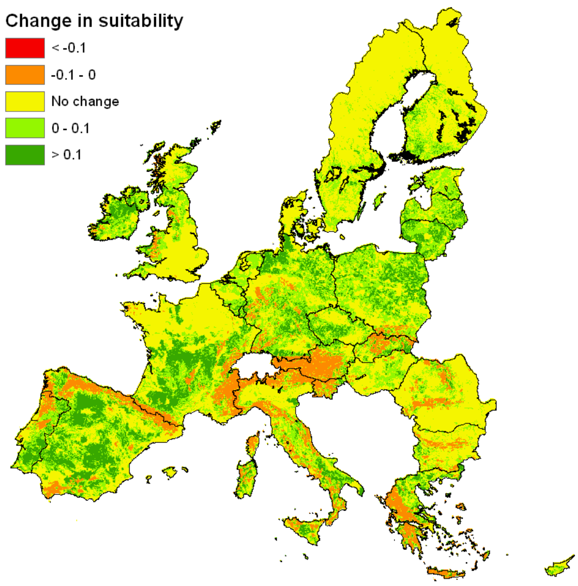
For the reference and soil and climate change scenario it is assumed that biofuel cultivation occurs on 5% of the area in the period 2000-2010, 15% for the period 2010-2020 and 20% for the period 2020-2030. For the biodiversity scenario no biofuel cultivation on set-aside land will occur.

Supplement 1 Technical procedure locspec coding
The coding refers to ArcGIS coding while the map names refer to the maps as documented in the factsheets.

Reference B1 scenario

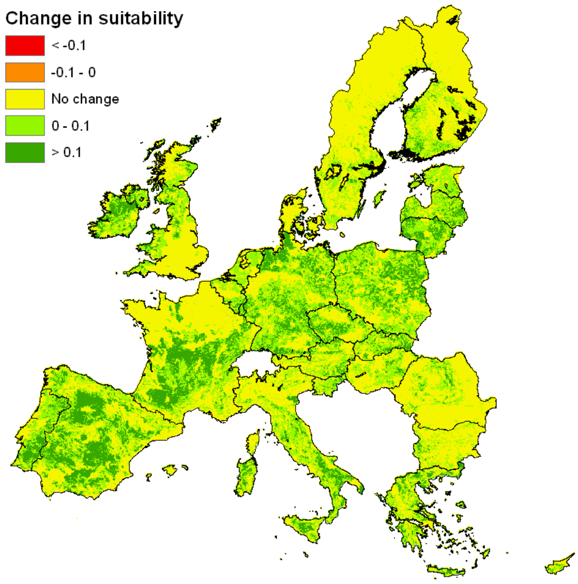
Arable and permanent crops
First step: raster calculation:
[LFA_recl] * 100 + [nat2000] * 10 + [erosion]
This results in 11 combinations
Second step: reclassification
See 'ref_1_6' table (for this case the file is shown below)

Value	Number grid cells (km^2)	Locspec value
0	2859628	0
1	340329	-0.1
10	46075	0.1
11	785	-0.1
500	246019	0.1
501	8959	-0.1
510	21352	0.15
511	755	-0.1
1000	686715	0.2
1001	51606	-0.1
1010	74857	2
1011	7783	-0.1



Result:

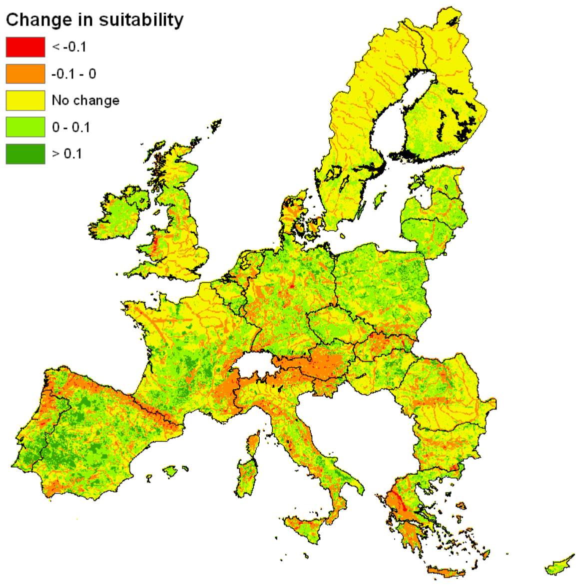
Pasture
First step: raster calculation:
[LFA_recl] * 10 + [nat2000]
This results in 6 combinations
Second step: reclassification
See 'ref_2' table



Result:

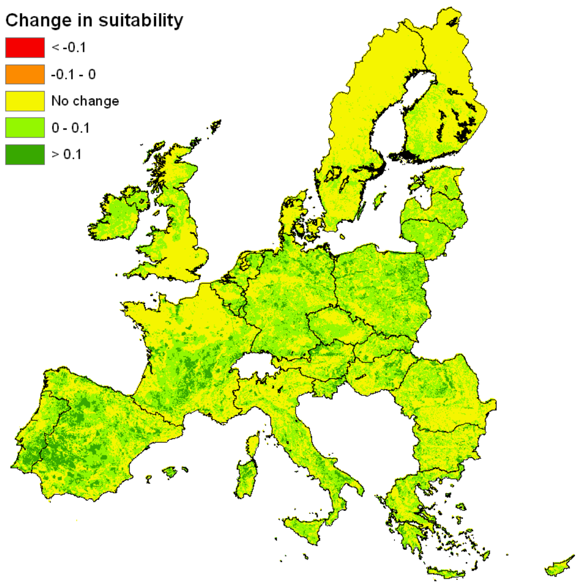
Biodiversity scenario

Arable and permanent crops
First step: raster calculation:
[LFA_recl] * 10000 + [Nat2000] * 1000 + [HNV] * 100 + [corridor] * 10 + [erosion]
This results in 47 combinations
Second step: reclassification
See 'bio_1_6' table



Result:

Pasture
First step: raster calculation:
Int([LFA_recl] * 100 + [Nat2000] * 10 + [HNV])
This results in 12 combinations
Second step: reclassification
See 'bio_2' table



Result:

Soil and climate change scenario

Arable land

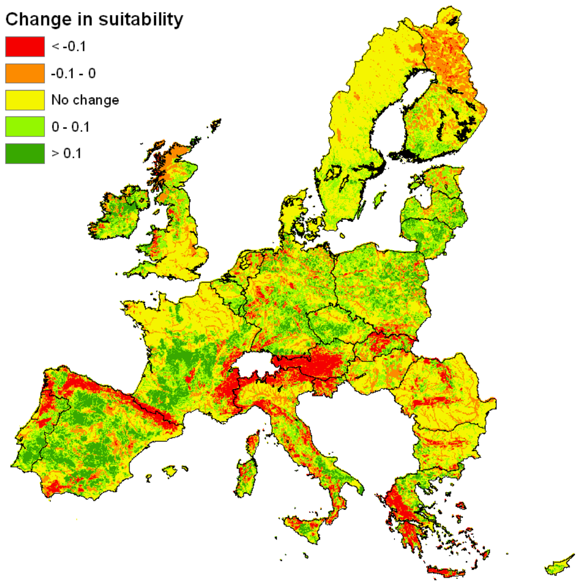
First step: raster calculation:

Int([LFA_recl] * 100000 + [Nat2000] * 10000 + [Upstream] * 1000 + [flooding] * 100 + [Peat] * 10 + [erosion])

This results in 62 combinations

Second step: reclassification

See 'scc_1' table



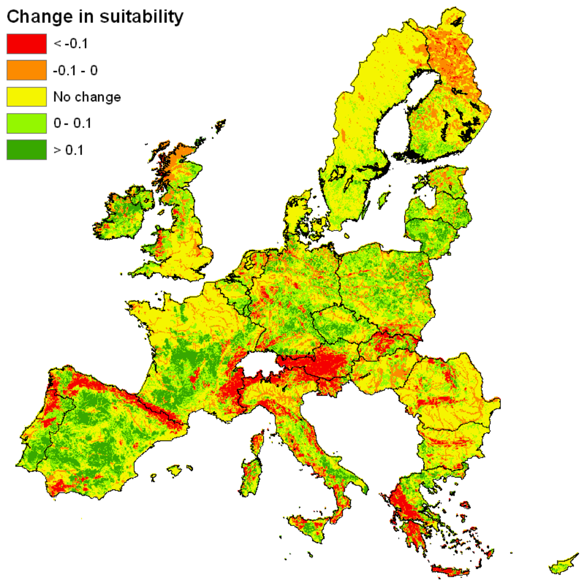
Result:

Permanent crops
First step: raster calculation:

Int([LFA_recl] * 10000 + [Nat2000] * 1000 + [Peat] * 100 + [flooding] * 10 + [erosion])

This results in 40 combinations
Second step: reclassification

See 'scc_6' table



Result:

Pasture
Same as reference scenario

Built-up
Reclassification to -0.4 for the upstream area map.

Supplement 2 Calculation succession allow files

Necessary files:
<sucabar> - Default succession time from abandoned land to (semi)-natural
<poppressB1> - Reclassified population pressure for B1 scenario
<livestock_nat> - Reclassified livestock density map
<natura_peen> - New Natura 2000 map
<semisuc> - Default succession time from (semi)-natural to forest
<factor> - A factor (between 1 and 4) that increases the succession time from (semi)-natural to forest, which appeared to be too fast and is now corrected for dispersion
<Expand_n2000> - New Natura 2000 map with including a buffer zone of 2 km
<random7-20> - Random generated files with values between 7 and 20

X8: B1 scenario succession recently abandoned arable to semi-natural vegetation. Influence of population pressure in different zones 100/20/10/2/0 more years needed for succession; grazing in different zones 10/5 years needed; In Natura2000 area succession takes 4 years shorter due to favourable management.

Calculation:
X8 = [sucabar] + [poppressb1] + [livestock_nat] - (4 * [natura_peen]) + 1000

X9: B1 scenario succession recently abandoned grassland to semi-natural vegetation. Influence of population pressure in different zones 100/20/10/2/0 more years needed for succession; grazing in different zones 10/5 years needed; In Natura2000 area succession takes 4 years shorter due to favorable management. 2 years are added everywhere because of the slower succession on grassland

Calculation:
X9 = [sucabar] + [poppressb1] + [livestock_nat] - (4 * [natura_peen]) + 2 + 1000

X10: Succession semi-natural vegetation to forest. Grazing in different zones 10/5 years more are needed except for inside Natura2000 areas; succession is 4 years shorter due to favorable management

Calculation:
X10 = ([semisuc] * [factor]) + [livestock_nat] - (4 * [natura_peen]) + 1000

X11: B1 biodiversity scenario succession recently abandoned arable to semi-natural vegetation. Influence of population pressure in different zones 100/20/10/2/0 more years needed for succession; grazing in different zones 10/5 years needed; In Natura2000 area and buffer zone of 2 km around Natura2000 succession takes 4 years shorter due to favourable management.

Calculation:
X11 = [sucabar] + [poppressb1] + [livestock_nat] - (4 * [Expand_n2000]) + 1000

X12: B1 biodiversity scenario succession recently abandoned grassland to semi-natural vegetation. Influence of population pressure in different zones 100/20/10/2/0 more years needed for succession; grazing in different zones 10/5 years needed; In Natura2000 area succession takes 4 years shorter due to favorable management; in buffer of 2 km around Natura2000 no influence op population pressure. 2 years are added everywhere because of the slower succession on grassland

Calculation:
X12 = [sucabar] + [poppressb1] + [livestock_nat] - (4 * [Expand_n2000]) + 2 + 1000

X13: B1 biodiversity scenario for succession semi-natural vegetation to forest. Grazing in different zones 10/5 years more are needed except for inside Natura2000 areas; In addition in Natura2000 areas and the surrounding 2 km, the succession is retarded by 7 to 20 years (randomly allocated) due to active management of the (semi)-natural vegetation by grazing/mowing (the previous reduction of succession by 4 years due to favorable management from the reference scenario is still kept).

Calculation:
X13 = ([semisuc] * [factor]) + [livestock_nat] - (4 * [natura_peen]) + ([Expand_n2000 * [Random7-20]) +1000

Annex 3. Indicator fact sheets

I. Land use related indicators

Land use

Indicator name	Land use
Short description (max. 3 lines)	Land-use pattern of the main land-use types with a spatial resolution of 1 km^2. In addition two indicators are provided that described changed land use. For each changed location they describe the original (changed_from) and final (changed_to) land use. These indicator values are available for 2000, 2010, 2020 and 2030.
Developer:	Peter Verburg, VU University, the Netherlands: Peter.Verburg@ivm.vu.nl and Maarten Hilferink, Object Vision, the Netherlands
Source:	EU-ClueScanner project

Indicator data type: quantitative

Indicator	Units
LU10	10 discrete classes
changed_from	10 discrete classes
changed_to	10 discrete classes

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
Only at 1x1 km grid

Description of causality in calculation method (max. 10 lines)
Direct output of the EU-ClueScanner land-use allocation model. This model simulates competition among land uses for the available land resources based on the demand at national level (output LEITAP/IMAGE calculations) and the local options set by the biophysical and socio-economic environment. The total area of agricultural and urban land uses is constrained by sector-specific calculations at the national level while the succession of natural vegetation is determined by the local conditions. A wide range of location factors, spatial policies, neighborhood interactions and specific conversion trajectories are included as determinants of the simulated land use changes

Calculation input parameters:

Name	Quantity	Source	Description
LU18	18 classes	Primary EU-ClueScanner output	Land use resulting from simulation. This is initially based on Corine Land Cover 2000.

Technical implementation of calculation method (Incl aggregation method)
To enhance visualisation of the modelling results, the 18 land-use types resulting from simulation with the EU-ClueScanner model (LU18) are aggregated to 10 more general types of land use (LU10):

Simulation class (LU18)	Aggregation class (LU10)	Description
0	0	Built-up area
1	1	Arable land (non-irrigated)
2	2	Pasture
3	3	(semi-) Natural vegetation (including natural grasslands, scrublands, regenerating forest below 2 m, and small forest patches within agricultural landscapes)
4	4	Inland wetlands
5	5	Glaciers and snow
6	6	Irrigated arable land
7	7	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)
8	8	Permanent crops
9	1	Arable land devoted to the cultivation of (annual) biofuel crops
10	9	Forest
11	5	Sparsely vegetated areas
12	5	Beaches, dunes and sands
13	not shown	Salines
14	not shown	Water and coastal flats
15	3	Heather and moorlands
16	7	Recently abandoned pasture land (includes very extensive pasture land not reported in agricultural statistics, grasses and shrubs below 30cm)
17	1	Perennial biofuel crop cultivation

Please note that the actual number of simulated land use types depends on the model configuration. The scenarios implemented for DG Environment have no specific reference to biofuel crops (the land demand of such crops is included in non-irrigated arable land) and only consist of 16 types of land use.
The aggregated classes (LU10) are visualized and named as follows:

nr.	name	visualisation (RGB values)
0	Built-up area	219/0/0
1	Arable land (non-irrigated)	254/250/194
2	Pasture	163/222/133
3	(semi-) Natural vegetation	114/137/68
4	Inland wetlands	173/164/254
5	Glaciers, Snow, Sands and Sparsely vegetated areas	160/160/160
6	Irrigated arable land	254/172/0
7	Recently abandoned farmland	205/205/102
8	Permanent crops	207/152/107
9	Forest	1/99/0

Changed land-use is obtained by comparing the initial (2000) land use with the final land use. Location s that have not changed are not shown. The initial land use is shown in the changed_from layer, the final land use in the changed_to layer.

Change hot spots

Indicator name	Change hot spots
Short description (max. 3 lines)	This set of three indicators highlights three types of land-use change: agricultural abandonment, agricultural expansion and urban development. These show the amount of similar change surrounding changed locations. These indicator values are available for 2000, 2010, 2020 and 2030.
Developer:	Peter Verburg, VU University, the Netherlands: Peter.Verburg@ivm.vu.nl
Source:	EU-ClueScanner project

Indicator data type: Qualitative

Indicator	Units
agricultural abandonment	4 classes (no hot spot, existing hotspot, new hotspot, intensive hotspot)
agricultural expansion	4 classes (no hot spot, existing hotspot, new hotspot, intensive hotspot)
urban development	4 classes (no hot spot, existing hotspot, new hotspot, intensive hotspot)

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
GRID (1x1 km) level with no possibilities for aggregation to other levels

Description of causality in calculation method (max. 10 lines)
Based on output of the EU-ClueScanner land use allocation model by the identification of regions where this land use change process occurs in several, neighbouring locations. The model simulates competition among land uses for the available land resources based on the demand at national level (output GTAP/IMAGE calculations) and the local options set by the biophysical and socio-economic environment. The total area of agricultural and urban land uses is constrained by sectoral calculations at the national level while the succession of natural vegetation is determined by the local conditions. A wide range of location factors, spatial policies, neighborhood interactions and specific conversion trajectories are included as determinants of the simulated land use changes. Based on the simulation three indicators are created that enhance hot spots of change associated with three specific land-use change processes: agricultural abandonment, agricultural expansion and urban development. The agricultural abandonment indicator highlights areas where large tracts of previously agricultural land) are left idle, thus showing marginal agricultural areas that are abandoned by farmers. This hot-spot map excludes agricultural areas that are converted to urban uses, as these lose their agricultural function as a result of different process (urbanisation). These areas are included in the urban development hotspots.

Calculation input parameters:

Name	Quantity	Source	Description
changed_from	18 classes	Based on primary EU-ClueScanner output	Original land use of changed locations
changed_to	18 classes	Based on primary EU-ClueScanner output	Final land use of changed locations

See the ‘Land use’ fact sheet for the origin of the changed_from and changed_to indicators

Technical implementation of calculation method (Incl aggregation method)

This set of indicators aggregates the amount of change in a 5 kilometre radius around a cell for three specific processes: agricultural abandonment, agricultural expansion and urban development. It sums up the total amount of change related to these processes and uses that information to visually enhance those regions where a substantial change takes place. This process has the following steps:

1. select all cells that represent a certain process

The following selections are applied :

- for agricultural abandonment: changed from Arable land, Pasture, Irrigated arable land, or Permanent crop **and not** changed to any of these crops (to exclude locations where one crop replaced another) or to urban;
- for agricultural expansion: changed to Arable land, Pasture, Irrigated arable land, or Permanent crop **and not** changed from any of these crops (to exclude locations where one crop replaced another);
- for urban expansion: changed to Built-up area.

2. count the number of cells belonging to any of these processes in a 5 kilometre radius

For each cell in the grid the number of cells belonging to any of the three processes in a predefined circular neighbourhood of 81 cells (see below) is counted using the DMS-functions potential (similar to the focalsum function in ArcGIS)

				1	1	1				
			1	1	1	1	1			
		1	1	1	1	1	1	1		
	1	1	1	1	1	1	1	1	1	
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	**1**	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	
		1	1	1	1	1	1	1		
			1	1	1	1	1			
				1	1	1				

3. reclassify the amount of change in the neighbourhood

The amount of change per type of process in the neighbourhood is classified in two classes:

- 01-31 changed cells: hotspot (reclassified value =2)
- 32-81changed cells: intensive hotspot (reclassified value =10)

So when 32 or more cells surrounding an 'agricultural abandonment cell' also show agricultural abandonment, the cell is classified as being an intensive hotspot of change.

4. visualize the amount of change in the neighbourhood

A separate indicator map is created for each change process. These maps use the legend provided below. Unchanged locations in the direct vicinity of change will be shown as either no hot spot, or existing hot spot. Existing hotspots are locations that in the year of comparison represent agriculture (in case of the agricultural abandonment process), urban (for urban development) or other land-use types (agricultural expansion). These locations are shown in light grey to offer a context for visualizing the hotspots of change. The hot spot maps then show, for changed locations, the amount of similar change in the surroundings.

nr.	name	visualisation (RGB-values)
0	No hot spot	Gray 20% (156/156/156)
1	Existing hot spot in year of comparison (2010, 2020 and 2030)	Grey 40 % (204/204/204)
2	New hot spot	Yellow (255/170/0)
10	Intensive hot spot	Red (230/0/0)

NOTE: for 2000 this indicator is not available; for 2010 this indicator considers the change over the period 2000-2010; for 2020 the period 2000-2020; for 2030 the period 2000-2030.
NOTE2: IT IS NOT POSSIBLE TO CALCULATE ‘difference’ maps for this indicator; this option is blocked for this indicator
NOTE3: this indicator will not be aggregated to other levels

Shares of agricultural land uses

Indicator name	Shares of agricultural land uses
Short description (max. 3 lines)	This set of indicators shows the shares of agricultural land uses per region. It is based on an aggregation of the land-use simulation results and distinguishes between: total agricultural use, irrigated arable land, arable land, permanent pastures and permanent crops. It consists of two separate sets: - state; containing the share in the year of observation (2010, 2020, 2030); and - change; representing the change in share since year of reference (2000).
Developer:	Maarten Hilferink, Object Vision, the Netherlands: mhilferink@objectvision.nl
Source:	EU-ClueScanner project

Indicator data type: quantitative

Indicator	Units
State subfolder	
total agricultural use	share of total land area (%)
irrigated arable land	share of total land area (%)
arable land	share of total land area (%)
permanent pastures	share of total land area (%)
permanent crops	share of total land area (%)
Change subfolder	
total agricultural use	share of total land area (%) - initial share of total land area (%)
irrigated arable land	share of total land area (%) - initial share of total land area (%)
arable land	share of total land area (%) - initial share of total land area (%)
permanent pastures	share of total land area (%) - initial share of total land area (%)
permanent crops	share of total land area (%) - initial share of total land area (%)

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
Nuts3, Nuts2 and national level

Description of causality in calculation method (max. 10 lines)
Direct output of the EU-ClueScanner land use allocation model. This model simulates competition among land uses for the available land resources based on the demand at national level (output LEITAP/IMAGE calculations) and the local options set by the biophysical and socio-economic environment. The total area of agricultural and urban land uses is constrained by sector-specific calculations at the national level while the succession of natural vegetation is determined by the local conditions. A wide range of location factors, spatial policies, neighborhood interactions and specific conversion trajectories are included as determinants of the simulated land use changes. The simulated agricultural land use is then aggregated to regional and national levels to summarise the results. The changed shares are calculated by subtracting the share in the observation year by the share in the reference year (2000).

Calculation input parameters

Name	Quantity	Source	Description
LU10	10 classes	Aggregated EU-ClueScanner output	Aggregated land use resulting from simulation. This is initially based on Corine Land Cover 2000.

Technical implementation of calculation method (including aggregation method)
The agricultural land use shares are based on a regional aggregation of the land-use simulation results. For each regional level the shares are calculated based on the actual amounts of land taken by the respective types of use in that region. So the higher levels of aggregation (e.g. Country) are not based on an aggregation of lower levels (e.g. Nuts3), thus preventing potential inaccuracies. The following indicators are calculated: **Total agricultural use** is calculated by aggregating all simulated agricultural land uses per regional area and dividing it by the total land area (thus excluding inland and maritime water bodies) in that region. The EU-ClueScanner distinguishes the following agricultural land uses: irrigated arable land, arable land, permanent pastures and permanent crops. The **shares of the different agricultural land uses** (irrigated arable land, arable land, permanent pastures and permanent crops) are calculated by aggregating the simulated amount of land for that crop per regional area and dividing it by the total land area.

Shares of natural land uses

Indicator name	Shares of natural land uses
Short description (max. 3 lines)	This set of five indicators shows the shares of natural land uses per region. It is based on an aggregation of the land-use simulation results and distinguishes between: total natural area, forest, (semi-) natural vegetation, recently abandoned farmland and other nature (inland wetlands, glaciers, snow, sands and sparsely vegetated areas). It consists of two separate sets: - state; containing the share in the year of observation (2010, 2020, 2030); and - change; representing the change in share since year of reference (2000).
Developer:	Maarten Hilferink, Object Vision, the Netherlands: mhilferink@objectvision.nl
Source:	EU-ClueScanner project

Indicator data type: quantitative

Indicator	Units
State subfolder	
total natural area	share of total land area (%)
forest	share of total land area (%)
(semi-) natural vegetation	share of total land area (%)
recently abandoned farmland	share of total land area (%)
other nature	share of total land area (%)
State subfolder	
total natural area	share of total land area (%) - initial share of total land area (%)
forest	share of total land area (%) - initial share of total land area (%)
(semi-) natural vegetation	share of total land area (%) - initial share of total land area (%)
recently abandoned farmland	share of total land area (%) - initial share of total land area (%)
other nature	share of total land area (%) - initial share of total land area (%)

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
Nuts3, Nuts2 and national level

Description of causality in calculation method (max. 10 lines)
Direct output of the EU-ClueScanner land use allocation model. This model simulates competition among land uses for the available land resources based on the demand at national level (output LEITAP/IMAGE calculations) and the local options set by the biophysical and socio-economic environment. The total area of agricultural and urban land uses is constrained by sector-specific calculations at the national level while the succession of natural vegetation is determined by the local conditions. A wide range of location factors, spatial policies, neighborhood interactions and specific conversion trajectories are included as determinants of the simulated land use changes. The simulated natural land use is then aggregated to regional and national levels to summarise the results. This regional aggregation is performed on the thematically aggregated land-use results (LU10, see land use factsheet) that distinguishes between: forest, (semi-) natural vegetation (including heather and moorland), recently abandoned farmland and other nature (inland wetlands, glaciers, snow, sands and sparsely vegetated areas). The changed shares are calculated by subtracting the share in the observation year by the share in the reference year (2000).

Calculation input parameters

Name	Quantity	Source	Description
LU10	10 classes	Aggregated EU-ClueScanner output	Aggregated land use resulting from simulation. This is initially based on Corine Land Cover 2000.

Technical implementation of calculation method (including aggregation method)
The natural land-use shares are based on a regional aggregation of the land-use simulation results. For each regional level the shares are calculated based on the actual amounts of land taken by the respective types of use in that region. So the higher levels of aggregation (e.g. Country) are not based on an aggregation of lower levels (e.g. Nuts3), thus preventing potential inaccuracies. The following indicators are calculated: **Total natural area** is calculated by aggregating all simulated natural land-use types per regional area and dividing it by the total land area (thus excluding inland and maritime water bodies) in that region. The EU-ClueScanner distinguishes the following natural types of land use: forest, (semi-) natural vegetation, other nature (inland wetlands, glaciers, snow, sands and sparsely vegetated areas) and recently abandoned farmland. The recently abandoned farmland is a result from simulation and does not occur in the underlying Corine Land Cover (CLC) types. The other types of natural land use find their origin in the CLC-data set. Forest and (semi-) natural vegetation are simulated in the model, implying that their quantity and location changes during the course of simulation. The aggregated class of other land-use types (containing: inland wetlands, glaciers, snow, sands and sparsely vegetated areas) remain stable. The **shares of the different natural land-use types** (forest, (semi-) natural vegetation, other nature and recently abandoned farmland) are calculated by aggregating the simulated amount of land for that class per regional area and dividing it by the total land area.

II. Thematic indicators

Carbon sequestration

Indicator name	Carbon sequestration
Short description (max. 3 lines)	Large amounts of CO_2 can be sequestered in the terrestrial ecosystem, thus contributing to climate change mitigation. This indicator represents the amount of carbon that is sequestered in or emitted from land use, land use change and forestry. Indicator values are available at local (1x1 km) and aggregated level for 2000, 2010, 2020 and 2030.
Developer:	Nynke Schulp, Wageningen University Research (WUR), the Netherlands: nynke.schulp@wur.nl
Source:	EURURALIS project (WUR/MNP, 2008)

Indicator data type: quantitative

Indicator	Units
Sink (1x1km level)	ton C/km^2 per year
Cumulative sink (1x1 km level)	ton C/km^2
Mean sink (aggregated)	ton C/km^2 per year
Mean cumulative sink (aggregated)	ton C/km^2

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
1x1km grid, Nuts3, Nuts2 and national level

Description of causality in calculation method (max. 10 lines)
Different land use types differ in the amount of carbon they sequester or emit in soil and vegetation. Carbon is sequestered in soils of forests, pasture, natural vegetation and emitted by croplands and parts of wetlands. Additionally, in forests large amounts of carbon are stored in vegetation as well. Changes in land use can thus result in changes in carbon emission / sequestration. Emission / sequestration is defined by an emission factor; this is a country-specific, land use type specific amount of sequestration / emission per km2 per year. Thus, the emission for a grid cell is the emission factor. When the land use changes, the emission factor changes to the emission factor of the new land use type. Additionally, deforestation causes loss of carbon from biomass. Emission factors from Janssens et al. (2005) and Karjalainen et al. (2003) are used. Besides land use change, other factors influencing carbon emission and sequestration are the amount of carbon already present in the soil (the higher the soil carbon content, the higher the emission (Sleutel et al., 2003; Bellamy et al., 2005)) and the age of certain land use types: when for example a forest is still growing fast, more carbon can be sequestered than in old forests.

Calculation input parameters

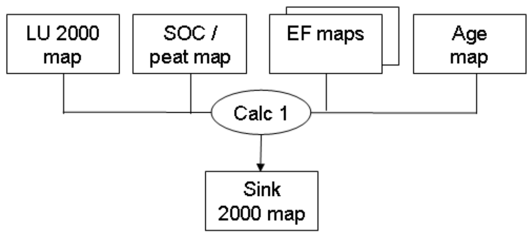
Name	Quantity	Source	Description
LU18	18 classes	Primary EU-ClueScanner output for all subsequent time steps (individual years) in simulation.	Land use resulting from simulation. This is initially based on Corine Land Cover 2000.
Soil organic carbon	0-8 (SOC classes); 9 (peat)	European Soil Database (ESDB)	Combination of JRC soil organic carbon map (Jones et al., 2004) and ESB soil map (European Soil Bureau, 2004).
Age of land use		EU-ClueScanner and EFISCEN	1x1 km grid with age of gridcells (Nabuurs, 2001; Pussinen et al., 2001).

Emission factors	Ton C/ km^2 per year	Calculated within the model	Based on emission factors for each land use type at 1x1 km grid (see calculation rules)
Forest biomass content	Ton C/ km^2	Own data source	Map of forest biomass carbon content per country as 1x1 km grid.

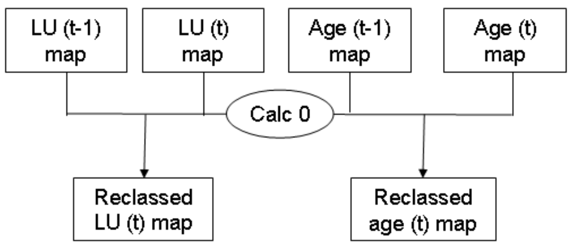
Technical implementation of calculation method (including aggregation method)

The following flowcharts describe the main calculation steps. Calc1 to Calc5 refer to separate calculation steps. These are briefly described below.

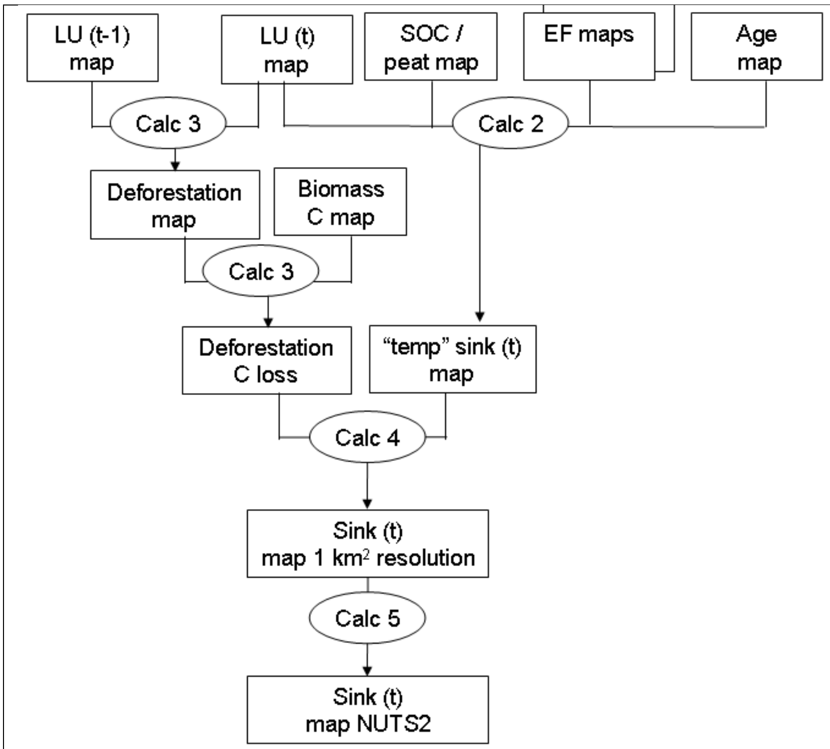
2000:



2001 to 2030 (pre-processing for each year):



2001 to 2030 (carbon budgeting for each year):



Calculation / decision rules:
Emission is allocated to each grid cell; land use type is read from EU-ClueScanner output and emissions from maps with emission factors. Maps with emission factors for arable land, pasture, forest and peatland are supplied, emission factors for other land use types are derived from these (Calc2 in flowchart) as is described below.

The following emission factors are applied in calculation (Janssens et al., 2005; Karjalainen et al., 2003).

:

LU18 class	Description	Emission factor
0	Built-up area	0
1	Arable land (non-irrigated)	see below
2	Pasture	see below
3	(semi-) Natural vegetation	as forest/ 5
4	Inland wetlands	as peat land
5	Glaciers and snow	0
6	Irrigated arable land	as arable
7	Recently abandoned arable land	as forest
8	Permanent crops	as forest/ 3
9	Arable land devoted to the cultivation of (annual) biofuel crops	as arable
10	Forest	see below
11	Sparsely vegetated areas	0
12	Beaches, dunes and sands	0
13	Salines	0
14	Water and coastal flats	0
15	Heather and moorlands	as pasture
16	Recently abandoned pasture land	as forest
17	Perennial biofuel crop cultivation	as forest/ 3

Please note that these emission factors have been partly redefined for the EU-ClueScanner project and may thus deviate from previous descriptions.

For *pastures* on peat, the emission factor is the peatland emission factor. For pastures on mineral soils there is a separate emission factor. These emission factors are essentially defined at the national level (with a few local additions for special circumstances) and stored in pre-processed datasets at a 1x1 km resolution (Peat and Grass2 stored in the IndicatorData/Carbon/AdditionalData/EmissionFactors folder in the model treeview).

For *arable lands*, including non-irrigated and irrigated arable lands and annual biofuel crops, the emission factor is differentiated for soil organic carbon content (SOC) as specified below. The SOC data is provided by JRC (Jones et al., 2004) and ESB soil map (European Soil Bureau, 2004).

SOC-class	SOC [%]	Emission factor
1	0	No emission
2	0.01-1	0.1
3	1-2	0.2
4	2- 6	0.65
5	6-12.5	1.6
6	12.5-25	2
7	25-35	2.5
8	>35	3.5
9	peat (ESB)	emission of peatland

These emission factors have been used to calculate emission figures at a 1x1 km resolution (stored in the crop2 data set) that are furthermore based on additional country-specific data. For SOC-class 9 the emission of peatland is used.

For *forest*, the emission factor is corrected for its age (Nabuurs, 2001; Pussinen et al., 2001):

Age	correction factor
0-5 years	No sequestration
6 -21 years	(0.0525* age) – 0.085
22-43 years	1.05
44-120 years	(-0.007*age) + 1.35
> 120 years	0.50

The age in this approach is based on simulation results and updated on a yearly basis. The obtained emission factors are then multiplied with the national average forest emissions (stored in the forest data set).

During modelling, succession of forest in newly afforested lands is modelled using four land use types: abandoned arable land and pasture, natural vegetation, and forest. Before calculation, the succession land use types are reclassified to forest (Calc0 in flowchart). In the unlikely case forest is changed into natural vegetation during simulation its age and emission factor are considered to as if it had remained forest.

Deforestation (Calc3 in flowchart) only happens from 2001 onwards. Upon deforestation, 80% of carbon in forest biomass is considered to be lost. This figure is provided in a cforbio map that contains an average value. The precise amount of biomass available at a certain location is age dependent: when the forest is younger than 50, the forest biomass carbon content is modified by 0.02*age, when forest is older than 50, the standard number is used.

Total sequestration is then calculated (Calc4) by subtracting deforestation carbon loss from the emission/sequestration values from other land use changes. This map is aggregated to various regional levels (Calc5). A distinction is made between the actual sink in a specific year and the cumulative sink over the preceding 10-year period.

References

Bellamy, P.H., Loveland, P.J., Bradley, R.I., Lark, R.M., Kirk, G.J.D., 2005. Carbon losses from all soils across England and Wales 1978-2003. Nature 437: 245-248.

Janssens, I.A., Freibauer, A., Schlamadinger, B., Ceulemans, R., Ciais, P., Dolman, A.J., Heiman, M., Nabuurs, G.J., Smith, P., Valentini, R., Schulze, E.D., 2005. The carbon budget of terrestrial ecosystems at country scale - a European case study. Biogeosciences: 15-26.

Jones, R.J.A., Hiederer, R., Rusco, E., Loveland, P.J., Montanarella, L., 2004. The map of organic carbon in topsoils in europe, version 1.2, September 2003: Explanation of special publication ispra 2004 no.72 (s.P.I.04.72).

Karjalainen, T., Pussinen, A., Liski, J., Nabuurs, G.J., Eggers, T., Lapvetelainen, T., Kaipainen, T., 2003. Scenario analysis of the impacts of forest management and climate change on the European forest sector carbon budget. Forest policy and economics 5: 141-155.

Nabuurs, G.J., 2001. European forests in the 21st century: Long- term impacts of nature oriented forest management assessed with a large scale scenario model. In: University of Joensuu, Finland, pp. 130.

Pussinen, A., Schelhaas, M.J., Verkaik, E., Liski, J., Karjalainen, T., Paivinen, R., Nabuurs, G.J., 2001. Manual for the European forest information scenario model (efiscen); version 2.0. In: European Forest Institute. Joensuu, Finland, Joensuu, Finland, pp. 49.

Sleutel, S., De Neve, S., Hofman, G., 2003. Estimates of carbon stock changes in Belgian cropland. Soil use and management 19: 166-171.

Soil sealing

Indicator name	Soil sealing
Short description (max. 3 lines)	The percentage sealed surface per grid cell is calculated based on EEA soil sealing data (2006) and simulation results. It consists of several separate sets describing sealing degrees in the year of observation (2006, 2010, 2020, 2030) and changes since the year of reference (2006). These values are provided at various aggregation levels.
Developer	Eric Koomen, Geodan Next/ VU University, the Netherlands: ekoomen@feweb.vu.nl in cooperation with Maarten Hilferink from Object Vision, the Netherlands, Astrid Bräuer and Allard Warrink from the Netherlands Environmental Assessment Agency
Source	EU-ClueScanner project

Indicator data type: quantitative

Indicator	Units
Sealing degree per year	%

Level of map presentation (e.g. 1x1km gird, nuts2, HARM, etc)
local (1x1 km), circular region (10 km radius), Nuts3, Nuts2 and national level

Description of causality in calculation method (max. 10 lines)
The best possible local representation of soil sealing degree is provided in the EEA-FTSP data set. This data set describes the percentage of soil sealing in 100x100 meter grid cells for 2006 based on even finer country-specific data (with an initial resolution of 20x20 meters, see Kahabka and Lucera, 2006) The EEA data set is used to describe the sealing degree for those locations whose land use remains unchanged during simulation. For those locations where land use changes during simulation the initial sealing degree is replaced by the median sealing degree of the new land-use type. These median values are obtained from a country-by-country comparison of the sealing data set with CLC2000 that was especially performed for the EU-ClueScanner project. This comparison provided a table with characteristic, country-specific soil sealing percentages for each land-use type distinguished in simulation. These tables can be found in the indicator data folder in EU-ClueScanner model.

Calculation input parameters:

Name	Quantity	Source	Description
SoilSealing2006	%	EEA-FTSP soil sealing data	EEA FTSP core land cover data for built-up areas, including degree of soil sealing, 2006.
MedianSealingDegree	%	EEA-FTSP soil sealing data and CLC2000	Table that lists per country the median sealing degree per land-use type
Clue10	10 classes	Primary EU-ClueScanner output	Land use resulting from simulation. This is initially based on Corine Land Cover 2000.

Technical implementation of calculation method (Incl aggregation method)
Two different calculation methods were used to account for the differences in resolution and thematic aggregation between the 100m and 1km version. For the 100m version the following approach was taken: 1) Specifying the initial value As initial value the the 2006 sealing degree is read from the EEA-FTSP data set

2) Replacing the sealing degree for changed locations
The 2006 sealing degree is kept for those locations that remain unchanged. For all changed locations this value is replaced by the median sealing degree for the new land-use type. Those values are obtained in a separate analysis in which per country the CLC data set is compared with the sealing degree. For all grid cells belonging to any of the aggregated land-use classes the median sealing value is calculated within the EU-ClueScanner model. The median value is selected as this is considered to provide the most characteristic central tendency value for each land-use type. It is less influenced by untypical (and probably faulty) sealing values that, for example, occur when spatial or temporal mismatches occur between the two data sets.

3) Calculating the change in sealing degree
The change in sealing degree is calculated by subtracting the local sealing degree following step2 by the value following step 2.

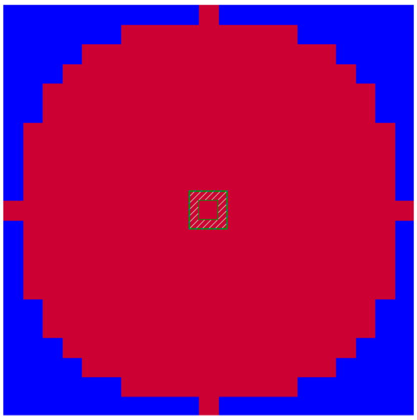
For the 1km version the original 100m data needed to be aggregated as is specified below:

1) Specifying the initial value
The mean 2006 sealing degree per 1km calculated by comparing the 1km aggregated 2000 CLC data (in 10 aggregated classes) with the original 100m EEA-FTSP data set. The unweighted mean of the underlying 100 values was calculated per 1km cell to reflect the heterogeneous character of the underlying data.

2) Replacing the sealing degree for changed locations
The mean 2006 sealing degree per 1km is kept for those locations that remain unchanged. For all changed locations this value is replaced by the median sealing degree for the new land-use type. In case of the 1km grid a median value per country was obtained by comparing the 1km aggregated 2000 CLC data (in 10 aggregated classes) with the original 100m EEA-FTSP data set. For all 100m grid cells belonging to any of the aggregated land-use classes the median sealing value is obtained. The median value is selected as this is considered to provide the most characteristic central tendency value for each land-use type.

3) Calculating the change in sealing degree
The change in sealing degree is calculated by subtracting the local sealing degree following step2 by the value following step 2.

4) Aggregating results
The local level (1x1km) map resulting from step 3 is aggregated to coarser spatial resolutions by averaging the sealing degree of all grid cells within the region over the total land area. Besides these aggregations to various NUTS levels, the local results have also been highlighted by applying a moving window type of filter. This window has a circular shape and consists of 317 cells within a 10km radius of the central cell (see below). Each cell in this neighbourhood has the same weight (1/317 = approximately 0.003155) and this is applied to calculate an average sealing degree in the area.



The circular neighbourhood with a 10 km radius surrounding a central that is used in the visualisation of the sealing degree.

References

Kahabka, H. and Lucera, L. (2008) Delivery report European Mosaic, EEA-FTSP-Sealing-DeliveryReport-EuropeanMosaic, Issue 1.0. European Environment Agency, Copenhagen.

Biodiversity index

Indicator name	Biodiversity
Short description (max. 3 lines)	This indicator is constructed to show the potential impact of land-use change on biodiversity. Biodiversity is described by the Mean Species Abundance (MSA) and the approach used is derived from the GLOBIO3 concept. The biodiversity indicator responds to land-use change and is affected by fragmentation, N deposition, infrastructure development and land-use intensity. These factors are driven by the (global) driving forces but also by specific nature policies which are spatially explicit.
Developer:	Jana Verboom, Alterra the Netherlands: jana.verboom@wur.nl Rob Alkemade, Netherlands Environmental Assessment Agency: rob.alkemade@mnp.nl Willem Rienks Alterra the Netherlands: willem.rienks@wur.nl Igor Staritsky, Wageningen University: igor.staritsky@wur.nl
Source:	Verboom et al. (2007)

Indicator data type: quantitative

Indicator	Units
Biodiversity index (MSA)	0 (none)-100 (maximum)

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
1x1km grid, Nuts3, Nuts2 and national level

Description of causality in calculation method (max. 10 lines)
The biodiversity index or MSA is derived from land-use, land use intensity (agriculture and forestry), the N-deposition, fragmentation, infrastructure developments and policy assumptions on high nature value (HNV) farmland protection and organic agriculture. The methodology used is the GLOBIO3 approach initially developed for biodiversity assessments at a global scale (Alkemade et al., 2009), but also applied to level of Europe (Verboom et al., 2007). The indicator provides an approximation of the land-use related changes in biodiversity. As it is not able to discern actual habitats, applies a 1x1 km resolution that is too coarse to capture detailed ecological processes and only uses a limited range of factors that influence biodiversity, the results do not provide a precise, local account of biodiversity. It does, however, allow for the comparison between the current and different future situations. It shows potential changes in biodiversity at a generalised level.

Calculation input parameters

Name	Quantity	Source	Description
LU18	18 classes	Primary EU-ClueScanner output	Land use resulting from simulation. This is initially based on Corine Land Cover 2000.
Dairy density	0-9999 Large Stock Units (LSU)	Result of EURURALIS dairy density metamodel	Scenario specific 1x1 km map showing dairy density for 2000. 1 LSU is equivalent to one bovid weighing 420 kg.
Forest age	Years	EU-ClueScanner	This is a dynamic file that is updated for each year of simulation.
MSA land-use conversion table	0-100	Expert judgement table created by Rob Alkemade / Jana Verboom	The table describing the relation between land-use type and MSA is provided below

Forest use intensity factor	1 or 1.1	Scenario-based assumption by experts (Jana Verboom, Rob Alkemade, Willem Rienks)	For the B1 scenario, the values 1 (for the years 2000 & 2010) and 1.1 (2020, 2030) are used as a decrease in forest use (thus 10% increase in MSA) is expected because more wood will be imported from outside Europe
High Nature Value (HNV) farmland	Yes/no	EC-JRC	1x1 km map showing approximate extent of potential HNV areas
Organic agriculture table	0-300	Expert judgement table created by Pytrik Reidsma and others	The tables showing the increase in % organic agriculture over time and its land-use specific impact on MSA are provided below
Road map 2000	Yes/no	TEN-Stack project through NEA company	1x1 km road map of 2000
Road map 2010	Yes/no	TEN-Stack project through NEA company	1x1 km road map of 2000
Road map 2020	Yes/no	TEN-Stack project through NEA company	1x1 km road map of 2020
Road map 2030	Yes/no	TEN-Stack project through NEA company	1x1 km road map of 2020
Road disturbance table	0-0.39	Expert judgement table (Jana Verboom and Rien Reijnen of Alterra Wageningen)	Based on type of road and distance to road a disturbance factor is calculated that ranges from 0 (no disturbance) to 0.39 (maximum disturbance). See table below.
Natura 2000	Yes/no	EC-JRC	1x1 km showing areas under Nature2000 designation. Please note that many Natura2000 areas are too small to be adequately captured at this scale
Nature fragmentation table	0-0.45	Expert judgement table (Fleur Smout and Rob Alkemade of Netherlands Environmental Assessment Agency).	The degree of fragmentation of natural areas depends on their size. The impact of fragmen-tation on MSA ranges from 0 to a 0.45 decrease. See table below.
N-deposition	Kg N/ha	IMAGE model	Scenario specific Nitrogen deposition maps for 2000, 2010, 2020, 2030. Initial resolution approximately 50x50km.
Critical Nitrogen load	Kg N/ha	Netherlands Environmental Assessment Agency (Rob Alkemade)	Map showing critical Nitrogen load at approximately 50x50 km resolution

Critical load formulas	-	Expert judgement (Netherlands Environmental Assessment Agency).	The relation between Nitrogen load and MSA is described in three different formulas that apply to different groups of land-use types. The approach applies critical load exceedence for N as does the Streamlining European 2010 Biodiversity Indicators project (EEA, 2007).

Technical implementation of calculation method (including aggregation method)

The main approach is the following (example 2000):

MSA_{2000} = MSA-$landuse_{2000}$ * MSA-$infrabuffer_{2000}$ * MSA-$fragmentation_{2000}$* MSA-$Ndeposition_{2000}$ * 100

The main components (*MSA-landuse, MSA-infrabuffer, MSA-fragmentation and MSA-Ndeposition*) in this formula are calculated as follows:

MSA-landuse

1. Select land-use map;
2. Split up land-use class Pasture into Intensive pasture and Extensive pasture with the Livestock density map (Extensive pasture is pasture with less than 50 LSU/km2);
3. Split up land-use category Forest into Forest plantation and natural forest with the Forest age map. Age classes are younger than 10, 20, 30, 40 50-80 years, and older than 80 years;
4. Join the land-use map with the land-use conversion table that specifies a MSA value per land-use class (see below);
5. Multiply all agricultural classes with 1.25 when within boundaries of HNV map;
6. Multiply all agricultural classes with Organic correction factor (e.g. times 2 for intensive agriculture, see table below);
7. Multiply all forest with the scenario-specific and year-dependent Forest use intensity factor.

Land-use class[1]	MSA-value[2]	Organic correction[3]	Type[4]	Crit.load formula[5]	Description
0	5	1	Other	0	Built-up area
1	10	2	Agriculture	0	Arable land (non-irrigated)
2	10	1	Agriculture	0	Pasture intensive (>60 LSU/km2)
3	70	1	Nature	F1	(semi-) Natural vegetation
4	100	1	Nature	F1	Inland wetlands
5	100	1	Nature	F2	Glaciers and snow
6	5	3	Agriculture	0	Irrigated arable land
7	30	1	Agriculture	0	Recently abandoned arable land
8	20	1.4	Agriculture	0	Permanent crops
9	10	2	Agriculture	0	Biofuel crops (Intensive)
10	70	1	Nature	F3	Forest (natural/plantation – average forest age in region between 50 and 80 years)
11	100	1	Nature	F2	Sparsely vegetated areas
12	100	1	Nature	F2	Beaches, dunes and sands
13	100	1	Nature	F2	Salines
14	100	1	Nature	F2	Water and coastal flats
15	100	1	Nature	F2	Heather and moorlands
16	30	1	Nature	0	Recently abandoned pasture land
17	30	1.4	Agriculture	0	Woody Biofuel crops
18	40	1.4	Agriculture	0	Pasture extensive(<60 LSU/km2)
19	60	1	Nature	F3	Forest (plantation with average forest

					age in region below 50 yrs)
20	45	1	Nature	F3	Forest (plantation with average forest age in region below 40 yrs)
21	35	1	Nature	F3	Forest (plantation with average forest age in region below 30 yrs)
22	25	1	Nature	F3	Forest (plantation with average forest age in region below 20 yrs)
23	15	1	Nature	F3	Forest (plantation with average forest age in region below 10 yrs)
24	100	1	Nature	F3	Forest (natural – average forest age in region older than 80 years)

Notes:
[1]The original 18 EU-ClueScanner classes have been subdivided for pastures (based on livestock density) and forests (based on forest age map). Please note that the latter subdivision is done again for every year the indicator is calculated as the forest age map is dynamically updated during simulation.
[2]The MSA values are based on the expert judgment of Rob Alkemade (Netherlands Environmental Assessment Agency) and Jana Verboom (Alterra).
[3]The correction factor for organic farming is based on Reidsma et al (2006) and was elaborated for the EURURALIS project. In addition this factor is multiplied with a scenario and year-specific conversion factor that represents the increased attention for organic farming over time. The B1 scenario has a relatively strong increase of organic farming of 1, 1.05, 1.10 and 1.15 for the years 2000, 2010, 2020 and 2030 respectively.
[4]Type is used in various calculations to distinguish between areas with a predominant agricultural, natural or other character.
[5]Per group of land-use types one of three available formulas (F1-F3) is applied to link local nitrogen exceedence to MSA (see below at MSA-Ndeposition).

MSA-infrabuffer

1. Select the road map
2. Buffer road map with Table road buffer. Depending on road type (0 = smallest, 4 = largest) and distance to these roads (in number of grid cells) this produces a map with disturbance factors ranging from 0 to 0.39 (39% decrease). See the table below for all disturbance factor values. The MSA is then multiplied by (1-disturbace factor).

Road type	Distance to road (nr. of cells)	Disturbance factor
0	0	0.1344
0	1	0.0000
0	2	0.0000
0	3	0.0000
1	0	0.2878
1	1	0.0115
1	2	0.0000
1	3	0.0000
2	0	0.3641
2	1	0.0401
2	2	0.0000
2	3	0.0000
3	0	0.3903
3	1	0.0776
3	2	0.0229
3	3	0.0115
4	0	0.3903
4	1	0.1081
4	2	0.0229
4	3	0.0115

Source: Jana Verboom and Rien Reijnen of Alterra Wageningen

MSA-fragmentation

1. Select the land-use map;
2. Select all the nature categories and make map Yes/no nature;
3. Select the Road map and the Natura 2000 map; in case of the B1 scenario, grid cells referring to a road within Natura 2000 boundaries in the years 2020 or 2030 are considered as nature cells as it is assumed that their fragmenting effect will be compensated in this scenario that stresses the importance of ecological values;
4. Subtract the Road map from the Yes-nature map resulting in smaller patch sizes;
5. Calculate patch sizes;
6. Join the patch size with the Fragmentation table (see below) to calculate the MSA-fragmentation factor. The amount of fragmentation depends on the size of the nature areas and ranges from 0 to 45%, see below. The MSA-fragmentation is then calculated as 1-fragmentation degree. When land use is agriculture or other, the MSA-fragmentation factor (showing the impact of fragmentation on MSA of agricultural or other areas) equals 1. This implies that the (limited) species richness of these areas is not affected by their size.

Nature area (km^2)	Fragmentation degree
0-1	0.45
1-10	0.25
10-100	0.15
100-1000	0.05
> 1000	0.0

Source: Fleur Smout and Rob Alkemade of Netherlands Environmental Assessment Agency

MSA-Ndeposition

1. Select the N-deposition map and the Critical load map;
2. Calculate the N-exceedence by subtracting both maps: Nexc = N-dep - CL;
3. When Nexceedence > 0 calculate MSA N-deposition for each location based on the step described below;
4. The MSA-Ndepostion factor is then calculated based on N-exceedance (NE) according to one of the following three land-use specific formulas (F1-F3, see first table in this section):

   F1 0.8-0.08 * ln(NE)
   F2 0.9-0.05 * ln(NE)
   F3 0.8-0.14 * ln(NE)

   These formulas express empirically observed relations between critical-load level and the relative local species richness (considered as a proxy for MSA) in different land-use environments (Alkemade et al., 2009). These relations have been adjusted for the European context. As can be seen in one of the tables above (under the MSA-land use heading), formula 1 (F1) is applied to locations that are classified as being with (semi-) Natural vegetation or Inland wetlands, formula 2 (F2) is applied to locations that are classified as being sparsely vegetated areas, beaches, dunes etc.

   When no N exceedance occurs, or the impact of exceedence according to the above formulas is higher than 1, or when land-use class is not sensitive to N-deposition, the MSA N-deposition equals 1.

Present aggregated results:
The results are aggregated to various NUTS levels by taking the mean value for the region. In addition a smoothed 1x1 km resolution representation is created by taking the mean value for that location based on the surrounding 10x10 grid cells. The indicator thus shows the mean MSA value in a $100km^2$ neighbourhood.

References

Alkemade, R., van Oorschot, M., Miles, L., Nellemann, C., Bakkenes, M. and ten Brink, B. (2009) GLOBIO3: A Framework to Investigate Options for Reducing Global Terrestrial Biodiversity Loss. Ecosystems 12(3): 374-390.

EEA (2007) Halting the loss of biodiversity by 2010: proposal for a first set of indicators to monitor progress in Europe. EEA Technical report No 11/2007, European Environmental Agency, Copenhagen.

Reidsma, P., Tekelenburg, T., van den Berg, M. & Alkemade, R. (2006) Impacts of land-use change on biodiversity: an assessment of agricultural biodiversity in the European Union. Agriculture, Ecosystems and Environment 114: 86-102.

Verboom, J., Alkemade, R., Klijn, J., Metzger, M.J. and Reijnen, R. (2007) Combining biodiversity modeling with political and economic development scenarios for 25 EU countries. Ecological Economics, 62:267-276.

Land cover connectivity potential

Indicator name	Land cover connectivity potential
Short description (max. 3 lines)	This indicator measures to what extent habitat patches are connected to larger habitats within the landscape
Developer:	Peter Verburg, VU University, the Netherlands: Peter.Verburg@ivm.vu.nl in cooperation with Maarten Hilferink from Object Vision, the Netherlands
Source:	EU-ClueScanner project

Indicator data type: quantitative

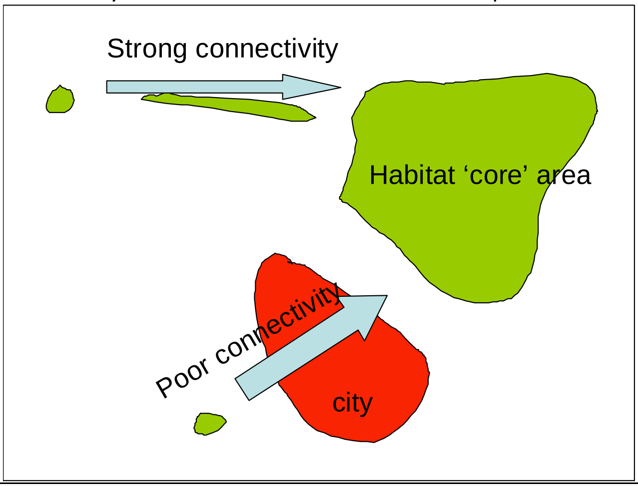
Indicator	Units
Habitat connectivity	5 classes

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
1x1 km grid and Nuts2 level

Description of causality in calculation method (max. 10 lines)

This indicator assesses the difficulty to reach the nearest larger sized habitat from smaller habitats based on output of the EU-ClueScanner land-use allocation results. This is an approximation of the connectivity potential of the landscape for species and the viability of smaller habitats within the landscape matrix. The difficulty to reach other habitats is differentiated between land use types, assuming, for example, a high resistance for urban and arable areas to allow migration of species, a medium to low resistance of permanent grassland areas and a low resistance of other small patches of (semi-) natural area. As the indicator is not including information on the quality of different land-use types, it only offers an initial indication of the potential coherence of possibly valuable natural areas.

The indicator has been defined in such a way to be as much as possible independent of the area of natural land use types in the region. Therefore, also areas with limited natural area may still have, in theory, a good connectivity potential. This way the indicator has added value to the biodiversity indicator that is included as well. This indicator has been developed to best identify differences in landscape connectivity potential (here: permeability) at the relatively coarse scale of analysis. Other indicators such as the frequently used proximity indicator (Gustafson and Parker, 1994) are not sufficiently sensitive to the data used at the spatial and thematic resolution of analysis.



Calculation input parameters:

Name	Quantity	Source	Description
LU18	18 classes	Primary EU-ClueScanner output	Land use resulting from simulation. This is initially based on Corine Land Cover 2000.

Technical implementation of calculation method (Incl aggregation method)
The following steps are performed to calculate the indicator:

1. reclassify the land use map to the following classes.

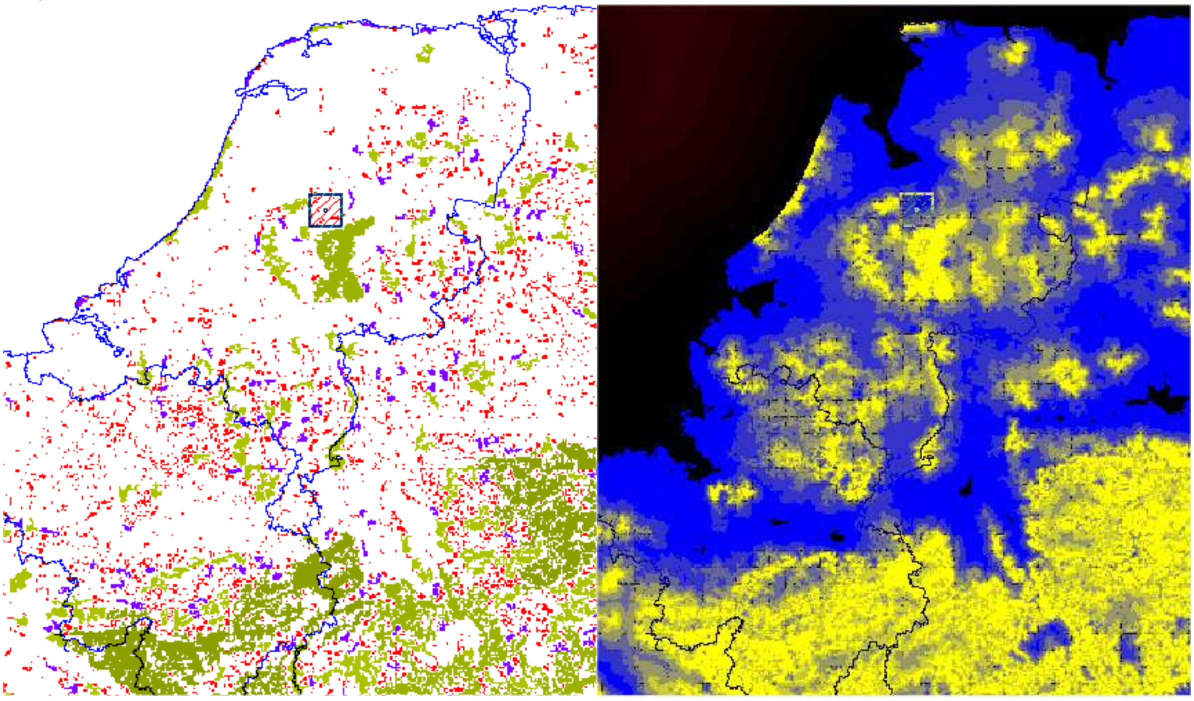
New class	Friction	Nr.:	Land cover class:
0	10	0	Built-up area
1	4	1	Arable land (non-irrigated)
2	1	2	Pasture
3	0	3	(semi-) Natural vegetation
3	0	4	Inland wetlands
4	2	5	Glaciers and snow
2	4	6	Irrigated arable land
2	1	7	Recently abandoned arable land
1	4	8	Permanent crops
1	4	9	Arable land devoted to the cultivation of (annual) biofuel crops
3	0	10	Forest
4	2	11	Sparsely vegetated areas
4	2	12	Beaches, dunes and sands
4	2	13	Salines
5	4	14	Water and coastal flats
3	0	15	Heather and moorlands
2	1	16	Recently abandoned pasture land
1	1	17	Perennial biofuel crop cultivation
1	4	-9999	No data. Most no data values relate to marine waters and have therefore been given the friction value of water. This prevents islands to be complete cut off from mainland Europe.

2. identify continuous patches of New class 3 (natural areas) and calculate patch size.
3. classify all patches > 25 km^2 as ‘destinations’.
4. classify the remaining landscape following the friction indicated in the table above.
5. calculate the ‘cost’ (= friction * distance) from each location to the nearest ‘destination’ (= larger patch, see example below).
6. retain the ‘cost’ for each patch (note that all cells in a patch have the same value since the travel cost within a patch is 0). Cost for ‘destination’ patches = 0.
7. for presentation on 1 km grid search all patches within a 15 km radius (diameter 30 km) and calculate the average cost for these patches. This is the value of the grid cell. Note that each patch counts one time irrespective of its size. Patches that fall partly within the 15km radius only count for the share they fall within the radius.
8. for presentation on NUTS2: calculate average of all patches in NUTS2, each patch counts 1 time, irrespective of size.

The images on the next page represent the main steps in this process.

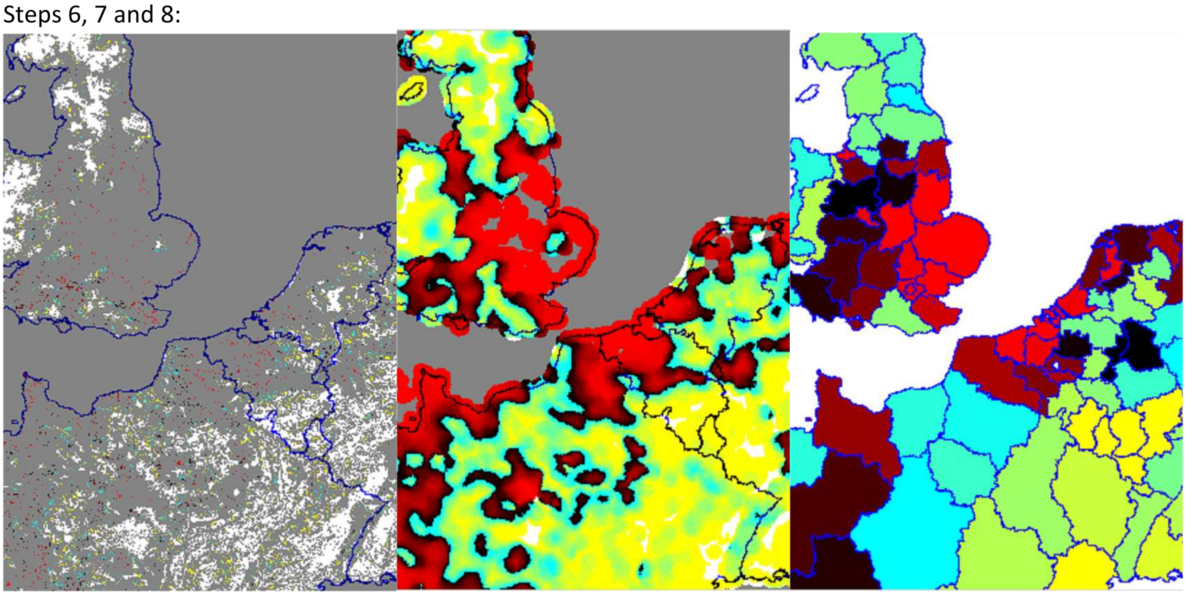
The land cover connectivity potential indicator is newly developed for the EU-ClueScanner project. It aims to capture the difficulty species have to move from a nature area to the nearest larger habitat. As such it describes potential connectivity (or rather the lack thereof: fragmentation) based on a straightforward assessment of land-use types. More detailed analyses can be performed when quality differences of habitats (e.g. forest age) can also be included. This is a topic for further research.

Steps 2 and 5:



Part of Europe showing patches of natural areas (at left, with patch size ranging from red=small to green=large) and the cost to travel to nearest patch of more than 25km2 (at right, with costs ranging from yellow=low to blue/black = high).

Steps 6, 7 and 8:



Part of Europe showing cost per patch (left, ranging from red = high cost to white= destination patch), average cost within 15 km radius (middle, ranging from red = high to white = low), average cost per NUTS2 region (right, red = high to yellow = low).

References

Gustafson, E.J. and Parker G.R. (1994) Using an index of habitat patch proximity for landscape design. Landscape and Urban Planning 29: 117- 130.

Soil erosion risk

Indicator name	Soil erosion risk map
Short description (max. 3 lines)	Soil erosion (sheet and rill) is a major factor in land degradation and loss of soil quality. Furthermore, eroded sediment ends up in rivers and water bodies, where it disturbs fragile water ecosystems. Soil erosion strongly responds to land use, particularly to spatial patterns of land use. These indicator values are available at local (1x1 km) and aggregated level for 2000, 2010, 2020 and 2030.
Developer:	Martha Bakker, Wageningen University Research (WUR), the Netherlands: Martha.Bakker@wur.nl
Source:	Eickhout and Prins (2008)

Indicator data type: quantitative

Indicator	Units
Erosion risk (1x1km level)	ton/ha
Median erosion risk (aggregated)	ton/ha
Mean erosion risk (aggregated)	ton/ha

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
1x1km grid, Nuts3, Nuts2 and national level

Description of causality in calculation method (max. 10 lines)
A soil erosion risk map is calculated according to the Universal Soil Loss Equation (USLE) principle (Wischmeier and Smith, 1978). First a potential for soil erosion is derived from topography, rainfall regime and soil erodibility according to the USLE principle, whereby rainfall regime is considered to be variable in time. Second the land-use maps resulting from each scenario are used to derive a measure for the protective vegetation cover, so that an actual soil erosion map can be obtained by multiplying the potential soil erosion map with vegetation cover maps.

Calculation input parameters

Name	Quantity	Source	Description
R map	-	IMAGE/HADCM rainfall projections	The rainfall erosivity map based on monthly precipitation data.
KLS map	-	European Soil Database and SRTM 90m resolution Digital Elevation Model (DEM).	This is the product of the soil erodibility (K) and slope length (L) and slope steepness (S) factors. The K-map is calculated from soil properties and the LS map from the DEM.
C-map	0-1	Reclassification of the EU-ClueScanner LU18 land-use maps.	The cover management factor (C) map based on the land-use maps (LU18) from the EU-ClueScanner model. These are reclassified to cover factors (ranging from 0 to 1) based on climate-zone specific parameter values described in the table below.

More detailed information on the calculation of these factors is provided below.

Technical implementation of calculation method (including aggregation method)

For the calculation of the soil erosion indicator the Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) was used. The USLE is a simple empirical model, based on regression analyses of soil loss rates on erosion plots in the USA. The model is designed to estimate long-term annual erosion rates on agricultural fields. Although the equation has many shortcomings and limitations, it is widely used because of its relative simplicity and robustness (Desmet and Govers, 1996).

Soil erosion is estimated using the following empirical equation:

$$A = R \cdot K \cdot L \cdot S \cdot C$$

in which:
- A = mean (annual) soil loss (ton ha^{-1} yr^{-1})
- R = rainfall erosivity factor (MJ mm ha^{-1} h^{-1} yr^{-1})
- K = soil erodibility factor (ton h MJ^{-1} mm^{-1})
- L = Slope factor (-)
- S = Slope length factor (-)
- C = cover management factor (-).

The R-factor was calculated from monthly rainfall data, using the formula of Renard and Freimund (1994):

$R = 0.739F^{1.847}$ $F < 55$

$R = 95.77 - 6.081F + 0.477F^2$ $F > 55$

in which $F = \Sigma$ (monthly precipitation^2)/ annual precipitation

Fine resolution (1 km) WorldClim monthly precipitation data for the year 2000 was used, which was incremented with coarse resolution (50 km) year-by-year changes from the IMAGE model for each base scenario. The data from IMAGE were based on simulations with the HADCM models.

The K-factor map was derived from texture and organic matter using the USLE formulae (Wischmeier and Smith, 1978):

$K = 27.66 \cdot M^{1.14} \cdot 10^{-8} \cdot (12\text{-}a)$

in which:
- M = silt (%) · (100-clay (%))
- a = organic matter fraction

No spatial variability in drainage class and structure class was included and we assumed a structure-class of 2 (fairly structured) and a drainage-class of 3 (moderate permeability). Clay, sand and silt percentages were taken from the European Soil Database, whereby the assignment of representative texture fractions to ordinal classes was based on the assumptions from (Knijff et al., 2000). Organic matter was taken from the Topsoil Organic matter map from the ESDB, and was topped-off at values > 4%, as higher organic matter percentages show no, or no reliable relationship with soil erodibility. As volcanic soils have chemical properties that make them very erodible, these soils were set to a K-value of 0.8 (Knijff et al., 2000).

The S-factor was computed as follows:

$(\sin \beta / 0.0896)^{1.3}$

in which: β = slope

Given the resolution of the original DEM (from SRTM images: around 90 m, see slope_final data set) it was not considered feasible to incorporate the slope length factor (L), so this was considered a constant value of 1.94, which is based on the following formula:

$1.4 \cdot (A / 22.14)^{0.4}$

while assuming one single value for A (specific contributing area) of 50 m^2 m^{-1} (Knijff et al., 2000).

The C-factor was based on the land-use maps generated by the EU-ClueScanner model. A classification table was applied to three climatic zones: boreal, temperate and Mediterranean (Table 1). The C-values per land cover type were obtained by an overlay of the land use map in 2000 with the C-factor map made by Knijf et al. (2000), who used satellite images (Normalized Difference Vegetation Index) to estimate the C-factor for a large part of Europe. The obtained average values were adapted according to recommendations Knijf et al. (2000) made with respect to this approach. For example, land cover types with low vegetation vitality could still have a high cover, which was the case for heather and moorland; and the fact that arable land is ploughed while permanent crops and pasture are not was incorporated by a lower C-value for the latter two land use types. Furthermore, stone cover was considered to protect sediment from being washed away, which was implemented by multiplying the reclassification by a stone protection map, which ranged from 0.5 for very stony areas, i.e. soil mapping units with an agricultural limitation due to stones and gravel according to the ESDB, to 1 for areas with few or no stones.

Table 1. Classification key for land cover classes to C-factor values for the different climate zones

Code	**Land cover class**	**Climate zone**		
		Mediterranean	Boreal	Temperate
0	Built-up area	0	0	0
1	Arable land	0.32	0.32	0.24
2	Pasture	0.1	0.05	0.03
3	(semi-) Natural vegetation	0.1	0.03	0.03
4	Inland wetlands	0	0	0
5	Glaciers and snow	0	0	0
6	Arable land - irrigated	0.32	0.32	0.24
7	Recently abandoned arable land	0.2	0.2	0.15
8	Permanent crops	0.25	0.15	0.15
9	Forest	0.005	0.001	0.001
10	Annual biofuel crops	0.32	0.32	0.24
11	Sparsely vegetated areas	0.25	0.15	0.15
12	Beaches, dunes and sands	0	0	0
13	Salines	0	0	0
14	Water and coastal flats	0	0	0
15	Heather and moorlands	0.005	0.001	0.001
16	Recently abandoned pasture land	0.1	0.05	0.03
17	Perennial biofuel crops	0.25	0.15	0.15

The resulting grids are aggregated to the various NUTS levels by calculating the mean and median of all grid values. The mean is influenced by individual high erosion values and indicates those regions where erosion can pose a local problem. The median is less influenced by extremely high individual values and gives an indication of areas where erosion is a wide-spread problem. The applied, straightforward USLE-based approach differs from the more process-oriented approach applied in the PESARA-model (Kirkby et al, 2004). It would be an interesting line of future research to compare these two approaches.

References

Desmet, P.J.J., Govers, G., 1996. A GIS-procedure for automatically calculating the USLE LS-factor on topographically complex landscape units. Journal of Soil and Water Conservation, 51 (5): 427-433.

Eickhout, B. and A.G. Prins (2008) Eururalis 2.0 Technical background and indicator documentation. Wageningen UR and Netherlands Environmental Assessment Agency (MNP) Bilthoven, The Netherlands

Kirkby, M.J., Jones, R.J.A., Irvine, B., Gobin, A, Govers, G., Cerdan, O., Van Rompaey, A.J.J., Le Bissonnais, Y., Daroussin, J., King, D., Montanarella, L., Grimm, M., Vieillefont, V., Puigdefabregas, J., Boer, M., Kosmas, C., Yassoglou, N., Tsara, M., Mantel, S., Van Lynden, G.J. and Huting, J. (2004). Pan-European Soil Erosion Risk Assessment: The PESERA Map, Version 1 October 2003. Explanation of Special Publication Ispra 2004 No.73 (S.P.I.04.73). European Soil Bureau Research Report No.16, EUR 21176, Office for Official Publications of the European Communities, Luxembourg.

Knijff, J.M.v.d., Jones, R.J.A., Montanarella, L., 2000. Soil Erosion Risk Assessment in Europe. In: European Commission - Joint Research Centre, pp. 34.

Renard, K.G., Freimund, J.R., 1994. Using monthly precipitation data to estimate the R-factor in the revised USLE. Journal of Hydrology 157, 287-306.

Wischmeier, W.H., Smith, D.D. 1978. Predicting rainfall erosion losses. USDA Agricultural Research Service Handbook 537.

Increased river flood risk

Indicator name	Increased river flood risk
Short description (max. 3 lines)	The increased river flood risk indicator describes the current and newly developed urban areas in river-flood prone areas. It aims to indicate those areas that face an additional river flood risk compared to the current situation. The indicator is available for several years (2000, 2010, 2020, 2030) and various spatial aggregation levels.
Developer:	Eric Koomen, Geodan Next/ VU University, the Netherlands: ekoomen@feweb.vu.nl and Maarten Hilferink, Object Vision, the Netherlands: mhilferink@objectvision.nl
Source:	EU-ClueScanner project

Indicator data type: quantitative

Indicator	Units
Current and new urban area within river flood prone area per year (1x1km level)	1 (yes) or 0 (no)
Share of (new) urban area under river flood risk (aggregated)	pro mille (of total land area)

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
local (1x1 km), circular region (10 km radius), Nuts3, Nuts2 and national level

Description of causality in calculation method (max. 10 lines)
The indicator focuses on areas that are prone to rare river floods that have a statistical return period of occurring once every 100 years under the future climate conditions of the A2 scenario. It highlights the urban areas within the potential flooding zone that are newly developed since 2000. This subset of new urban areas is created by overlaying it with a map of flood-prone areas. The latter map, provided by JRC, shows those locations (1x1 km) where at least 25% of the area may be inundated with a water depth of more than 50 cm. It indicates those areas that face an additional river flood risk compared to the current situation following projected climatic and socio-economic changes. The A2 scenario is used to describe the future climate conditions. Unfortunately this deviates from the B1 scenario used for the socio-economic changes, but no water depth maps were available for this scenario when the indicator was developed. Please note that this assessment of potential river-flood risk does not incorporate the conditions of flood defence systems, meaning that risks are overestimated in case solid defence systems are implemented that are bale to withstand (future) flooding conditions. The indicator is especially meant to highlight those areas where such areas may be necessary. Furthermore, It should be noted that flood-risk resulting from sea water is not included in this analysis as this calls for the application of additional hydrologic models. In addition most areas below sea water level (most notably in the Netherlands) are excluded from the river-flood risk assessment as floods from the sea are thought to be the dominant risk.

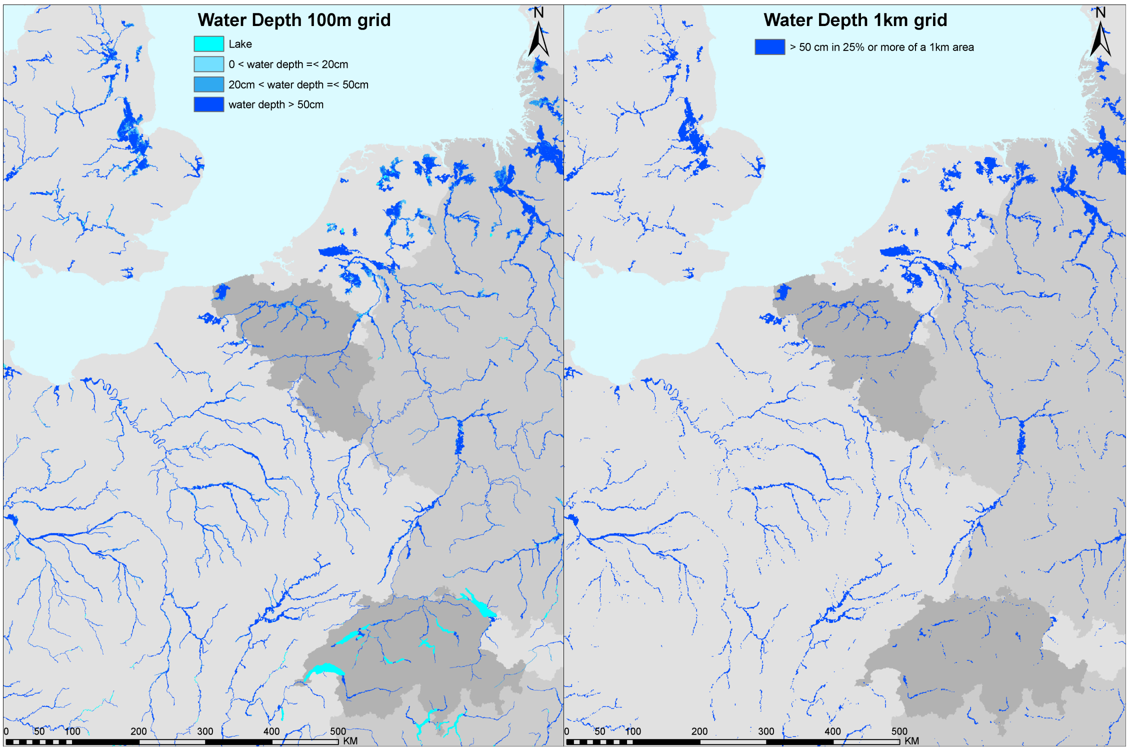
Calculation input parameters

Name	Quantity	Source	Description
LU18	18 classes	Primary EU-ClueScanner output	Land use resulting from simulation. This is initially based on Corine Land Cover 2000.
RiverFloodProneAreas	4	JRC-IES	100x100 m grid with water depths for 100-years flood, under A2 scenario in 4 classes: 0 (lakes); 1 (0-20cm); 2 (20-50cm); and 3 (>50cm).

Technical implementation of calculation method (including aggregation method)

The indicator is calculated in several steps:

1) Definition of river-flood prone areas
These areas are derived from a 100x100 m grid data set provided by JRC (WDCLASS_SCEN) that describes the water depth resulting from a 100-years river flood under future climate conditions of the A2 scenario. This highly detailed map (see below) is aggregated to a 1x1km resolution by selecting those locations where at least 25% of the 1 km^2 grid cell (thus 25 original 100 metre cells) will be flooded with a water depth of more than 50 cm.



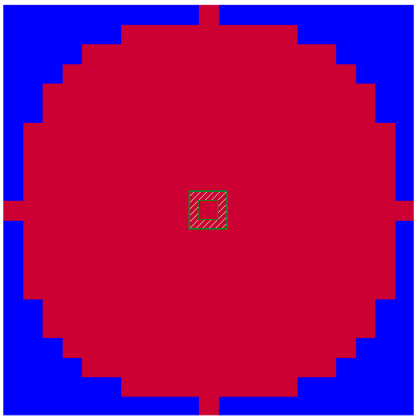
Original 100x100m water depth map (left) and derived 1x1km version (right) showing those locations where 25% of the area has a water depth of more than 50 cm.

2) Selection of new urban areas
To select the newly urbanised areas a binary (0/1) map with urban areas in the initial year is subtracted from an initial map in the simulation year. This results in a binary map with new built-up areas (a loss of urban area is, by definition, not possible in the model).

3) Highlighting the new urban areas within flood-prone areas
The new urban areas within flood-prone areas are highlighted by making a simple spatial overlay.

4) Aggregating results
The local level (1x1km) map resulting from step 3 is aggregated to coarser spatial resolutions by counting the number of grid cells that are likely to be flooded in a region and dividing that by the total land area of that region. This relative river flood risk is expressed as a pro mille. Besides these aggregations to various NUTS levels, the local results have also been highlighted by applying a moving window type of filter. This window has a circular shape and consists of 317 cells within a 10km radius of the central cell (see below). Each cell in this neighbourhood has the same weight (1/317 = approximately 0.003155) and thus receives a value of 0.003155 in case it is (newly) urban and prone to flooding. The values of all cells within the circular neighbourhood are added up, attached to the central cell and expressed as a pro mille to reflect a total probability on river flooding within the neighbourhood. In case all 317 cells within the circle are (newly) urban and prone to flooding the value of the central cell equals 1000 pro mille, when only two cells are (newly) urban and flood-prone the value is 6.30 pro mille. This approach has the

advantage of highlighting the local occurrences of flood risk in larger regions.



The circular neighbourhood with a 10 km radius surrounding a central that is used in the visualisation of river flood risk prone urban areas.

Urban sprawl

Indicator name	Urban sprawl
Short description (max. 3 lines)	This set of five indicators provides insight in the extent of urbanisation. Based on a selection of urban land-use types indicator values are obtained that describe the general composition of urban land use (total urban area, urban population density, urbanisation degree) and their spatial configuration (number of urban areas, average urban area size). The indicators are available for individual years (2000, 2010, 2020 and 2030) and changes between these years (2000-2030, 2000-2010, 2010-2020 and 2020-2030)
Developer	Eric Koomen, Geodan Next/ VU University, the Netherlands: ekoomen@feweb.vu.nl
Source	Ritsema van Eck and Koomen (2008)

Indicator data type: quantitative

Indicator	Units
total urban area	ha
urban population density,	persons/ha
urbanisation degree	%
number of urban areas,	Count
average urban area size	Ha

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
Nuts2 and national level

Description of causality in calculation method (max. 10 lines)
The process of urbanisation is described by indicators that deal with the general land-use composition and the spatial configuration of individual urban areas. By using this combination of composition and configuration indicators at various scales we can quantify the extent to which urban growth differs between scenarios or policy alternatives and furthermore typify which simulated urban patterns are closest to the environmental objective of concentrated, compact urbanisation. The spatial configuration indices focus on the concentrations formed by sets of contiguous areas. This type of measurements looks at the size and shape of individual urban constellations as is also common in literature (e.g. Geurs and van Wee 2006; Longley and Mesev 2000, Ritsema van Eck and Koomen, 2008). This approach can be related to spatial policies that aim at preserving the alternation of relatively large urban areas surrounded by sizeable non-urban (open) spaces and thus combat urban sprawl. The focus on individual urban constellations is similar to the approach ecologists take when studying landscape patterns. Crucial in their description of changes in the landscape is the distinction of individual 'patches' that consist of a single landscape type. From their extensive work (e.g. Gustafson 1998; O'Neill et al. 1999; Turner et al. 2001), we select a limited number of indicators relating to patch-size distribution.

Calculation input parameters

Name	Quantity	Source	Description
LU18	18 classes	Primary EU-ClueScanner output	Land use resulting from simulation. This is initially based on Corine Land Cover 2000.
Total population	inhabitants	PHOENIX projections, disaggregated to NUTS2 regions	Population projections for the B1 scenario from the Phoenix model (Hilderink, 2003; 2004). The disaggregation is described in the population indicator factsheet.

Technical implementation of calculation method (including aggregation method)
The *composition metrics* are based on a regional aggregation of the simulated built-up area. Please note that the same Nuts2 regional division is applied as for the population indicator. See that factsheet for more information on this regional division that deviates from the Nuts2 shapes used to calculate other indicators. The following composition indicators are calculated: **Total urban area** is calculated by aggregating the simulated built-up area per regional area. The built-up area class in the EU-ClueScanner contains the complete 'artificial surfaces' main class in the underlying Corine Land Cover types. **Urban population density** is calculated by dividing population totals per region (derived from Phoenix projections, see population indicator factsheet) by the total urban area in that region. **Urbanisation degree** is calculated by dividing the total urban area in a region by the total land area in a region. The land area consists of the total area covered by all land-use types excluding water. The water class in the EU-ClueScanner contains all inland and marine water bodies, salt marshes and intertidal flats distinguished in the Corine Land Cover data set. The *spatial configuration indicators* are based on contiguous urban areas. These are derived from the simulated built-up area, based on the DMS operator district. This operator assigns a unique identifier to groups of adjacent urban cells that are connected through any of their four direct neighbours. Individual urban cells are considered to be part of a greater urban form when they are bordering other urban cells in any of their four adjacent cells. This method discerns extensive connected urban agglomerations that are typically much larger than individual cities. As connectivity is defined based on the four direct neighbours only (and not includes the four diagonal neighbours) the selection of extremely large urban areas following , for example large infrastructure lines, is prevented. The configuration of the urban areas is most clearly described by the following indicators: **Number of urban areas**: the total number of urban areas in a region. All areas that are partly situated in a region are considered. **Average urban area size**: the average size of the urban areas in a region. For urban areas that only partially belong to a region we still use their total size to prevent the artificial cutting up of large urban areas. **Weighted average urban area size**: the average size of the urban areas in a region weighted for their size. This indicator emphasis the importance of larger urban areas in a region. It is obvious that all individual indicators have their specific advantages and drawbacks, but in combination they offer a fairly complete description of the various dimensions of urban sprawl. The (regional) total urban area and urban population density are able to show the general developments in terms of, for example, increasing urban area and decreasing density. In addition the indicators related to individual urban areas, characterise spatial patterns and may, for example, indicate a decreasing compactness of urban areas in terms of a decreasing average size.

References

Ritsema van Eck, J. and Koomen, E. (2008) Characterising urban concentration and land-use diversity in simulations of future land use, Annals of regional Science 42 (1): 123-140.

Bubeck, P. and Koomen, E. (2008) Indicators for evaluating land-use change, Spinlab Research Memorandum SL-07, Vrije Universiteit Amsterdam.

Geurs, K.T. and van Wee, B. (2006) Ex-post evaluation of thirty years of compact urban development in the Netherlands. Urban Studies 43(1): 139-160.

Hilderink, H. B. M. (2003) PHOENIX pluss: the population user support system, Version 1.4, Rijksinstituut voor Volksgezondheid en Milieu (RIVM), Bilthoven/Utrecht.

Hilderink, H. B. M. (2004) Population & Scenarios, Worlds to win?, Netherlands Environmental Assessment Agency (RIVM-MNP), Bilthoven, the Netherlands, 550012001, pp. 70.

Longley, P.A. and Mesev, V. (2000) On the measurement and generalization of urban form. Environment and Planning A 32: 473-488

Gustafson, E.J. (1998) Quantifying landscape spatial pattern: what is the state of the art? Ecosystems 1: 143-156.

O'Neill, R.V., Riitters, K.H., Wickham, J.D. and Jones, K.B. (1999) Landscape pattern metrics and regional assessment. Ecosyst Health 5(4):225–233

Turner, M.G., Gardner, R.H., O'Neill, R.V. (2001) Landscape ecology in theory and practice. Patt Process. Springer, New York

III. Economic and social indicators

Economic Indicators

Indicator name	Economic indicators
Short description (max. 3 lines)	This set of key economic indicators is derived from the LEITAP model and reflects the scenario-specific conditions of general economic and specific agricultural themes such as employment, production values. Values are available at the national level for most EU27 member states for 2001, 2010, 2020, 2030.
Developer:	Hans van Meijl, Agricultural Economics Institute (LEI), The Hague, the Netherlands: Hans.vanmeijl@wur.nl.
Source:	LEITAP model runs performed for EU-ClueScanner project

Indicator data type: quantitative

Indicator	Units
Gross Domestic Product (GDP)	2001 dollars and index value (2001=100)
Added value of agricultural sector	2001 dollars and index value (2001=100)
Agricultural production share in GDP	%
Total employment	index value (2001=100)
Agricultural employment	index value (2001=100)
Added value per farmer	index value (2001=100)
Net agricultural export	2001 dollars and index value (2001=100)

Level of map presentation (e.g. 1x1km grid, nuts2, HARM, etc)
National level indicators values are available for the following 18 EU27 member states: Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, the Netherlands, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom. The remaining 9 member states are grouped: Belgium and Luxembourg (belu), the Baltic countries (euba), Romania and Bulgaria (apeu) and Cyprus, Malta (euis). Please note that for the grouped countries the included values represent average values. This may be slightly misleading in the graphical representation that shows all individual country boundaries. Index values were calculated to represent these indicators as they allow for a more easy comparison between countries. For a limited number of economic indicators the absolute values are also available. This is the case for GDP, agricultural income and net agricultural export values that are expressed in 2001 dollars.

Description of causality in calculation method (max. 10 lines)
The indicator values have been calculated in the LEITAP model as part of the model runs performed for EU-ClueScanner project. The LEITAP model philosophy and main assumptions are: 1) elasticity of substitution between endowments (labor, capital and land) indicating how easily labor can be substituted by capital or land. 2) Population growth influences the demand for agricultural products and defines the total labor supply, which is growing parallel with population. 3) Labor demand by non-agricultural sectors depending on the growth of these sectors. 4) Segmentation of labor market. The labor market is segmented in a market for agricultural and a market for non-agricultural labor, because different skills are required. 5) Economic growth (GDP) influences consumption and in particular food demand and therefore the sectoral production.

Calculation input parameters

Name	Quantity	Source	Description
Economic growth: GDP compared to 2001	%	scenario-based assumptions (worldscan)	steers demand for food, energy and urban land
Population	inhabitants	scenario-based assumptions	steers demand for food, energy and urban land

In addition to these basic input parameters the LEITAP model uses a series of assumptions related to consumer demand, trade and production capacity. Based on the demand for food and the supply of agricultural products (depending on the availability and productivity of land, labour, capital and natural resources) commodity prices and regional production volumes are calculated as is described in the text and references below.

Technical implementation of calculation method (including aggregation method)
The global economy is modelled with an extended version of the Computable General Equilibrium (Global Economy) model GTAP (Global Trade Analysis Project), which combines the advantages of the Global Economy approach, taking into consideration the impact of non-agricultural sectors on agriculture and a full treatment of factor markets, with the specific features of partial equilibrium models concerning land modelling. The standard GTAP model is characterized by an input-output structure based on regional and national input-output tables. It explicitly links industries in a value added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. For this analysis an extended version of the standard GTAP model was developed that improved the treatment of agricultural production and land use. Since it was assumed that the various types of land use are imperfectly substitutable, the land use allocation structure was extended by taking into account different degrees of substitutability between land use types. LEITAP is based on the standard GTAP model (https://www.gtap.agecon.purdue.edu/models/current.asp). Changes in LEITAP compared to GTAP are documented in Van Meijl et al. (2006). Recent improvements on the land supply curve, biofuels and the consumption function are documented in Eickhout et al. (2009); Banse et al. (2008) respectively. The included indicators are briefly discussed below. **Gross Domestic Product (GDP)** Gross Domestic Production per region is based on the total added value of all economic sectors. The indicator shows the development of the total size of the economy compared to 2001. **Added value of agricultural sector** This indicator represents the total added value of the agricultural sector in a similar way as the GDP does for the whole economy. **Agricultural production share in GDP** Represents the share of total agricultural production (expressed in added value) as part of the GDP. **Employment** The number of employees in a region standardized as full time employees, as index value relative to the number of employees in 2001. This indicator develops to a large extent parallel with population growth. **Agricultural employment** This indicator shows the relative agricultural employment compared with 2001. The agricultural employment is calculated at the national level and it is an important indicator characterizing the development of the agricultural sector and its importance for the economy. It is influenced by agricultural production and labor productivity development. **Added value per farmer** Value added per worker in agriculture as a percentage of the value added per worker in 2001. It is deflated by the national GDP deflator. It indicates the growth in welfare of farmers. Be aware that the indicator includes not only income from labor, but also from capital and land. This indicator is calculated on a national level. **Net agricultural export** The surplus of export-import for all agricultural commodities expressed as index value with 2001 as base

year. It is the sum of the net export values of the following groups of commodities: Paddy and processed rice; Wheat; Cereal grains; Oil seeds; Sugar cane, sugar beet; Vegetables, fruit, nuts; Plant-based fibers; Cattle (sheep, goats, horses for wool and meat); Animal and meat products; Raw milk; Dairy products; Sugar; Vegetable oils and fats; Food products.

References

Van Meijl, H., T. van Rheenen, A. Tabeau and B. Eickhout (2006) The impact of different policy environments on land use in Europe. Agriculture, Ecosystems and Environment, 114: 21-38.

Eickhout, B., H. van Meijl, A. Tabeau and E. Stehfest (2009) The impact of environmental and climate constraints on global food supply. In: Hertel, T.W., Rose, S. and Tol, R. (eds.) Economic Analysis of Land Use in Global Climate Change Policy, Routledge, USA.

Banse, M., A. Tabeau, G. Woltjer, G. and H. van Meijl (2008) Will EU Biofuel Policies Affect Global Agricultural Markets? European Review of Agricultural Economics 35(2):117-141.

For more information see also: http://www.eururalis.nl/current/background/kader/index.html

Population

Indicator name	Population
Short description (max. 3 lines)	A representation of population projections (derived from the Phoenix model) at regional (Nuts2) and national level. The indicators show: - absolute number of inhabitants for the years 2000, 2010, 2020, 2030 - differences in absolute values for the periods 2010-2000, 2020-2010, 2030-2020, 2030-2000 - inhabitants per hectare for the years 2000, 2010, 2020, 2030 - differences in inhabitants per hectare for the periods 2010-2000, 2020-2010, 2030-2020, 2030-2000
Developer	Martin van der Beek, Object Vision, the Netherlands: mtbeek@objectvision.nl and Eric Koomen, Geodan Next/ VU University, the Netherlands: ekoomen@feweb.vu.nl
Source	Eickhout and Prins (2008)

Indicator data type: quantitative

Indicator	Units
2000_abs etc.	absolute number of inhabitants in specified year
diff_2000_2030_abs etc.	absolute difference in number of inhabitants between specified years
2000_density etc.	number of inhabitants per hectare in specified year
diff_2000_2030_dens etc.	absolute difference in number of inhabitants per hectare between specified years

Level of map presentation (e.g. 1x1km gird, nuts2, HARM, etc)
Nuts2 and national level

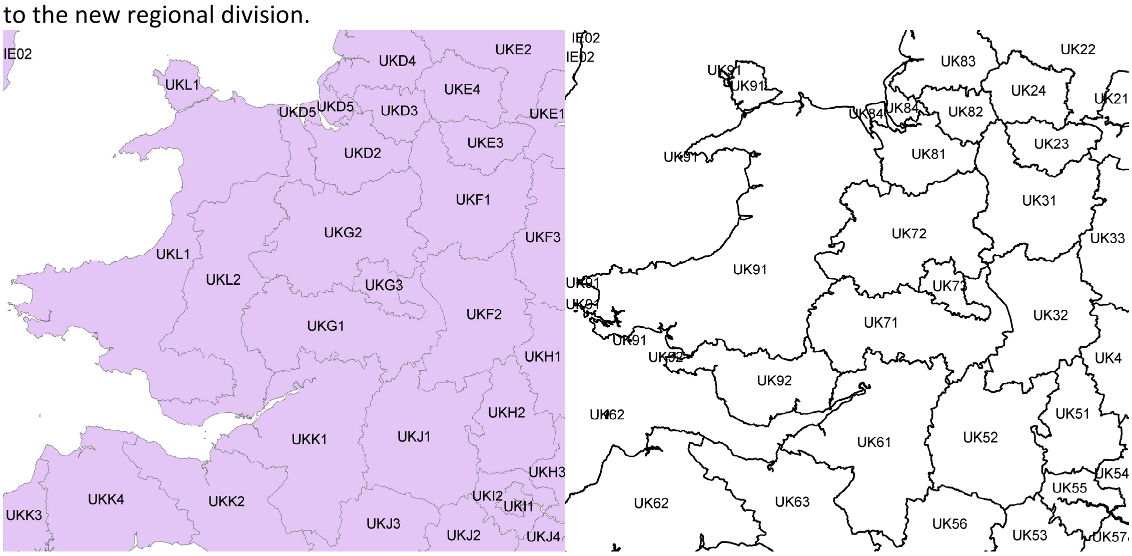
Description of causality in calculation method (max. 10 lines)
Population size and structure are determined by three fundamental demographic processes: fertility, mortality and migration. The projections included here relate to the SRES B1-scenario (Nakicenovic, 2000) and are derived from the Phoenix simulation model (Hilderink, 2000; 2003). To obtain the population at NUTS2 level, the Phoenix scenarios have been downscaled applying the outcomes of the Eurostat regional population projections at NUTS2 for EU15 (Eurostat, 2003). For B2 the low variant was used. When this information was lacking another NUTS2 disaggregation was performed assuming the 2000 distribution of the population over the NUTS2 regions.

Calculation input parameters:

Name	Quantity	Source	Description
Fertility	children/woman	scenario-based assumptions	See Hilderink (2004)
Life expectancy	years	scenario-based assumptions	See Hilderink (2004)
Migration	% of total population	scenario-based assumptions	See Hilderink (2004)

Technical implementation of calculation method (Incl aggregation method)
Phoenix is a simulation model developed to assess the impact of developmental and policy factors on population dynamics (Hilderink, 2000). The model is part of an integrated framework of global change models developed by RIVM. Describing this separate model is beyond the scope of this factsheet, but adequate descriptions are available in the references indicated below.

The regionalized population data were produced for the EURURALIS2.0 study (Eickhout and Prins, 2008) and are linked to a slightly outdated NUTS2 division. To properly visualize the data at this specific regional division a matching spatial representation was obtained from Wageningen University. The images below show some typical differences between the current ETRS (left) and older NUTS2 boundaries (right). The images make clear that the spatial boundaries have changed considerably at specific locations, making it impossible to create a translation table that would link the old NUTS2-data to the new regional division.



References

Eickhout, B. and A.G. Prins (2008) Eururalis 2.0 Technical background and indicator documentation. Wageningen UR and Netherlands Environmental Assessment Agency (MNP) Bilthoven, The Netherlands

Eurostat (2003) New Cronos, European Union, (europa.eu.int/newcronos).

Hilderink, H. B. M. (2000) World population in transition: an integrated regional modelling framework, Thela Thesis / Rozenberg, Amsterdam.

Hilderink, H. B. M. (2003) PHOENIX pluss: the population user support system, Version 1.4, Rijksinstituut voor Volksgezondheid en Milieu (RIVM), Bilthoven/Utrecht.

Hilderink, H. B. M. (2004) Population & Scenarios, Worlds to win?, Netherlands Environmental Assessment Agency (RIVM-MNP), Bilthoven, the Netherlands, 550012001, pp. 70.

Nakicenovic (ed.) (2000) Special Report on Emission Scenarios. Intergovernmental Panel on Climate Change (IPCC), Geneva, Switzerland.