MINATURA DELIVERABLE D1.4

FUTURE LAND USE MAPS SHOWING POTENTIAL CONSTRAINTS IN CASE STUDY REGIONS

Version 1.2

Summary:
This deliverable summarises the result of the future spatial allocation of various land uses relevant to MINATURA2020, applying the iCLUE model in MINATURA2020's case study countries (onshore).

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1. EXECUTIVE SUMMARY

This report summarises the result of the future spatial allocation of various land uses relevant to MINATURA2020, applying the iCLUE model in MINATURA2020's case study countries (onshore). Eleven land use classes were dynamically modelled into the future until 2050: forest, arable land with annual crops, arable land with permanent crops, grassland, non-grazed grassland, shrubland, non-grazed shrubland, sparsely vegetated areas, non-grazed sparsely vegetated areas, built-up area, and open pit mineral extraction sites or dump sites.

iCLUE output is given in the form of a time series of land use maps. Changes in land use can be identified from the maps (as stack bar charts: amount of change, visually on maps: location of change). Overall, the most prominent changes are the increase in built-up area (urban sprawl) and the decrease in cropped land. For several case study countries, we see a major increase in shrubland, which can be seen as land abandonment. The latter can be judged in varying ways. In some countries (e.g. Poland), the extended land abandonment can give room for extraction of resources. However, in the UK, there may be a high risk that these grounds will be bought by conservation organisations and will be managed extensively as traditional agricultural land, which consequently leads to no room for extraction of resources.

2. INTRODUCTION

2.1 THE CONTEXT OF THE STUDY

The exploitation of minerals in Europe is an indispensable activity to ensure that the present and future needs of the European society can be met. This means that sufficient access is required to explore and exploit minerals. At the same time the mineral requirements of our society must be met without compromising the ability of future generations to meet their own needs. Accordingly, potentially exploitable mineral deposits and resources (known deposits, abandoned mines and historical mining sites) need to be assessed against other land uses, taking into account criteria such as habitats, other environmental concerns, priorities for settlements, etc. Decisions on the development or management of these diverse land uses requires adequate consideration of their significance and exclusiveness; the positive or negative impacts associated with their development and the extent to which potential negative mining impacts may be reversed, mitigated or offset; and consequences of the development on the surrounding area.

The objective of WP1 is to identify mineral resources in relation to current and future competition between their development and that of other land uses, based on existing methodologies and approaches at EU and national level. And by doing so, the basis for a concept and methodology for protecting mineral deposits of public importance can be developed (to be accomplished in WP2).

As a first step in the localisation of mineral resources and assessment of the extent of land use competition, WP1 collected the necessary existing spatial data for the MINATURA case study areas. Such data included current existing spatial data on the delineation of Natura 2000 areas, Nationally Protected areas (Common Database on Designated Areas - CDDA) and other (national/regional) protected areas, Corine land cover (http://land.copernicus.eu/pan-european/corine-land-cover), population density maps, spatial planning zones, and locations of actual and potential mining resources and claims. It was considered probable that not all required data would be available for all case study areas.

In Task 1.1 of WP1 identified the availability of the spatial data and indicated the possible applicability of comparable data (i.e. proxies) in case of data gaps, which indeed proved to be necessary. Gaps in data availability could have consequences for the development and functionality of the regulatory framework concept for the EU as a whole.

In Task 1.2 of WP1 identified (i) mineral resource areas for a selection of important minerals and (ii) the extent and/or significance of competition with other land uses. While doing this, indicative rules that could be used as the basis to support the mapping and regulatory framework of mineral deposits of public importance (MDoPI; WP2) were created. The rules can be also used to extrapolate the methodology to EU level. The work was carefully designed to allow a high interaction between the MINATURA land use experts and the project partners from the case study regions.

The present report covers the work undertaken in Task 1.3 of WP1.

2.2 THE OBJECTIVE OF TASK 1.3

To evaluate whether and to what extent new conflicts may rise, or constraints may expand or diminish in the future, expected land use changes for the coming decades were incorporated in the mapping of constrained and unconstrained mineral resources. Based on existing EU socio-economic pathways, MINATURA2020 developed a time series of future land use maps for the case study countries. Projecting future land use was undertaken using the iCLUE model (Verweij et al. in prep.). The iCLUE model is a flexible, generic land use modelling framework that allows scale and context sensitive specification for regional application. Applications of the iCLUE model and its precursors CLUE-S and Dyna-CLUE (Verburg et al. 1999) have been implemented around the world in many different environments. Typical applications include the simulation of deforestation, land degradation, urbanisation, land abandonment and integrated assessment of land cover change.

In MINATURA2020, the iCLUE model projected future land use in terms relevant to the context of mineral resources, showing possible future constraints. These projections will be used in WP2 to evaluate the implications for the requirements in the mapping framework. WP4 and WP5 can use these results to discuss the extent of constraints with other land use classes and users.

3. IMPLEMENTATION OF LAND USE CHANGE MODELLING IN MINATURA2020

In MINATURA2020, the iCLUE model was used to project future land use. We start this chapter with a general description of the iCLUE model (Section 3.1). A land use map for the initial or current situation is a prerequisite for the modelling with iCLUE. We describe the creation of this map for MINATURA2020 in Section 3.2. Furthermore, the model requires three types of input, namely the future demands for land use types in terms of area (Section 3.3.1), the suitabilities for the occurrence of land use types based on specific location characteristics (Section 3.3.2), and the allowed conversions of one land use type to another (Section 3.3.3).

We calculated the land use demands according to a 'business as usual' (BaU) scenario. This scenario represents a lack of additional land use policies in the future and demands were, hence, calculated as the extrapolation of past trends in areas of land use. Since these historical data are freely accessible only at country level or higher, we modelled future land use changes for countries as a whole (Hungary, Italy, Poland, Portugal, Slovenia, Sweden, United Kingdom), instead of just the case study areas. We additionally modelled future land use changes for the Netherlands, as a check since we know this country best. We do not present here the resulting maps for the Netherlands.

Next to the BaU scenario, we investigated implications of spatial restrictions in land use conversions for the United Kingdom. This was predominantly guided by the idea that conservation organisations will buy recently abandoned farmlands and manage these lands as traditional agricultural land. As this is expected to happen especially in (inter)nationally designated conservation areas, we designed different land use conversion rules for these areas, as opposed to the remainder of the United Kingdom.

3.1 DESCRIPTION OF THE iCLUE MODEL

The CLUE (Conversion of Land Use and its Effects) modelling framework is a tool to simulate the spatial allocation of land use changes (Verburg et al. 2002; Verburg and Veldkamp 2004; Verburg et al. 2004). This modelling framework combines different mechanisms that capture the various processes leading to changes in land use patterns. Depending on the study area and scenario conditions, the user can configure the model in different ways that provide the user with great flexibility in addressing specific scenarios or policy cases.

The model requires three types of input, namely the future demands for land use types in terms of area (number of grid cells), the suitabilities for the occurrence of land use types on specific locations, and the conversion possibilities of one land use type to another (Figure 1). For the land use demand, different types of input data are possible, ranging from simple trend extrapolations to complex economic models. The choice for a specific input type is very much dependent on the nature of the most important land use conversions taking place within the study area and the scenarios that need to be considered. The future land use demands need to specify, at least for the final year of model simulation, the area covered by the different land use types.

Each location (grid cell) is allocated to a specific land use type, based on a sample drawn from a probability distribution. For each location, the probability per land use type is calculated as the sum of a number of determinants. One determinant is the difference between the future demand and the actual area covered by a land use type. The larger this difference, the higher the 'demand weight' and the more important this determinant is in the probability.

Another determinant of the probability is the current location preference in response to location characteristics, such as soil type, slope angle, climate and accessibility of markets. These preferences can be estimated based on expert knowledge or by statistical models (e.g. logistic regression analyses of the land use pattern versus the location characteristics) and are expressed in terms of the suitability for the occurrence of a land use type on a specific location.

The third component of the probability reflects the conversion possibilities of land use types. Some land use conversions involve high costs and land owners are often reluctant to change land use as result of tradition or tenure conditions, which lowers the 'ease of change' or makes a conversion even impossible. Policies may restrict conversions outside specific areas (e.g. nature areas) or, on the contrary, may subsidise conversions at specific locations. It is possible to include these types of policies by changing the conversion probabilities at specific locations for the targeted land use types. Moreover, autonomous conversions such as natural vegetation succession may occur over time, which can be indicated in the model.

The total probability of a location for a specific land use type is the sum of these different factors. Differences between scenarios are obtained by differences in demand and the values that make up the total probability of the different locations.

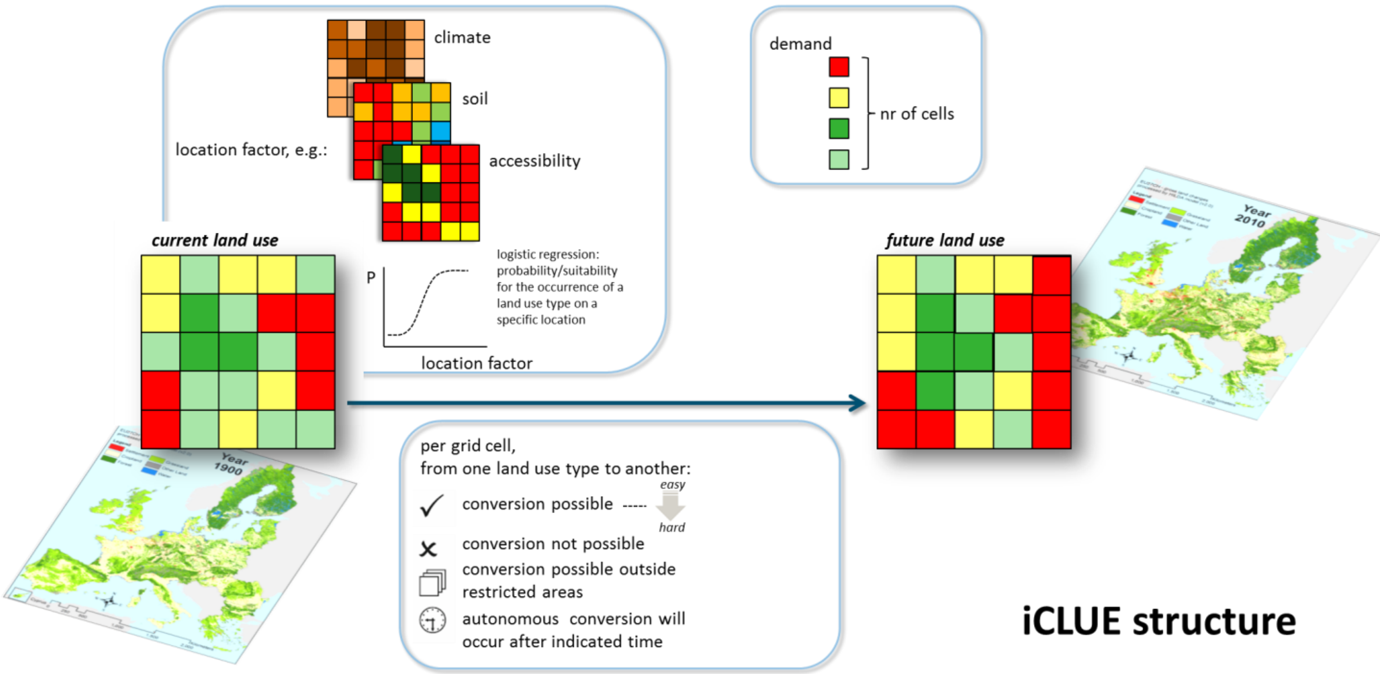

Figure 1. The structure of iCLUE with its three components determining the probability for allocation of a specific type of land use: future demands for land use types in terms of number of grid cells, the suitabilities for the occurrence of land use types on specific locations, and the conversion possibilities of one land use type to another

3.2 INITIAL LAND USE CLASSIFICATION AND MAP

Based on a thorough consideration of what is feasible and reliable in terms of modelling, what is available regarding demands and statistics, and what is needed, the following 17 classes were considered as being of relevance the project:

- forest
- arable land with annual crops
- arable land with permanent crops
- grassland
- non-grazed grassland

- shrubland
- non-grazed shrubland
- sparsely vegetated areas
- non-grazed sparsely vegetated areas
- built-up area
- open pit mineral extraction or dump sites
- inland wetlands
- glaciers and perpetual snow
- beaches, dunes and sand
- salines
- water and Intertidal flats
- heather and moorlands

From these 17 classes six were expected to be static in time and space (inland wetlands, glaciers and perpetual snow, beaches, dunes and sand, salines, water and Intertidal flats, and heather and moorlands). The remaining classes were dynamically modelled using the iCLUE model.

A spatial resolution of 100 m x 100 m was considered as the most detailed resolution needed to indicate future constrained and unconstrained mineral resources. However, for some relatively large case study countries (Sweden, UK, Poland), a spatial resolution of 300 m x 300 m was used. Although not all spatial databases were available at these levels, it was possible to perform all iCLUE runs at these resolutions.

Based on the following data sources the basic MINATURA2020 land use map was created using an expert knowledge-based approach with the following maps in QUICKScan (Cormont et al. 2016; Verweij et al. 2015):

- Copernicus high resolution Tree Cover Density map 2012 (http://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density)
- Copernicus high resolution imperviousness layer (http://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/view)
- A Cropland Mask (derived from Cropland management intensity, ETC SIA 2014)
- Corine land cover 2012 (http://land.copernicus.eu/pan-european/corine-land-cover)
- ESA CCI Land Cover dataset (v 1.6.1) (http://www.esa-landcover-cci.org/)
- Livestock densities for Cattle Goat and Sheep (http://livestock.geo-wiki.org/home-2/)

The high-resolution Copernicus layers where combined in a first step with the Cropland Mask and the ESA CCI Land Cover map to create a basic map showing a precise spatial division of forest/non-forest, built-up area, grassland and cropland. In a second step, this map was crossed with the Corine land use map aiming at the conversion of multi-thematic classes in Corine land cover (such as classes 141, 242 and 243[1]) into mono-thematic raster cells. That is, areas indicated as 'Green urban areas' on the Corine land use map could be reclassified into either forest or built-up area based on the Copernicus high resolution layers. In a last step, to distinguish between grazed and non-grazed agricultural land for the current situation, we used the livestock density map of, putting a threshold value of >10 heads per km2 for grazed land. The thus acquired land use map for the current situation was based on 2012 data.

[1] Class 141: Green urban areas,
Class 242: Complex cultivation patterns;
Class 243: Land principally occupied by agriculture, with significant areas of natural vegetation

3.3 iCLUE MODEL INPUT

3.3.1 Land use demands for 2012-2050

We calculated the demands only for the dynamic land use classes, hence not for inland wetlands, glaciers and perpetual snow, beaches, dunes and sand, salines, water and intertidal flats, nor heather and moorlands.

Demands were determined per country for the period 2012 to 2050, where the demanded areas in 2012 resemble those of the basic land use map. The demanded areas were expressed in numbers of grid cells. We calculated the demands according to a 'business as usual' (BaU) scenario. Below, we explain how we calculated the demands according to this scenario for each dynamic land use type. On the short term, land use statistics show a certain amount of fluctuation in area over time. Obviously, fitting a linear trend based on statistical data showing fluctuation for the past can result in considerable over- or underestimation of demand for land use. However, for this study we are interested in the spatial patterns following from long term trends. These represent a possible future without additional land use policies. Extrapolation using time series with just four time slots should be interpreted with more care, especially for land use classes with relatively small coverage. Area changes of these classes are within the uncertainty range of the model. In this case, this is especially valid for the two classes smallest in area, namely built-up area and open pit mineral extraction sites & dump sites. Normally, we would not take a land use class of this size into consideration with an (iCLUE) exercise like this, but since the project is about mineral deposits, we felt we could not neglect them.

Forest

FAOSTAT (http://faostat3.fao.org/download/R/RL/E) gives the area of forest (in 1000 ha) per country from 1990 (1992 for Slovenia) to 2013. For this BaU scenario, we chose to linearly project the forest area present per country into the future up to 2050 and to present this as the forest demand. The 2012 data on forest area present by FAOSTAT did not always resemble the area derived from the basic land use map. In these cases, we rescaled the projection by starting it from the basic land use map area.

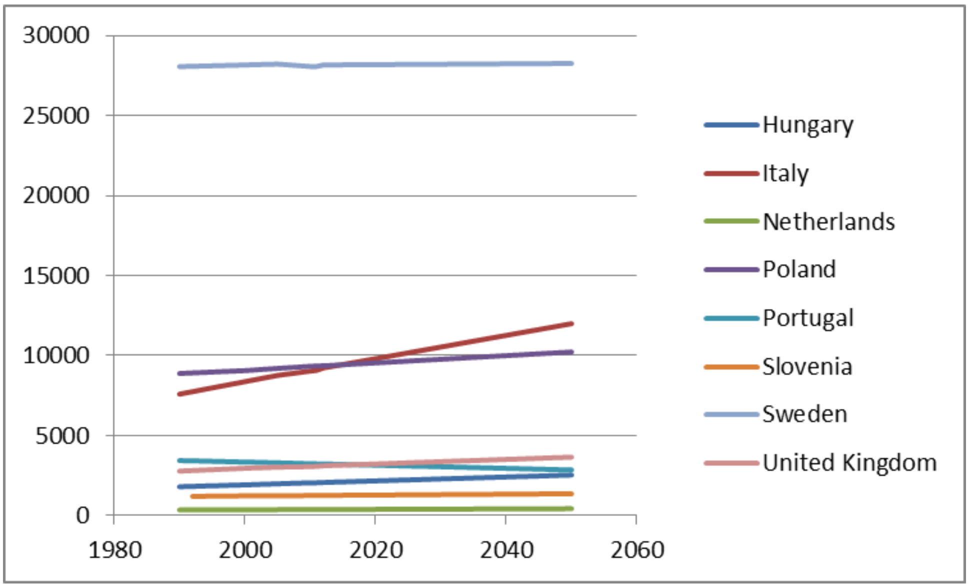

Figure 2. The forest area (in 1000 ha) per country from 1990 (1992 for Slovenia) to 2013 and the extrapolation of these historical trends up to 2050 (in agreement with other land use change studies, such as Lavalle et al. 2011)

Arable land with annual crops

FAOSTAT (http://faostat3.fao.org/download/R/RL/E) gives the area of temporary crops (in 1000 ha) per country from (the unfortunately relatively short period of) 2001 to 2013. For this BaU scenario, we chose to linearly project the temporary crops area present per country into the future up to 2050 and to present this as the demand for arable land with annual crops. The 2012 data on temporary crops area presented by FAOSTAT did not always resemble the area for arable land with annual crops derived from the basic land use map. In these cases, we rescaled the projection by starting it from the basic land use map area.

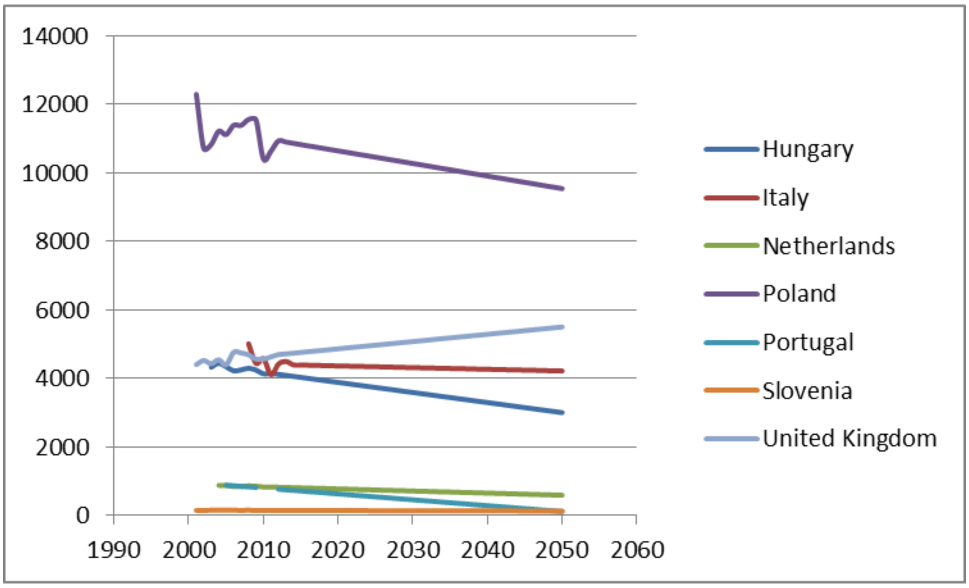

Figure 3. The annual crop area (in 1000 ha) per country from 2001 to 2013 and the extrapolation of these historical trends up to 2050

Arable land with permanent crops

FAOSTAT (http://faostat3.fao.org/download/R/RL/E) gives the area of permanent crops (in 1000 ha) per country from 1961 (1992 for Slovenia) to 2013. For this BaU scenario, we chose to linearly project the permanent crops area present per country from 1990 into the future up to 2050 and to present this as the demand for arable land with permanent crops. The 2012 data on permanent crops area present by FAOSTAT did not always resemble the area for arable land with permanent crops derived from the basic land use map. In these cases, we rescaled the projection by starting it from the basic land use map area.

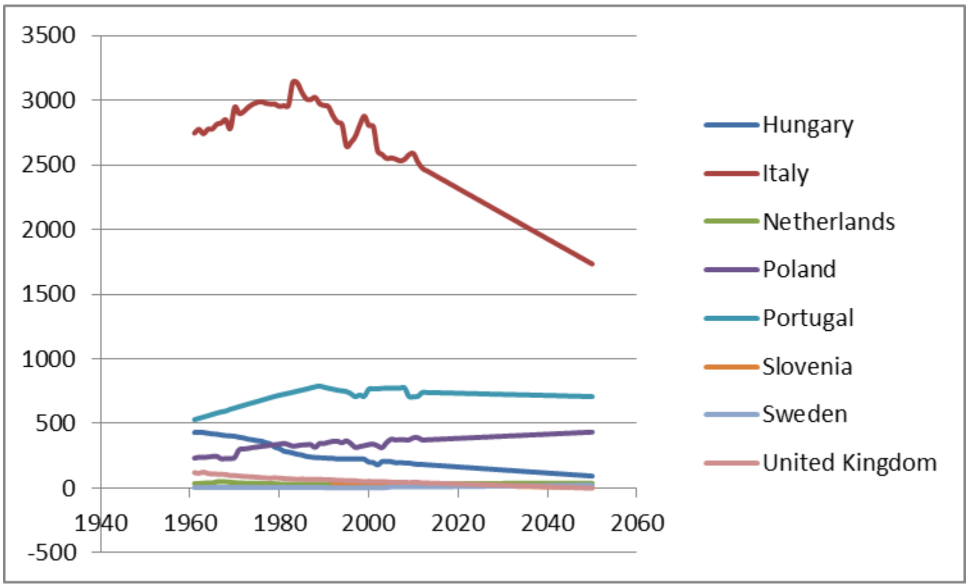

Figure 4. The permanent crop area (in 1000 ha) per country from 1961 (1992 for Slovenia) to 2013 and the extrapolation of these historical trends up to 2050.

Grazed and non-grazed grassland

FAOSTAT (http://faostat3.fao.org/download/R/RL/E) gives the area of permanent meadows and pastures (in 1000 ha) per country from 1961 (1992 for Slovenia) to 2013. For this BaU scenario, we chose to linearly project the permanent meadows and pasture area present per country from 1990 into the future up to 2050. This represents the demand for both grazed and non-grazed grassland together.

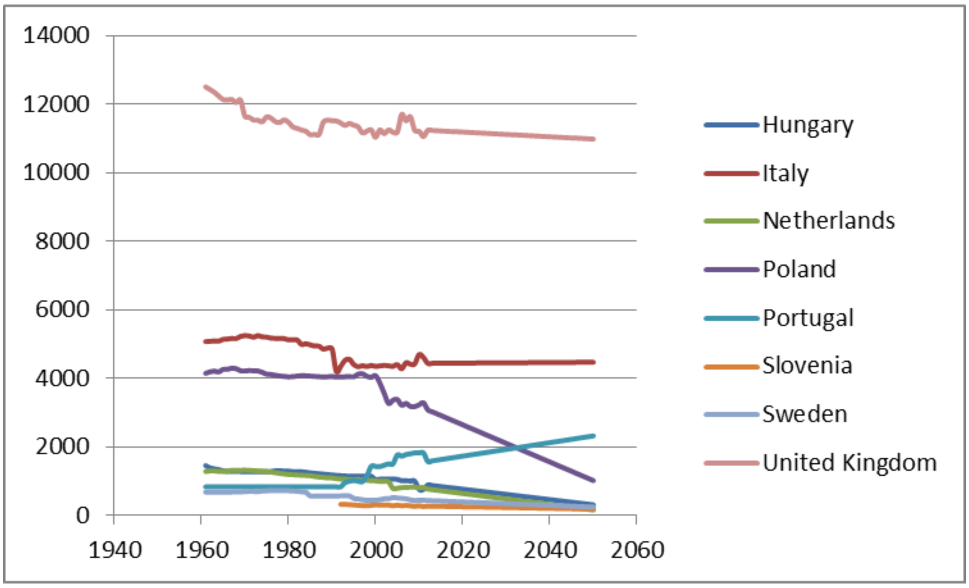

Figure 5. The permanent meadow and pasture area (grazed and non-grazed grassland together; in 1000 ha) per country from 1961 (1992 for Slovenia) to 2013 and the extrapolation of these historical trends up to 2050.

To distinguish between grazed and non-grazed grassland for the current situation, we used the livestock density map of http://livestock.geo-wiki.org/home-2/, putting a threshold value of >10 heads per km^2 for grazed land. To distinguish between grazed and non-grazed grassland for the future, we used two FAOSTAT datasets:

- The number of live animals (heads for buffaloes, cows, sheep and goats) per country from 1961 (1992 for Slovenia) – http://faostat3.fao.org/download/Q/QA/E
- The number of live animals (heads for buffaloes, cows, sheep and goats) per ha of agricultural area per country from 1961 (1992 for Slovenia) - http://faostat3.fao.org/download/E/EK/E
-

From these two datasets, we calculated the grazed agricultural area (ha) per country from 1961 (1992 for Slovenia) to 2013. We linearly projected the grazed agricultural area present per country from 1961 into the future up to 2050 and presented this as the demand for grazed agricultural land.

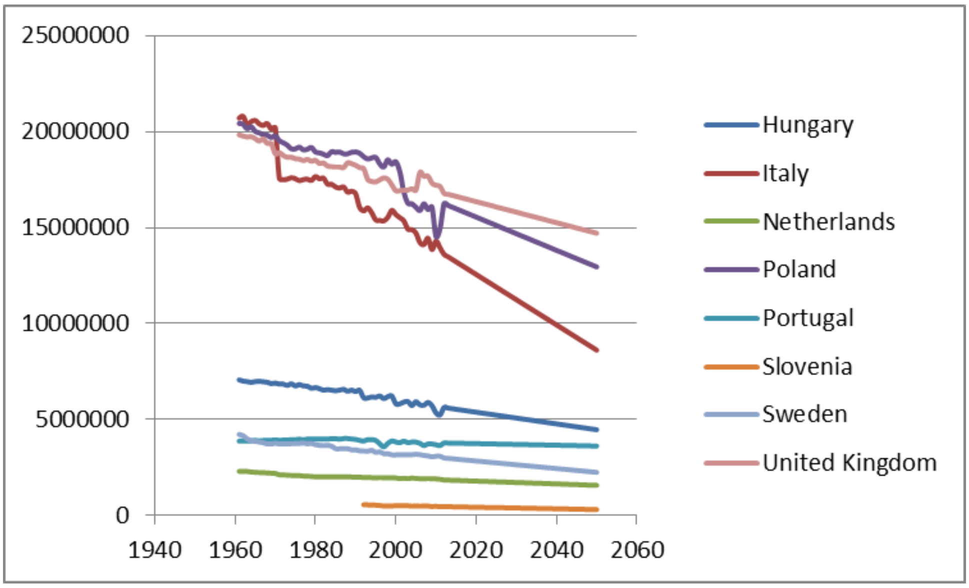

Figure 6. The grazed agricultural area (in ha) per country from 1961 (1992 for Slovenia) to 2013 and the extrapolation of these historical trends up to 2050

The 2012 value for agricultural grazed area from the calculation with FAOSTAT data did not always resemble the area for agricultural grazed land derived from the basic land use map. In these cases, we rescaled the projection by starting it from the basic land use map area.

We used the ratio between the current area of grazed grassland (derived from the basic land use map) and the 2012 value for grazed agricultural area, in combination with the (rescaled) 2050 value for grazed agricultural area to calculate the demand for grazed grassland per country for 2050. The remainder of the demanded grassland for 2050, or a minimum of 1 ‰ of the 2012 value for non-grazed grassland, was assigned as the demand for non-grazed grassland for 2050.

Grazed and non-grazed shrubland

Since the historical development of shrubland is not known from census data, we used the area of shrubland (in ha) on the Corine land use maps from 1990, 2000, 2006 and 2012 and linearly projected this into the future up to 2050. This represents the demand for both grazed and non-grazed shrubland together. For Sweden, we assumed the value to be constant from 2030, since the area would drop too much otherwise.

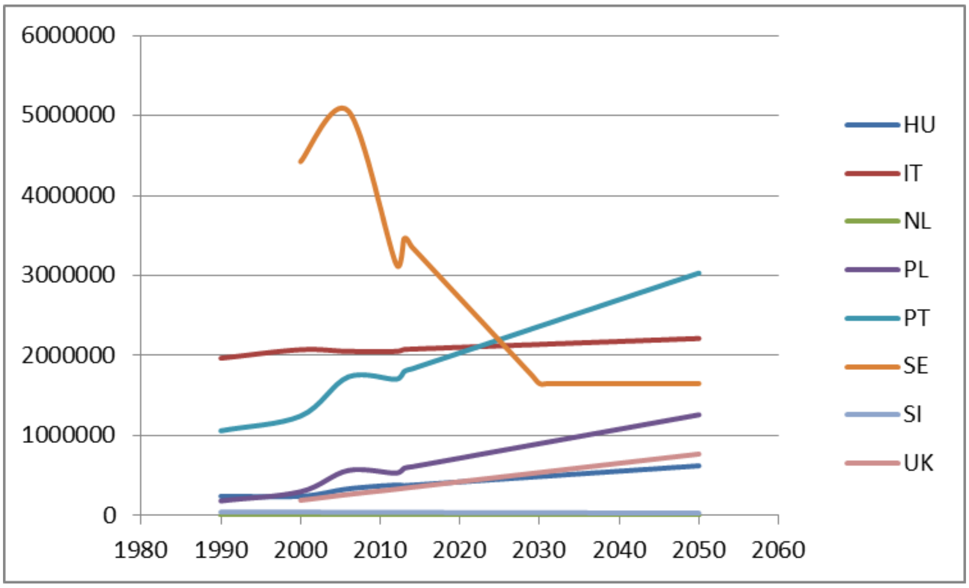

Figure 7. The shrubland area (in ha) per country for 1990, 2000, 2006 and 2012, and the extrapolation of these historical trends up to 2050

To distinguish between grazed and non-grazed shrubland for the current situation, we used the livestock density map of http://livestock.geo-wiki.org/home-2/, putting a threshold value of >10 heads per km^2 for grazed land.

We used the ratio between the current area of grazed shrubland (derived from the basic land use map) and the 2012 value for grazed agricultural area, in combination with the (rescaled) 2050 value for grazed agricultural area to calculate the demand for grazed shrubland per country for 2050. The remainder of the demanded shrubland (grazed and non-grazed together) for 2050, or a minimum of 1 ‰ of the 2012 value for non-grazed shrubland, was assigned as the demand for non-grazed shrubland for 2050.

Grazed and non-grazed sparsely vegetated area

Since the historical development of sparsely vegetated area is not known from census data, we used the sparsely vegetated area (in ha) on the Corine land use maps from 1990, 2000, 2006 and 2012 and linearly projected this into the future up to 2050. This represents the demand for both grazed and non-grazed sparsely vegetated area together. For the United Kingdom, we assumed the value to be constant from 2030, since the area would drop too much otherwise.

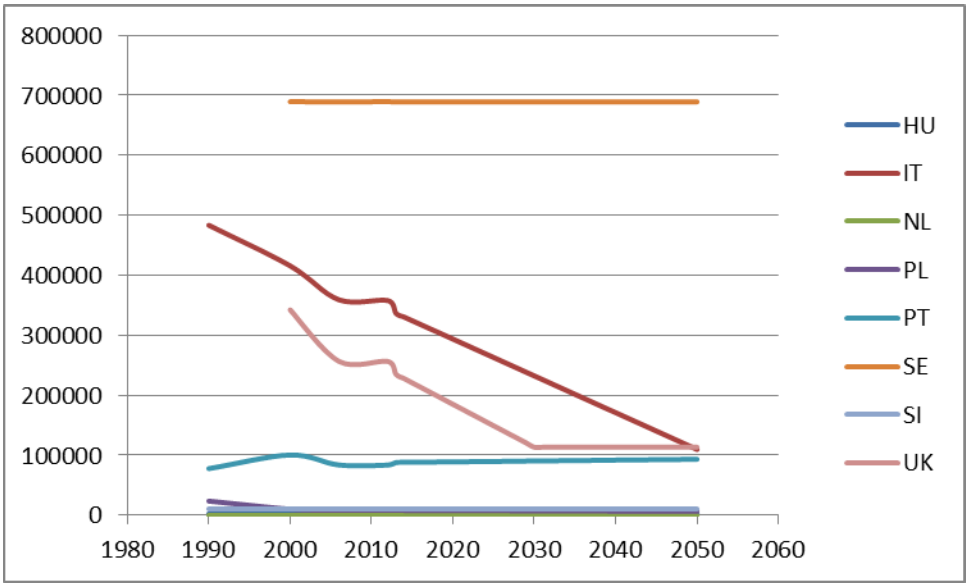

Figure 8. The sparsely vegetated area (in ha) per country for 1990, 2000, 2006 and 2012, and the extrapolation of these historical trends up to 2050

To distinguish between grazed and non-grazed sparsely vegetated area for the current situation, we used the livestock density map of http://livestock.geo-wiki.org/home-2/, putting a threshold value of >10 heads per km² for grazed land.

We used the ratio between the current sparsely vegetated area (derived from the basic land use map) and the 2012 value for grazed agricultural area, in combination with the (rescaled) 2050 value for grazed agricultural area to calculate the demand for grazed sparsely vegetated area per country for 2050. The remainder of the demanded sparsely vegetated area (grazed and non-grazed together) for 2050, or a minimum of 1 ‰ of the 2012 value for non-grazed sparsely vegetated area, was assigned as the demand for non-grazed sparsely vegetated area for 2050.

Built-up area

We used the urban area (in ha) on the Corine land use maps from 1990, 2000, 2006 and 2012 to specify the historical development, and linearly projected this into the future up to 2050. This represents the demand for built-up area.

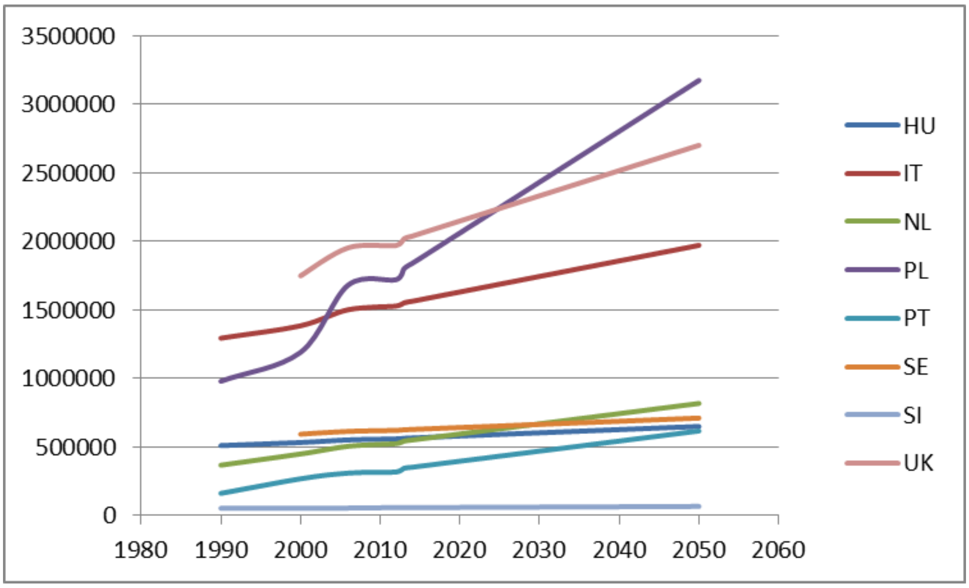

Figure 9. The urban area (in ha) per country for 1990, 2000, 2006 and 2012, and the extrapolation of these historical trends up to 2050

The 2012 value for urban area from the Corine land use map did not always resemble the built-up area from the basic land use map. Minor changes are caused by areas indicated as green urban area on the Corine land use map, which we reclassified into either forest or built-up area based on the Copernicus high resolution forest layer http://land.copernicus.eu/pan-european/high-resolution-layers/forests and imperviousness layer http://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/view. In these cases, we rescaled the projection by starting it from the basic land use map area.

Open pit mineral extraction sites or dump sites

We used the mining area (in ha) on the Corine land use maps from 1990, 2000, 2006 and 2012 to indicate the historical development, and linearly projected this into the future up to 2050. This represents the demand for open pit mineral extraction sites or dump sites.

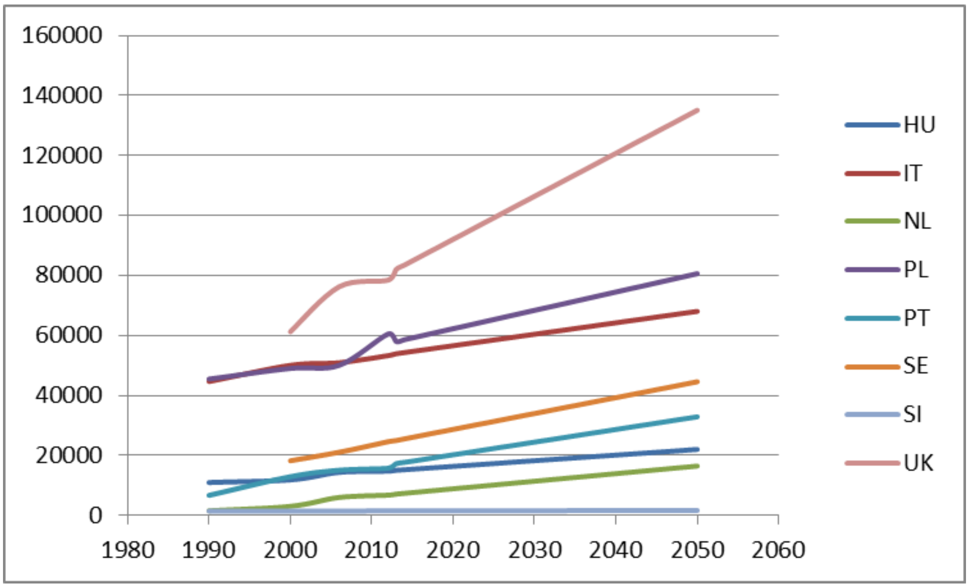

Figure 10. The mining area (in ha) per country for 1990, 2000, 2006 and 2012, and the extrapolation of these historical trends up to 2050

Rescaling of demands

The demands for all land use types as described above were summed and compared with the total country areas. For some countries, the demands exceeded the total country area. In these cases, we rescaled the demands proportionally. For other countries, the demands did not yet sum up to the total country area. For these countries, we redistributed the demands, taking the relative percentages of increase or decrease compared to 2012 into account.

In Annex 1, the demands used in the simulations are listed per case study country and shown as stacked bar charts.

3.3.2 Spatial location characteristics used in the iCLUE modelling

In Annex 2, the spatial location characteristics that determine the current land use are listed with their origin. We selected these variables based on the spatial and thematic consistency over the EU as a whole. All listed variables were available on a resolution comparable to the initial 2012 land use map. We searched for variables that are hypothetically relevant to the land use classes and we used similar land use change projections from previous FP6/FP7-projects as a starting point (e.g. Eururalis; http://www.eururalis.eu/, VOLANTE; http://www.volante-project.eu/). Spatial variables used are biophysical factors (elevation, slope, topographic wetness, soil fertility, climate, etc.), socio-economic factors (population density, urban night light index), current distribution of land use, and accessibility, i.e. travel time and distance maps (to coast, nature areas, airports, etc.).

3.3.3 Allowed land use conversions

We calculated the land use changes according to a 'business as usual' (BaU) scenario, which represents a lack of additional land use policies in the future. We therefore basically allowed the conversions between all land use types. However, some land use conversions involve high costs and land owners are often reluctant to change the land use. The 'ease of change' differs therefore between land use types as follows:

- Forest, arable land with annual crops, arable land with permanent crops, grassland, shrubland: very easy
- Non-grazed grassland, built-up area: easy
- Non-grazed shrubland, sparsely vegetated areas, non-grazed sparsely vegetated areas, open pit mineral extraction sites or dump sites: hard

Policies may restrict conversions outside specific areas (e.g. nature areas) or, to the contrary, may subsidise conversions at specific locations. Next to the BaU scenario, we therefore investigated implications of spatial restrictions in land use conversions for the United Kingdom. This was predominantly guided by the current perceived trend that conservation organisations will buy recently abandoned farmlands and manage these lands as traditional agricultural land. As this is expected to happen especially in (inter)nationally designated conservation areas, we designed different land use conversion rules for these areas, as follows:

*Table 1. Land use conversions between the following land use types are **not** allowed in (inter)nationally designated conservation areas*

From	To
arable land with annual crops	built-up area
arable land with annual crops	forest
arable land with annual crops	open pit mineral extraction sites or dump sites
arable land with annual crops	non-grazed shrubland
arable land with annual crops	shrubland
arable land with annual crops	non-grazed sparsely vegetated areas
arable land with annual crops	sparsely vegetated areas
built-up area	arable land with annual crops
built-up area	open pit mineral extraction sites or dump sites

From	To
forest	arable land with annual crops
forest	built-up area
forest	non-grazed grassland
forest	grassland
forest	open pit mineral extraction sites or dump sites
forest	arable land with permanent crops
forest	non-grazed shrubland
forest	shrubland
forest	non-grazed sparsely vegetated areas
forest	sparsely vegetated areas
non-grazed grassland	arable land with annual crops
non-grazed grassland	built-up area
non-grazed grassland	grassland
non-grazed grassland	open pit mineral extraction sites or dump sites
non-grazed grassland	arable land with permanent crops
non-grazed grassland	non-grazed shrubland
non-grazed grassland	shrubland
non-grazed grassland	sparsely vegetated areas

grassland	arable land with annual crops
grassland	built-up area
grassland	forest
grassland	open pit mineral extraction sites or dump sites
grassland	arable land with permanent crops
grassland	non-grazed shrubland
grassland	shrubland
open pit mineral extraction sites or dump sites	arable land with annual crops
open pit mineral extraction sites or dump sites	built-up area
open pit mineral extraction sites or dump sites	arable land with permanent crops
arable land with permanent crops	arable land with annual crops
arable land with permanent crops	built-up area
arable land with permanent crops	forest
arable land with permanent crops	open pit mineral extraction sites or dump sites
arable land with permanent crops	non-grazed shrubland
arable land with permanent crops	shrubland
arable land with permanent crops	sparsely vegetated areas
non-grazed shrubland	arable land with annual crops
non-grazed shrubland	built-up area
non-grazed shrubland	grassland
non-grazed shrubland	open pit mineral extraction sites or dump sites
non-grazed shrubland	arable land with permanent crops
non-grazed shrubland	shrubland
non-grazed shrubland	sparsely vegetated areas
shrubland	arable land with annual crops
shrubland	built-up area
shrubland	grassland
shrubland	open pit mineral extraction sites or dump sites
shrubland	arable land with permanent crops
non-grazed sparsely vegetated areas	arable land with annual crops
non-grazed sparsely vegetated areas	built-up area
non-grazed sparsely vegetated areas	grassland
non-grazed sparsely vegetated areas	open pit mineral extraction sites or dump sites
non-grazed sparsely vegetated areas	arable land with permanent crops
non-grazed sparsely vegetated areas	shrubland
non-grazed sparsely vegetated areas	sparsely vegetated areas
sparsely vegetated areas	arable land with annual crops
sparsely vegetated areas	built-up area
sparsely vegetated areas	open pit mineral extraction sites or dump sites
sparsely vegetated areas	arable land with permanent crops

In Annex 3, an iCLUE input file (‘properties file’) used in the simulations is shown as example.

4. RESULTING MAPS AND CHARTS

The MINATURA2020 simulations with iCLUE resulted in three types of output maps per case study country for each year between 2012 and 2050:

- Land use maps
- Land use age maps
- Maps indicating per grid cell the number of changes between land use types

With iCLUE, these maps can easily be converted to pie charts, stacked bar charts and gain-loss bar charts.

The most important maps and charts are shown in Annex 4. Below, we present snapshots of the maps and charts that show the storylines from the projections for a few case study countries.

4.1 HUNGARY:

We expect annual cropland areas to diminish, where forest and shrubland areas increases. This takes place mainly at the edges of existing forest and shrubland patches. Consequently, hardly any land use changes occur in the main agricultural basins of the Danube and Tisza rivers. From the model perspective, these patterns are mainly driven by the cropping and tree cover density, the distance to the current forest areas and the elevation.

4.2 ITALY/EMILIA-ROMAGNA:

For Italy as a whole, we expect that annual crop areas will change into grassland, which subsequently will develops into shrubland. This reflects the process of agricultural land abandonment. However, in the case study area Emilia-Romagna, the opposite process is expected to occur: agricultural areas will expand in the current agricultural zone (river Po valley). This intensification is expected to occur at the expense of forest areas and shrublands. From the model perspective, these patterns are mainly driven by the tree cover density (especially low in Emilia-Romagna, which leads to the disappearance of forest patches), the cropping frequency over the past 15 years and the population density.

The main minerals in Emilia-Romagna are sand and gravel. Exploitable deposits are expected to be increasingly constrained by the intensifying agriculture. Natura 2000 areas are mainly located near the coast (wetlands), and therefore are not constraining the sand and gravel deposits, neither at this moment, nor in the future.

4.3 POLAND:

Looking at Poland, with a special focus on the Dolnoslaskie voivodeship, we expect quite an uneven spatial distribution of land use changes and driving processes. Mainly in valleys, urban expansion is expected to occur, while in other areas land abandonment will be a predominant process. The most important driving processes are expected to be climate change, shifting habitats, a tendency towards more land protection, and urban sprawl linked to increased accessibility.

4.4 PORTUGAL:

For Portugal, we expect a clear segregation in land use change: along the coast, extensive urban sprawl is expected to occur, while in inland annual crop areas will change into grassland, which subsequently will develop into shrubland. The latter reflects the process of agricultural land abandonment. Natura 2000 areas are expected to consist mainly of shrublands. From the model perspective, these patterns are mainly driven by distance to the coast, population density (strongly related to global night lights index, impervious area and cropping frequency (agricultural land abandonment is lowest where cropping frequency is highest).

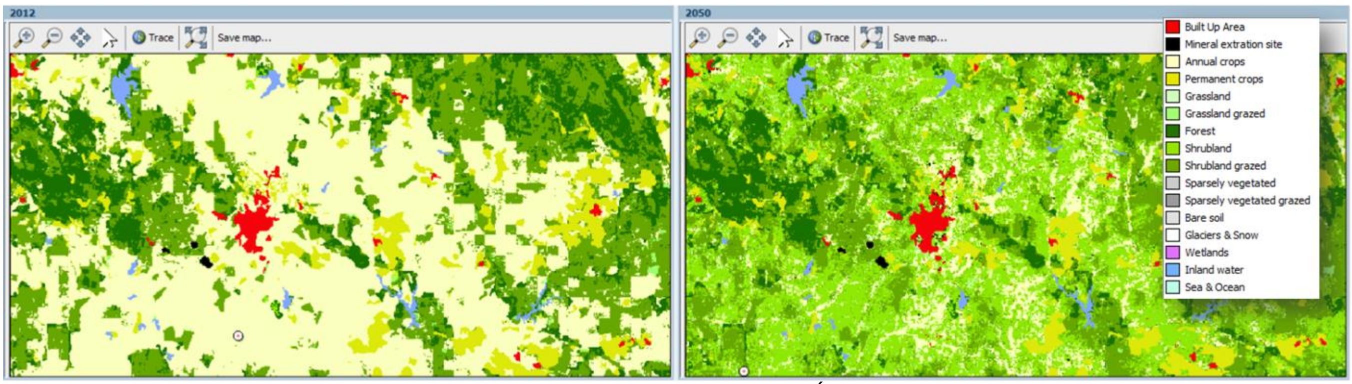

Figure 11. Extreme expansion of shrubland (abandoned land) near Évora, Portugal; left map 2012, right map 2050

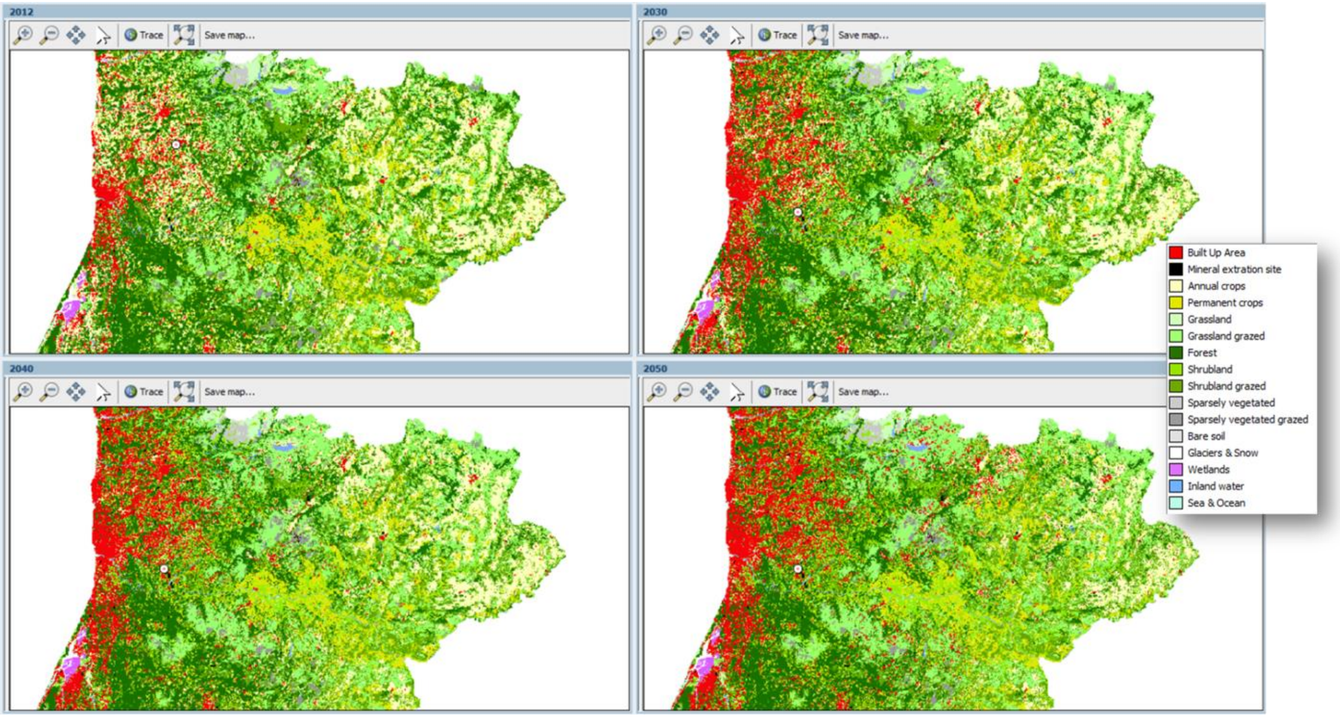

Figure 12. Extensive urban sprawl along the Portuguese coast near Porto; upper left map 2012, upper right map 2030, lower left map 2040, lower right map 2050

4.5 SLOVENIA:

For Slovenia, we expect the forest area to increase at the expense of agricultural land (grazed grassland and shrubland, and arable land with annual or permanent crops). This takes place mainly at the edges of existing forest patches. To a lesser extent, built-up area increases, mainly at the edges of current settlements in river valleys. Forest is a dominant class in Slovenia (>60% of the current land use), which makes forest-related factors (forest density) drive the land use allocation patterns forest density, in combination with grazing density and urban sprawl.

4.6 SWEDEN:

We expect most land use changes to occur in the vicinity of Stockholm. Concerning the arable land, annual crops will be replaced by permanent crops (e.g. willows as energy crop, Trubins 2013). In the rest of Sweden including the case study area Norbotten, the forest area is expected to increase. This will occur at the edges of currently forested land. Forest is a dominant class in Sweden (almost 70% of the current land use), which makes forest-related factors (forest density) drive the land use allocation patterns forest density, in combination with grazing density and urban sprawl.

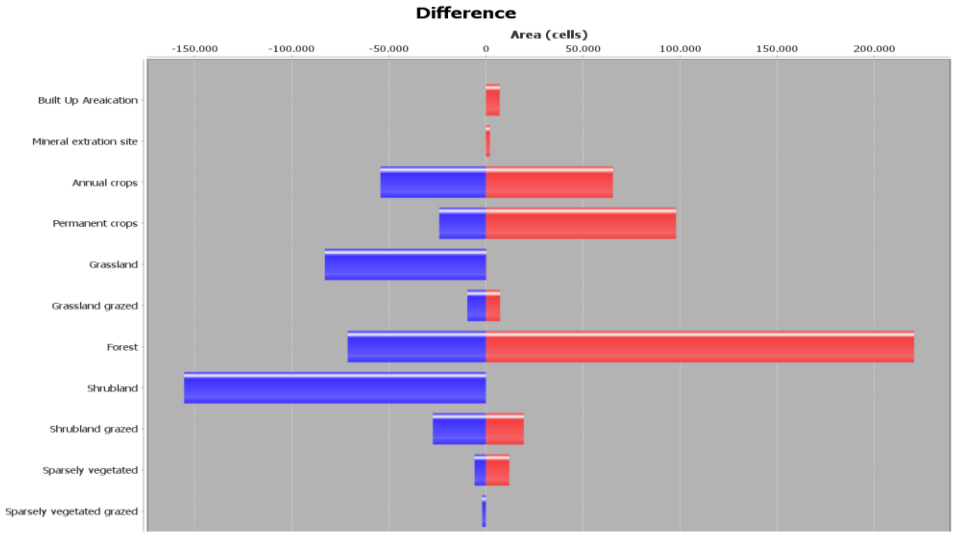

Figure 13. Overview of the amount of land use change and shift in Sweden. Area gained (red) and area lost (blue) are shown per land use class. If area is both gained and lost for a specific land use class, this land use is spatially shifted over time.

4.7 UNITED KINGDOM:

For the United Kingdom, it is difficult to see clear spatial patterns from the sequence of land use maps. It is the only country modelled, where forest, shrubland, annual cropland and built-up areas are expected to increase. As the probabilities for allocation of these land uses on specific locations are equally high, there is competition for these land uses. This results in a speckled, diffuse spatial pattern. From the land use maps we can even see that occasionally some built up area pixels are transformed into agricultural land, while new built-up areas appear on other places. This is an unexpected result (which on forehand could be turned off in the model (by rule)), but it indicates that the model has difficulties to allocate the land use due to strong completion between land use classes. From the model perspective, these patterns are mainly driven by accessibility, population density, impervious area, and cropping and grazing density.

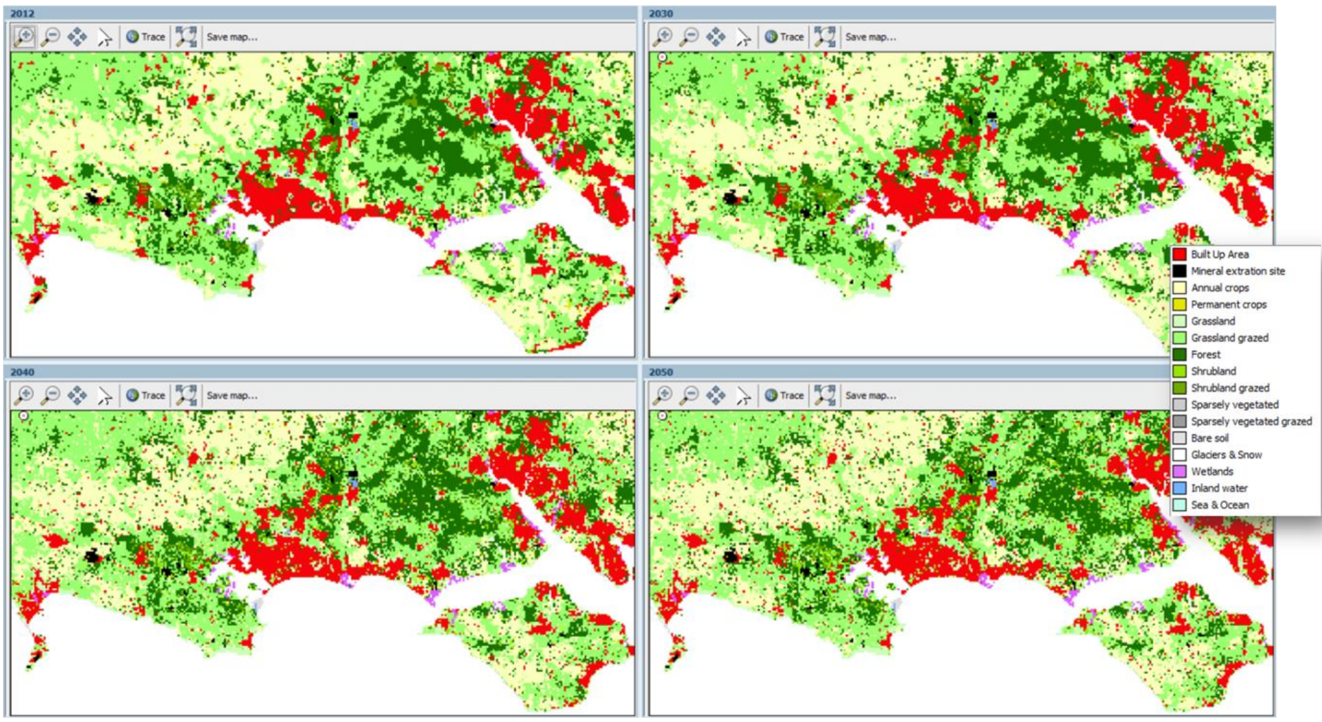

Figure 14. Speckled increase of forest and built-up area in the agricultural land of South England near Southampton due to the high competition for land; upper left map 2012, upper right map 2030, lower left map 2040, lower right map 2050

5. VERIFICATION WITH CASE STUDY REPRESENTATIVES

To verify our predictions based on the iCLUE maps, we organized a workshop with case study representatives from the MINATURA2020 project in La Palma on 27 and 28 September 2016. The list of participants of the workshop is presented in Annex 5.

The overall objective of this workshop was to support the development of a harmonized mapping framework by future-oriented thinking. During the workshop, the BaU land use scenario was reviewed for the case study countries by analysing the resulting iCLUE maps and charts. Two SRES (Special Report on Emissions Scenarios) derived scenarios (Nakicenovic & Swart, 2000) were then integrated into the discussions to understand how raw materials extraction and use would evolve differently in different future contexts.

The modelled scenario seemed plausible to all participants. Generally, urban sprawl was seen as major future constraint to mineral resources. However, land abandonment was judged in divergent ways. In some countries (e.g. Poland), the extended land abandonment can give room for extraction of resources. However, in the UK, there may be a high risk that these grounds will be bought by conservation organisations and will be managed extensively as traditional agricultural land, which consequently gives no room for extraction of resources. As this is expected to happen especially in (inter)nationally designated conservation areas, we decided to design different land use conversion rules for these areas, as indicated in Table 1.

The land use maps resulting from the scenario with restrictions at nature areas were compared with the outcomes of the scenario modelled initially (Figure 15). As can be expected, we see more land use changes occurring outside conservation areas than inside these areas in the scenario with spatial restrictions. The demand for more built-up areas increases in both, within and without conservation areas, and is allocated to the close neighbourhood of existing cities. Similarly, new forest patches are expected to arise in the close vicinity of existing forests. Thus, the scenario with spatial restrictions leads to a less speckled spatial pattern. Consequently, changes in agricultural areas are expected to be minor.

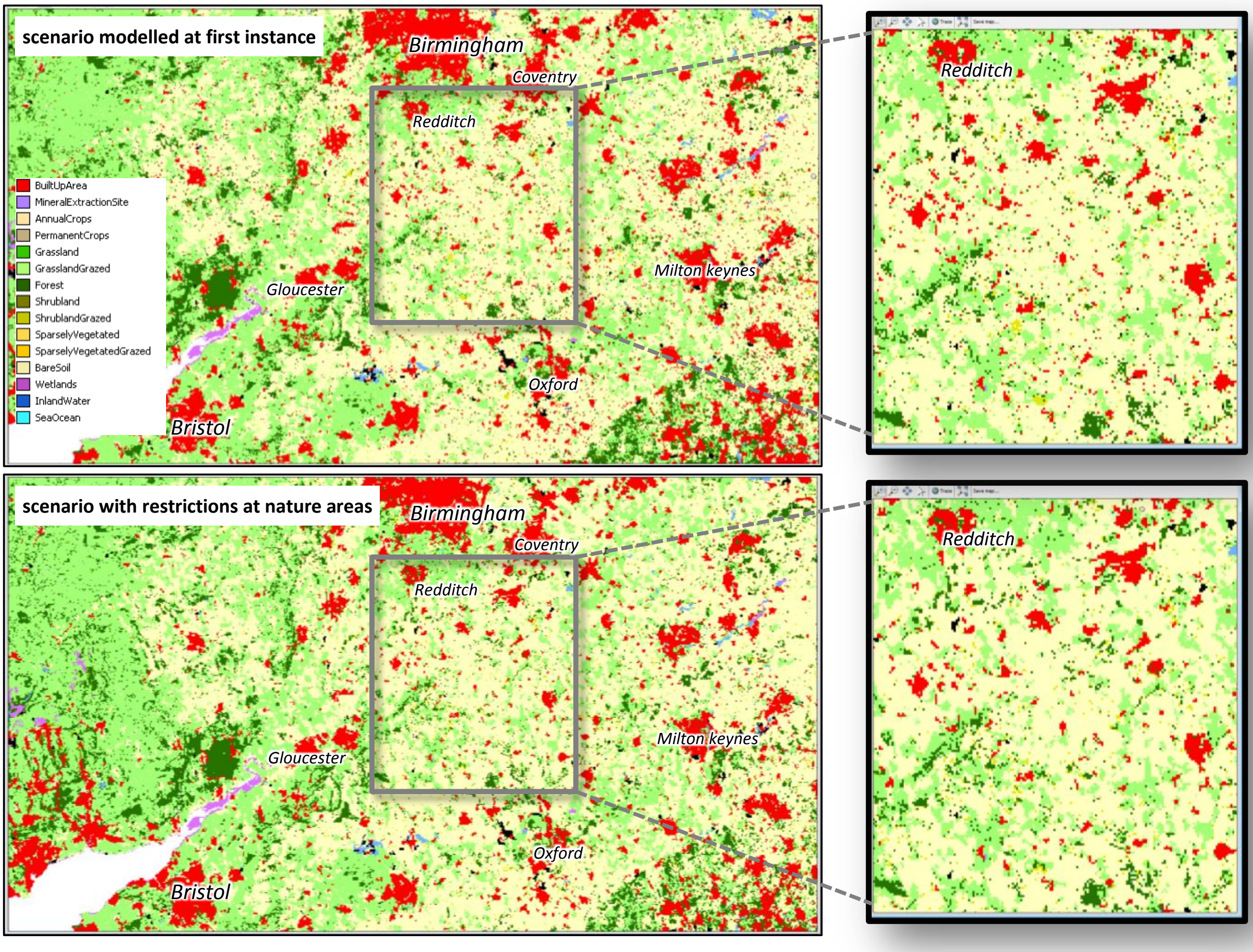

Figure 15. Land use map resulting from the scenario with restrictions at nature areas compared with the land use map of the scenario modelled at first instance (2050)

6. LESSONS LEARNED

During the La Palma workshop, future scenarios were discussed to understand how raw materials extraction and use would evolve differently in different future contexts. This helped to identify a 'desirable future' with regards to MDoPI. This would be a future where socio-economic and governance developments leads to an attitude of responsibility for mined-out sites, resulting in orderly closure rather than abandonment and to remediation and return to a desirable land-use. In this desirable future MDoPI sites and Natura 2000 sites are not in conflict, but in fact Natura 2000 offers an additional framework of protection to MDoPI wherever they overlap (referred to as "working with nature", "building with nature", "mining with nature" during our discussions).

Suggestions from the workshop:

- Strategic project goals (long-term reduction) separate from immediate 'conflict issues'. If we are to propose a 'framework' that has a chance of still being in effect around 2050 then this can only be formulated now on a fairly strategic level, and we must avoid getting lost in details.
- These strategic goals must, however, be based on real life experience from the present (including tacit/qualitative expert knowledge) and must consider the various conflicts that can emerge around today's permitting and licensing procedures as a baseline.

- The strategic framework should consider the 'sustainability principle' i.e. the goal is to protect mineral deposits for future generations. In this sense 'temporary sterilisation' (in the present) may be considered a positive development as this would provide additional protection on a longer timeframe. One example that was discussed is, if agricultural land is converted into shrubland due to land abandonment and is subsequently populated by protected species. This makes permitting in the present difficult (or impossible), but does not necessarily sterilise mineral deposits for future generations.
- Conversion from e.g. agricultural use to mineral extraction could be decided on financial terms (i.e. costs and benefits) and according to local/national/EU regulations (and effective land use plans), with MDoPI being a part of the regulatory framework.
- The emphasis of the immediate project work should be on the finalisation of a MDoPI classification framework (that defines what is a MDoPI and what is not) and the formulation of recommendations for the subsequent protection of MDoPI from (near) irreversible land use changes (in line with the recommendations above), working along (rather than competing) with other nature conservation instruments.

7. FOLLOW-UP

The iCLUE MINATURA2020 projections indicated possible future constraints to mineral resources. These projections will be used in WP2 to evaluate the implications for the requirements in the mapping framework. WP4 and WP5 can use these results to discuss the extent of constraints with other land use classes and users.

8. ACKNOWLEDGEMENTS

We thank the participants of the La Palma workshop for their active participation and the fruitful discussions. We thank Johnny te Roller for his contribution in the development of the iCLUE model.

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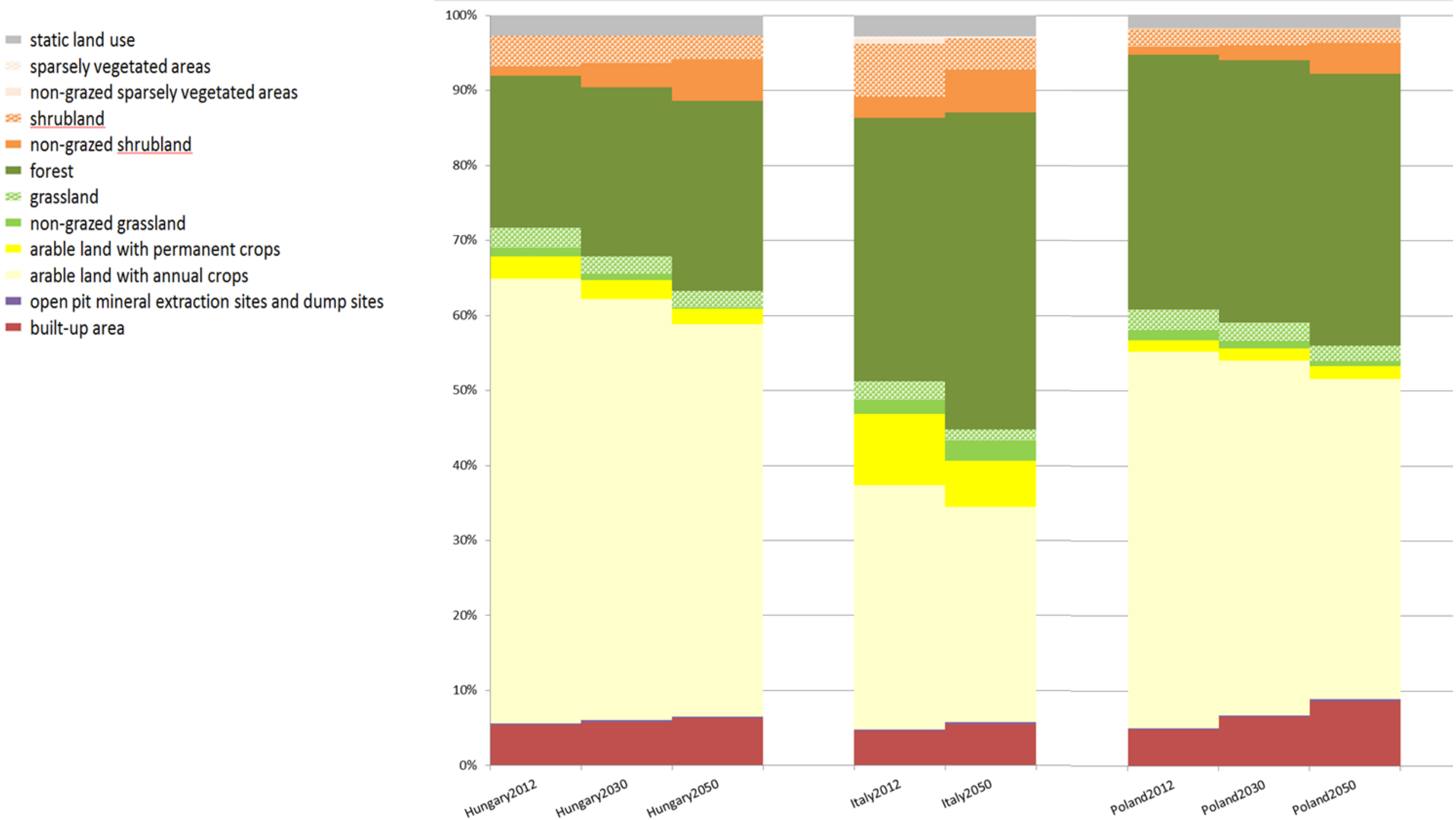
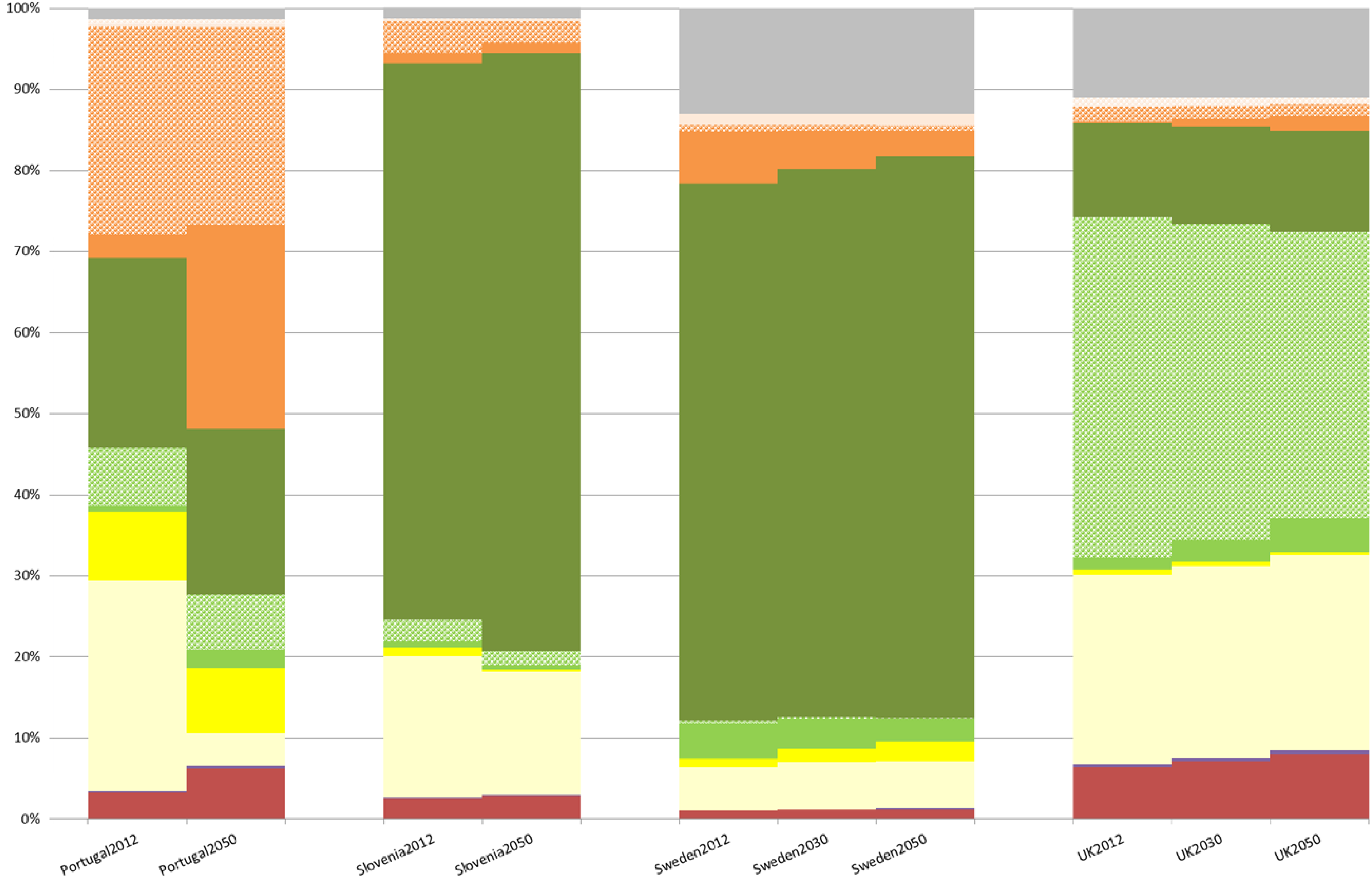
ANNEX 1 – DEMANDS USED IN THE SIMULATIONS LISTED PER CASE STUDY COUNTRY AND SHOWN AS STACKED BAR CHARTS




100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Portugal2012
Portugal2050
Slovenia2012
Slovenia2050
Sweden2012
Sweden2030
Sweden2050
UK2012
UK2030
UK2050

ANNEX 2 – SPATIAL LOCATION CHARACTERISTICS THAT DETERMINE THE CURRENT LAND USE

File name	Explanation	Link/Source
BioGeographRegion.tif	Biogeographic regions	http://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe
CD_Cities_25plus_250m.tif	Cost distance (travel time) to cities >25.000 inhabitants	Cities: World Cities provides a base map layer of the cities for the world. The cities include national capitals, provincial capitals, major population centers, and landmark cities. https://www.arcgis.com/home/item.html?id=dfab3b294ab24961899b2a98e9e8cd3d
CD_Cities_50plus_250m.tif	Cost distance (travel time) to cities >50.000 inhabitants	Cities: World Cities provides a base map layer of the cities for the world. The cities include national capitals, provincial capitals, major population centers, and landmark cities. https://www.arcgis.com/home/item.html?id=dfab3b294ab24961899b2a98e9e8cd3d
CD_MainHarbors_250m.tif	Cost distance (travel time) to main harbors (World Port Index)	http://msi.nga.mil/MSISiteContent/StaticFiles/NAV_PUBS/WPI/WPI_Shapefile.zip
CD_MUA_1000plus_250m.tif	Cost distance to morphological urban areas >1.000.000 inhabitants	MUA: http://database.espon.eu/db2/resource?idCat=43
CD_MUA_100plus_250m.tif	Cost distance to morphological urban areas >100.000 inhabitants	MUA: http://database.espon.eu/db2/resource?idCat=43
CD_MUA_500plus_250m.tif	Cost distance to morphological urban areas >500.000 inhabitants	MUA: http://database.espon.eu/db2/resource?idCat=43
CDDA_IUCN_V2.tif	National protected areas	http://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-11
country_mask.tif	Country	ESRI, World Countries represents the boundaries for the countries of the world as they existed in December 2014: https://www.arcgis.com/home/item.html?id=3864c63872d84aec91933618e3815dd2
Cropland_YN_1km2.tif	Cropland present per gridcel yes/no, derved from cropland management	ETC SIA 2014, Assessment of European Ecosystem pressures - Concept, Data, and Methodology; Final Report – task 18413_Ecosystem_pressure
cropping_frequency.tif	Number of years with cropland activity per gridcel between 2000 - 2012	Source: Estel et al.(2015) Stephan Estel, Tobias Kuemmerle, Camilo Alcántara, Christian Levers, Alexander Prishchepov, Patrick Hostert, Mapping farmland abandonment and recultivation across Europe using MODIS NDVI time series, Remote Sensing of Environment, Volume 163, 15 June 2015, Pages 312-325, ISSN 0034-4257, http://dx.doi.org/10.1016/j.rse.2015.03.028.
dem_curvature.tif	Variation in elevation within radius of 1km	DEM: http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1.1

dem_focalmean.tif	Average elevation within radius of 1km	DEM: http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1.1
dem_smoothedTWI.tif	DEM derived Topographic wetness index	DEM: http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1.1
Dist_main_coast.tif	Eucledian distance to coast	Coast: http://www.eea.europa.eu/data-and-maps/data/eea-coastline-for-analysis-1/gis-data/europe-coastline-shapefile
Dist_main_watercourses.tif	Eucledian distance to water courses	Water courses: http://www.eurogeographics.org/products-and-services/euroglobalmap
ESA_Landcover_LCCS_ETRS_100x100m.tif	ESA CCI Land Cover dataset 2014 (v 1.6.1)	http://www.esa-landcover-cci.org/
eudem_dem_3035_europe_100x100m.tif	European Digital Elevation Model (EU-DEM), Version 1.1	http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1.1
flooding_JRC.tif	Flooding according to worst case scenario 2050 LISFLOOD 2008	Dankers R, Feyen L. Climate change impact on flood hazard in Europe: an assessment based on high-resolution climatic simulations. Journal of Geophysical Research, 2008, 113:D19105. Dankers R, Feyen L. Flood hazard in Europe in an ensemble of regional climate scenarios. Journal of Geophysical Research, 2009, 114:D16108.
g100_clc12_V18_5_CLCCode_LEV3.tif	Corine land cover	http://land.copernicus.eu/pan-european/corine-land-cover)
GlobalNightLights_2004_2008stab.tif	Global Night Lights index, Version 4 DMSP-OLS Nighttime Lights Time Series	https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html
Impervious_imd_eur110m.tif	Built-up area Copernicus data	http://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/view
LandCovMinaturaLarge_V2.tif	Basic land use with MINATURA classification	WUR-Minatura
LivestockDensities_CatGoatSheepInt.tif	Livestock densities	http://livestock.geo-wiki.org/home-2/
lspop2011_laea_100x100m_ETRS.tif	Population density 2011	http://ec.europa.eu/eurostat/statistics-explained/index.php/Population_grids
N2000_V2.tif	Natura2000	http://www.eea.europa.eu/data-and-maps/data/natura-7
npp-2010.tif	Net primary production	
PollinationEU.tif	Pollination index	Zulian, G., Polce, C., and Maes, J. (2014). ESTIMAP: a GIS-based model to map ecosystem services in the European Union. Ann di Bot, 4, 1–7.
Precipitation_year_30sec.tif	Annual precipitation per ca. 1km	http://worldclim.org/version2
slope_focalmean.tif	Average slope within radius of 1km	DEM: http://land.copernicus.eu/pan-european/satellite-derived-products/eu-dem/eu-dem-v1.1
SOC_LUCAS.tif	Soil organic carbon	http://esdac.jrc.ec.europa.eu/content/lucas-2009-topsoil-data
TCD_eur_100m_fin_ETRS_100x100m.tif	Tree cover density Copernicus data	http://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density
Tmean_Year_30sec.tif	Mean annual temperature per ca. 1km	http://worldclim.org/version2
Tstdev_Year_30sec.tif	Standard deviation in annual temperature per ca. 1km	http://worldclim.org/version2

ANNEX 3 – PROPERTIES FILE

```
# property file uses key=value notation. The symbol '=' cannot be used for other purposes
# key cannot contain any white spaces. Use camel casing instead
# key uses namespace notation (a '.' between key-parts) to denote a hierarchical relation
# a value can contain white spaces
# in value the symbol ',' is used to separate list elements. It can therefore not be used for
      other purposes

# Baseline land use map and year that the map represents

Baseline.filename=..\\LandCovMinaturaLarge_V2.tif
Baseline.year=2012

# Landuse classes
# code in map file, colour code in hex rgb, ease of change, initial age in years, demand
      deviation type, demand deviation amount
# colour examples: (red ff0000), (green 00ff00), (blue 0000ff), (yellow ffff00), (white
      ffffff), (black 000000), (grey aaaaaa), (orange ffaa00), (purple aa00ff)
# see also: http://www.color-hex.com/color-names.html
# ease of change: {'Very easy', 'Easy', 'Hard', 'Very hard', 'Cannot change'}
# demand deviation type: {'AbsoluteDeviation' [cell count], 'PercentageDeviation' [0..100]}.
# Example 1: LanduseClass.Forest=10001,38a800,Hard,100,AbsoluteDeviation,2047
# Example 2: LanduseClass.Urban=10002,38a800,Very easy,22,PercentageDeviation,15

# LanduseClass.Nodata=-9999,ffffff,Cannot change,50,AbsoluteDeviation,0
# Built-up area (100):
LanduseClass.BuiltUpArea=100,ff0000,Hard,100,PercentageDeviation,5
# Mineral extraction site (110):
LanduseClass.MineralExtractionSite=110,c29bff,Hard,5,PercentageDeviation,10
# Annual crops (210):
LanduseClass.AnnualCrops=210,ffe7ba,Very easy,1,PercentageDeviation,10
# Permanent crops (220):
LanduseClass.PermanentCrops=220,cdba96,Very easy,3,PercentageDeviation,15
# Grassland (231):
LanduseClass.Grassland=231,00cd00,Easy,5,PercentageDeviation,15
# Grassland grazed (232):
LanduseClass.GrasslandGrazed=232,b7f995,Very easy,1,PercentageDeviation,10
# Forest (310):
LanduseClass.Forest=310,267200,Hard,80,PercentageDeviation,10
# Shrubland (321):
LanduseClass.Shrubland=321,8b8b00,Hard,5,PercentageDeviation,10
# Shrubland grazed (322):
LanduseClass.ShrublandGrazed=322,cdcd00,Easy,1,PercentageDeviation,15
# Sparsely vegetated (331):
LanduseClass.SparselyVegetated=331,ffdc73,Hard,50,AbsoluteDeviation,3000
# Sparsely vegetated grazed (332):
LanduseClass.SparselyVegetatedGrazed=332,ffcf00,Hard,50,AbsoluteDeviation,3000
# Bare soil (350) - static:
LanduseClass.BareSoil=350,f6edc0,Cannot change,50,AbsoluteDeviation,1000
# Glaciers & snow (360) - static:
#LanduseClass.GlaciersSnow=360,cccccc,Cannot change,50,AbsoluteDeviation,1000
# Wetlands (400) - static:
LanduseClass.Wetlands=400,cd69c9,Cannot change,50,AbsoluteDeviation,1000
# Inland water (510) - static:
LanduseClass.InlandWater=510,1874cd,Cannot change,50,AbsoluteDeviation,1000
# Sea & ocean (520) - static:
LanduseClass.SeaOcean=520,00f5ff,Cannot change,50,AbsoluteDeviation,1000
# Abandoned land (600):
# LanduseClass.AbandonedLand=600,83c3f2,Very easy,1,PercentageDeviation,10

# Administrative units map and list of unit name and unit code
# Example: AdministrativeUnits.filename=D:\\clue\\Europe\\masker
# Example: AdministrativeUnit.Netherlands=1
# Example: AdministrativeUnit.Belgium=2
AdministrativeUnits.filename=..\\country_mask.tif
AdministrativeUnit.UK=58

# Demands
# line with sequence of landuse classes
# line with same sequence of landuse demands per year
# Example: LanduseDemands.sequence=Forest,Urban
# Example: LanduseDemand.Netherlands.2025=430787,232460
# Example: LanduseDemand.Netherlands.2050=530787,132460
# Example: LanduseDemand.Belgium.2010=300,200
```

```
# Example: LanduseDemand.Belgium.2050=400,100

LanduseDemands.sequence=BuiltUpArea,MineralExtractionSite,AnnualCrops,PermanentCrops,Grassland
      ,GrasslandGrazed,Forest,Shrubland,ShrublandGrazed,SparselyVegetated,SparselyVegetatedGra
      zed,BareSoil,Wetlands,InlandWater,SeaOcean

# 100m resolution original demands:
# LanduseDemand.UK.2012=
      1578262,78511,5733871,171236,342099,10308857,2869729,44717,445100,4744,251156,57938,2350
      347,225819,85368
# LanduseDemand.UK.2030=
      1746990,98035,5962620,102269,753488,9400869,2968206,157192,405897,3683,229035,57938,2350
      347,225819,85368
# LanduseDemand.UK.2050=
      1955418,122152,6159943,17074,1261675,8279236,3089854,381381,357469,2372,201708,57938,235
      0347,225819,85368

# 300m resolution:
LanduseDemand.UK.2012=
      175246,8733,637227,18916,37934,1145604,319021,4996,49315,525,27889,6412,261158,25051,951
      4
LanduseDemand.UK.2030=
      193980,10905,646233,14691,72116,1064125,328332,25634,44267,525,25034,6412,261158,25051,9
      514
LanduseDemand.UK.2050=
      217124,13587,657358,9472,114340,963474,339834,51127,38031,525,21508,6412,261158,25051,95
      14

# Drivers
# Can be 'Constant', or 'Dynamic' driver. Dynamic drivers change over time
# For every driver:
# line 1: DataType= {'Qualitative', 'Quantitative'}
# line 2: filename=full path
# line 3 etc: class.className=class code in map file, class colour in hex rgb
# the following 4 examples illustrate: 1. qualitative constant driver, 2. quantitative
      constant driver, 3. qualitative dynamic driver, 4. quantitative drynamic driver
# Example 1: ParameterMap.Constant.EcoRegions.DataType=Qualitative
# Example 1: ParameterMap.Constant.EcoRegions.filename=D:\\clue\\Mexico\\wwf_ecoregion
# Example 1: ParameterMap.Constant.EcoRegions.class.Boreal=204,ffaa5b
# Example 1: ParameterMap.Constant.EcoRegions.class.Pannonioal=205,22e4ff
# Example 1: ParameterMap.Constant.EcoRegions.class.Tundra=206,ffff00
# Example 2: ParameterMap.Constant.EnergyCropHectare.DataType=Quantitative
# Example 2: ParameterMap.Constant.EnergyCropHectare.filename=D:\\clue\\Mexico\\rk_encrop_ha
# Example 3: ParameterMap.Dynamic.Temperature.DataType=Qualitative
# Example 3: ParameterMap.Dynamic.Temperature.class.Cool=1,0000ff
# Example 3: ParameterMap.Dynamic.Temperature.class.Moderate=2,ffaa00
# Example 3: ParameterMap.Dynamic.Temperature.class.Hot=3,ff0000
# Example 3: ParameterMap.Dynamic.Temperature.filename.2005=D:\\samplePath\\filename_2005
# Example 3: ParameterMap.Dynamic.Temperature.filename.2012=D:\\samplePath\\filename_2012
# Example 3: ParameterMap.Dynamic.Temperature.filename.2020=D:\\samplePath\\filename_2020
# Example 4: ParameterMap.Dynamic.PopulationDensity.DataType=Quantitative
# Example 4:
      ParameterMap.Dynamic.PopulationDensity.filename.2005=D:\\samplePath\\filename_2005
# Example 4:
      ParameterMap.Dynamic.PopulationDensity.filename.2010=D:\\samplePath\\filename_2010
# Example 4:
      ParameterMap.Dynamic.PopulationDensity.filename.2020=D:\\samplePath\\filename_2020

ParameterMap.Constant.CD_Cities_25plus_250m.DataType=Quantitative
ParameterMap.Constant.CD_Cities_25plus_250m.filename=..\\CD_Cities_25plus_250m.tif

ParameterMap.Constant.CD_Cities_50plus_250m.DataType=Quantitative
ParameterMap.Constant.CD_Cities_50plus_250m.filename=..\\CD_Cities_50plus_250m.tif

ParameterMap.Constant.CD_MainHarbors_250m.DataType=Quantitative
ParameterMap.Constant.CD_MainHarbors_250m.filename=..\\CD_MainHarbors_250m.tif

ParameterMap.Constant.CD_MUA_1000plus_250m.DataType=Quantitative
ParameterMap.Constant.CD_MUA_1000plus_250m.filename=..\\CD_MUA_1000plus_250m.tif

ParameterMap.Constant.CD_MUA_100plus_250m.DataType=Quantitative
ParameterMap.Constant.CD_MUA_100plus_250m.filename=..\\CD_MUA_100plus_250m.tif

ParameterMap.Constant.CD_MUA_500plus_250m.DataType=Quantitative
ParameterMap.Constant.CD_MUA_500plus_250m.filename=..\\CD_MUA_500plus_250m.tif

ParameterMap.Constant.dem_curvature.DataType=Quantitative
```

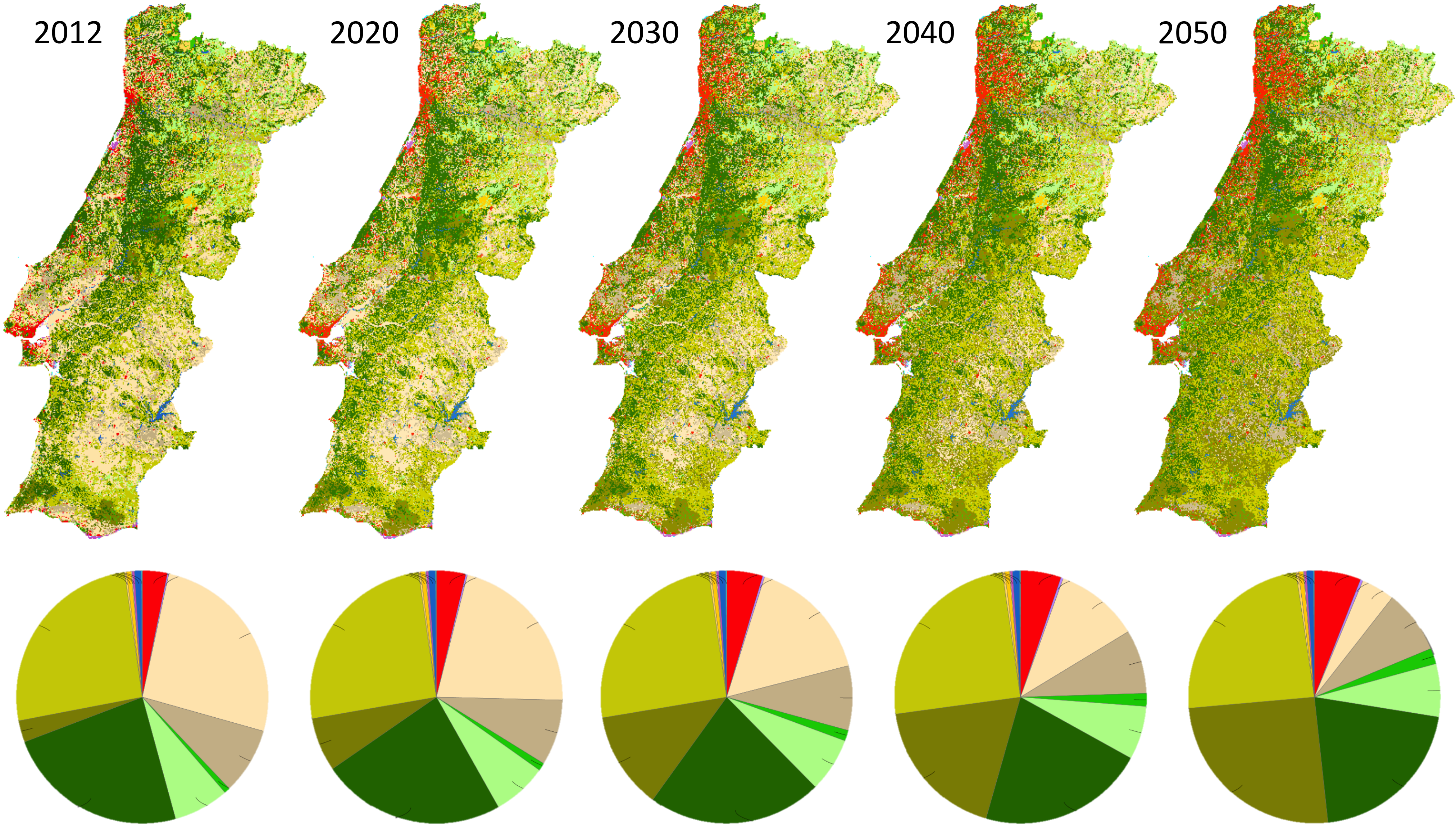
```
ParameterMap.Constant.dem_curvature.filename=..\\dem_curvature.tif

ParameterMap.Constant.dem_focalmean.DataType=Quantitative
ParameterMap.Constant.dem_focalmean.filename=..\\dem_focalmean.tif

ParameterMap.Constant.dem_smoothedTWI.DataType=Quantitative
ParameterMap.Constant.dem_smoothedTWI.filename=..\\dem_smoothedTWI.tif

ParameterMap.Constant.Dist_main_coast.DataType=Quantitative
ParameterMap.Constant.Dist_main_coast.filename=..\\Dist_main_coast.tif

ParameterMap.Constant.Dist_main_watercourses.DataType=Quantitative
ParameterMap.Constant.Dist_main_watercourses.filename=..\\Dist_main_watercourses.tif

# ----------------------------------------------------------------------------
# Distance to Minatura Land use classes, drivers enhance allocation in the proximity of
      existing land use of the same class (clustering)
ParameterMap.Constant.Dist_100.DataType=Quantitative
ParameterMap.Constant.Dist_100.filename=..\\Dist_100.tif

ParameterMap.Constant.Dist_110.DataType=Quantitative
ParameterMap.Constant.Dist_110.filename=..\\Dist_110.tif

ParameterMap.Constant.Dist_210.DataType=Quantitative
ParameterMap.Constant.Dist_210.filename=..\\Dist_210.tif

ParameterMap.Constant.Dist_220.DataType=Quantitative
ParameterMap.Constant.Dist_220.filename=..\\Dist_220.tif

ParameterMap.Constant.Dist_231.DataType=Quantitative
ParameterMap.Constant.Dist_231.filename=..\\Dist_231.tif

ParameterMap.Constant.Dist_232.DataType=Quantitative
ParameterMap.Constant.Dist_232.filename=..\\Dist_232.tif

ParameterMap.Constant.Dist_310.DataType=Quantitative
ParameterMap.Constant.Dist_310.filename=..\\Dist_310.tif

ParameterMap.Constant.Dist_321.DataType=Quantitative
ParameterMap.Constant.Dist_321.filename=..\\Dist_321.tif

ParameterMap.Constant.Dist_322.DataType=Quantitative
ParameterMap.Constant.Dist_322.filename=..\\Dist_322.tif

ParameterMap.Constant.Dist_331.DataType=Quantitative
ParameterMap.Constant.Dist_331.filename=..\\Dist_331.tif

ParameterMap.Constant.Dist_332.DataType=Quantitative
ParameterMap.Constant.Dist_332.filename=..\\Dist_332.tif

ParameterMap.Constant.Dist_350.DataType=Quantitative
ParameterMap.Constant.Dist_350.filename=..\\Dist_350.tif

ParameterMap.Constant.Dist_1.DataType=Quantitative
ParameterMap.Constant.Dist_1.filename=..\\Dist_1.tif
# ----------------------------------------------------------------------------

ParameterMap.Constant.eudem_dem_3035_europe_100x100m.DataType=Quantitative
ParameterMap.Constant.eudem_dem_3035_europe_100x100m.filename=..\\eudem_dem_3035_europe_100x10
      0m.tif

ParameterMap.Constant.flooding_JRC.DataType=Quantitative
ParameterMap.Constant.flooding_JRC.filename=..\\flooding_JRC.tif

ParameterMap.Constant.g100_clc12_V18_5_CLCCode_LEV3.DataType=Quantitative
ParameterMap.Constant.g100_clc12_V18_5_CLCCode_LEV3.filename=..\\g100_clc12_V18_5_CLCCode_LEV3
      .tif

ParameterMap.Constant.GlobalNightLights_2004_2008stab.DataType=Quantitative
ParameterMap.Constant.GlobalNightLights_2004_2008stab.filename=..\\GlobalNightLights_20042008.
      tif

ParameterMap.Constant.Impervious_imd_eur100m.DataType=Quantitative
ParameterMap.Constant.Impervious_imd_eur100m.filename=..\\Impervious_imd_eur100m.tif

ParameterMap.Constant.LivestockDensities_CatGoatSheepInt.DataType=Quantitative
```

```
ParameterMap.Constant.LivestockDensities_CatGoatSheepInt.filename=..\\LivestockDens_CatGoatShe
      ep.tif

ParameterMap.Constant.lspop2008_laea_100x100m_ETRS.DataType=Quantitative
ParameterMap.Constant.lspop2008_laea_100x100m_ETRS.filename=..\\lspop2008_laea_100x100m_ETRS.t
      if

ParameterMap.Constant.npp-2010.DataType=Quantitative
ParameterMap.Constant.npp-2010.filename=..\\npp-2010.tif

ParameterMap.Constant.PollinationEU.DataType=Quantitative
ParameterMap.Constant.PollinationEU.filename=..\\PollinationEU.tif

ParameterMap.Constant.Precipitation_year_30sec.DataType=Quantitative
ParameterMap.Constant.Precipitation_year_30sec.filename=..\\Precipitation_year_30sec.tif

ParameterMap.Constant.slope_focalmean.DataType=Quantitative
ParameterMap.Constant.slope_focalmean.filename=..\\slope_focalmean.tif

ParameterMap.Constant.SOC_LUCAS.DataType=Quantitative
ParameterMap.Constant.SOC_LUCAS.filename=..\\SOC_LUCAS.tif

ParameterMap.Constant.TCD_eur_100m_fin_ETRS_100x100m.DataType=Quantitative
ParameterMap.Constant.TCD_eur_100m_fin_ETRS_100x100m.filename=..\\TCD_eur_100m_fin_ETRS_100x10
      0m.tif

ParameterMap.Constant.Tmean_Year_30sec.DataType=Quantitative
ParameterMap.Constant.Tmean_Year_30sec.filename=..\\Tmean_Year_30sec.tif

ParameterMap.Constant.Tstdev_Year_30sec.DataType=Quantitative
ParameterMap.Constant.Tstdev_Year_30sec.filename=..\\Tstdev_Year_30sec.tif

ParameterMap.Constant.CDDA_IUCN_V2.DataType=Qualitative
ParameterMap.Constant.CDDA_IUCN_V2.filename=..\\CDDA_IUCN_V3.tif
ParameterMap.Constant.CDDA_IUCN_V2.class.0=0,494d47
ParameterMap.Constant.CDDA_IUCN_V2.class.40=40,f415c9
ParameterMap.Constant.CDDA_IUCN_V2.class.50=50,e7f665
ParameterMap.Constant.CDDA_IUCN_V2.class.80=80,65f6f3

ParameterMap.Constant.Cropland_YN_1km2.DataType=Qualitative
ParameterMap.Constant.Cropland_YN_1km2.filename=..\\Cropland_YN_1km2_V2.tif
ParameterMap.Constant.Cropland_YN_1km2.class.0=0,494d47
ParameterMap.Constant.Cropland_YN_1km2.class.1=1,54f415

ParameterMap.Constant.cropping_frequency.DataType=Quantitative
ParameterMap.Constant.cropping_frequency.filename=..\\cropping_frequency.tif

ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.DataType=Qualitative
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.filename=..\\ESA_LCCS_ETRS_100x100m.tif
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.10=10,494d47
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.11=11,54f415
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.12=12,4915f4
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.20=20,f46f15
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.30=30,65f6f3
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.40=40,e7f665
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.60=60,f415c9
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.61=61,04542a
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.70=70,15a0f4
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.90=90,e4f4e4
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.100=100,066002
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.110=110,066002
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.120=120,67280d
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.130=130,32f0a8
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.150=150,905e13
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.180=180,220540
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.190=190,ceabf2
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.200=200,c3addb
#ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.201=201,91c9ec
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.210=210,f0a9e2
ParameterMap.Constant.ESA_Landcover_LCCS_ETRS_100x100m.class.220=220,91c9ec

ParameterMap.Constant.N2000_V2.DataType=Qualitative
ParameterMap.Constant.N2000_V2.filename=..\\N2000_V2.tif
ParameterMap.Constant.N2000_V2.class.0=0,000000
ParameterMap.Constant.N2000_V2.class.1000=1000,06ee16
ParameterMap.Constant.N2000_V2.class.2000=2000,200465
```

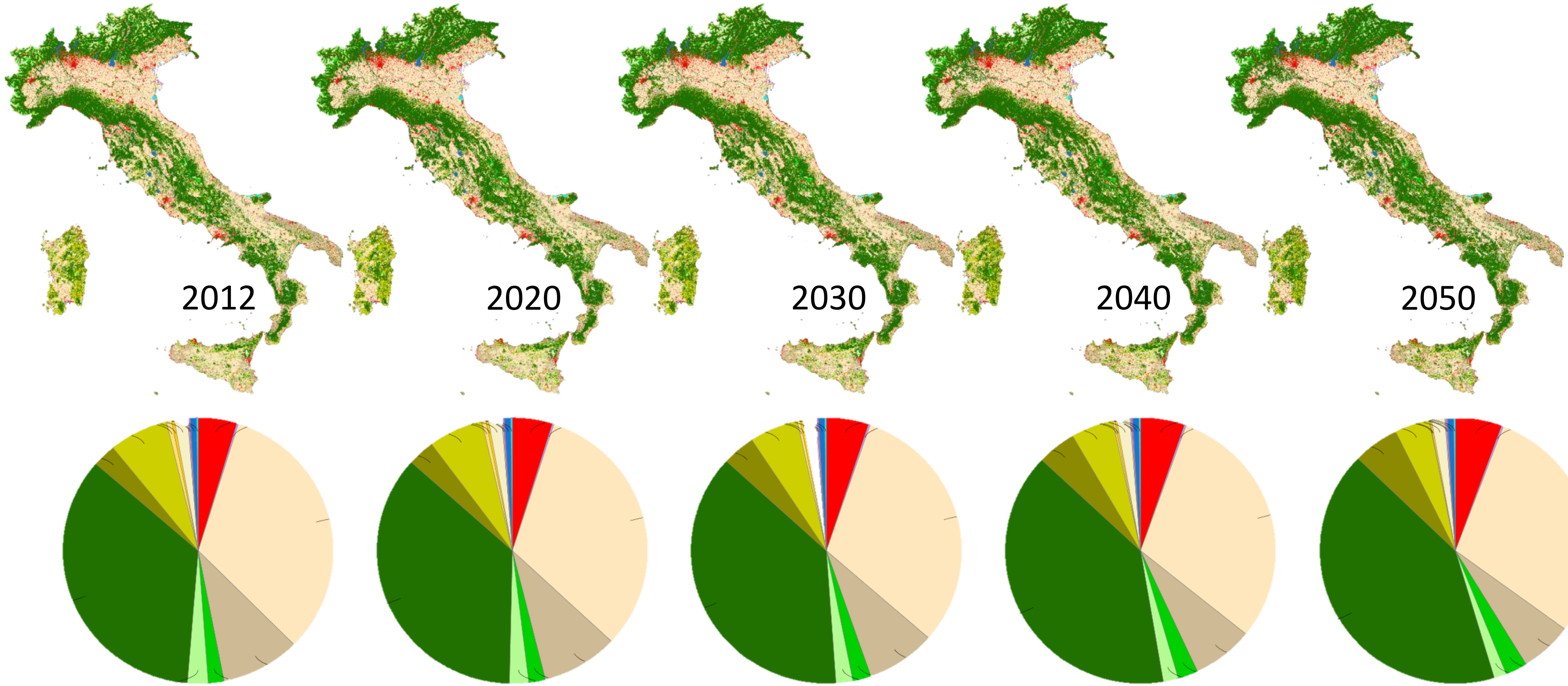
```
# Suitability calculation
# line 1: Method={StepwiseRegression, FunctionDictionary}
# line 2: depending the method
# line 2: StepwiseRegression.SampleSizePercentage=decimal number between 0..100 (percentage of
      the number of cells for each land use class that'll be used to do the regression upon)
# line 3: StepwiseRegression.CorrelationThreshold=decimal number between 0..1 (drivers are
      being correlated for each landuse. If drivers are highly correlated (above threshold),
      the the driver with the lowest correlation with the landuse class is omitted)
# line 4: StepwiseRegression.ExportFileName=d:\\path\\filename.prop
# Example: Suitability.Method=StepwiseRegression
# Example: Suitability.StepwiseRegression.SampleSizePercentage=7.5
# Example: Suitability.StepwiseRegression.CorrelationThreshold=0.85
# line 2: FunctionDictionary.<adminUnit>.<landuseClass>.<FunctionConstant>= decimal number
      between -1..1 (constant value in function)
# line 3: FunctionDictionary.<adminUnit>.<landuseClass>.<FunctionCoefficient>.<Driver>=
      decimal number between -1..1 (coefficient value in function for quantitative driver)
# line 4:
      FunctionDictionary.<adminUnit>.<landuseClass>.<FunctionCoefficient>.<Driver>.class.<clas
      sName>= decimal number between -1..1 (coefficient value in function for qualitative
      driver)
# line 5: etc. for driver and landuse class

Suitability.Method=StepwiseRegression
Suitability.StepwiseRegression.SampleSizePercentage=2.00
Suitability.StepwiseRegression.CorrelationThreshold=0.99

# Conversion
# choose from the options: {'always', 'never', 'years, 7'}
# default is 'always' (no need to include a land use conversion that can take place always)
# Example 1: Conversion.Urban.Forest=never
# Example 2: Conversion.Forest.Urban=years, 15
# Conversion.AnnualCrops.BuiltUpArea=location,..\\CDDA_isData.tif

# Target time
# define until what time land use allocation calculations take place
# Example: TargetTime=2030

TargetTime=2050
```

ANNEX 4 – RESULTING MAPS & CHARTS

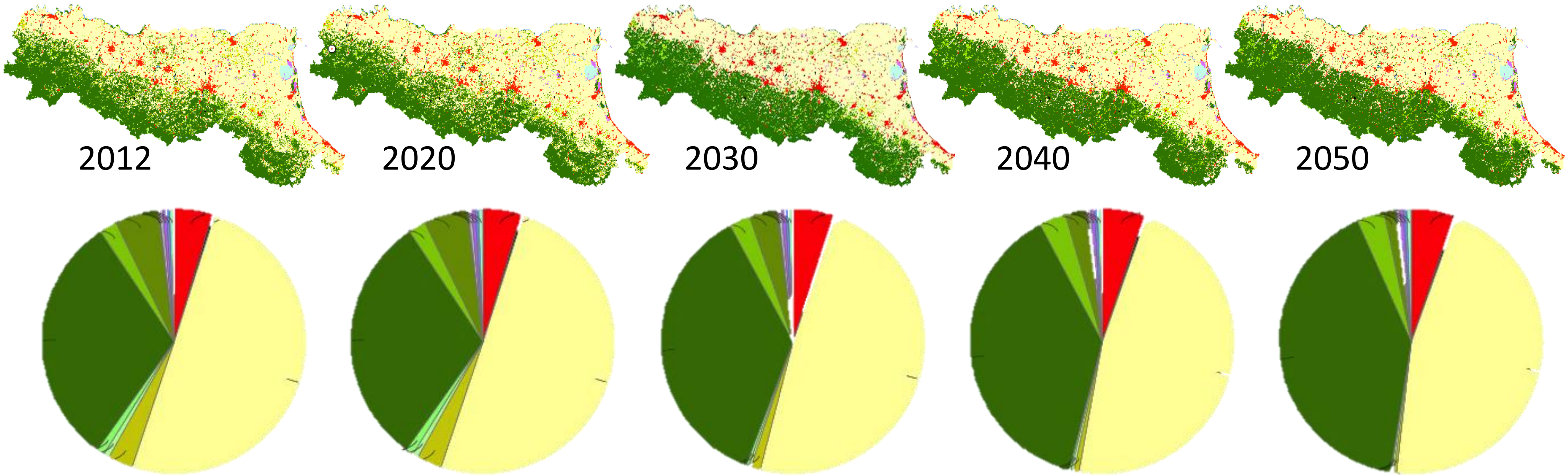
Legend used for all maps



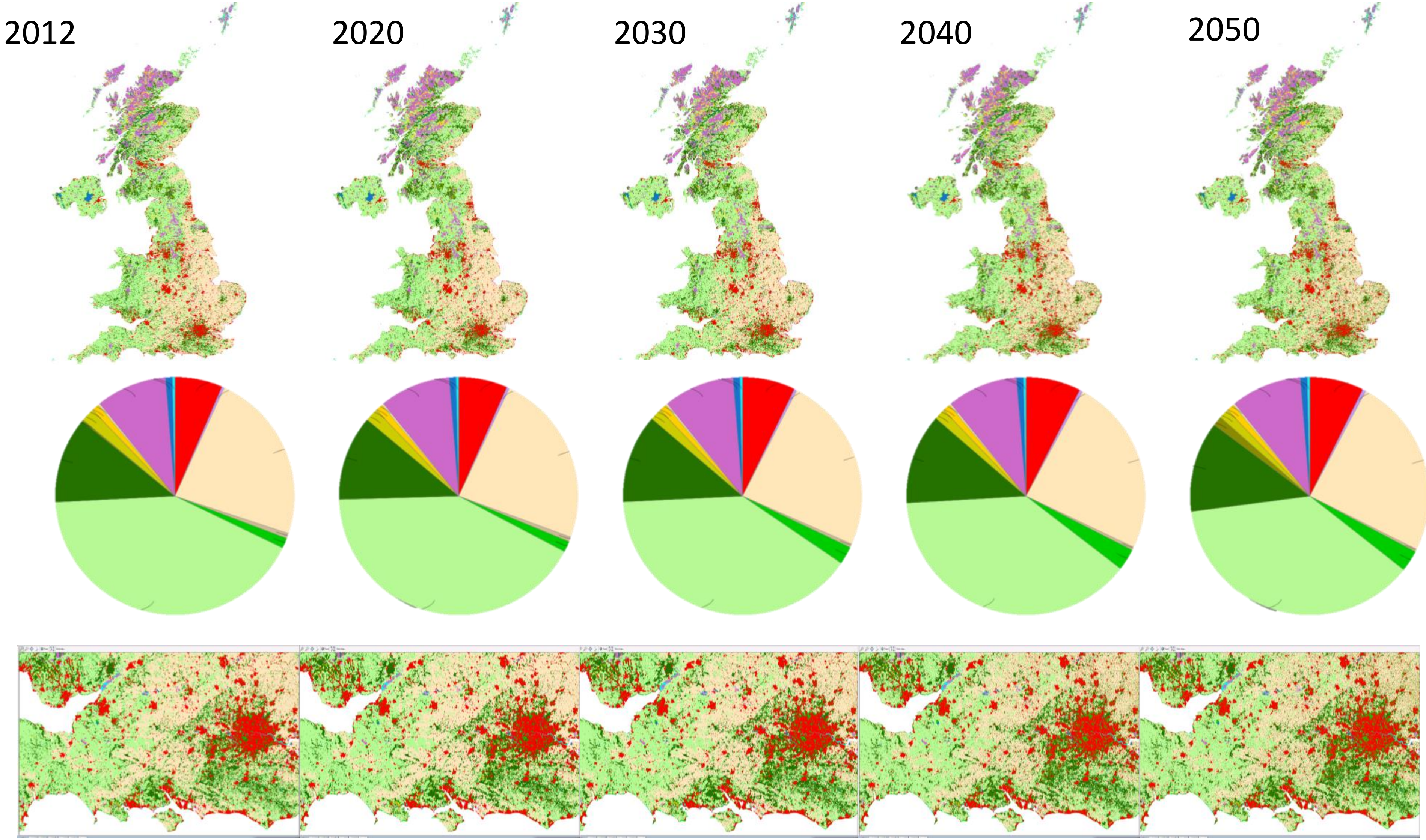
MAP & CHART 1 - Portugal 2012-2050



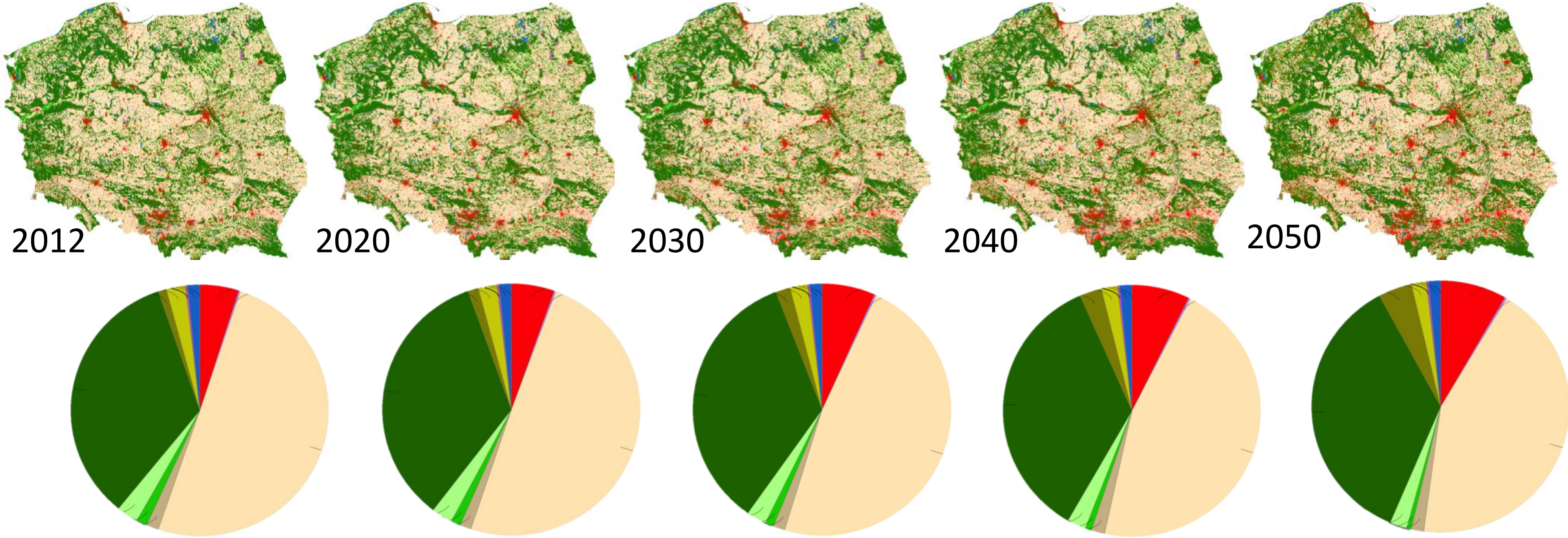
MAP & CHART 1 - Italy 2012-2050



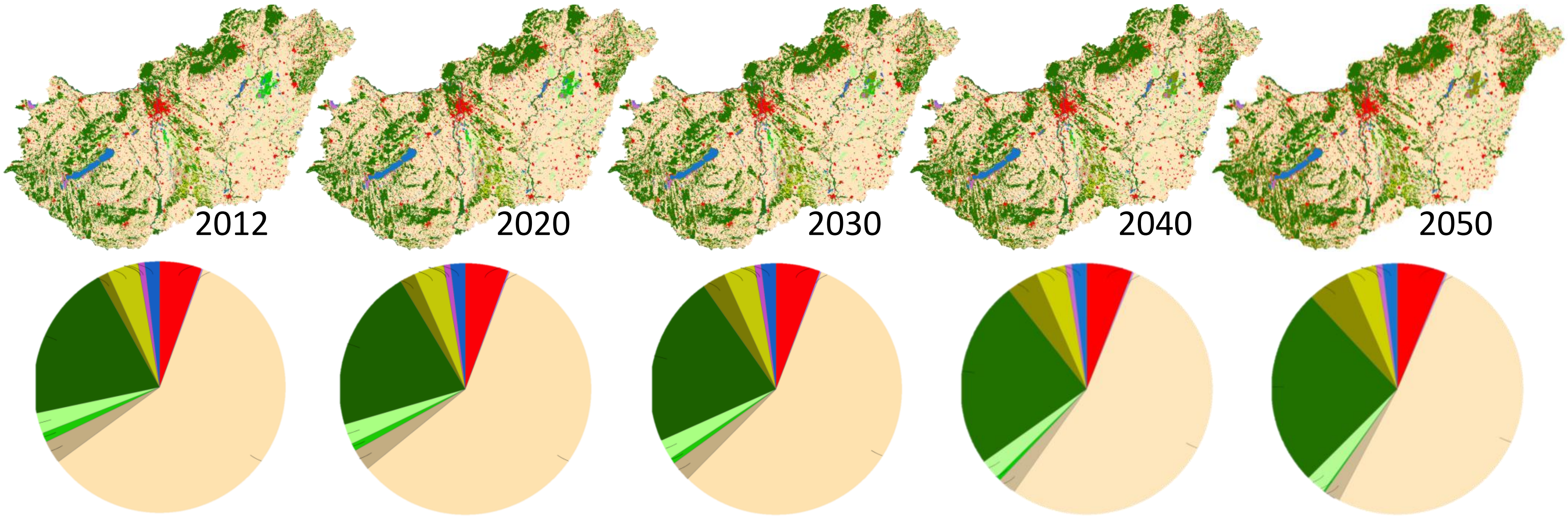
MAP & CHART 1 – Emilia-Romagna 2012-2050



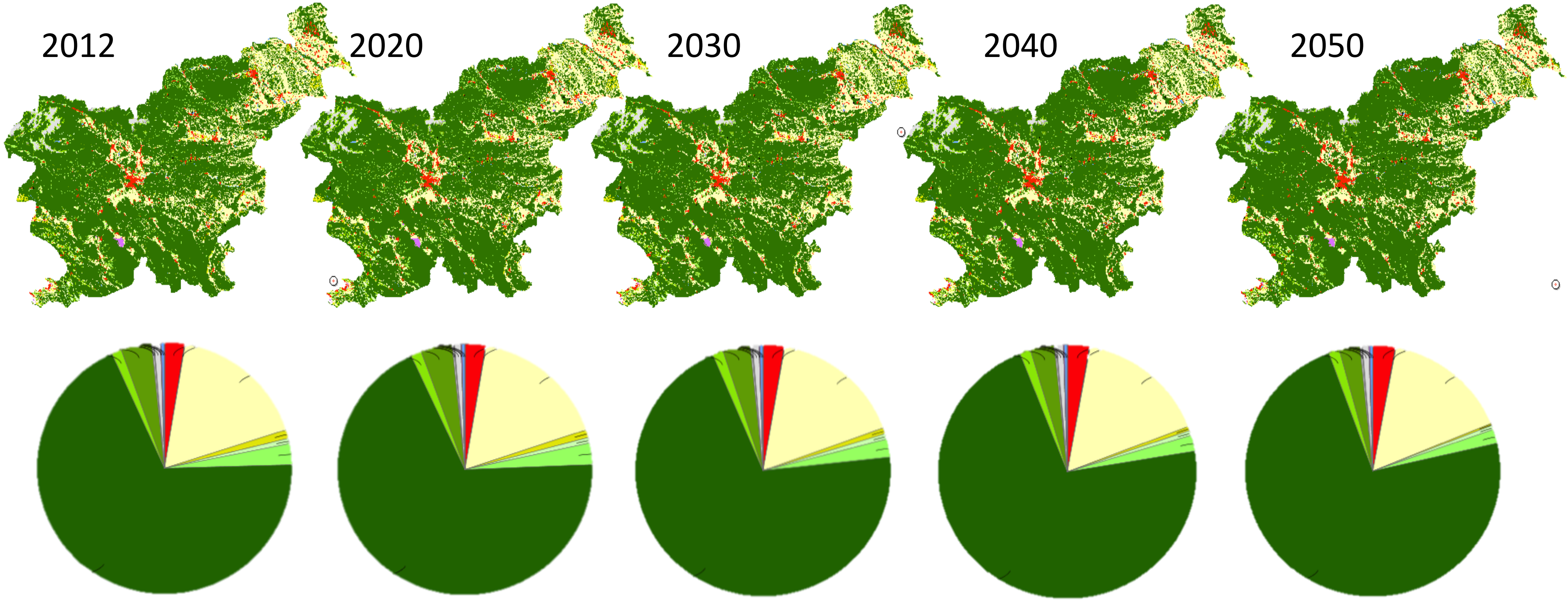
MAP & CHART 1 – United Kingdom 2012-2050 + Zoom



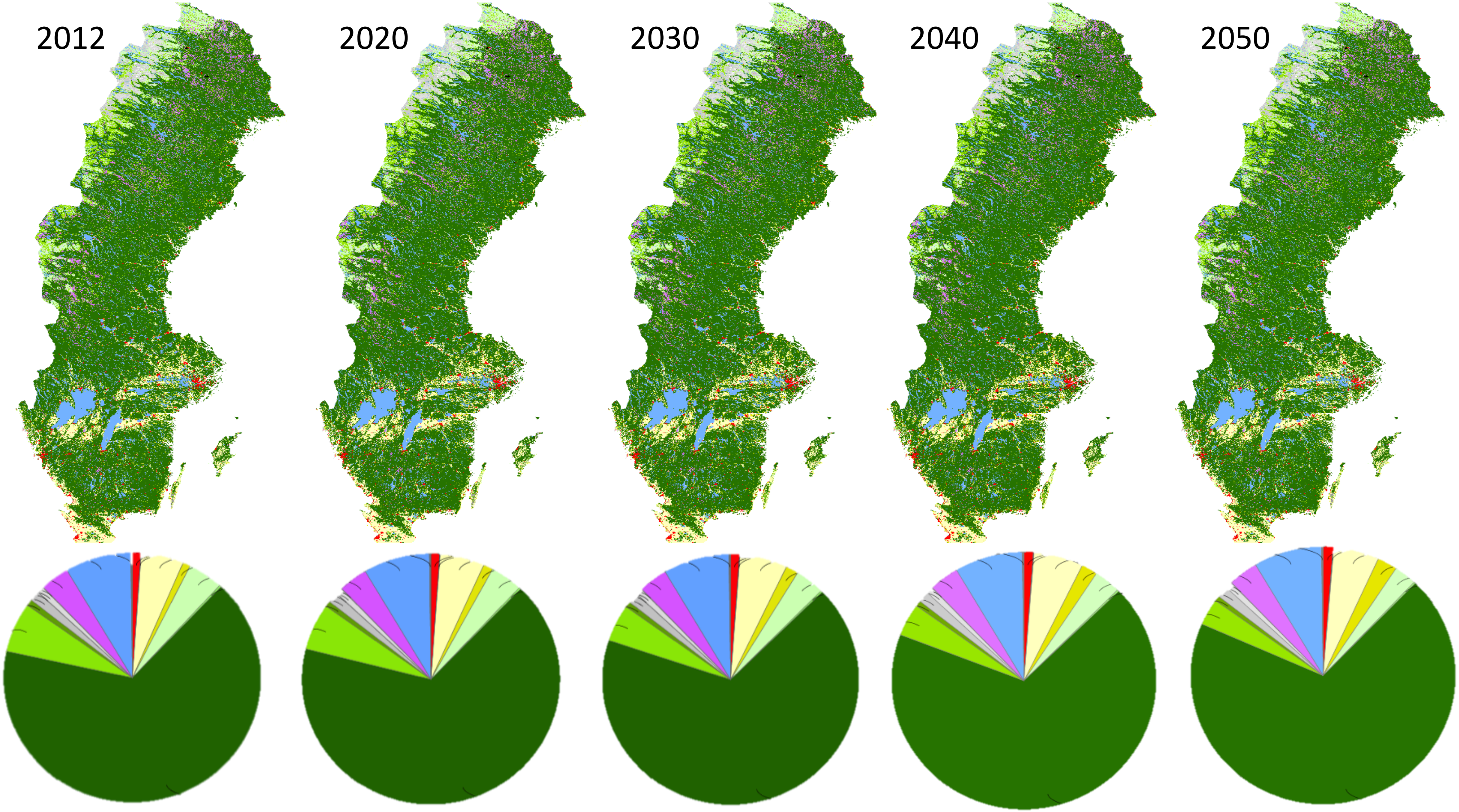
MAP & CHART 1 - Poland 2012-2050



MAP & CHART 1 - Hungary 2012-2050



MAP & CHART 1 - Slovenia 2012-2050



MAP & CHART - Sweden 2012-2050

ANNEX 5 – LIST OF PARTICIPANTS

Workshop	Country	Name	Company
Workshop La Palma September 27 & 28, 2016	UK	John Cowley	MRPA - Mineral & Resource Planning Associates Ltd, UK
	IE	Gerry Sutton	UCC - University College Cork, National University of Ireland, Cork
	PL	Alicja Kot- Niewiadomska	Meeri Pas - Mineral & Energy Economy Research Institute, Poland
	ER	Christian Marasmi	Regione Emilia Romagna, Italy
	ER	Massimo Romagnoli	Regione Emilia Romagna, Italy
	NL	Michiel van Eupen	Wageningen Environmental Research (Alterra)
	ES	Balázs Bodo	La Palma Research Centre for Future Studies
	ES	Adrienn Cseko	La Palma Research Centre for Future Studies
	ES	Cameron Sword	La Palma Research Centre for Future Studies
	ES	Ariadna Ortega	La Palma Research Centre for Future Studies
	ES	Luís Lopes	La Palma Research Centre for Future Studies
	ES	Tamás Miklovicz	La Palma Research Centre for Future Studies