JRC Scientific and Technical Reports

Implementation of the CAP Policy Options with the Land Use Modelling Platform

A first indicator-based analysis

Carlo Lavalle, Claudia Baranzelli, Sarah Mubareka, Carla Rocha Gomes,
Roland Hiederer, Filipe Batista e Silva, Christine Estreguil

EUR 24909 EN - 2011

EUROPEAN COMMISSION
Institute for Environment and Sustainability

The mission of the JRC-IES is to provide scientific-technical support to the European Union's policies for the protection and sustainable development of the European and global environment.

European Commission
Joint Research Centre
Institute for Environment and Sustainability

Contact information
Address: Via E. Fermi 2749, 21027 Ispra (VA) - Italy
E-mail: Carlo Lavalle (carlo.lavalle@jrc.ec.europa.eu)
Tel.: +39-0332-785231
Fax: +39-0332-789085

http://ies.jrc.ec.europa.eu/
http://www.jrc.ec.europa.eu/

JRC JRC66060

EUR 24909
ISBN 978-92-79-20917-8 (print) / 978-92-79-20918-5 (pdf)
ISSN 1018-5593 (print) / 1831-9424 (online)
doi: 10.2788/45131

Luxembourg: Publications Office of the European Union

Printed in Italy

Implementation of the CAP Policy Options with the Land Use Modelling Platform

A first indicator-based analysis

Authors:
Carlo Lavalle, Claudia Baranzelli, Sarah Mubareka, Carla Rocha Gomes, Roland Hiederer, Filipe Batista e Silva, Christine Estreguil

Contributors:
Alex Vakrou, Bettina Baruth, Maria Luisa Paracchini, Fabio Micale, Sergio Gomez y Paloma, Pavel Ciaian, Mihaly Himics

Acknowledgements:
The work herein presented is executed in the frame of the Administrative Arrangement between DG ENV and JRC on "Support for improving land-use modelling for informing environmental policy making".

The authors are extremely grateful to several colleagues from DG AGRI for guidance on the definition of the policy alternatives and comments on preliminary versions of this report.

We would also like to thank Viviane Andre for her support throughout the process, information and comments on the draft report.

An important contribution to the work has also been provided by Maarten Hilferink and Martin van der Beek (Object Vision) in the frame of the technical support for the maintenance of the EUClueScanner100 software.

Table of Contents

Figures

Tables

List of Acronyms

AGLINK	AGLINK-COSIMO is a recursive-dynamic, partial equilibrium, supply demand model of world agriculture, developed by the OECD Secretariat
CAP	Common Agricultural Policy of the European Union
CAPRI	Common Agricultural Policy Regionalised Impact Modelling System
CLC	Corine Land Cover
CoCo	Complete and Consistent, refers to historical time series in CAPRI
ECFIN	Directorate General Economic and Financial Affairs
EFDM	European Forest Dynamic Model
EU	European Union
EUCS100	EUClueScanner – 100 m resolution
EUROPOP	Eurostat Population Projection
GAEC	Good Agricultural and Environmental Condition
GHG	Greenhouse Gas
HNV	High Nature Value farmland areas
IPCC	Intergovernmental Panel on Climate Change
JRC-IES	Institute for Environment and Sustainability of the European Commission Joint Research Centre
JRC-IPTS	Institute for Prospective Technological Studies of the European Commission Joint Research Centre
LFA	Less Favoured Areas
LOCSPEC	Location Specific Preference Addition
LUC	Land Use Change
LUMP	Land Use Modelling Platform
MARS	JRC-IES Monitoring Agricultural ResourceS Unit
NUTS	Nomenclature of Territorial Units for Statistics
NVZ	Nitrates Vulnerable Zones
OC	Organic Carbon
RHOMOLO	Dynamic general equilibrium framework for regional holistic model
SOC	Soil Organic Carbon
UAA	Utilized Agricultural Area

Executive Summary

Background

In November 2010, the European Commission launched the revision of the Common Agricultural Policy (CAP) with the Communication "The CAP towards 2020"[1], based on the outcome of a wide public debate (initiated in April 2010). This document identifies the challenges that should be addressed in the forthcoming years, and in line with the "Europe 2020 Strategy" defines as main objectives of the reform i) *Viable food production*; ii) *Sustainable management of natural resources and climate action*; and iii) *Balanced territorial development*. In order to accomplish these aims, three policy options are outlined: the "Adjustment", the "Integration" and the "Re-Focus". These options differ mainly in the weight that is given to a specific objective and present diverse ways to achieve these objectives.

In this context, and in the framework of the impact assessment procedure, the Institute for Environment and Sustainability of the European Commission Joint Research Centre (JRC-IES) was requested by DG Environment (DG ENV)[2] to assess a range of environmental impacts resulting from the implementation of different policy settings foreseen under the CAP reform, focusing on the greening component of Direct Payments, as defined in the Integration policy option.

Therefore, a range of environmental impacts of the CAP reform are presented and assessed within this report. The work is based on a modelling approach that translates socio-economic driven land use projections for the year 2020.

The methodology

The results presented here are derived from the application of the Land Use Modelling Platform (LUMP), developed by the JRC-IES to support the exploration of future policies and the impact assessments of

[1] COM(2010) 672 final: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "*The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future*".

[2] This work was developed in the scope of an Administrative Agreement between JRC and DG ENV - *Support for improving land-use modelling for informing environmental policy making* (AA N. 070307/2010/555750/F1 JRC Ref. N. 31656-2010 NFP ISP).

alternative implementation measures. The core component of this platform is the land use model *EUClueScanner* (EUCS100), developed in collaboration with DG ENV.

LUMP integrates diverse and specialized models and data into a coherent workflow. For this assessment, the profiles of the current CAP scenario and the Integration policy option are quantified within the LUMP through three modules: i) the amount of land claimed per land-use type (derived from external models); ii) a set of rules to allocate this requested land; and iii) the computation of indicators to facilitate the analysis of results.

The amount of land claimed is computed based upon regional and global parameters. These parameters are derived from dedicated external models for a range of issues such as demography, agriculture, regional economy, climate change. All contribute to the definition of the requirements for land use/cover transformations. The forecasted amount of land required for the agricultural sector is computed using the projection for 2020 from the "Common Agricultural Policy Regionalised Impact Modelling System" (CAPRI)[3] in a special configuration for farm level policy analysis (CAPRI-FARM). The scenario from this CAPRI-FARM configuration is a direct payment scenario with flat rate premiums at Member State level. The amount of land claimed for built-up areas for the 2020 forecast is based on future population estimations from DG ECFIN/Eurostat (EUROPOP 2008).

The spatial allocation of land use is determined within EUCS100 by a set of locally influencing factors which together define the suitability of each land parcel for each land use type. These factors include accessibility, policy-driven restrictions and biophysical properties such as topography, soil characteristics and crop suitability maps (provided by the JRC-IES AGRI4CAST Action). A spatially refined Corine Land Cover (CLC) map for the year 2006 is used as the initial year for the simulations.

As a final step, a set of indicators is computed in order to give an overview of the impacts of the reform proposals on the European territory. These indicators are designed to highlight spatially varying impacts of the assessed policy options, thus enabling an evaluation of the impacts of the new CAP within a geographical context which is comparable to that of the reform itself. Additional indicators can be computed, covering other environmental issues, such as water quality, in order to gain a deeper insight into the regional impacts of CAP.

[3] CAPRI is an economic model developed by the University of Bonn with the aim of providing sound scientific support to policy makers regarding the CAP.

A baseline scenario and a policy alternative are defined and implemented in the LUMP resulting in two different simulated land use/cover maps for year 2020:

- the *Status Quo* scenario represents the current socio-economic and environmental trends with existing policy provision maintained (business-as-usual scenario);
- the *Integration* policy option builds on the present policy provisions but it encompasses a specific set of greening measures.

The Status Quo is considered to be the reference scenario to which the impacts of the Integration policy option are compared. For the Integration policy option, the following specific greening measures were implemented as part of the assessment:

- ecological focus area,
- maintenance of permanent pastures,
- separate payment for Natura 2000 areas.

The implementation of these policy settings in the EUCS100 model were based in assumptions that are briefly exposed in Box I.

Box I: Main assumptions used in this study

Common/shared assumptions for both scenarios

- Future land claims for arable land and pasture were derived from the CAPRI-FARM 2020 scenario with the assumption of national-flat rates.
- Future land claims for urban land were derived from Eurostat data (EUROPOP2008), based on a single convergence scenario, whereby demographic structural differences between EU countries are assumed to fade out by 2150.
- Land use change from forest or semi-natural vegetation to agricultural land is only allowed outside protected areas (i.e. Natura 2000).
- Land use change from agricultural land to urban or industrial land is only allowed outside protected areas (i.e. Natura 2000).
- Abandoned land is driven by economic factors, i.e. emerges as a result of the decline in agricultural claims, and thus its definition does not take directly into consideration any other variable related with economic or demographic conditions (e.g. holdings with low income or proportion of farmers close to retiring age).

Status Quo scenario

- Land use change to arable land and permanent crops is encouraged in Less Favoured Areas (art.18 and 20) and discouraged in environmental sensitive areas: a 50m strip width along water courses in currently designated Nitrate Vulnerable Zones; and in erosion sensitive areas (where erosion is between 20 and 50 ton/ha/year and higher than 50 ton/ha/year).

Integration policy option

- As in Status Quo, land use change to arable land and permanent crops is encouraged in Less Favoured Areas (art.18 and 20) and discouraged in environmental sensitive areas: a 50m strip width along water courses in currently designated Nitrate Vulnerable Zones; and in erosion sensitive areas (where erosion is between 20 and 50 ton/ha/year and higher than 50 ton/ha/year), however due to the emphasis that is given to the sustainable management of natural resources, these conditions are combined with a slightly higher degree of discouragement in this policy option.
- Maintenance of agricultural land is encouraged in Natura 2000 areas currently cropped and in the High Nature Value Farmland.
- Maintenance of pasture/grassland that has not been in rotation for at least 5 years in its current status is enhanced.
- The occurrence of Semi-natural vegetation is encouraged in a 50m strip width along water courses within current Nitrates Vulnerable Zones.
- Agricultural abandonment is enhanced in a 50m strip width along water courses.

The results

The overall (EU27) changes in land use/cover (2006-2020) are presented in Figure I.

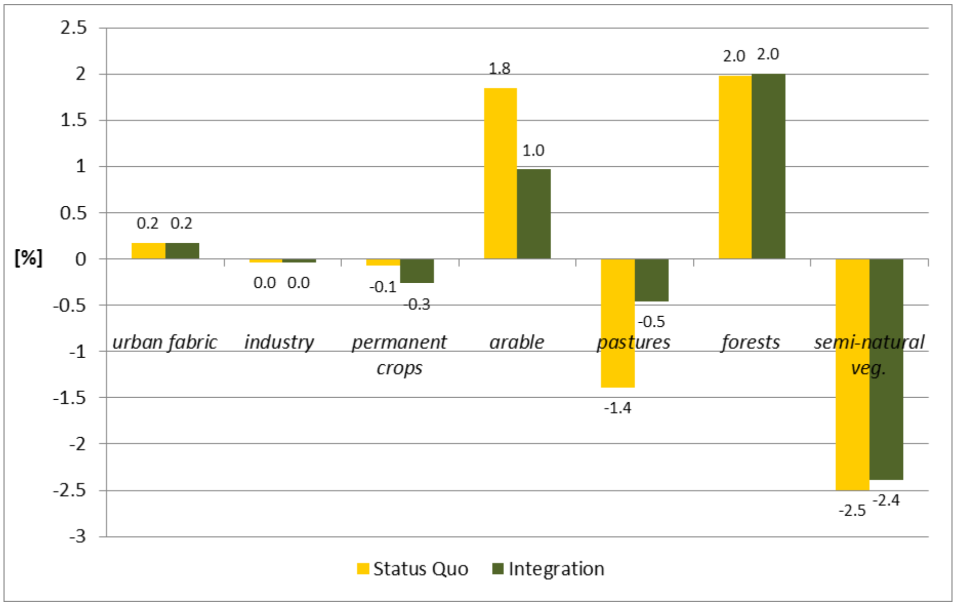


Figure I: Net change (%) in EU27 from 2006 to 2020, per land use/cover

For EU27, both simulations estimate an increase of arable land (higher in Status Quo) and a slight decrease of permanent crops and pastures. For pastures the reduction is less significant in the Integration policy option due to the greening measure 'maintenance of permanent pastures'. This difference is particularly evident in Ireland, Greece and Romania. Forest increases in both simulations (especially in Sweden, Finland, Portugal and Czech Republic), while semi-natural vegetation decreases (mainly in Sweden, Finland, Estonia and Bulgaria). The decline of semi-natural vegetation and the growth of forest in Sweden and Finland are partly due to the natural succession process.

To assess the impact of the projected changes in land use/cover in 2020, a set of indicators are generated by linking the changes with specialized thematic models. A number of quantitative conclusions can be drawn from analysing these indicators:

1. Distribution of agricultural land use categories

   The shares of the three types of agricultural land uses (arable, permanent crops and pasture) are consistent in all countries between the two simulations for 2020, except for the United Kingdom where the share of pastures is significantly higher under the Status Quo scenario and for Ireland, where the share of pastures is significantly higher under the Integration policy option. Although there is an overall increase of arable land in the EU27 under both simulations for 2020, this trend is not consistent among all Member States: an overall decrease was forecasted for the Czech Republic, Denmark, Poland, Portugal, Slovenia and Sweden. There is a slight overall decrease in permanent crops in the EU27 under both Status Quo scenario and Integration policy option for 2020, especially in Spain.

2. Land cover change

   The expansion of agricultural land at the expense of semi-natural vegetation is, in general, higher under the Integration policy than the Status Quo scenario. The difference is particularly relevant in Greece, Slovakia and Cyprus, whereas Ireland, Sweden and Finland manifest a higher conversion from semi-natural areas to agricultural land under the Status Quo scenario than under the Integration policy option.

   The loss of forest due to the expansion of agriculture is particularly pronounced in Latvia, Estonia and Lithuania, especially under the Integration policy option. This same pattern of change is also evident in the vicinity of Natura2000 sites.

   While there is an overall increase in arable land, there is also abandonment of some agricultural areas. In the EU27, this change is less than 1% and is slightly more pronounced in Slovenia (6% in Status Quo, 3% in Integration policy) and Ireland (around 2% for both model runs). The Integration policy option results in a high value of abandonment in riparian areas (25% in the Integration and 2% in the Status Quo), due to the greening measure ecological focus area, which promotes the establishment of buffer strips along water courses. In the scope of this project, riparian areas were considered as a 50m strip width (both sides) along water courses.

3. Agricultural land converted to artificial surfaces

   At EU27 level, the loss of agricultural land due to urbanisation is less than 0.35% for the Status Quo scenario and for the Integration policy option. This process is more intense (higher than 1%) in Cyprus (especially under the Status Quo scenario), but also in Ireland, the Netherlands and the United Kingdom for the Status Quo and the Integration. Similar trends, as those previously described for EU27, are found around Natura2000 sites (in a 500m buffer zone), where agricultural loss to urbanization is higher than 1% only in Ireland, Netherlands and Cyprus (in this case only under Status Quo).

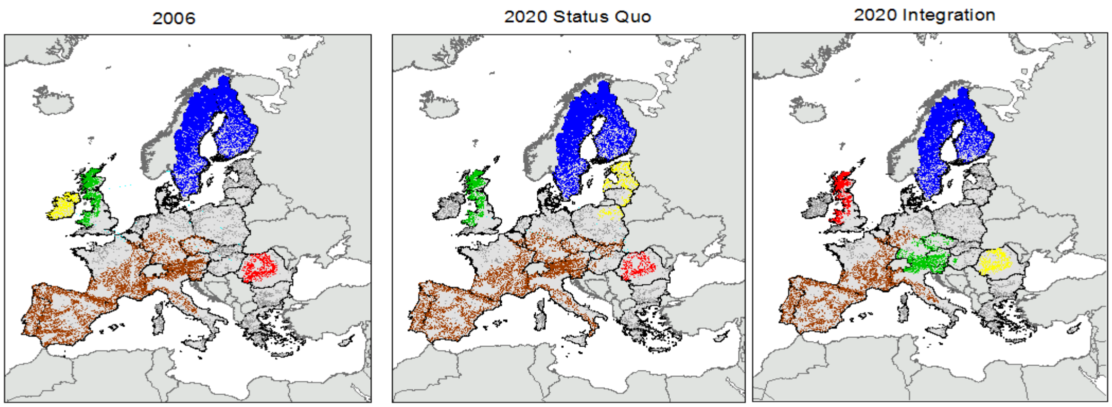
4. Conservation of natural areas

   In the vicinity of Natura2000 sites, the loss of semi-natural vegetation to agricultural land in 2020 varies considerably between Member States, with notable loss in Estonia, Greece and Spain for both runs, and Latvia for the Integration policy option.

   In buffer zones along rivers the expansion of agricultural land over semi-natural vegetation is less intensive under the Integration policy option than under the Status Quo scenario for all countries with the exception of Austria, Germany, Poland, Slovakia and the United Kingdom.

5. Conservation and connectivity of Green Infrastructure

   The net amount of Green Infrastructure increases under the Integration policy option with respect to the Status Quo scenario. However, whereas there is a gain in the number of connecting elements within Green Infrastructure under the Integration policy option, there is a net loss of number of compact core natural areas referred to as *nodes*. Two per cent of core natural areas are infringed upon by agriculture in the Integration policy option. On the contrary, this trend of loss of core natural areas is not seen within the Natura 2000 sites. The majority of this network of protected areas (54%) manifests an improvement of core natural areas. In the Integration policy option, according to the results of this modelling exercise, some natural areas which are key to Green Infrastructure components are ruptured. **This result emphasizes the importance of targeting the support through localising areas to be beneficiaries of greening, as opposed to just increasing the quantity of natural areas *ad hoc***.



units: km^2	2006	SQ	INT
average size	480.9552	437.8538	468.7005
number of components	3663	3817	3653
size of largest component	597111	612464	603491
size of 2nd largest component	573636	568922	422350
size of 3rd largest component	83538	79528	131448
size of 4th largest component	67414	62179	78644
size of 5th largest component	65084	51157	63559

Figure II: The five largest components are shown for the 2006 Green Infrastructure map and the 2020 output for Status Quo and Integration

6. Homogeneous agricultural areas

Important from a biodiversity perspective is the level of homogeneity of agricultural regions, likely to reflect more intensive agriculture. The results show that areas with a 'pure core' agricultural pattern become more heterogeneous in the Integration policy option (hence more favourable to biodiversity), with only two exceptions (Estonia and Latvia). Only a very small percentage of Natura 2000 polygons worsen under the Integration policy option (5.14%) whereas 22.14% improve (72.72% do not show any changes).

7. Soil Organic Carbon stocks

The estimated changes in soil organic carbon (SOC) stocks have been found to be very responsive to evaluating the differences in land use change. For both the Status Quo scenario and the Integration policy option, a loss of SOC-stocks for EU27 is modelled, showing a loss more than twice as high under the Status Quo scenario than those estimated for the Integration policy option.

The losses in SOC-stocks are not evenly spread across the area of the EU27 and also divergent trends between the regions of a single country were modelled. The estimated changes in SOC from Status Quo to Integration policy option over 10 years and aggregated at NUTS2 are presented in Figure III.

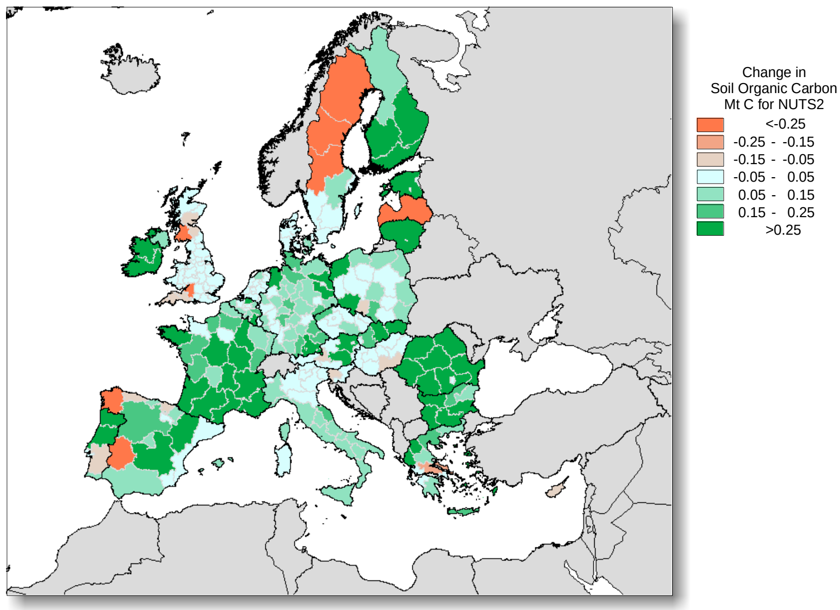


Figure III: Estimated Changes in Soil Organic Carbon from Status Quo scenario to Integration policy option over 10 Years (NUTS2)

In conclusion, these simulations have shown that the greening options implemented under the Integration policy option produce an overall impact that can be measured with a set of land use/cover based indicators. In general terms, the modelled greening options reduce the pressure on naturally vegetated areas and on environmentally sensitive sites. When comparing the results obtained for the two simulations, the Integration policy option points towards a lower level of environmental impact as compared to the Status Quo scenario globally at the EU27 level. However, several indicators also show pronounced regional differences and local developments, which do not follow the national or European trends.

The method developed and the tools applied within this project have been proven to provide highly relevant results to evaluate the potential impact of measures affecting land use/cover change. The Land Use Modelling Platform has been found highly adaptable to model even complex scenarios and an expert instrument to support further evaluation of European agricultural policies. In fact, the possibility to evaluate geographically differentiated impacts is one of the key assets of the methodology since it allows to assess EU policy proposals from a wide continental perspective as well as from a more detailed regional viewpoint. This is essential for policies such as the CAP where local characteristics (related to biophysical features and management practice) are the main elements to be considered when evaluating their impacts. Furthermore, the combination of an economically driven schema (as projected by CAPRI) with a high resolution biophysical analysis (as deduced by LUMP) allows the quantification of phenomena otherwise not possible. In the wider perspective of the impact assessment procedure within the European Commission, the proposed methodology adds essential quantitative and qualitative elements, in particular because of its multi-sectoral approach.

1 Introduction

The changes in the cover and use of the surface of the earth depend on natural processes, and are – at the same time - shaped by demographic, economic, cultural, political and technological drivers. A land-use/cover model can help understanding and interpreting the interactions between the bio-physical and human systems which are at the basis of the land dynamics by explaining the consequences of “where” and “when” in addition to “what” and “how much”.

The Land Use Modelling Platform (LUMP) has been developed by the Institute for Environment and Sustainability of the European Commission Joint Research Centre (JRC-IES) to support the policy needs of different services of the European Commission, such as exploration of future policies and impact assessments of specific proposals. The high-resolution land use/cover model EUClueScanner (EUCS100), developed in collaboration with DG Environment, is the core component of the platform which links specialized models and data within a coherent workflow.

The definition of global and regional economic scenarios entails the interface with external models related to different categories of drivers (demography, agriculture, regional economy, climate change, etc.). A set of other factors are also defined on the basis of local bio-physical features (e.g. accessibility maps, soil characteristics, topography, etc.) and of defined policies (e.g. subsidies, nature protection measures, land management options, etc.).

The land use modelling exercise described in this document focuses on the environmental part of the CAP reform and particularly on the greening component of Direct Payments. Two scenarios have been implemented in LUMP:

- *Status Quo* scenario represents the current socio-economic and environmental trends with current policy provision maintained (business-as-usual scenario);
- *Integration* policy option builds on the current policy provision a specific set of greening measures/options.

In the context of this work it is noteworthy the fact that the present modelling exercise is targeted at the assessment of the impacts of specific greening measures and not at considering the whole CAP policy provision for all greening measures.

2 Methodological framework

The Land Use Modelling Platform (LUMP) has a modular structure and is organized in three main components: the land demand module, the land allocation module (EUCS100) and the indicator module (see Figure 1).

At the core of the LUMP is the EUCS100 model operating at 100-meters spatial resolution (Lavalle et al., 2011). It is based on the dynamic simulation of competitions between land uses. Its spatial allocation rules are based on a combination of land demand, overall suitability, neighbourhood characteristics and scenario/policy-specific decision rules. It combines the top-down allocation of land use/cover drivers at national/regional level for all EU Member States with a bottom-up determination of conversions for specific land use transitions (Verburg and Overmars, 2009).

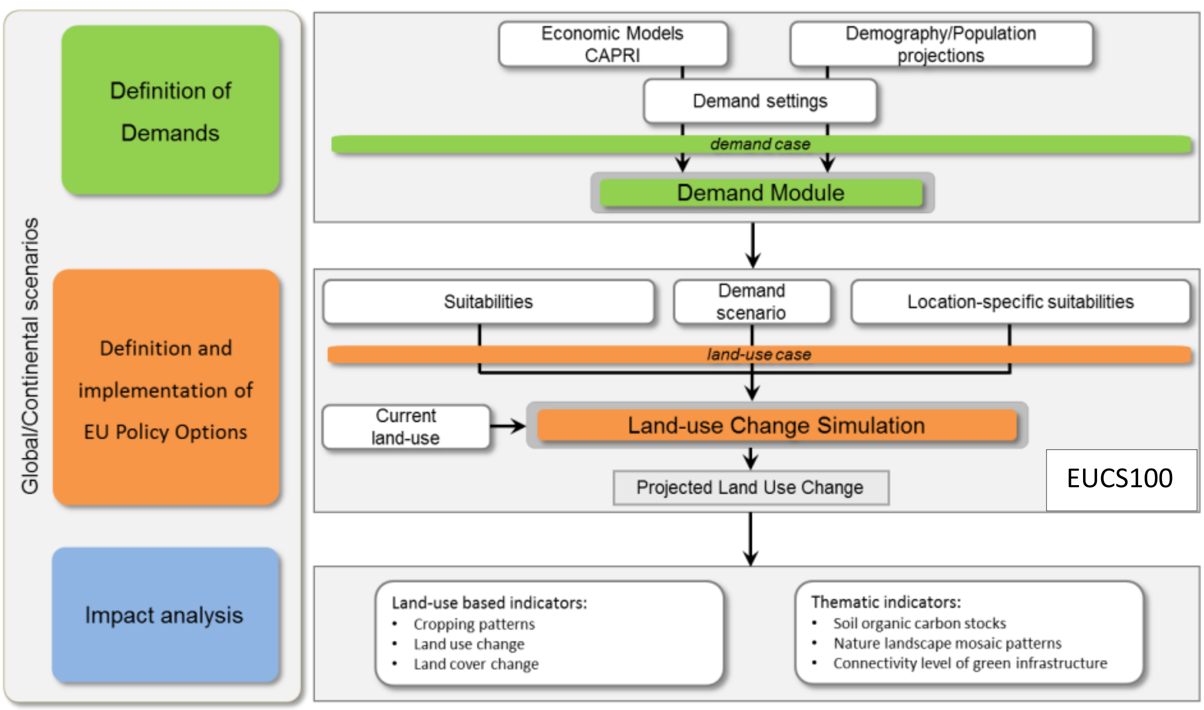


Figure 1: Overall workflow of LUMP highlighting the three main modules of the model

The CLC land use/cover map for year 2006 (reference year for the simulations) has been refined in both spatial and thematic resolution using additional sectoral datasets with continental coverage (Batista et al., 2011).

The *Simulated* land use/cover classes are subject to change over the simulation period (in this work from 2006-starting state, to 2020) according to the above workflow, whereas the *Non-simulated* classes are fixed throughout the time span, therefore not varying in their overall presence (area in hectares), nor in their geographic position.

The legend for the present modelling exercise has been defined as follow (Table 1):

Table 1: *Simulated* and *Non-simulated* land-use/cover classes

Land use classes	
Urban	Simulated
Industrial	Simulated
Arable	Simulated
Permanent crops	Simulated
Pastures	Simulated
Forests	Simulated
Semi-natural vegetation	Simulated
Abandoned arable	Simulated
Abandoned permanent crops	Simulated
Abandoned pastures	Simulated
Infrastructure	Non simulated
Other nature	Non simulated
Wetlands	Non simulated
Water bodies	Non simulated

Note: Arable land includes cereals, maize and root crops.

There are three main inputs for land claims in the LUMP:

1. Common Agricultural Policy Regionalised Impact Modelling System (CAPRI) for agricultural land;
2. Corine Land Cover (CLC) for all endogenous classes;
3. EUROPOP 2008 projections for urban land (EUROSTAT / ECFIN).

The supply detail data of crops from the CAPRI model are used to define the demands for agricultural land in LUMP. The EUCS100 model is therefore driven by the land claimed in CAPRI for crops. The crop types are detailed to such a high level in CAPRI that they must be aggregated in order to concur with the legend used in EUCS100, as shown in Table 2.

Table 2: Aggregation of CAPRI supply detail legend for crops to the EUCS100 legend

CAPRI class	CAPRI acronym	EUCS class
Soft wheat	SWHE	cereals
Durum wheat	DWHE	
Rye and Meslin	RYEM	
Barley	BARL	
Oats	OATS	
Other cereals	OCER	
Grain Maize	MAIZ	maize
Fodder maize	MAIF	
Potatoes	POTA	root crops
Sugar Beet	SUGB	
Fodder root crops	ROOF	
Apples Pears and Peaches	APPL	permanent crops
Other Fruits	OFRU	
Citrus	CITR	
Olives	OLIV	
Table Olives	TABO	
Nurseries	NURS	
Flowers	FLOW	
Wine	TWIN	
Table Grapes	TAGR	
Oilseeds	OILS	other arable
Pulses	PULS	
Tomatoes	TOMA	
Other Vegetables	OVEG	
Fodder other on arable land	OFAR	
Set-aside voluntary	VSET	
Fallow land	FALL	
Flax and hemp	TEXT	
Tobacco	TOBA	
Other industrial crops	OIND	
Paddy rice	PARI	
Other crops	OCRO	

The process of reading data from CAPRI, the aggregation and the interpolation of data from the Completeness and Consistency (CoCo) database (1990-2005) to the FARM 2020 CAPRI database (2020) was made in the LUMP on a Nomenclature of Territorial Units for Statistics (NUTS) 2 level in parallel to the extrapolation of data read from the Corine Land Cover (CLC) datasets (also at a NUTS 2 level). All these input data for land per NUTS 2 region were compiled into a single demand files for each country, while maintaining sub-national NUTS 2 divisions in order to drive EUCS100. Ranges for land claims for agricultural classes are given to EUCS100 according to the minimum and maximum claims from the two sources (CLC and CAPRI). Land claimed for industry and forestry are given by CLC alone and the land claimed for urban areas is given by a measure of residential density, computed using the Eurostat/ECFIN population projections (EUROPOP 2008). These projections incorporate a single convergence scenario, whereby demographic structural differences between countries are assumed to fade out by 2150. All of this data is merged within the LUMP configuration to provide input to EUCS100 as shown in Figure 2.

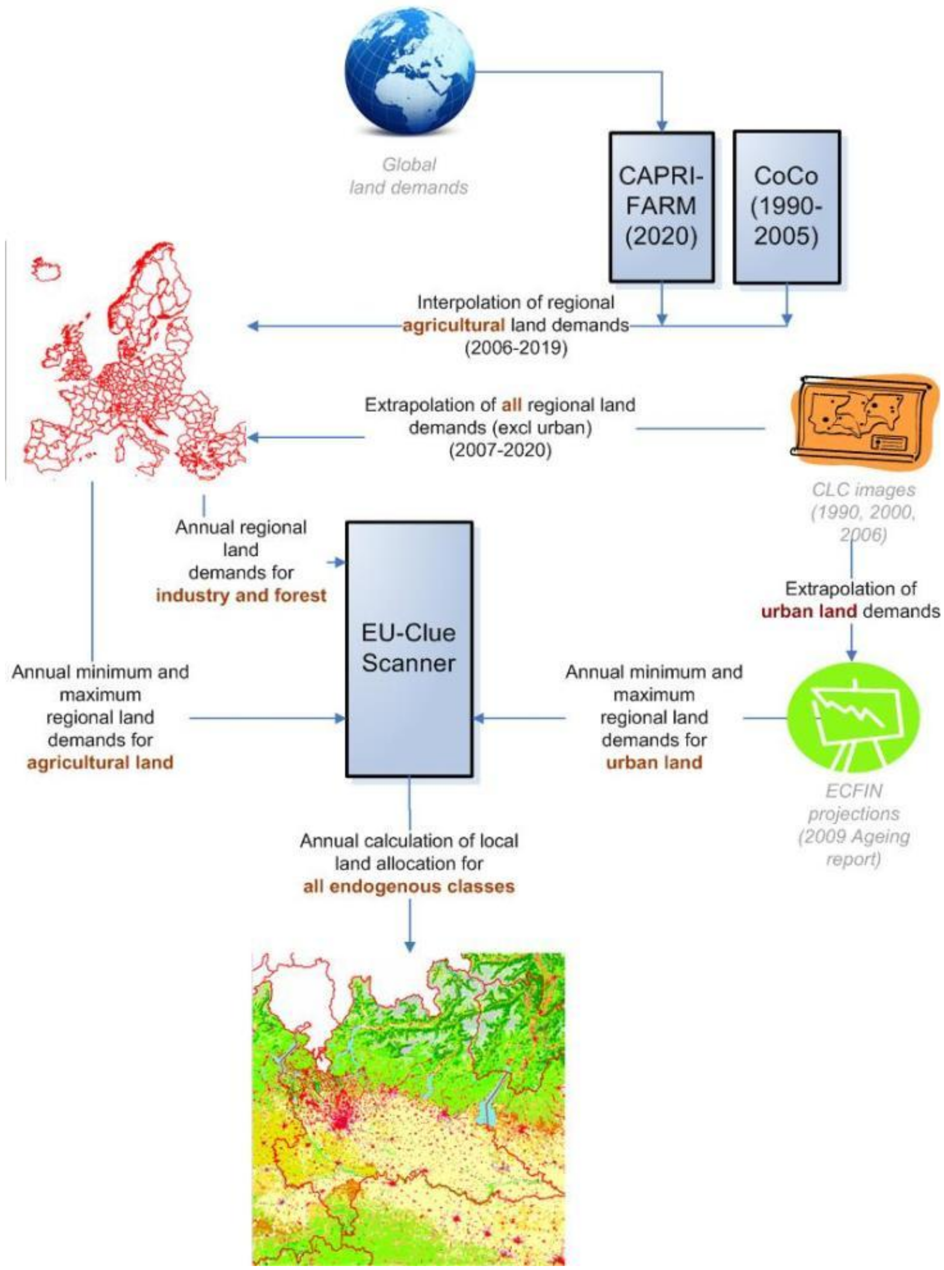


Figure 2: Process of integrating land claims from various sources to land allocation in EUCS100 through the LUMP

It is noteworthy to add that there is no specific claim for forested areas coming from an exogenous forestry sector-specific model. Afforestation and exploitation of forest products are therefore not taken into consideration in LUMP at this stage, although this feature will soon be implemented.

Semi-natural vegetation and *Abandoned* classes are simulated, although no specific claims are provided for these land use classes. Changes to these classes are governed primarily by the dynamics of the active classes and by specific policy-driven layers (when provided for the specific Policy Option implemented). In particular, *Abandoned arable land*, *Abandoned permanent crops* and *Abandoned pastures* may emerge as a consequence of the decline in the claims of the respective 'active' class (i.e. *Arable land*, *Permanent crops*, *Pastures*). Once land has been abandoned, it may remain in this state from one year to the next and undergo a natural succession process, passing after a certain number of years to Semi-natural vegetation and, possibly, to Forest. On the contrary, if the conditions (i.e. if the land claims from CAPRI at NUTS 2 level increase) favour the recovery of that area into a productive state, it may change back to *Arable land*, *Permanent crops* or *Pastures* respectively. Nevertheless, as time pass by this recovery implies higher conversion costs, resulting less probable to take place (Britz *et al.,* 2011).

As is shown in Table 2, fallow land and voluntary set aside are considered as part of the arable land claims. Although conceptually this inclusion may be imprecise, any alternative to this choice would have a negative impact on the model runs because of the very rules governing the model which allow for a realistic simulation of land dynamics: EUCS100 attempts to allocate the land claimed in its demand module. If fallow land was not included in the arable land, but rather was part of abandoned land, as may conceptually be correct, the model would incorporate this claim for "abandoned land" as a rule and would then allow the transition of natural succession on this land. This process would be incorrect because fallow land is, by definition, a temporary form of land use which is maintained and would therefore not exhibit the same behaviour as abandoned agricultural land. Furthermore, the voluntary set-aside land in CAPRI is set-aside in excess of the requirement, as it appears in statistics. It is therefore highly variable from year to year but is considered to be somewhat of an artefact, compensated by the trend figures given by CAPRI and CLC as minimum and maximum ranges.

Specific scenarios and policy-related settings are implemented in the EUCS100 module by means of the conversion matrix. This matrix defines which transitions are allowed: these may be either natural (natural succession) or anthropogenic. In some cases the conversions may be constrained by succession maps that specify the locations where they are allowed to take place (e.g. outside Natura2000 sites). In the context of the present modelling exercise, the same conversion settings are common for the implemented scenario and policy option. Given the current land-use/cover legend (see Table 1), Tables 3 and 4 summarise the conversions to and from agricultural land (i.e. *Arable*, *Permanent crops*, *Pastures*).

Table 3: Conversion settings from any land-use class to agricultural land

'From' land use class	Status Quo/Integration
Urban	Not allowed
Industrial	Not allowed
Arable	Allowed
Permanent crops	Allowed
Pastures	Allowed
Forests	Allowed with restrictions*
Semi-natural vegetation	Allowed with restrictions*
Abandoned arable land	Allowed
Abandoned permanent crops	Allowed
Abandoned pastures	Allowed
* *Allowed outside protected areas, i.e. Natura 2000*	

Table 4: Conversion settings from agricultural land to other land-use classes

'To' land use class	Status Quo/Integration
Urban	Allowed with restrictions*
Industrial	Allowed with restrictions*
Arable	Allowed
Permanent crops	Allowed
Pastures	Allowed
Forests	Allowed
Semi-natural vegetation	Allowed
Abandoned arable land	Allowed/Not allowed**
Abandoned permanent crops	Allowed/Not allowed**
Abandoned pastures	Allowed/Not allowed**
* *Allowed outside protected areas, i.e. Natura 2000* ** *Depending on the 'from' agricultural land- use class*	

The actual transformation from the current land-use state to a future state is computed considering the most suitable land-use for that specific location at each specific time. In the case of agricultural classes suitability maps were provided by the JRC-IES Monitoring Agricultural ResourceS Unit (MARS) which were developed within the context of the MARS Crop Yield Forecasting System (Baruth *et al.*, 2006). The probability that a specific land use will be allocated to any given cell is defined according to the combination of two main factors: a) specific bio-physical and geographical properties and b) the neighbourhood effect, which takes into consideration distance dependent on attraction and repulsion factors.

The factors contributing to this probability can be altered by specific combinations of spatial policies or measures (e.g. subsidies), each one contributing to the definition of a *policy option*. Consequently, a location specific modification can be made to each individual cell based on its location within the grid. This alteration is different depending on the type of spatial policy and on the possible overlap of different policies. These are called *Location Specific Addition Factors* and are then combined in one map for each land-use type (Location Specific Preference Addition - *locspec*).

Based on discussions with DG AGRI, the land use modelling exercise focuses on the environmental part of the CAP reform and particularly on the greening component of Direct Payments. In order to achieve this objective, a baseline scenario and a policy option representing the greening components have been implemented in LUMP, thus allowing an assessment of the effects of the policy option over the baseline:

- The *Status Quo* scenario represents the current socio-economic and environmental trends with current policy provision maintained (business-as-usual scenario). No further specific options are implemented. It is considered as the reference scenario.
- The *Integration* policy option builds on the current policy provision specific greening measures/options, as further specified below.

It is worth noting that the present modelling exercise is targeted at the assessment of the impacts of specific greening measures, without consideration of the CAP policy provision in its entirety or all greening measures.

The policy provisions taken into consideration in the implementation of Status Quo scenario are detailed as follows:

- Natura 2000: Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora and Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds;
- Nitrate Vulnerable Zones (NVZ): Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC);

- Erosion sensitive areas: the current GAEC framework (Council Regulation (EC) No. 73/2009, Annex III);
- Less Favoured Areas (LFA): this payment scheme promotes agriculture production in areas with natural handicaps (Articles 18 and 20 of Council Regulation (EC) 1257/1999).

Each of the issues listed above, with the exception of Natura2000, constitutes an input to a *Location Specific Addition Factors* for Status Quo and is therefore included in a *locspec* file for specific modelled land-uses. More specifically, NVZ have been taken into consideration by means of mapping riparian areas (buffer of 50m width along water bodies) which are currently designated NVZ[4]. Regarding erosion sensitive areas, two classes have been taken into consideration for this modelling exercise: areas where erosion is between 20 and 50 ton/ha/year, and areas where erosion is >50 ton/ha/year. LFAs are those defined in accordance with Articles 18 ("*mountain areas*") and 20 ("*areas affected by specific handicaps*") [5].

Figure 3 shows a zoom into the detail of the *locspec* map applied to arable land in the Status Quo scenario. It includes any overlap of the *Location Specific Addition Factors* for Status Quo, resulting in areas where arable land is encouraged (e.g. in LFAs) or discouraged (e.g. in Nitrate Vulnerable Zones and Erosion sensitive areas) at varying degrees. This *locspec* is also implemented in the permanent crops land-use class.

Under the Status Quo scenario, the Natura 2000 instrument is implemented through the transition matrix, thus determining where specific transitions between land-uses are not allowed to take place (see Tables 3 and 4 as examples).

[4] As reference, see FATE Data Portal at http://fate-gis.jrc.ec.europa.eu/geohub/MapViewer.aspx?id=2.

[5] Article 19 from Council Regulation (EC) 1257/1999 has not been taken into consideration. A proposal is being debated for identifying areas with natural handicaps other than those which are mountainous in character and those with specific handicaps, as newly defined by Article 50.3 (a) of Regulation (EC) No. 1698/2005.

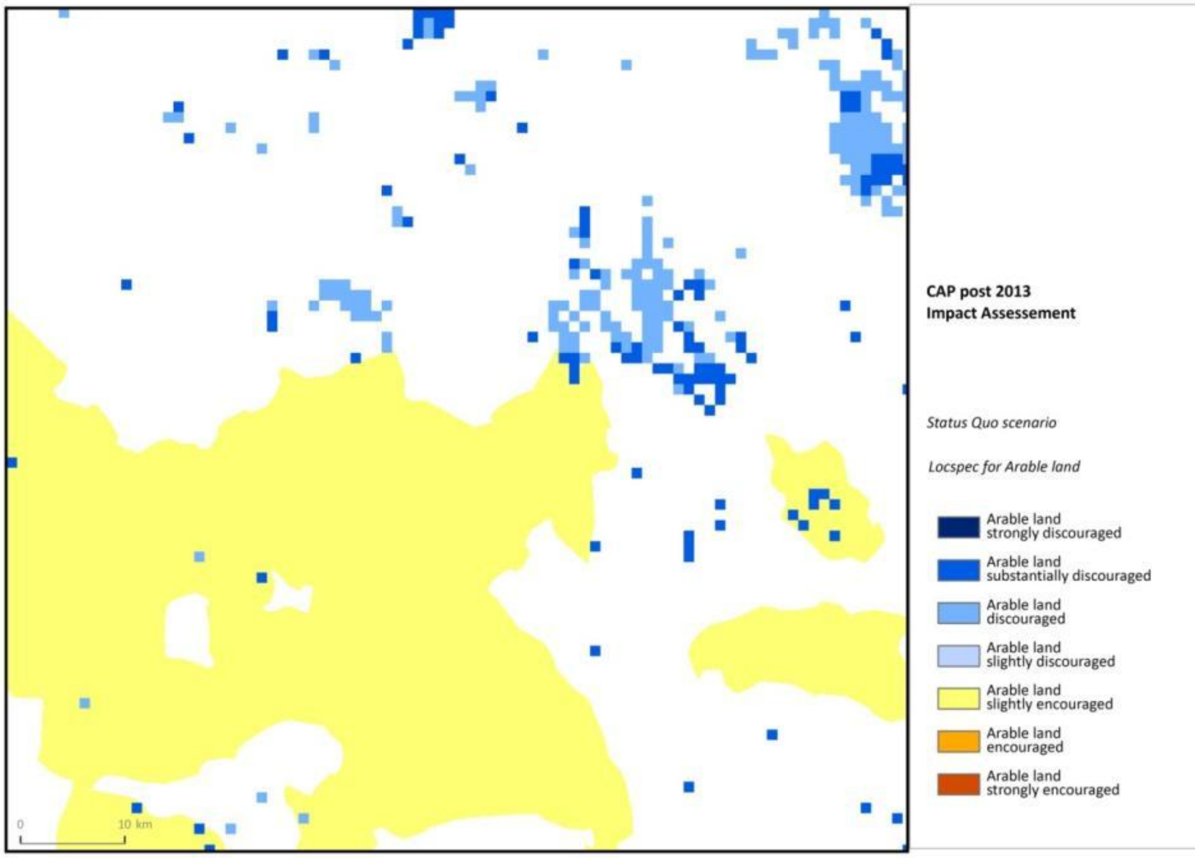


Figure 3: Detail from *locspec* map for arable land, as implemented in the Status Quo scenario

In addition to considering the spatial policies implemented in the Status Quo scenario alone (Natura 2000 areas, Erosion sensitive areas, Nitrate Vulnerable zones, Less Favoured Areas), the Integration policy option takes other *Location Specific Addition Factors* into consideration in order to accomplish the following greening measures:

- Ecological focus areas;
- Permanent pastures: maintaining the land in its current status;
- Natura 2000: maintaining the land in its current status (support to all designated agricultural Natura 2000 areas).

Ecological focus areas can be described as agricultural land that is no longer in production, primarily for environmental benefits. Following this interpretation, this greening measure is potentially applicable on arable land and open air horticulture as well as on permanent crops. In the latter case, ecological focus areas may take the form of grass buffer strips.

Consequently, within the current modelling exercise Ecological focus areas are implemented as a *Location Specific Addition Factor* which consists of buffers zones identified along water courses (50m each side)[6], all across the European territory[7]. This configuration is consistent with the current CAP and the definition of minimum requirements (conceived at two levels, compulsory and optional) named *Good Agricultural and Environmental Condition* (GAEC) under which direct payments are conditional[8]: *"… Retention of landscape features, including, where appropriate, hedges, ponds, ditches trees in line, in group or isolated and field margins; Establishment of buffer strips along water courses;…*". This concept is enforced in the Integration policy option.

This *Location Specific Addition Factor* is the only component of the *locspec* map assigned to Abandoned arable land, Abandoned permanent crops and Abandoned pastures land-use classes. The aim of these *locspec* is to enhance the probability of occurrence of these classes in riparian areas. This same rationale is applied for the *locspec* map assigned to Semi-natural vegetation. For this latter case, the Ecological focus areas represent only one of a series of *Location Specific Addition Factors.*

The **Permanent pastures** measure is about maintaining pasture/grassland that has not been in rotation for at least 5 years in its current status. The definition of permanent pastures/grassland used for the purposes of agricultural policy is very broad, thus potentially including all permanent grassland regardless whether it is actually grazed by animals[9]. Specifically, the maintenance of permanent pasture is part of the GAEC framework: in Article 2 of Council Regulation (EC) 796/2004 the following definition is stated: *"… 'Permanent pasture': shall mean land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that is not included in the crop rotation of the holding for five years or longer;…*".

For the purpose of the present modelling exercise, Permanent pastures measures have been implemented according to the above definition. The respective *Location Specific Addition Factor*

[6] Hereafter referred to as riparian areas/zones.

[7] The original dataset encompassing water courses is CCM2 (CCM River and Catchment Database © European Commission - JRC, 2007).

[8] See Article 6 and Annex III of Council Regulation (EC) No 73/2009.

[9] As reference, see Council Regulation (EC) No 1782/2003 and Council Regulation (EC) No 73/2009.

identifies permanent pastures as Corine land-use classes *Pastures* and *Natural grassland* that have been constant between 2000 and 2006[10]. This *Location Specific Addition Factor* is the only component of the *locspec* assigned to the Pastures land-use class. The preservation of the current status (Pastures) enhances the probability of maintaining it in the mapped areas.

Natura 2000 greening measure should contribute to keeping farming in place in Natura 2000 areas, thus compensating for the restrictions farmers face under the current legislation. Therefore, in this modelling exercise the Natura 2000 measure has been implemented as a *Location Specific Addition Factor* which identifies the Natura 2000 areas containing agricultural land. This factor is then used as a component of the *locspec* assigned to Arable land and Permanent crops classes, thus enhancing the probability of maintaining the present status of agricultural land within those sites. The entire Natura 2000 areas are also used to constitute one component of the *locspec* for Semi-natural vegetation, increasing the probability of occurrence of this land-use class. Moreover, the role of Natura 2000 sites in influencing specific land-use/cover transitions by means of the transition matrix is maintained between the Status Quo and Integration model runs.

In addition to the greening measures specified above and completing our methodological approach, a specific mention is needed for the High Nature Value farmland concept. According to Paracchini *et al* (2008), "typical high nature value (HNV) farmland areas" can be defined as "*extensively grazed uplands, alpine meadows and pasture, steppic areas in eastern and southern Europe and dehesas and montados in Spain and Portugal. Certain more intensively farmed areas in lowland western Europe can also host concentrations of species of particular conservation interest, such as migratory waterfowl*".

A crucial issue related to HNV is the provision of public goods associated with agriculture[11]. According to Cooper *et al.* (2009), the most significant of these are related to agricultural landscapes and specific farmland characteristics[12], thus "*public goods provided through European agriculture can take the form*

[10] In the case of countries for which Corine Land Cover 2006 was not available yet (i.e. Greece and United Kingdom) were considered the pastures, which were constant between 1990 and 2000.

[11] For further details and a comprehensive coverage of this issue, see Cooper *et al.* (2009) and European Network for Rural Development (2010).

[12] Extensive citation from Cooper *et al.* (2009): "…*There is a wide range of public goods associated with agriculture, many of which are highly valued by society. The most significant of these are environmental – such as agricultural landscapes, farmland biodiversity, water quality, water availability, soil functionality, climate stability (greenhouse gas emissions), climate stability (carbon storage), air quality, resilience to flooding and fire*".

of physical entities – such as cultural landscapes or a specific habitat – or the form of services – such as resilience to flooding or fire" (Cooper *et al.*, 2009).

In addition, Cooper *et al.* (2009) argue that "*there are a number of reasons why the current policy framework has not achieved the improvement in the provision of public goods on the scale that is required*"[13]. In fact, the policy provision of Status Quo, which draws from the current situation and the current implementation of CAP, does not include any specific policy targeted at preserving HNV farmland.

On the other hand, given the increasingly important role that the preservation of public goods plays within the proposal of the new CAP[14] and the tight relation between HNV and public goods, it has been chosen to take HNV explicitly into consideration in the implementation of the Integration policy option run. In fact, even though the current proposal of Integration policy option for CAP does not include any explicit measure/framework specifically targeting HNV farmland, it can be inferred that low-intensity HNV farming should benefit under Integration in comparison to the Status Quo. This can be seen as follow-up from a number of elements as included in Integration: greening measures related to Pillar I (as also taken into consideration in the current modelling exercise) have the potentiality for providing the basis for the delivery of public goods through agriculture, whereas Rural Development measures, aimed at delivering public goods, should possibly benefit from the release of funds consequence of the introduced greening measures.

In the light of the above assumptions, a *Location Specific Addition Factor* has been created for Integration policy option, based on the HNV map of Paracchini *et al.* (2008) which represents the

---

[13] Extensive citation from Cooper *et al.* (2009): "*…there are a number of reasons why the current policy framework has not achieved the improvement in the provision of public goods on the scale that is required. These relate to the relative weight afforded to the different objectives of policy, the choice of policy instruments, the design and subsequent implementation of policy measures, the extent of governance and institutional capacity and critically, the adequacy of budgetary resources. Indeed, current levels of expenditure on rural development measures with environmental objectives appear insufficient when compared to the scale of societal demand and estimates of the scale of funding required to meet EU targets for specific public goods*."

[14] In the *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - The CAP towards 2020: Meeting the food, natural resources and territorial challenges of the future* (COM(2010) 672 final) Objective 2 focuses on "Sustainable management of natural resources and climate action" and, among other priorities, it is aimed at guaranteeing "*sustainable production practices and secure the enhanced provision of* ***environmental public goods*** *[bold from the source] as many of the public benefits generated through agriculture are not remunerated through the normal functioning of markets*".

likelihood of presence of HNV farmland and an estimate of its distribution at the European scale. This factor has been used as a component for the *locspec* assigned to Arable land, Permanent crops, Pastures and Semi-natural vegetation land-use/cover classes (these classes receive an enhanced probability of occurrence in the mapped areas).

On the whole, the *locspec* map for Arable land contains all the possible combinations resulting from the overlap of the following *Location Specific Addition Factors,* as shown in an example in Figure 4:

- Riparian zones (along water courses each side 50m) inside Nitrates Vulnerable Zones;
- Erosion sensitive areas (two classes: 20 – 50 and >50 t ha^{-1} yr^{-1});
- Less Favoured Areas (art. 18 and 20);
- Natura 2000 areas currently cropped;
- High Nature Value Farmland.

At the current state (2006) cropped areas mapped as belonging to both Natura 2000 sites and HNV are considered to benefit from this combination, being more likely to maintain their current status than belonging to only one of the two *Location Specific Addition Factors*.

The *locspec* map previously described is also implemented for Permanent crops.

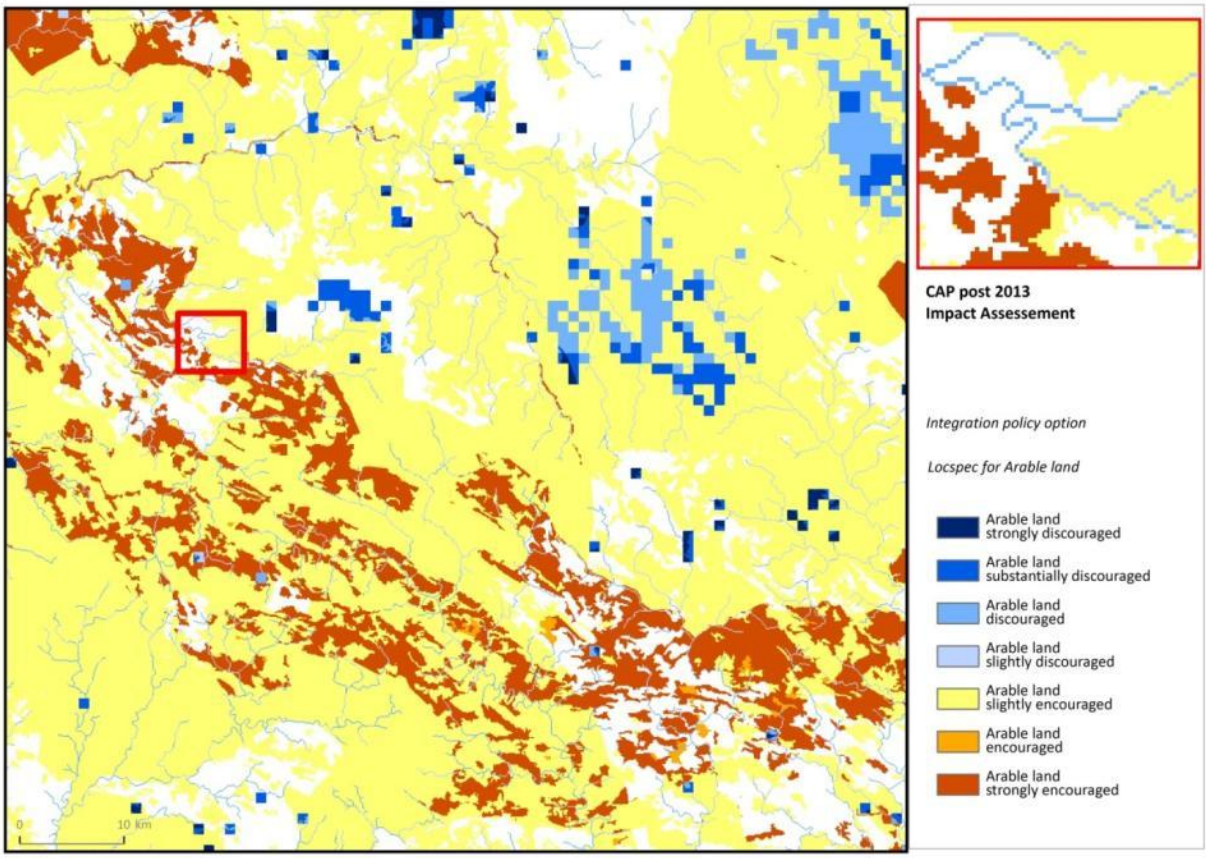


Figure 4: Detail from *locspec* map for arable land, as implemented in Integration policy option

As a last exemplification of *locspec* maps implemented in the Integration option, the one assigned to Semi-natural vegetation is depicted in Figure 5 (detail). It contains all possible combinations resulting from the overlap of the following *Location Specific Addition Factors*:

- Riparian zones (along water courses each side 50m);
- Natura 2000 sites;
- High Nature Value Farmland.

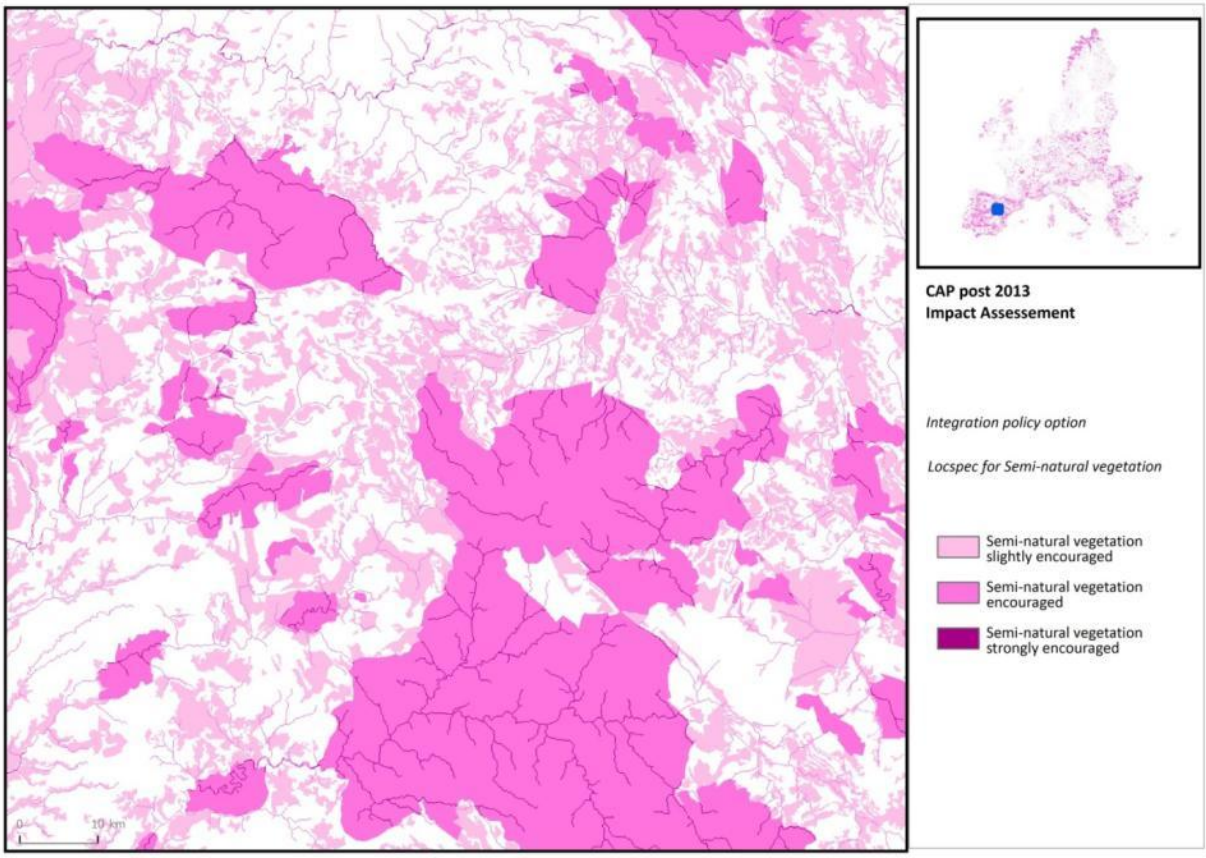


Figure 5: Detail from *locspec* map for semi-natural vegetation, as implemented in Integration policy option

3 Land use changes for year 2020

Following the above described methodology, LUMP has been applied to simulate European-wide (EU27) land use/cover maps from year 2006 to year 2020 for both the Status Quo scenario and the Integration policy option (Figures 6 and 7).

The overall (EU27) land use/cover transformations 2006-2020 are rather similar for the two simulations. Both simulations estimate an increase of arable land (higher in Status Quo) and a slight decrease of permanent crops and pastures (Figure 8). As regards the trend of pasture, this reduction is less significant in Integration policy option due to the greening measure ‘maintenance of permanent pastures’.

In addition, it is important to highlight a general decrease of semi-natural vegetation (around -2.5%) and an increase of forest areas (2%).

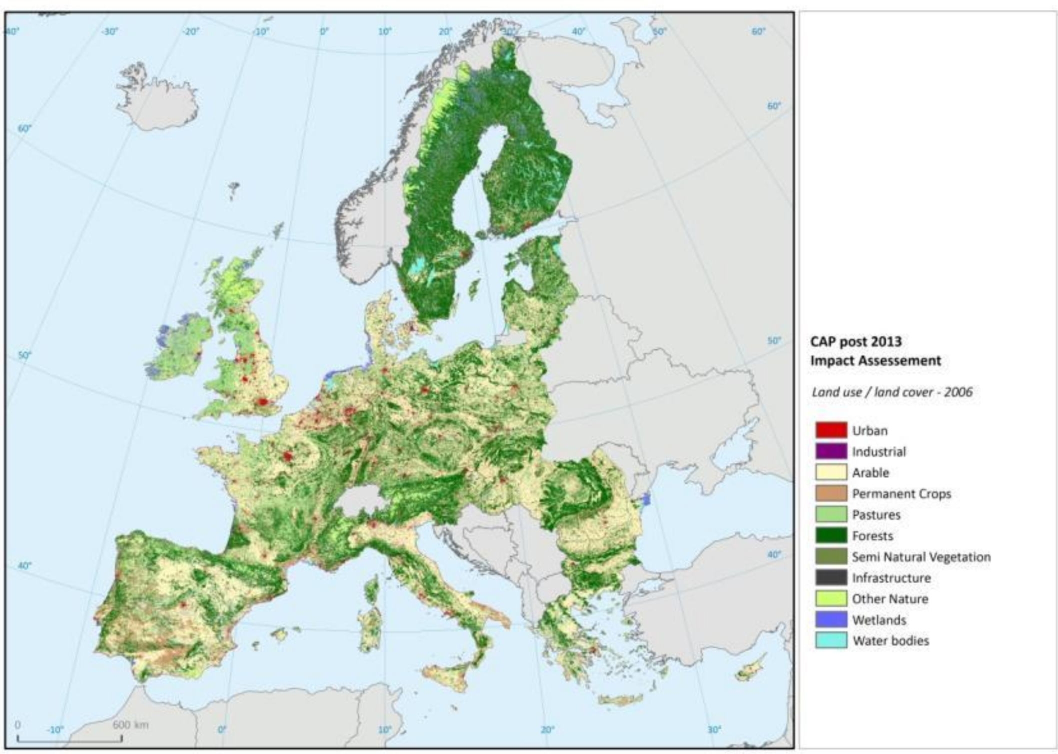
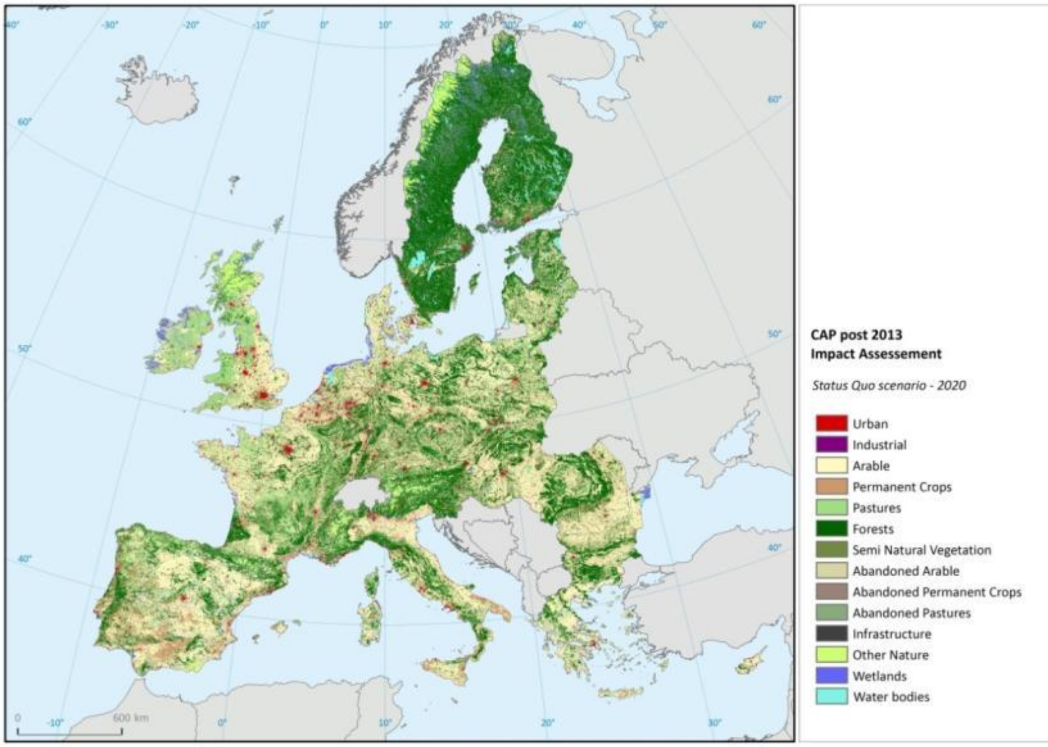


Figure 6: Land use/cover in 2006 (initial year of simulation)



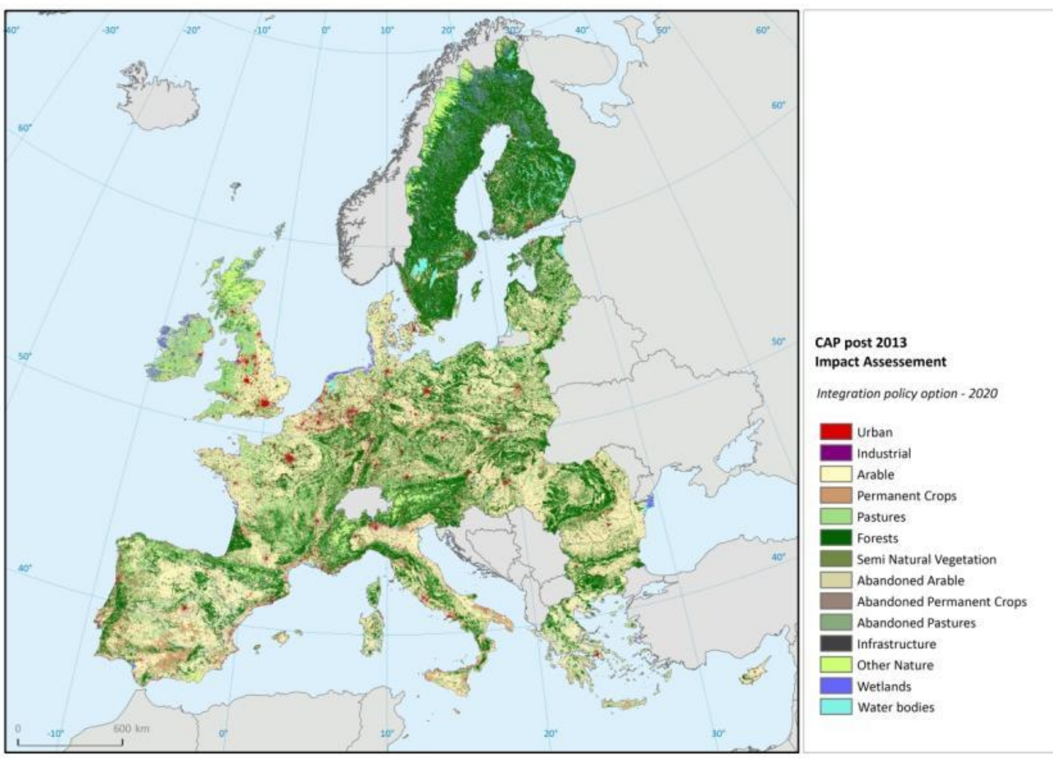


Figure 7: Land use/cover in 2020, according to Status Quo scenario (above) and Integration policy option (below)

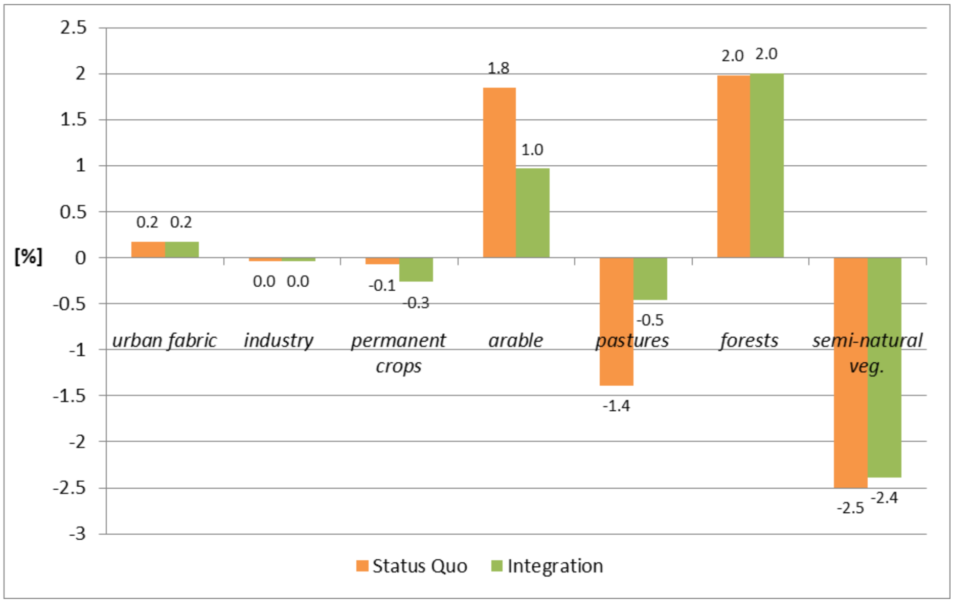


Figure 8: Net change (%) in EU27 from 2006 to 2020, per land use/cover

A more detailed analysis at country level puts in evidence considerable asymmetries between Member States. Concerning arable land, the Czech Republic, Denmark, Poland, Portugal, Slovenia and Sweden register a decrease in area from 2006 to 2020 under both scenarios (Figure 9).

On the other hand, among the countries with an increase of arable land, one may want to focus on Belgium and Luxembourg[15], Greece, Ireland, Romania and Slovakia, since they show a more intense change in arable land in Status Quo scenario than in Integration policy option (dissimilarity higher than 2.5%). Latvia also registers a considerable contrast between Status Quo and Integration, but in this case, the Integration policy option has the highest change.

The large increase of arable land in year 2020 in Ireland for the Status Quo scenario is compensated for by an equivalent decrease in pasture for the same scenario, because of an exchange between the two land types.

[15] In the scope of the present section, results for Belgium and Luxemburg are presented aggregated.

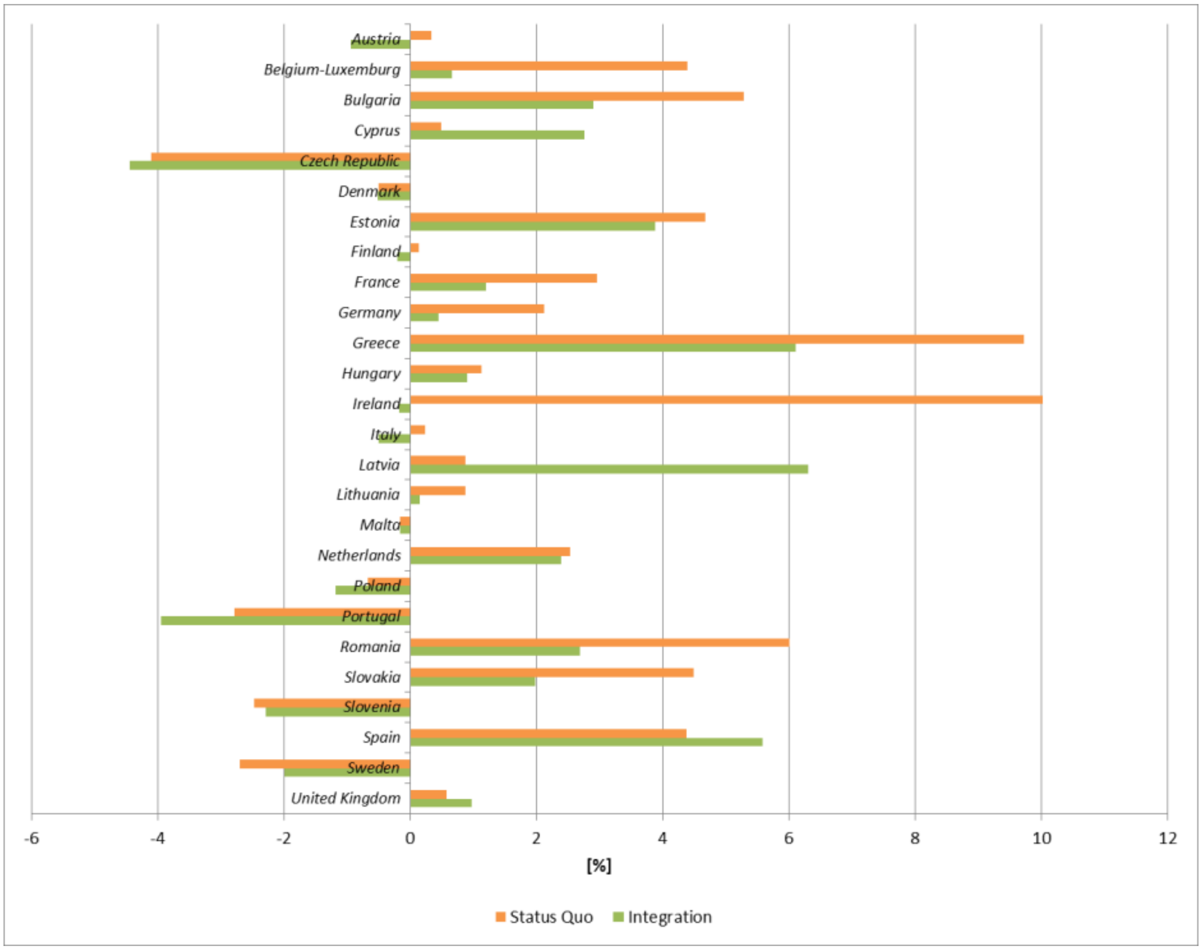


Figure 9: Net change (%) in arable land, from 2006 to 2020, per country

Regarding permanent crops, almost every country follows the general trend of a minor decline, with the exception of Ireland, Hungary, Poland and Denmark (Figure 10). However, only in Ireland the difference between the Status Quo scenario and the Integration policy option is higher than 1%.

Spain, one of the European countries with the largest share of permanent crops, registers a relatively more intense decrease under the Integration policy option due to a higher conversion of permanent crops to arable land.

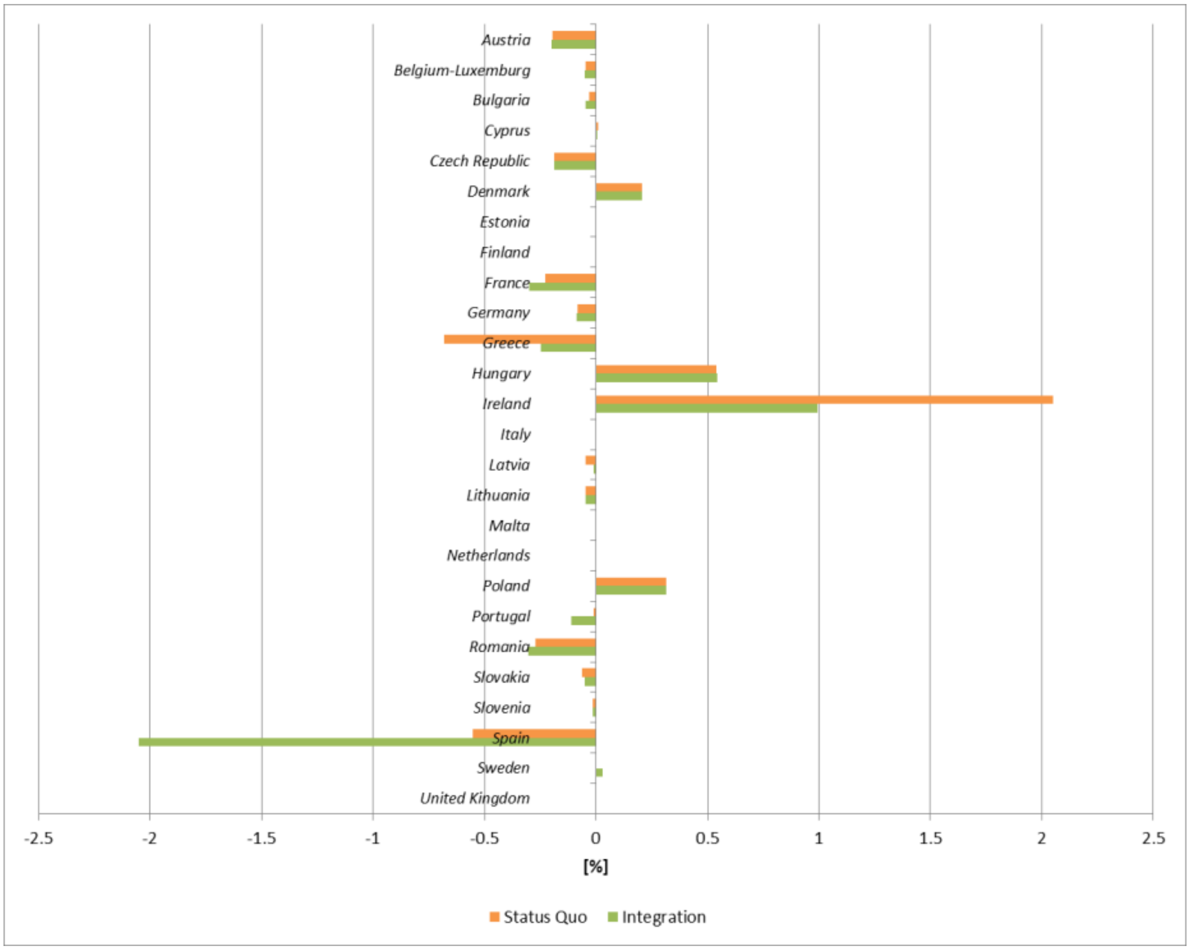


Figure 10: Net change (%) in permanent crops, from 2006 to 2020, per country

Concerning pastures, there is a general decline of this land cover type, which is less significant in the Integration policy option than in the Status Quo scenario, which is due to the effect of the greening measure 'maintenance of permanent pastures'. This is particularly evident in Ireland, Greece and Romania, where the difference between the Status Quo scenario and the Integration policy option is above 3 percentage points (see Figure 11).

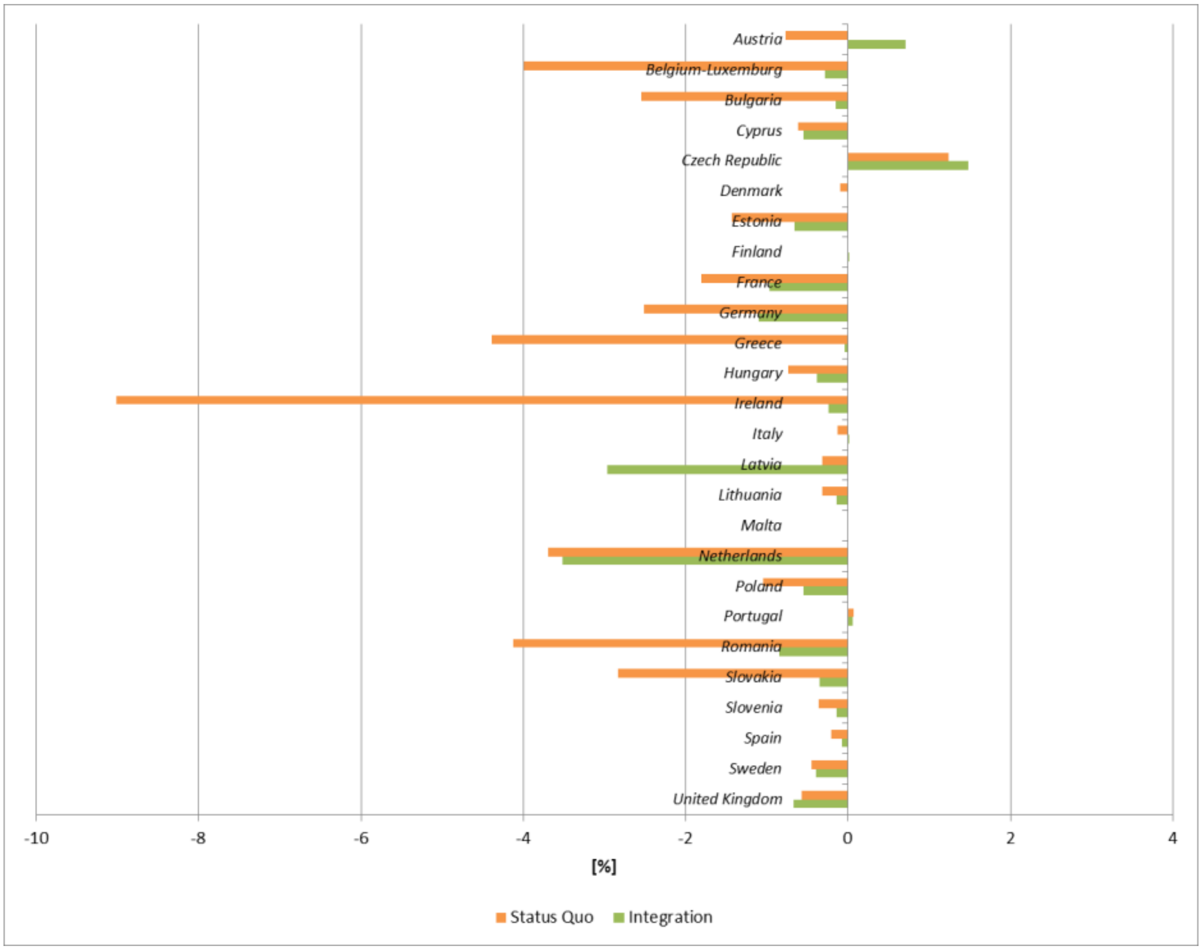


Figure 11: Net change (%) in pastures, from 2006 to 2020, per country

4 Land use indicators for environmental assessment of CAP reform

The main output of the EUCS100 model is a series of projected land use/cover maps for the coming years up to 2020 for different policy alternatives. Once produced, the EUCS100 outputs can be used to compute a set of various indicators within the framework of LUMP by direct or indirect linkage with thematic models.

The following indicators have been computed and are presented in this report:

- Cropping patterns (share of agricultural land use);
- Land use change (agricultural land to artificial surfaces);
- Land cover change (agricultural expansion; agricultural abandonment; agricultural conversion to natural areas);
- Conservation and connectivity of green infrastructure;
- Conservation of core natural areas;
- Agricultural heterogeneity ;
- Soil organic carbon stocks.

The following water related indicators are not presented in this report and will be computed at a later stage:

  - Water quantity (e.g. upper and lower groundwater storage, surface runoff, soil moisture content; delivered at a later stage since requires the running of the LISFLOOD model);
  - Water quality (e.g. contaminants loads and concentration by pathways).

4.1 Share of agricultural land use

For the purpose of computing indicators, agricultural land use is separated into three aggregated typologies: arable land[16], permanent crops and pastures. This indicator measures in percentage the contribution of each typology to the total area occupied by agricultural land in year 2020. The values are hereafter presented per country and depicted at NUTS2 level (values aggregated for EU12, EU15 and EU27 Member States are given in the Annex I).

4.1.1 Arable Land

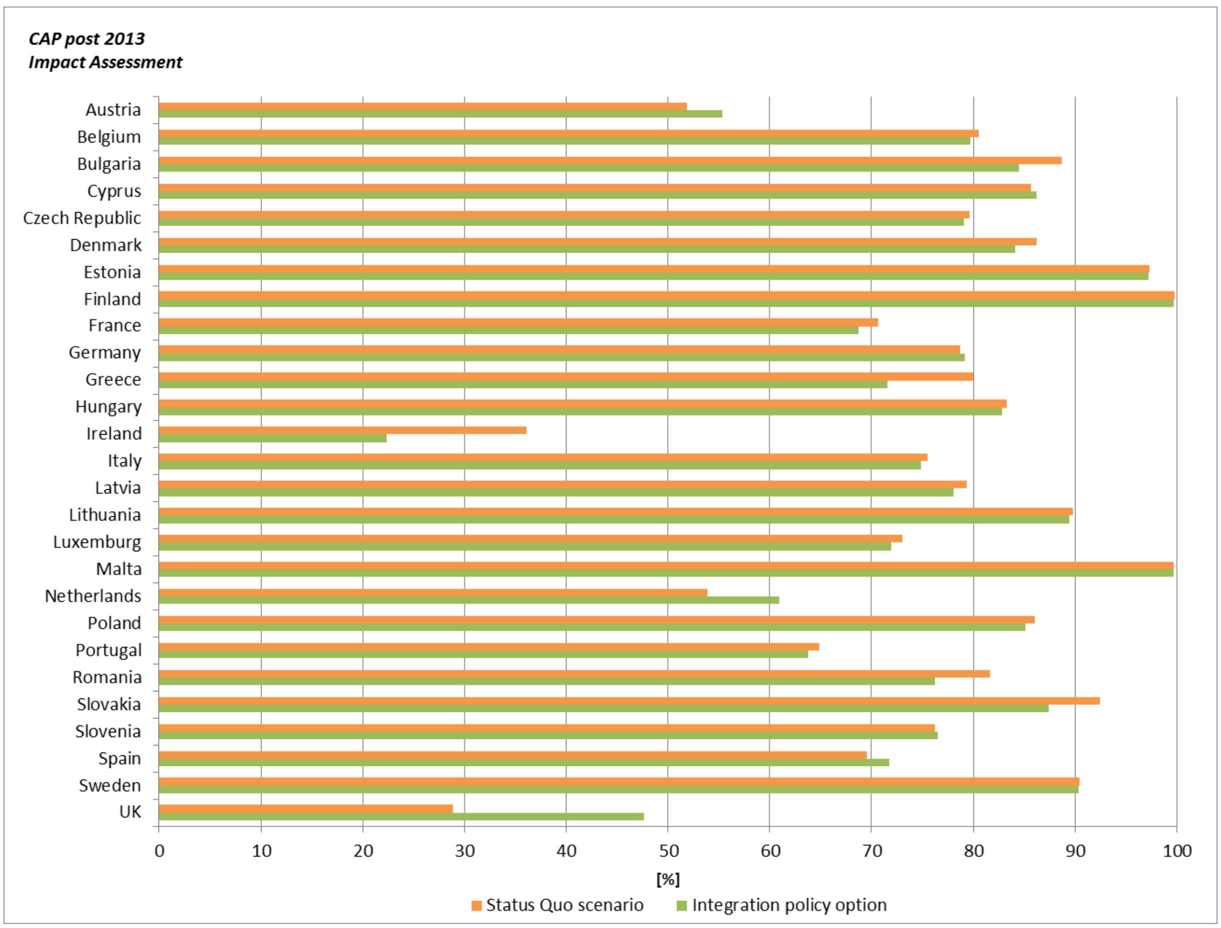
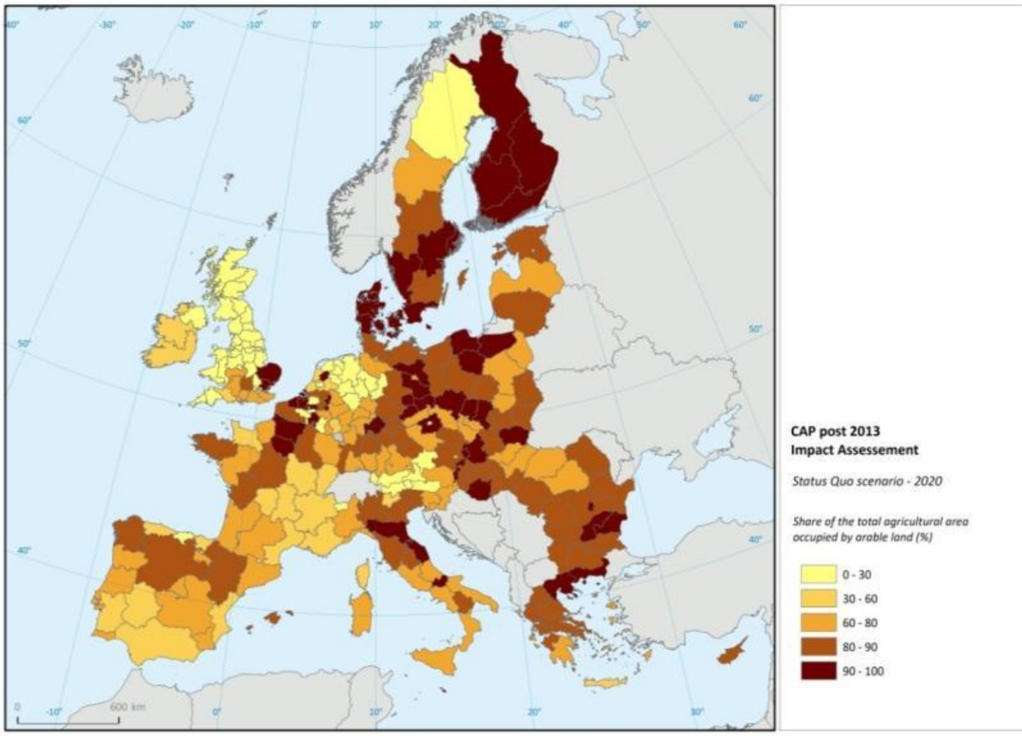


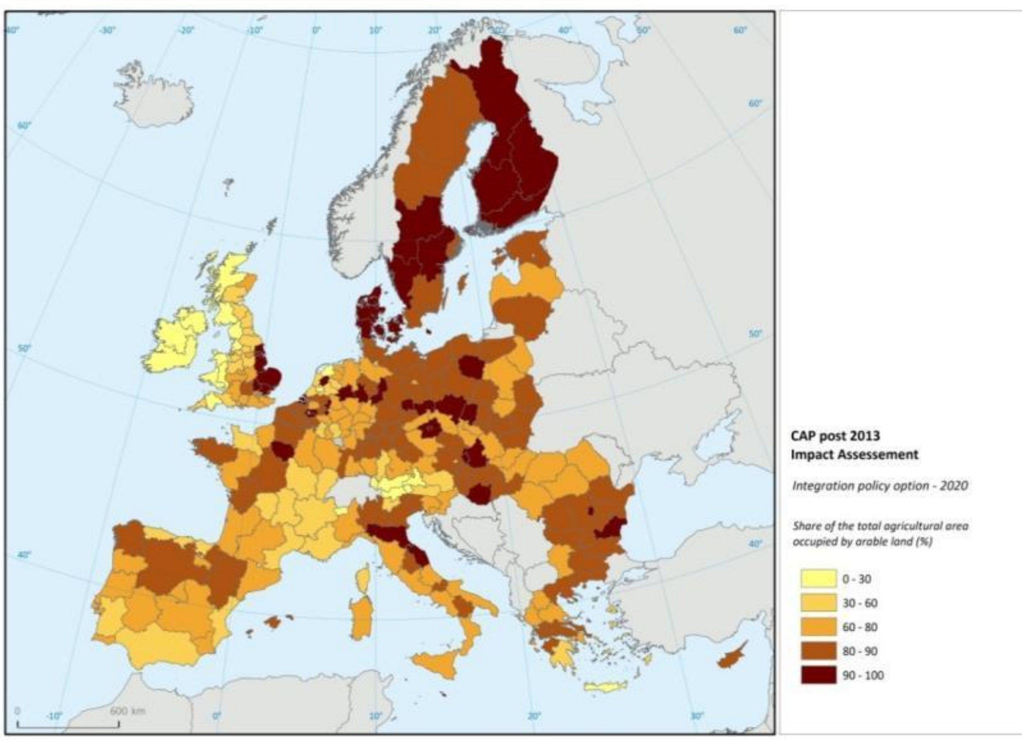
Figure 12: Share (%) of agricultural area occupied by arable land in year 2020

[16] The land use model further breaks down the arable class into cereals, maize and root crops. These are aggregated into a single class when computing indicators.

As shown in Figure 12, the share of arable land varies from country to country depending on its historical landscape patterns. For instance, the share is above 90% in Estonia, Finland and Malta, but less than 50% in Ireland and the United Kingdom. Regarding the differences between the Status Quo scenario and the Integration policy option, these are more relevant in the United Kingdom, the Netherlands (a dissimilarity of 18 and 7 percentage points respectively, higher in Integration policy option), and on the opposite Ireland and Romania (more than 13 and 5 percentage points respectively, in the Status Quo scenario). Figure 13 puts in evidence that diverse landscape patterns emerge at NUTS 2 level between the Status Quo scenario and the Integration policy option. The differences are evident for some regions of Sweden, United Kingdom, and central Europe (mostly in Germany and Netherlands).



a



b

Figure 13: Regional (NUTS-2) share (%) of arable land vs. total regional agricultural area (a) for the Status Quo scenario; (b) for the Integration policy option

4.1.2 Permanent crops

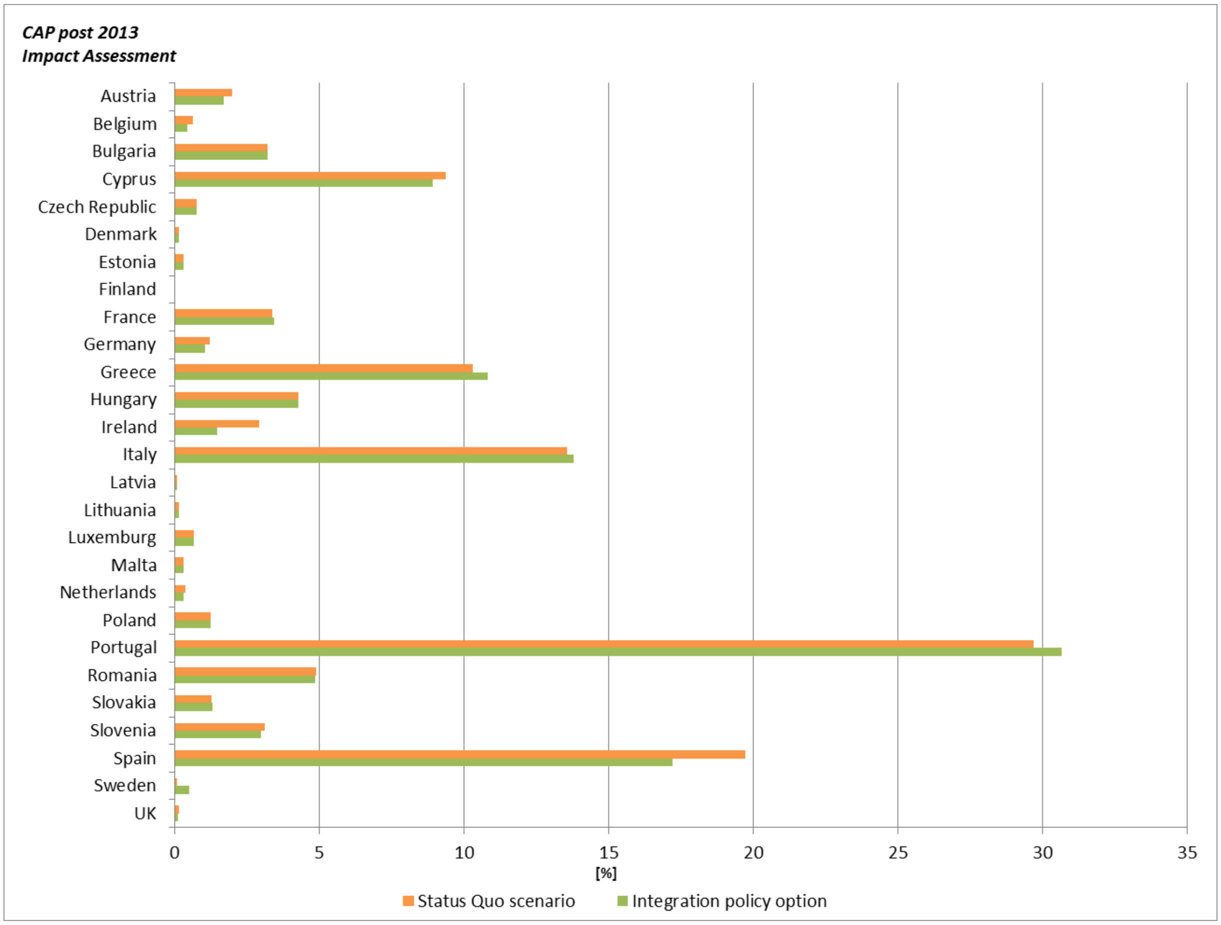
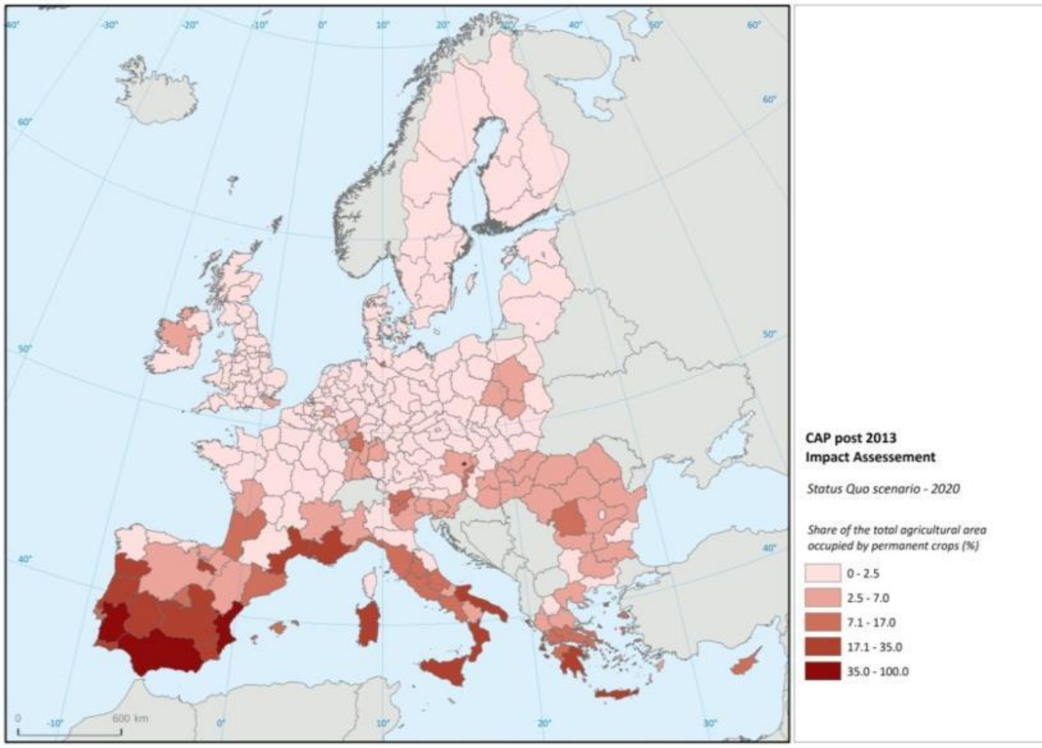


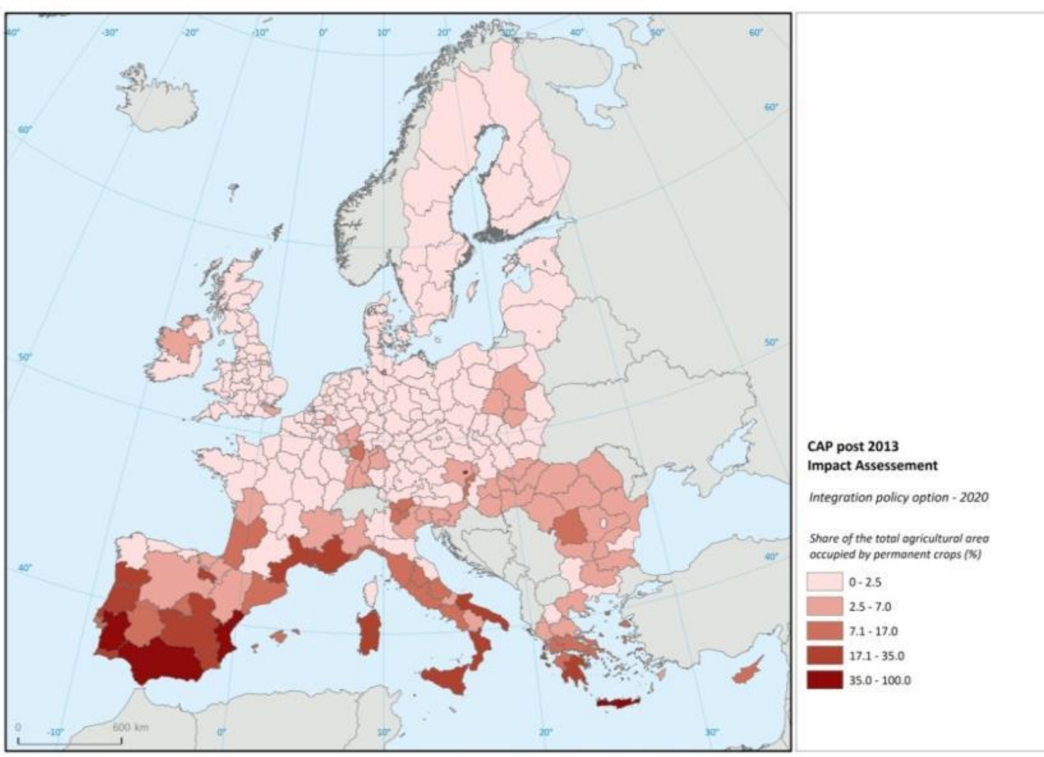
Figure 14: Share (%) of agricultural area occupied by permanent crops in year 2020

As regards permanent crops no significant difference between Status Quo scenario and Integration policy option were found (see Figure 14).

In relation to permanent crops, and despite a representation of almost 6% at EU27 level (higher in Status Quo), there is a clear discrepancy among Member States: the contribution of 'permanent crops' to the total share of agricultural land is particularly important in countries such as Portugal and Spain, and some southern regions of France and Italy (see Figure 15).



a



b

Figure 15: Regional (NUTS-2) share (%) of permanent crops vs. total regional agricultural area (a) for the Status Quo scenario; (b) for the Integration policy option

4.1.3 Pastures

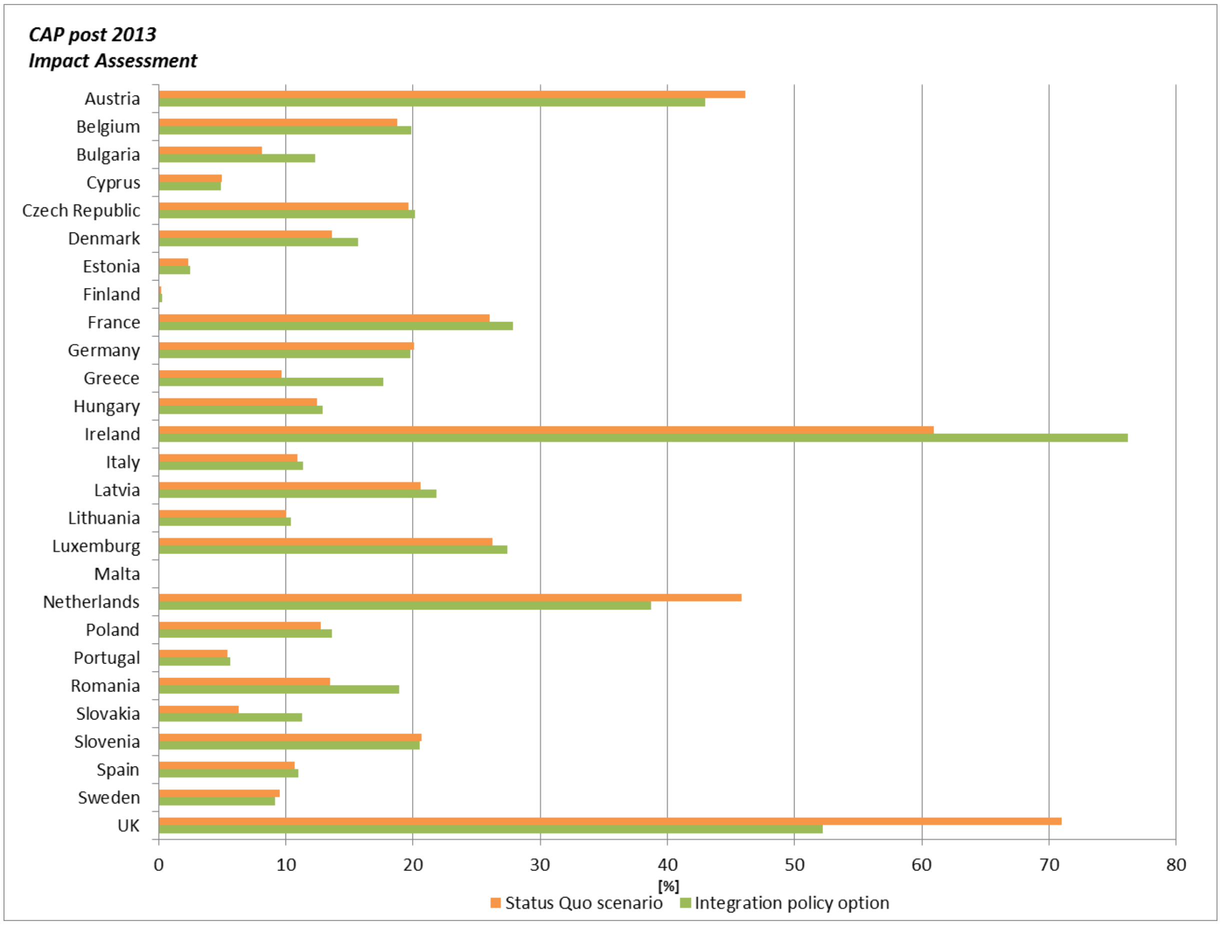
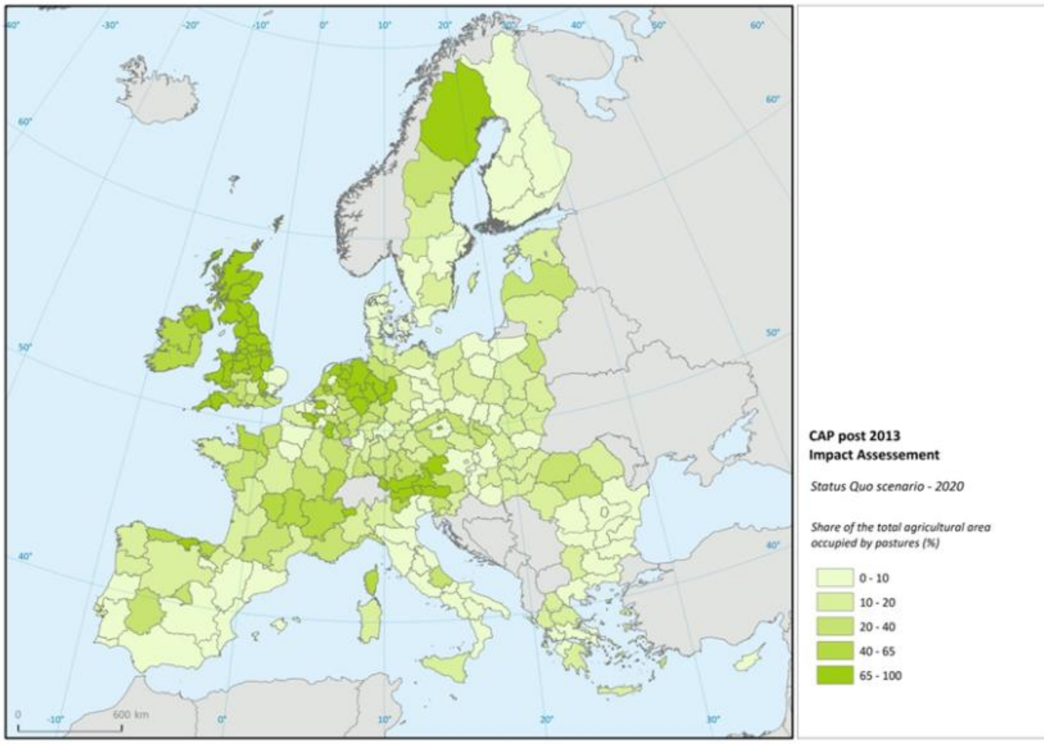


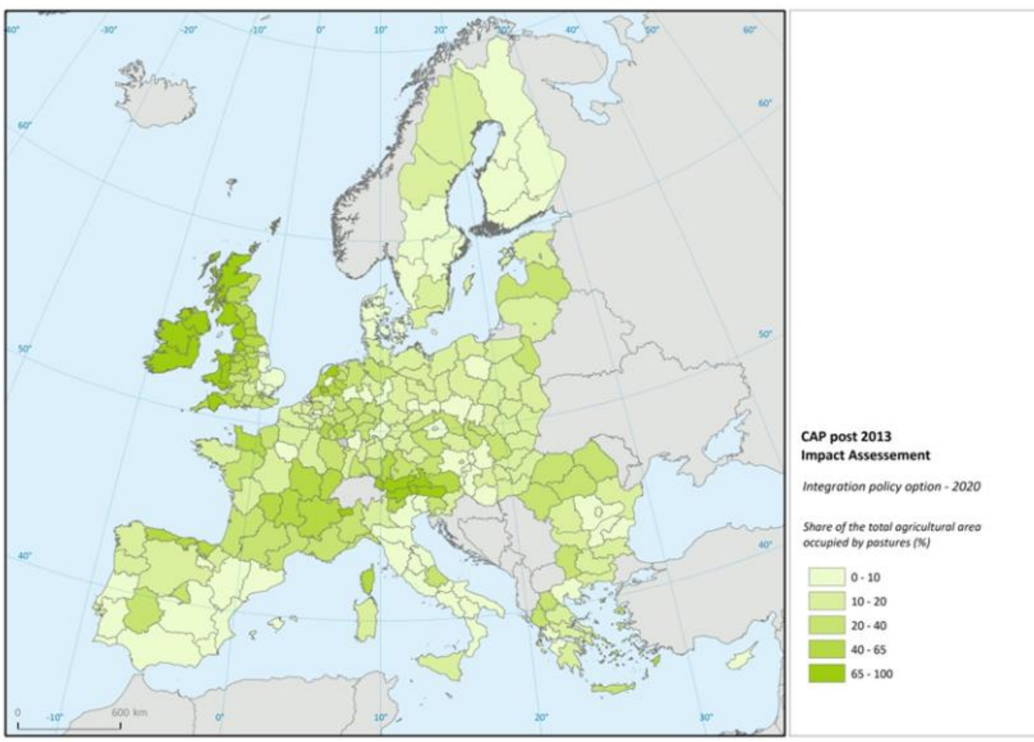
Figure 16: Share (%) of agricultural area occupied by pastures in year 2020

The share of the total agricultural area occupied by pastures is, in general, slightly higher in the Integration policy option than in the Status Quo scenario (Figure 16) - approximately 21% and 20%, respectively in EU27. This overall trend is due to the fact that under the Integration policy option the greening measure 'maintenance of permanent pastures' enhances the presence of this land cover. However, Figure 17 depicts some exceptions that occur mainly in the Netherlands and the United Kingdom[17].

[17] United Kingdom represents an exception due to the absence of CLC coverage for 2006, which was important to identify permanent pastures.



a



b

Figure 17: Regional (NUTS-2) share (%) of pastures vs. total regional agricultural area (a) for the Status Quo scenario; (b) for the Integration policy option

4.2 Agricultural expansion

4.2.1 Conversion from semi-natural vegetation into agriculture

This indicator considers the transition of land from semi-natural vegetation (in 2006) to agricultural land (in 2020), i.e. arable land, permanent crops and pastures. The indicator is given as percentage of the total agricultural land in 2006, per country.

Figure 18 shows that the expansion of agricultural land at the expense of semi-natural vegetation is, in general, higher under the Integration policy option. The difference between the Status Quo scenario and the Integration policy option is particularly relevant in some countries, such as Greece, Slovakia and Cyprus. Conversely, in Ireland, Sweden and Finland a higher conversion is modelled under the Status Quo scenario than under the Integration policy option.

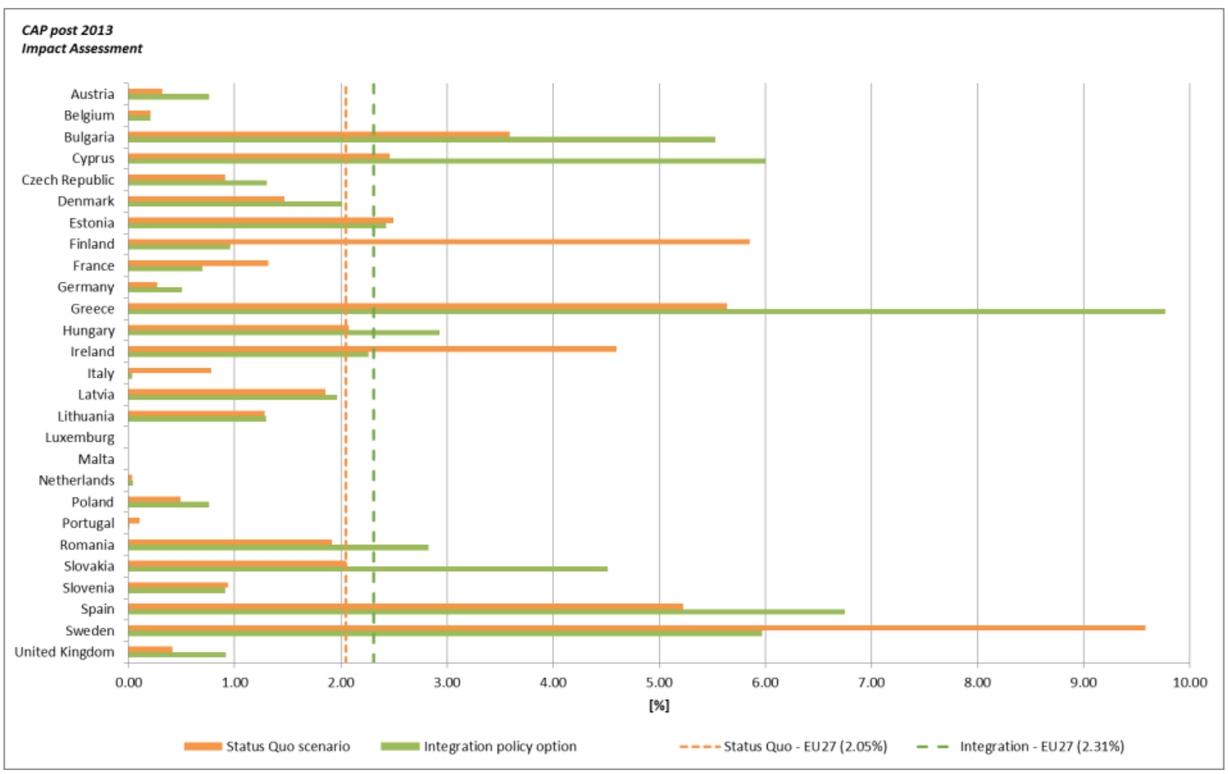
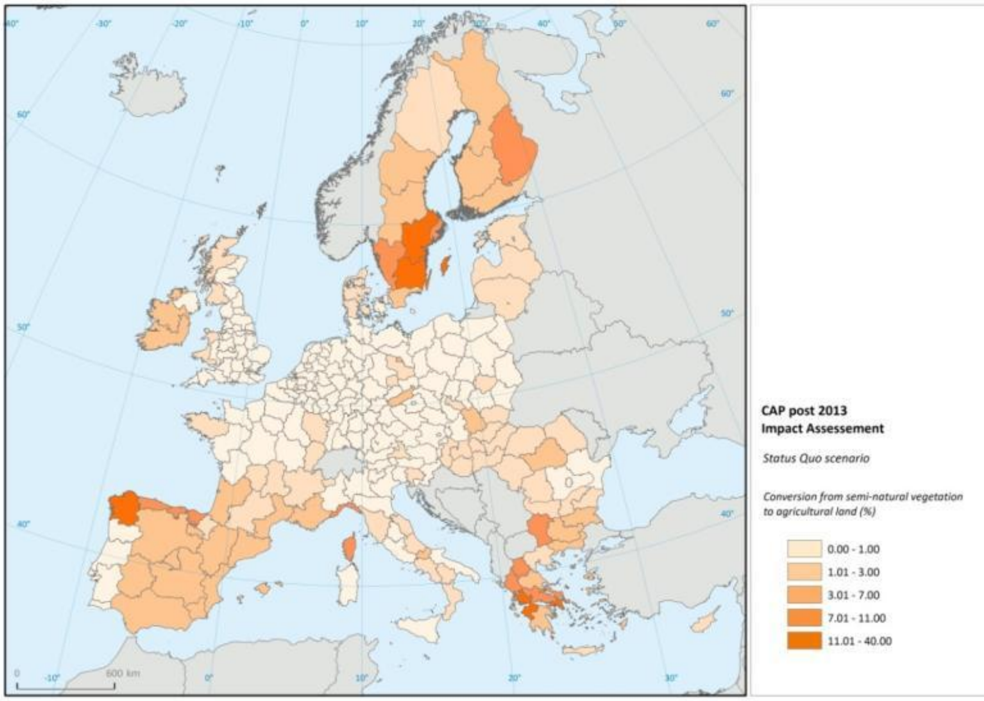
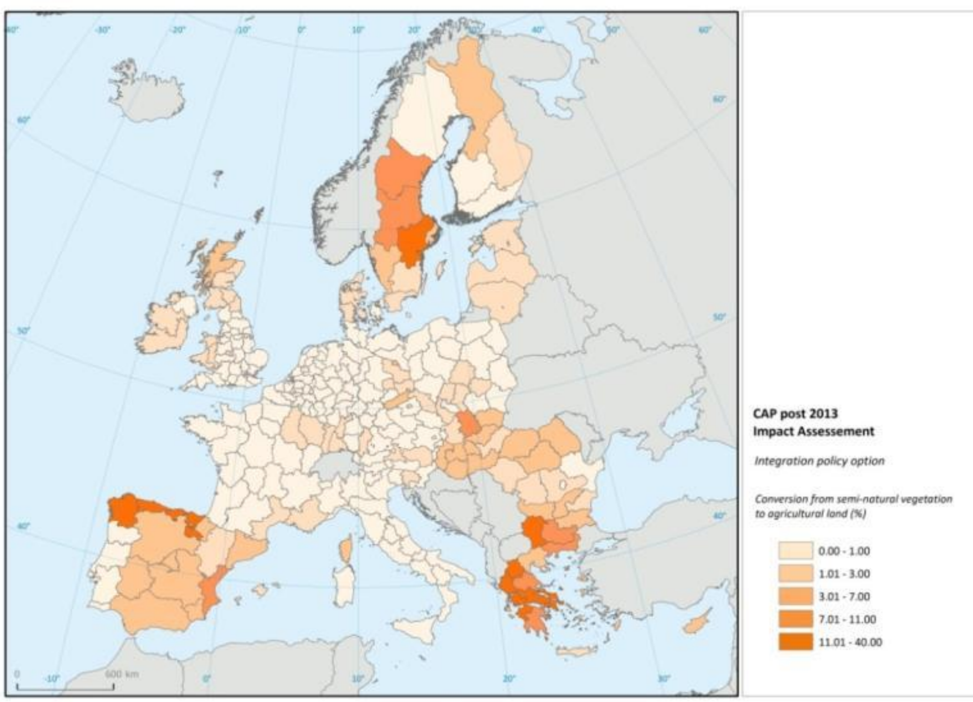


Figure 18: Semi-natural vegetation converted into agricultural land (arable, permanent crops, pastures), as percentage of agricultural land in 2006



a



b

Figure 19: Regional (NUTS-2) share (%) of areas converted from semi-natural vegetation in agriculture as percentage of the total regional agricultural area in 2006, (a) for the Status Quo scenario; (b) for the Integration policy option

At regional level (NUTS2), it is important to highlight that most of the regions have a conversion of semi-natural vegetation to agricultural land lower than 1%, in both model runs. Figure 19 (a, b) shows that the regions mostly affected by this conversion under the Status Quo scenario (some NUTS in Sweden, Greece, and northern parts of Spain), are also those more intensively affected by this transition under the Integration policy option.

4.2.2 Conversion from semi-natural vegetation to agriculture around Natura2000 sites

This indicator presents the share of area converted from semi-natural vegetation to agriculture in 500 meters-wide buffer around Natura 2000 sites (Figure 20).

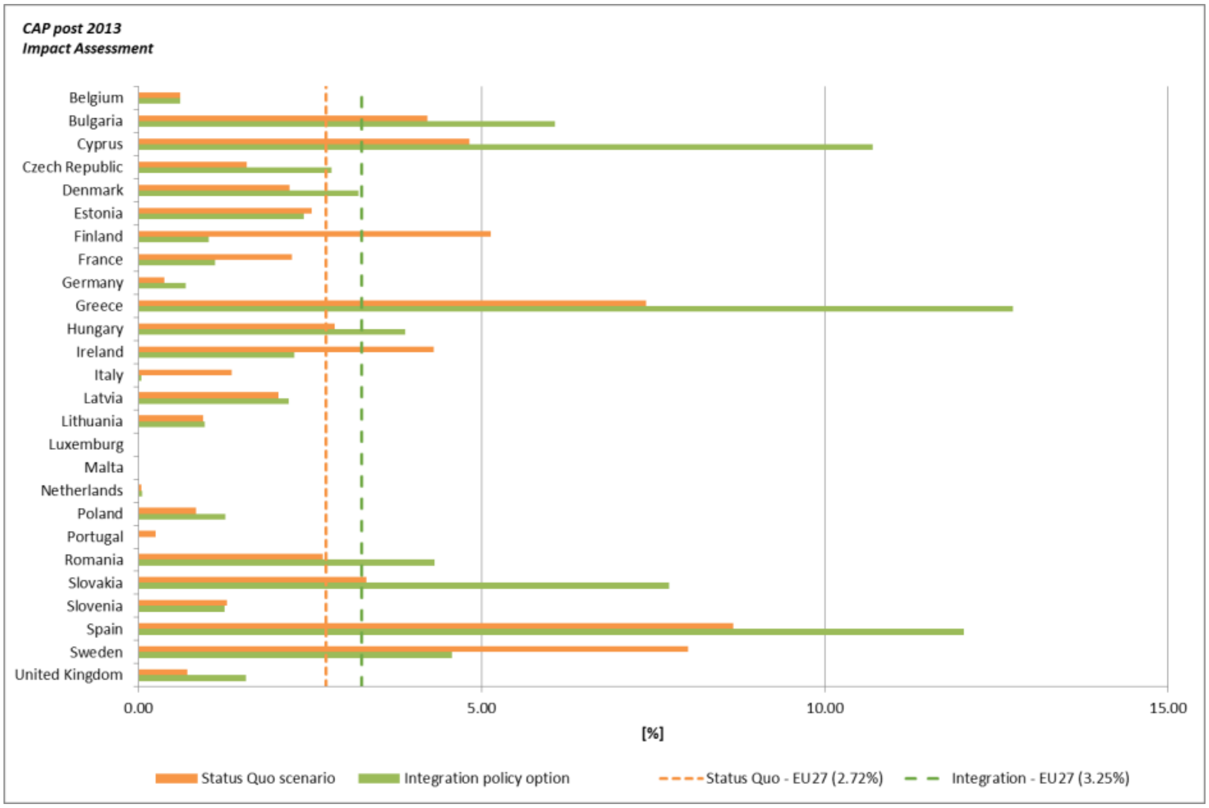


Figure 20: Semi-natural vegetation converted into agricultural land (arable, permanent crops, pastures), in a buffer of 500m width around Natura2000 sites, as percentage of agricultural land in 2006 within the same buffer

At EU27 level, the loss of semi-natural vegetation due to the expansion of agricultural land is higher under the Integration policy option than the Status Quo scenario. This condition reaches values slightly higher in the vicinity of Natura 2000 sites (3.25% and 2.72% respectively). Although with a different intensity, almost every country follows the overall trend.

4.2.3 Conversion from semi-natural vegetation into agriculture in riparian areas

This indicator, shown in Figure 21, presents the share of the area converted from semi-natural vegetation into agriculture in 50 meters-wide strip around river beds (both sides).

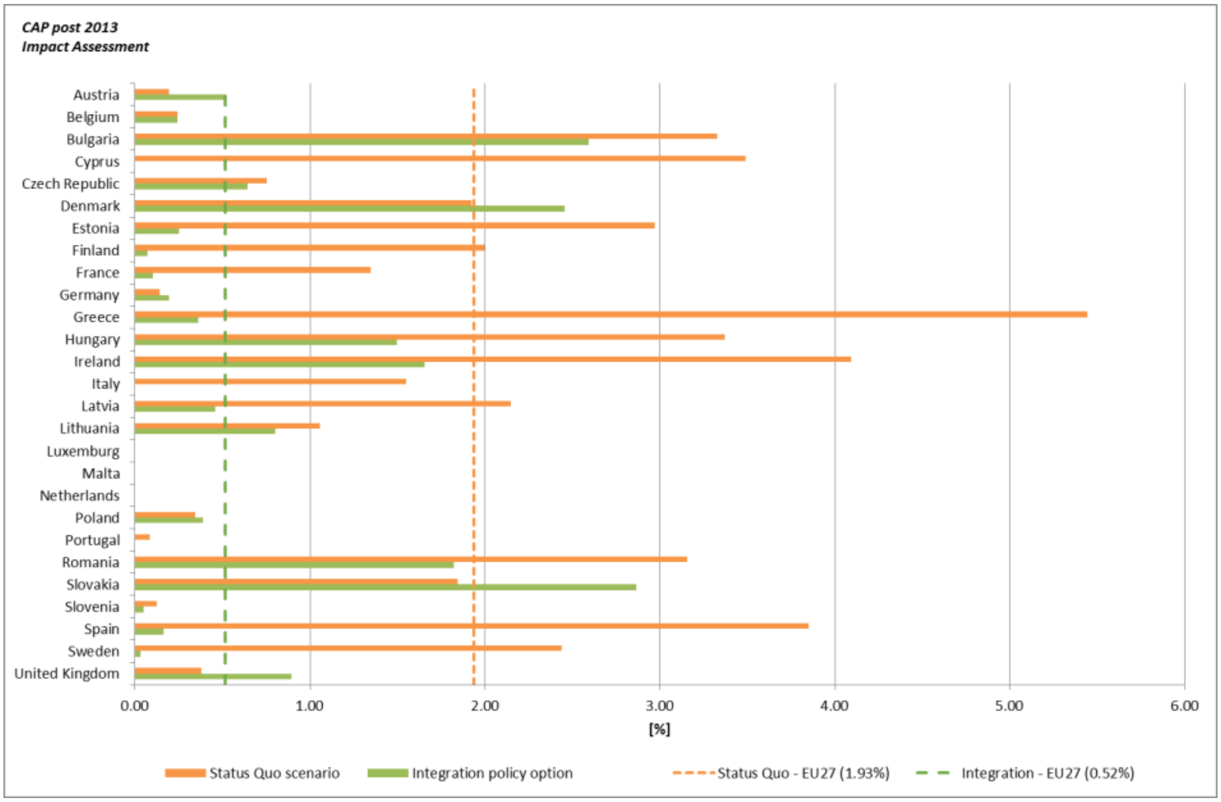


Figure 21: Semi-natural vegetation converted into agricultural land (arable, permanent crops, pastures), in a strip of 50m width along water courses, as percentage of agricultural land in 2006

In riparian areas the expansion of agricultural land over semi-natural vegetation is less intensive under the integration policy option, being this particularly evident in Greece, Spain, Cyprus, Estonia and Ireland.

This is due to the fact that the greening measure “ecological set aside/ecological focus areas” considered in this policy option contributes to maintaining semi-natural vegetation along water courses.

Nevertheless, this effect is less marked in Slovakia, Denmark, United Kingdom and Austria, where the percentage of conversion to agricultural land in riparian areas is slightly higher under the Integration policy option than the Status Quo scenario (the difference among scenarios is always below one percent point).

4.2.4 Conversion from forest into agriculture

This indicator considers the transition of forest land (in 2006) into agricultural land (in 2020), i.e. arable land, permanent crops and pastures converted from forest. The indicator is given as percentage of the total agricultural land in 2006, per country.

Regarding this indicator, as Figure 22 depicts, at EU27 level the difference between the Status Quo scenario and the Integration policy option is not significant. In general, the values per country reflect this trend of similarity between model runs, with the Baltic countries the most relevant exceptions: Latvia, Estonia and Lithuania (where this phenomenon is higher under the Integration policy option).

The countries most affected by the expansion of agricultural land at expenses of forest (above 2%) are Estonia, Greece, Austria, Slovenia and Latvia (the latest only under the Integration policy option).

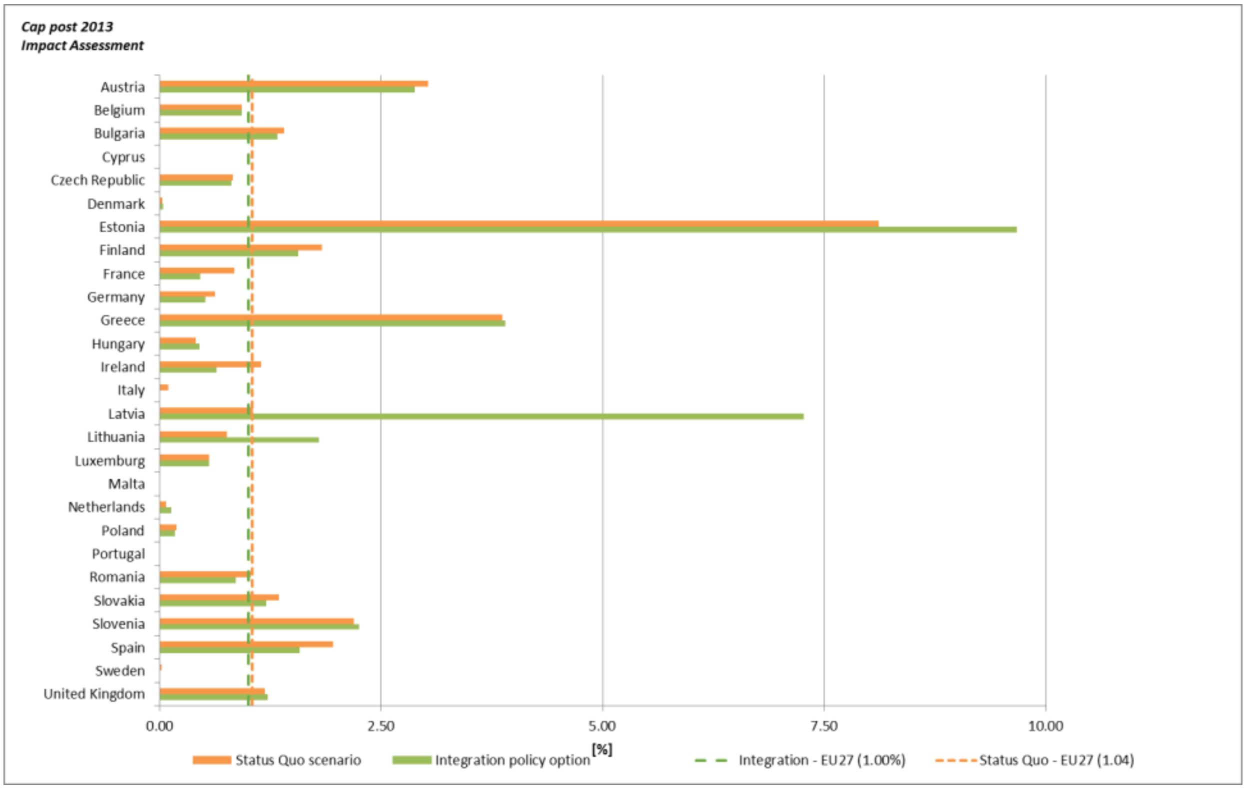


Figure 22: Forest converted into agricultural land (arable, permanent crops, pastures), as percentage of agricultural land in 2006

4.2.5 Conversion from forest into agriculture around Natura2000 sites

This indicator presents the share of area converted from forest into agriculture in a 500 meters-wide buffer around Natura 2000 sites, taking into consideration the total agricultural land of these areas in 2006.

Although, in general, this conversion is higher under the Status Quo scenario than under the Integration policy option, Figure 23 suggests that there is no homogeneity in the results per country. For instance, in Estonia, Latvia, and Lithuania the values are considerable higher for the Integration policy option than the Status Quo scenario. On the contrary, Spain and France show a lower conversion for the policy option.

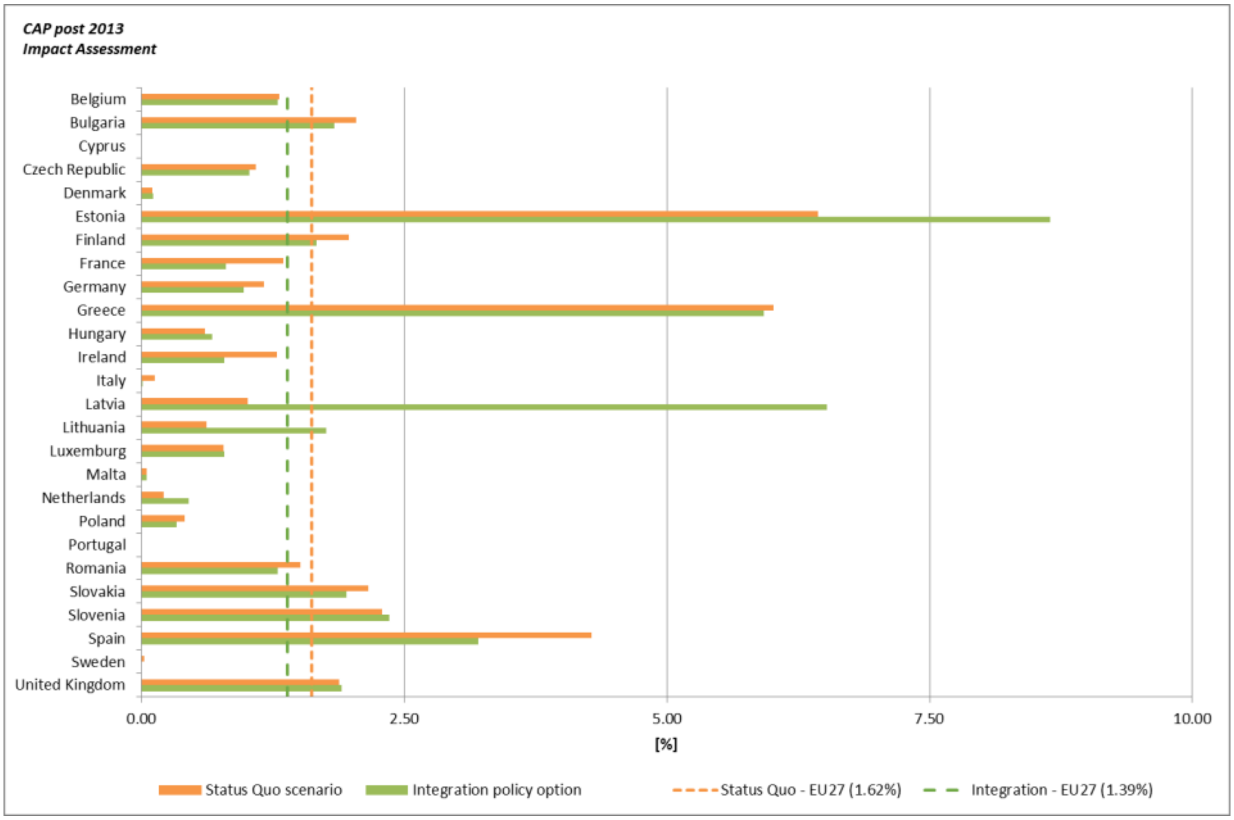


Figure 23: Forest converted to agricultural land (arable, permanent crops, pastures), in a buffer of 500m width around Natura2000 sites, as percentage of agricultural land in 2006

4.2.6 Conversion from forest into agriculture in riparian areas

This indicator presents the share of area converted from forest into agriculture in a 50 meters-wide strip along river beds (both sides) taking into consideration the total agricultural land of these areas in 2006.

Due to the natural value of riparian areas, agricultural expansion at the expense of forest might represent a loss of environmental benefits from these areas. Figure 24 depicts the overall results, where it is possible to see that this conversion is more relevant under the Status Quo scenario than under the Integration policy option. As previously mentioned, the greening measure 'ecological set aside/ecological focus areas' of the Integration policy option contributes to preventing agricultural expansion in these areas, where its impact is reflected in this indicator. Nonetheless, Latvia and Lithuania present an opposite trend, i.e. with a lower share of conversion under the Status Quo scenario than the Integration policy option.

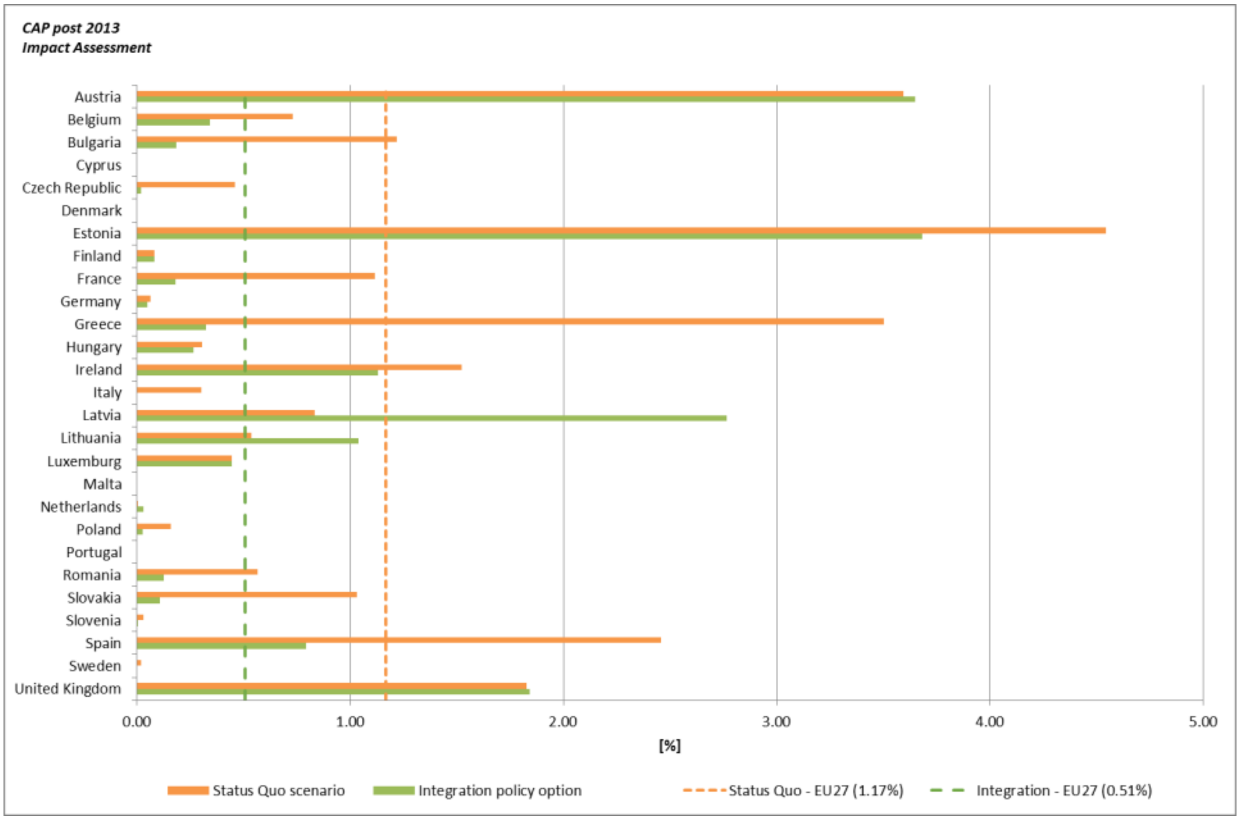


Figure 24: Forest converted into agricultural land (arable, permanent crops, pastures), in a strip of 50m width along water courses, as percentage of agricultural land in 2006

4.3 Agricultural loss

4.3.1 Agricultural areas converted into artificial surfaces

Conversion from agricultural land to artificial surfaces represents an irreversible land use change. This indicator of land use change measures the area converted from agricultural land (in 2006) into artificial areas in 2020 (Figure 25). In this context, agricultural land includes arable land, permanent crops and pastures; artificial areas include urban and industrial/commercial classes. The conversion is represented as percentage of agricultural land in 2006.

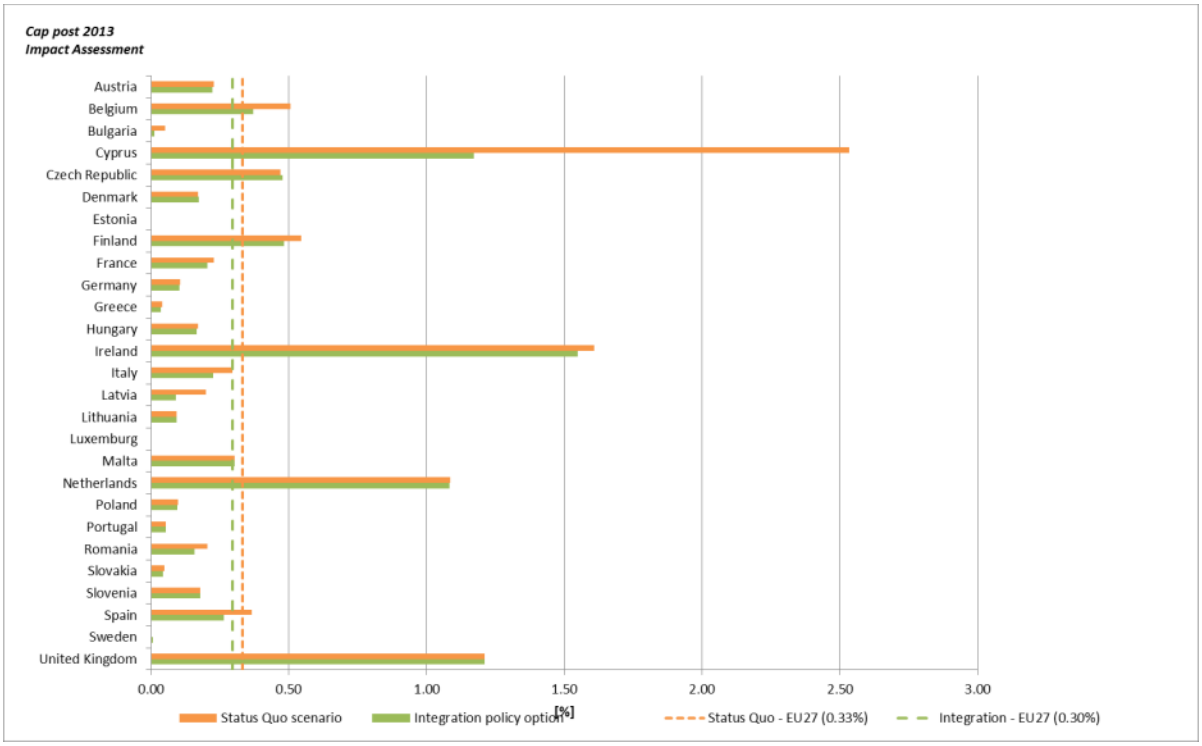


Figure 25: Agricultural land (arable, permanent crops, pastures) converted into artificial land (urban, industrial), as percentage of agricultural land in 2006

This conversion affects less than 0.35% of the agricultural land at EU27 level under both, the Status Quo scenario and the Integration policy option. Figure 25 shows that the overall percentage of currently managed agricultural land that is converted to artificial surfaces, are below 1% in the Status Quo scenario and the Integration policy option at country level. Few exceptions occur in Ireland, the Netherlands and United Kingdom, where the agricultural claims decline during the simulation period. Another exception occurs in Cyprus, where urban demand is quite high, thus amplifying the competition for available land.

For almost all countries the range of conversion is between 0.10% and 2.50% with the exception of Bulgaria, Estonia, Greece, Luxemburg and Sweden, for which this indicator shows a negligible value or no change. Under the Integration policy option almost all countries are characterized by a lower degree of loss of agricultural land due to the expansion of artificial land. On the contrary, in the Czech Republic and Sweden agricultural land are lost under the Status Quo scenario, although the difference between the two alternatives is small.

4.3.2 Agricultural areas converted into artificial surfaces around Natura2000 sites

This indicator presents the conversion of agricultural land into artificial surfaces within the buffer zone (500 m width) around Natura 2000 sites. The computation of this indicator serves as a proxy of the degree of urban pressure in the proximity of these environmentally sensitive areas. A higher urban pressure might be regarded as a menace to the biodiversity of these areas, caused by a potential increase in pollution, or by the fragmentation of natural corridors.

Overall, the values reported in Figure 26 are below 1%. Regarding the difference between the changes under the Status Quo scenario and the Integration policy option, this indicator is greater under the Status Quo scenario, suggesting a corresponding slightly higher urban pressure (0.37% and 0.32% respectively, at EU27 level).

There are differences among countries: the urban pressure nearby Natura 2000 sites is less under the Integration policy option than under the Status Quo scenario for the majority of the countries, except for Czech Republic, Malta, Slovakia and United Kingdom and to a lesser extent, for Belgium.

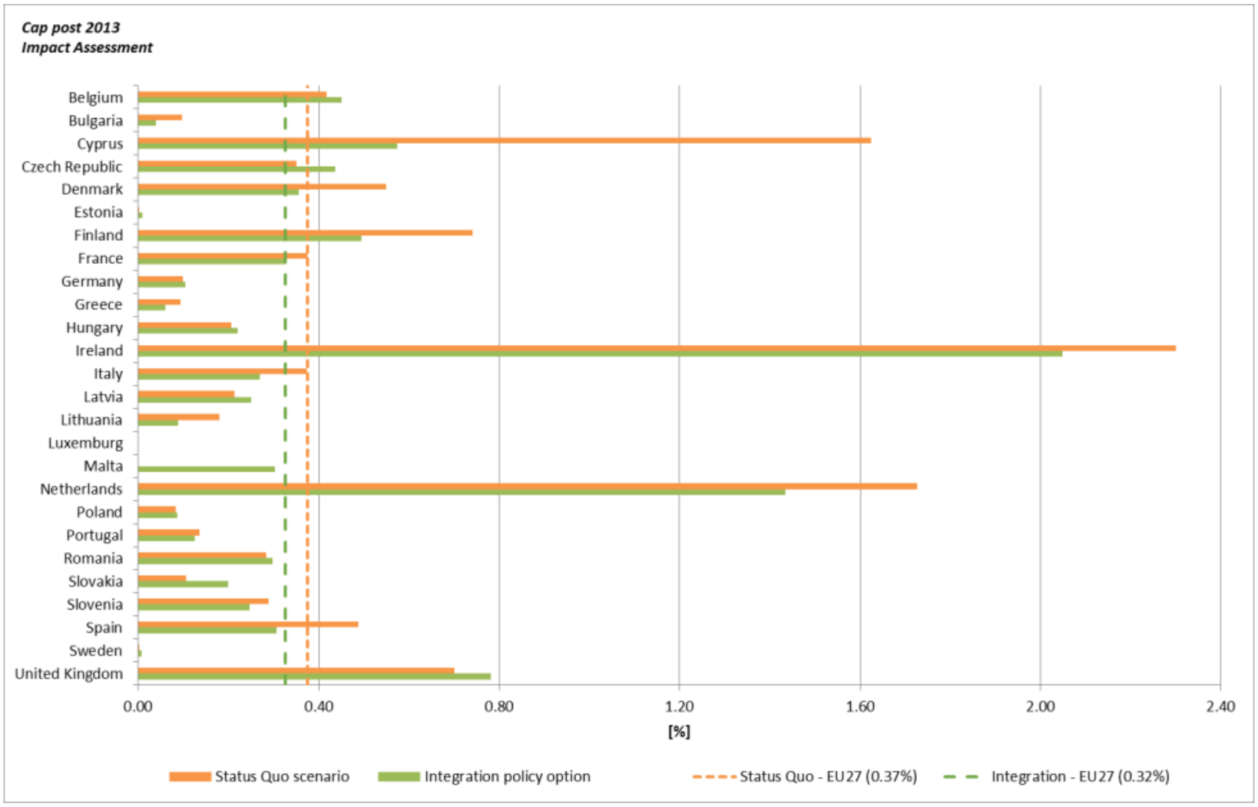


Figure 26: Agricultural land (arable, permanent crops, pastures) converted into artificial land (urban, industrial), in a buffer of 500m width around Natura2000 sites, as percentage of agricultural land in 2006

Figures 27 and 28 depict an example of the diverse urban patterns that occur around Natura 2000 sites under the Status Quo scenario and the Integration policy option. In Figure 28, the yellow circles highlight the areas where urban pressure is lower under the Integration policy option than under the Status Quo scenario.

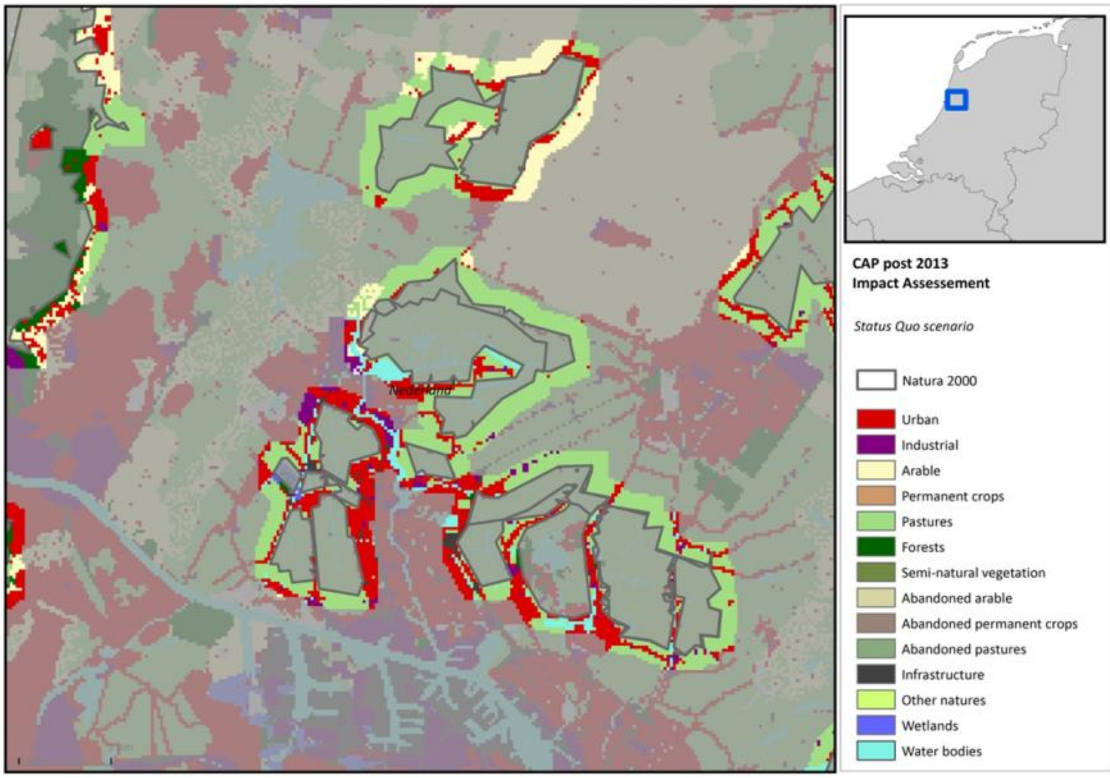


Figure 27: Urban pressure around Natura 2000 areas, in Status Quo scenario (2020): zoom in Netherlands

Note: a grey mask covers the areas outside the 500m buffer zone.

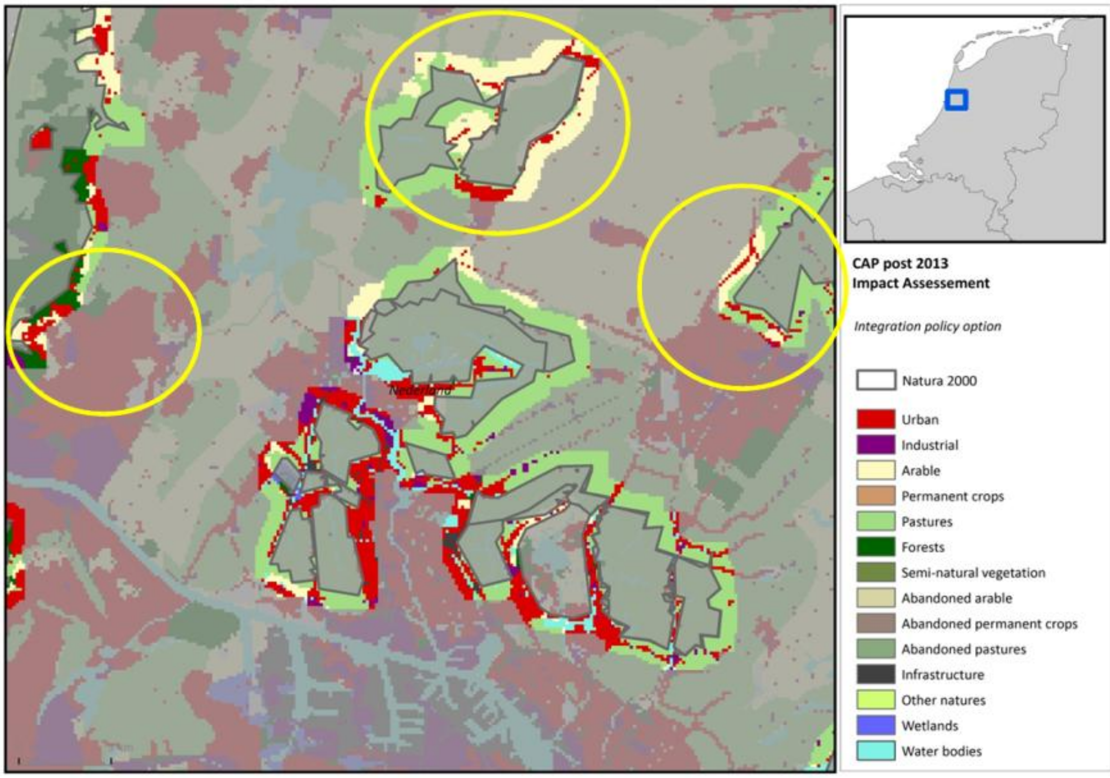


Figure 28: Urban pressure around Natura 2000 areas, in Integration policy option (2020): zoom in Netherlands

Note: a grey mask covers the areas outside the 500m buffer zone.

4.3.3 Agricultural areas converted into semi-natural vegetation

This indicator represents the transition from initially agricultural land (arable, permanent crops and pastures) in 2006, to semi-natural vegetation in 2020. The indicator is expressed as a percentage of the agricultural land in the initial year (Figure 29) and is computed at country level, within Natura 2000 sites and along river beds (riparian areas).

This type of land conversion is partially due to the mechanism of natural succession implemented in the model: abandoned agricultural land (i.e. agricultural land without current use), if not re-converted to agricultural land, may undergo a transition to semi-natural vegetation and possibly forest.

At EU27 level, the agricultural land occupied by semi-natural vegetation is higher under the Integration policy option than under the Status Quo scenario (1.08% and 0.21% respectively). This trend occurs in every country with the exception of Slovenia. This general trend is partially due to the fact that agricultural abandonment is also higher under the Integration policy option than under the Status Quo scenario (this indicator will be further detailed in section 4.4), thus contributing to the enhancement of this conversion.

In most of the countries this indicator is less than 2.5% in magnitude in both model runs, with the exception of Slovenia, Portugal and Finland (the latter only under the Integration policy option).

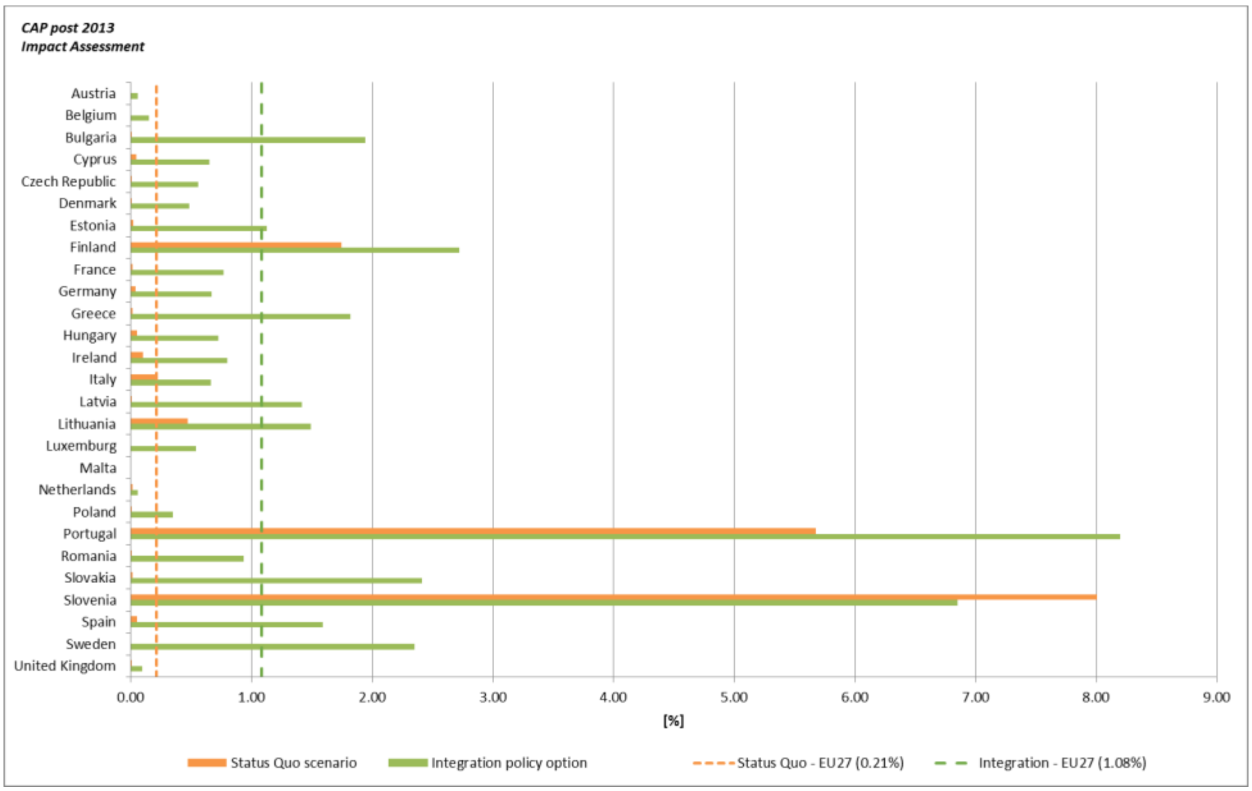
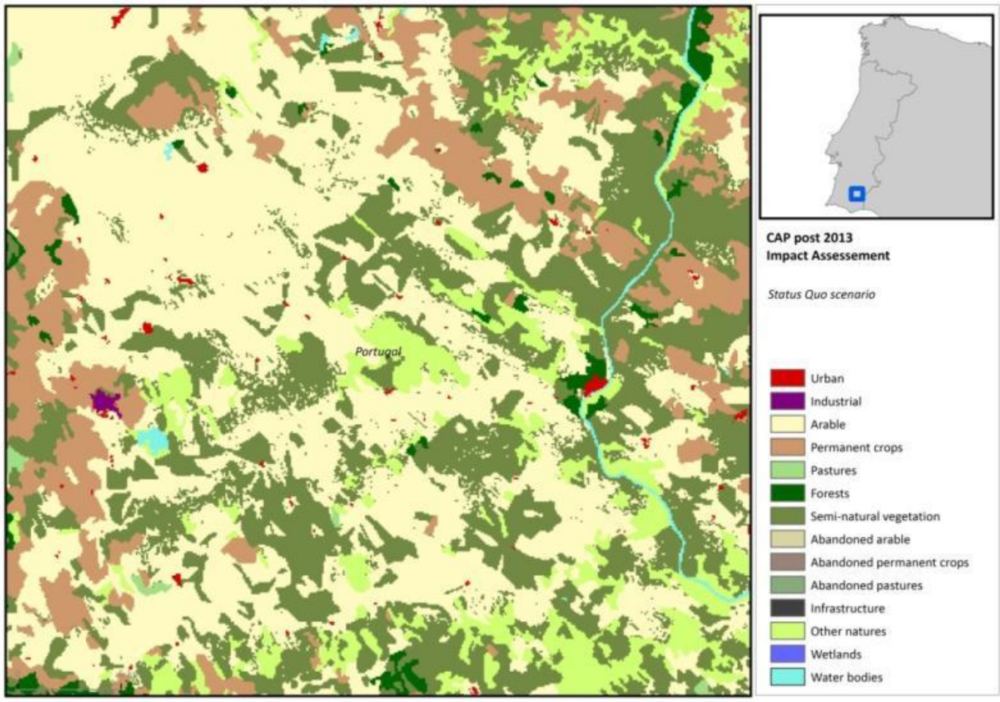
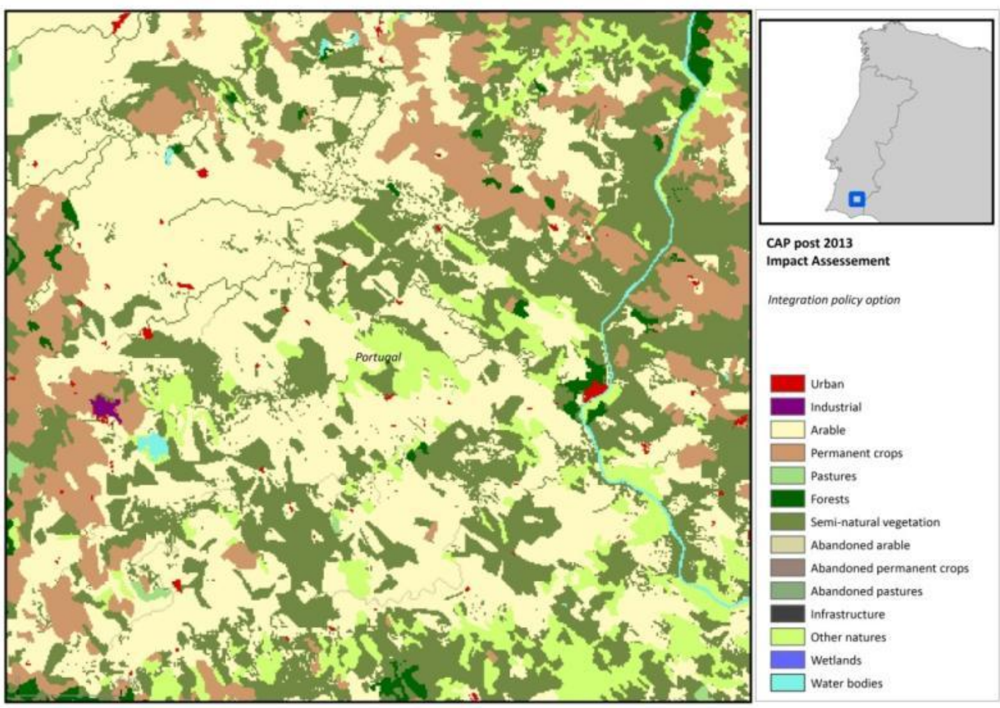


Figure 29: Agricultural areas (arable, permanent crops, pastures) converted into semi-natural vegetation areas as percentage of agricultural land in 2006

Figures 30 (a, b) depict an example of the different patterns that emerge in Portugal from this conversion under the Status Quo scenario and the Integration policy option.



a



b

Figure 30: Loss of agricultural land to semi-natural vegetation in Portugal, (a) under the Status Quo scenario; (b) under Integration policy option

4.3.4 Agricultural areas converted to forest

This indicator represents the agricultural loss due to conversion from agricultural land (arable, permanent crops and pastures) in 2006 to forest in 2020. As with the conversion of agricultural areas to semi-natural vegetation, this type of land conversion is partially driven by the mechanism of natural succession implemented in the model: abandoned agricultural land (i.e. agricultural land without current use), if not re-converted to agricultural land, may undergo a transition to semi-natural vegetation and, possibly, evolve to forest.

The indicator is computed as percentage of the overall agricultural land in 2006, at country level, within Natura 2000 sites and along river beds (riparian areas).

At EU27 level, the agricultural land lost due to this conversion is higher under the Status Quo scenario than under the Integration policy option (1.8% and 1.5%, respectively). Figure 31 illustrates this overall trend per country, with only Lithuania and Estonia as an exception. In most of the countries and in both scenarios, this conversion is lower than 2%. This value is only exceeded in Austria, Czech Republic, Finland, Poland, Slovenia and Sweden.

With respect to Sweden, even though this conversion reaches 44% under the Status Quo scenario and 29% under the Integration policy option, it is worth pointing out that the net change of agricultural land (taking into consideration the total area of the country) is -3.15% under the Status Quo scenario and -2.36% under the Integration policy option. This trend is partially due to a decline in the demands for agricultural land in this country. Furthermore, the landscape pattern is strongly characterized by forest: being the dominant land use, the influence of forest on the land allocation through the neighbourhood effect often overcomes the other competing land uses.

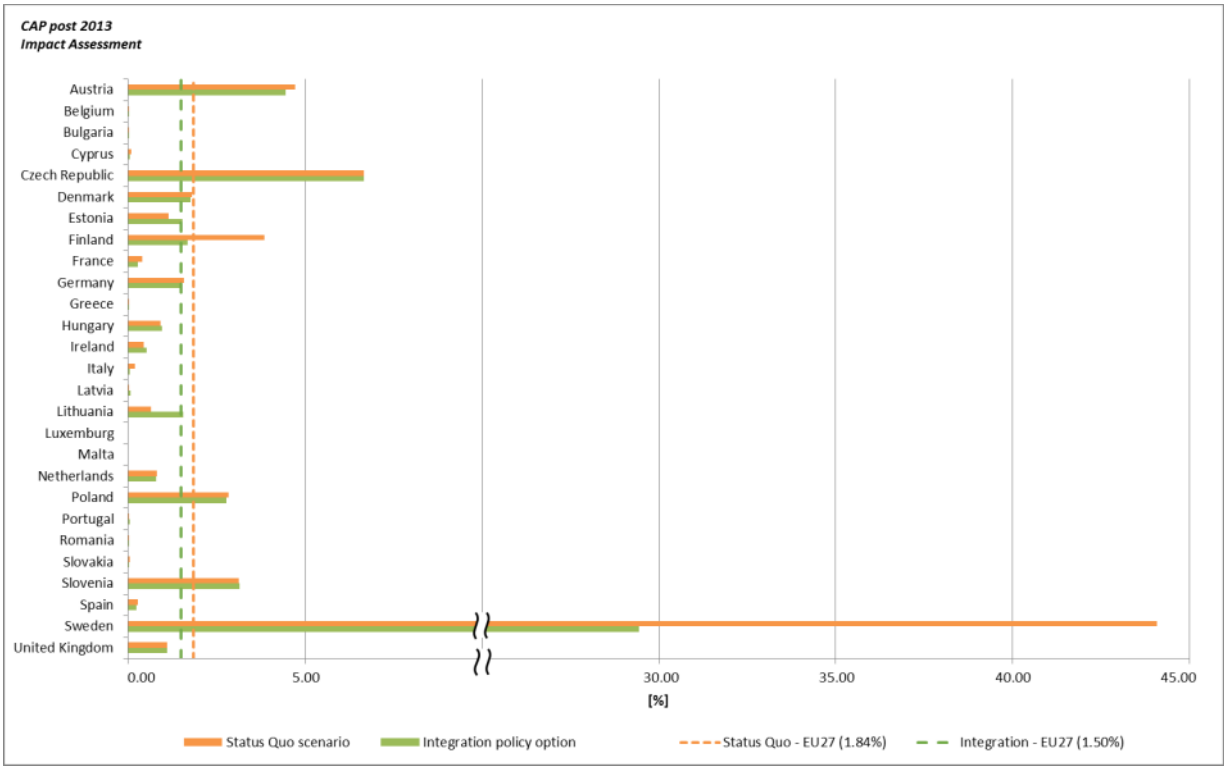


Figure 31: Agricultural land (arable, permanent crops, pastures) converted into forest, as percentage of agricultural land in 2006

4.4 Agricultural abandonment

Land taken out of agricultural production may be due to land marginalisation (process driven by social, economic, political or environmental factors) or may have at its origin a conversion to set-aside. In both cases, this land may return again to agricultural production or evolve in a natural succession process. The main distinction between abandonment of agricultural land due to marginalisation and set-aside is that in the case of set-aside the farmer dedicates specific parcels of his holding to this purpose and undertakes a minimum level of maintenance of its features in order to enhance the environmental benefits of this procedure.

In the current CAP, under the Good Agricultural and Environmental Conditions (GAECs) framework[18] it is considered an issue to "ensure a **minimum level of maintenance** and avoid the deterioration of habitats[19]", which is complemented by the compulsory standards of:

- "Retention of landscape features, including, where appropriate, hedges, ponds, ditches, trees in line, in group or isolated and field margins;
- Avoiding the encroachment of unwanted vegetation on agricultural land;
- Protection of permanent pasture."

As previously mentioned, "*Ecological Set aside / ecological focus area"* is presented as one of the *Greening Measures* of the Integration policy option. This land left fallow for environmental purposes should contribute to the retention of landscape features (e.g. hedges, ponds, ditches, trees in line, terraces) and preferably occurs along water courses (riparian zones).

Although conceptually agricultural abandonment and ecological set-aside are different, both represent land taken out of production and, in a certain extent, both can have positive environmental impacts. According to Keenleyside (2010), "*in many circumstances abandonment may be damaging as it will threaten a range of semi-natural habitats and associated species of nature conservation importance, many of which are concentrated in Natura 2000 sites and other High Nature Value (HNV) farmland. But in some locations abandonment could be highly beneficial, particularly in highly fragmented landscapes and where it could provide the opportunity for significant large-scale restoration of non-agricultural*

[18] Council Regulation (EC) No 1782/2003.

[19] Annex III of Council Regulation (EC) No 73/2009.

habitats (e.g. re-wilding)". Moreover, agricultural abandonment can have a positive environmental impact in agricultural intensive areas. Under the Integration policy option the probability of occurrence of these classes is enhanced in a buffer strip of 50m along rivers beds (each side).

Specifically, this indicator measures the amount of agricultural land (arable and permanent crops) converted to land without current use, i.e. abandoned (not in production) and its definition does not take into consideration any other variable related with economic or demographic conditions (e.g. holdings with low income or proportion of farmers close to retiring age). The indicator is computed as a percentage of the overall agricultural land in 2006 at country level within Natura 2000 sites and along river beds (riparian areas).

In 2020, in both scenarios, the overall agricultural abandonment for EU27 is less than 1% (0.18% under the Status Quo scenario and 0.7% under the Integration policy option). Moreover, some countries do not present agricultural abandonment under the Status Quo scenario. Figure 32 depicts this trend of a slightly higher abandonment under the Integration policy option (with the exception of Slovenia and Finland).

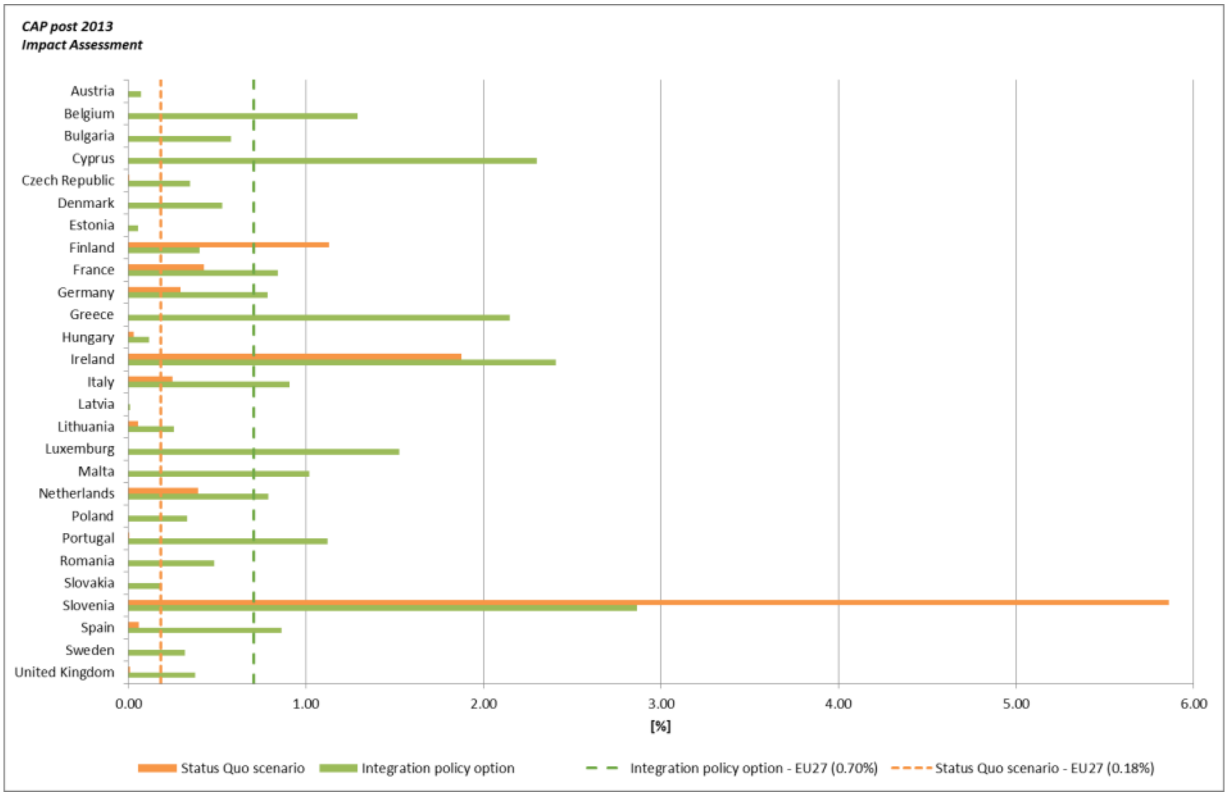


Figure 32: Overall agricultural abandonment, as percentage of total agricultural area in 2006

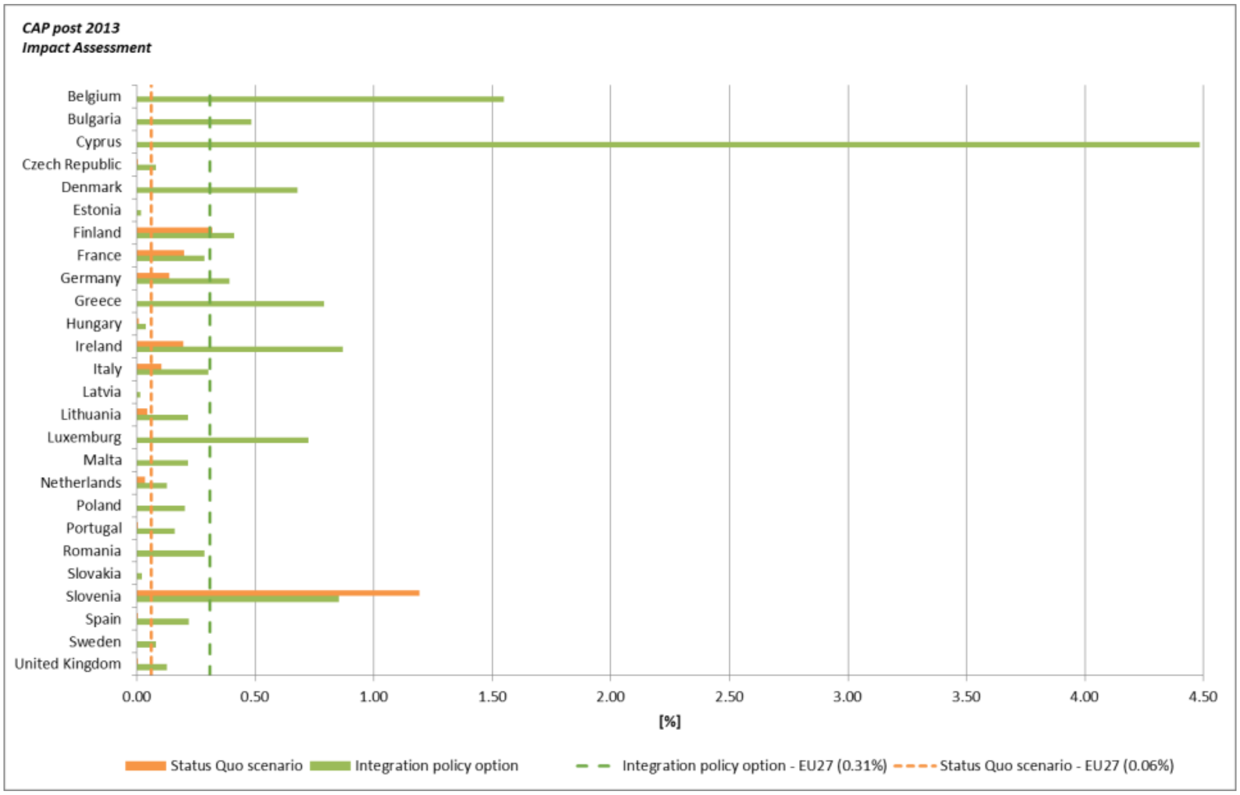


Figure 33: Agricultural abandonment within Natura 2000 site as percentage of total agricultural area in 2006

Figures 33 and 34 focus on agricultural abandonment within Natura 2000 sites and along river beds (riparian areas) and once again the shares are higher under the Integration policy option.

Figure 34 denotes that under the Integration policy option in some countries most of the agricultural abandonment occurs in riparian areas. This is due, as previously referred, to the enhancement of probability of occurrence of abandonment in these areas as specified under the Integration policy option.

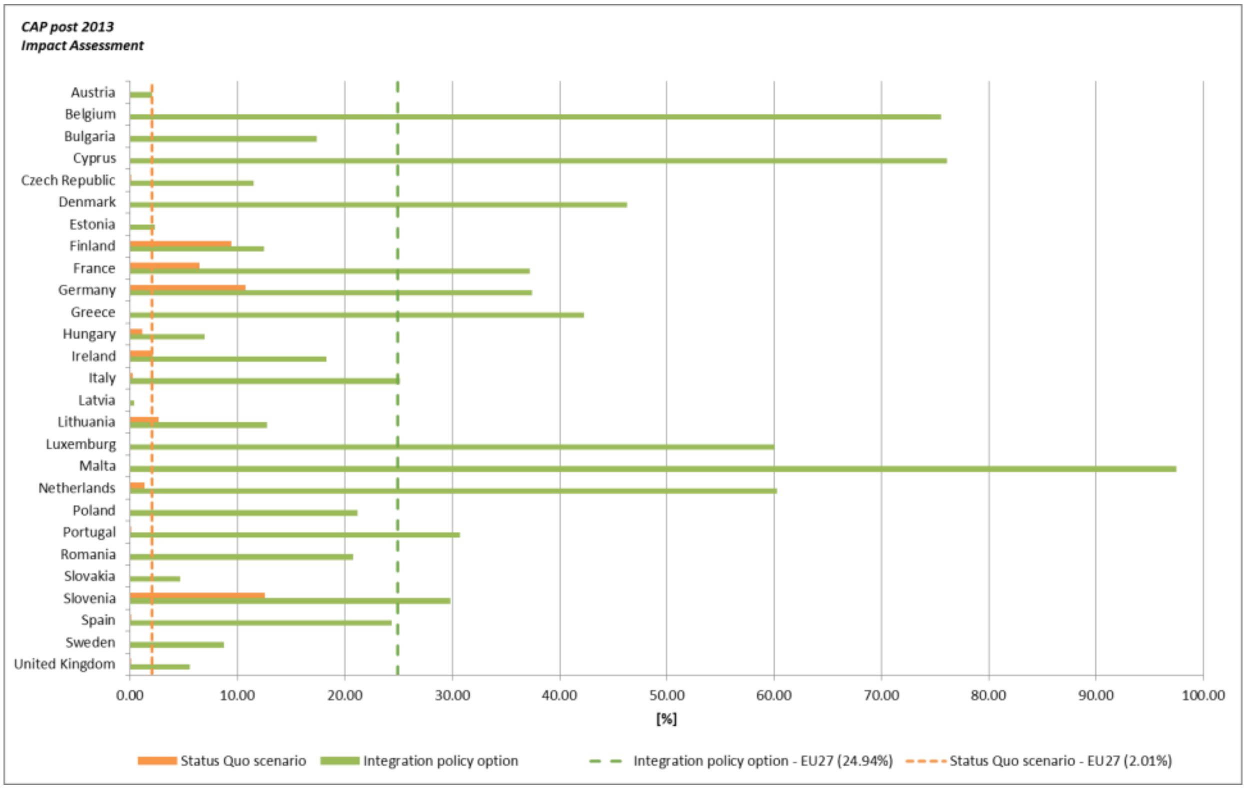
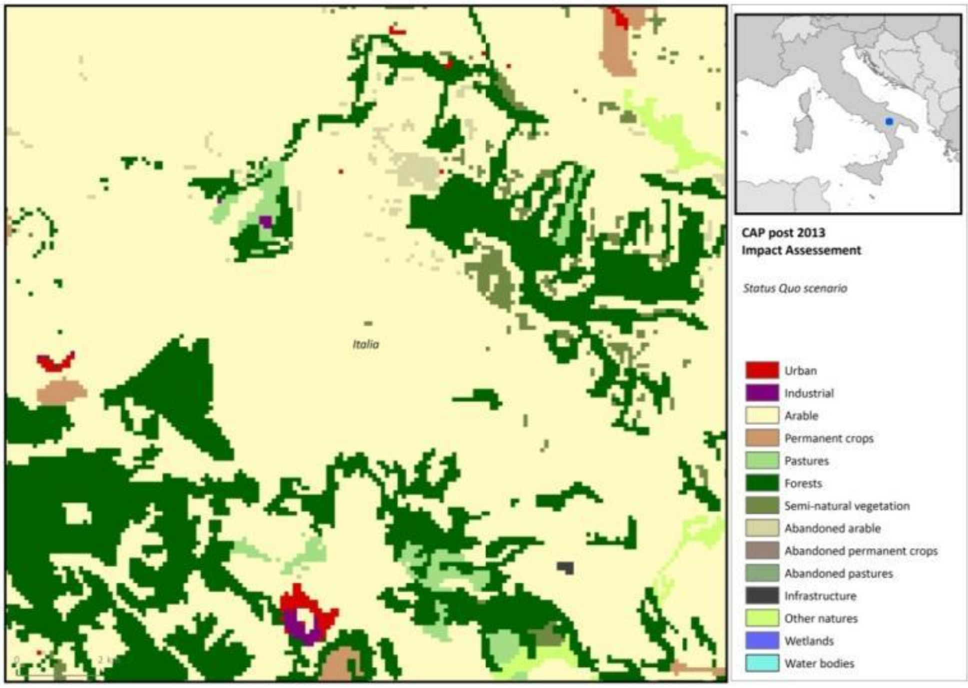
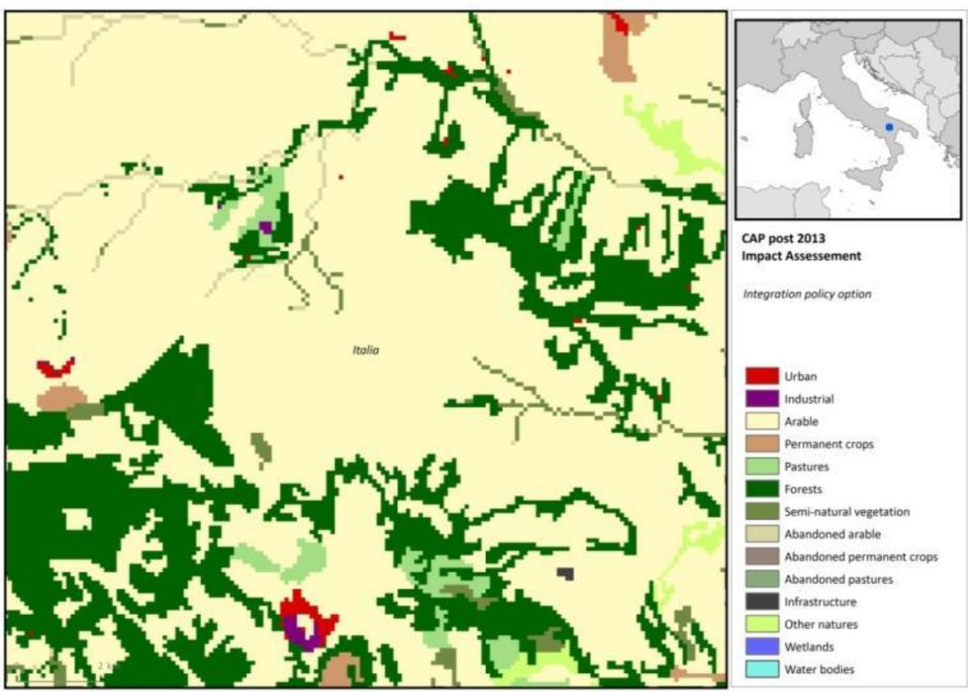


Figure 34: Agricultural abandonment in riparian areas as percentage of total agricultural area in 2006

As an example for illustrating the differences in the spatial allocation of abandoned agricultural land between the Status Quo scenario and the Integration policy option, a detailed area in southern Italy is depicted in Figures 35 a and b.



a



b

Figure 35: Agricultural abandonment in southern Italy, (a) under the Status Quo scenario; (b) under Integration policy option

4.5 Effectiveness of greening measures on conservation of Green Infrastructure

4.5.1 Defining Green Infrastructure

The new Biodiversity strategy for the European Union[20] (EU) has the ambitious aim of halting the loss of biodiversity and ecosystem services in the EU by 2020. To reach this goal, six main targets have been defined, among which, a better protection for ecosystems, and more use of green infrastructure (GI). A Green Infrastructure initiative at EU level will most likely be developed by 2012. GI has been implemented at different scales (national, interregional and regional examples) but there is a lack of common concepts, approaches and coordination throughout Europe. A Working Group on Green Infrastructure has been established by DG ENV as policy support to this process and with among others aims, to reach a definition of GI by the end of 2011. Green infrastructure is a concept which stresses the importance of the natural environment and should help to better integrate the needs of biodiversity and the provision of ecosystem services when taking decisions related to land use management and spatial planning. One key ecosystems service is habitat provision which implies an enhancement, conservation and restoration of biodiversity through the improvement of landscape connectivity. Besides this contribution, an objective of GI is to mitigate fragmentation and the erosion of the natural/semi-natural ecosystems due to the slow but continued intensification of land management and the expansion of what is now often termed grey infrastructure.

A preliminary typology of GI elements would include (1) core areas (areas of healthy and functioning ecosystems with minimal intervention required like national parks, and areas that require management intervention like Natura 2000), (2) restoration zones, (3) Sustainable use/Ecosystem Service Zones as areas for improved ecological quality and permeability of landscape, (4) green urban and peri-urban areas (5) natural connectivity features like ecological corridors, stepping stones, riparian river vegetation, and (6) artificial connectivity features like those designed specifically to assist species movement (such as green bridges and eco-ducts).

Since the origins of the term, which was originally coined to refer to urban green areas, the definitions have evolved to cover rural applications and have consequentially diversified extensively. Within the

[20] COM (2011) 244 final.

rural context, several definitions of Green Infrastructure are specified in the literature. According to La Greca *et al* (2011), the territory can be divided into two main categories in so far as regulating pollution and mitigating climate change are concerned: 1) urbanized; 2) non urbanized. According to these authors, the latter category can be further broken down to Agricultural and Green Infrastructure components. Weber *et al* (2008) define Green Infrastructure as a network of large intact *natural* areas interconnected by connectors such as riparian or upland vegetation. Furthermore, from the landowner's perspective within Europe, intensive agriculture is not considered as part of the Green Infrastructure (Elands and Praestholm, 2008). In an early paper by Angelstam *et al* (2003), Green Infrastructure is interpreted as being a network of inter-connected habitats. This implies also the inclusion of agricultural areas conducive to hosting fauna. Even less restrictive is the interpretation of Lucas (2010) whereby, from the hydrological point of view, any surface that is not impervious is a part of the Green Infrastructure.

These differences in the definitions of "Green Infrastructure" depend on the application for the measure. In the first example presented by La Greca *et al* (2011), Green Infrastructure is considered one of two components that are put under pressure by urban sprawl; from the perspective of Weber *et al* (2008), the health of the bird community was assessed using Green Infrastructure as a proxy. Therefore, land cover considered as part of Green Infrastructure was rigorously natural and not agricultural at all. From the perspective of Angelstam *et al* (2003), any land cover which can be considered as a habitat should be counted as Green Infrastructure etc. Due to a mixed answer in the literature, and in collaboration with experts in the field, we chose to define Green Infrastructure according to the benefits of each land use class to enable and foster species biodiversity and habitat. The main guidelines for the selection of the Green Infrastructure land use classes is the 2010 report on the topic, issued by the European Commission DG-ENV (Pedro Silva *et al.*, 2010). Table 5 summarizes the land use classes which have been included in our definition of Green Infrastructure.

Table 5: Land use classes considered part of the Green Infrastructure category in this study

Not part of Green Infrastructure	Part of Green Infrastructure
Urban	Forest
Industry and services	Semi natural vegetation
Cereals	Permanent crops
Maize	Pasture
Root crops	Abandoned arable
Other arable	Abandoned permanent crops
Other infrastructure (roads, rail, mines etc.)	Abandoned pasture
	Other nature
	Water bodies

4.5.2 Net amount of Green Infrastructure

The net amount of land considered part of Europe's Green Infrastructure was calculated between the Status Quo scenario and the Integration policy option based on a binary map of land use classes belonging to Green Infrastructure and those not belonging to this category. Table 6 shows the overall net land with a land use belonging to the Green Infrastructure category for the base year as well as for the 2020 model runs for both the Status Quo scenario and the Integration policy alternative.

Table 6: Totals of land use classes belonging to the Green Infrastructure category for the Status Quo scenario and the Integration policy option

	2006 [km^2]	Status Quo [km^2]	Integration [km^2]
Green Infrastructure	2 599 071	2 515 417	2 564 856

Figure 36 illustrates the Green Infrastructure that is common to both the Status Quo scenario and the Integration policy option, as well as the differences in Green Infrastructure between the two model runs. The Green Infrastructure existing only for the Status Quo scenario is given in pink, the Green Infrastructure existing only for the Integration policy option is given in dark green and the land common to both scenarios is shown in light green.

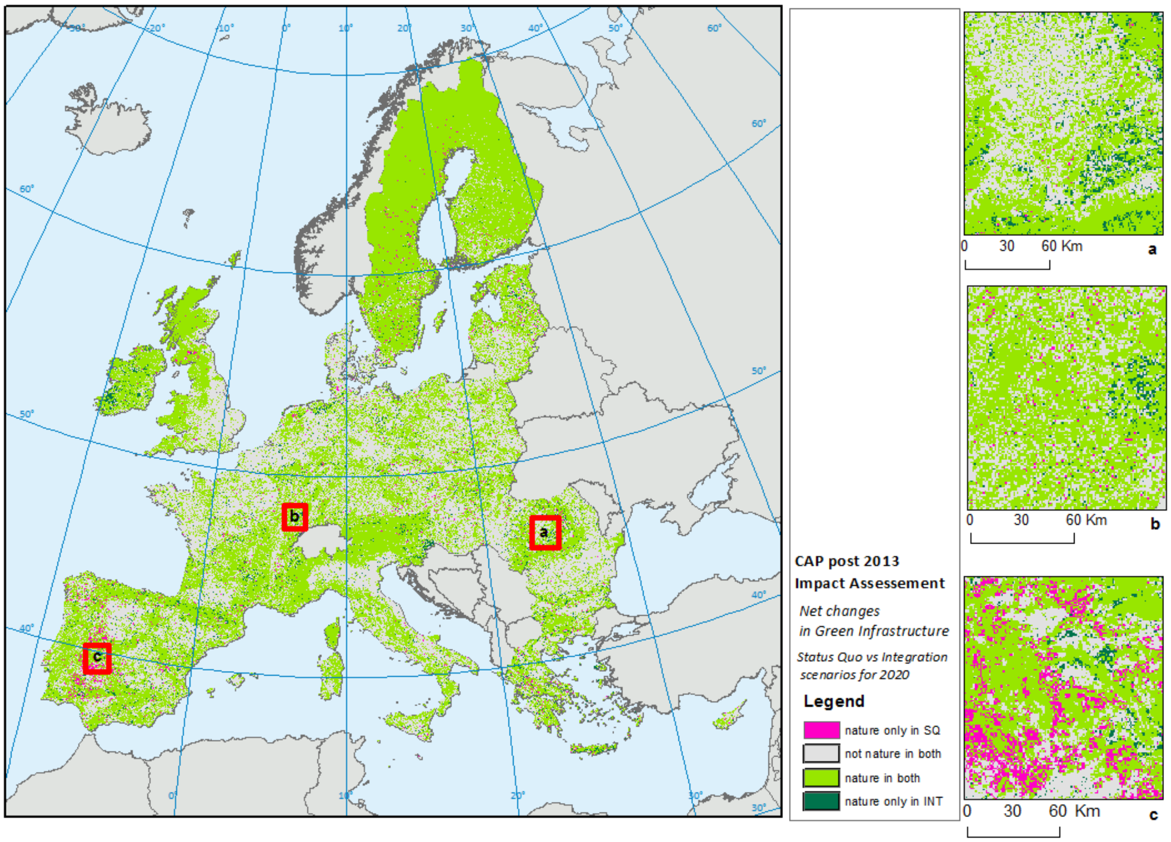


Figure 36: Land belonging to Green Infrastructure which is common to both runs (light green); only in the Status Quo scenario (pink) and only in the Integration policy option (dark green)

4.5.3 Spatial arrangement of Green Infrastructure

The motivation for investigating the pattern (spatial arrangement) of Green Infrastructure is to address issues related to its fragmentation. There is no one single fragmentation metric that is able to answer all questions related to this multi-faceted topic in particular for Europe. In recent European-wide fragmentation studies for forest and natural-semi-natural areas (Estreguil and Caudullo, 2011), the pattern of a focal class was assessed from three perspectives that inspired this Green infrastructure assessment: its morphological spatial pattern, its connectivity and its landscape mosaic context. Pattern and connectivity of Green Infrastructure will be addressed in this section while mosaic context will be addressed in section 4.6.

The indicators related to the spatial arrangement of Green Infrastructure are derived from the application MSPA (Morphological Spatial Pattern Analysis) available in the freeware called GUIDOS (Soille and Vogt, 2009). The derived indicators are described in Vogt *et al* (2007) and in Estreguil and Caudullo (2011). The application enables the automatic implementation of spatial pattern mapping based on mathematical morphology analysis. The input binary map is in this case a map representing classes belonging to the category “Green Infrastructure” (foreground) and not belonging to this category (background). The map undergoes a series of mathematical operators and results in seven mutually exclusive classes for the foreground class that describe the geometry of the Green Infrastructure patterns using a given edge size parameter *s* (Table 7, Figure 37a).

Table 7: Description of the morphological spatial analysis classes

MSPA pattern class	Description
Core	Foreground pixels whose distance exceeds 1 cell (s) from the background
Edge	Outer boundaries of core
Islet	Foreground that do not contain any core
Perforation	Inner boundaries of core
Loop	Connector pixels that connects to the same core unit (*loop*)
Bridge	Connector pixels that connects at least two different core units (*bridge*)
Branch	Connector pixels that is connected at one end only to a connector, an edge of core or an edge of perforation

The GUIDOS/MSPA pattern classes can be aggregated in main pattern categories in different ways, depending on the user interest and focus. The morphological Green Infrastructure pattern map retained the following three main pattern classes (Table 8, Figure 37b): Green Infrastructure Nodes (*Core*, *edge* and *perforation* MSPA classes), Green Infrastructure connectors (*bridge*, *loop* and *branch* MSPA classes) and Green Infrastructure fragments (*islets* MSPA class). Figure 37 shows a zoom of an area in southern Sweden in order to better illustrate the indicator:

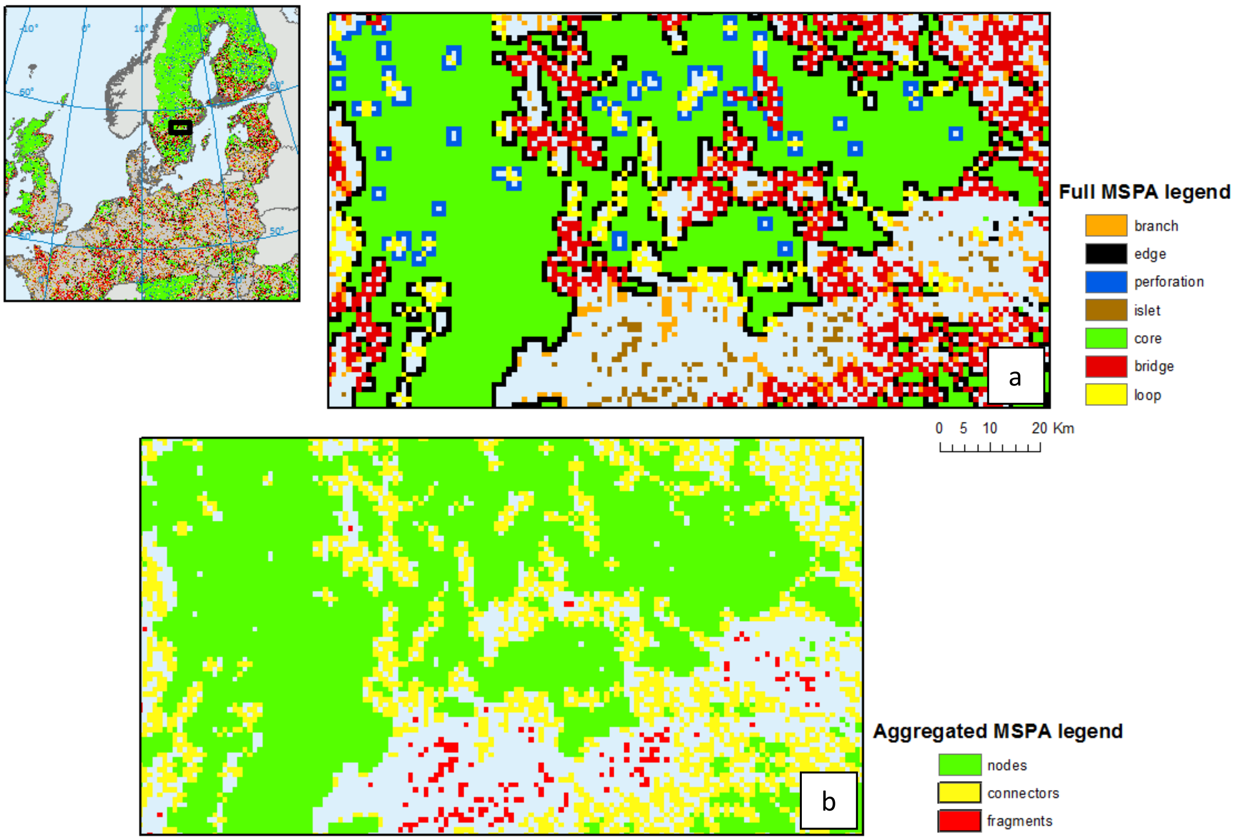


Figure 37: A zoom of an area in Sweden showing the MSPA pattern classes (a) as described in Table 7; and (b) with the simplified 3 GI pattern classes as described in Table 8

The result of this process is a EU 27 map showing the Green Infrastructure areas classified according to their spatial arrangement and geometry (Figure 38).

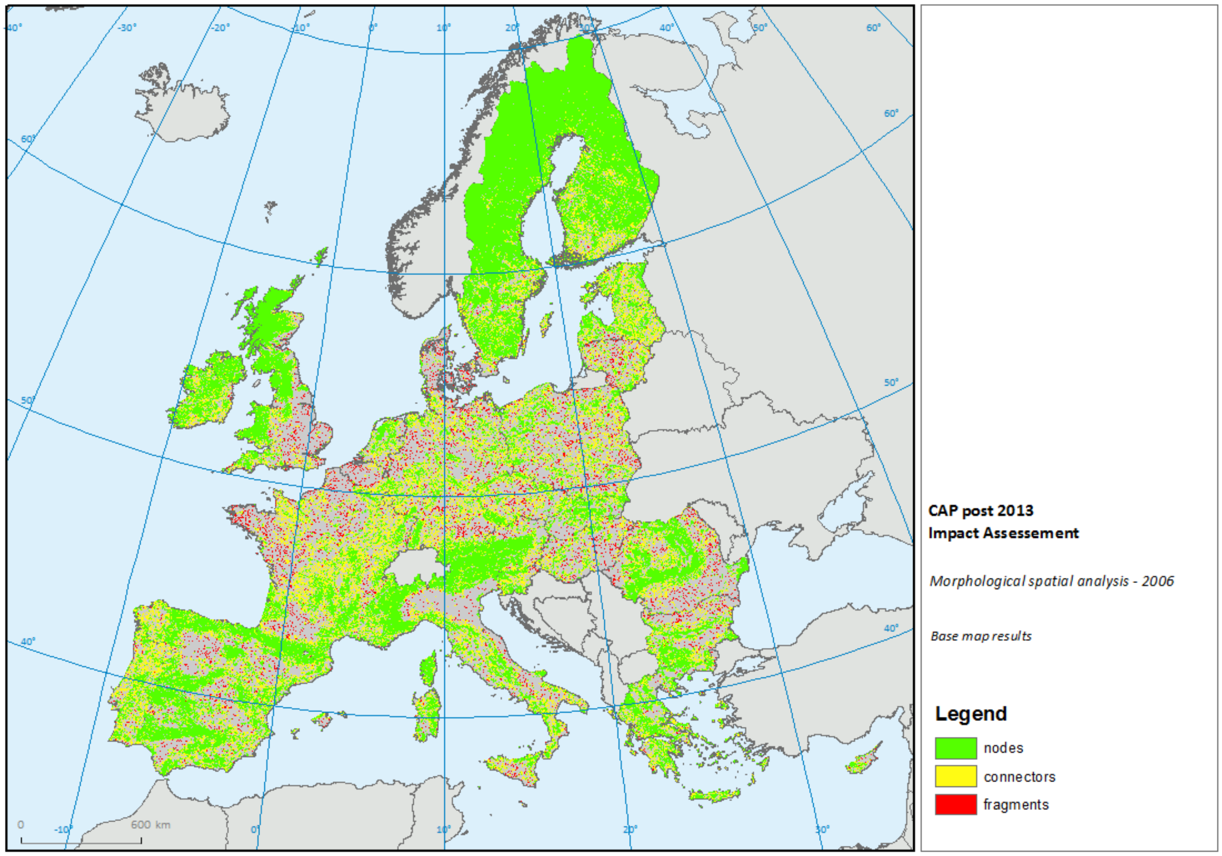


Figure 38: The resulting image from the morphological spatial pattern analysis for the year 2006

Table 8: The amount of Green Infrastructure land, its connectors and fragments as a percentage of all Green Infrastructure in the EU 27

	2006 [% of land]	Status Quo [% of land]	Integration [% of land]
Nodes of Green Infrastructure areas	64.38	61.74	61.37
Connectors of Green Infrastructure areas	29.73	31.71	32.22
Fragments of Green Infrastructure areas	5.89	6.54	6.43

A decrease in areas of GI nodes is shown from 2006 to 2020 for both the Status Quo and the Integration; however the surface area of connectors improves, especially for Integration. The amount of land in fragments belonging to the Green Infrastructure category also increases for both scenarios, implying a disjunction of formerly compact areas.

Whereas the table above shows the net GI nodes and connector areas for the EU 27 with respect to the total amount of land contributing to Green Infrastructure only, the figures below show the differences in pattern shares in the Green Infrastructure land for the base year of the simulation (2006) and the 2020 results for both Status Quo and Integration for all of the EU 27 territory combined (Figure 39, a-c):

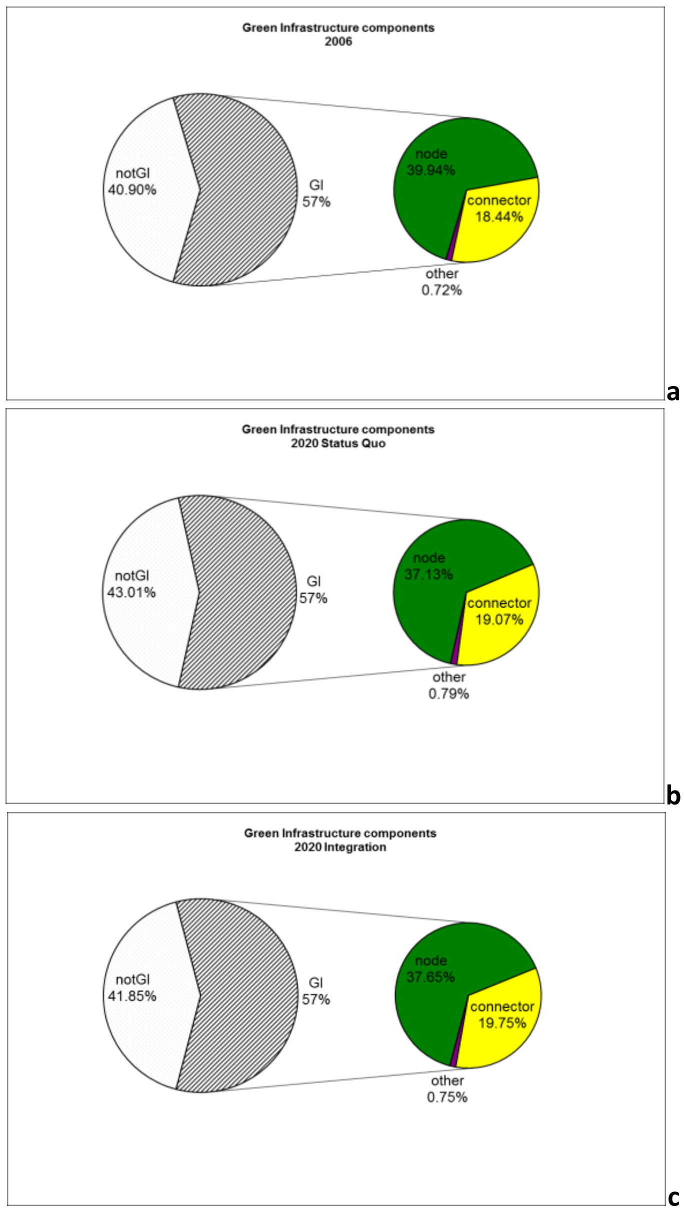
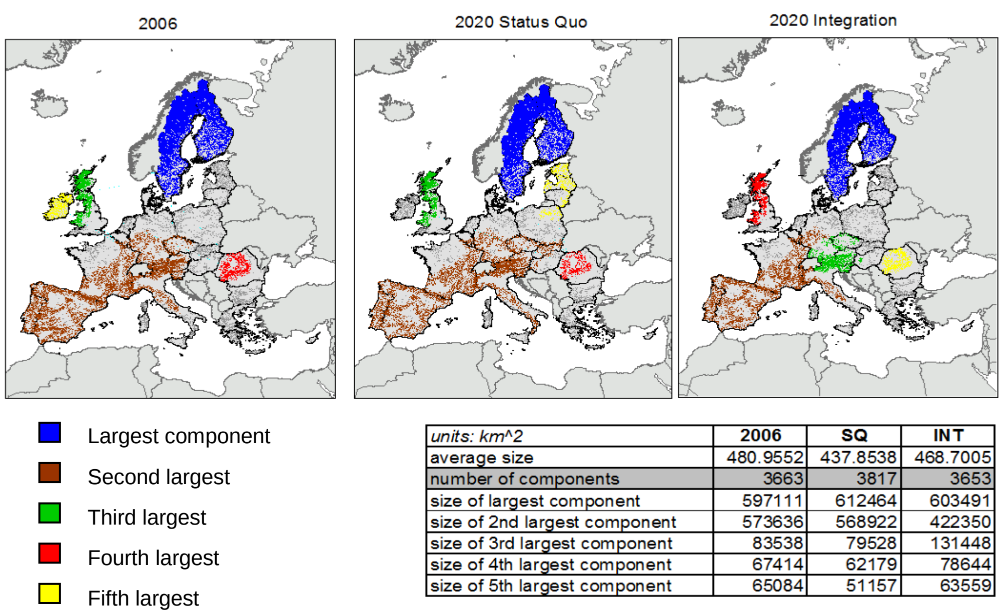


Figure 39: The breakdown of Green Infrastructure categories for all of the EU 27 territory combined for (a) base year 2006; (b) Status Quo scenario; (c) Integration policy option

These results show that for both scenarios, the Green Infrastructure is affected by land developments up until 2020. The shares of total node area however for EU 27 is adversely affected to a lesser extent in the Integration policy option, with a loss in share of 2.29% with respect to the 2006 start year. The Status Quo scenario shows a loss in share of 2.81% of node area with respect to 2006.

The overall Green Infrastructure network components are defined and assessed (adapted from a previous study using morphological MSPA pattern in the United States, described in Wickam et al 2010). A network component is a series of interconnecting nodes and links, whereby the links are only MSPA *bridges* connecting different nodes areas (see Table 7 for further definition of bridges and cores).

In the first analysis, the average size and total number of components are assessed (Figure 40) to identify the scenario leading to a major fragmentation of the Green Infrastructure components.



units: km^2	**2006**	**SQ**	**INT**
average size	480.9552	437.8538	468.7005
number of components	3663	3817	3653
size of largest component	597111	612464	603491
size of 2nd largest component	573636	568922	422350
size of 3rd largest component	83538	79528	131448
size of 4th largest component	67414	62179	78644
size of 5th largest component	65084	51157	63559

Figure 40: Total component and average component size of the Green Infrastructure map with map and sized details for the five largest components (the 2006 Green Infrastructure map and the 2020 output for Status Quo and Integration shown)

The results show that the total number of components increase and the average size component decrease from 2006 to 2020 for the Status Quo scenario. On the contrary, the total number of components decreases slightly with a greater average size component in the same time frame for the Integration policy alternative. Both of these results lead to the conclusion that the fragmentation of the green infrastructure network is more significant for Status Quo as opposed to Integration. Further analysis however, on the importance of the components and the vulnerability of the networks shows that an important network is broken under the Integration run. As shown in the figure above, the fifth largest component located in 2006 in Ireland, has lost its status and is ranked lower by a component in the Estonia, Latvia, Lithuania and northern Poland in the Status Quo scenario. In the Integration policy option, a significant link is broken in the second largest component covering the mainland of the EU from the Iberian Peninsula to the Czech Republic, thus decreasing the size of the second largest component significantly and pushing the components in the UK, Ireland and Romania down one rank.

Further, an analytical look at the degree of importance of the main nodes and links in the Green Infrastructure map of 2006 over the European territory, and how they are affected in the Status Quo scenario and the Integration policy option was made. The degree of importance is measured according to a method outlined in Saura and Rubio (2010) that was recently combined with the morphological pattern analysis (Saura *et al*, 2011) whereby a series of calculations are made in order to assess the criteria contributing to importance: in this case, the connectivity of nodes according to size and connectivity of nodes according to the type of connection. The method is applied to the Green Infrastructure components (nodes and links) in order to identify key important links and nodes for connectivity (respectively Figures 41 and 42).

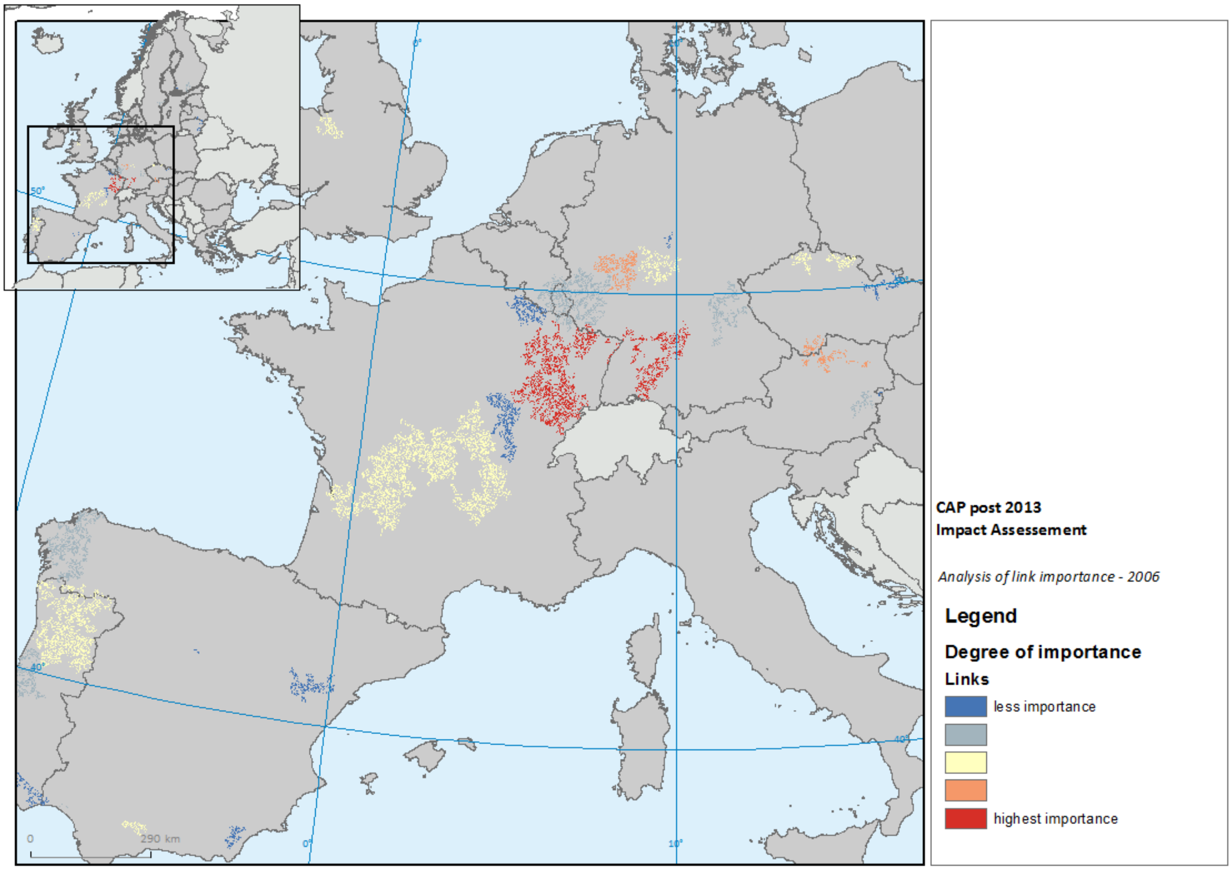


Figure 41: The five most important links in 2006 in Europe, assessed according to their role in connectivity and ranked by their degree of importance

As is illustrated in Figure 42, a very important link (shown in red) is indeed one which is broken in the Integration policy option (eastern France to Germany region), resulting in the division of a very large component, which was shown in Figure 40. Implementing this information into the land use model would lead to protecting this sensitive area. When overlain with satellite imagery, the important links are shown to cover a heterogeneous landscape, as seen in Figure 42.

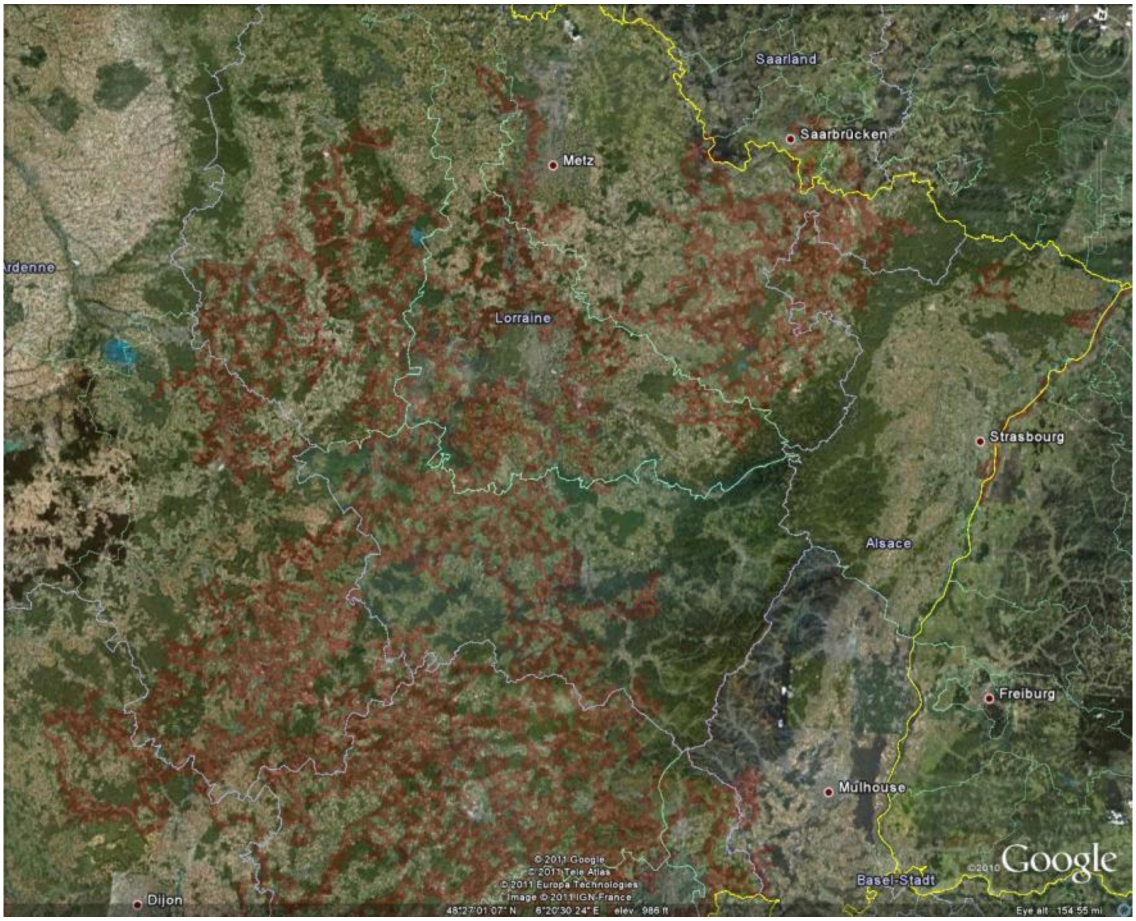


Figure 42: Important but vulnerable link in the east of France into Germany shown here in dark red overlaying satellite imagery in Google Earth, broken in Integration

Figure 43 shows the most important nodes according to their role in connectivity. The legend specifies the degree of importance of these nodes, but only the most important nodes in Europe are presented in the figure.

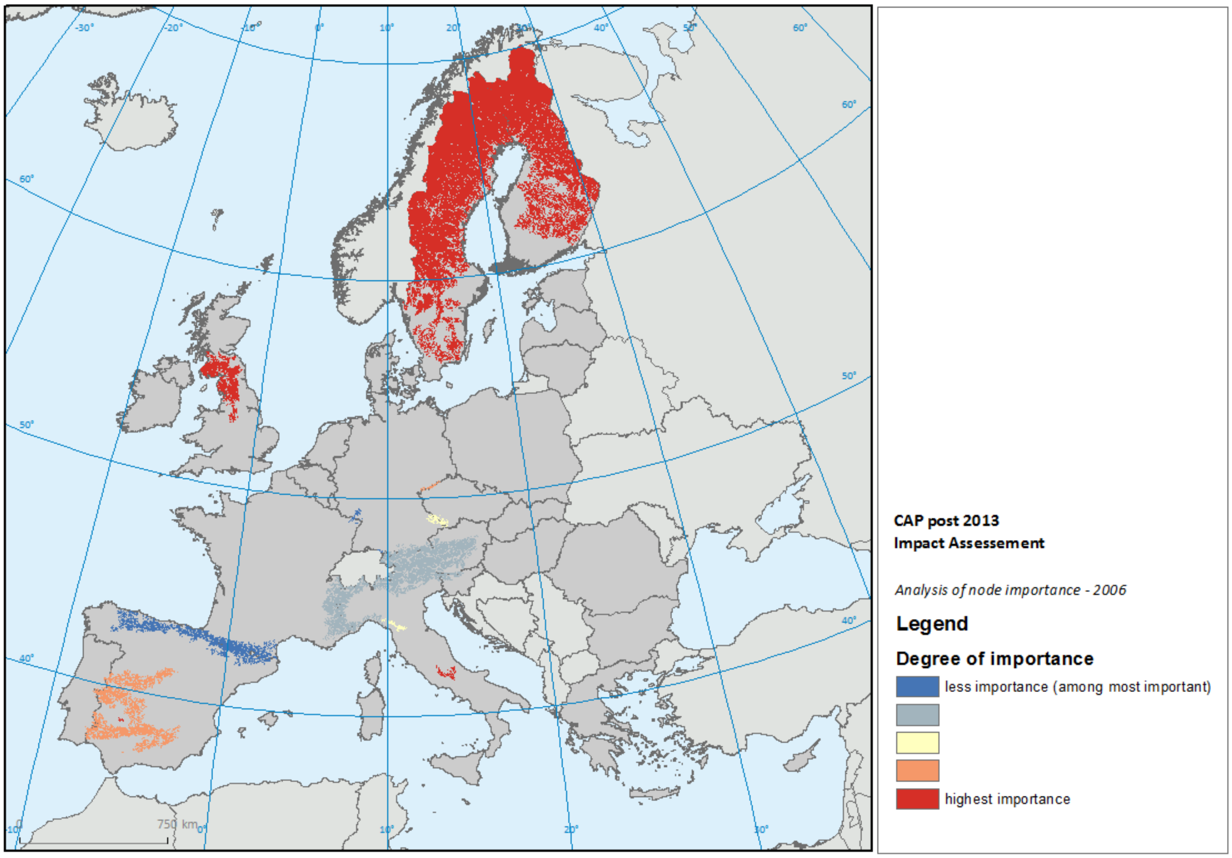
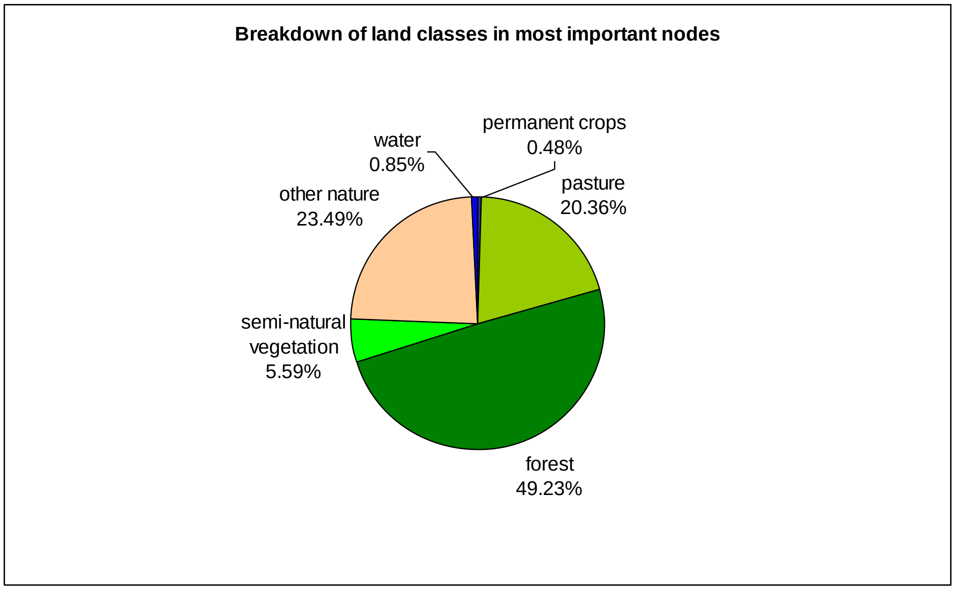
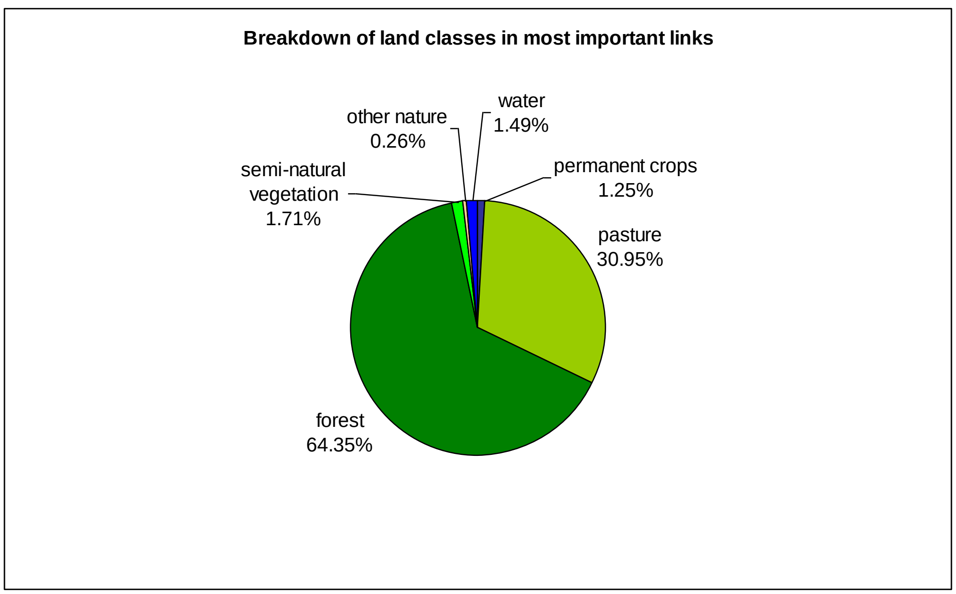


Figure 43: The five most important nodes in 2006 in Europe, based on their role in connectivity and ranked by their degree of importance among the most important nodes

As shown in Figures 44 (a,b) through the breakdown of the five most important nodes in Europe and the five most important links in Europe, the most valuable land use in this context is forest, followed by pasture land, especially for links.



a



b

Figure 44: Breakdown of land classes under a) important nodes; and b) important links

4.6 Effectiveness of greening measures on the landscape mosaic

4.6.1 Defining the Landscape Mosaic

It is known that large patches of natural and semi-natural land support a larger variety of habitats and are more likely to be colonized by new species (Weber *et al* 2008) and that large homogenous (often intensive) agricultural lands can be negative to both biodiversity and natural processes (Benini *et al*. 2010). The landscape mosaic model described in Riitters *et al* (2009) and adapted in Estreguil and Mouton (2009) and Estreguil and Caudullo (2011) is implemented for the lands belonging to Green Infrastructure from only two perspectives at this stage: 'Pure' core natural and semi-natural land and homogenous agricultural land are discriminated and their land shares under the two scenarios are analysed. For these two indicators, local spatial information was aggregated by NUTS 0 region, and by Natura 2000 sites.

Table 9 shows the division of land use classes into "natural" intended for both natural and semi-natural classes within the baseline data (CLC); and "non-natural" classes, further sub-divided in agricultural and artificial classes.

Table 9: Land use classes belonging to the aggregated agriculture, nature and urban classes

Agriculture	Natural	Urban
Permanent crops	Forest	Urban
Pasture	Semi natural vegetation	Industry and services
Cereals	Other nature	Other infrastructure (roads, rail, mines etc)
Maize	Water bodies	
Root crops		
Other arable		

The landscape mosaic index is essentially a categorization of the landscape composition context of each one hectare parcel of land according to the share of agricultural, natural/semi-natural and artificial/urban lands in its immediate surroundings (in this case around 50 hectares). Figure 45 shows the tri-polar description given to the landscape. The implementation of this description is done by running a filter over each one hectare cell in the image, assigning a value for landscape composition within a 50ha radius of that cell. Interface zones of each cell (land parcel) with adjacent land cover (for example natural and semi-natural land with agriculture) and mosaic pattern classes (more or less 'pure' and homogeneous) are discriminated. This series of spatially-implemented algorithms provides insight to the presence, and thus potential impacts, of unnatural influences upon nature.

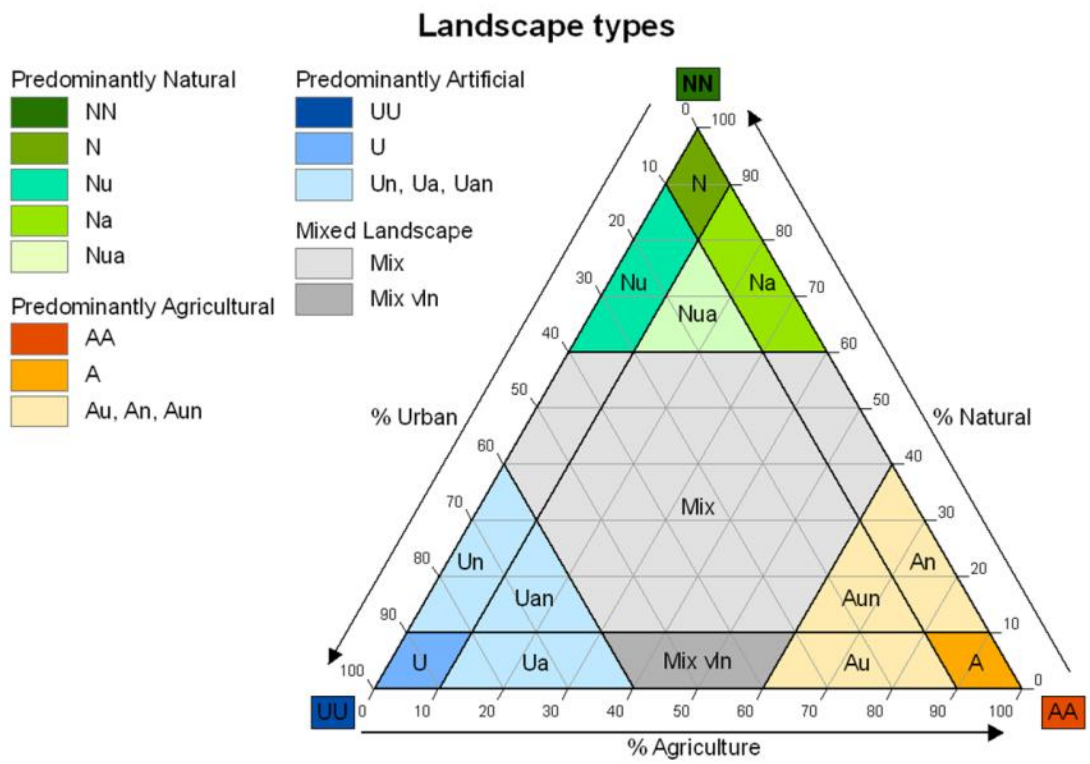


Figure 45: Conceptual schema describing the landscape mosaic classes (taken from Estreguil and Mouton, 2009)

For the sake of simplicity in this study, we focus upon the 'pure core agricultural' (AA) and the 'pure core natural' (NN) patterns, although the matrix was computed in its entirety. The output map from which the indicators are derived resembles Figure 46. The entire landscape is assessed for land shares in AA and in NN at this stage, regardless of whether or not it belongs to Green Infrastructure.

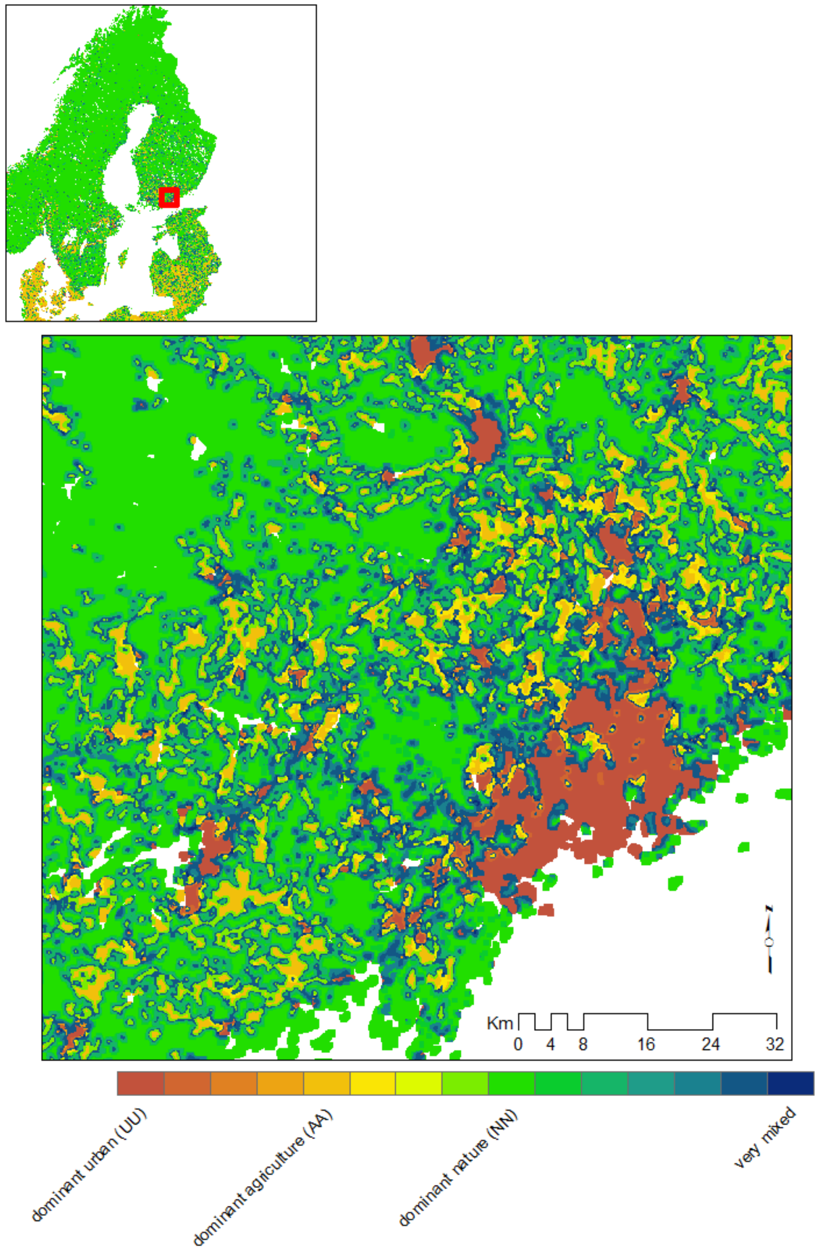


Figure 46: The landscape mosaic image from which the indicators are derived. In this example, the 2006 image in the south of Finland

The indicators are computed for both the Status Quo scenario and the Integration policy option, as well as for the 2006 refined Corine map in order to give the reader a sense of the changes occurring from 2006 to 2020 under both the scenario and the policy option.

4.6.2 Analysis of *pure core natural areas*

The indicator for 'pure core natural areas' is derived from the landscape mosaic map. Lands with a pure core natural pattern (NN) are always adjacent to other natural/semi-natural lands. These areas are compared per country between the two model forecasts for 2020. An understanding is thus gained on *if* and *where* regions benefit from the greening measures proposed in the Integration policy options.

Figure 47 shows the relative changes in areas with a pure core natural pattern from 2006 to 2020 for both the Status Quo and Integration runs by country, regardless if the area belongs to Green Infrastructure. Countries benefitting the most from the greening measures in terms of gain of a pure core natural areas are Lithuania, Slovenia and Portugal. Several countries also show to benefit more than others in the Status Quo scenario when the greening measures are applied (Sweden, Netherlands, Poland, Czech Republic and Germany).

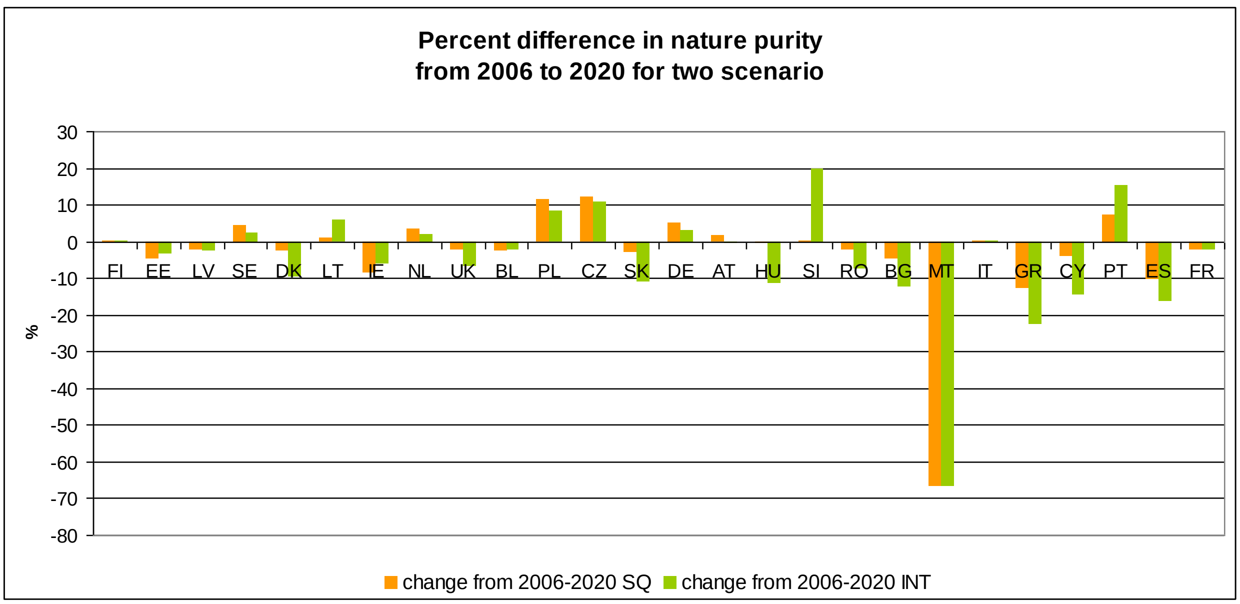


Figure 47: The rate of change in 'pure core natural areas' on a country basis from 2006 to 2020 for both Status Quo and Integration model runs

Figure 48 shows the data transformed to express the differences between the Status Quo scenario and the Integration policy option.

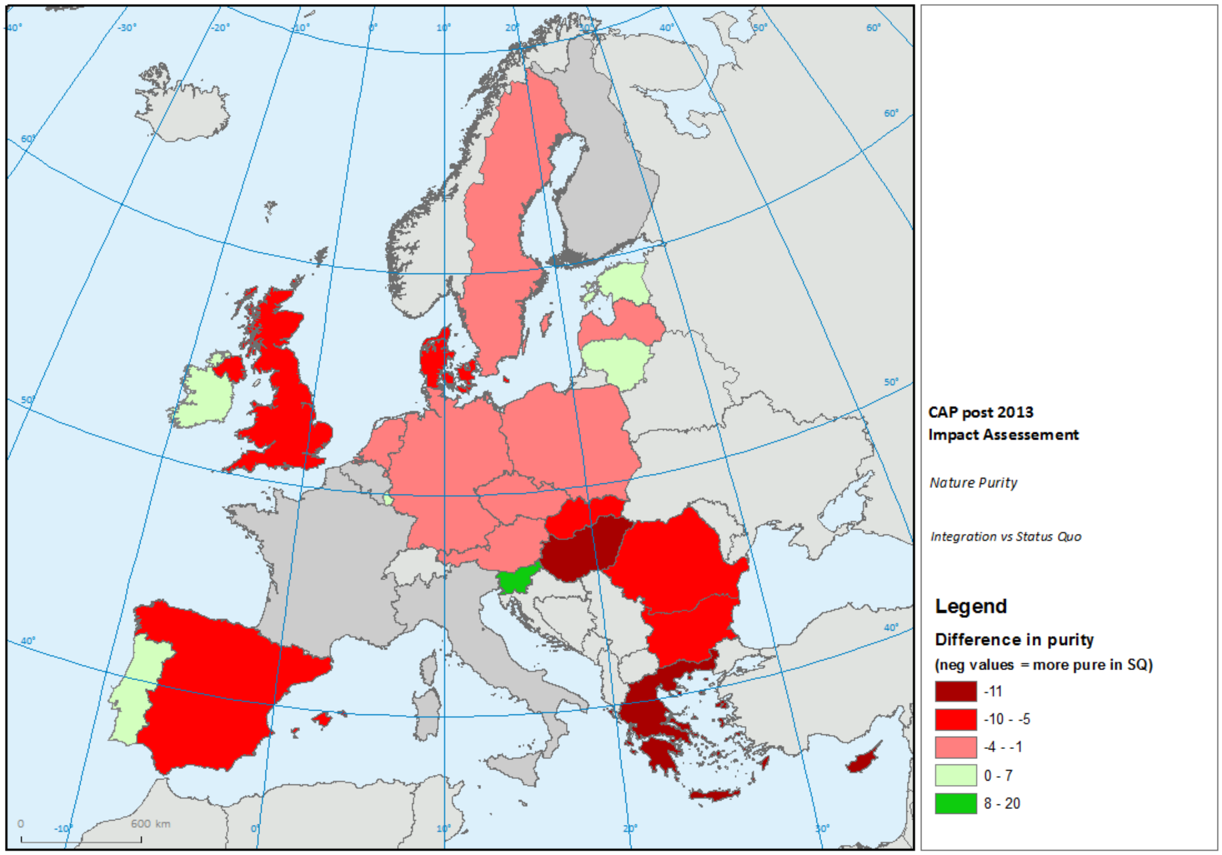


Figure 48: Relative differences in the 'pure core natural' pattern index between the Status Quo scenario and the Integration policy option per country (countries in darker grey show less than 1% change)

The above figure shows that few countries benefit from the greening measures as they were configured in the model in terms of pure core natural areas. Indeed more core areas are ruptured under the Integration policy option. In order to understand these results, a closer look at the situation inside of Natura 2000 sites was taken. Figure 49 shows an inset of the results of calculations made on Natura 2000 sites with respect to the pure core natural pattern Index. Red polygons indicate a decrease in pure core natural areas for the greening measures and all other colours show a gradient of increased effectiveness on Natura 2000 areas.

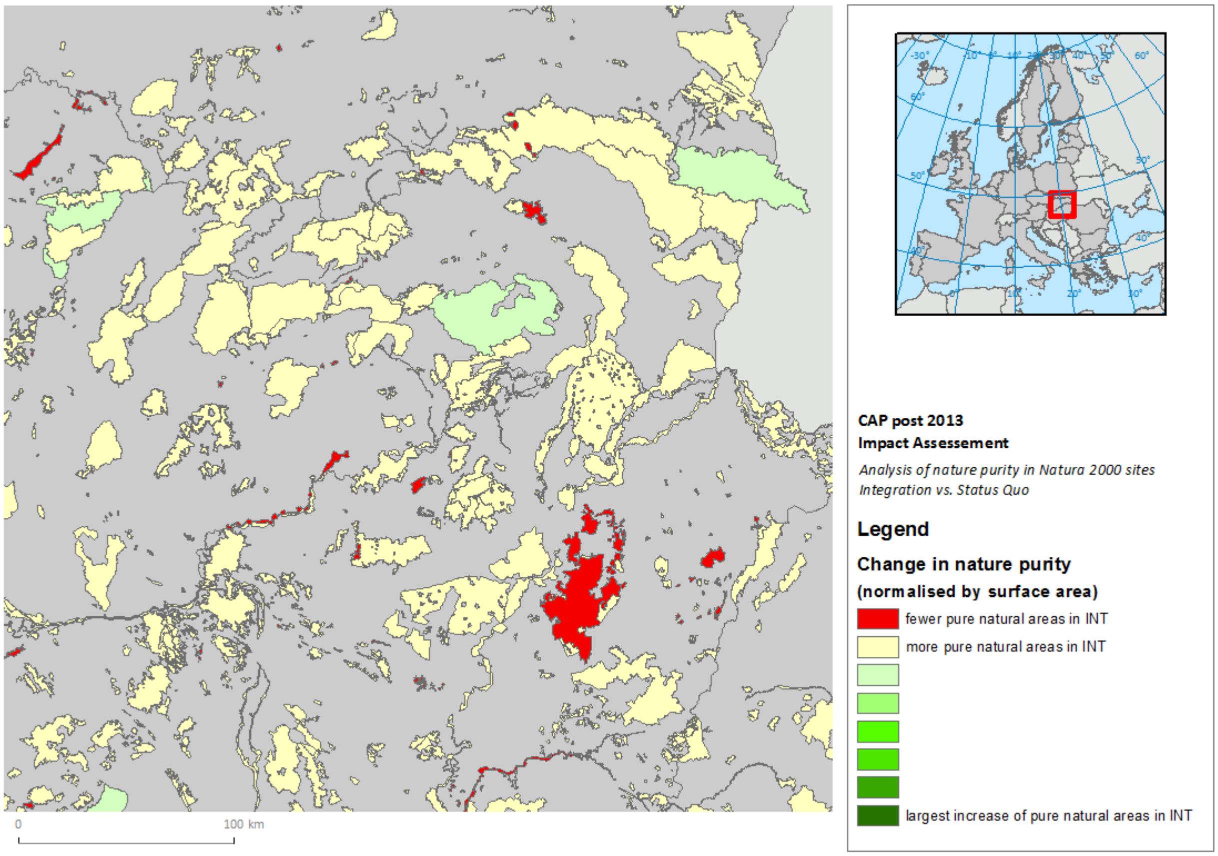


Figure 49: Enlargement of differences in 'pure core natural areas' between the Status Quo scenario and the Integration policy option within Natura 2000 sites

Only a very small percentage of Natura 2000 polygons deteriorate under the Integration policy option (4.31%) whereas 54.29% improve (43.38% do not show any change). Thus, whereas the greening measures applied in the Natura 2000 sites are effective with respect to conserving pure core natural areas, the measures are not strong enough when acting independently of the additional restrictions applied in protected areas.

4.6.3 Analysis of *pure core agricultural areas*

Important from a biodiversity perspective is the overall change in areas of homogeneous agricultural regions, likely to reflect more intensive agriculture. This is relevant from a high nature value point of view whereby areas with a pure core agricultural areas are undesirable since they likely represent obstacles to transit for fauna and low floral biodiversity. Figure 50 shows the impact of the scenario runs on the overall pure core agricultural pattern (AA pattern) on a per country basis. Countries benefitting from both the Status Quo scenario and the Integration policy option, thus showing a decrease in land shares of AA pattern, exceed those not benefitting from any.

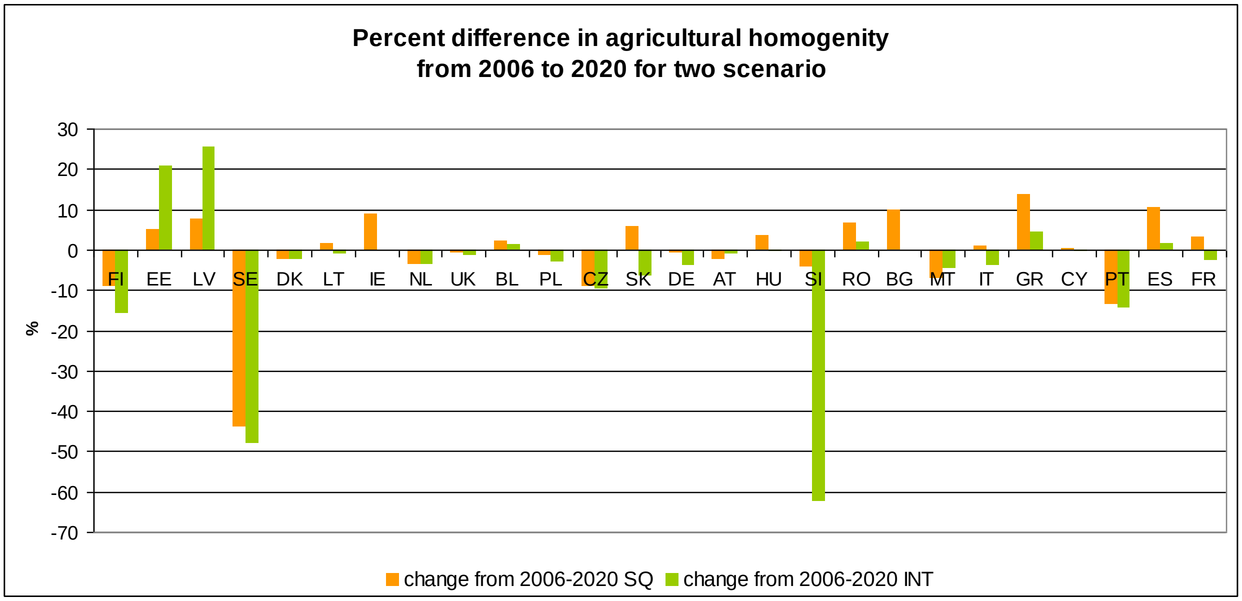


Figure 50: The rate of change in 'pure core agricultural' pattern (homogeneity) on a per country basis between 2006 and 2020 for the Status Quo scenario and the Integration policy option

Figure 51 shows the difference in this indicator between the Status Quo and the Integration runs on a per country basis. The overall results show that areas with a 'pure core agricultural pattern' become more heterogeneous in the Integration policy option, with only two exceptions (Estonia and Latvia).

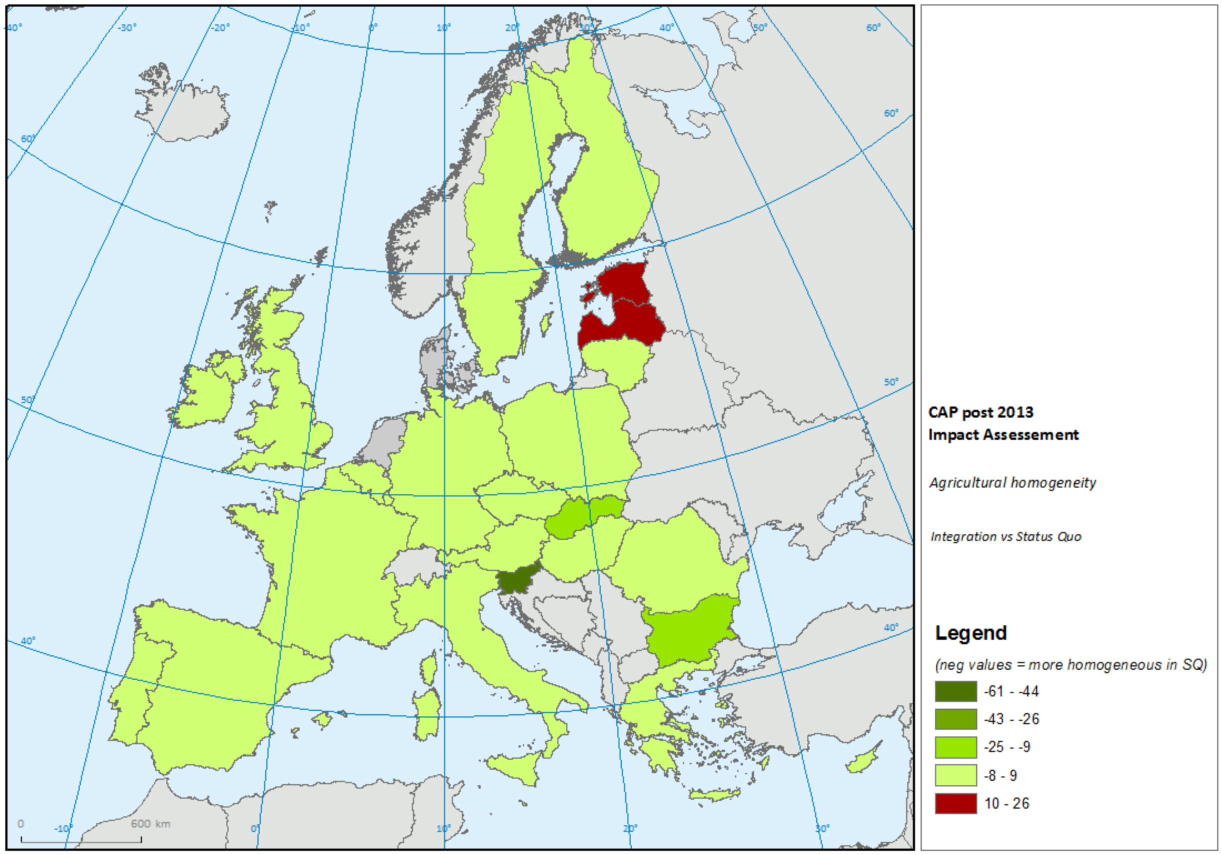


Figure 51: Relative difference in the 'pure core agricultural areas' between the Status Quo scenario and the Integration policy alternative per country (countries in darker grey show less than 1% change)

An assessment was made on the shares of pure core agricultural areas within the Natura 2000 sites (Figure 52). Only a very small percentage of Natura 2000 polygons deteriorate under the Integration policy option (5.14%) whereas 22.14% improve (72.72% do not show any changes).

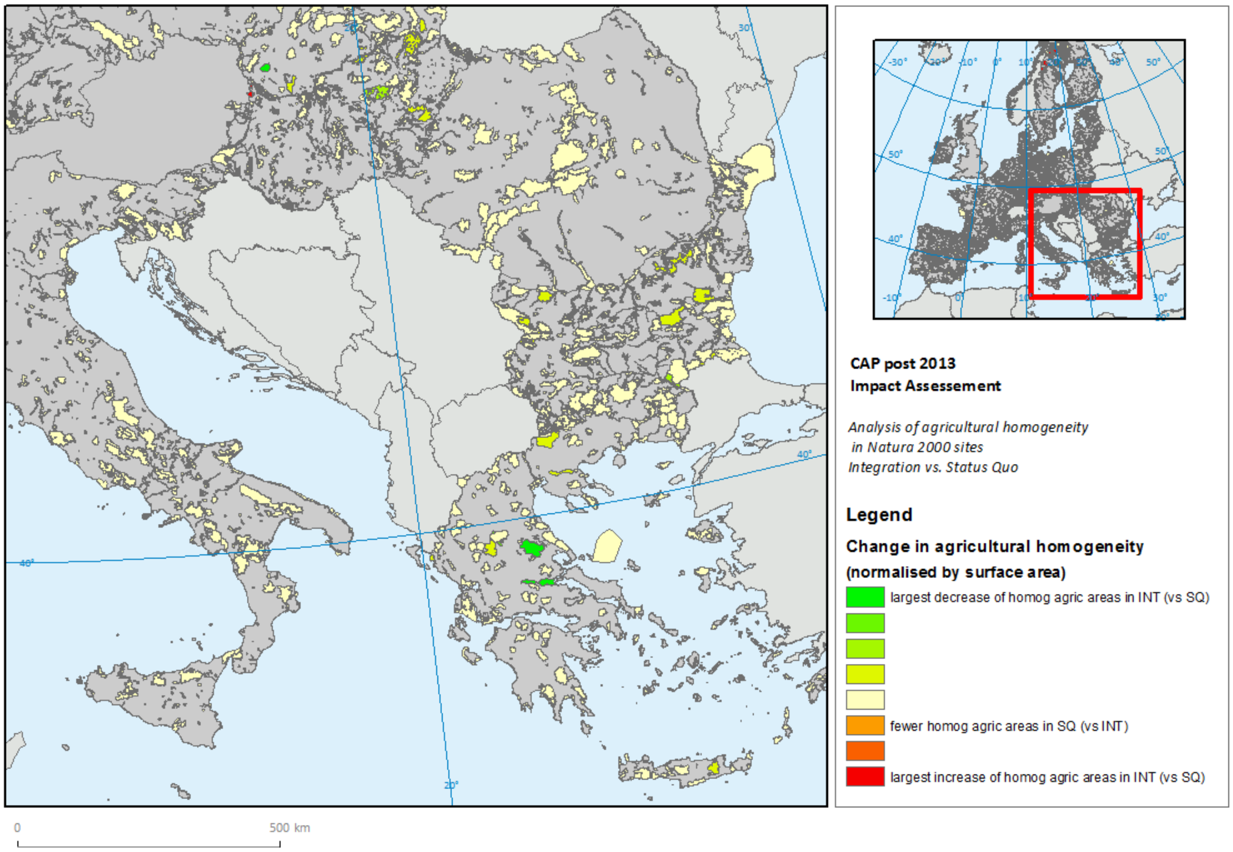


Figure 52: Enlargement of differences in 'pure core agricultural areas' between the Status Quo scenario and the Integration policy option within Natura 2000 sites

4.6.4 Landscape mosaic composition within Green Infrastructure

In a conclusive step to this series of spatial, ecological indicators, the mosaic pattern information is retrieved only for the Green infrastructure lands over the EU. As shown in Table 6 of the previous section on Green Infrastructure, the overall net amount of land contributing to Green Infrastructure is higher for the Integration policy alternative with respect to the baseline scenario. Figure 53 shows this net difference (length of bars), as well as the landscape mosaic composition of the green infrastructure in hectares.

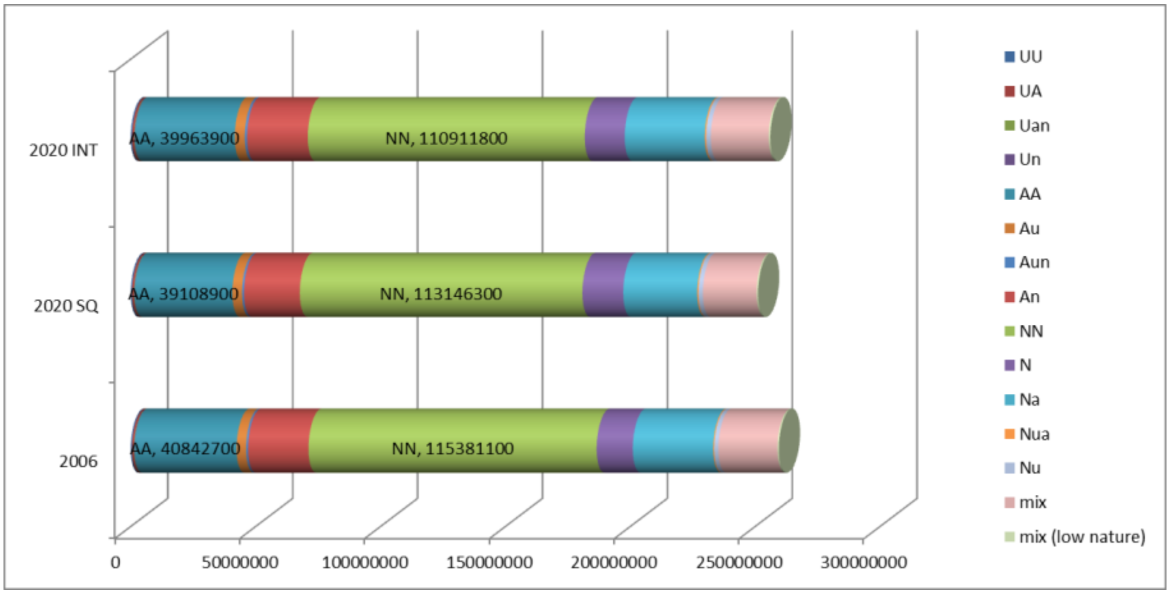
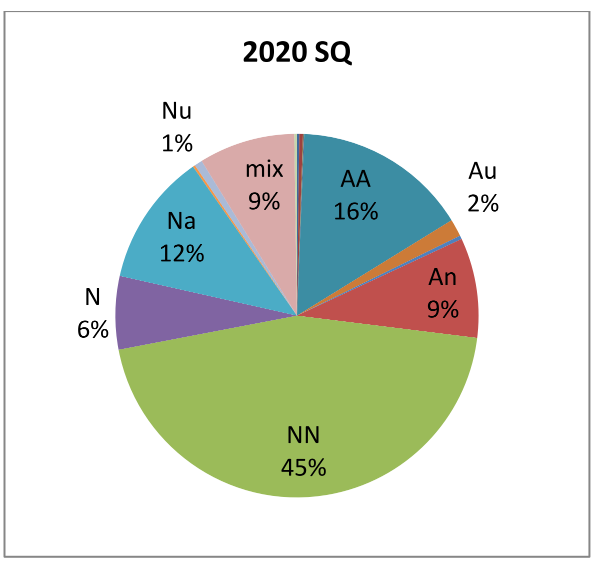


Figure 53: The landscape mosaic composition of Green Infrastructure for 2006 and the 2020 projections with reference to the net amount of Green Infrastructure (/ha). The legend is described in Figure 45

In Figure 54 (a,b), the breakdowns of the composition of the landscape mosaic is shown again, but in terms of percent of total Green Infrastructure within each of the model runs.



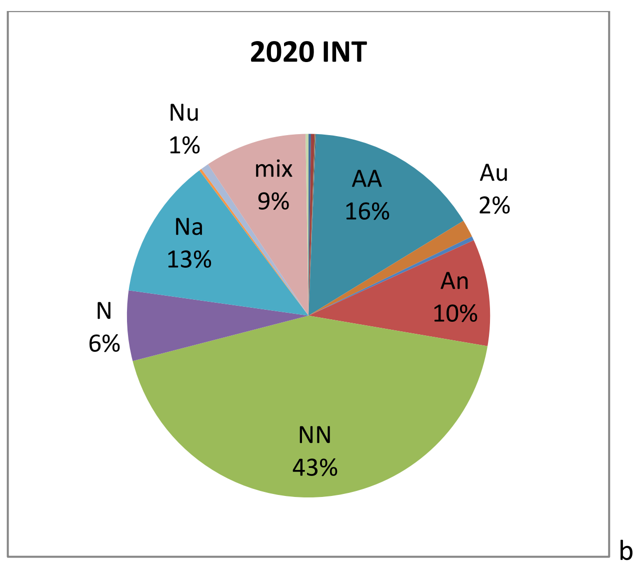


Figure 54: The contribution (/%) of each of the landscape mosaic classes to all Green Infrastructure in (a) the Status Quo scenario; (b) the Integration policy alternative

As seen in Figure 54, the net amount of core natural areas within the Green Infrastructure diminishes by 2% within Green Infrastructure for the Integration policy alternative. This loss is compensated by an increase in the “An” and “Na” classes, which correspond to a mix of 60-90% agriculture and 10-40% nature and 60-90% nature and 10-40% agriculture respectively. This result confirms a better heterogeneity in agricultural lands in the Integration policy alternative at the expense of core natural areas.

4.7 Estimation of changes in soil organic carbon

Soil Organic carbon (SOC) forms a major component of the terrestrial carbon pool. The total pool is estimated at 2,700 Pg of carbon, excluding the oceans and rock, of which about 55% are stored in the soil, 27% in the atmosphere and 18% in the biosphere. Land use and management practices impact directly on the type and amount of carbon stored in the soil and the biosphere. Organic carbon (OC) in the soil originates from decomposing organic material, mainly from plants. A higher OC content in the soil is beneficial to the soil structure, water holding capacity and nutrient status. It thus contributes significantly to soil stability against loss from erosion and soil fertility for crop production.

By processing carbon from vegetation the SOC-stock is linked to the earth-atmosphere CO_2 cycle. Therefore, increasing the SOC stock removes CO_2 from the atmosphere. Conversely, the oxidation of the SOC releases CO_2 to the atmosphere. The processes involved in the SOC dynamics are complex. The main influencing factors are the soil type and parent material, climatic regime and land use. The direct and comparatively short-term effect of changes in land use on SOC stock, in particular the upper layer to a depth of about 30cm, make land use and managing practices an important factor in influencing the soil functional capacity.

Method for estimating SOC Changes

The Intergovernmental Panel on Climate Change (IPCC) details a method for estimating changes in SOC as a result of land use change - LUC (IPCC, 2006). The method is based on classifying mineral soils into 6 types and defining 12 climatic regions.

For the definition of the SOC default values in the topsoil layer from 0 to 30cm the 6 soil types and 9 climate regions are arranged in a matrix of possible combinations. No default values are defined for polar regions and the boreal moist and dry regions are combined into a single boreal region. A graphical presentation of the method is presented in Figure 55.

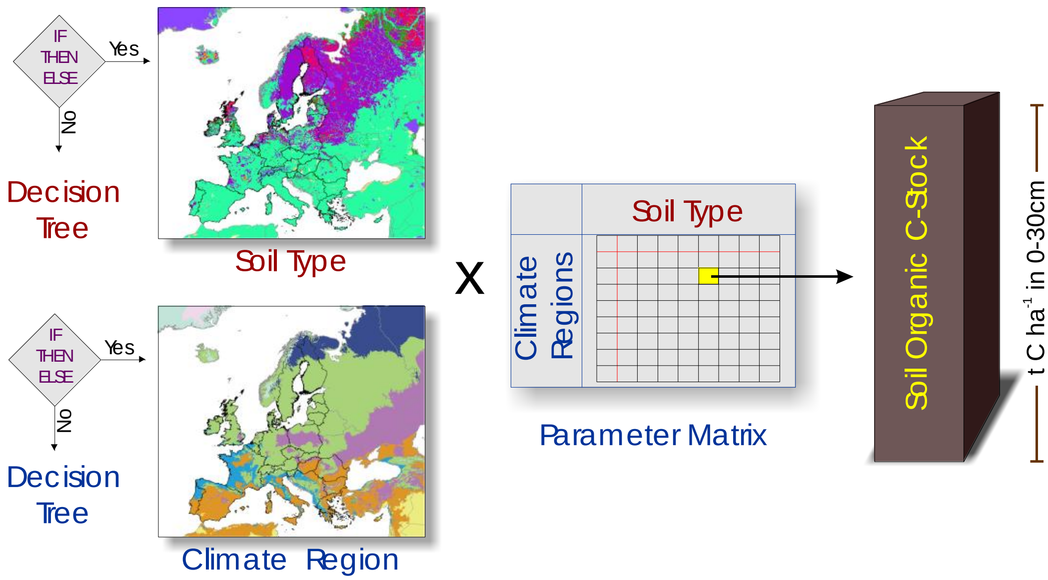


Figure 55: Schematic presentation of method for defining IPCC SOC default values

These default SOC values are then moderated by the prevalent land use, management practice and fertilizer input. The combination of these parameters into a single value is hereafter referred to as the *Land Use System Factor*. Changes in any of the defining parameters lead to subsequent changes in the SOC. A schematic presentation of the parameters defining the land use system factor is given in Figure 56.

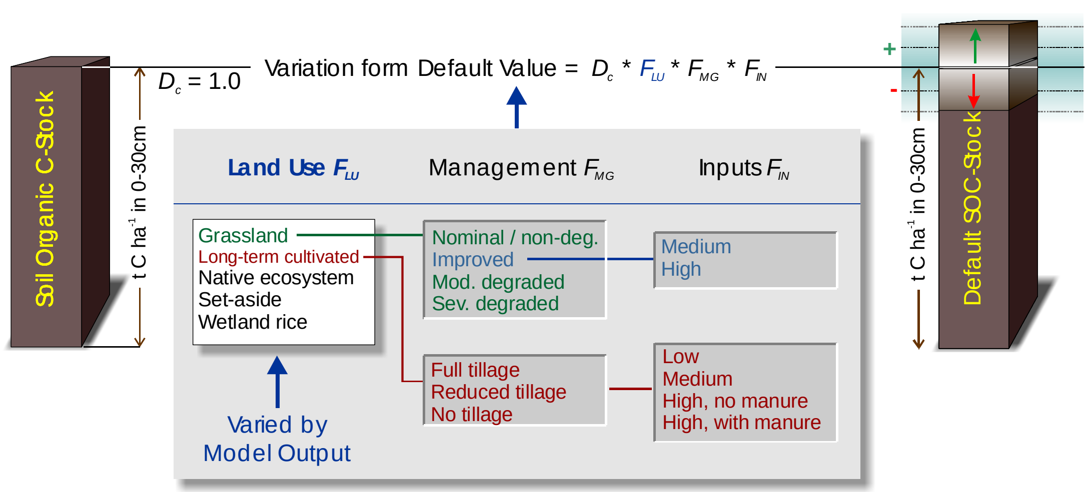


Figure 56: Schematic presentation of parameters defining Land Use System Factor for varying SOC default values

In the case of this work the data on SOC default values and climatic regions conform to the reference data developed by the JRC for the estimation of SOC changes and greenhouse gas (GHG) emissions[21]. The land use system factor was adjusted following changes to the land use as given by the model output, but the soil and climate regions were kept constant.

The IPCC Tier 1 method results in an estimate of SOC density in t C ha^{-1}. The changes in density are aggregated to changes in C-stock by NUTS 2 and country (NUTS 0).

The IPCC Tier 1 approach assumes that the SOC stocks following a land use change reach an equilibrium after 20 years with a linear rate of change (IPCC, 2003). This makes estimating changes in SOC for a 10-year period as used in this work straight-forward. Not taken into account by this approach is that the rate of change in SOC following changes in land use or management practice varies with time. Converting grassland to arable land under tillage causes a larger loss of SOC and release of CO_2 into the atmosphere in the years immediately following the conversion than in later years. Conversely, converting arable land to grassland is followed by a more steady increase in SOC. The conditions of a linear and progressive change in SOC are graphically presented in Figure 57.

[21] Commission Decision of 10 June 2010 on guidelines for the calculation of land carbon stocks for the purpose of Annex V to Directive 2009/28/EC (2010/335/EU), OJ L151 17.06.2010 pp. 19-41.

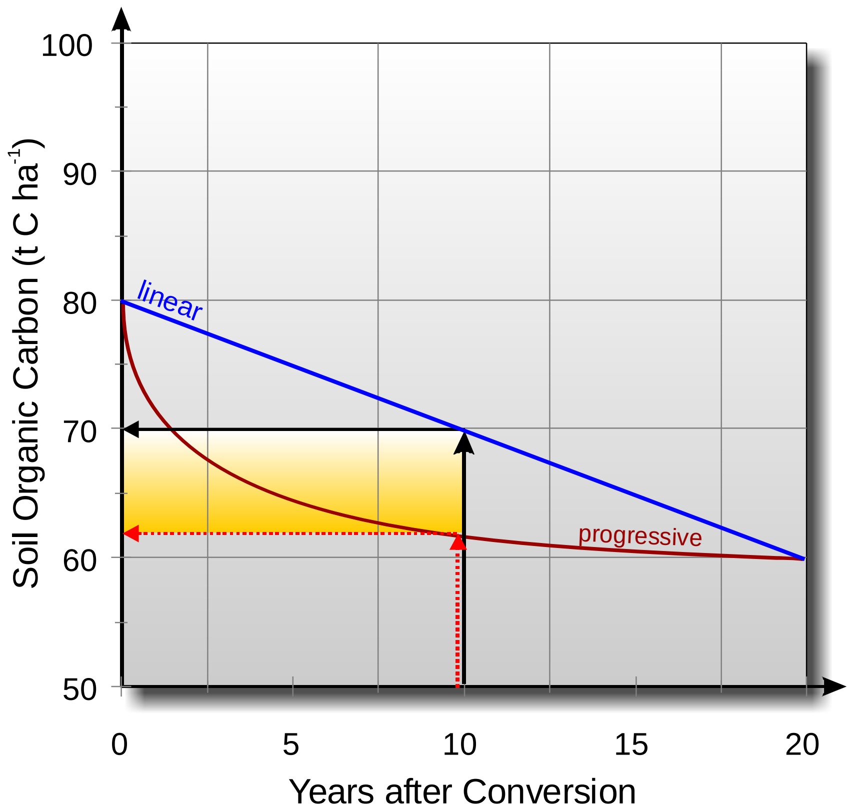


Figure 57: Exemplified linear and progressive rate of change in SOC after land conversion

The example shows a loss of 20 t C ha^{-1} over a period of 20 years. Under the linear model of Tier 1 a loss of 10 t C ha^{-1} is calculated. Under a progressive model the loss of SOC may be much higher during the same period. However, using more complex models for estimating the rate of change after land use conversion, such as applied in higher Tier approaches, require also more detailed and site-specific data. In the absence of such data the Tier 1 approach is recommended.

Special mentioning goes to the analysis of changes of SOC-stocks on organic soils (peat), which are not included in this work. The IPCC Tier 1 approach of estimating changes in stocks is not applicable to these soils (emissions are estimated directly as CO_2). The main losses in carbon from land use change occur when converting a native ecosystem to cultivation. Before areas with organic soils become suitable for cultivation they require draining. However, in Europe remaining areas with undrained organic soils are often covered by nature protection schemes which limit the scope for land cover conversions (not considered in the land use scenarios are changes in peat extraction sites, for example in Ireland and Finland).

Compared to the land use data the ancillary data used are coarse in spatial resolution. The reference climate data are in 5 arc min., which corresponds to approx. 6 km at latitude of 50°N and can be considered very high resolution for the data. The highest resolution soil data with European coverage comes from the Soil Geographic Database of Eurasia. At a scale of 1:1 mil, the data can be rasterized to 1 km. To avoid any loss in the land use information all processing was performed at the resolution of the model output (100m).

EU27 Overview

In keeping with the IPCC Tier 1 method the impact of modelled changes in land use on SOC stocks are expressed as estimated changes over a reference status and a period of 10 years based on a constant annual change, i.e. 1/20 per year of the total change estimated for 20 years. To facilitate the presentation of the results the changes in SOC stock are given separately for the changes from the reference to the Status Quo scenario and for the reference to the Integration policy option. The effect of the Integration policy option is presented as a deviation (delta) from the Status Quo scenario.

The changes in SOC stock by country are summarized in Table 10.

Table 10: Changes in SOC Stock from Status Quo scenario and Integration policy option, by country

Country	Scenario		Delta
	Status Quo	Integration	
	Mt C	*Mt C*	*Mt C*
Austria	-0.9	0.8	1.7
Belgium & Luxembourg	-1.5	-0.2	1.3
Bulgaria	-4.6	-2.3	2.3
Cyprus	-0.0	-0.1	-0.1
Czech Republic	3.2	3.5	0.4
Denmark	0.2	0.3	0.1
Estonia	-2.5	-2.1	0.3
Finland	-0.3	1.0	1.3
France	-16.1	-6.5	9.7
Germany	-6.6	-1.6	5.0
Greece	-8.8	-6.3	2.5
Hungary	-0.6	-0.6	0.1
Ireland	-5.6	-0.4	5.2
Italy	-0.5	0.9	1.5
Latvia	-4.4	-5.4	-1.0
Lithuania	-0.8	-0.2	0.6
Malta	+0.0	+0.0	+0.0
Netherlands	-1.3	-1.1	0.2
Poland	0.9	2.3	1.4
Portugal	1.4	2.4	1.0
Romania	-13.8	-6.2	7.6
Slovakia	-2.8	-1.3	1.4
Slovenia	0.7	0.5	-0.1
Spain	-14.7	-15.0	-0.3
Sweden	14.4	10.4	-3.9
United Kingdom	-1.4	-2.3	-0.9
Total	**-66.6**	**-29.5**	**37.0**

For EU27 the Status Quo scenario results in estimated losses of 66.6 Mt C in the topsoil layer over the 10-year period from LUC. The measures of the Integration policy option are also expected to lead to a decrease in SOC over the reference status, but with estimates losses of 29.5 Mt C the losses amount to less than half of those of the Status Quo scenario. These changes in SOC-stocks estimated from the modelled changes in land use compare to an estimated total SOC stock of 72 Pg (72,000 Mt) for EU27 (ClimSoil, 2008).

The areas occupied by the land use types of the SOC evaluation between the Status Quo scenario and the Integration policy option are compared based on a cross-tabulation of all possible categories. The results for EU27 are presented in Table 11.

Table 11: Comparison of area of land use types between Status Quo scenario and Integration policy option (EU27)

Area	**Status Quo**					**Total**
Integration	**Grassland**	**Cultivated**	**Native**	**Set-aside**	**Other**	**Integration**
	km²	*km²*	*km²*	*km²*	*km²*	*km²*
Grassland	394,031	101,101	8,036	14	2,773	505,954
Cultivated	9,146	3,222,637	116,367	7,040	18,598	3,373,788
Native	3,244	90,126	4,421,198	459	7,356	4,522,383
Set-aside	844	19,056	68,873	4,164	3,238	96,175
Other	579	4,702	1,605	303	1,704,463	1,711,652
Total Status Quo	407,844	3,437,621	4,616,079	11,979	1,736,428	10,209,952
Difference Integration to Status Quo	98,110 (*24.1%*)	-63,834 (*-1.9%*)	-93,696 (*-2.0%*)	84,196 (*702.9%*)	-24,777 (*-1.4%*)	

The table columns give the areas of a land use type in the Integration policy option which fall onto a land use type of the Status Quo scenario. The difference of the area of a land use type in the Integration policy option as compared to the Status Quo scenario is given in absolute and relative terms in the last row.

The cross-tabulation of areas indicates that at EU27 level the Integration policy option shows increases on the areas under grassland (98,110 km^2) and set-aside (84,196 km^2). These areas are expanded mainly at the cost of cultivated land (-63,834 km^2) and areas classified as being under native vegetation (-93,696 km^2). The distribution of the changes in cultivated areas from the reference to the modelled status differs markedly between the two model configurations. Cultivated land of the Status Quo scenario is approx. evenly distributed on grassland and native vegetation in the Integration policy option. In contrast, more than 75% of the cultivated land under the Integration policy option is located on areas classified as native vegetation in the Status Quo scenario. This disproportion in the distribution of land use types between the scenarios results in changes in SOC-stocks, which are not proportional to the overall changes in area.

Table 12: Difference in Soil Organic Carbon Density (t C ha^{-1}) between Status Quo scenario and Integration policy option (EU27)

Density	**Status Quo**				
Integration	**Grassland**	**Cultivated**	**Native**	**Set-aside**	**Other**
	t C ha^{-1}	*t C ha^{-1}*	*t C ha^{-1}*	*t C ha^{-1}*	*t C ha^{-1}*
Grassland		4.9	0.6	2.8	0.4
Cultivated	-10.3		-3.2	-0.2	-0.7
Native	-2.3	3.9		1.6	0.0
Set-aside	-5.7	0.2	-0.0		-0.7
Other	-4.0	3.5	0.0	2.0	

The areas which are cultivated under the Integration policy option have a SOC density which is 10.3 *t C ha*$^{-1}$ lower than the density of the areas which are grassland under the Status Quo scenario. Yet, the SOC density of areas under grassland in the Integration policy option is only 4.9 *t C ha*$^{-1}$ higher than the corresponding areas under cultivation in the Status Quo scenario.

SOC Changes at the level of NUTS 2

While there is a general trend for loosing SOC from either scenario at EU27 level the results aggregated by country show noteworthy differences between countries. In some cases the modelled changes in land use lead to increases in SOC from the modelled LUC, such as the Czech Republic, Portugal or Sweden. The model output further suggests significant variations at sub-national level, which were evaluated by aggregating the data at NUTS 2.

Such variations in SOC-stock from the conditions defined by the reference status to the Status Quo scenario with an aggregation to NUTS 2 are shown in Figure 58.

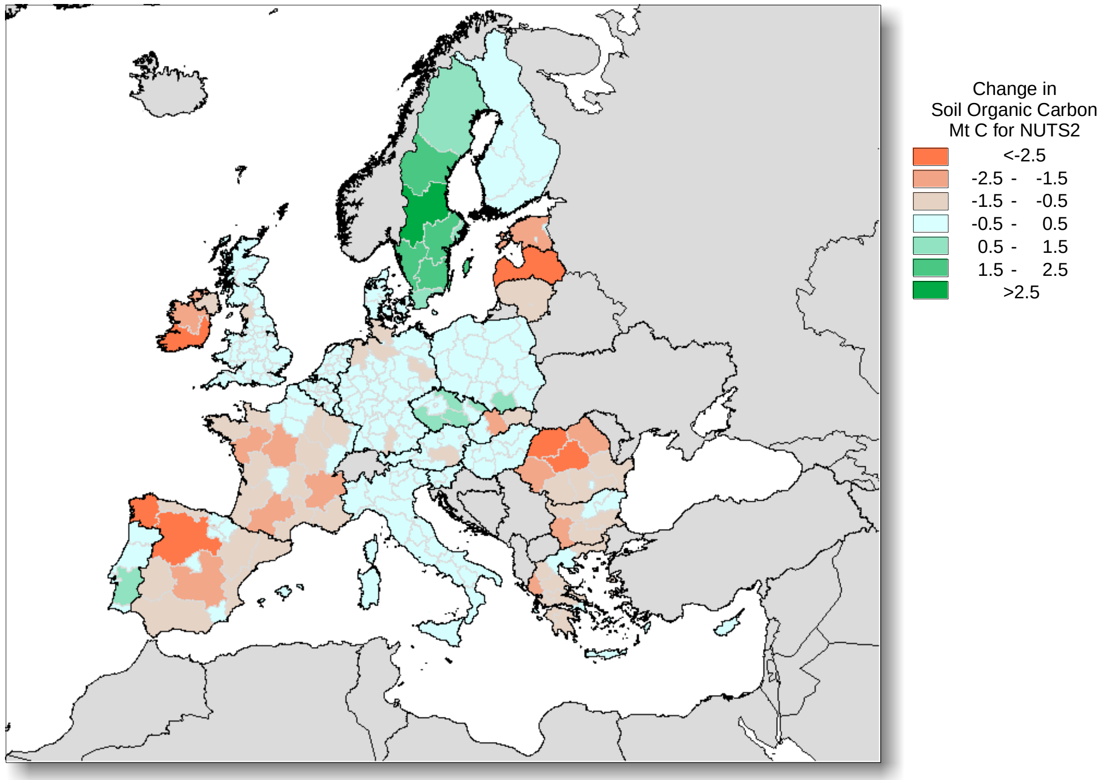


Figure 58: Estimated change in Soil Organic Carbon from Reference to Status Quo scenario over 10 Years (NUTS2)

The map shows the prominent differences in changes in SOC-stocks from the modelled LUC form the reference status to the Status Quo scenario by NUTS 2. It indicates that in some countries the changes are more spatially heterogeneous than in others. Examples where divergent trends in the development of estimates SOC-stocks are modelled are Bulgaria, France, Greece and Spain. Small variations between NUTS 2 areas are modelled, for example, for the BENELUX countries, Poland and Hungary.

The differences in estimated SOC-stocks of the Integration policy option from the Status Quo scenario and aggregated to NUTS 2 are presented in Figure 59.

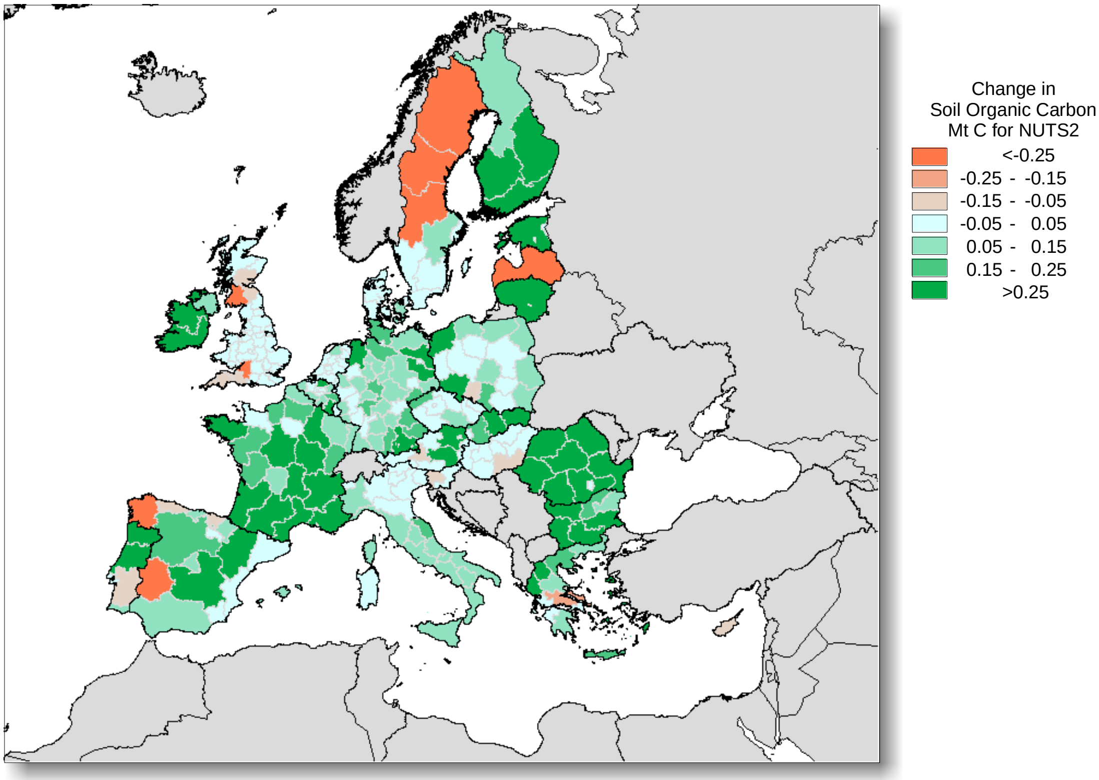


Figure 59: Estimated changes in Soil Organic Carbon from Status Quo scenario to Integration policy option over 10 Years (NUTS2)

The graph illustrates that there are regional exceptions to the general trend for lower losses of SOC under the Integration as compared with the Status Quo scenario. Greater losses in the Integration policy option are estimated for Estonia and Sweden, but also for regions in Greece, Spain and the United Kingdom. An assessment to the sources for these locally different developments requires an analysis of the LUC at the resolution of the model output data.

Review of changes by selected country: Spain

To better evaluate the conditions leading to the estimated changes in SOC stocks the values were also aggregated to the spatial units of NUTS 2. Aggregating at NUTS 2 provides an estimate of the changes in SOC stocks at the level of applying regional policies.

For an assessment of the measures applied under the scenarios the differences in SOC-stocks are estimated for three combinations of reference and scenario data:

- Change in SOC-stocks from reference to Status Quo scenario;
- Difference in SOC-stocks between Status Quo and Integration;
- Variations in SOC density in LUC areas.

Compared to the evaluation of the changes in SOC-stock at country level the changes from the reference to the Integration policy option were included to assist in the appraisal of spatially different developments induced by the measures defining the scenarios. As the analysis is quite protracted only a selected number of countries are presented in this section.

Figure 60 shows for Spain the change in SOC-stocks in Mt C at NUTS 2 from 2010 to 2020 for the Status Quo scenario.

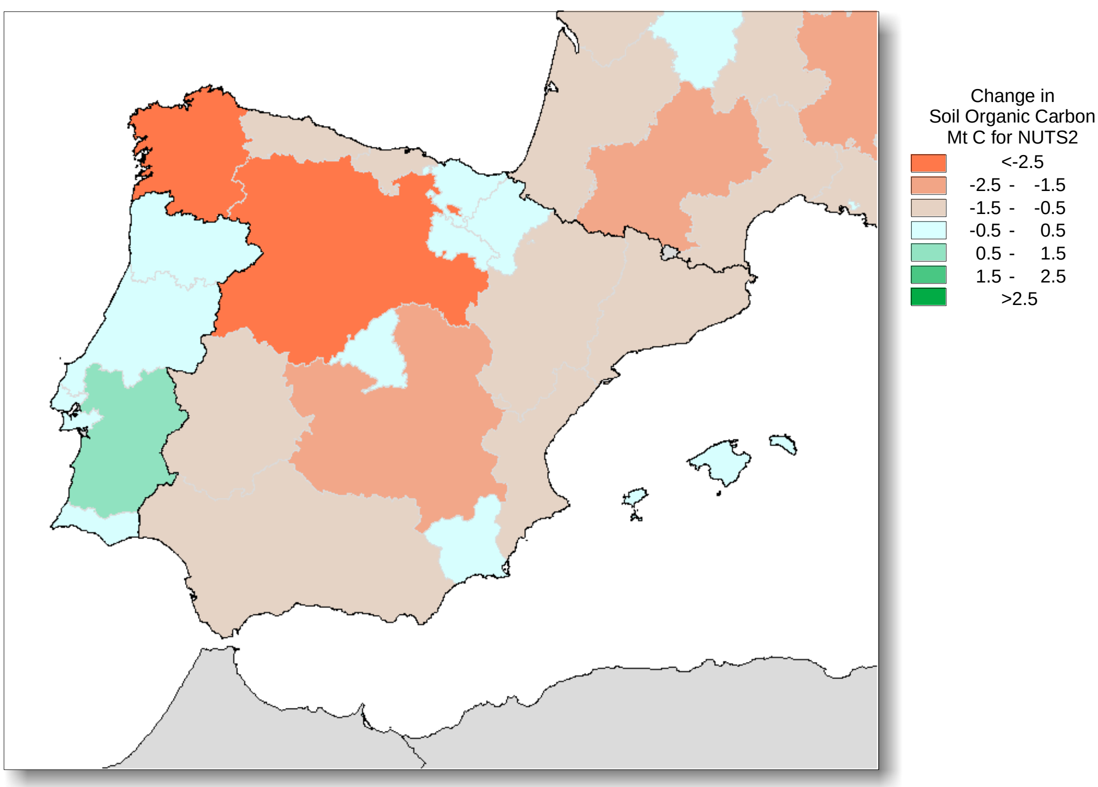


Figure 60: Estimated change in Soil Organic Carbon from Reference to Status Quo Scenario over 10 Years (Spain)

For Spain the changes in SOC-stocks due to LUC modelled for the Status Quo scenario result in an estimated reduction of 14.7 Mt C. These losses occur mainly in Galicia, Castile-Leon and Castile-La-Mancha. Hardly any changes in SOC-stocks are estimated for Murcia, Madrid, Navarre, Basque Country and the Balearic Islands. More moderate losses are modelled in the remaining areas.

The effectiveness of the measures under the Integration policy option was evaluated by comparing the difference in the changes between the Status Quo scenario and the Integration policy option. The outcome is shown in Figure 61.

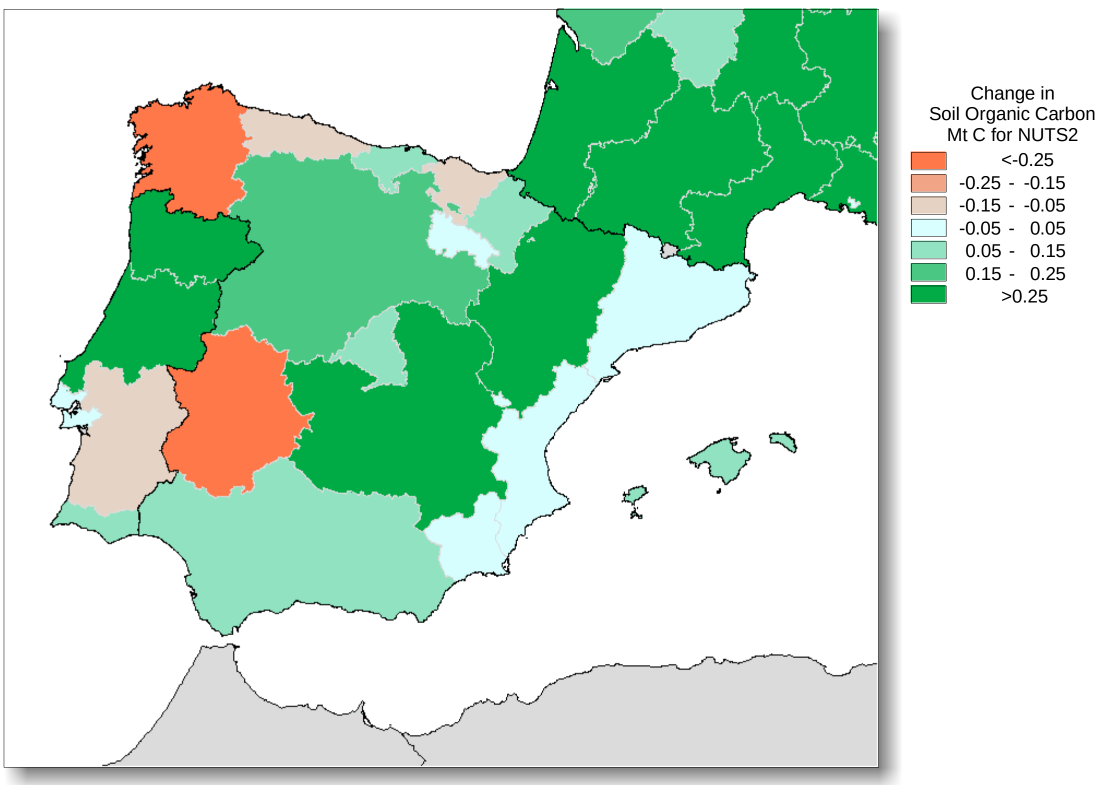


Figure 61: Estimated Change in Soil Organic Carbon of Integration Policy Option over Status Quo Scenario over 10 Years (Spain)

In accordance with the overall trend for EU27 also for Spain the Integration policy option results in a reduction of SOC losses as compared to the changes introduced by the Status Quo scenario. However, the changes in land use of the Integration policy option result in significantly higher losses in Galicia and Extremadura, which contrasts with the trend in most other areas.

The main land use changes contributing to the difference in estimated changes in SOC-stocks were assessed by studying the transmutations between land cover types. For the IPCC land use types the differences between the conversion from the reference situation to the Status Quo scenario and to the Integration policy option were compared as area differences. The results of the cross-tabulation are given as a matrix in Table 13.

Table 13: Comparison of area of land use types between Status Quo scenario and Integration policy option (Spain)

Area	**Status Quo**					**Total**
Integration	**Grassland** *km²*	**Cultivated** *km²*	**Native** *km²*	**Set-aside** *km²*	**Other** *km²*	**Integration** *km²*
Grassland	29,012	6,044	362	4	37	35,460
Cultivated	1,182	495,089	30,221	538	5,443	532,473
Native	1,118	19,393	320,849	0	1,233	342,594
Set-aside	43	3,955	24	18	611	4,650
Other	112	1,346	83	0	89,838	91,379
Total Status Quo	31,467	525,827	351,540	560	97,161	1,006,556
Difference Integration to Status Quo	3,993 (*12.7%*)	6,646 (*1.3%*)	-8,947 (*-2.5%*)	4,090 (*730.0%*)	-5,782 (*-6.0%*)	

The table compares the areas occupied for the 4 main land cover types of the IPCC Tier 1 approach between the Integration policy option and the Status Quo scenario, with all remaining areas grouped into the class “Other”. The measures of the Integration policy option lead to 6,646 km^{-2} (1.3%) more cultivated land than the measures of the Status Quo scenario. These additional areas in the Integration policy option are mainly occupied by native vegetation (80.8% of non-corresponding areas).

The table also indicates that despite the similarity of the total areas there are some pronounced shifts within land use types between the scenarios. These are more readily apparent when comparing the transmutations of land use in relative terms, as presented in Table 14.

Table 14: Relative difference in area of land use types between Status Quo scenario and Integration policy option (Spain)

Relative	Area of Integration on Area of Status Quo					Relative to Integration
	Grassland	Cultivated	Native	Set-aside	Other	
	%	%	%	%	%	%
Grassland	92.2	1.1	0.1	0.8	0.0	112.7
Cultivated	3.8	94.2	8.6	96.0	5.6	101.3
Native	3.6	3.7	91.3	0.0	1.3	97.5
Set-aside	0.1	0.8	0.0	3.1	0.6	830.0
Other	0.4	0.3	0.0	0.0	92.5	94.0
Relative to Status Quo	88.7	98.8	102.6	12.0	106.3	

The table presents the relative distribution of the land use areas of the Integration policy option on the land use areas of the Status Quo scenario. For example, 92.2% of grassland in the Status Quo scenario is also grassland in the Integration policy option. The “Relative Integration” states the total area in the Integration policy option over the area of the corresponding class in the Status Quo scenario and is therefore not the row sum. The Integration policy option leads to less native vegetation than the Status Quo scenario (-2.5%). This loss of native land is only partially compensated for by gains in grassland with a subsequent overall decrease in SOC-stocks.

Since the modelled LUC shows spatially divergent trends the conversion from one land use to another also differs depending on the area concerned. In other words, the changes in SOC-stocks following a conversion of arable land to grassland may lead to different results, depending on where the changes are sited. Such distinctions can be evaluated based on the SOC density (t C ha^{-1}). A summary of the changes in SOC density by is presented in Table 15.

Table 15: Difference in Soil Organic Carbon Density (t C ha^{-1}) between Status Quo scenario and Integration policy option (Spain)

Density	**Status Quo**				
Integration	**Grassland**	**Cultivated**	**Native**	**Set-aside**	**Other**
	t C ha^{-1}	*t C ha^{-1}*	*t C ha^{-1}*	*t C ha^{-1}*	*t C ha^{-1}*
Grassland		4.4	-0.0	1.6	0.1
Cultivated	-8.0		-2.6	-0.2	-0.6
Native	-2.1	3.0		1.4	0.0
Set-aside	-6.2	0.9	-1.8		-0.4
Other	-1.4	2.5	0.0	1.0	

The table shows that the most effective change to conserve SOC in the Integration policy option as compared to the Status Quo scenario is the conversion of cultivated areas to grassland (4.4 t C ha^{-1}). This is followed by the conversion of cultivated areas to native land use (3.0 t C ha^{-1}). The inverse land use conversions do not result in the same values of changes in SOC density. Thus, the cultivated areas under the Integration policy option which are grassland in the Status Quo scenario are estimated to have a SOC density 8.0 t C ha^{-1} less than the grassland under the Status Quo scenario. Hence, the grassland areas in the Status Quo scenario lead to far stronger losses in SOC when cultivated under the Integration policy option than the grassland areas of the Integration policy option on cultivated areas of the Status Quo scenario.

SOC Summary

The estimated changes in SOC-stock have been found to be very responsive to evaluating the differences in land use change from the modelled scenarios. Overall, both the modelled land use changes from both scenarios result in a loss of SOC-stocks in EU27. However, the losses in SOC-stocks under the Status Quo scenario (-66.6 Mt C) were more than twice as high as those estimated from the land use changes model for the Integration policy option (29.5 Mt C). The evaluation found that the changes in SOC-stocks were not evenly spread across the area of the EU27 Member States and also that divergent trends in the changes in SOC-stock may develop between the regions of a country. The largest losses in SOC-stocks under the Status Quo scenario are estimated for France (-16.1 Mt C), Spain (-14.7 Mt C) and Romania (-13.8 Mt C). For the Integration policy option the largest losses are estimated for Spain (-15.0 Mt C), France (-6.5 Mt C) and Greece (-6.3 Mt C).

With respect to identifying spatial differences in the application of measures leading to changes in land use the aggregation at NUTS 2 was found to be useful. Aggregating changes in SOC-stocks at country level masks the at times markedly diverging developments within a country. At the level of NUTS 2 divergent trends in the changes in SOC-stocks were found for Spain, Greece and the United Kingdom. For Spain it would appear that the measures leading of areas with native vegetation in the Status Quo scenario to be occupied by cultivated land in the Integration policy option results in sizeable losses of SOC-stocks.

5 Assumptions, uncertainties and potential improvements

As is the case with all modelling activities, the simulation of future land use/cover is based on a series of expert-based assumptions about land use transitions; bio-geographical suitability characteristics for given land use types; intra-annual trends and neighbourhood effects. While these assumptions are made to the best of our knowledge and upon consultation with experts, a degree of uncertainty is associated with them. Under normal circumstances, this uncertainty is quantified and supplied with the reported results, however given the complexity of estimating uncertainties in spatial data and the constraints of the time-schedule for the assessment, we have not yet quantified the uncertainties in the model outputs. The following issues were identified as sources of uncertainties associated with the data and assumptions used in the assessment:

1. The Corine Land Cover (CLC) product for the year 2006 was not available for Greece and the UK at the time of simulation runs. The year 2000 CLC product was therefore used as a base year for these two countries.
2. The amount of land allocated to any given land use type depends on the land claims which are based on a statistical database associated with the land use model. Future land claims for urban land were derived from Eurostat data (EUROPOP2008); future land claims for industry were derived from the trends in Corine data from 1990-2006; and future land claims for arable land (cereals, maize, root crops and others) and pasture were derived from the CAPRI-FARM scenario run with the assumption of national-flat rates[22]. As it is confirmed repeatedly in the literature, there is no absolute agreement between the land use legends in CLC and CAPRI. Furthermore, for the best agreement combination we obtained, there is still a discrepancy between the amount of land available for arable, permanent crop and pasture classes, denoted by the CLC 2006 figures; and the number of hectares required to produce the analogous individual agricultural commodities according to CAPRI. In order to account for this, a mechanism has been implemented in the land claims module of the land use model to derive a temporally dynamic “compromise” set of land claims. The model uses the CAPRI information where possible and adjusts it, on a NUTS 2 level, for what is already classified in 2006 as being arable land, pasture

[22] Gocht, A., Britz, W., Adenauer, M., Farm Level Policy Scenario Analysis. Editors: Ciaian, P. and Gomez y Paloma, S, EUR 24787 EN 2011.

or permanent crop. The mechanism fails, however, when there is a very large difference between the two sources of information. It is know that this occurs in Portugal and Belgium, whereby CAPRI figures are far below the CLC figures and consequently the model is unable to compute a solution to satisfy both sources. What is yet unknown due to time constraints, is which other NUTS 2 succumb to this discrepancy and therefore artefacts could still be present in other areas.

3. The output from the FARM 2020 CAPRI simulation with national flat rates was used to estimate land claims in the land use model for arable, permanent crops and pasture lands. This data was delivered by JRC-IPTS on April 18, 2011. The baseline for this run is AGLINK 2009 whereas the CAPRI baseline runs for 2020 are under continuous updating, running with AGLNIK 2010 at the time of writing.
4. The simulated Integration policy option does not take into account specific local information on, for example, traditional farming practices and economic importance of current crops located in areas to be greened. This limitation had to be accepted since only EU-wide spatial layer, often at quite coarse resolution, could have been used in the exercise. This might result in an overestimation of areas available for greening.
5. Although embedded in the model is a breakdown of the arable class into allocation rules for cereals, maize and root crops, the degree of intensity in terms of fertilizer use, soil exhaustion and water requirements between these crop types is not taken into consideration in the configuration of the model.

A number of improvements are potentially applicable to this assessment and are being considered as next steps of work. Specific areas for further development identified are:

1. Improvement of forest cover class by: introducing tree species suitabilities and refined forest demand and succession rules. This step is being undertaken in parallel to the development of the European Forest Dynamic Model (EFDM) in the FOREST Action of JRC-IES.
2. Evaluation of the inclusion of the riparian zone map as generated by the new riparian zonation modelling for Europe by Clerici *et al*., 2011 not available for the current simulation.
3. Inclusion of dynamic drivers for economic sectors (industry, commerce, etc.) derived from the Regional Economic model RHOMOLO, under implementation at JRC-IPTS.

4. Refinement of the crop suitability maps to include climatic zones (only partially included in the current simulation) and accurate validation of resulting crop maps. The latter requires the use of regional data, not widely available at EU level.
5. Dynamic feed-back from the LISFLOOD hydrological model to include maps of water availability as input to agricultural suitability.
6. Refined calibration and definition of the confidence interval for land use allocation as indicator of accuracy (or uncertainty) of the model. This is only partially included in the current simulation.
7. In-depth analysis of indicators, including the development of new indicators, to focus on specific environmental and/or territorial issues (e.g. urban/rural developments, impact on key ecosystem services) or on defined geographical areas (e.g. a catchment, a region subject to a specific stress) in agreement with and following requirement from DG ENV and DG AGRI.

6 Conclusions

The aim of this study was to assess the environmental impact of two alternative policy settings for the new CAP, evaluated by using the features of the Land Use Modelling Platform (LUMP). The first scenario set the baseline conditions in form of the Status Quo; the second was a policy option, Integration. The scenarios set the framework for the economic drivers as analysed by CAPRI, which the LUMP integrates to produce detailed and geographically specific projections of changes in land use/cover between 2006 and 2020. The changes in land use/cover were then evaluated for their impact on various environmental sectors by comparing their effect on a set of relevant indicators of environmental conditions.

The modelling assessment presented here differs from the previous studies[23] and adds value for the following reasons:

- The spatial resolution is considerably improved, thus capturing fine changes and avoiding the problem of modelling only dominant land use classes which is the case when using 1km resolution as in the previous studies;
- The CAPRI input used for this exercise is from the FARM 2020 CAPRI model, using a flat rate scenario at Member State level;
- This series of model runs is unique in its interpretation and configuration of the latest greening measures proposed in the Integration policy option;
- A broad range of environmental indicators has been used, exploiting the higher spatial resolution data and capturing the subtle differences between the baseline Status Quo scenario and the Integration policy option.

This exercise was designed to show also differences in spatial allocation of land given a set of spatial restrictions. For this purpose, the same CAPRI scenario was used to drive both the Status Quo scenario and the Integration policy option. According to the report on the CAPRI-FARM scenario runs (Gocht *et al*., 2011), the MS flat rate scenario (used to drive the EUCS100 land use model for this exercise) has a considerable impact on the redistribution of payments between the Member States. The highest losses

[23] Other studies have been made using the land use modelling algorithm and CAPRI land claims model for the agricultural sector: SCENAR I and SCENAR II (European Commission, 2007); EURURALIS (Westhoek *et al.*, 2006; Verburg *et al.*, 2006) and LUM-I (Pérez-Soba *et al.*, 2010). The configurations and main outcomes of these studies are outlined in a report written by the IEEP in 2010 (Keenleyside *et al.*, 2010).

are seen for Sweden (-4.9%), Denmark (-3.6%), Greece (-3.6%) and Italy (-3.3%), but gains are seen for Germany (1.8%) and Ireland (1.1%).

A number of quantitative conclusions can be drawn in terms of land conversions:

1. There is an overall increase of arable land in the EU27 under both the Status Quo scenario and Integration policy option for 2020, although this trend is not consistent for all Member States: an overall decrease was modelled for the Czech Republic, Denmark, Poland, Portugal, Slovenia and Sweden;
2. The highest variation in the increase of arable land between the Status Quo and the Integration runs (dissimilarity higher than 2.5%) occurs in Belgium and Luxembourg, Greece, Ireland, Romania, Slovakia and Latvia;
3. There is a slight overall decrease in permanent crops in the EU27 under both the Status Quo scenario and Integration policy option for 2020, especially in Spain. This is a reflection of the CAPRI scenario chosen to drive the land use claims (Member State flat-rate), whereby permanent crops is a farm type which does not benefit from the re-allocation of premiums and thus shows an overall decrease;
4. Pastures are better preserved in 2020 under the Integration policy option, although the general trend for the EU 27 is of a slight overall decrease in this land use;
5. There is a decrease in semi-natural vegetation and an increase in forest for both model runs;
6. The shares of the three types of agricultural land uses (arable, permanent crops and pasture) is consistent in all countries between model runs for 2020, except the UK and Ireland, where the share of pasture land is significantly altered from the Status Quo scenario to the Integration policy option;
7. The expansion of agricultural land at the expense of semi-natural vegetation is, in general, higher under the Integration policy option than the Status Quo scenario, the difference is particularly relevant in Greece, Slovakia and Cyprus whereas Ireland, Sweden and Finland present a higher conversion under the Status Quo scenario than under the Integration policy option;
8. In the vicinity of Natura2000 sites, the loss of semi-natural vegetation to agricultural land in 2020 varies very much between Member States, with notable loss in Estonia, Greece and Spain for both runs, and Latvia for the Integration policy option;

9. In buffer zones along rivers the expansion of agricultural land over semi-natural vegetation is less intensive under the Integration policy option than under the Status Quo scenario for all countries with the exception of Austria, Germany, Poland, Slovakia and the United Kingdom;
10. The loss of forest due to the expansion of agriculture is particularly pronounced in Latvia, Estonia and Lithuania, especially under the Integration policy option and is also evident in the vicinity of Natura2000 sites, where also Bulgaria, Finland, Greece, Slovakia, Slovenia, Spain and UK show a loss of forest above the EU27 average;
11. The expansion of agricultural land at the expense of forest along watercourses is lower in the Integration policy option in all countries except Latvia;
12. Loss of agricultural areas due to urbanisation is evident mainly in Cyprus in the Status Quo scenario, but also in Ireland, the Netherlands and the United Kingdom for both model runs. Similar trends were found around Natura2000 sites;
13. Overall (EU27 total) the abandonment of agricultural areas is less than 1%. Nevertheless, it is slightly more pronounced in Slovenia (6% in Status Quo, 3% in Integration), Ireland (around 2% for both). The Integration policy option resulted in a high value of abandonment in riparian areas.

The environmental indicators used in this work to evaluate the environmental impact provided a detailed insight into the magnitude and spatial variability of the measures taken under the scenarios.

a) Green Infrastructure and landscape patterns

The net amount of Green Infrastructure increases under the Integration policy option with respect to the Status Quo scenario, however whereas there is a gain in the number of connecting elements within Green Infrastructure, there is a net loss of number of nodes contributing to Green Infrastructure. Important also is the decrease in fragments under the Integration policy option.

The landscape composition for the territory and of particular interest, within Green Infrastructure, shows a decrease in core natural areas in the Integration policy option. In the policy option, 2% of core natural areas are infringed upon by agriculture. This trend of loss of core natural areas is not applicable to the Natura 2000 sites. The majority of this network of protected areas (54%) sees an improvement of core natural areas and more Natura 2000 sites incur a decrease in homogeneous agricultural areas (22%) with respect to an increase (5%).

Furthermore, it was shown that some areas of Green Infrastructure within Europe are of a high importance in terms of connectivity, and that measures should be taken to preserve these local connectors. When a single important link is broken, as occurred in the Integration policy option, a major network can be fragmented.

b) Soil Organic Carbon stocks

The estimated changes in Soil Organic Carbon stock have been found to be very responsive to evaluating the differences in land use change from the two model configurations which both result in a loss of SOC-stocks for EU27. However, the losses in SOC-stocks under the Status Quo scenario were more than twice as high as those estimated from the land use changes model for the Integration policy option. The losses in SOC-stocks are not evenly spread across the area of the EU27 Member States and also divergent trends between the regions of a single country were modelled.

In conclusion, this series of simulations has shown that the greening options expressed under the Integration policy option produce an overall impact that can be measured with a set of land use/cover based indicators. In general terms, the greening options reduce the pressure on naturally vegetated areas and on environmentally sensitive sites.

The modelling approach based upon the combination of economic drivers derived from CAPRI and the land use/cover projections produced by LUMP has proven to be applicable for the evaluation of the new CAP scenario and the implementation of policy options. Because of the characteristics of the modelling setting, the set of computed indicators shows the differentiation of the impacts at national and regional levels. This allows evaluating the impacts of the new CAP in the proper geographical context – in the frame of the overall objectives of the reform.

The use of very detailed geographic data to compute the indicators allows the identification of distinct and regionally variable effects of the two scenarios from the base year to 2020, but also between the policy settings. This allows evaluating the impacts of the new CAP in the proper geographical context – in the frame of the overall objectives of the reform. The results modelled with LUMP give a strong indication for the effectiveness of the proposed green measures which are generally contributing to the improvement the environmental state of the European Territory. The method developed and the tools applied within this evaluation project have been proven to provide highly relevant results to evaluate the potential impact of measures affecting land use/cover change. The LUMP has been found highly adaptable to model even complex scenarios and an expert instrument to support further evaluation of European agricultural policies.

References

Angelstam, P., Mikusiński, G., Rönnbäck, B.-I., Östman, A., Lazdinis, M., Roberge, J.-M., Arnberg, W., Olsson, J. (2003). Two-dimensional Gap Analysis: A Tool for Efficient Conservation Planning and Biodiversity Policy Implementation. Ambio. Volume 32, Issue 8, December 2003, pp. 527-534.

Baruth, B., Genovese, G., Montanarella, L., (editors) (2006). New soil information for the MARS Crop Yield Forecasting System. JRC Report. ISBN 92-79-03376-X.

Batista e Silva, F., Lavalle, C., Koomen, E. A procedure to obtain a refined European land use/cover map (submitted to Journal of Land Use Science, June 2011).

Benini, L., Bandini, V., Marazza, D., Contin, A. (2010). Assessment of land use changes through an indicator-based approach: A case study from the Lamone river basin in Northern Italy. Ecological Indicators. 10, pp. 4-14.

Britz, W., Verburg, P. H., Leip, A. (2011). Modelling of land cover and agricultural change in Europe: Combining the CLUE and CAPRI-Spat approaches. Agriculture, Ecosystems and Environment. 142, pp. 40–50.

Clerici N., Weissteiner C.J., Paracchini M.L., Strobl, P. (2011). Riparian zones: where green and blue networks meet. JRC Scientific and Technical Report EUR 24774-2011. ISBN 978-92-79-19799-4.

ClimSoil (2008). Report on the existing information on the interrelationships between soil and climate change. Contract number 070307/2007/486157/SER/B1 tendered by Alterra, Wageningen UR, The Netherlands. 208p.

Cooper, T., Hart, K. and Baldock, D. (2009). The Provision of Public Goods Through Agriculture in the European Union. Report Prepared for DG Agriculture and Rural Development, Contract No 30-CE-0233091/00-28, Institute for European Environmental Policy: London.

EEA (2005). Agriculture and environment in EU-15 — the IRENA indicator report, EEA Report 6/2005, European Environment Agency, Copenhagen.

Elands, B.H.M., Praestholm, S. (2008). Landowners' perspectives on the rural future and the role of forests across Europe. Journal of Rural Studies. Volume 24, Issue 1, January 2008, pp. 72-85.

ENRD (2010). Public Goods and Public Intervention. Final Report for the Thematic Working Group 3 of the European Network for Rural Development, ENRD.

Estreguil, C., Mouton, C. (2009). Measuring and reporting on forest landscape pattern, fragmentation and connectivity in Europe: methods and indicators. Report 69pp. Joint Research Centre - European Commission publication reference EUR 23841 EN – 2009.

Estreguil, C., Caudullo, G. (2010). Harmonized measurements of spatial pattern and connectivity: application to forest habitats in the EBONE European Project. In proceedings of IUFRO Landscape ecology international conference, Sept. 21-27, 2010. Bragança, Portugal. pp. 730-736.

Estreguil, C., Caudullo, G., (2011). European-wide forest fragmentation (1990-2000-2006): pattern and connectivity. Official Publications of the European Communities, EUR report in preparation including map viewer to view pattern map and indicator layers at http://efdac.jrc.ec.europa.eu/pattern/map/.

European Commission (2007). Scenar 2020—Scenario study on agriculture and the rural world. European Commission, Directorate General Agriculture and Rural Development, Directorate G Economic Analysis and Evaluation, Directorate G4 Evaluation of Measures Applicable to Agriculture.

Gocht, A., Britz, W., Adenäuer, M., Editors: Ciaian, P. and Gomez y Paloma, (2011). Farm level policy scenario analysis. Joint Research Centre - European Commission publication reference. EUR 24787 EN – 2011.

Intergovernmental Panel on Climate Change (IPCC) (2006). 2006 Guidelines for National Greenhouse Gas Inventories Volume 4. Eggelstone, S., L. Buemdia, K. Miwa, T. Ngara and K. Tanabe (Eds.). IPCC/OECD/IEA/IGES, Hayama, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html.

Intergovernmental Panel on Climate Change (IPCC) (2003). Good Practice Guidance for Land Use, Land-Use Change and Forestry. Penman, J., M. Gytarsky, T. Hiraishi, T. Krug, D. Kruger, R. Pipatti, L. Buendia, K. Miwa, T. Ngara, K. Tanabe and F. Wagner (Eds.). IPCC/OECD/IEA/IGES, Hayama, Japan. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_contents.html.

Keenleyside, C and Tucker, G M (2010). Farmland Abandonment in the EU: an Assessment of Trends and Prospects. Report prepared for WWF. Institute for European Environmental Policy, London.

Lavalle, C., Baranzelli, C., Batista e Silva, F., Mubareka, S., Rocha Gomes, C., Koomen E., Hilferink, M. (2011). A high resolution land use/cover modelling framework for Europe. ICCSA 2011, Part I, LNCS 6782, pp. 60–75, 2011.

La Greca, P., La Rosa, D., Martinico, F. , Privitera, R. (2011). Agricultural and green infrastructures: The role of non-urbanized areas for eco-sustainable planning in a metropolitan region. Environmental Pollution. Volume 159, Issue 8-9, August 2011, pp. 2193-2202.

Lucas, W.C. (2010). Modeling impervious area disconnection with SWMM. Low Impact Development 2010: Redefining Water in the City - Proceedings of the 2010 International Low Impact Development Conference, pp. 897-909.

Paracchini, M.L., Petersen, J.E., Hoogeveen, Y., Bamps, C., Burfield, I., van Swaay, C. (2008). High Nature Value Farmland in Europe - An estimate of the distribution patterns on the basis of land cover and biodiversity data. Report 87pp. Joint Research Centre - European Commission publication reference EUR 23480 EN – 2008.

Pedro Silva, J., Toland, J., Jones, W., Eldridge, J., Hudson, T., O'Hara, E., Thevignot, C. eds. Salsi, A., Gross, S. (2010). LIFE Building up Europe's green infrastructure. ISBN 978-92-79-15719-6 Luxemburg Publications Office of the European Union, 2010.

Pérez-Soba, M., Verburg, P.H., Koomen, E., Hilferink, M., Benito, P., Lesschen, J.P., Banse, M., Woltjer, G., Eickhout, B., Prins, A.-G. and Staritsky, I. (2010). Land use modelling - implementation; Preserving and enhancing the environmental benefits of "land-use services". Final report to the European Commission, DG Environment. Alterra Wageningen UR/ Geodan Next/ Object Vision/ BIOS/ LEI and PBL, Wageningen.

Pontius, R., Shusas, E., McEachern, M., (2004). Detecting important categorical land changes while accounting for persistence. Agriculture, Ecosystems & Environment, volume: 101, Issue: 2-3, pp. 251-268.

Riitters, K., Vogt, P., Soille, P., Kozak, J., Estreguil, C. (2007). Neutral model analysis of landscape patterns from mathematical morphology. Landscape Ecology. Volume 22, pp. 1033-1043.

Riitters, K.H., Wickham, J.D., Wade, T.G. (2009). An indicator of forest dynamics using a shifting landscape mosaic. Ecological Indicators. 9, pp. 107-117.

Saura, S. and Rubio, L. (2010). A common currency for the different ways in which patches and links can contribute to habitat availability and connectivity in the landscape. Ecography 33: 523-537.

Saura, S., Vogt, P., Velazquez, J., Hernando, A., Jejera, R. (2011). Forest Ecology and Management – Key structural forest connectors can be identified by combining landscape spatial pattern and network analyses, doi: 10.1016/j.foreco.2011.03.017.

Saura, S., Estreguil, C., Mouton, C., Rodríguez-Freire, M. (2011). Ecological Indicators - Network analysis to assess landscape connectivity trends: Application to European forests (1990–2000) (11) 407–416. doi:10.1016/j.ecolind.2010.06.011

Verburg, P. H., Overmars, K. P. (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. Landscape Ecology. 24, pp. 1167-1181.

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

Vogt, P., Riiters, K., Iwanowski, M., Estreguil, C., Kozak, J., Soille, P. (2007). Mapping Landscape corridors. Ecological Indicators. 7, pp. 481-488.

Vogt, J., Soille, P., De Jager, A., Rimaviciute, E., Mehl, W., Foisneau, S., Bodis, K., Dusart, J., Paracchini, M., Haastrup, P., Bamps, C. (2007). A pan-European River and Catchment Database. Report 120pp. Joint Research Centre - European Commission publication reference EUR 22920 EN - 2007.

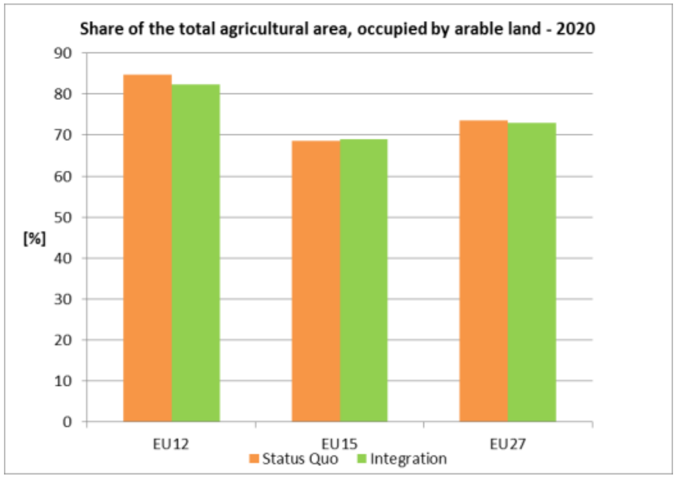
Weber, T.C., Blank, P.J. , Sloan, A. (2008). Field validation of a conservation network on the eastern shore of Maryland, USA, using breeding birds as bio-indicators. Environmental Management. Volume 41, Issue 4, April 2008, pp. 538-550.

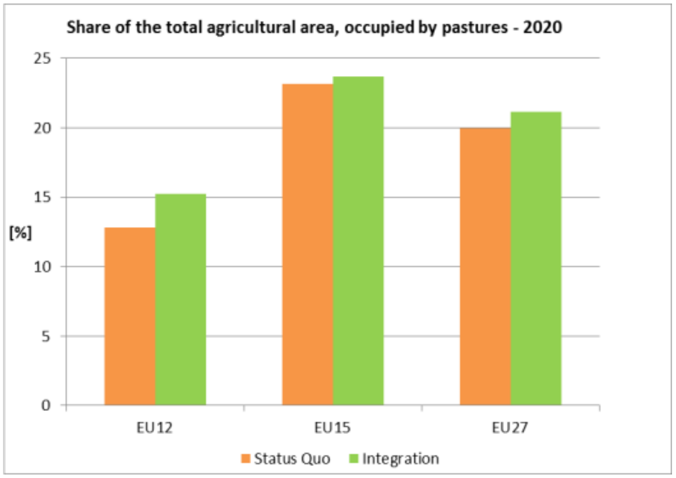
Westhoek, H.J., Van den Berg, M., Bakkes, J.A. (2006). Scenario development to explore the future of Europe's rural areas. Agriculture, Ecosystems & Environment. 114, pp. 7–20.

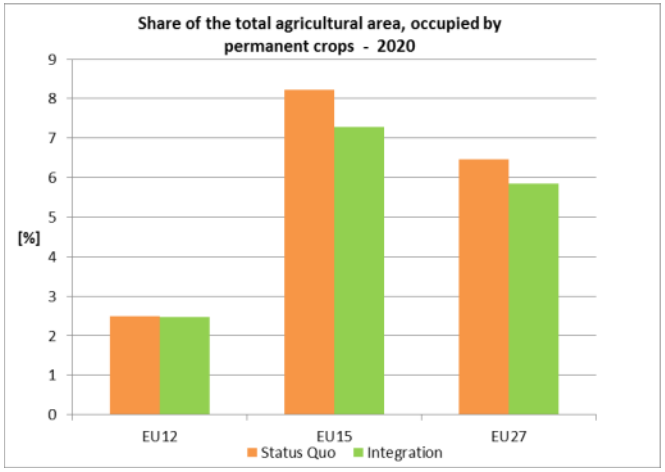
Wickham, J.D., Riiters, K.H., Wade, T.G., Vogt, P. (2010). A national assessment of green infrastructure and change for the conterminous United States using morphological image processing. Landscape and Urban Planning, volume 94, Issues 3-4, pp. 186-195.

Annex I

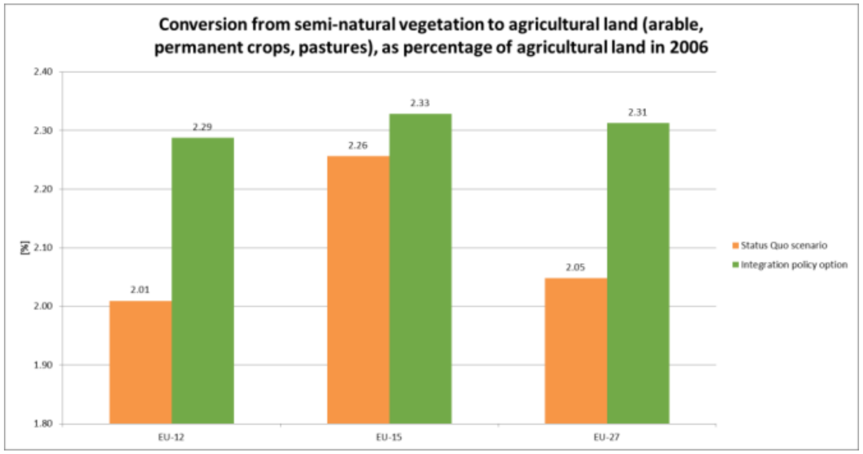
Share of agricultural land use

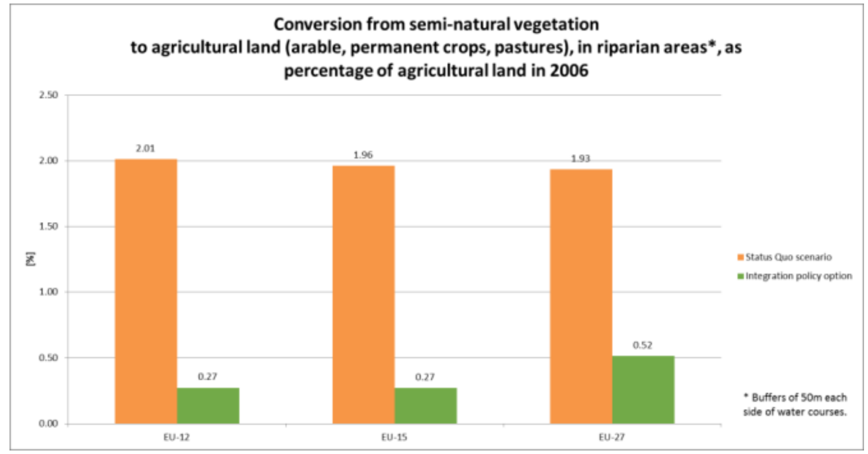


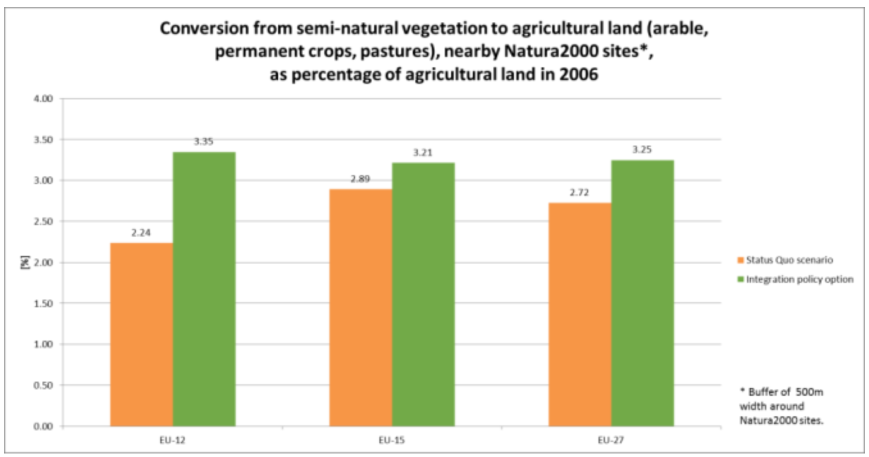


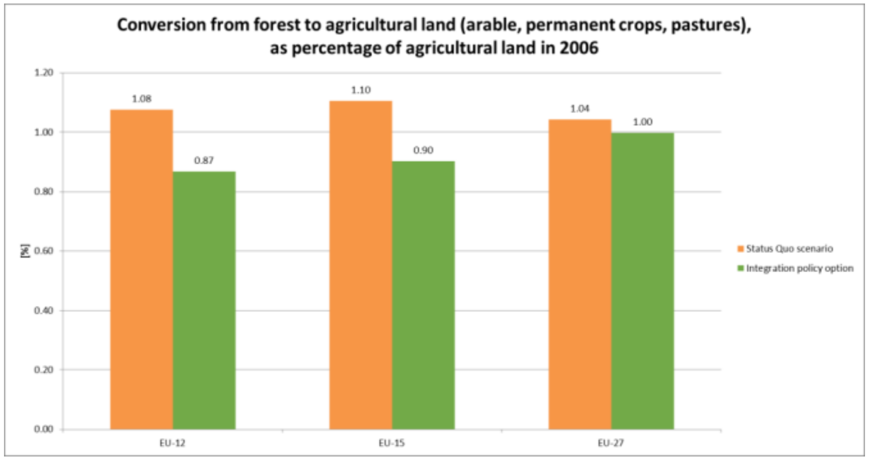


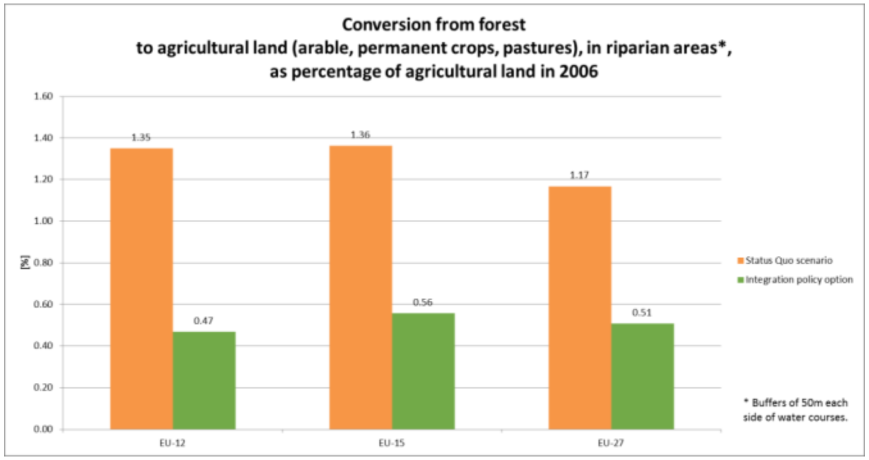
Agricultural expansion

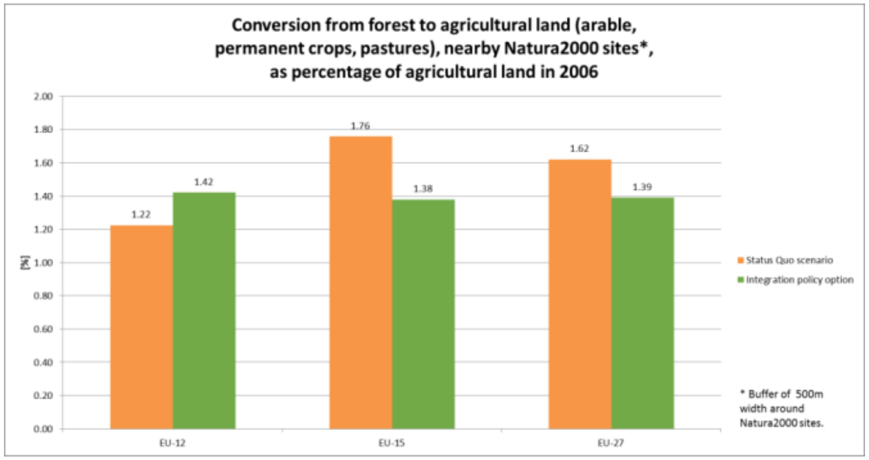




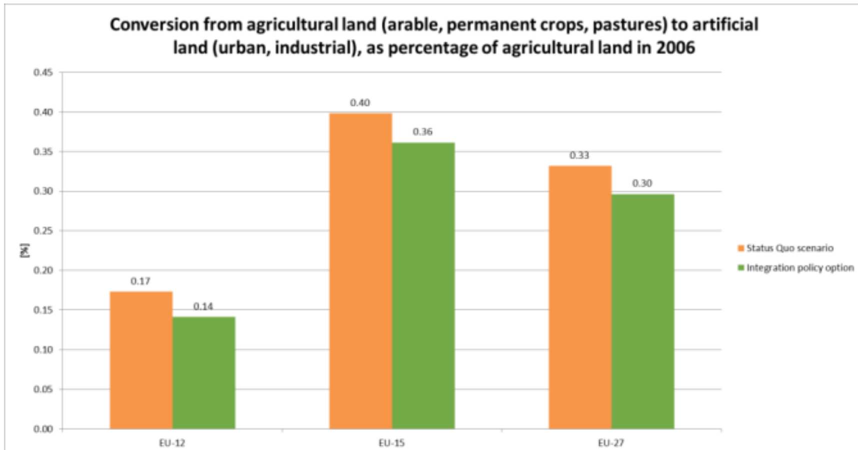


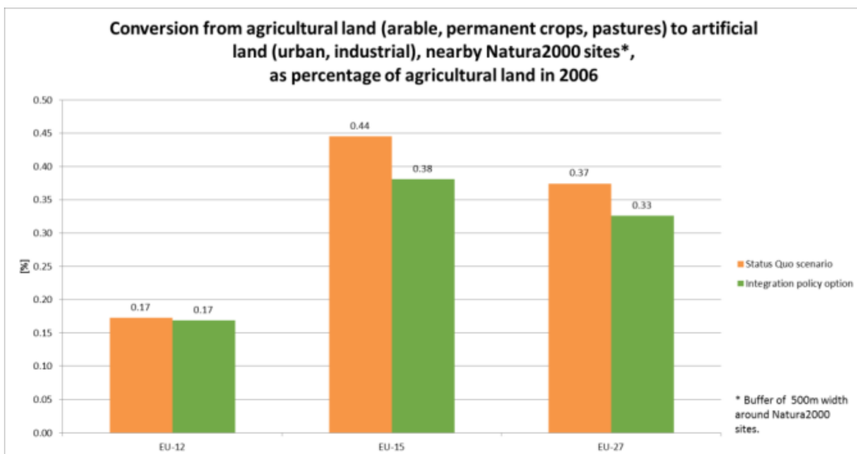

Conversion from forest to agricultural land (arable, permanent crops, pastures), as percentage of agricultural land in 2006
[%]
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.08
0.87
1.10
0.90
1.04
1.00
EU-12
EU-15
EU-27
Status Quo scenario
Integration policy option

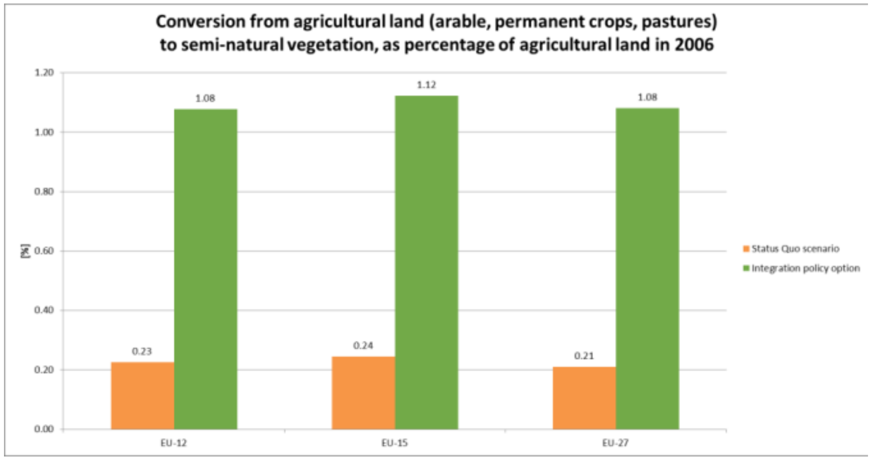

Conversion from forest to agricultural land (arable, permanent crops, pastures), in riparian areas*, as percentage of agricultural land in 2006
[%]
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.35
0.47
1.36
0.56
1.17
0.51
EU-12
EU-15
EU-27
Status Quo scenario
Integration policy option
* Buffers of 50m each side of water courses.


Conversion from forest to agricultural land (arable, permanent crops, pastures), nearby Natura2000 sites*, as percentage of agricultural land in 2006
[%]
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
1.22
1.42
1.76
1.38
1.62
1.39
EU-12
EU-15
EU-27
Status Quo scenario
Integration policy option
* Buffer of 500m width around Natura2000 sites.

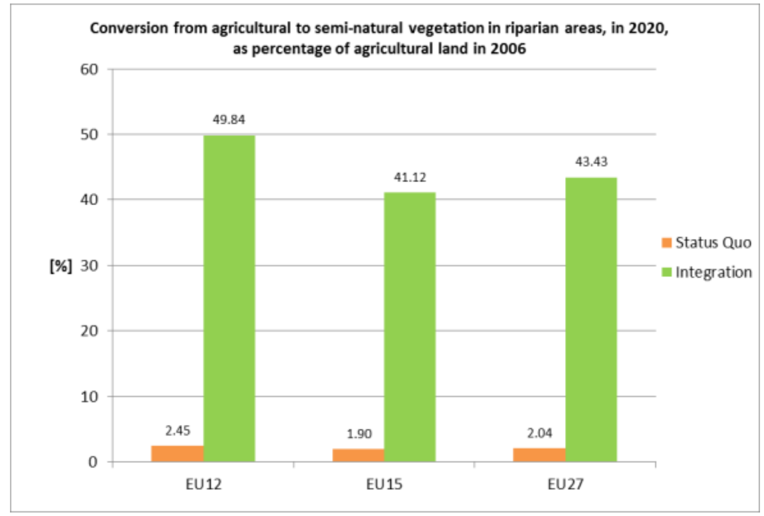
Agricultural loss



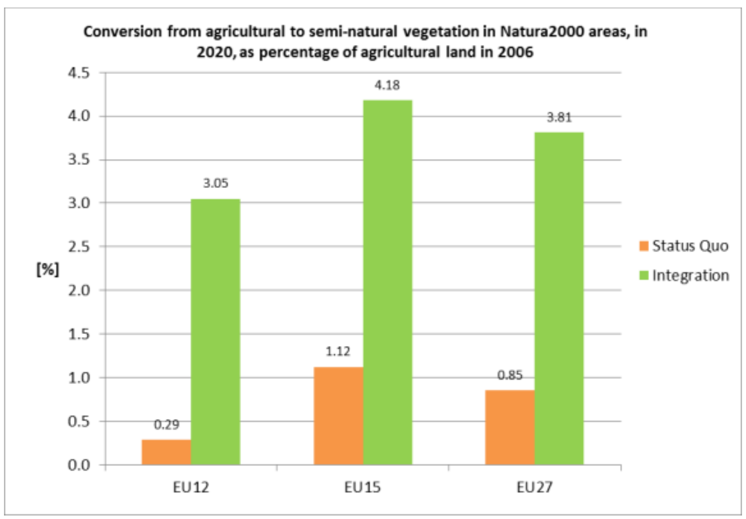




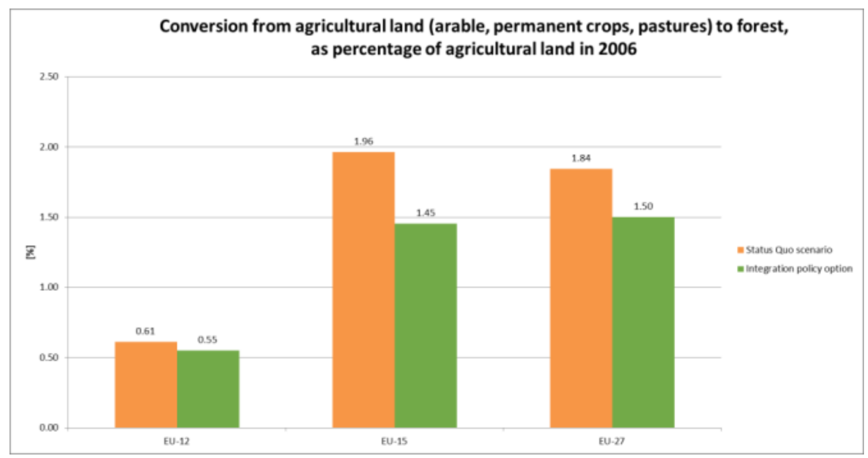
Conversion from agricultural land (arable, permanent crops, pastures) to semi-natural vegetation, as percentage of agricultural land in 2006
[%]
Status Quo scenario
Integration policy option
EU-12
EU-15
EU-27



Conversion from agricultural to semi-natural vegetation in riparian areas, in 2020, as percentage of agricultural land in 2006
[%]
Status Quo
Integration
EU12
EU15
EU27

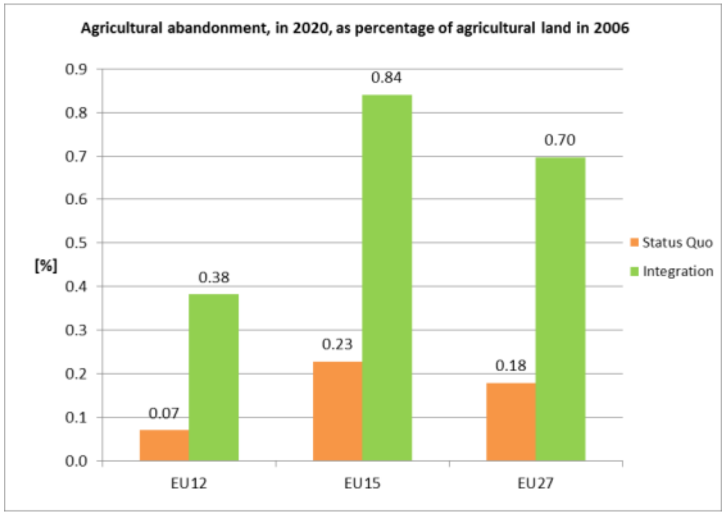


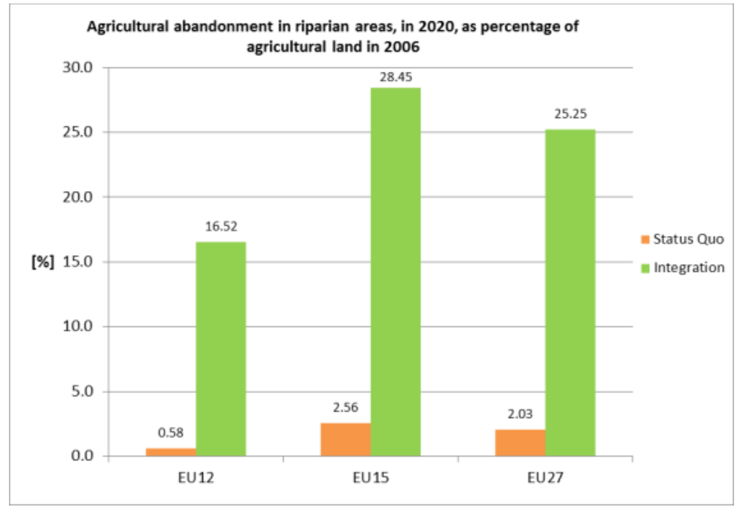
Conversion from agricultural to semi-natural vegetation in Natura2000 areas, in 2020, as percentage of agricultural land in 2006
[%]
Status Quo
Integration
EU12
EU15
EU27

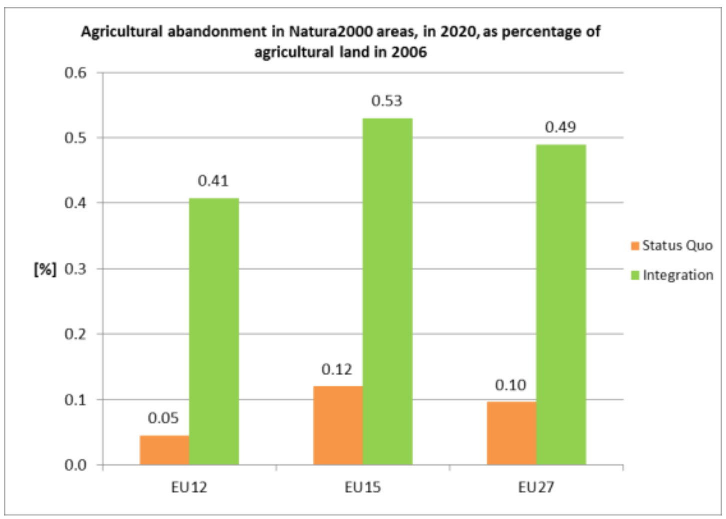


Conversion from agricultural land (arable, permanent crops, pastures) to forest, as percentage of agricultural land in 2006
[%]
Status Quo scenario
Integration policy option
EU-12
EU-15
EU-27

Agricultural abandonment







Annex II

Austria

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.10	0.00	0.10	**0.00**	**0.10**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.01	0.21	0.22	**0.02**	**0.20**
Arable	3.20	2.86	6.06	**5.72**	**0.34**
Pastures	1.76	2.53	4.29	**3.51**	**0.77**
Forests	2.04	1.20	3.24	**2.39**	**0.85**
Semi-natural	0.00	0.31	0.31	**0.00**	**0.31**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.10	0.00	0.10	**0.00**	**0.10**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.01	0.21	0.22	**0.02**	**0.20**
Arable	1.28	2.22	3.50	**2.56**	**0.93**
Pastures	1.20	0.50	1.70	**1.00**	**0.70**
Forests	1.78	1.14	2.93	**2.28**	**0.64**
Semi-natural	0.02	0.33	0.35	**0.04**	**0.31**

Belgium and Luxembourg

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.39	0.00	0.39	**0.00**	**0.39**
Industry	0.00	0.01	0.01	**0.00**	**0.01**
Permanent crops	0.00	0.05	0.05	**0.00**	**0.05**
Arable	4.42	0.02	4.45	**0.05**	**4.40**
Pastures	0.00	4.00	4.00	**0.00**	**4.00**
Forests	0.26	0.53	0.79	**0.51**	**0.27**
Semi-natural	0.00	0.45	0.45	**0.00**	**0.45**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.39	0.00	0.39	**0.00**	**0.39**
Industry	0.00	0.02	0.02	**0.00**	**0.02**
Permanent crops	0.00	0.05	0.05	**0.00**	**0.05**
Arable	0.87	0.22	1.09	**0.44**	**0.66**
Pastures	0.00	0.28	0.28	**0.00**	**0.28**
Forests	0.26	0.61	0.86	**0.51**	**0.35**
Semi-natural	0.10	0.44	0.55	**0.21**	**0.34**

Bulgaria

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.03	0.00	0.03	**0.00**	**0.03**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.03	0.03	**0.00**	**0.03**
Arable	5.32	0.04	5.36	**0.07**	**5.29**
Pastures	0.00	2.55	2.55	**0.00**	**2.55**
Forests	1.75	1.34	3.09	**2.68**	**0.41**
Semi-natural	0.57	3.73	4.30	**1.15**	**3.16**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.03	0.00	0.03	**0.00**	**0.03**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.05	0.05	**0.00**	**0.05**
Arable	3.97	1.07	5.05	**2.15**	**2.90**
Pastures	0.00	0.16	0.16	**0.00**	**0.16**
Forests	1.38	0.73	2.11	**1.46**	**0.65**
Semi-natural	1.07	4.46	5.53	**2.15**	**3.39**

Cyprus

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	1.41	0.00	1.41	**0.00**	**1.41**
Industry	0.01	0.00	0.01	**0.00**	**0.01**
Permanent crops	0.01	0.00	0.01	**0.00**	**0.01**
Arable	1.83	1.33	3.16	**2.66**	**0.50**
Pastures	0.00	0.61	0.61	**0.00**	**0.61**
Forests	0.04	1.64	1.68	**0.09**	**1.59**
Semi-natural	1.66	1.38	3.04	**2.76**	**0.28**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	1.41	0.00	1.41	**0.00**	**1.41**
Industry	0.01	0.00	0.01	**0.00**	**0.01**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	3.72	0.95	4.67	**1.90**	**2.77**
Pastures	0.00	0.55	0.55	**0.00**	**0.55**
Forests	0.03	0.00	0.03	**0.00**	**0.03**
Semi-natural	0.35	4.01	4.35	**0.70**	**3.66**

Czech Republic

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.27	0.00	0.27	**0.00**	**0.27**
Industry	0.01	0.00	0.01	**0.01**	**0.01**
Permanent crops	0.00	0.19	0.19	**0.00**	**0.19**
Arable	1.98	6.08	8.06	**3.96**	**4.10**
Pastures	2.36	1.12	3.48	**2.24**	**1.24**
Forests	4.13	0.47	4.60	**0.94**	**3.66**
Semi-natural	0.01	0.89	0.89	**0.02**	**0.88**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.27	0.00	0.27	**0.00**	**0.27**
Industry	0.01	0.00	0.01	**0.00**	**0.01**
Permanent crops	0.00	0.19	0.19	**0.00**	**0.19**
Arable	1.66	6.11	7.76	**3.31**	**4.45**
Pastures	2.07	0.59	2.66	**1.18**	**1.48**
Forests	4.11	0.46	4.56	**0.91**	**3.65**
Semi-natural	0.32	1.08	1.40	**0.63**	**0.77**

Denmark

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.13	0.00	0.13	**0.00**	**0.13**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.21	0.00	0.21	**0.00**	**0.21**
Arable	1.25	1.74	2.99	**2.49**	**0.49**
Pastures	0.00	0.10	0.10	**0.00**	**0.10**
Forests	1.46	0.10	1.56	**0.20**	**1.37**
Semi-natural	0.07	1.19	1.26	**0.15**	**1.11**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.13	0.00	0.13	**0.00**	**0.13**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.21	0.00	0.21	**0.01**	**0.21**
Arable	1.57	2.08	3.65	**3.14**	**0.51**
Pastures	0.00	0.00	0.00	**0.00**	**0.00**
Forests	1.39	0.03	1.42	**0.06**	**1.36**
Semi-natural	0.37	1.56	1.93	**0.74**	**1.19**

Estonia

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.00	0.00	0.00	**0.00**	**0.00**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	5.07	0.39	5.46	**0.79**	**4.67**
Pastures	0.00	1.44	1.44	**0.00**	**1.44**
Forests	4.20	3.28	7.47	**6.55**	**0.92**
Semi-natural	0.51	4.66	5.17	**1.02**	**4.16**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.00	0.00	0.00	**0.00**	**0.00**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	4.79	0.90	5.69	**1.80**	**3.88**
Pastures	0.00	0.66	0.66	**0.00**	**0.66**
Forests	4.37	3.48	7.85	**6.96**	**0.89**
Semi-natural	0.56	4.68	5.23	**1.11**	**4.12**

Finland

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.05	0.00	0.05	**0.00**	**0.05**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	0.68	0.54	1.22	**1.08**	**0.14**
Pastures	0.01	0.01	0.02	**0.02**	**0.00**
Forests	6.06	0.16	6.22	**0.32**	**5.90**
Semi-natural	0.15	6.24	6.39	**0.30**	**6.09**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.05	0.00	0.05	**0.00**	**0.05**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	0.22	0.42	0.64	**0.44**	**0.20**
Pastures	0.00	0.00	0.00	**0.00**	**0.00**
Forests	6.07	0.15	6.21	**0.29**	**5.92**
Semi-natural	0.24	6.01	6.25	**0.48**	**5.77**

France

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.14	0.00	0.14	**0.00**	**0.14**
Industry	0.00	0.00	0.01	**0.00**	**0.00**
Permanent crops	0.01	0.24	0.24	**0.02**	**0.23**
Arable	3.64	0.67	4.31	**1.34**	**2.97**
Pastures	0.43	2.24	2.68	**0.86**	**1.81**
Forests	1.19	0.57	1.76	**1.14**	**0.62**
Semi-natural	0.06	1.75	1.81	**0.12**	**1.69**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.14	0.00	0.14	**0.00**	**0.14**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.02	0.32	0.33	**0.04**	**0.30**
Arable	2.01	0.80	2.81	**1.61**	**1.21**
Pastures	0.15	1.12	1.27	**0.30**	**0.97**
Forests	1.23	0.29	1.52	**0.57**	**0.95**
Semi-natural	0.47	1.50	1.97	**0.94**	**1.03**

Germany

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.23	0.00	0.23	**0.00**	**0.23**
Industry	0.01	0.18	0.18	**0.01**	**0.17**
Permanent crops	0.01	0.09	0.09	**0.01**	**0.08**
Arable	3.15	1.03	4.18	**2.07**	**2.12**
Pastures	0.15	2.66	2.81	**0.29**	**2.51**
Forests	1.07	0.39	1.46	**0.78**	**0.69**
Semi-natural	0.04	0.31	0.36	**0.09**	**0.27**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.23	0.00	0.23	**0.00**	**0.23**
Industry	0.00	0.18	0.18	**0.01**	**0.17**
Permanent crops	0.01	0.09	0.10	**0.01**	**0.09**
Arable	1.72	1.28	3.00	**2.55**	**0.45**
Pastures	0.04	1.14	1.19	**0.09**	**1.10**
Forests	1.00	0.30	1.30	**0.61**	**0.69**
Semi-natural	0.39	0.41	0.80	**0.78**	**0.02**

Greece

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.02	0.00	0.02	**0.00**	**0.02**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.68	0.68	**0.00**	**0.68**
Arable	9.76	0.03	9.79	**0.06**	**9.73**
Pastures	0.00	4.40	4.40	**0.01**	**4.39**
Forests	0.89	3.33	4.22	**1.78**	**2.44**
Semi-natural	1.43	3.67	5.10	**2.86**	**2.24**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.03	0.00	0.03	**0.00**	**0.03**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.25	0.25	**0.00**	**0.25**
Arable	6.90	0.79	7.68	**1.58**	**6.11**
Pastures	0.00	0.04	0.04	**0.00**	**0.04**
Forests	0.68	1.92	2.60	**1.36**	**1.24**
Semi-natural	0.90	5.50	6.40	**1.79**	**4.61**

Hungary

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.12	0.00	0.12	**0.00**	**0.12**
Industry	0.01	0.00	0.01	**0.00**	**0.01**
Permanent crops	0.62	0.07	0.69	**0.15**	**0.54**
Arable	2.32	1.19	3.51	**2.39**	**1.13**
Pastures	0.08	0.82	0.90	**0.16**	**0.74**
Forests	1.56	0.35	1.91	**0.70**	**1.21**
Semi-natural	0.11	2.36	2.47	**0.21**	**2.26**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.12	0.00	0.12	**0.00**	**0.12**
Industry	0.01	0.00	0.01	**0.00**	**0.01**
Permanent crops	0.62	0.07	0.69	**0.15**	**0.54**
Arable	2.61	1.71	4.32	**3.41**	**0.90**
Pastures	0.08	0.47	0.55	**0.17**	**0.38**
Forests	1.34	0.31	1.65	**0.62**	**1.03**
Semi-natural	0.50	2.71	3.21	**0.99**	**2.22**

Ireland

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.63	0.00	0.64	**0.01**	**0.63**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	2.05	0.00	2.05	**0.00**	**2.05**
Arable	11.89	1.87	13.76	**3.74**	**10.02**
Pastures	0.01	9.03	9.04	**0.03**	**9.02**
Forests	0.02	2.06	2.08	**0.04**	**2.04**
Semi-natural	1.60	3.24	4.84	**3.20**	**1.64**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.63	0.00	0.63	**0.00**	**0.63**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.99	0.00	0.99	**0.00**	**0.99**
Arable	1.41	1.59	3.00	**2.83**	**0.17**
Pastures	0.00	0.24	0.24	**0.00**	**0.24**
Forests	0.00	0.06	0.07	**0.01**	**0.06**
Semi-natural	0.03	1.19	1.23	**0.07**	**1.16**

Italy

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.23	0.00	0.23	**0.00**	**0.23**
Industry	0.00	0.01	0.01	**0.00**	**0.01**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	0.63	0.39	1.02	**0.78**	**0.24**
Pastures	0.00	0.13	0.14	**0.00**	**0.13**
Forests	1.00	0.05	1.05	**0.11**	**0.95**
Semi-natural	0.12	1.39	1.51	**0.25**	**1.26**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.23	0.00	0.23	**0.00**	**0.23**
Industry	0.00	0.01	0.01	**0.00**	**0.01**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	0.02	0.53	0.55	**0.04**	**0.51**
Pastures	0.00	0.00	0.00	**0.00**	**0.00**
Forests	0.99	0.00	0.99	**0.00**	**0.99**
Semi-natural	0.37	1.07	1.44	**0.75**	**0.70**

Latvia

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.06	0.00	0.06	**0.00**	**0.06**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.05	0.05	**0.00**	**0.05**
Arable	1.61	0.73	2.35	**1.47**	**0.88**
Pastures	0.00	0.32	0.32	**0.01**	**0.32**
Forests	1.45	0.46	1.91	**0.92**	**0.99**
Semi-natural	0.29	1.84	2.13	**0.57**	**1.56**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.09	0.00	0.09	**0.00**	**0.09**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.01	0.01	**0.00**	**0.01**
Arable	6.93	0.63	7.55	**1.25**	**6.30**
Pastures	0.00	2.97	2.97	**0.00**	**2.97**
Forests	4.30	3.26	7.55	**6.51**	**1.04**
Semi-natural	0.66	5.12	5.79	**1.33**	**4.46**

Lithuania

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.06	0.00	0.06	**0.00**	**0.06**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.05	0.05	**0.00**	**0.05**
Arable	1.61	0.73	2.34	**1.46**	**0.88**
Pastures	0.00	0.32	0.32	**0.01**	**0.32**
Forests	1.44	0.46	1.90	**0.92**	**0.99**
Semi-natural	0.29	1.84	2.12	**0.57**	**1.55**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.06	0.00	0.06	**0.00**	**0.06**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.05	0.05	**0.00**	**0.05**
Arable	2.04	1.88	3.92	**3.76**	**0.16**
Pastures	0.00	0.14	0.14	**0.00**	**0.14**
Forests	2.02	1.09	3.11	**2.19**	**0.92**
Semi-natural	0.91	1.86	2.77	**1.81**	**0.95**

Malta

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.17	0.00	0.17	0.00	0.17
Industry	0.00	0.00	0.00	0.00	0.00
Permanent crops	0.00	0.00	0.00	0.00	0.00
Arable	0.00	0.17	0.17	0.01	0.16
Pastures	0.00	0.00	0.00	0.00	0.00
Forests	0.00	0.00	0.00	0.00	0.00
Semi-natural	0.00	0.00	0.00	0.00	0.00

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.17	0.00	0.17	0.00	0.17
Industry	0.00	0.00	0.00	0.00	0.00
Permanent crops	0.00	0.00	0.00	0.00	0.00
Arable	0.00	0.17	0.17	0.01	0.16
Pastures	0.00	0.00	0.00	0.00	0.00
Forests	0.00	0.00	0.00	0.00	0.00
Semi-natural	0.00	0.00	0.00	0.00	0.00

Netherlands

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.70	0.00	0.70	**0.00**	**0.70**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.00	0.01	**0.00**	**0.00**
Arable	3.56	1.02	4.59	**2.05**	**2.54**
Pastures	0.10	3.79	3.89	**0.20**	**3.69**
Forests	0.53	0.11	0.64	**0.22**	**0.42**
Semi-natural	0.07	0.03	0.10	**0.07**	**0.04**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.70	0.00	0.70	**0.00**	**0.70**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.00	0.01	**0.00**	**0.00**
Arable	3.44	1.05	4.49	**2.10**	**2.39**
Pastures	0.03	3.54	3.57	**0.05**	**3.52**
Forests	0.51	0.09	0.60	**0.17**	**0.43**
Semi-natural	0.04	0.04	0.07	**0.07**	**0.00**

Poland

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.06	0.00	0.06	**0.00**	**0.06**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.33	0.01	0.34	**0.02**	**0.31**
Arable	1.14	1.80	2.94	**2.28**	**0.67**
Pastures	0.04	1.08	1.12	**0.07**	**1.05**
Forests	2.09	0.13	2.21	**0.25**	**1.96**
Semi-natural	0.01	0.63	0.64	**0.02**	**0.62**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.06	0.00	0.06	**0.00**	**0.06**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.33	0.01	0.34	**0.02**	**0.32**
Arable	0.89	2.07	2.95	**1.77**	**1.18**
Pastures	0.02	0.57	0.60	**0.05**	**0.55**
Forests	2.06	0.11	2.17	**0.21**	**1.96**
Semi-natural	0.21	0.82	1.03	**0.43**	**0.60**

Portugal

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.02	0.00	0.02	**0.00**	**0.02**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.01	0.01	**0.00**	**0.01**
Arable	0.06	2.84	2.90	**0.11**	**2.79**
Pastures	0.08	0.01	0.08	**0.01**	**0.07**
Forests	4.06	0.01	4.07	**0.01**	**4.06**
Semi-natural	2.74	4.10	6.85	**5.49**	**1.36**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.02	0.00	0.02	**0.00**	**0.02**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.11	0.11	**0.00**	**0.11**
Arable	0.00	3.95	3.96	**0.00**	**3.95**
Pastures	0.08	0.02	0.09	**0.03**	**0.06**
Forests	3.91	0.96	4.86	**1.91**	**2.95**
Semi-natural	4.91	3.89	8.80	**7.78**	**1.02**

Romania

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.12	0.00	0.12	**0.00**	**0.12**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.27	0.27	**0.00**	**0.27**
Arable	6.14	0.13	6.27	**0.26**	**6.01**
Pastures	0.00	4.13	4.13	**0.00**	**4.13**
Forests	0.59	0.76	1.35	**1.18**	**0.16**
Semi-natural	0.15	1.72	1.87	**0.30**	**1.58**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.13	0.00	0.13	**0.00**	**0.13**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.30	0.30	**0.00**	**0.30**
Arable	3.32	0.63	3.95	**1.26**	**2.69**
Pastures	0.00	0.85	0.85	**0.00**	**0.85**
Forests	0.36	0.51	0.87	**0.71**	**0.15**
Semi-natural	0.56	2.06	2.62	**1.11**	**1.51**

Slovakia

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.03	0.00	0.03	**0.00**	**0.03**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.06	0.06	**0.00**	**0.06**
Arable	4.54	0.05	4.59	**0.10**	**4.49**
Pastures	0.00	2.83	2.83	**0.00**	**2.83**
Forests	1.74	0.66	2.40	**1.33**	**1.07**
Semi-natural	0.02	2.72	2.73	**0.03**	**2.70**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.03	0.00	0.03	**0.00**	**0.03**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.05	0.05	**0.00**	**0.05**
Arable	3.18	1.20	4.39	**2.41**	**1.98**
Pastures	0.00	0.36	0.36	**0.00**	**0.36**
Forests	1.21	0.59	1.79	**1.17**	**0.62**
Semi-natural	1.17	3.39	4.57	**2.35**	**2.22**

Slovenia

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.06	0.00	0.06	**0.00**	**0.06**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.01	0.01	**0.00**	**0.01**
Arable	2.05	4.53	6.58	**4.11**	**2.47**
Pastures	0.63	0.99	1.62	**1.27**	**0.36**
Forests	2.09	0.77	2.85	**1.53**	**1.32**
Semi-natural	2.79	1.33	4.11	**2.65**	**1.46**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.06	0.00	0.06	**0.00**	**0.06**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.02	0.03	0.05	**0.03**	**0.01**
Arable	1.18	3.46	4.64	**2.36**	**2.28**
Pastures	0.00	0.14	0.14	**0.00**	**0.14**
Forests	2.10	0.78	2.88	**1.57**	**1.31**
Semi-natural	2.39	1.32	3.71	**2.65**	**1.06**

Spain

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.21	0.00	0.21	**0.00**	**0.21**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.52	1.07	1.59	**1.04**	**0.55**
Arable	5.39	1.02	6.40	**2.03**	**4.37**
Pastures	0.44	0.65	1.09	**0.87**	**0.21**
Forests	0.97	1.74	2.71	**1.94**	**0.77**
Semi-natural	0.68	3.73	4.41	**1.35**	**3.06**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.21	0.00	0.21	**0.00**	**0.21**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.51	2.56	3.08	**1.03**	**2.05**
Arable	7.06	1.47	8.53	**2.94**	**5.59**
Pastures	0.09	0.16	0.25	**0.18**	**0.07**
Forests	0.85	0.88	1.73	**1.70**	**0.03**
Semi-natural	0.88	4.53	5.41	**1.76**	**3.65**

Sweden

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.20	0.00	0.20	**0.00**	**0.20**
Industry	0.00	0.20	0.20	**0.00**	**0.20**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	0.91	3.60	4.51	**1.81**	**2.69**
Pastures	0.00	0.45	0.45	**0.00**	**0.45**
Forests	10.21	0.00	10.21	**0.00**	**10.21**
Semi-natural	0.00	7.07	7.07	**0.00**	**7.07**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.20	0.00	0.20	**0.00**	**0.20**
Industry	0.00	0.20	0.20	**0.00**	**0.20**
Permanent crops	0.03	0.00	0.03	**0.00**	**0.03**
Arable	0.60	2.59	3.20	**1.20**	**1.99**
Pastures	0.01	0.40	0.41	**0.02**	**0.39**
Forests	9.15	0.00	9.15	**0.00**	**9.15**
Semi-natural	0.21	7.01	7.23	**0.43**	**6.80**

United Kingdom

Land use/cover changes (%) from 2006 to 2020 in Status Quo

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.37	0.00	0.37	**0.00**	**0.37**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	1.04	0.47	1.51	**0.94**	**0.57**
Pastures	0.21	0.78	0.99	**0.41**	**0.57**
Forests	0.15	0.15	0.30	**0.30**	**0.01**
Semi-natural	0.06	0.43	0.48	**0.11**	**0.37**

Land use/cover changes (%) from 2006 to 2020 in Integration

	Gain	Loss	Total change	SWAP	Abs value 'net change'
Urban	0.37	0.00	0.37	**0.00**	**0.37**
Industry	0.00	0.00	0.00	**0.00**	**0.00**
Permanent crops	0.00	0.00	0.00	**0.00**	**0.00**
Arable	1.52	0.54	2.05	**1.08**	**0.98**
Pastures	0.46	1.13	1.59	**0.92**	**0.68**
Forests	0.06	0.06	0.11	**0.11**	**0.00**
Semi-natural	0.06	0.73	0.80	**0.13**	**0.67**

European Commission

EUR 24909 – Joint Research Centre – Institute for Environment and Sustainability

Title: Implementation of the CAP Policy Options with the Land Use Modelling Platform – a first indicator-based analysis

Author(s): Carlo Lavalle, Claudia Baranzelli, Sarah Mubareka, Carla Rocha Gomes, Roland Hiederer, Filipe Batista e Silva, Christine Estreguil

Luxembourg: Publications Office of the European Union

2011 – XXI, 130 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1018-5593 (print), 1831-9424 (online)
ISBN 978-92-79-20917-8 (print) / 978-92-79-20918-5 (pdf)
doi: 10.2788/45131

Abstract

This report presents the results of a study aiming to assess the environmental impact of two alternative scenarios for the new Common Agricultural Policy, evaluated by using the features of the Land Use Modelling Platform (LUMP). The first scenario set the baseline conditions in form of the Status Quo; the second was a policy alternative, Integration. The scenarios set the framework for the economic drivers as analysed by CAPRI, which the LUMP integrates to produce detailed and geographically specific projections of changes in land use/cover between 2006 and 2020. The changes in land use/cover were then evaluated for their impact on various environmental sectors by comparing their effect on a set of relevant indicators of environmental conditions.

The simulations have shown that the greening options expressed under the Integration policy option produce an overall impact that can be measured with a set of land use/cover based indicators. In general terms, the greening options reduce the pressure on naturally vegetated areas and on environmentally sensitive sites.

This modelling approach has proven to be applicable for the evaluation of the new CAP scenario and the implementation of policy options, in the frame of the overall objectives of the reform. Due to the characteristics of the modelling framework, the set of computed indicators shows the differentiation of the impacts at national and regional levels, allowing the assessment of the impacts of the new CAP in the proper geographical context.

How to obtain EU publications

Our priced publications are available from EU Bookshop (http://bookshop.europa.eu), where you can place an order with the sales agent of your choice.

The Publications Office has a worldwide network of sales agents. You can obtain their contact details by sending a fax to (352) 29 29-42758.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

LB-NA-24909-EN-N

EUROPEAN COMMISSION

Publications Office

ISBN 978-92-79-20918-5