European Commission

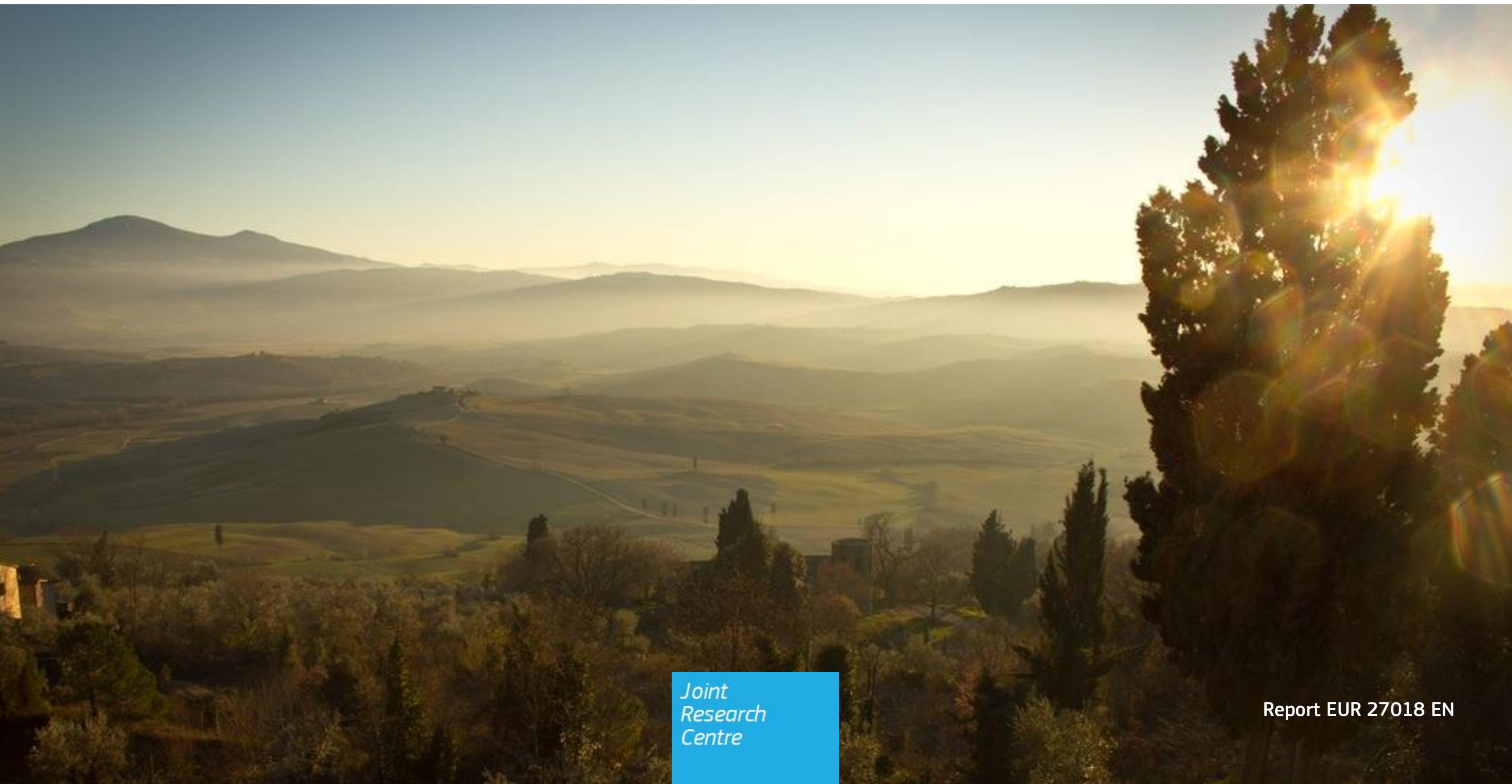
JRC TECHNICAL REPORTS

Evaluation of the land demands for the production of food, feed and energy in the updated Reference Configuration 2014 of the LUISA modelling platform

Methodological framework and preliminary considerations

Claudia Baranzelli, Carolina Perpiña Castillo,
Carlo Lavalle, Roberto Pilli, Giulia Fiorese

2014



Joint Research Centre

Report EUR 27018 EN

European Commission
Joint Research Centre
Institute for Environment and Sustainability

Contact information
Carlo Lavalle
Address: Joint Research Centre, Institute for Environment and Sustainability
Sustainability Assessment Unit (H08), Via E. Fermi 1 21027 Ispra (VA) - TP290
E-mail: carlo.lavalle@jrc.ec.europa.eu

JRC Science Hub
https://ec.europa.eu/jrc

JRC94076

EUR 27018 EN

ISBN 978-92-79-44701-3 (PDF)

ISSN 1831-9424 (online)

doi:10.2788/99908

Luxembourg: Publications Office of the European Union, 2015

Abstract

The main purpose of this document is twofold. On the one hand, the land demands, methods and preliminary findings, especially in terms of forest and agricultural land, for the production of food, feed and energy are fully described. The modelling exercise is developed for the Updated Reference Configuration 2014 of the LUISA (Land Use Integrated Sustainability Assessment) modelling platform for the period 2010-2050. On the other hand, a brief description of how LUISA is configured in order to be consistent with macro-economic models within the integrated modelling chain, including the incorporation of the legally binding objectives, directives and regulations is also included in this document.

Table of Contents

Table of Figures

List of Tables

Acronyms and abbreviations

CAP	Common Agricultural Policy of the European Union
CAPRI	Common Agricultural Policy Regionalised Impact Modelling System
CBM	Carbon Budget Model
CLC	Corine Land Cover
DG CLIMA	Directorate-General for Climate Action
DG ECFIN	Directorate-General for Economic and Financial Affairs
DG ENER	Directorate-General for Energy
EU	European Union
EUCLIMIT	European Climate Mitigation modelling platform
FAWS	Forest available for wood supply
G4M	Global Forest Model
GDP	Gross Domestic Product
GVA	Gross Value Added
ha	Hectares
HNV	High Nature Value farmland areas
kha	Thousands of hectares
LUISA	Land Use Integrated Sustainability Assessment modelling platform
MS	Member State
NUTS	Nomenclature of Territorial Units for Statistics
RED	Renewable Energy Directive
UNFCCC	United Nations Framework Convention on Climate Change

1 INTRODUCTION: CONTEXT AND SCOPE

The work presented in this report is an application of the Land Use-based Integrated Sustainability Assessment platform (LUISA), configured in compliancy with the "EU Energy, Transport and GHG emission trends until 2050 – Reference Scenario 2013"[1] (EU Reference Scenario 2013 hereinafter), as explained in Baranzelli et al., 2014, and derived from an earlier implementation (Lavalle et al., 2013). Within the scope of the present report, this scenario configuration in LUISA is referred to as the Updated Reference Scenario 2014 (or EU Reference Scenario 2014).

LUISA is able to provide insights on the potential land competition arising from uses due to different economic, demographic and political drivers, and the associated economic and environmental impacts. In doing so, LUISA moves from the spatial scale of the EU Reference Scenario 2013 and focuses on the regional and local scales: it thus ensures that the available most up-to-date and accurate data is being used in a consistent way, in particular capturing the effects of spatially explicit policies at local level.

With reference to the Energy Climate Package, it is of particular interest the evaluation, at local scale, of the land resources necessary to support the production of land-based energy sources, such as dedicated energy crops or forest, forecasted by the upstream economic and energy models. Possible implications for the production of food and feed, especially in terms of land suitability and productivity, are also discussed.

The policy framework for climate and energy in the period from 2020 to 2030[2] encompasses policy options and target-based measures based upon the analysis of impacts of a series of scenarios; these scenarios have been developed using a consolidated framework primarily based upon economic modelling[3]. The EU Reference Scenario assumes full implementation of the legally binding targets that were established in order to ensure that the EU meets its climate and energy targets already agreed up to 2050[4]. The socio-economic assumptions (namely GDP and population growth projections until 2050) are in line with those set by DG ECFIN and the Economic Policy Committee (EPC).

[1] http://ec.europa.eu/energy/observatory/trends_2030/index_en

[2] COM(2014) 15

[3] SWD(2014) 15

[4] EU ENERGY, TRANSPORT AND GHG EMISSIONS TRENDS TO 2050 – EU Reference Scenario 2013, ISBN 978-92-79-33728-4, doi: 10.2833/17897.

For the purpose of the present report, of particular importance are the policy and settings updates implemented in the demand module and allocation modules of LUISA, as regarding the allocation of forest land, energy crops and agricultural activities under the EU Reference Scenario 2014 configuration. Chapter 2 summarises the main components of the LUISA modelling platform, the link between the macro-economic drivers and regional land-use demands, and it briefly describes the policy provisions that are newly modelled and integrated in the updated configuration. Chapter 3 describes in detail the land demand for forest land, agricultural land and energy crops, while Chapter 4 further focuses on the concept of available land and presents the analysis of the amount of land allocated for forest, food and feed, and energy, under the EU Reference Scenario 2014.

In the context of this report, the expressions “land demand”, “land claim” and “land requirement” share the same meaning and are used interchangeably. They all refer to the amount of land that, in a specific geographical context (e.g. a region) and in a given year of the simulation horizon, is demanded/claimed/required in order to satisfy the assumed economic and demographic projections.

2 THE UPDATED REFERENCE CONFIGURATION IN LUISA

2.1 An overview of the LUISA modelling platform

The LUISA platform was developed to produce a comprehensive framework to assess the impact of environmental, socio-economic and policy changes in Europe. The Reference Scenario in the LUISA platform – Updated Configuration 2014 provides the basis for comparing policy options and includes current national and EU policies. A detailed description of this scenario is presented in Baranzelli et al., 2014.

Based on the modular structure of LUISA, the implementation of the EU Reference Scenario 2014 required a number of updates with respect to the EU Reference Scenario 2013 (Lavalle et al., 2013). These updates have been implemented in both the demand module, where the land claimed per sector is computed, and in the allocation module, where location-specific subsidies and restrictions affecting land use conversions are introduced. A schematic representation of the LUISA platform, as configured for the Updated Reference Scenario 2014, is represented in Figure 1.

LUISA is structured in three main modules: the 'demand module', the 'land use allocation module' and 'the indicator module' (Lavalle et al., 2011a; Batista e Silva et al., 2013b). The demand module takes into account sector specific land requirements. The allocation module spatially distributes the regional land use demands at 100 m pixel resolution, on the basis of bio-physical characteristics, neighbourhood factors, the competition for different land uses and policy-based restrictions. The main output of the allocation module is a yearly land use map, from 2007 to 2050 at 100 m resolution for the EU28; yearly grid-level accessibility and population maps are computed as well. The indicator module assesses the impact of the policy measures implemented upstream, computing various indicators based on the main output of the allocation module.

The allocation mechanism implemented in the LUISA platform, incorporates yearly land demand and, within the policy and biophysical constraints imposed, the model attempts to achieve an optimal land-use distribution, based on spatially varying local suitabilities for competing land uses. Those suitability values for given land uses, in turn, are derived from fitting biophysical, socio-economic and neighbourhood factors on spatial land-use patterns with a multinomial discrete choice method (Lavalle et al., 2011a).

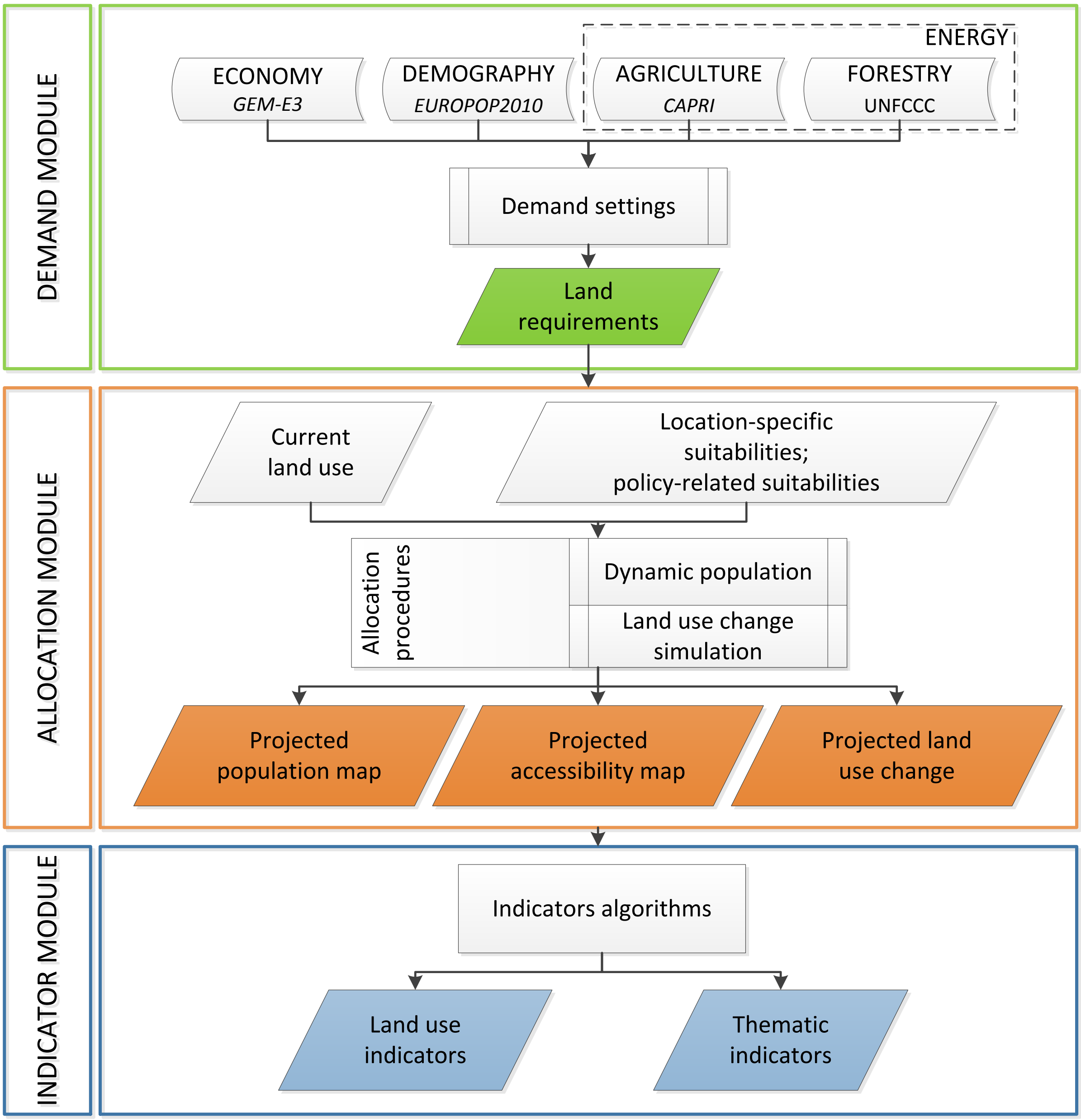


Figure 1. Flow chart of the LUISA platform for the Reference Scenario 2014.

The LUISA platform relies on the CORINE land cover (CLC) 2006 dataset for complete and consistent information on land use/cover across Europe. In particular, a refined version of CLC2006 (Batista et al., 2013c) is used as base map (starting state for the simulation). CLC data are also used for calibrating the land allocation model and as input for other spatial layers used in LUISA, such as the population distribution map (Batista e Silva et al., 2013a) and suitability maps for arable land.

2.2 Land requirements

The land use legend of the simulated output of LUISA is detailed in Table 1. The 46 CLC 2006 refined land use categories have been aggregated in broad classes for use in LUISA, while other classes, originally not present in CLC 2006 refined, have been added in order to meet specific project requirements. For example, a set of 'abandoned' classes have been introduced in order to better capture land abandonment processes, for both artificial (urban and industry) and agricultural uses. The category "arable land" has also been broken down in more specific crop classes, in order to better assess the impacts of the Common Agricultural Policy (CAP) reform. The land use classes for which land demand is computed are: urban, industry, other arable, cereals, maize, root crops, permanent crops, pastures, forest and energy crops. Transitional woodland shrub and Scrub and/or herbaceous vegetation association classes are dynamically simulated, but their evolution is not driven by any macro-economic sectoral model (in Table 1, this is indicated by the class' attribute "passive").

The CAPRI model (Britz and Witzke, 2008) provides projections for agricultural commodities and dedicated energy crops (see Chapter 3). Each of the agricultural land use classes corresponds to an aggregation of CAPRI commodities, with the exception of the energy crops, which are already represented as one unique class in CAPRI.

Table 1. Land-use/cover legend in LUISA.

Land use classes	Land use / cover change	Dynamic
Urban (*active/abandoned*)	*Simulated*	*YES*
Industry (*active/abandoned*)	*Simulated*	*YES*
Other arable (*active/abandoned*)	*Simulated*	*YES*
Permanent crops (*active/abandoned*)	*Simulated*	*YES*
Cereals, Maize, root crops (*active/abandoned*)	*Simulated*	*YES*
Pastures (*active/abandoned*)	*Simulated*	*YES*
Forest *(active)*	*Simulated*	*YES*
Transitional woodland shrub *(passive)*	*Simulated*	*YES*
Scrub and/or herbaceous vegetation associations *(passive)*	*Simulated*	*YES*
Energy crops *(active)*	*Simulated*	*YES*
Infrastructure	*Not simulated*	*YES*
Other nature	*Not simulated*	*NO*
Wetlands	*Not simulated*	*NO*
Water bodies	*Not simulated*	*NO*

The spatial detail of the agricultural land demand is maintained as provided by CAPRI: in most countries it corresponds to the NUTS2 level, such as for Italy or Poland; in other countries it corresponds to the NUTS1 level, such as in the United Kingdom.

The evolution of the artificial land uses is driven by the official demographic projections produced by Eurostat EUROPOP 2010 (urban land use) and the GVA projections from the GEM-E3 model (industrial land use, i.e. industry/commerce/service). Population projections (EUROSTAT, 2010) are available at country level and are subsequently downscaled at NUTS2 level using EUROPOP 2008 (Batista e Silva et al., 2013b). GDP and GVA projections are originally available from GEM-E3 at country level, but the procedure to obtain land requirements for industrial land allows to produce land demands at NUTS2 level (Batista e Silva et al. 2014).

In the EU Reference Scenario 2013, forest land demand was based on the projections provided by the G4M model, which were originally available at country level and downscaled to regional levels. In the LUISA EU Reference Scenario 2014, a new method to compute forest land demands is introduced. This method is based on the official figures reported for UNFCCC and the Kyoto protocol: an exhaustive description of it can be found in Baranzelli et al. (2014).

2.3 Spatially explicit European policies

Besides the policies included in the Energy Climate Package, the LUISA configuration includes other policies with potential direct spatial repercussions on the European landscape. As described in section 2.1, the EUCLIMIT modelling framework was designed to assess the Energy Roadmap. Thus, a significant portion of relevant legislation is included in the configuration of the models upstream to LUISA, especially PRIMES (energy sector). LUISA has been linked to the suite of models which constitute a part of the EUCLIMIT platform: each of these models constitutes the basis for the specialised representation of economy sub-systems and the suite itself covers the entire economy-wide system, including the energy and transportation sectors, the industrial processes, and the sectors of agriculture and forestry.

However, some aspects (spatially explicit) of European law are better captured at high spatial resolution. The main policies included in the EU Reference 2014 Scenario at the spatial level of the land use model (100m) are the Renewable Energy Directive (RED), the Common Agricultural Policy (including support schemes and certain elements of cross-compliance), TEN-T transport network, and the 2020 biodiversity strategy.

3 LAND DEMAND FOR FOREST, AGRICULTURE AND ENERGY

This section illustrates how the demand for land is computed for the Updated Reference Scenario 2014 for the forest and agriculture sectors. Demand is derived either from up-stream models or internally in LUISA and consider the need for food, feed and energy over the period 2010-2050, as set in the EU Energy reference scenario 2013.

The demand for forest land is based upon official statistics declarations from Countries. CAPRI provides the demand for agricultural land for both food and energy.

3.1 Demand for forest land

As mentioned in Chapter 2, the demand for forest land in the EU Reference Scenario 2013 configuration was based on the projections provided by the G4M model, originally available at country level. In the current configuration of the EU Reference Scenario 2014, the national demands for forest areas are obtained from projected trends (2013 - 2050) that are extrapolated from historical annual afforestation and deforestation rates as reported under the UNFCCC scheme. This new approach of obtaining forest demands yields results that are consistent with the UNFCCC reports and demonstrate a better fit with the land cover data reported in the CLC 2006 maps. Some country examples are given in Baranzelli et al. (2014), with the aim to compare the trends in total forest land between the LUISA EU Reference Scenario 2013 and the LUISA EU Reference Scenario 2014.

3.2 Demand for agricultural land and energy crops

Agricultural land demand

As mentioned above, the agricultural demand is provided by the CAPRI model (PRIMESCOR run, from 2010 up to 2050). The CAPRI model is an agricultural partial equilibrium model that assesses the effects of the EU trade and agricultural policy on the European agriculture. The CAPRI model focuses on the EU28 plus Norway, Turkey and the Western Balkans. There are two interlinked modelling components developed in CAPRI: a regional non-linear programming model related to the supply of crops and animal outputs per NUTS1/2 region, and a global trading model. The data in the supply module are based on the Economic Accounts of Agriculture (EAA). CAPRI builds upon an analysis of observed historical trends, on expert information for particular issues, and on standard economic modelling.

The data for agricultural products extracted from the CAPRI model runs for the post-2010 periods covers 33 product classes corresponding to 6 agricultural land uses in LUISA. This aggregation is presented in Table 2 and will be used throughout the study.

Table 2. Land-use/cover legend in LUISA, implemented Baseline Scenario.

CAPRI activities	LUISA land-use class
Soft wheat Durum wheat Rye and meslin Barley Oats Other cereals	**Cereals**
Potatoes Sugar beet Fodder root crops	**Root crops**
Apples, pears, peaches Other fruits Citrus Olives Table olives Nurseries Flowers Wine Table grapes	**Permanent crops**
Grain maize Fodder maize	**Maize**
Paddy rice Oilseeds Pulses Flax and hemp Tobacco Other industrial crops Other crops Tomatoes Other vegetables Fodder other on arable land Set-aside voluntary Fallow land	**Other arable**
New energy crops	**Energy crops**

The outputs from CAPRI are used to drive the agricultural land use allocation performed by LUISA. This ensures consistency between the CAP-compliant economic and market assumptions, and the physical space occupied by the commodities grown in each simulated region.

Land claimed for each agricultural activity from CAPRI simulations cover the time window from 2010 to 2050, in ten-year steps. From 2006 up to 2010 agricultural claims rely on historical data also provided by the CAPRI model. Linear interpolations methods are used in order to compute the years in between, on a yearly basis.

Energy crops demand

One of the main novelties of the Reference Scenario implementation in LUISA (both updates, 2013 and 2014), is the introduction of a new land use class dedicated to energy crops. According to the projections provided by CAPRI, energy crops start to appear in Europe around the year 2020 and usually have a pick towards the end of the simulation period (2050). Overall, energy crops are forecasted to appear not before the year 2020 in all EU28: this is largely due to the particular configuration of CAPRI, where all the information related to the energy sector, in particular about the status of energy supply and demand at national scale, is provided by the PRIMES model. In addition, the base year assumed by the CAPRI model under the Reference Scenario is 2004: therefore, the possible presence of energy crops in the current (2010) European landscape, is not taken into account.

From the analysis of the land requirements, it can be inferred that within the CAPRI model the expansion of energy crops in Europe takes place at the expenses of other agricultural land use classes, especially arable land and, within this category, cereals. This behaviour, together with the rapid diffusion of energy crops and, in some cases, their decline, might cause ‘swap’ effects in the allocation of such land uses in LUISA, especially among different agricultural land use classes.

In the current modelling exercise, and in compliance with the CAPRI model specifications, energy crops are hereinafter regarded as non-food, lignocellulosic crops, belonging to the 2nd generation feedstock. They are considered as perennial energy crops grown specifically for their fuel value (BEE project, 2010). Lignocellulosic crops generally fall into two categories: herbaceous and woody crops (short rotation coppice), see Fisher et al., 2010a; UNCTAD, 2008; Baraniecki et al., 2009; DEFRA, 2004. Specifically, the following species were included in the analysis:

- Herbaceous lignocellulosic crops: Miscanthus (Miscanthus spp.), Switchgrass (Panicum virgatum), Reed canary grass (Phalaris arundinacea), Giant reed (Arundo donax) and Cardoon (Cynara cardunculus);
- Woody lignocellulosic tree crops: Willow (Salix spp.), Poplar (Populus spp.) and Eucaliptus (Eucaliptus spp.).

3.3 Aggregated land demand

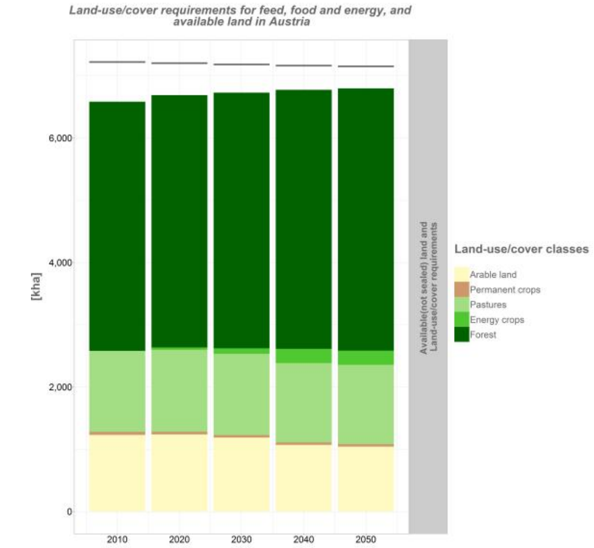
The aggregated demand for forest and agricultural land, including dedicated energy crops, can potentially exert a considerable pressure on the land resources of the MSs.

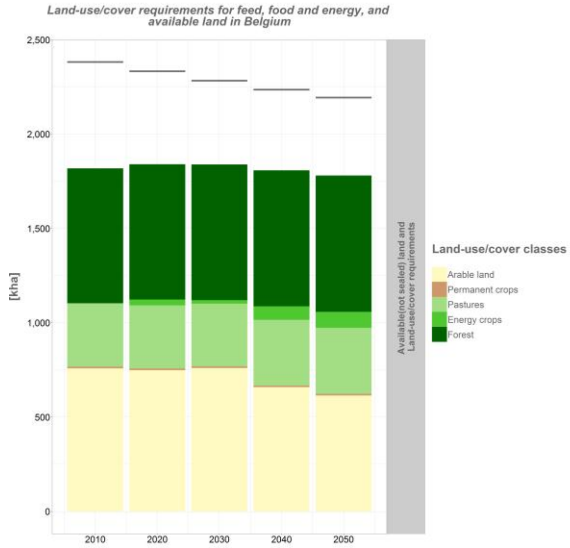
Figure 2 below represents the aggregated land demand for the EU-28 Member States. The stacked columns of the charts represent the land requirements for arable land, permanent crops, pastures, energy crops and forest land, for the years 2010, 2020, 2030, 2040 and 2050. The dark grey horizontal line indicates the amount of available land, i.e. the land overall potentially available for the allocation of the reported land requirements. This is computed as the amount of land not sealed, excluding the land use classes not simulated by LUISA i.e. water bodies and wetlands, beaches, bare rocks and glaciers. It is worth mentioning that this reported amount of land has to be considered available for the allocation, altogether, of forest, agricultural land for food and feed, and energy crops.

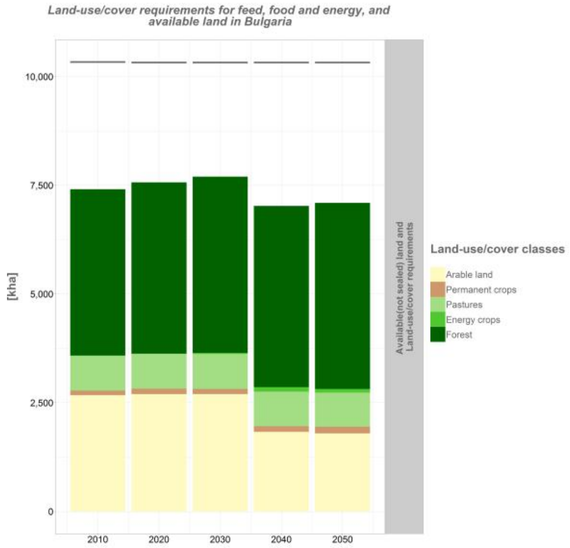
Due to the increase in built-up areas, the amount of land available is constantly decreasing across Europe: in some countries, the land requirements for forest, agriculture and energy altogether, represent over the 80% of the land available at country level, all along the simulation period. This is the case for Austria, Germany, Finland, France, Ireland, Latvia, Sweden and Slovenia. In particular, in Austria this percentage goes up to 95% in the year 2050.

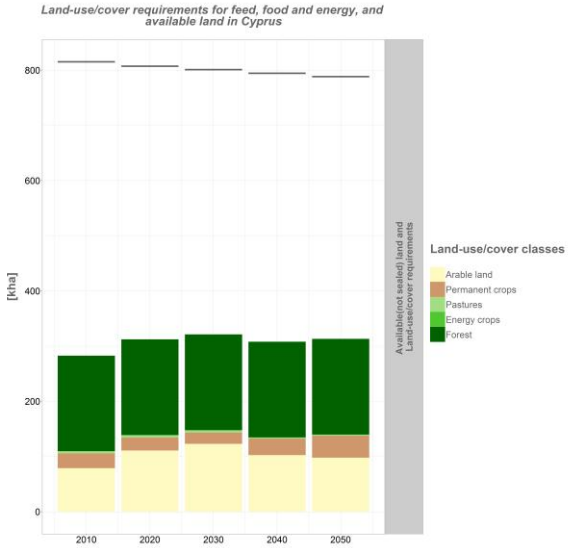
In some countries like Portugal, Spain, Greece, Malta and Cyprus, the difference between the land requirements and the available land for forest, food, feed, and energy, is substantial, showing a considerable amount of land that can be potentially allocated to satisfy the land demands. This might be due a low rate of increase of artificial areas (built-up), to an overall decrease of land requirements, or a combination of these two. In Denmark and Romania, for instance, the aggregated land requirements for forest, agriculture and energy, decrease throughout the simulation period, while the availability of not-sealed land decreases only marginally. Conversely, in the United Kingdom the ratio between land requirements and land available remains quite constant, due to a combined decrease of both land availability and land requirements.

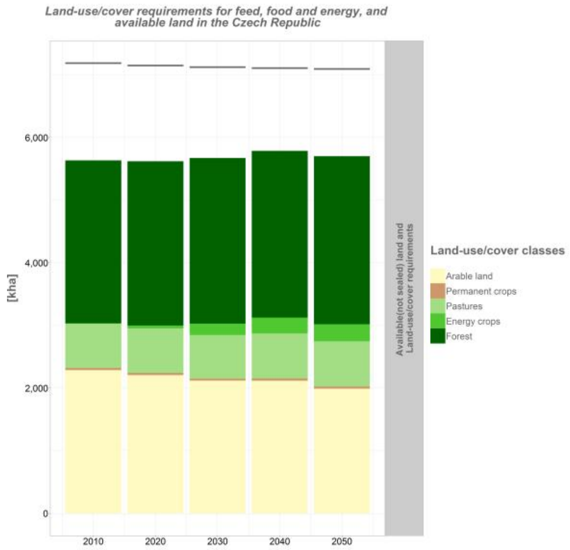
Finally, in other countries the ratio between land requirements and land availability fluctuates, as in the case of Lithuania.

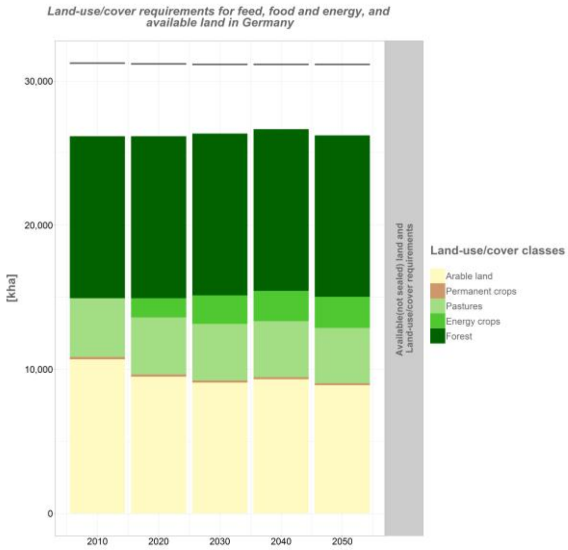

Land-use/cover requirements for feed, food and energy, and available land in Austria
[kha]
0
2,000
4,000
6,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

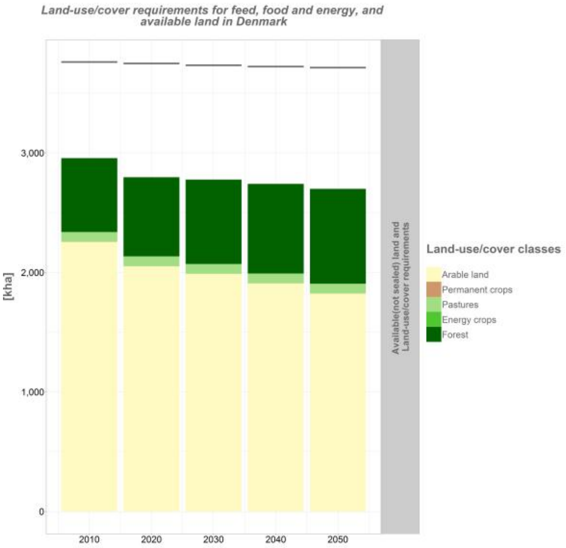

Land-use/cover requirements for feed, food and energy, and available land in Belgium
[kha]
0
500
1,000
1,500
2,000
2,500
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

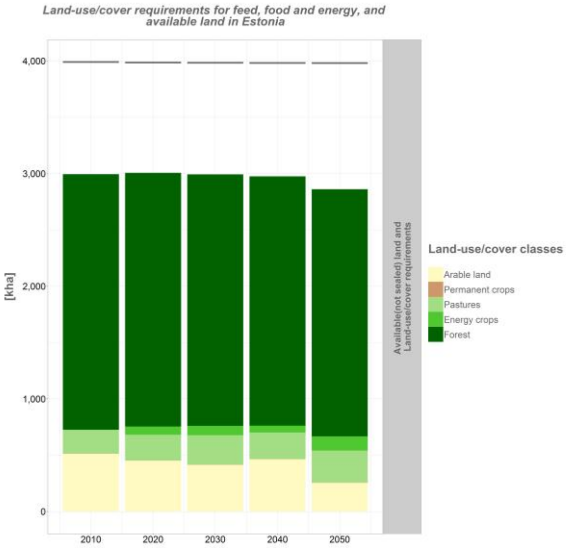

Land-use/cover requirements for feed, food and energy, and available land in Bulgaria
[kha]
0
2,500
5,000
7,500
10,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

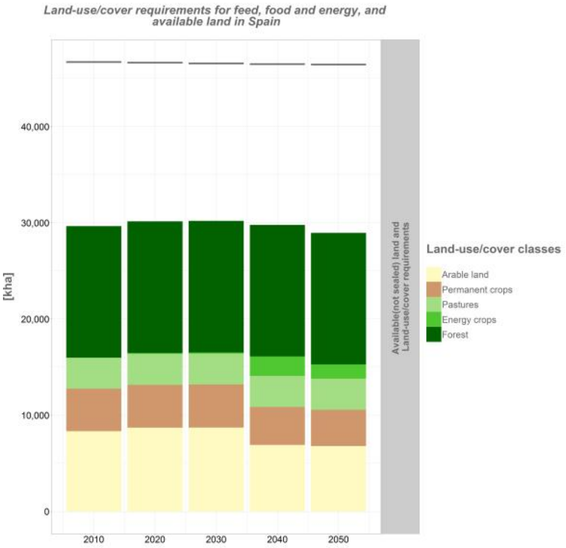

Land-use/cover requirements for feed, food and energy, and available land in Cyprus
[kha]
0
200
400
600
800
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

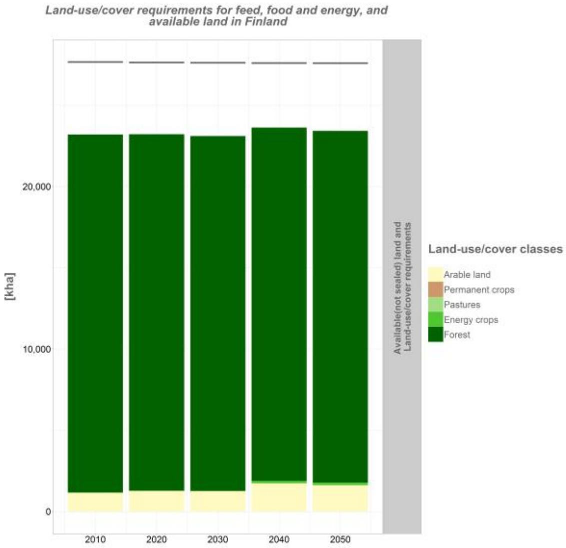

Land-use/cover requirements for feed, food and energy, and available land in the Czech Republic
[kha]
0
2,000
4,000
6,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

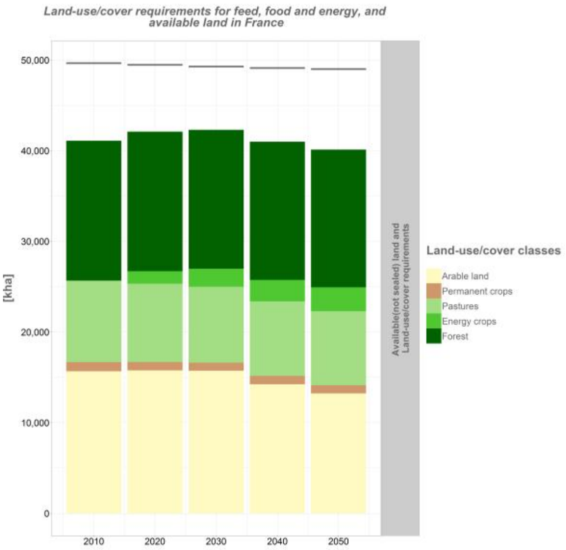

Land-use/cover requirements for feed, food and energy, and available land in Germany
[kha]
0
10,000
20,000
30,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

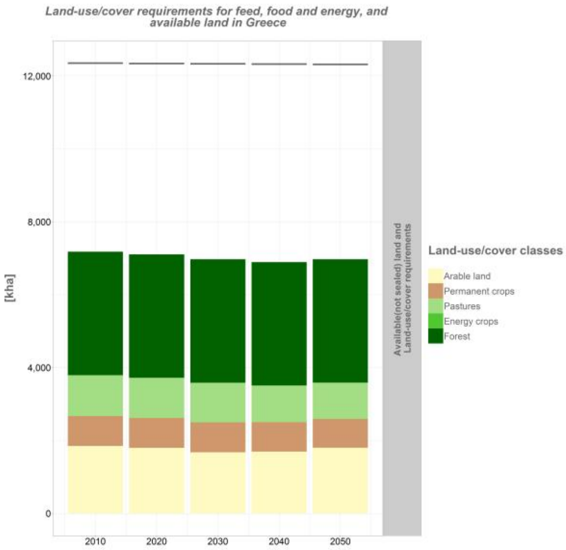

Land-use/cover requirements for feed, food and energy, and available land in Denmark
[kha]
0
1,000
2,000
3,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

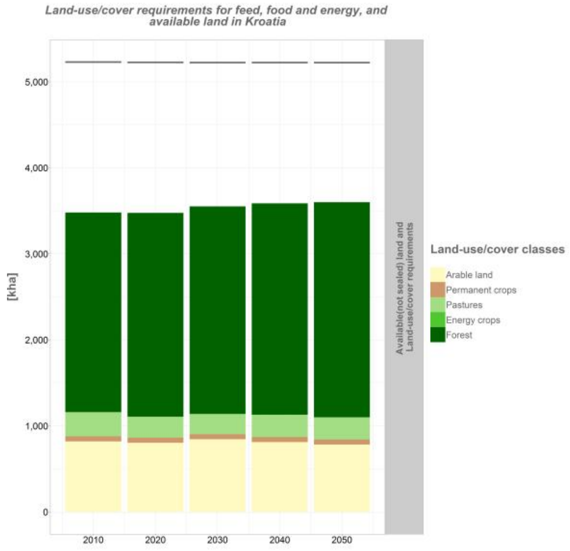

Land-use/cover requirements for feed, food and energy, and available land in Estonia
[kha]
0
1,000
2,000
3,000
4,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

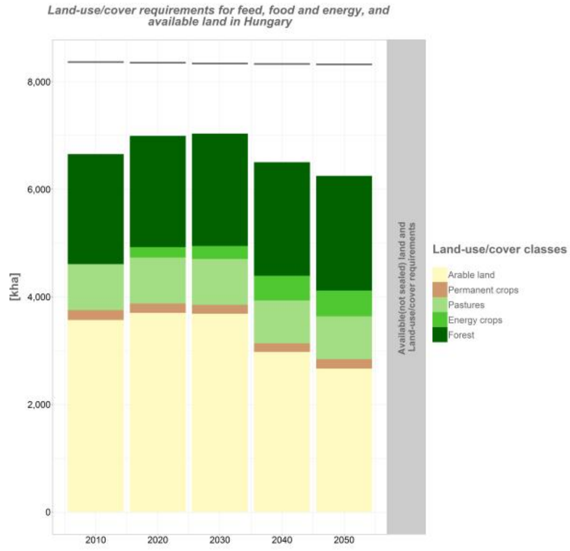

Land-use/cover requirements for feed, food and energy, and available land in Spain
[kha]
0
10,000
20,000
30,000
40,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

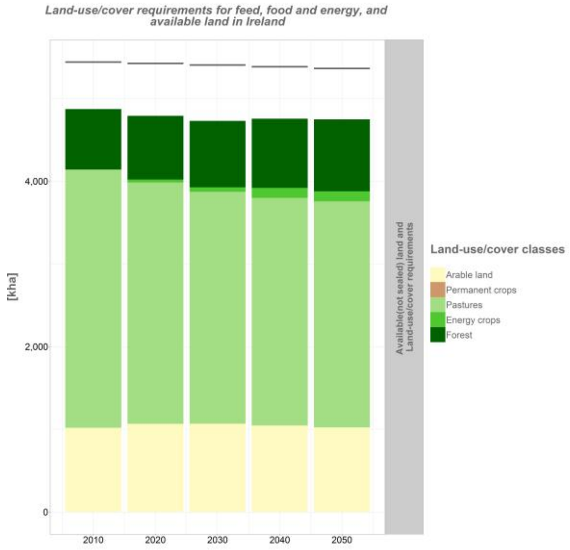

Land-use/cover requirements for feed, food and energy, and available land in Finland
[kha]
0
10,000
20,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

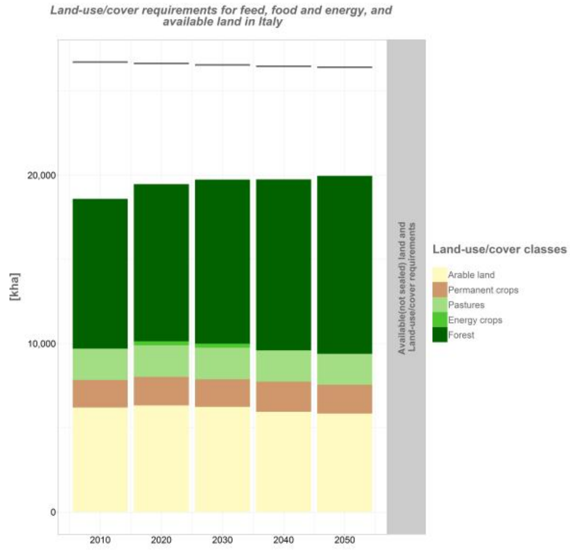

Land-use/cover requirements for feed, food and energy, and available land in France
[kha]
0
10,000
20,000
30,000
40,000
50,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

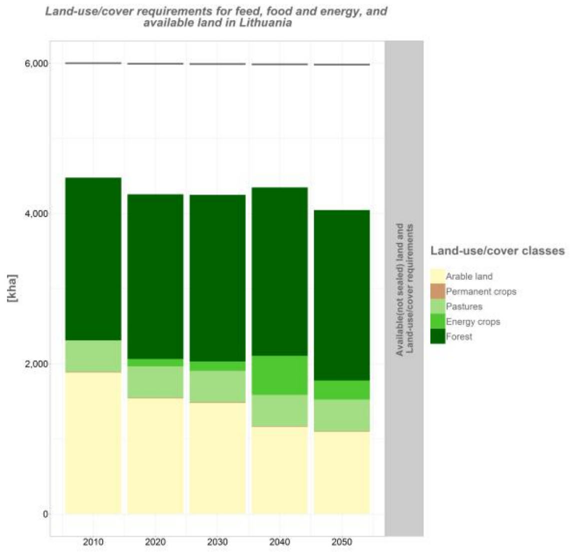

Land-use/cover requirements for feed, food and energy, and available land in Greece
[kha]
0
4,000
8,000
12,000
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

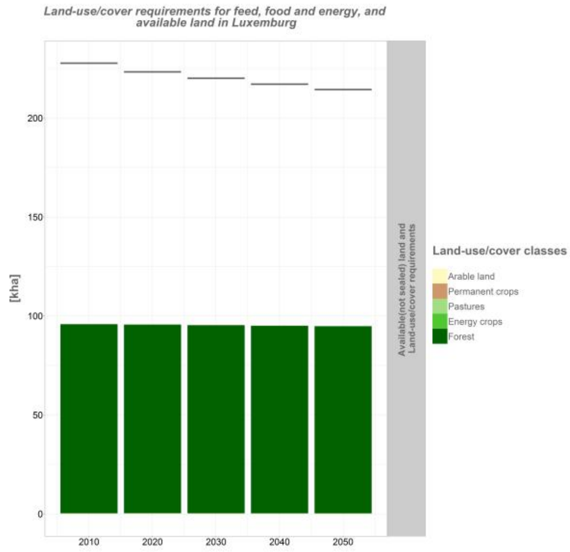

Land-use/cover requirements for feed, food and energy, and available land in Kroatia
[kha]
5,000
4,000
3,000
2,000
1,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

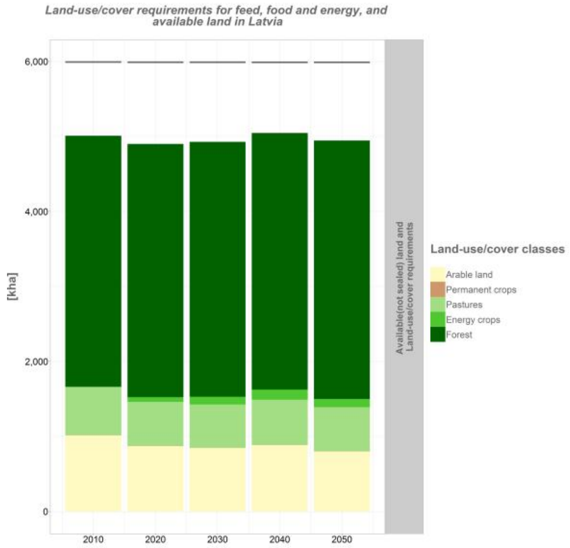

Land-use/cover requirements for feed, food and energy, and available land in Hungary
[kha]
8,000
6,000
4,000
2,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

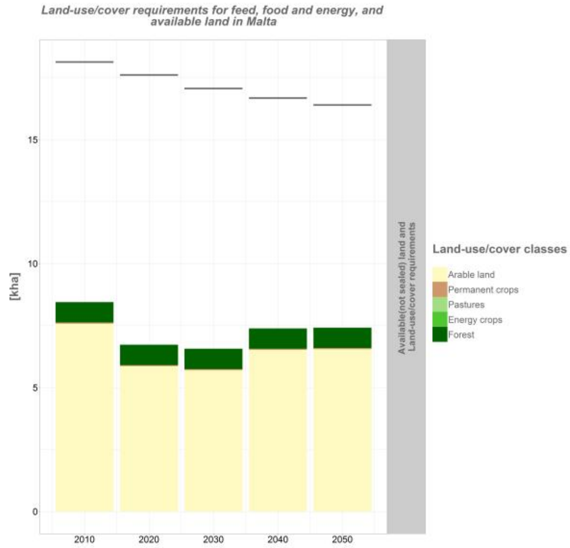

Land-use/cover requirements for feed, food and energy, and available land in Ireland
[kha]
4,000
2,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

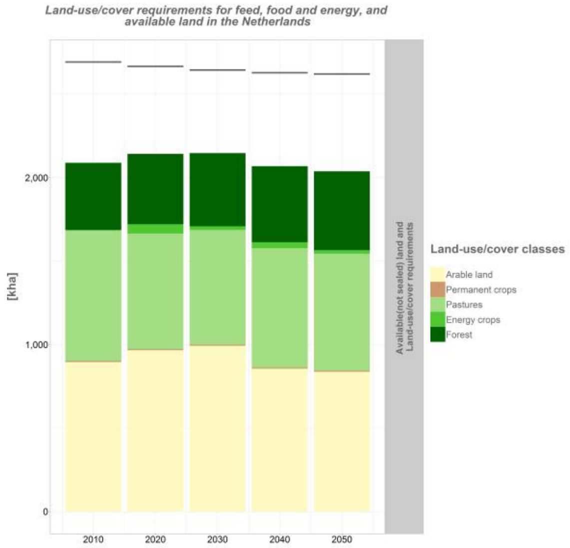

Land-use/cover requirements for feed, food and energy, and available land in Italy
[kha]
20,000
10,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

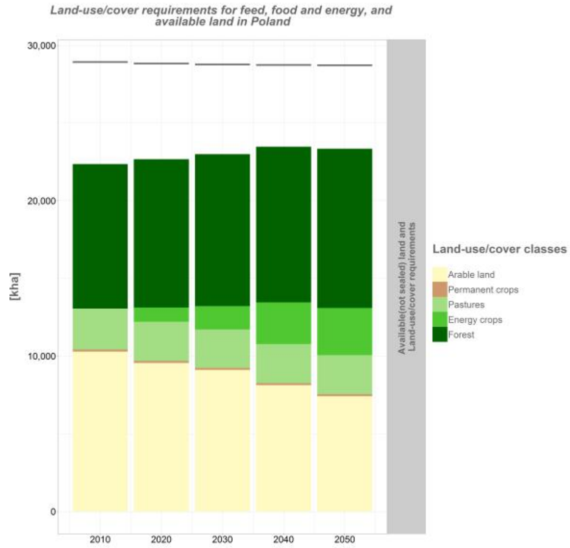

Land-use/cover requirements for feed, food and energy, and available land in Lithuania
[kha]
6,000
4,000
2,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

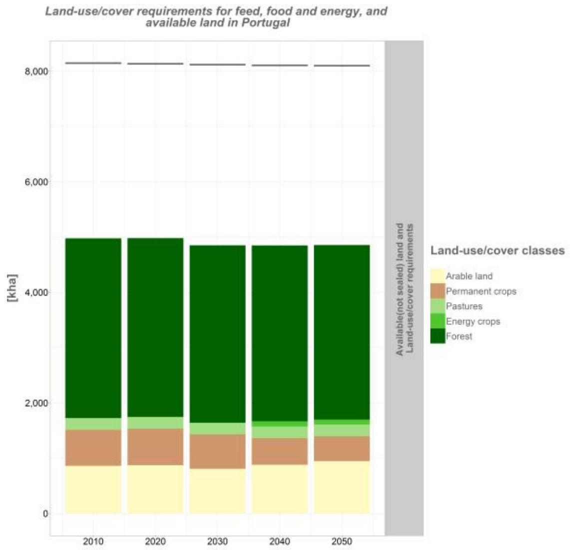

Land-use/cover requirements for feed, food and energy, and available land in Luxemburg
[kha]
200
150
100
50
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

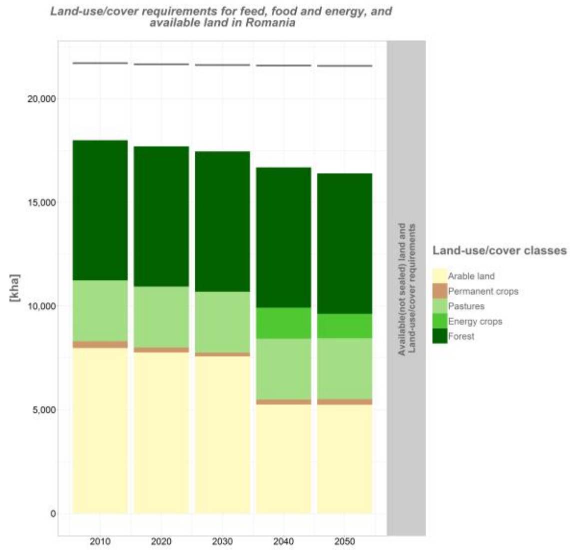

Land-use/cover requirements for feed, food and energy, and available land in Latvia
[kha]
6,000
4,000
2,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest


Land-use/cover requirements for feed, food and energy, and available land in Malta
[kha]
15
10
5
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest


Land-use/cover requirements for feed, food and energy, and available land in the Netherlands
[kha]
2,000
1,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest


Land-use/cover requirements for feed, food and energy, and available land in Poland
[kha]
30,000
20,000
10,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest


Land-use/cover requirements for feed, food and energy, and available land in Portugal
[kha]
8,000
6,000
4,000
2,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest


Land-use/cover requirements for feed, food and energy, and available land in Romania
[kha]
20,000
15,000
10,000
5,000
0
2010
2020
2030
2040
2050
Available(not sealed) land and Land-use/cover requirements
Land-use/cover classes
Arable land
Permanent crops
Pastures
Energy crops
Forest

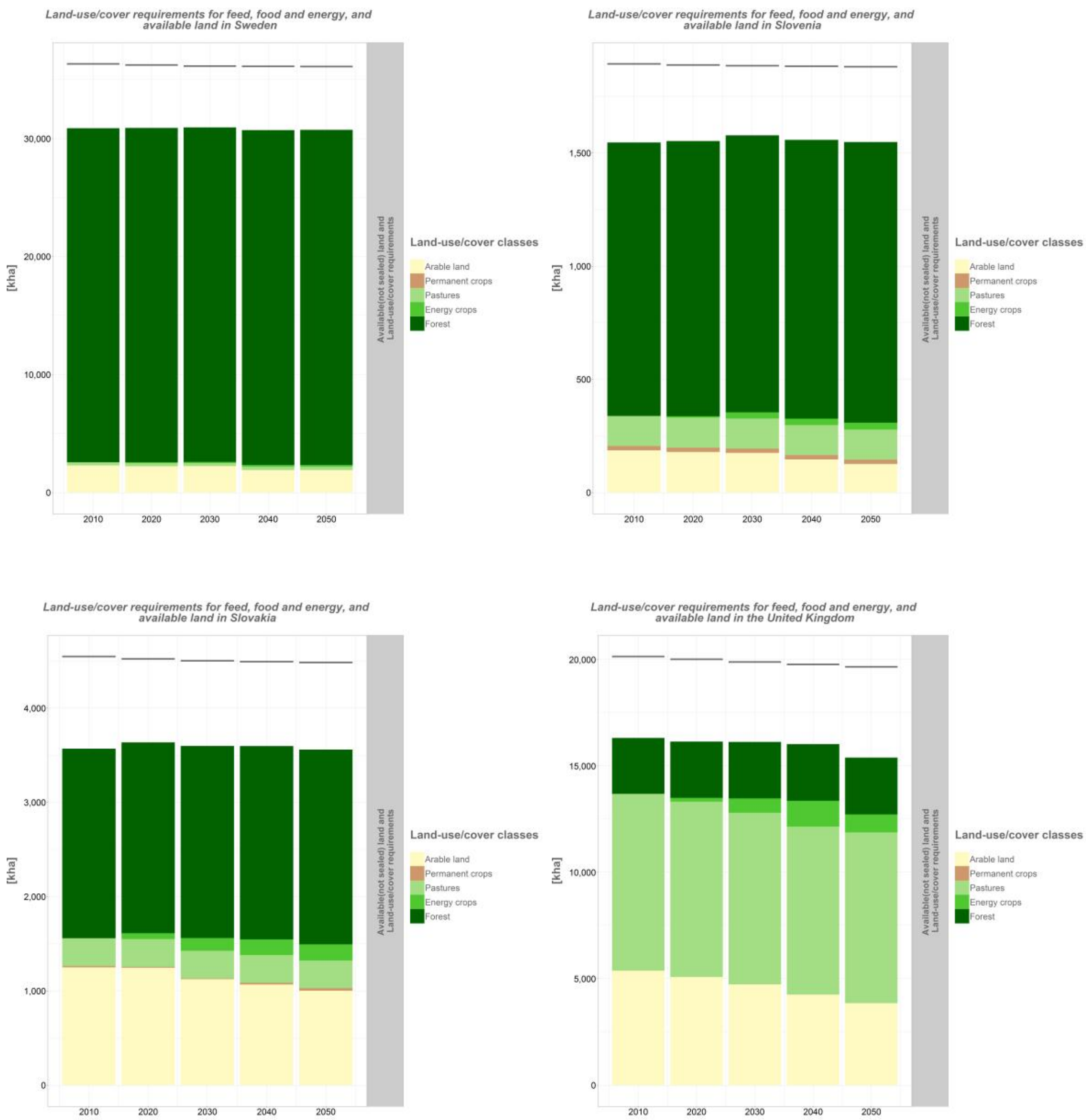


Figure 2. Land requirements for forest, agriculture (food and feed) and energy per MS.

4 LAND AVAILABILITY FOR FOREST, AGRICULTURE AND ENERGY

4.1 *Availability of forest land for harvesting*

Based on the requirements for forest land, as described in section 3.1, the allocation module of LUISA determines where forest expansion (or deforestation) takes place along the simulation horizon.

Forest expansion processes might be caused by human intervention or be due to natural processes of natural vegetation regrowth: therefore, both forest land remaining forest and newly afforested land, might be located in areas not suitable for forestry operations e.g. where currently used machinery cannot operate. The concept of forest land available for harvesting, i.e. where harvesting operations can take place, has been introduced in LUISA, with the aim of developing a dynamic indicator of forest biomass, by coupling the LUISA platform and the forest growth model Carbon Budget Model (CBM, Kurz et al., 2009; Pilli et al., 2013). In order to achieve that scope, two main improvements have been introduced in the LUISA platform: first, forest areas for the years 2006 – 2010 have been updated in order to be aligned with the most recent and available up-to-date official statistics; in addition, sylvicultural practices have been mapped in LUISA, in order to offer a simplified representation of current practices that match the detailed, but not spatial-explicit, representation of sylvicultural practices as in the CBM model.

Forest areas in the LUISA platform and in the CBM model were, in their original configurations, based on very different data sources, created for accomplishing rather different aims. In LUISA, the starting state of the simulation is a refined version of Corine Land Cover 2006 (CLC06ref; Batista et al., 2013). Corine maps are developed from satellite images, with a spatial resolution of 100m and focusing on the detection of homogeneous landscapes. On the other hand, the CBM model makes use of the most recent national forest inventories (NFI) and is based on the concept of “forest available for wood supply” (FAWS), i.e. forest where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood. This implies that forest land in LUISA is derived from land cover-related data sources at high (100m) spatial resolution and for the year 2006, whereas CBM is primarily based on land use-related data, available at national and, in some cases, regional level, for the year 2010. Land requirements in LUISA have been adjusted so to minimise possible differences between forest area estimates derived from CLC06ref and the national statistics. Further details are provided in Baranzelli et al. (2014).

Two different sylvicultural practices are taken into consideration in LUISA: clear cut and thinning. In order to identify forests where a combination of both forestry operations can be applied, and where only thinning is allowed, the following assumptions have been taken into account:

- Technical constraints
  - Forests allocated on slopes steeper than 35% are considered technically not accessible for harvesting operations. For few specific cases, this limit was modified, based on current practices reported in the literature; for example a 50% limit was set for Austria.
- Legal constraints:
  - Forest areas protected under the most restrictive regimes, are not available for wood supply (no harvest can be provided by forest part of natural protected areas classified as I, Ia and Ib, according to the IUCN international classification);
  - Forest areas belonging to Natura2000 sites and national protected areas classified as IUCN categories II, III and IV, are partially available for wood supply: only low impact sylvicultural treatments are allowed, i.e. thinnings;
  - Forest areas that are not under any protection regime or that do not belong to national protection areas classified as IUCN categories V and VI, are fully available for wood supply: both thinnings and final cuts are allowed.

Figure 3, Figure 4, Figure 5, Figure 6, Figure 7 and Figure 8 present the forest land potentially available for harvesting for broadleaves, conifers and mixed forest at NUTS2 level. In Figure 3, Figure 5 and Figure 7 and Figure 8 forest land in 2010 is reported as percentage of the total regional area; both forest land available for clear cut and thinning, and forest available only for thinning are reported, in the left and right map of each figure respectively. In Figure 4, Figure 6 and Figure 8 the change in forest land is reported for the period 2010 - 2050.

Forest land available for both clear cut and thinning operation is the one contributing the most to the provision of biomass: for all the species groups (broadleaves, conifers and mixed), the availability of this type of forest land decreases, from 2010 to 2050, in Eastern France, few regions in Spain and the southern NUTS2 of Sweden and Finland.

The availability of forest harvestable with only thinning operations is in general more stable across Europe, until 2050. For all the species groups, bigger changes can be detected in the Iberian Peninsula, Eastern Europe, the United Kingdom and Ireland.

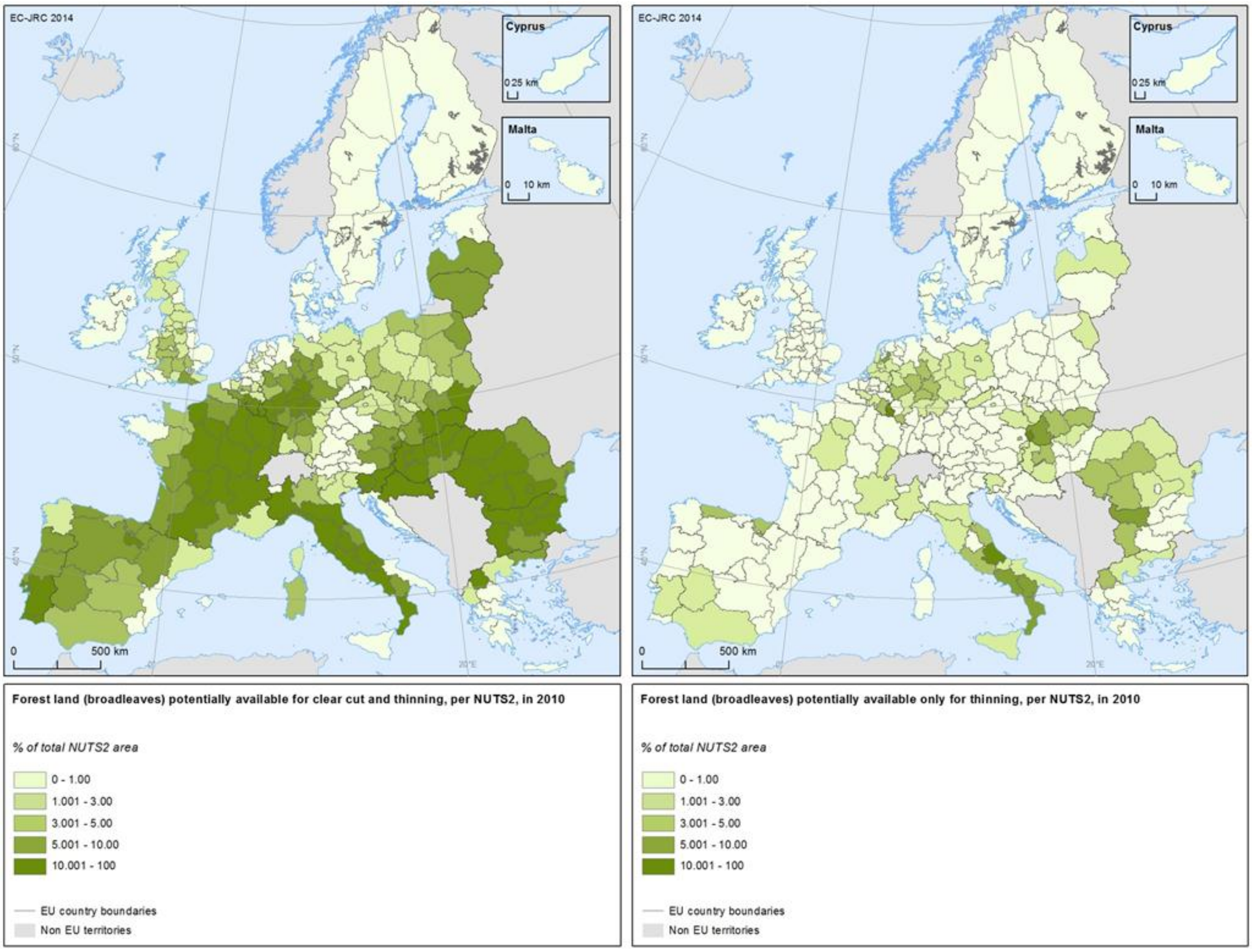


Figure 3. Forest land (broadleaves) potentially available for harvesting (combination of clear cut and thinning – left, only thinning - right), for the year 2010.

In general, in almost all European regions, the share of broadleaves that can be harvested with a combination of clear cut and thinning operations in 2010 (Figure 3) is higher than the share of broadleaves available just for thinning operations. Few exceptions are, for instance, few NUTS2 in South Italy and the western regions of Slovakia. The share of forest land occupied by broadleaves that can be harvested with both clear cut and thinning operations is higher than 10% in many regions of France, Italy, Hungary, Slovakia, Slovenia, Romania and Bulgaria.

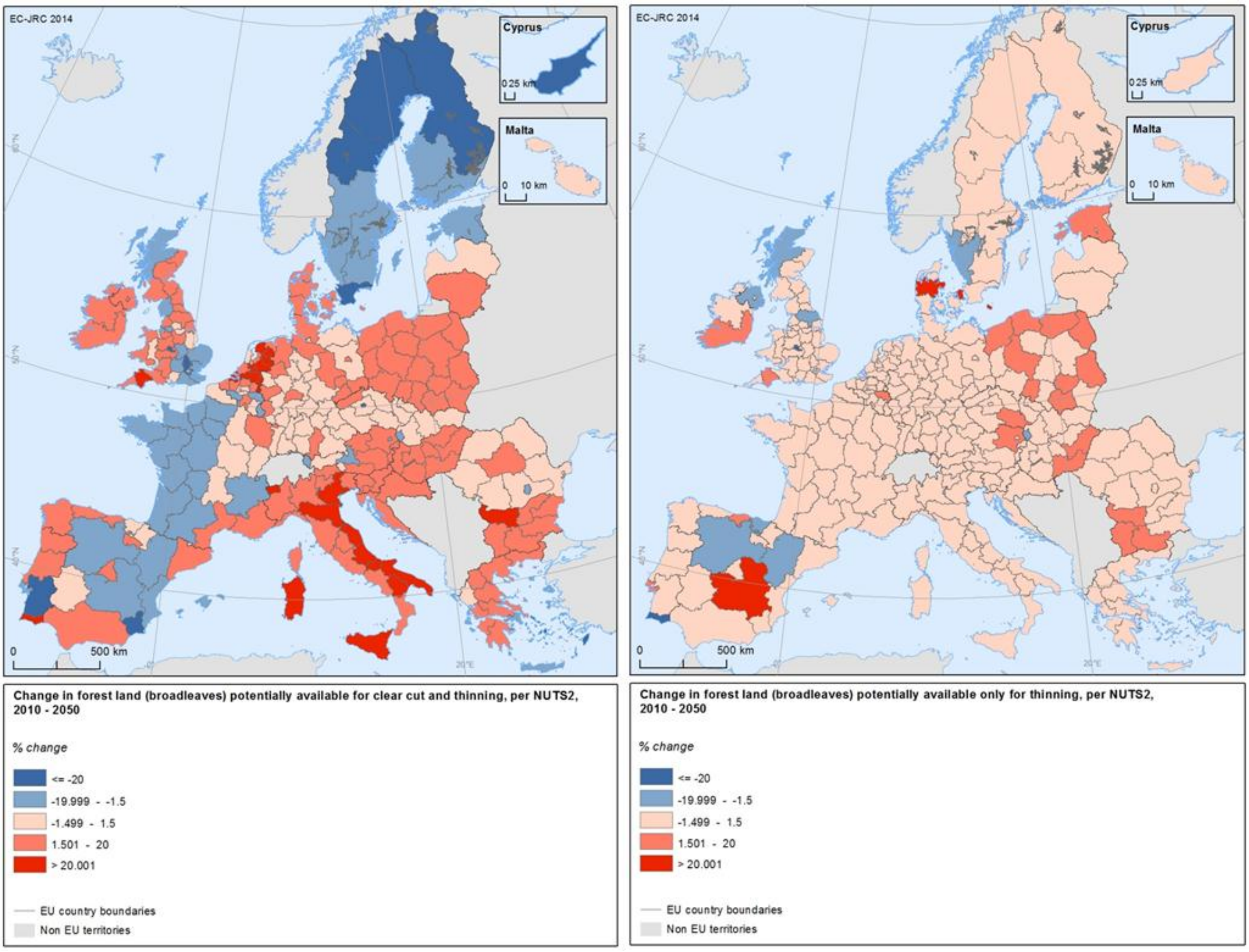


Figure 4. Change in forest land (broadleaves) potentially available for harvesting (combination of clear cut and thinning, left map; only thinning, right map), for the simulation period 2010 2050.

As shown in Figure 4, across Europe and over the simulation period from 2010 up to 2050, the broadleaves available for harvesting (both clear cut and thinning) tend to increase or, mainly in central Europe and Romania, don’t change considerably. Italian regions on the Adriatic coast, Sardinia and Sicily islands, the Netherlands and few regions in Bulgaria, the United Kingdom and Portugal, are characterised by the highest increase (greater than 20%). Conversely, negative trends can be found in Finland, Sweden and Estonia, together with Eastern France and some NUTS2 in Spain and the United Kingdom.

Broadleaves available just for thinning operations don’t change considerably along the simulation horizon: greater changes can be detected in some regions of Ireland, the United Kingdom, Estonia, Poland, Hungary, Bulgaria, Austria and Czech Republic (increase), and in the United Kingdom, Sweden, Portugal and Spain (decrease).

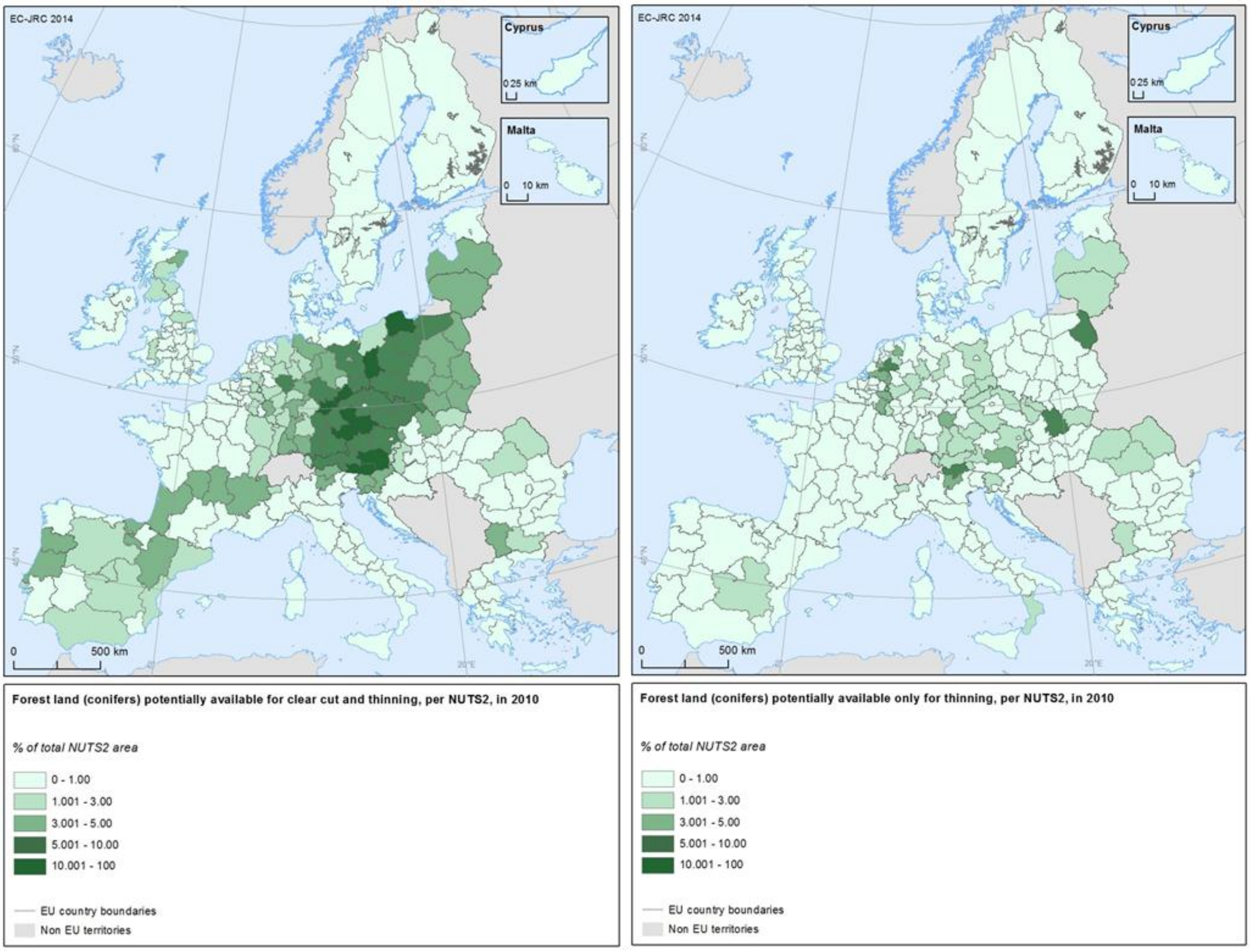
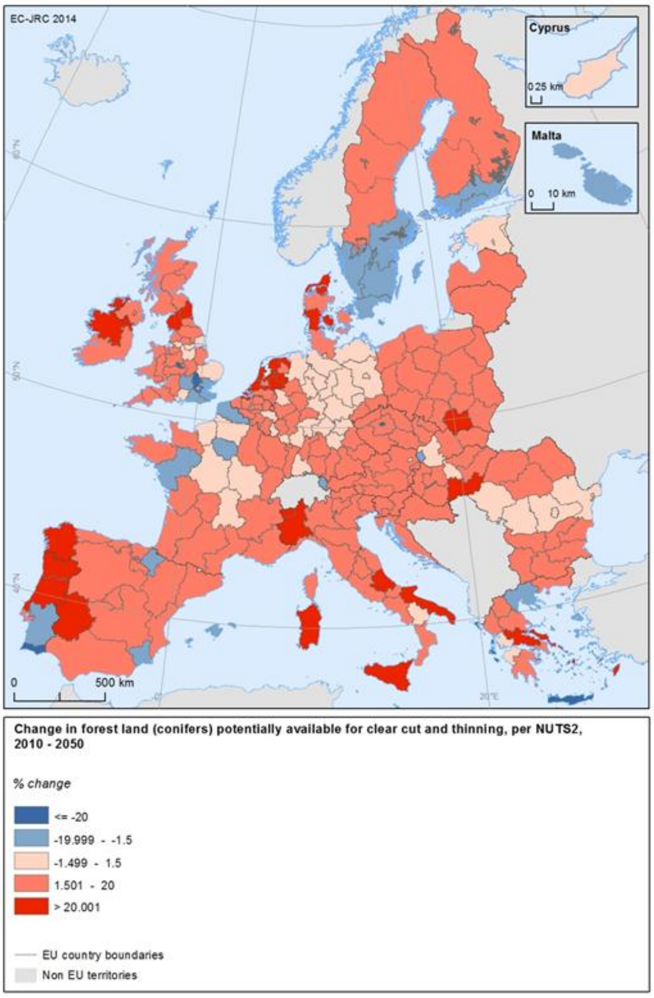


Figure 5. Forest land (conifers) potentially available for harvesting (combination of clear cut and thinning – left, only thinning - right), for the year 2010.

From Figure 5, it can be observed that in almost all European regions, the share of conifers that can be harvested with both clear cut and thinning operations in 2010 is higher than the share of conifers available just for thinning operations. Few exceptions can be found in Poland, the Netherlands and Belgium. The share of forest land occupied by conifers that can be harvested with both clear cut and thinning operations is higher than 10% in few regions of Poland, Austria, Czech Republic and Germany.



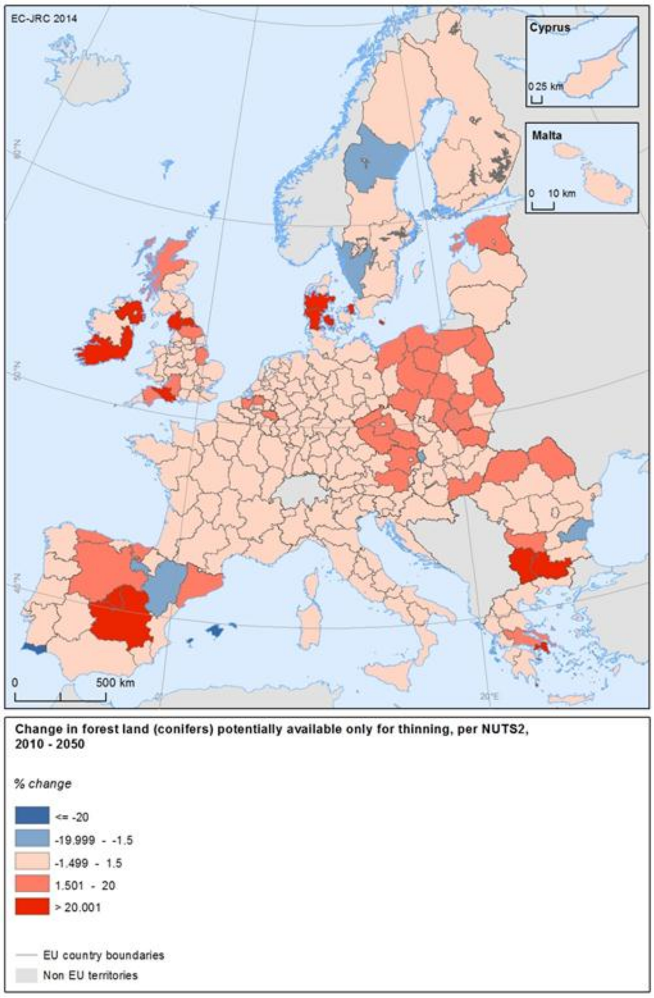


Figure 6. Change in forest land (conifers) potentially available for harvesting (combination of clear cut and thinning, left map; only thinning, right map), for the simulation period 2010 2050.

Similarly to the broadleaves, the availability of conifers for both clear cut and thinning tend to increase across Europe. Many regions, from Spain to the Baltic basin, are characterised by changes up to 20%. Only few regions in Finland, Sweden, the United Kingdom, France, Spain, Portugal and Greece are characterised by a negative trend.

Conifers available just for thinning operations don’t change considerably along the simulation horizon: greater positive changes can be detected in Eastern Europe, Spain, Denmark and the United Kingdom. On the opposite, reductions in the area of conifers available only for thinning are observed in Sweden, Bulgaria and Spain.

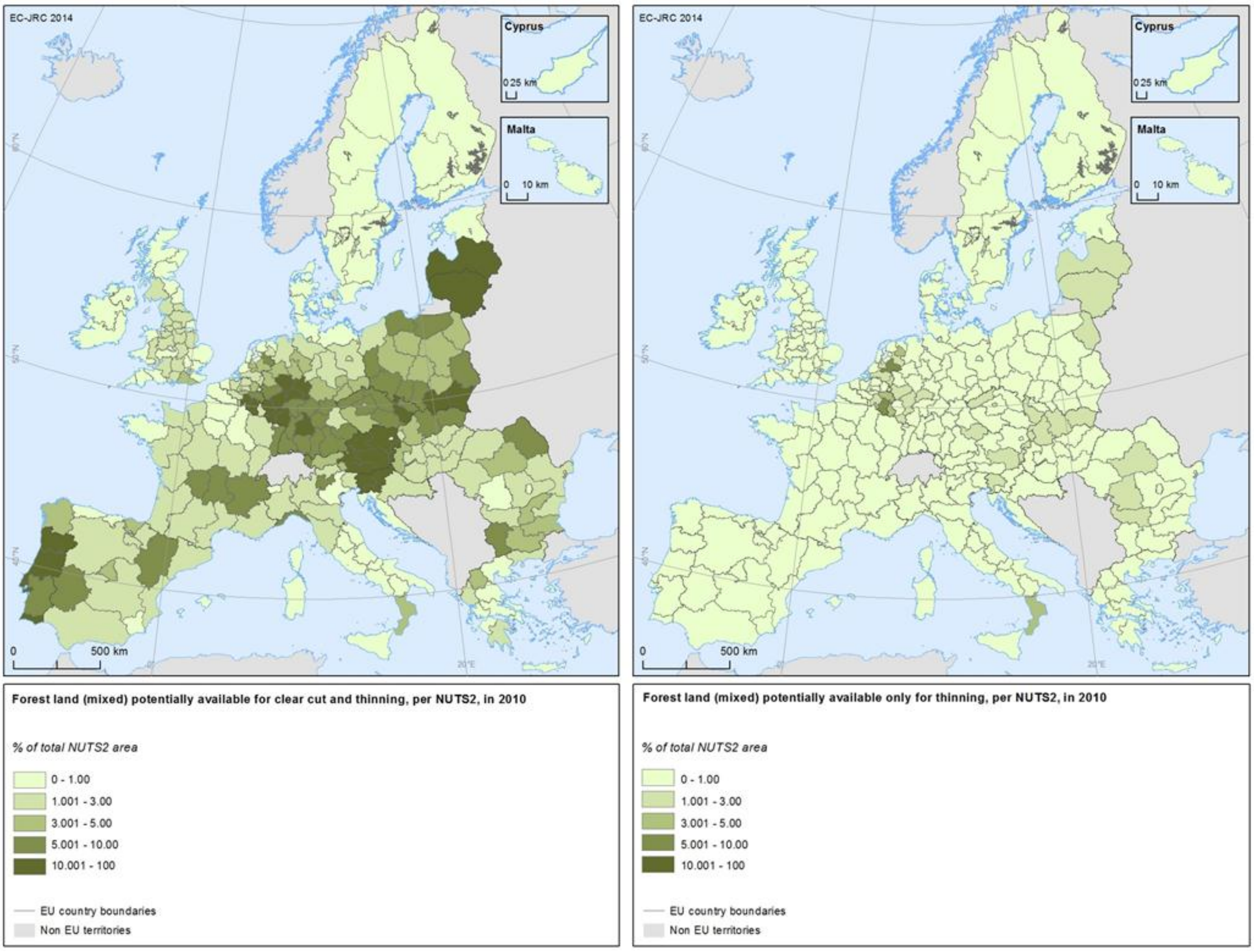


Figure 7. Forest land (mixed) potentially available for harvesting (combination of clear cut and thinning – left, only thinning - right), for the year 2010.

Mixed forest in Europe in the year 2010 is represented in Figure 7: in general, the land covered by mixed forest is mostly available for both clear cut and thinning operations. Mixed forest available only for thinning represents, in almost all European NUTS2, a negligible share of the regional territory.

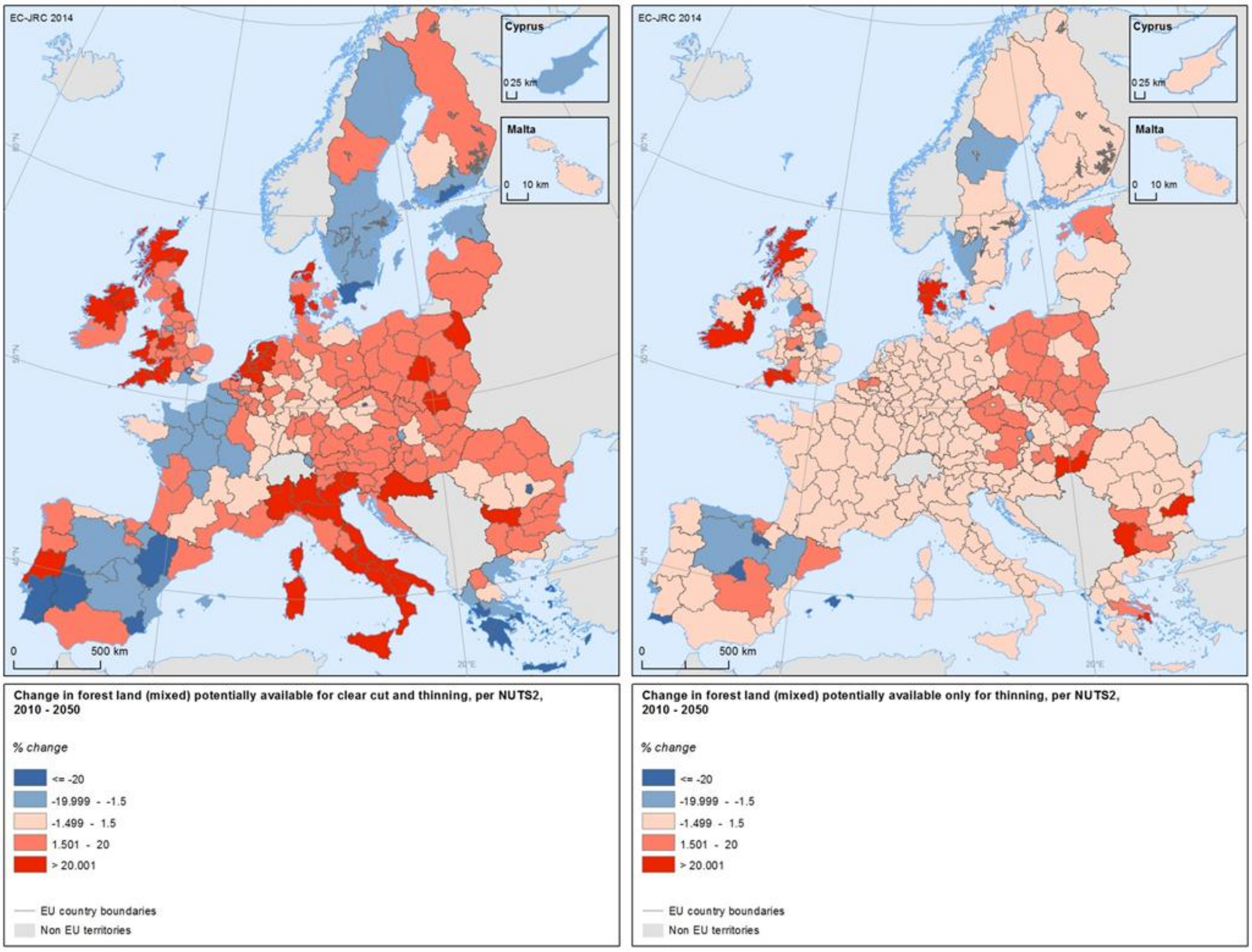


Figure 8. Change in forest land (mixed forest) potentially available for harvesting (combination of clear cut and thinning, left map; only thinning, right map), for the simulation period 2010 2050.

In general, the availability of mixed forest for both clear cut and thinning tend to increase across Europe, following a trend similar to the one observed for the broadleaves. A decrease in the availability of mixed forest land available for clear cut and thinning can be observed in some regions in Sweden, Finland, Estonia, France, Spain, Portugal and Greece.

Mixed forest available just for thinning operations tend to increase up to 20% in few regions of Spain, Ireland, the United Kingdom, Denmark, Poland, Czech Republic, Eastern Austria, Bulgaria, Hungary. In almost all the remaining regions, the changes are very small. Only in very few NUTS2 in Sweden, the United Kingdom, Spain and Portugal, the availability of mixed forest for just thinning operations decreases more sharply.

4.2 Availability of agricultural land for the production of food, feed and energy

Availability of agricultural land for the production of food and feed

The production of food and feed takes place on land allocated to the following land use classes: cereals, maize, root crops, other arable, permanent crops and pasture.

Land not already used for agricultural production, can be converted in one of the above classes if classified as energy crops, forest, transitional woodland, scrubland and other herbaceous vegetation, other natural land and abandoned agricultural land. Thus, the availability of land for the production of food and feed commodities does not correspond to the territorial area of the countries, but to a fraction of it. This can be due to different reasons, the most important of which is the expansion of artificial surfaces, such as residential and industrial areas, which erodes the amount of land potentially available for agriculture, generating an almost irreversible (within the current time horizon the modelling framework) process.

The percentage of land allocated for the production of food and feed at NUTS3 level in 2010 is illustrated in Figure 9, computed as share over the overall territorial area of each region. Some regions in France, the United Kingdom, Italy, Spain, Hungary, Romania and Bulgaria yield the highest food and feed production land shares, exceeding 80% of the total area for those regions. On the contrary, Sweden, Finland, most of the northern regions of the United Kingdom, the Alpine regions in Italy, north Spain and north Portugal are predominantly classified in the least agricultural productive class (ranging from 0 % - 20%). Overall, intermediate classes (from 20% to 60%) are homogeneously distributed across all MS in Europe.

Figure 10 reports relative changes in the land allocated for the production of food and feed, per decade (2010 – 2020, 2020 – 2030, 2030 – 2040, and 2040 – 2050). Throughout all decades, in almost all the NUTS3 of Sweden and Finland, a steady increase of agricultural land allocated for the production of food and feed is observed, mostly above 20% per decade. In Central and Eastern Europe, especially in Germany, in many NUTS3 a decrease in agricultural land is observed in the first two decades, up to 2030. In Poland a similar behaviour is observed, but up to the year 2050.

The 2040-2050 decade is the most stable period, only showing relative changes between -5% and 5% for the land dedicated to the production of food and feed.

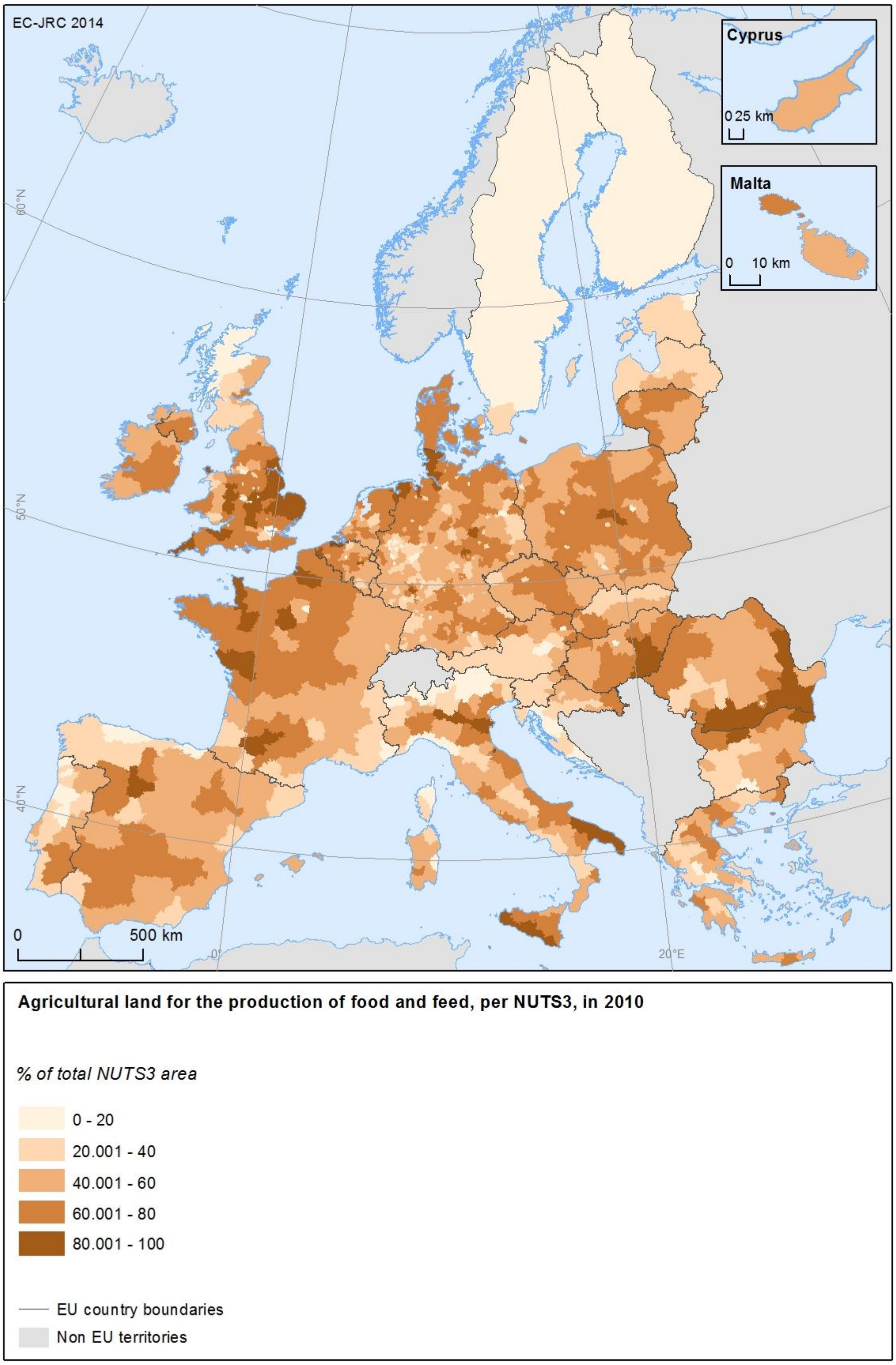


Figure 9. Land allocated for the production of food and feed, at NUTS3 level, in 2010.

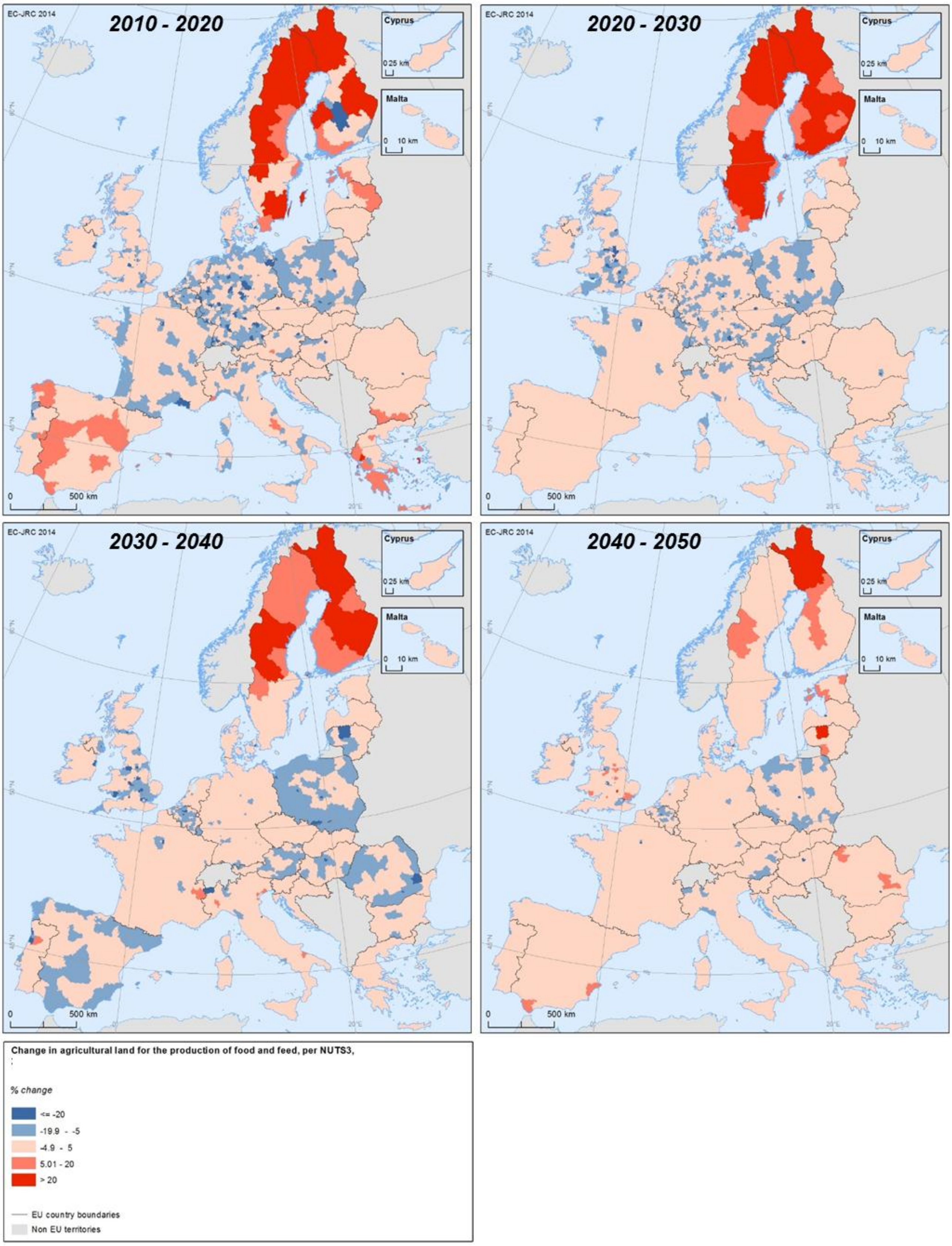


Figure 10. Change in land allocated for the production of food and feed, at NUTS3 level, for the decades 2010-2020 (upper-left map), 2020-2030 (upper-right map), 2030-2040 (lower-left map) and 2040-2050 (lower-right map).

Availability of agricultural land for energy

In the current configuration of LUISA, the production of energy from agricultural land takes place on land allocated to energy crops. Energy crops can be allocated on any of the simulated land uses (Table 1) with the exception of urban and industrial, according to different levels of suitability derived from local biophysical conditions (selected factors: temperature, precipitation, length growing period, frost free days, soil pH, soil texture, soil drained, soil type, slope and salinity.)[5].

The availability of land suitable for the cultivation of dedicated energy crops, is shown in Figure 11 as fraction of the overall available land, classified into five levels of suitability. It is correct noting that the amount of land overall available may change over time. However, since the statistics are presented at country level, they change only marginally throughout the simulation period.

Overall, growing energy crops on high biophysically suitable land results in a reduction of water consumption, inputs use, such as fertilizers and pesticides, thus minimising the associated negative environmental impacts.

On the other hand, the cultivation of energy crops could be in competition with other conventional agricultural crops (e.g. for food and feed) in geographical areas characterised by high suitability levels. In the LUISA configuration herein adopted, food production is given priority in getting access to good quality soils, allowing degraded and contaminated lands to be reclaimed for planting energy crops. Soil salinity, severe erosion areas and contaminated lands (Table 3) are considered as unfavourable conditions for food/feed crops.

[5] Further details on this classification can be found in Perpiña et al. (IN PRESS).

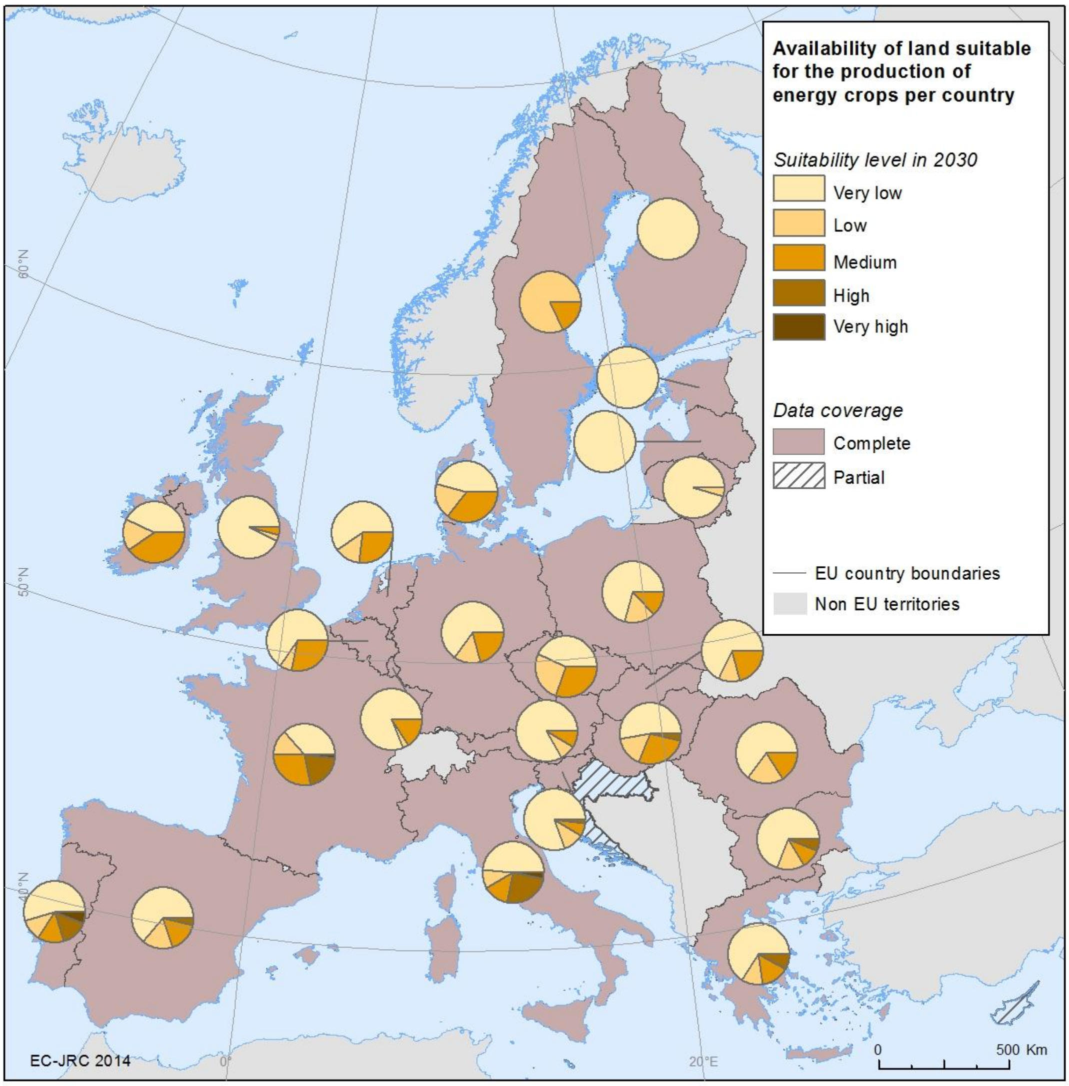


Figure 11. Availability of land for the allocation of energy crops, per suitability level and country-wise, for the year 2030.

Table 3. Unfavourable agriculture soil conditions

Unfavourable soil conditions for agriculture	Description
Saline concentration	Medium and high salinity concentration areas are proposed as potential locations for energy crops, where food-crops might be affected by moderate salinity. The saline concentration areas were compiled from the SINFO project (EC, 2013a) which is based on ESDB.
Severe erosion areas	For agriculture purposes, a severe erosion area is unfavourable due to the lack of soil nutrients and drainage problem. By removing the most fertile topsoil, erosion reduces soil productivity. From the Pan European soil erosion map, very strong, strong and moderately strong erosion levels (expressed in [t/ha/yr]) were selected specifically as potential locations for planting energy crops (EC, 2013b).
Contaminated lands	High concentrations of Cd, Cu, Cr, Pb, Ni and Zn can be linked with human activities such as industrialization and intensive agriculture. The problem definition is similar to soil salinity since contaminated land should not be used for agriculture production. Individual spatial layer for each heavy metal were used in order to establish a threshold to classify an area as contaminated (Micó et.al, 2007). Heavy metals concentration (mg/kg) spatial data is provided by the European soil Portal (Soil Threats Data), and elaborated from the FOREGS Geochemical database at 5km resolution (Lado et al., 2008).

Figure 12 and Figure 13 show the distribution of these three categories (contaminated lands, severe erosion and high saline concentration), at country level, for the year 2030.

Greece (6,945 kha), Italy (5,594 kha), Spain (4,931 kha) and France (4,330 kha) have the highest - in absolute figures - total surface classified as low productive (unfavourable agriculture land) because of contamination, erosion or saline concentration altogether. The analysis of the distribution of the three land conditions for each individual country indicates that for Germany, the United Kingdom, Belgium, Poland, Ireland, the Netherlands and Sweden low productivity is largely due to soil contamination, while for Romania, Hungary, Bulgaria and Cyprus it is almost entirely due to high salinity concentration. Erosion is the only cause for unfavourable condition for Denmark, Lithuania and Latvia.

The detailed geographical distribution of unfavourable agriculture soil conditions is given in Figure 14. Dominant category of soils with presence of contaminated and low productivity lands for the allocation of energy crops. Values for the year 2030 are reported, at NUTS3 level., where the dominant (i.e. with the largest areal extent) low productivity land type is reported at sub-regional (NUTS3) level.

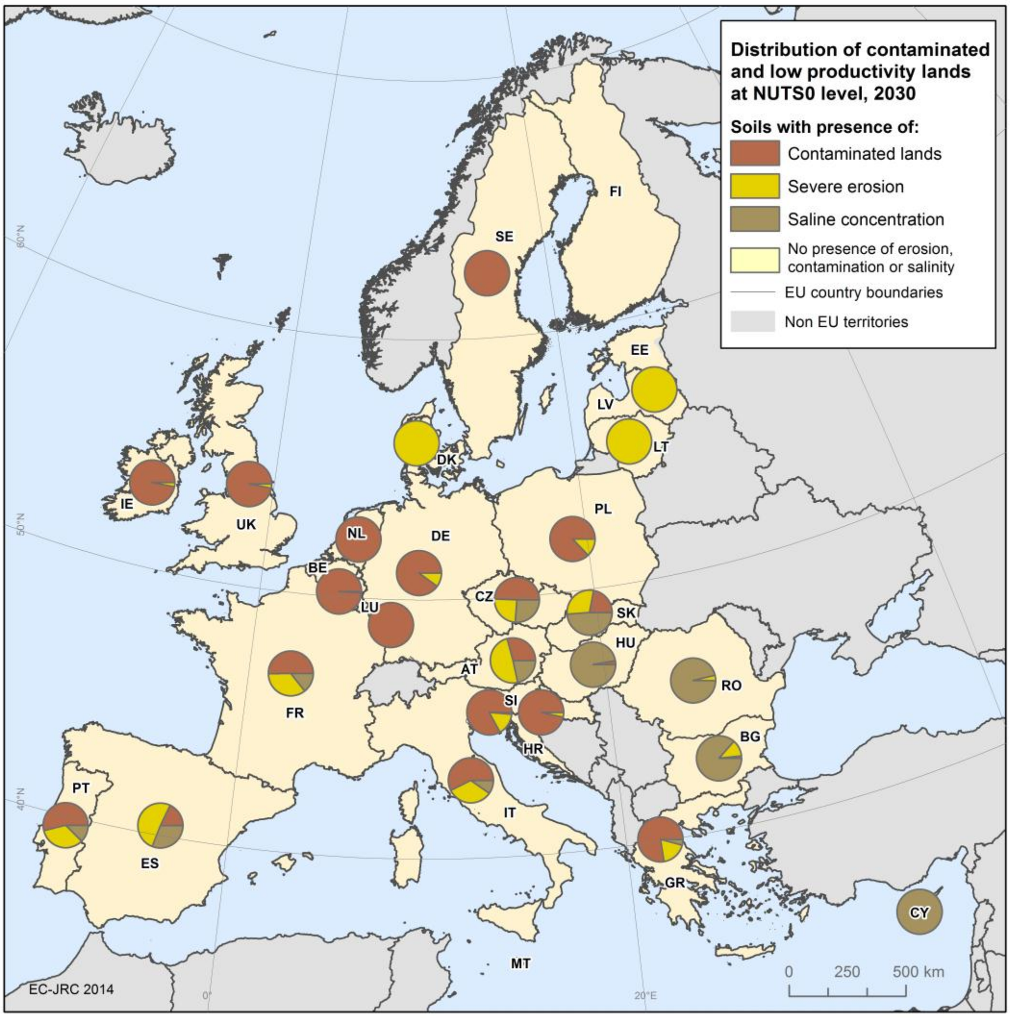


Figure 12. Distribution of different categories of contaminated land on the land available for the allocation of energy crops. Values for the year 2030 are reported, at country level.

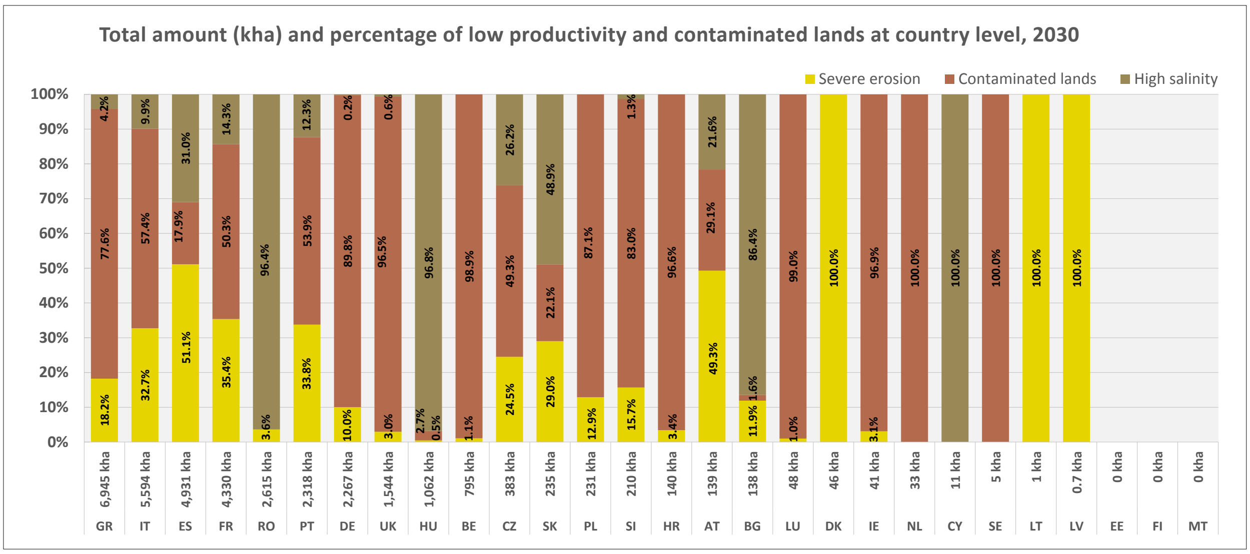


Figure 13. Distribution of different categories of contaminated land on the land available for the allocation of energy crops. Values for the year 2030 are reported, at country level.

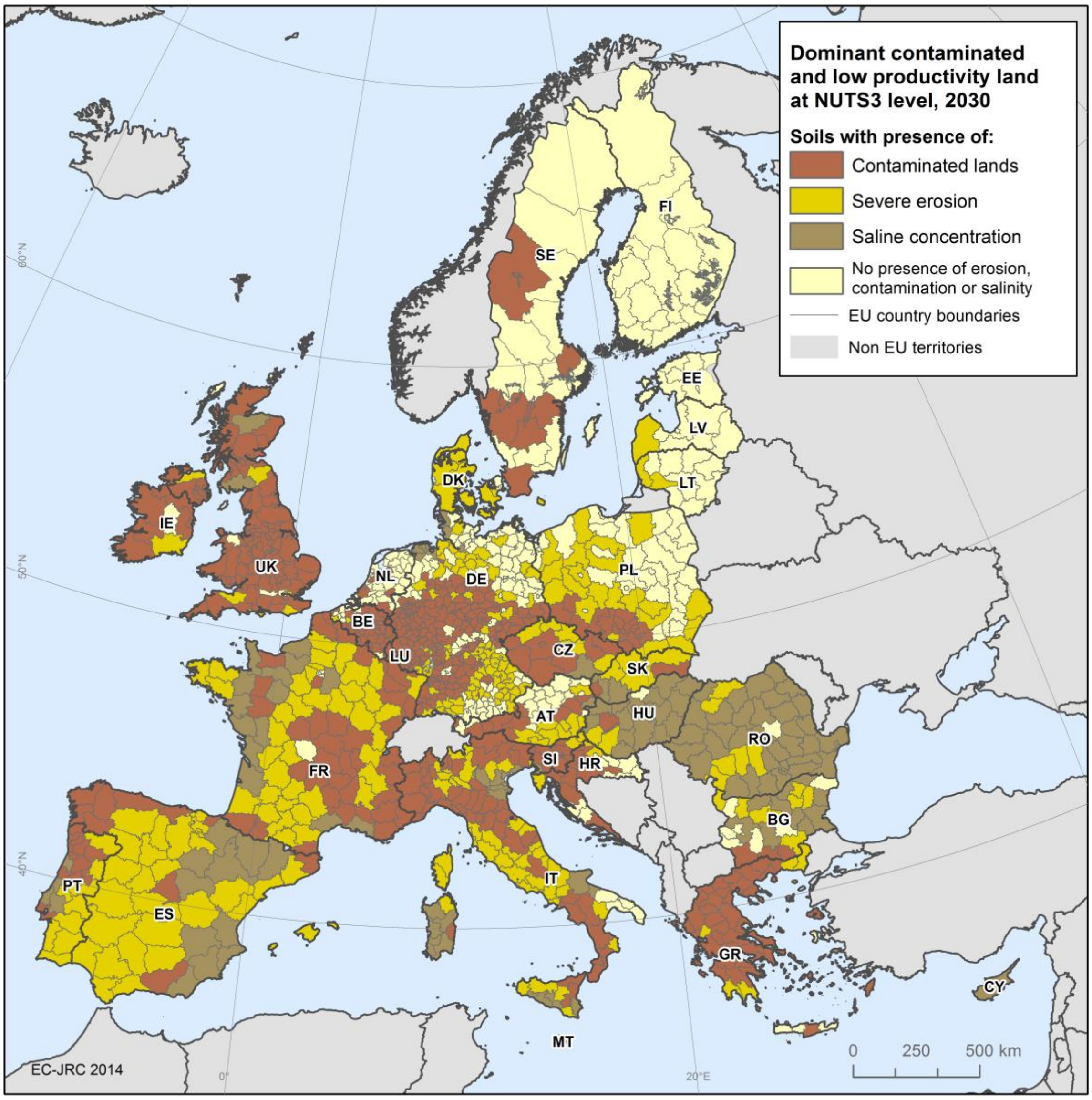


Figure 14. Dominant category of soils with presence of contaminated and low productivity lands for the allocation of energy crops. Values for the year 2030 are reported, at NUTS3 level.

Patterns of contaminated land are especially present in the United Kingdom, Central Europe, North Italy and Greece. Erosion-affected areas are more diffuse in the Iberian Peninsula, Central Italy, France and Poland. Finally, land affected by salinity problems is more present in Eastern Europe (Bulgaria, Romania and Hungary, especially), North-western France and Eastern Spain.

To sum up, the allocation procedure determines where energy crop cultivation, according to biophysical suitabilities and the current land uses, could potentially take place. Subsequently, the model attempts to avoid massive displacement of food production within the current agricultural area, by recovering degraded and contaminated lands (low productivity lands). Further criteria, established in the Renewable Energy Directive (RED - EC, 2009; Table 4) and not binding for solid and gaseous biomass, are next considered as supplemental factors to complete the allocation.

Table 4. Sustainability criteria and parameters in the field of bioenergy production based on the RED.

Sustainability Criteria	Parameters
The loss of habitats of high biodiversity value	Natura2000 areas
	Protected areas
	Wetlands and peat lands
Direct land cover changes	Avoid massive conversion of permanent grassland to arable
	Avoid massive conversion of continuous forest areas into arable land
Indirect land use changes	Preference of using surplus land
Support agro-biodiversity	Maximum extraction rates for primary agricultural residues
High Nature Value farmland	HNV farmland
Areas with high carbon stocks	Wetlands
	Continuous forest and permanent grassland
Negative impacts on soil	Maximum slope limits for cultivation
	Only perennial crops on sites susceptible to soil erosion
Protect soil quality	Maximum extraction rates for primary agricultural residues
	Adapt crop/trees to local biophysical conditions
Prevent overexploitation of water resources	Adapt crop/trees to local biophysical conditions. If irrigation is considered adapt water consumption to regional resources
Air pollutants emissions	Adapt crop/trees to local biophysical conditions
Avoid competition with food production and biomaterials	Preference of using surplus land

Whereas the total amount of energy crops allocated at country level depends on the land demand as specified by the CAPRI model, their distribution at regional and sub-regional level is therefore function of the competition with other land uses, the availability of suitable land and the presence of contaminated or low productivity land. The proportion of allocated energy crops over the total NUTS3 area is reported in Figure 15, for the years 2020, 2030, 2040 and 2050.

For instance, in Romania, along the simulation period energy crops are mainly allocated in the NUTS3 where the presence of forest is scarce and the presence of low quality soils is more diffuse.

In Italy, the demand for energy crops is relatively low (around 1% of the total land demand for forest, food and feed, and energy) and they tend to be allocated on land affected by salinity problems, especially in the proximity of the Po delta, Puglia and in the south of Sicily.

In Poland and Germany, the demand share for energy crops over the total demand for forest land, food and feed, and energy, is among the highest in Europe, reaching more than 10% towards the end of simulation period. Therefore, because of the competition with other land uses, energy crops are preferably allocated in the NUTS3 where erosion, contamination or salinity problems are present. This is particularly evident in Germany, where in the most Southern NUTS3 at the border with Austria, because the soil quality is higher than in the neighbouring regions, energy crops are scarcely present. Similarly, in Poland energy crops are preferably allocated outside the eastern regions. Nevertheless, the presence of protected areas in the south-western regions causes the energy crops to be allocated also on the higher quality land in some NUTS3 in the east part of the country.

The evolution of the potential competition of energy crops with other land uses is shown in Figure 16. It illustrates the change in land available for the allocation of energy crops at NUTS3 level. In the map of the left-hand side, the availability of suitable land is depicted for the year 2020 (when the allocation of energy crops begins), as percentage of the total NUTS3 area. In the map on the right-hand side, the percentage change is reported between 2020 and 2050. The regions where the land available decreases the most, especially in countries characterised by an overall high demand for energy crops, are likely to experience more competition for land. This is likely to happen in some NUTS3 in Poland, the United Kingdom, Lithuania, Hungary and Spain.

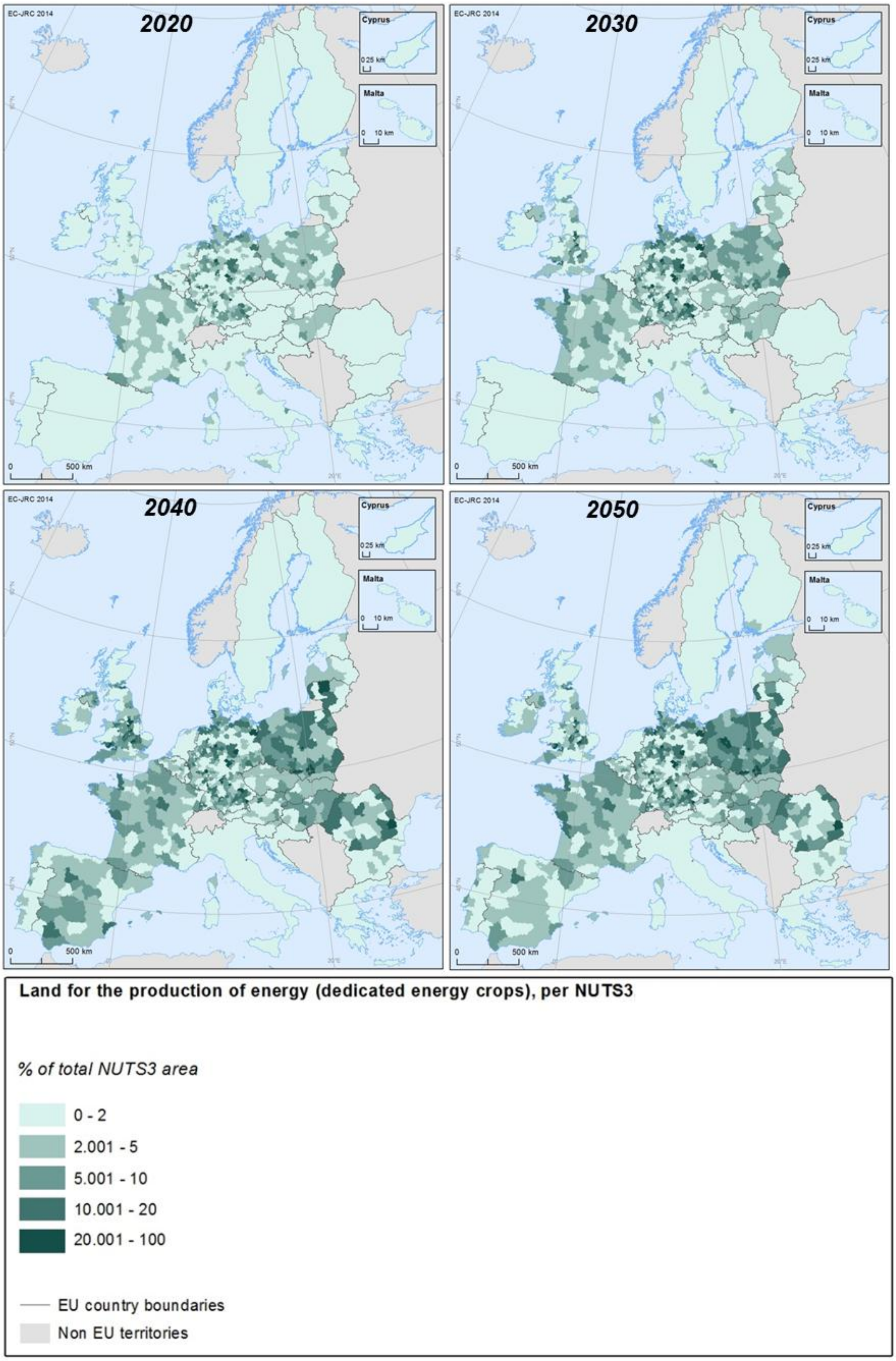


Figure 15. Allocated energy crops, represented as percentage of the total NUTS3 area, for the years 2020, 2030, 2040 and 2050.

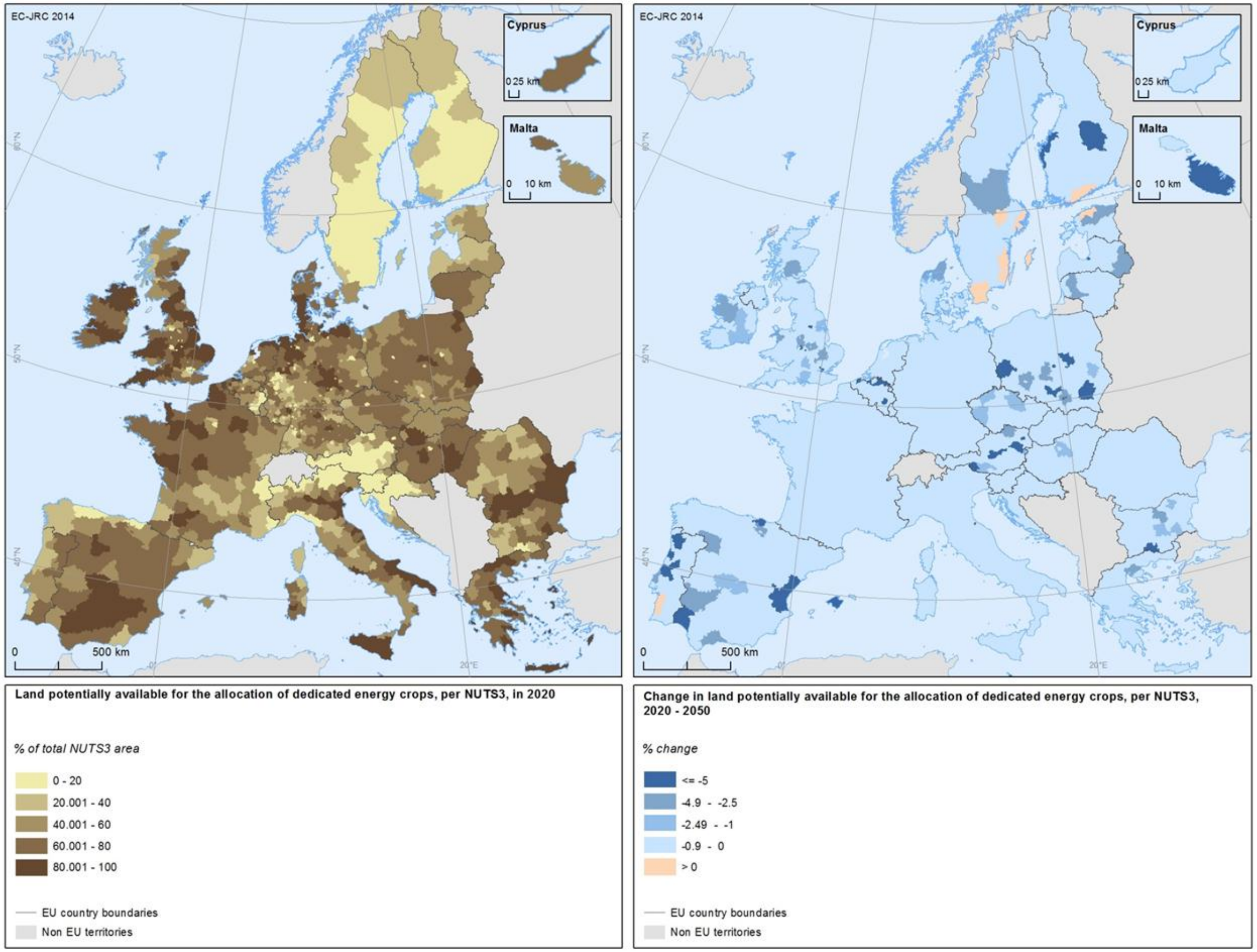


Figure 16. Land potentially available for the allocation of energy crops, represented as percentage of the total NUTS3 area in the year 2020 (left map) and as percentage change between the years 2020 and 2050, at NUTS3 level.

5 CONCLUSIONS AND NEXT STEPS

The LUISA (Land Use Integrated Sustainability Assessment) modelling platform allows for simulating the allocation of different land uses simultaneously, taking into account all the relevant policy constraints and incentives that have a direct impact on the spatial distribution of such uses. At the same time, LUISA allocation mechanisms for both population and all the other land uses (industrial, agricultural or forest), are based on spatially explicit suitability criteria, mainly related to bio-physical characteristics and neighbourhood relationships between the simulated land uses. The resulting simulations thus represent an optimised landscape that satisfy the given land demands, as from the macro-economic and demographic scenario, complying with the spatial policies in place.

Macro-economic models run up-stream of LUISA. EUROPOP for population, GEM-E3 for industry, commerce and services, CAPRI, for agricultural commodities (production of food, feed and energy crops), and GLOBIOM/G4M for forestry, at large scale, country or macro-regional level. Even though they implement modelling mechanisms for checking the availability of resources necessary in order to support the forecasted levels of production, they do not implement a full recursive check on the availability of land.

For certain land uses, such as the cultivation of agricultural activities, it is also important to consider the quality of the land that is being utilised. If in one region the availability of good quality land (suitable for certain types of crops) is limited, and the demand for these specific crops is nevertheless increasing, their cultivation will take place on land of lower quality. In this case, problems might arise because, for instance, additional inputs are needed, in order to obtain economically viable yields. The excessive exploitation of the soil might, in turn, cause or exacerbate environmental problems at regional and local level. In the mid and long term this might also bring negative economic repercussions, because the quality of the land is compromised and its recovery requires long-term and expensive investments.

The analysis of the land demands and the availability of the land devoted to certain land uses described in this report, is therefore an essential step to detect potential competition that might arise in regions where the land demands are close to or exceeding the overall amount of available land.

Future work and current on-going activities are mainly focused on estimating biomass indicators from forest, agricultural land and energy crops. LUISA allocation results from the updated Reference Scenario 2014 are being prepared for the overall European territory, at national and regional level.

Particularly, the indicator on the availability of biomass harvested from forest land, is computed by dynamically linking LUISA and the forestry growth model CBM. Harvested biomass from FAWS and newly afforested land will be presented as the maximum harvested supply, measured in ton of dry biomass for the year 2020 and 2030. In addition, the total biomass harvested on newly forested land, measured in cubic metres, will be estimated up to 2050, based on the CBM model.

The biomass from energy crops will be determine according to the total amount of energy crops aggregated at national and regional level with reference to the total available land (share), the identification of the land uses that will be converted to energy crops, and the amount of energy crops allocated on different suitability levels according to biophysical requirements. The estimation of the energy potential will be calculated using an average conversion factor[6] for woody and herbaceous lignocellulosic crops, established at 18.1 GJ t^{-1} (De Wit, 2010) for the years 2010, 2020, 2030, 2040 and 2050.

A further next step is the analysis of potential impacts on cultivated land, focusing on the allocation of the main crop groups simulated in LUISA. This analysis will allow to identify the regions where the displacement of food and feed is caused by either the expansion of artificial areas or the large increase in forest land or energy crops. The biomass indicator from agricultural residues, mainly from straw, will also be estimated. Straw is the most abundant source of biomass from agricultural production, which can be potentially used for energy purposes (BioBoost project, 2013). This estimation will also take into account spatial restrictions due to the competition with other uses (food, feed and fibre production) and other related to environmental criteria (e.g. nature conservation and soil protection: BEE project; WWF, 2012; Scarlat, 2010; Rettenmeier et al. 2010; Batidzirai et al., 2012).

[6] Conversion factor from energy crops (biomass, tonnes) to biofuel energy equivalent (energy, Joule).

6 BIBLIOGRAPHY

Baraniecki, P., Kołodziej, J., Kozlowski, R.M., Mackiewicz-Talarczyk, M., Mankowski J., 2009. CRES (CENTRE FOR RENEWABLE ENERGY SOURCES). Future Crops for Food, Feed, Fiber and Fuel (4F Crops, FP7-KBBE-2007-1). Task 2.4. Raw materials characteristics of fibre plants in Europe, Poland, 2009. Webpage: http://www.4fcrops.eu/.

Baranzelli, C., Jacobs, C., Batista E Silva, F., Perpiña Castillo, C., Lopes Barbosa, A., Arevalo Torres, J., Lavalle, C., 2014. The Reference Scenario in the LUISA platform – Updated configuration 2014 Towards a Common Baseline Scenario for EC Impact Assessment procedures. EUR 27019. Luxembourg (Luxembourg): Publications Office of the European Union; 2014. JRC94069.

Batidzirai, B., Smeets, E.M.W., Faaij, A.P.C., 2012. Harmonising bioenergy resource potentials—Methodological lessons from review of state of the art bioenergy potential assessments. Renewable and Sustainable Energy Reviews, 16(9): 6598-6630. ISSN 1364-0321, http://dx.doi.org/10.1016/j.rser.2012.09.002.

Batista e Silva, F., Gallego, J., Lavalle, C., 2013a. A high-resolution population grid map for Europe. Journal of Maps 9: 16-28.

Batista e Silva, F., Lavalle, C., Jacobs-Crisioni, C., Barranco, R., Zulian, G., Maes, J., Baranzelli, C., Perpiña, C., Vandecasteele, I., Ustaoglu, E., Barbosa, A., Mubareka, S., 2013b. Direct and Indirect Land Use Impacts of the EU Cohesion Policy: Assessment with the Land Use Modelling Platform. EUR 26460 EN. Luxembourg (Luxembourg): Publications Office of the European Union.

Batista e Silva, F., Lavalle, C., Koomen, E., 2013c. A procedure to obtain a refined European land use/cover map. Journal of Land Use Science 8 (3):255-283.

Britz W and Witzke HP. (2012) Capri model documentation 2012: Version 2. Bonn: Institute for Food and Resource Economics, University of Bonn.

Biomass Energy Europe (BEE) project, 2010. European Commission. Framework Programme 7.

De Mastro, G., Grassano, L., D'Andrea, N., Palumbo, A., 2011. GIS–based evaluation of cardoon suitability in Apulia region. Proceedings of the 19th European biomass conference and exhibition, 6-10 Junio, Berlin (Germany).

DEFRA (Department for Environment, Food and Rural Affairs), 2004. Best practice guide lands. Growing Short Rotation Coppice. For applicants to DEFRA'S Energy Crops Scheme. England

EC, 2009. European Commission. Directive 2009/28/EC of the European Parliament and of the Council on the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

EC, 2013a. European Commission. Joint Research Centre. European Soil Portal – Soil data and information system. Data for the Soil Information System for the MARS Crop Yield Forecasting System (SINFO). Webpage: http://eusoils.jrc.ec.europa.eu/library/data/sinfo/

EC, 2013b. European commission. Joint Research Centre. PESERA project (Pan-European Soil Erosion Risk Assessment). Webpage: http://eusoils.jrc.ec.europa.eu/library/esdac/Esdac_DetailData2.cfm?id=7.

EEA (European Environment Agency), 2013. Webpage: http://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-7

Fernandez J, Curt M.D., 2005. State of the art of the Cynara cardunculus as energy crop. Proceedings of the 14th European Biomass Conference, Biomass for Energy, Industry and Climate Protection, 17–21 October. Paris, (France).

Fernando, M.L., Duarte, M.P., Almeida, J., Boleo, S., Mendes, B., 2010. 4FCROPS- Future Crops for Food, Feed, Fibre and Fuel. WP4 - Task 4.1. Environmental impact assessment of energy crops production in Europe. Facultade de Ciencias e tecnologia, Portugal. (Seventh framework programme).

Fiorese, G., Baranzelli, C., Ciaian, P., Grassi, G., Hiederer, R., Kitous, A., Lavalle, C., M'Barek, R., Pilli, R., Russ, P, Salputra, G., Van Doorslaer, B., 2014. Analysis and modelling of energy, transport and climate change scenarios: future GHG emission from agriculture and forestry - AA AFO-CC, Final report, AA Nr 070307/2010/585065/A4.

Fischer, G., Prieler, S., Van Velthuizen, H., Lensink, S.M., Londo, M., De Wit, M., 2010a. Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures. Part I: Land productivity potentials. Biomass and Bioenergy 34, 159- 172.

Goor F., Davydchuk V. and Ledent J.F., 2001. Assessment of the potential of willow SRC plants for energy production in areas contaminated by radionuclide deposits: methodology and perspectives. Biomass and Bioenergy 21, 225 - 235.

Goor F., Davydchuk V. and Vandenhove H., 2003. GIS-based methodology for Chernobyl contaminated land management through biomass conversion into energy – a case study for Polessie, Ukraine. Biomass and Bioenergy 25, 409 - 421.

Isebrands, J.G., 2007. Best Management Practices Poplar Manual For Agroforestry Applications in Minnesota. Environmental Forestry Consultants, LLC.

Kurz, W.A., Dymond, C.C., White, T.M., Stinson, G., Shaw, C.H., Rampley, G.J., Smyth, C., Simpson, B.N., Neilson, E.T., Trofymow, J.A., Metsaranta, J., Apps, M.J., 2009. CBM-CFS3: a model of carbon-dynamics in forestry and land-use change implementing IPCC standards. Ecol. Model. 220, 480–504.

Lado, R., Hengl, T., Reuter, H.I., 2008. Heavy metals in European soils: a geostatistical analysis of the FOREGS Geochemical database. Geoderma 148, 189-199.

Land Use Consultants, 2007. Bioenergy: Environmental impact and best practice. Final report, Bristol.

Lavalle, C., Baranzelli, C., Batista e Silva, F., Mubareka, S., Rocha Gomes, C., Koomen, E., Hilferink, M., 2011a. A High Resolution Land use/cover Modelling Framework for Europe: introducing the EU-ClueScanner100 model. In Computational Science and Its Applications - ICCSA 2011, Part I, Lecture Notes in Computer Science vol. 6782, edited by B. Murgante, O. Gervasi, A. Iglesias, D. Taniar and B. O. Apduhan. Berlin: Springer-Verlag.

Lavalle, C., Baranzelli, C., Mubareka, S., Rocha Gomes, C., Hiederer, R., Batista e Silva, F., Estreguil, C., 2011b. Implementation of the CAP policy options with the Land Use Modelling Platform - A first indicator-based analysis. EUR 24909 EN. Luxembourg: Publications Office of the European Union.

Lavalle, C., Mubareka, S., Perpiña Castillo, C., Jacobs, C., Baranzelli, C., Batista E Silva, F., Vandecasteele, I., 2013. Configuration of a reference scenario for the land use modelling platform. EUR 26050. Luxembourg (Luxembourg): Publication Office of the European Union; JRC80684.

Micó, C., Peris, M., Recatalá, L., Sánchez, L., 2007. Baseline values for heavy metals in agricultural soils in an European Mediterranean region. Science of the total environment 378, 13-17.

Perpiña Cast illo, C., Baranzelli, C., Mubareka, S., Lavalle, C., IN PRESS. Modelling the spatial allocation of 2nd-generation feedstock (lignocellulosic crops) in Europe. International Journal of Geographical Information Science.

Pilli, R., Grassi, g., Kurz, W.A., Smyth, C.E., Blujdea, V., 2013. Application of the CBM-CFS3 model to estimate Italy's forest carbon budget, 1995–2020, Ecological Modelling vol. 266, pp. 144-171.

Power, J.F., and Prasad, R., 1997. Soil Fertility Management for Sustainable Agriculture. Published by CRC Press.

Rettenmeier, N., Reinhardt, G., Schorb, A., Köppen, S., von Falkenstein, E., Berndes, G., Christou, M., Dees, M., Elefheriadis, I., Goltsev, V., Kunikowski, G., Lakyda, P., Lehtonen, A., Lindner, M., Röder, J., Vasylyshyn, R., Vesterinen, P., Wirsenius, S., Zhelyezna, T. A., Zibtsev, S., 2010. Status of biomass resource assessments - Version 3. Biomass Energy Europe BEE D 3.6. Issue/Rev 1. IFEU (ed.).

UNCTAD (United Nations Conference on Trade and Development), 2008. Biofuel production technologies: status, prospects and implications for trade and development. New York and Geneva.

UNICT (Università degli Studi di Catania Future), 2009a. Crops for Food Feed, Fiber and Fuel (4F Crops). WP2 - Task 2.1. Choice of the crops. Dipartimento Scienze Agronomiche, Agrochimiche e delle Produzioni Animali, Italy. (Seventh framework programme).

UNICT (Università degli Studi di Catania Future), 2009b. Crops for Food Feed, Fiber and Fuel (4F Crops). WP2 - Task 2.6. Cropping posssibilities. Dipartimento Scienze Agronomiche, Agrochimiche e delle Produzioni Animali, Italy. (Seventh framework programme).

Van Slycken S. et al., 2013. Safe use of metal-contaminated agricultural land by cultivation of energy maize (Zea mays). Environmental Pollution 178, 375 - 380.

European Commission
EUR 27018 EN – Joint Research Centre – Institute for Environment and Sustainability

Title: **Evaluation of the land demands for the production of food, feed and energy in the updated Reference Configuration 2014 of the LUISA modelling platform**

Authors: Claudia Baranzelli, Carolina Perpiña Castillo, Carlo Lavalle, Roberto Pilli, Giulia Fiorese

Luxembourg: Publications Office of the European Union

2015 – 50 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9424 (online)

ISBN 978-92-79-44701-3 (PDF)

doi:10.2788/99908

LB-NA-27018-EN-N

JRC Mission

As the Commission's in-house science service, the Joint Research Centre's mission is to provide EU policies with independent, evidence-based scientific and technical support throughout the whole policy cycle.

Working in close cooperation with policy Directorates-General, the JRC addresses key societal challenges while stimulating innovation through developing new methods, tools and standards, and sharing its know-how with the Member States, the scientific community and international partners.

Serving society
Stimulating innovation
Supporting legislation

Publications Office

doi:10.2788/99908

ISBN 978-92-79-44701-3