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An assessment of dedicated energy crops in Europe under the EU Energy Reference Scenario 2013

Application of the LUISA modelling platform - Updated Configuration 2014

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Executive summary

The development of a sustainable and efficient energy system is one of the biggest challenges of the EU. As population and energy demand are increasing, renewable energies can play an important role contributing to reduce GHG emission, fossil fuel dependencies, social and economic development, more security of supply, and, in the end, more sustainable energy production development (IPCC, 2011). It is stated that renewable energy sources (RES) can help to a more sustainable energy mix in many regions and countries in Europe. However, renewable energy development is not risk free. Potential impacts have been studied over the last few decades using many diverse approaches and methods. Here, we present a Territorial Impact Assessment (TIA) based on land system dynamics focusing on the cultivation of crops solely dedicated to energy production and displacement on other land uses.

The Land Use-based Integrated Sustainability Assessment (LUISA) modelling platform has been applied to assess regionally the direct and indirect impacts arising from EU energy, transport and climate policies, as included in the EU Energy Reference Scenario 2013[1], with time horizon up to 2050. Besides this, other important drivers for increased competition for land (regional demographic and economic trends, investments in cohesion and infrastructural measures and environmental legislation) are included in the LUISA reference configuration 2014 (also referred to as 'updated configuration 2014') (Baranzelli et al., 2014). This spatial-explicit modelling approach would help to understand main sustainability and land competition issues, e.g. to what degree do urbanisation, industrialisation and an expected growing dependence on energy crops cost Europe valuable soil needed for food provision.

This report presents the main drivers, policies and methods used in the LUISA modelling platform to allocate land dedicated to energy crop (ENCR) production and assess to what extent such allocation might cause adverse land-use impacts up to 2050. Such impacts are directly related to the conversion from other land uses, such as arable land and forest, to land for ENCR plantations. Dedicated energy crops are considered non-food crops, mainly perennial grasses such as *miscanthus* or *switchgrass* and short rotation coppice such as *willow* or *poplar*. The main purpose of the ENCR cultivation is to produce biomass for the production of energy within a short time period. Projections for agricultural commodities and dedicated energy crops are derived from the Common Agricultural Policy Regional Impact (CAPRI) model, in consistency with the overall energy demand set in the EU Energy Reference Scenario 2013.

In the LUISA simulation framework, the land to be allocated for the cultivation of ENCR enters in competition with the agriculture and forestry sectors, in particular with land required for the production of food and feed, since built-up surfaces (e.g. for residential or economic purposes) are not affected. In the simulation, the use of degraded and contaminated lands (e.g. low productivity lands for food and feed) for ENCR is prioritised in the allocation process, to avoid massive displacement of food production within the current agricultural area.

According to the EU Energy Reference Scenario 2013 as implemented in LUISA, about 10.6% of land uses would change across the EU28 during the period 2010-2050. Within this change, the largest shift occur between agricultural land-use categories (35%). The increase of forest areas and expansion of ENCR are the second most important land use conversions over the period of analysis (18% and 17% of all land use changes respectively). Land transformations related to sprawl of urban fabric and related to economic developments are on average 3% and 1% of the total land use changes.

[1] EU Energy, Transport and GHG Emissions – Trends to 2050
http://ec.europa.eu/energy/observatory/trends_2030/index_en

In particular, ENCR occupy 4,733 kha in 2020 and 13,549 kha in 2050, which represent, on average, 1.3% and 3.6% of Europe's total available land. Poland, France, Germany, Spain, Romania and the United Kingdom are the largest ENCR producer countries, accounting all together for 83% of the total European acreage. At regional level, the European average of ENCR is approximately 3.2% and 7.5% of the total available land in 2020 and 2050 respectively. However, in some regions, ENCR exceed more than 20% of total land available i.e. in Düsseldorf and Köln regions (Germany) and in the Cheshire region (United Kingdom).

From a land-use/cover flow perspective (land that is converted from one land-use/cover type to another) the dominant flow contributing to the ENCR expansion in 2050 is the conversion from land for food and feed production, making up to 89.7% (121,281 km^2) of the total land-use changes. The second largest land flow towards ENCR comes from forests, followed by natural lands, with respective shares of 9.7% (13,252 km^2) and 0.6% (882 km^2). The highest impact occurs in Poland, Slovakia, Romania and France with more than 30% of the land-use changes due to convertion to ENCR. The main concern associated with the agricultural land losses is mainly the reduction of food and feed production. This circumstance might lead to a predominant situation of agricultural intensification with its associated environmental impacts (for instance on soils, water and biodiversity).

As indicated, food and feed production is undergoing a land reduction and also a displacement caused by the large increase of ENCR. Clearly, land suitable for the cultivation of arable crop is taken by ENCR the most, especially in Poland, Romania, Hungary, Germany and Austria reaching near 30% on those countries. The growth of residential and ICS (industry, commercial and services) sites, together with the introduction of ENCR, can exacerbate the competition for land resources, potentially causing food and feed crops to be allocated on land not highly suitable for their production. On the other hand, countries such as Italy, France, Portugal, Spain and Greece are losing the most fertile lands for energy production in favour of urban fabric and other economic activities. Once a piece of land is converted to an artificial surface, it is unlikely to become again agriculture land (for food, feed or energy) in the future.

In this modelling framework, some land categories with potential for ENCR production can provide positive environmental benefits. Degraded and contaminated lands converted to ENCR production account for 24% (2030) and 36% (2050) of the total energy crop production. In particular, Italy, Spain, Hungary, the United Kingdom and France, with high energy crop production, are recovering efficiently degraded and contaminated lands (more than 50% in most of their regions) while Germany and Poland, thought being part of the group of high producer countries of ENCR, do not practically make use of those land categories.

The overview of the main findings of the study is further provided with factsheets on ENCR allocation per Member State (MS), also including a regional analysis. From the factsheets, it is possible to group MSs under two main profiles. Italy, Spain, Hungary, the United Kingdom and France belong to the first profile: countries in which the production of ENCR is high and very much coming from the exploitation of degraded and contaminated lands; Germany and Poland also belong to this group but making a less efficient use of degraded and contaminated lands. Austria, Czech Republic, Bulgaria, Luxemburg and Belgium belong to the second profile: countries in which ENCR production is rather low but the exploitation of degraded and contaminated lands is high. In the case of Ireland, Sweden, the Netherlands, Lithuania, Slovakia and Slovenia, the figures show either very low or near zero allocation of ENCR on these land categories.

Some European policies currently integrate the conservation and preservation of biodiversity from different perspectives. In light of this, the relationship between changes in ENCR production and the provision of a set of ecosystem services (water retention, pollination potential, habitat quality for farmland birds, green infrastructure and nature-based recreation opportunities) is analysed for the Reference Scenario. In LUISA, ecosystem services are considered as land functions that provide a variety of services to people. The multiple regression models using each ecosystem service as dependent variable reveals that the growth rates of ENCR production affects in different ways the provision of these services. While pollination potential and habitat quality for birds are expected to decrease due to the expansion of dedicated energy crops, in the case of recreational opportunities and water retention (related to prevent flooding and to maintain soil moisture) the patterns are less evident. Finally, a loss of the Green Infrastructure network occurs as a consequence of the foreseen ENCR development.

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Abstract

This report presents a comprehensive analysis of dedicated energy crops (ENCR) performed with the LUISA (Land Use-based Integrated Sustainability Assessment) modelling platform across Europe between 2020 and 2050. LUISA is configured in compliance with the "EU Energy, Transport and GHG emissions trends until 2050" document in order to ensure that the EU meet its climate and energy targets up to 2050 (EU Reference Scenario 2013, updated LUISA configuration 2014). The spatial modelling of ENCR in LUISA requires determining a set of elements such as the land demand, availability and suitability of the land, and other land categories for the ENCR cultivation. Thus, the assessment is focused on the following steps:

1) Land accounts and dominant land use/cover flows for the expansion of energy crops at European scale,

2) A suitability analysis of the land dedicated to these crops based on suitability maps,

3) Recuperation of degraded and contaminated lands for energy purpose,

4) A detailed regional analysis per each Member State (factsheets) with a summary of the main important findings, and

5) Evaluation of energy crops' impacts on a selection of environmental indicators (provision of ecosystem services).

In LUISA, the displacement and cultivation of crops solely dedicated to energy production takes place on a specific land-use class named 'energy crop' (ENCR), which competes in particular with the demand for others land-uses, such as for food, feed and forest.

The amount of ENCR reaches about 13,549 kha in 2050 that represents, on average, 3.6% of Europe's total available land. This expansion occurs mainly at expenses of land for food and feed (90%). Forest and natural land (9% and 1%,) represent respectively the second and third land flows towards ENCR among total land-use changes (with these flows represented respectively 9 and 1% of all land use changes).

As result of this land competition, there is an increasing shift of food and feed crops towards low quality land, due not only to the ENCR expansion but also to the growth of residential and economic-driven land uses. It should also be noted that intensive agriculture practices for ENCR production might have some negative impacts on soil, water, biodiversity, amongst others. Owing to this potential impacts, the analysis performed on the supply of a set of ecosystem services identifies some services more sensitive than others to ENCR growth. In particular, pollination potential, habitat quality for birds and also the Green-Infrastructure network are expected to decrease due to ENCR growth, while patterns for recreational opportunities and water retention services are less evident.

List of abbreviations and definitions

CAP	Common Agricultural Policy of the European Union
CAPRI	Common Agricultural Policy Regionalised Impact Modelling System
CLC	Corine Land Cover
ENCR	(Dedicated) Energy Crops
EU	European Union
EUCLIMIT	European Climate Mitigation modelling platform
GI	Green Infrastructure
ha	Hectares
HNV	High Nature Value farmland areas
IPCC	Intergovernmental Panel on Climate Change
Kha	Thousands of hectares
LCF	Land cover/use flows
LUISA	Land Use Integrated Sustainability Assessment modelling platform
MS	Member State
NREAP	National Renewable Energy Action Plants
NUTS	Nomenclature of Territorial Units for Statistics
RED	Renewable Energy Directive
RES	Renewable energy sources
T.W.	Transitional woodland-shrubs
UNFCCC	United Nations Framework Convention on Climate Change

Glossary

This glossary defines the terminology used in the following technical reports listed below. All the concepts and corresponding definitions are coherent with the LUISA modelling platform configuration, as from Baranzelli et al. (2014).

Baranzelli, C., Perpiña Castillo, C., Lavalle, C., Pilli, R., Fiorese, G. (2014). 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. EUR 27018 EN. Luxemburg: Publication Office of the European Union.

Baranzelli, C., Perpiña Castillo, C., Lopes Barbosa, A., Batista E Silva, F., Jacobs-Crisioni, C., Lavalle, C. Land allocation and suitability analysis for the production of food, feed and energy crops in the period 2010 - 2050 EU Reference Scenario 2013 LUISA platform – Updated Configuration 2014. EUR 27018. European Commission; 2015. JRC98567.

Barbosa, A.L., Perpiña Castillo, C., Baranzelli, C., Aurambout, J.P., Batista e Silva, F., Jacobs-Crisioni, C., Vallecillo Rodriguez, S., Vandecasteele, I., Kompil, M., Zulian, G., Lavalle, C. 2015. European landscape changes between 2010 and 2050 under the EU Reference Scenario. EU Reference Scenario 2013 LUISA platform – Updated Configuration 2014. EUR 27586. European Commission; 2015. JRC98696.

Abandoned land

Land that was previously used to produce economic output (agricultural production, houses for residential purposes, industrial production, etc.) and that is no longer used for that purpose.

Abandoned land is land in a not productive state, which can be reclaimed back to the original use or possibly converted to other uses, in case demand for such uses be.

Agricultural land

Land that is used for the production of crop for food, feed and energy. Corresponding classes in LUISA are: cereals, maize, root-crops, permanent crops, other arable, pasture and dedicated energy crops (see Annex II, Table 6 for the definition of agriculture land-use classes in LUISA).

Available land for energy crops

Land available for the production of energy crops is land that, if need be, can be converted from a pre-existing use or cover (e.g. food and feed production, shrub land, etc.) to the cultivation of dedicated energy crops. The only simulated land uses considered not available for being converted to dedicated energy crops, are urban and industrial.

Built-up

Aggregated land use class, including land used for residential and industry/commerce/services uses. Built-up land constitutes a subset of the total artificial areas, which include transport infrastructures as well.

Degraded and contaminated land

Land affected by contamination and, in general, degradation processes that affect its quality. In particular, the following categories are identified: soils with high/medium saline concentration, soils affected by severe erosion, and soil contaminated by heavy metals. All these categories are considered potentially suitable for the expansion of energy crops.

Energy crops

Crops dedicated to production of energy. This category comprehends non-food, lignocellulosic crops, belonging to the 2nd generation feedstock. Species included are both herbaceous and woody: miscanthus, switchgrass, reed canary, giant reed, cardoon, willow, poplar and eucalyptus.

Food and feed crops

Crops used for the production of food and feed, grouped in: cereals, maize, root crops and other arable. The specific agricultural commodities included in each of these groups are determined by the CAPRI model (see Annex II, Table 6).

Forest

Forest land is simulated as a unique land cover class, encompassing the categories conifers, broadleaves and mixed forests.

Indirect land use change (ILUC)

Dedicated energy crop production typically takes place on cropland, which was previously used for other agriculture such as growing food or feed. Since this agricultural production is still necessary, it may be partly displaced to previously non-cropland such as grasslands and forests. This process is known as indirect land use change (ILUC).

Industry/commerce/services land

Land that is used for industrial activities, commerce and services.

Land accounts

The key focus of land cover accounts is the understanding of the way in which the stocks of different land covers and uses change over time.

Land use/cover flow

Land use refers to the purpose that the land serves, such as recreation, wildlife habitat or agriculture, without the need to describe the surface cover present on the ground. For example, a recreational type of land use could occur in a forest, shrub land, grasslands or on manicured lawns.

Land cover refers to the surface cover on the ground, be it vegetation (natural or planted), urban infrastructure, water, bare soil or other. For instance, forest, as land cover may be used for timber production, wildlife management or recreation.

Land use/cover flows refers to transfers (gains and losses) of land area between different use/cover types.

Land-use allocation

It is the spatial distribution of the land among different functions, assuming the land requirements dictated by macro drivers and modelled by specialised sector models. The spatial allocation mechanism is based on a multinomial discrete choice method and it is governed by local biophysical suitabilities, socio-economic and neighbourhood factors, land-use transition rules and policy constraints/incentives.

Land demand

Also referred to as land claim and land requirement, it is the amount of land that, in a specific geographical context (national or sub-national) and in a given year of the simulation horizon, is demanded/claimed/required in order to satisfy the assumed economic and demographic projections.

Land take

The area of land that is taken by artificial uses, such as residential buildings and supporting infrastructures/services, industry/commerce/services, and transport infrastructures and supporting areas.

Natural land

Natural land comprises transitional woodland-shrub, forest and other natural lands. This last group, in turn, includes scrub and/or herbaceous vegetation associations, natural grassland, moors and heathland and sclerophyllous vegetation.

Suitability of the land

The biophysical suitability of the land to be cultivated for the production of food and feed crops (cereals, maize, root crops and other arable) and energy crops. Though cereals, maize, root crops, other arable and energy crops are part of the agriculture land, the allocation of the land for food/ feed and energy response to different suitability maps.

Each food and feed crop mentioned above has a dedicated suitability layer, whose main components are related to soil characteristics, climate, current agricultural patterns and potential application of fertilisers. Each of these suitability layers is expressed on a scale from 0 – not suitable, to 1 – very suitable.

For energy crops, the land suitability is based on soil properties and climate conditions (see for more detailed explanation Annex III), plus three land categories (soils with moderate/high salinity, soils affected by severe erosion and soils with high heavy metal concentrations) considered unfavourable for food and feed production. Eight suitability maps, one per each energy crop, represent the land suitable (in a ranking from 0 –not suitable to 100-very suitable) for the allocation of ENCR.

Total available land

Total available land refers to all the simulated land-use classes with the exception of urban and industrial land (simulated land-use classes), infrastructures, other nature, wetlands and water bodies (non-simulated land-use classes).

Transitional woodland

Bushy or herbaceous vegetation with scattered trees. It can represent either woodland degradation or forest regeneration / recolonization

Urban land

Land that is predominantly used for residential purposes, including areas hosting local services to the population, such as sport and leisure facilities, and green urban areas.

1. Introduction

1.1 Context and scope

The 'Land-Use-based Integrated Sustainability Assessment' modelling platform (LUISA) is primarily used for the ex-ante evaluation of EC policies that have a direct or indirect territorial impact. To address the competition for land arising from the energy and climate dimensions of EU policies, the LUISA modelling platform has been configured according to the EU Energy Reference Scenario 2013 (updated configuration 2014)[2] to produce high-resolution land use/cover projections up to 2050 and a related series of thematic indicators. The updated configuration 2014 in LUISA take into account the Climate and Energy legislative package (December 2008) which established a range of measures to mitigate climate change and promote renewable energy (Council of the European Union 2008). This package was designed to aid in achieving the EU's overall environmental targets by 2020: a 20% reduction in greenhouse gas (GHG) emissions from 1990 levels, a 20%share of renewable energy in the EU's total energy consumption and a 20%improvement in the EU's energy efficiency. Therefore, the EU targets for 2030 are not implemented in the LUISA Configuration 2014.

In line with this, the EU will also need to take into account the impact of bioenergy on the environment, land use and food production.

With this push towards using more renewable resources, non-food crops are foreseen to play an increasingly important role. These are referred to (lignocellulosic) energy crops grown specifically for their fuel value (BEE project, 2010). One of the main advantages of using dedicated energy crops is that most of the crops are able to adapt to a wide range of climate and soils conditions, meaning that they can successfully be grown on lands not ecologically suited for conventional farming practices (Land use consultants, 2007; UNICT, 2009b; Fernando et al., 2010). Degraded and contaminated lands could therefore potentially be recovered by planting such ENCR, so reducing the current land abandonment in agriculture and offer an option to limit the impact of displacing food and feed production from current farmland sector (Goor, 2001a, 2003b; Van Slycken et al., 2013).

From an environmental point of view, the following impacts should be considered : 1) greenhouse gas emissions due to the changes on land use, 2) soil impacts (soil carbon and soil structure) such as the decline of organic carbon and increasing soil erosion rates directly associated to agricultural activities, 3) water and air impacts since some of the energy crop species require considerable volumes of water and the use of pesticides and fertilizers, and 4) biodiversity impacts might be locally significant but depend also of the crop type and management. Semi-natural habitats, as listed on the Habitat directive, deserve special attention if they were replaced by dedicated energy crops, since significant biodiversity losses could occur (Allen B, 2014).

The relationship between dedicated energy crop cultivation and ecosystem is the main reason of exploring here the potential impact on the provision of services across Europe. In this study, the main findings of this environmental impact assessment are described focus on five ecosystem services (pollination potential, habitat quality for birds, water retention, recreational potential and GI-network). In addition, some EU regions from The Netherlands, Estonia, Poland, The United Kingdom and Spain were selected as case studies in order to illustrate the impact of increasing ENCR production on the selected indicators.

[2] An updated (2015) definition of Reference Scenario is currently under preparation and still not available. Therefore, the analysis hereby presented has been carried out on the basis of the most up-to-date available macro-economic scenario, including the current policy provisions.

This work is a compilation of three previous technical JRC reports in the framework of LUISA modelling platform:

The first report is focused on the land demand and the availability of land allocated to different uses (Baranzelli et al., 2014a). The demand for forest and agricultural land, including dedicated energy crops, can potentially exert considerable pressure on the competition for land resource in the EU.

The second report describes the stocks and the main land cover/use flows (LCF) taking place in Europe and the processes that cause those flows, thus providing insight on how the European landscape might change in the Reference Scenario (Barbosa et al., 2015).

The third report explores in detail the land uses that are expected to be in direct competition as a result of the EU bioenergy targets (land for food and feed on one hand and land for energy crops on the other hand), and considering the suitability characteristics of the land for these uses. The results presented highlight where and how the displacement of food and feed crops from highly suitable land to lower levels of suitability can take place due to, inter alia, the expansion of dedicated energy crops (Baranzelli et al., 2015).

The herein report presents an overview of how energy crops are modelled in the LUISA platform, carrying out an assessment of how the spatial allocation of these crops unfolds throughout Europe over the period 2020 to 2050. LUISA modelling platform is used to determine future allocation of these crops, based on biophysical suitability maps as one of the main mechanism for the allocation. A policy Reference Scenario is used (EU Reference Scenario 2014 updated configuration), which takes into account current EU policy.

1.2. An introduction to the LUISA modelling Platform

LUISA is based on the principle that different land uses (or functions) compete for the most suitable locations, given available land, assumed demand and policy constraints or incentives. The actual allocation of each land-use is governed by an optimization approach so that, given the modelling assumptions (Baranzelli et al., 2014), the resulting projected landscape represents the best spatial distribution of the land functions (i.e. a system optimum, see Lavalle et al., 2011). This implies that each land-use transition (change) causes trade-offs between different uses (or functions).

LUISA receives direct input from several external models covering different aspects such as demography, economy, agriculture, forestry and hydrology. These sector-specific models define the main macro assumptions that drive LUISA. A more detailed information about LUISA, its structure, macro-economic models and further applications can be seen in Annex I.

In order to assess the development of dedicated energy crops in LUISA, diverse elements are needed: land demand[3] and other Reference Scenario characteristics, biophysical suitabilities, spatial interaction between land classes (neighbourhood effect), competition for different land-uses as well as conversion rules and transition costs between land-uses.

Through this report, these components are described and the main findings of modelling the spatial allocation of ENCR from 2020 to 2050 in EU28 are analysed.

[3] 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 future projections are not driven by any macro-economic sectoral model (see Table 5). The crops contained in each agriculture land-use class in LUISA can be seen in Annex II, Table 6.

1.3. Dedicated Energy crops in LUISA

Different definition for dedicated energy crops can be found from literature. It has been selected the following from Allen B. (2014) for its concurrence with our study:

"Dedicated energy crops can be defined as crops that are unsuitable for human or animal consumption and are grown for the purpose of producing biomass for energy in an agricultural rather than forestry context".

In LUISA, agricultural land is used for the allocation of arable land, permanent crops, pastures and dedicated energy crops (see Annex II, Table 6 for the distintion between agriculture land-use classes). However, through the report, it is made the distinction between land for food and feed production and land exclusively used for energy purposes (energy crop plantations). Not all land-use/cover classes can be converted into energy crops. Thus, land available for the cultivation of energy crops is land that, if need be, can be converted from a pre-existing use or cover (e.g. food and feed production, shrub land, etc.) to energy crops. The only simulated land uses always considered not available for being converted to dedicated energy crops, are urban and industrial lands.

In the current modelling exercise, dedicated energy crops are foreseen to appear in Europe from the year 2020 onward according to Common Agricultural Policy Regionalised Impact analysis model CAPRI (see Annex II for more detailed information). This analysis compares the years 2020 and 2050 and highlights different allocation patterns between ENCR and the other land-use classes, along the simulation period. In compliance with CAPRI specifications, dedicated energy crops are hereinafter regarded as non-food (lignocellulosic) crops. Lignocellulosic crops generally fall into two categories: herbaceous grasses and woody crops (see Fisher et al., 2010a; UNCTAD, 2008). Eight species were included in the simulation, specifically, five herbaceous and three woody crops (Short rotation Coppice) as shown in Table 1.

Table 1. Categories and species of energy crops considered in LUISA's simulation

Category	Description	Species
Herbaceous energy crops	Herbaceous energy crops are considered as perennial grasses. These grasses are usually harvested on a yearly basis over several years without the need for ploughing up and new planting. They regrow from their roots and do not require replanting for 15 years or more.	Miscanthus (Miscanthus spp.), Switchgrass (Panicum virgatum), Reed canary grass (Phalaris arundinacea), Giant reed (Arundo donax) and Cardoon (Cynara cardunculus)
Woody crops (Short rotation coppice)	Woody energy crops are typically short rotation coppices (SRC). SRC is a farming method with the purpose of producing high yields in terms of generating energy within a short time period. The cycle of harvest and re-growth can be repeated every three years on average, up to an expected life cycle of 25 years(Land Use Consultants, 2007, The Research Park, 2009) (corresponding to around 6 harvests).	Willow (Salix spp.) Poplar (Populus spp.) Eucaliptus (Eucaliptus spp.)

1.4. An overview of the European landscape under the Reference Scenario

The analysis of the total land stock and flow highlights trends at the European scale associated with the assumed macro-economic scenario (EU Reference Scenario 2014 updated configuration).

According to the LUISA simulation, about 10.6% (461,328 km^2) of land-use/cover types changes across the EU during the period 2010-2050. In particular, built-up areas (i.e. artificial areas comprising urban and industry/commerce/services) increase by 28,222 km^2 (10.3%) and forested land grows by 63,223 km^2 (4%). The expansion of ENCR shows a net increase of **135,412 km^2**, taking into account that, in the model, they start their development from 2020 onwards. Natural areas declined the most in terms of both absolute value (123,272 km^2) and percentage change (42.4%). Agricultural land shrank by 5.4%, which represents a loss of 107,392 km^2. Figure 1 reports the future projections of the main land-use classes at European scale, highlighting the expansion of ENCR (grey dark line) over the simulation horizon.

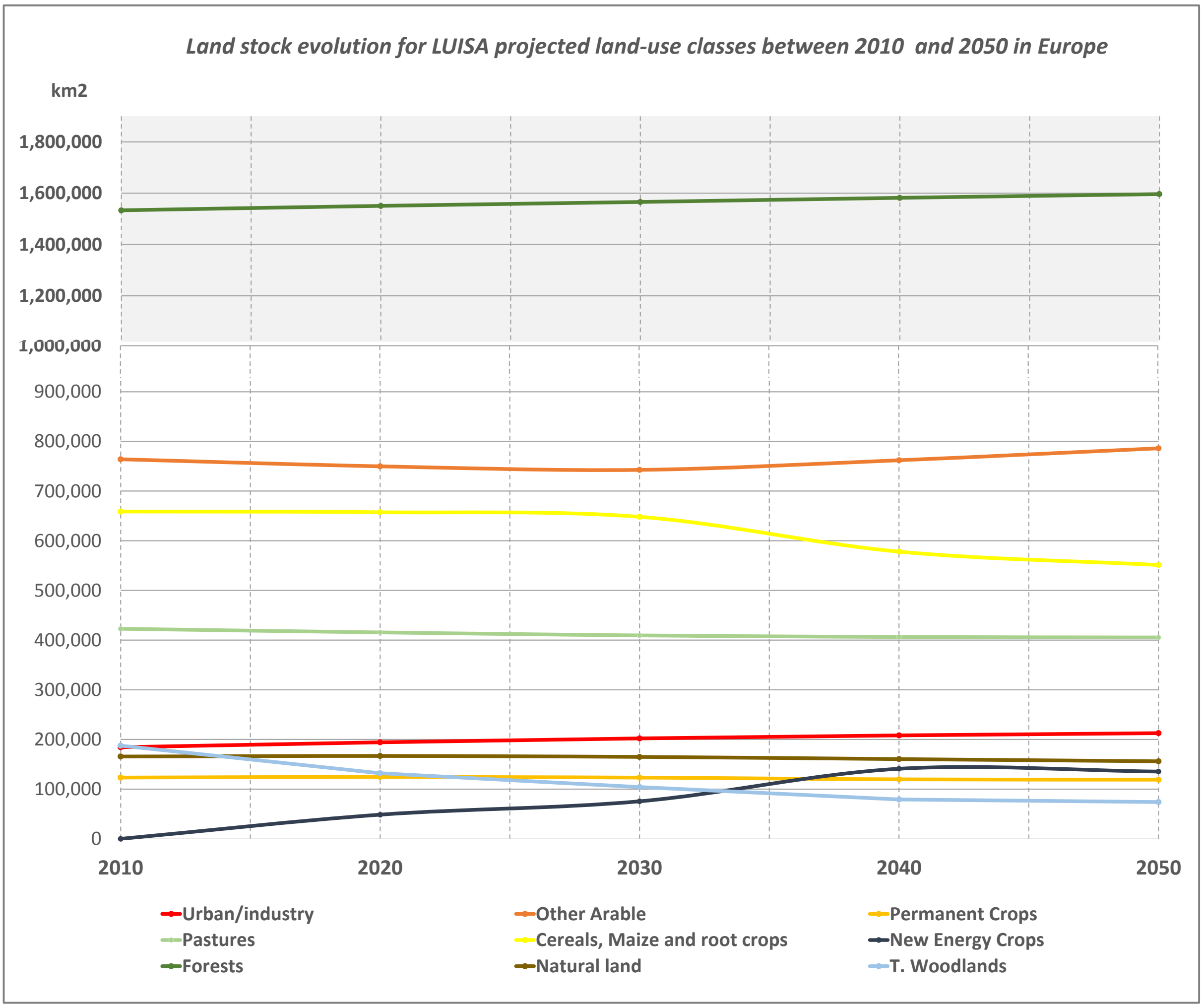


Figure 1. European trends (2010 – 2050) of the land-uses classes included in the LUISA modelling platform under the Reference Scenario (updated configuration 2014)

The land cover/use flows represent, between two points in time, the losses of one land use category to another land-use/cover type ("consumption") and the creation of new areas (“formation”) (EEA, 2006). Between 2010 and 2050, the dominant LCF is the conversion between farming types (internal conversions of land dedicated to food and feed), making up 35% of the total land use changes. The second largest LCF is the creation of forest[4], followed by the **expansion of dedicated energy crops[5]**, with respective shares of 18% and **17% of total land use changes**. The expansion of agricultural land accounts for 12% of the total land-use changes; at the same time, 7% of land previously used for agricultural purposes is expected to be converted to other uses. A more detailed description of the methods applied to compute land stock and flows can be found in (Barbosa et al., 2015).

1.5. The structure of this report

The remainder of this report is organized as followed. Chapter 2 provides an overview of essential components needed to model the spatial allocation of dedicated energy crop in LUISA in EU28. Chapter 3 analyses in detail the impact on other land uses due to the expansion of ENCR. Afterwards, the total amount of energy crop production (absolute figures and shares) is presented at national and regional level from 2020 to 2050. In addition, an assessment of the land suitability and the use of degraded lands for energy crop production is performed. This chapter ends with detailed information (factsheets per individual MS) on local land impacts due to the production of dedicated energy crops (linked to the Annex IV). Chapter 4 presents how land conversion to bio-energy crops impacts a selection of environmental indicators. Chapter 5 draws the main conclusions of the analysis presented in the report. Finally, four annexes and the glossary provide further information regarding different aspects of the modelling exercises.

[4] Forest creation and management comprises all the conversion from other land-uses to forest

[5] Energy crops expansion comprises all the conversion from other land-uses to energy crops

2. Modelling dedicated energy crops in Europe within LUISA

This section is focused on the basic elements needed for modelling energy crops in LUISA. In particular, the sections below describe the demand for land dedicated to energy crop production, the land available for this purpose, the identification of highly suitable land, the potential for reconversion of degraded and contaminated lands to produce energy, and other criteria .

2.1. Land demand for energy crops

In the context of this report, "land demand" is referred to as the amount of land that, in a specific geographical context (e.g. a region) and in a given year of the simulation horizon, is required in order to satisfy the assumed economic and demographic projections.

As indicated, land demand for ENCR for the period 2010 to 2050 was derived from CAPRI. CAPRI is a spatial agro-economic model of agricultural commodity markets at European scale (Britz, 2012) which assesses the impacts of the Common Agricultural Policy (CAP) at NUTS 0 and NUTS 2 level.

One of the main novelties of the Reference Scenario implementation in LUISA (Lavalle et al., 2013; Baranzelli et al., 2014a) was the introduction of a new land-use class: land dedicated to energy crops (ENCR). According to the projections provided by CAPRI, ENCR start to appear in Europe around the year 2020 and, in most of the countries, have a pick towards the end of the simulation period (see Annex 2 for further information).

2.2. Availability of the land for energy crops

In the current configuration of LUISA, the production of energy from agricultural land takes place on land allocated to energy crops. **ENCR can be allocated to any of the simulated land uses** (Annex I, Table 5) **with the exception of urban and industrial land** (simulated land-use classes), **infrastructures, other nature, wetlands and water bodies** (non-simulated land-use classes). **Land for energy crops therefore enters in competition with land for food, feed, and forest.** The availability of land suitable for the cultivation of ENCR is a fraction of the overall available land, which change over time in order to satisfy the land demand imposed by the exogenous macro-economic models. A comprehensive analysis of land demand and the availability of land allocated to different uses is given in Baranzelli et al. (2014a).

The evolution of the potential competition of ENCR with other land uses is shown in Figure 2. It illustrates the change in land available for the allocation of ENCR 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 ENCR begins), as percentage of the total NUTS3 area.

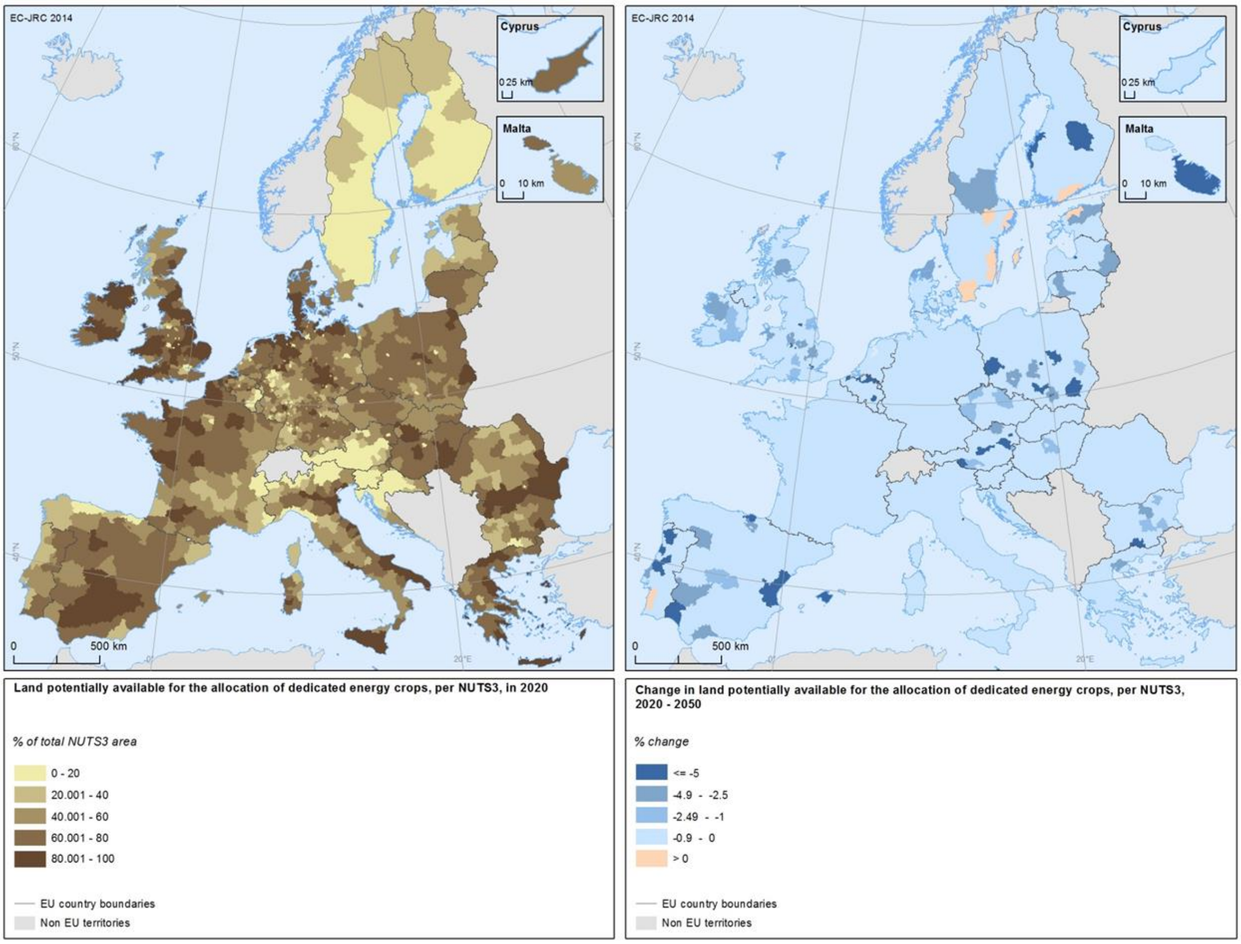


Figure 2. Land potentially available for the allocation of ENCR, represented as percentage of the total NUTS3 area in the year 2020 (left map) and as percentage change between the years 2020 and 2050, at NUTS3 level. *Source*: Baranzelli et al., 2014a.

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 ENCR, 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.

2.3. Suitable land for energy crops

The agriculture land-use allocation depends strongly on the land suitability for specific crops. Suitability maps are one of the main components driving the allocation of crops in LUISA together with, amongst other elements, policy-related spatial layers and allocation rules based on neighbourhood relations between different land-uses/covers. A new set of agriculture suitability maps were implemented within LUISA to improve the spatial distribution of the crop commodities as given by the CAPRI model. Baranzelli et al. (2014b) fully describes the characteristics and use of these spatial maps for food and feed production. For dedicated energy crops, a suitability map was developed, as briefly described below (Perpiña et al., 2015).

Biophysical and environmental information for each of these crops (see Table 1) is required in order to identify the most suitable location for their successful development, according to their adaptability to different regions of Europe. In terms of ecological requirements, a number of relevant factors were established according to topographical aspects, soil quality (physical and chemical characteristics) and climate conditions. Eleven factors maps (biophysical variables) were identified as being the most relevant according to an extensive literature review[6] and consultation with experts. These selected factors were: temperature, precipitation, length-growing period, frost-free days, soil pH, soil texture, soil drained, soil type, slope and salinity. Each factor corresponds to a spatial thematic layer with Pan-European extent. These biophysical variables (factor maps) were combined to create a suitability map for each energy crop in the context of multicriteria analysis (MCA) technique. A more detailed information about the methodology applied and the final suitability maps can be found in Annex III.

2.4. Degraded and contaminated land used for energy crop production

The cultivation of ENCR could be in competition with other conventional agricultural crops, i.e. for food and feed in geographical areas characterised by high suitability levels (e.g. soil fertility) of the land. In order to avoid a massive displacement of land devoted to food and feed production, priority is given to food production in getting access to good quality soils, allowing degraded and contaminated lands to be reclaimed for planting ENCR.

Soils with high saline concentration, severe erosion affected-areas and lands contaminated by heavy metals have been defined as unfavourable for the production of food and feed whereas they are well suited for energy crop production (see Figure 11). In fact, some of the selected lignocellulosic energy species have particular ecological properties that allow them to grow in such affected/degraded soils. The description of these soil conditions can be found in Table 2.

Table 2. Degraded and contaminated lands.

Soil characteristics	Description
Saline concentration	Medium salinity concentration areas are proposed as potential locations for ENCR, where food-crops might be affected by moderate and high salinity. The saline concentration areas were compiled from the SINFO project (EC, 2013a) which is based on ESDB (European Soil Data base).
Severe erosion	For agriculture purpose, 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 (t/ha/yr), very strong", "strong" and "moderately strong" erosion levels were selected as potential locations for planting ENCR (EC, 2013b).
Metals Contamination	High concentrations of Cd, Cu, Cr, Pb, Ni and Zn can be linked with human activities such as industrialization and intensive agriculture. The problem is similar to soil salinity since contaminated land should not be used for food and feed

[6] Baraniecki et al., 2009; DEFRA, 2004, The Research Park, 2009; De Mastro et al., 2011; Fischer, 2010; Fiorese and Guariso, 2010; Garcia et al.,2010; Bauen et al., 2010; Aylott et al., 2008; Teagasc, 2010; Finch et al., 2009; Kuhlman et al., 2012; Milovanović et al., 2011; Wisconsin Reed Canary Grass, 2009; IEA bioenergy, 2012; Biocard, 2009; Esser, 1993.

	production. Individual spatial layer for each heavy metal are used in order to establish a threshold from which an area is considered 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 3 and Figure 4 show the projected distribution of these three categories (contaminated lands, severe erosion and high saline concentration) and their shares, at country level, for the year 2030[7].

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, Greece, Portugal, Croatia and Sweden degraded lands are 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.

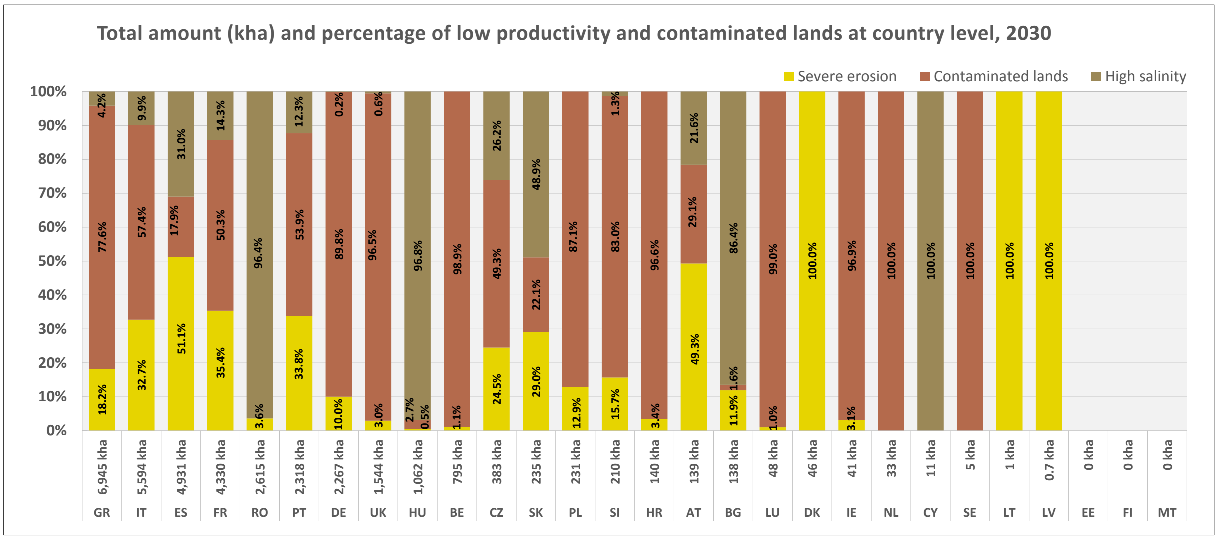


Figure 3. Distribution of different categories of degraded and contaminated land over the available land. Values for the year 2030 are reported, at country level. *Source*: Baranzelli et al., 2014a.

[7] It should be noted that, although degraded and contaminated lands are represented as a static layer during the simulation period (2010 – 2050), their shares related to the total available land for agriculture (including for food, feed and energy) vary as result of the yearly-based allocation process.

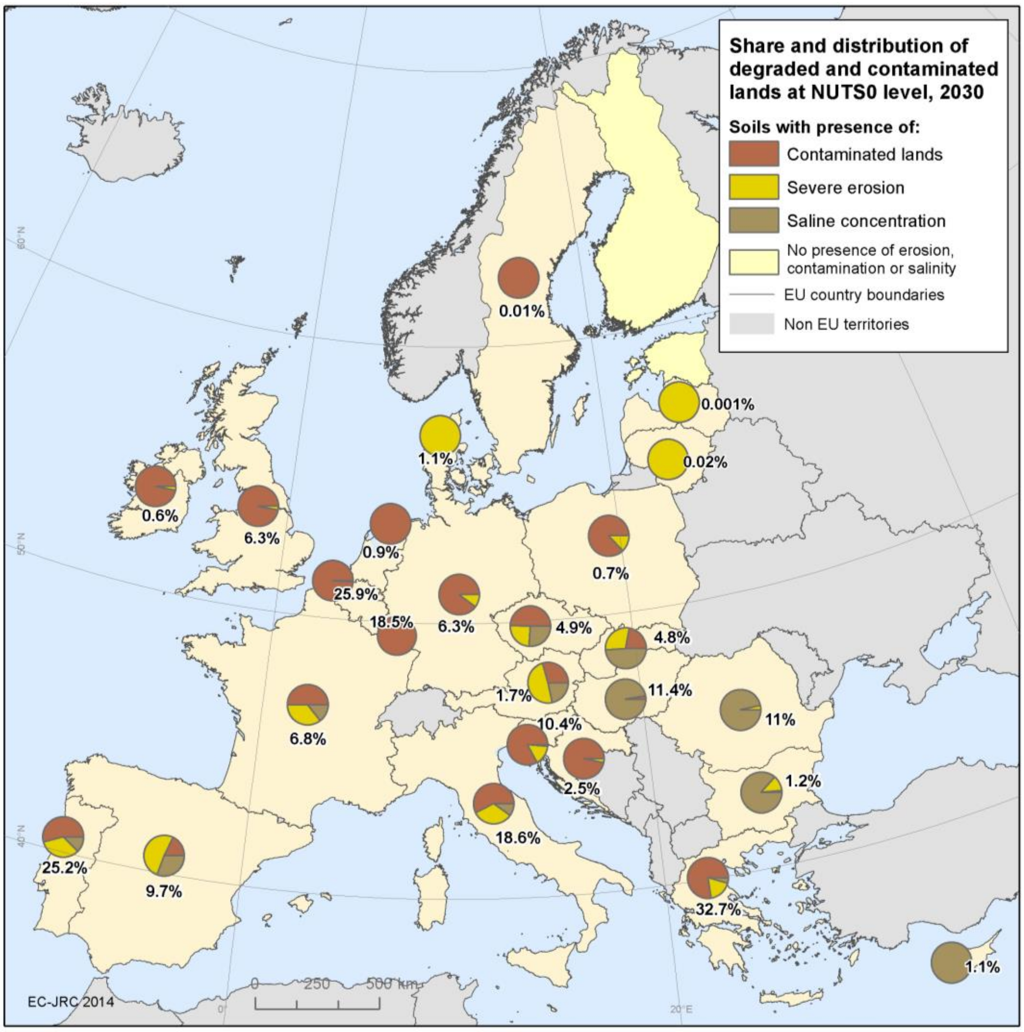


Figure 4. Shares and types of degraded lands reported, at country level, as a percentage of the total available land (all the simulated land-use classes except urban and industry lands) for the year 2030.

The shares reported in Figure 4 represent the percentage of degraded and contaminated lands on the land available for the production of food, feed and energy, at country level and for the year 2030. Of the countries studied, seven countries (Greece, Belgium, Portugal, Italy, Luxembourg, Slovakia, Romania and Slovenia) are above a 10% share. This fact is due especially to contaminated lands in central Europe, north Italy and Portugal 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.

2.5. Other criteria

In the LUISA modelling framework, 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 for ENCR (low productivity lands for food and feed).**

A set of additional criteria (Table 3), are also considered in the allocation of ENCR.

Table 3. Additional criteria used for allocating ENCR (adapted from the Renewable Energy Directive).

Criteria	ENCR Allocation rule
The loss of habitats of high biodiversity value	Natura2000 areas: ENCR excluded
	Protected areas: ENCR excluded
	Wetlands and peat lands: ENCR excluded
Indirect land use changes. Avoid competition with food/ feed and biomaterials	Use surplus (left-over) land for ENCR
High Nature Value farmland	HNV farmland: ENCR avoided if demands is satisfied elsewhere
Areas with high carbon stocks	Wetlands: ENCR excluded
Negative impacts on soil	Set maximum slope limits for ENCR cultivation
	Only perennial ENCR on sites susceptible to soil erosion
Protect soil quality, air pollutants emissions	Adapt ENCR to local biophysical conditions (suitability layers)

3. Assessment of the spatial allocation of energy crops in Europe

In this chapter, the simulated allocation of ENCR is analysed in detail up to 2050. Results are presented at different scale: European, Member State and regional. The assessment covers different aspects that involve the production of dedicated energy crop, such as the displacement of other land uses due to such expansion and the main consequences. A detailed analysis of the use of degraded and contaminated lands for production of energy crops, together with a suitability analysis of the land used to cultivate energy crops, is also carried out.

3.1. Energy crops from a European perspective: land accounts

According to the LUISA simulation for the Reference Scenario 2014 (updated configuration), energy crops in EU28 will occupy 4,733 kha in 2020 and 13,549 kha in 2050, which represent, on average, 1.3% and 3.6% of Europe's total available land. This corresponds to an increase of 186% between 2020 and 2050, with significant variability between Member States. Poland, France, Germany, Spain, Romania and the United Kingdom are the countries that contribute the most, in terms of acreage, to the production of ENCR, accounting all together for 83% of the European acreage (Figure 5).

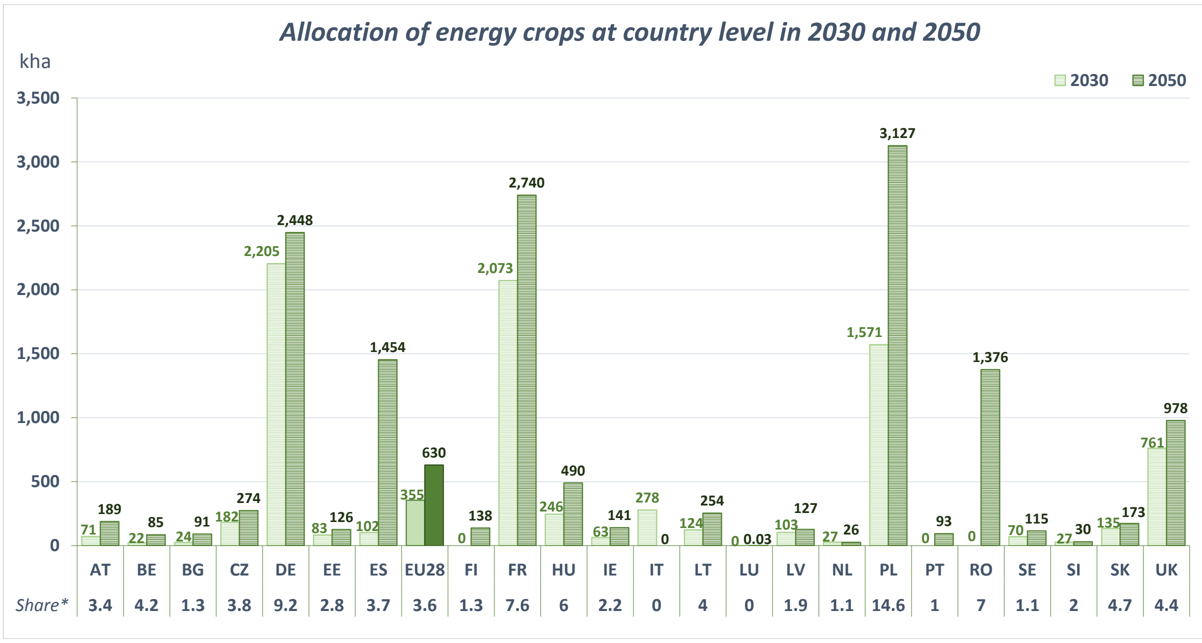


Figure 5. Amount of land, expressed in thousands of hectares, occupied by ENCR on total available land, at country level, for the years 2030 and 2050 in EU 28. Country values are represented by striped background; solid background indicates the European average. *Share represents the percentage of ENCR allocation over the total available land (all simulated land-use classes except urban and industry lands) per MS in 2050.**

In the final year of the simulation (2050), the area of ENCR reaches up to more than 3,000 kha (Poland), whereas the tiniest presence is below 100 kha (Luxembourg, Bulgaria, Belgium, Slovenia, the Netherlands and Portugal). It must be noted that, according to the CAPRI model projections, ENCR are not forecasted to be introduced in Denmark, Greece, Croatia, Malta and Cyprus.

Though it is important to analyse the quantification of the changes regarding the ENCR production over a time period, it is also relevant to analyse the land cover/use flows taking place in Europe. For that objective, the flow account of the expansion of ENCR can provide more precise information about the land consumed by such expansion (i.e., the losses endured by other land-use categories)[8].In the EU28, around 17% of all land use changes between 2020 and 2050 are associated to land-use changes towards ENCR.

Over the whole period (up to 2050), the expansion of ENCR shows a **net increase of 135,479 km^2** taking into account that, in the model, they start to be allocated in 2020. The highest impact occurs in the central part of Europe, in particular in Poland and Slovakia, in Romania and France, with more than 30% of the land-use changes taking place towards ENCR. The **dominant land flow contributing to the energy crop expansion in 2050 is the conversion from land for food and feed production to energy crops**, making up to 90% (121,281 km2) of the total land-use changes.

The second largest land flow toward ENCR comes from forests, followed by natural lands, with respective shares of 10% (13,252 km2) and 1% (882 km^2). Concerning the reconversion of abandoned agricultural land (arable land, pastures and permanent crops) to ENCR production, the contribution is about 0.03% (43 km^2) of the total changes. **The main concern associated with the agricultural land losses is mainly the reduction of food and feed production. This circumstance might lead to a predominant situation of agricultural intensification with its associated environmental impacts** (for instance on soils, water and biodiversity).

Figure 6 reports an overview of the total production of ENCR along with the land uses consumed by expansion of these crops at country level. Two groups are represented in the figure to make the interpretation easier and highlight its relevance. The first group corresponds to food and feed production classes that includes cereals, maize, other arable, permanent crops, root crop, pastures (see Annex II, Table 6 for the identification of crops belonging to each agriculture land-use class in LUISA) and their associated abandoned lands. The second group represents natural lands that comprise transitional woodland-shrub, forest and other natural lands (see the glossary for the definition of this terms).

Figure 6 should be interpreted in the following way. The map reports the total and relative presence of energy crops: taking Poland (PL) as example, the reported share (14.6%) corresponds to the percetange of ENCR on the total available land. The green colour scale shows the total amount of ENCR (measured in kha):above 3,000 kha in the case of Poland. On the left and right hand sides of the map, additionla information is reported: the blue text erefers to the absolute amount of energy crops allocated ("ENCR" - 3,127 kha in Poland) and the total available land (A.land - 21,417 kha in Poland). The light orange horizontal bars represent the share of ENCR that has expanded on land previously devoted to food and feed production (98.7% in Poland). Finally, the brown horizontal bars represent the share of ENCR that has expanded on natural land (about 1.3% in Poland).

[8] From urban residential, industrial/commerce/services, arable land, pastures and permanent crops, forest, Transitional-woodland, natural land woodland-shrub and agricultural abandoned to dedicated energy crops.

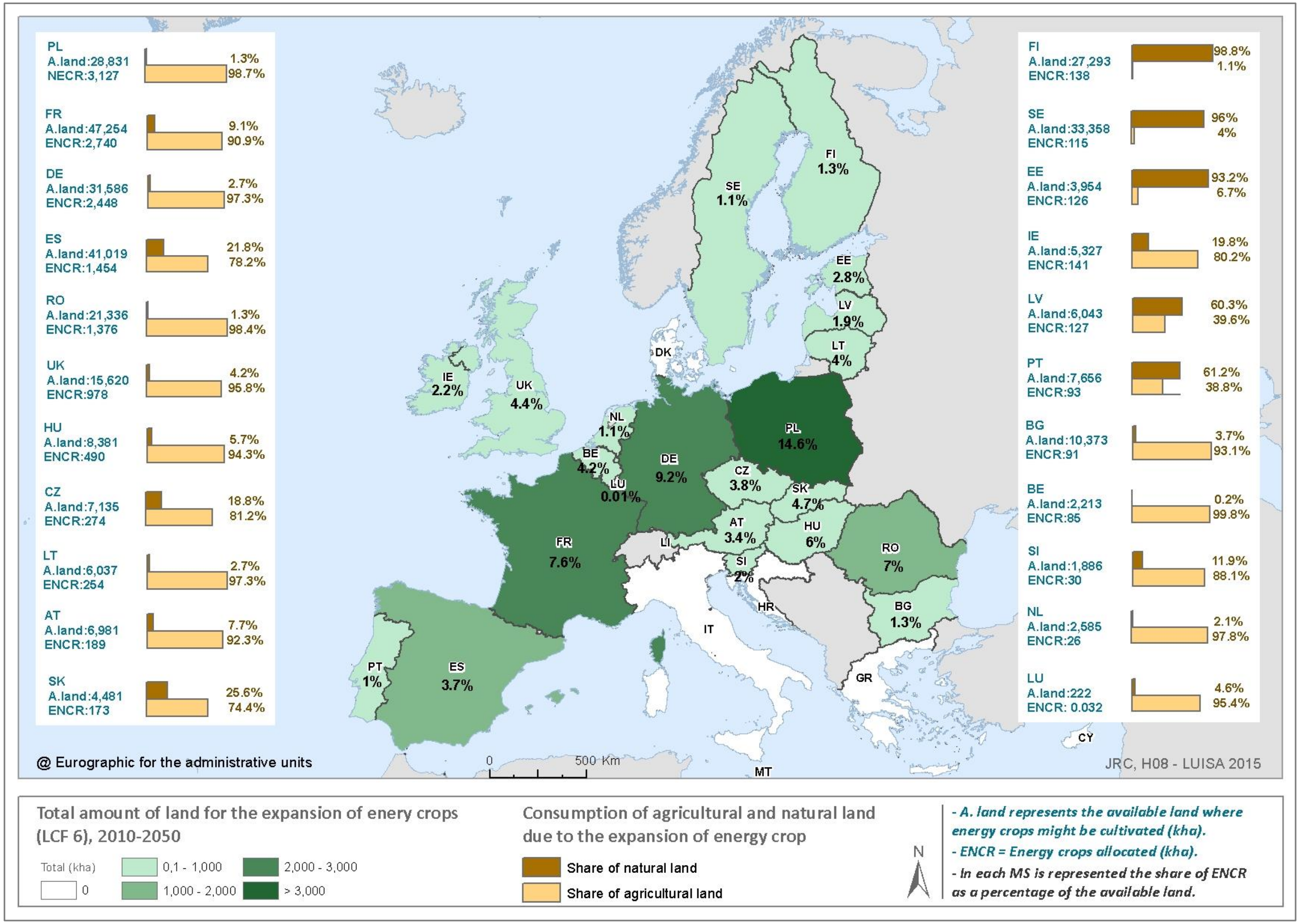


Figure 6. The central figure reports the amount of ENCR land at MS level in 2050, as total area and as percentage of the total available. Column bars (right and left side graphics) represent the percentage of the land-use conversion from natural land (transitional woodland-shrub, forest and other natural lands) and agricultural land (cereals, maize, other arable, permanent crops, root crop, pastures and their associated abandoned lands) due to conversion to ENCR, for each country between 2010 and 2050. The Available land (Kha) and the ENCR allocation (kha) at MS level is included and sorted by decreasing order (from the highest producer countries to the lowest).

In Sweden, Finland, Estonia, Latvia, and Portugal mainly natural lands are used for the expansion of ENCR. The remaining countries are predominantly losing agricultural lands due to ENCR expansion. Agricultural land loss for ENCR is particularly high in Belgium, the United Kingdom, the Netherlands, Germany, Poland, Romania, Bulgaria, Latvia and Slovenia.

A regional analysis (Figure 7) presents the expansion of ENCR as a result of conversion from other land-use categories. In this case, a more disaggregated classification is shown in order to identify the dominant land uses consumed by energy crop production.

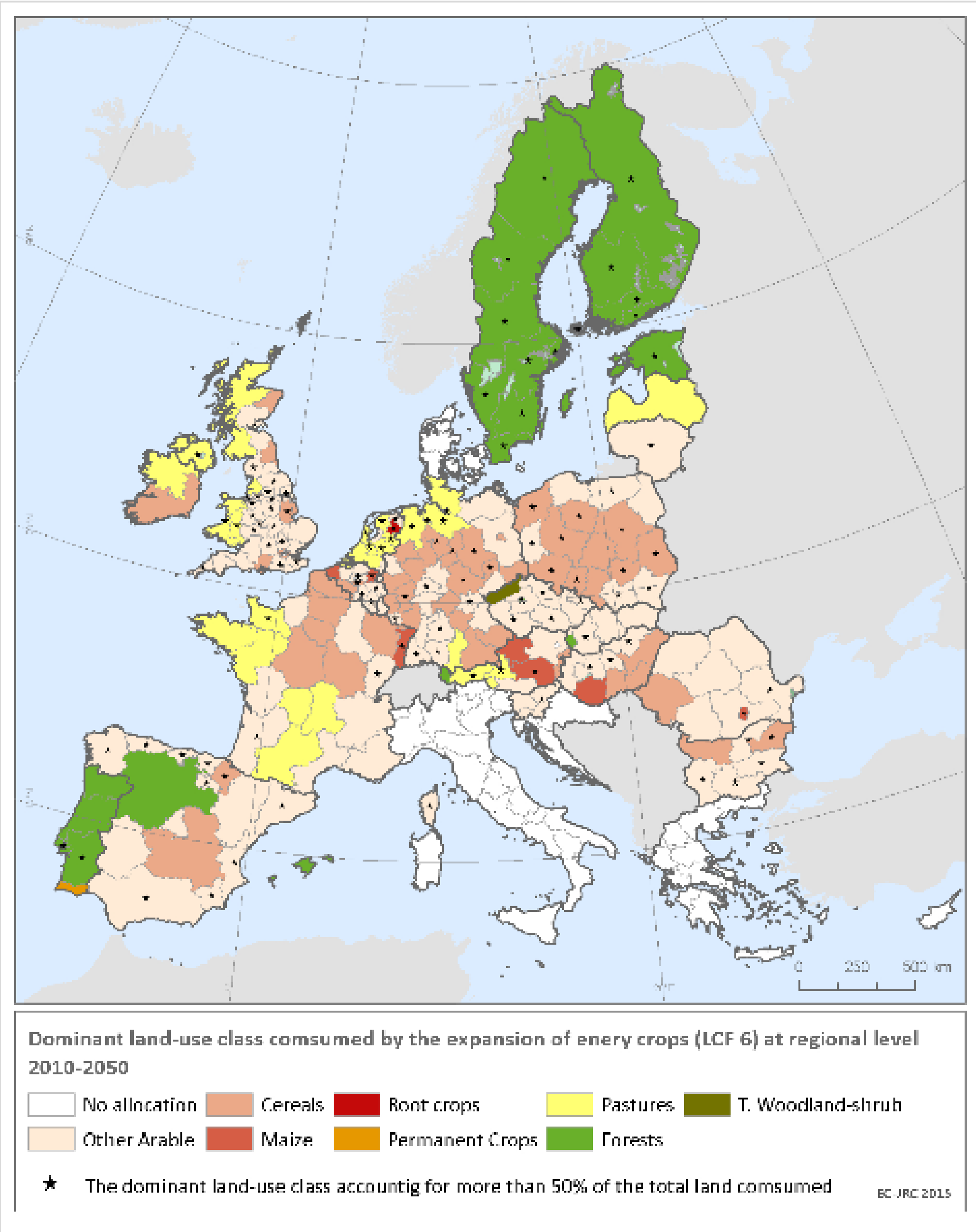


Figure 7. Expansion of dedicated ENCR between 2010 and 2050 at NUTS 2 level in the EU28.

Across Europe, in the majority of regions, arable and cereals are the dominant land-use class taken by energy crop expansion. Only in a few regions (in central Austria, southeast of Hungary, north of the Netherlands and Belgium), root crops are the dominant crops replaced by energy crop production. On the other hand, in all the regions in Finland, Sweden, Estonia, and in most of the regions in Portugal and some in Spain, forest land is decreasing due to the expansion of ENCR. Pasture land decrease in favour of energy crop expansion is taken place in Ireland, western parts of the United Kingdom and Austria, northern regions of the Netherlands and Germany, Latvia and some regions scattered throughout France. Transitional woodland and permanents crops are rarely converted to energy crops production.

It should be stressed that, in some regions, the dominant land-use class replaced by the expansion of ENCR, has a considerable weight compared to the other land use flows, accounting for more than 50% of the total land consumed (this is symbolized in the map below by an asterisk). This flow dominance, in some regions, can be due to the fact that one land use is governing that region: when the dominant Land Cover Flow is from forests, this is probably because the dominant land-use is forest. On the other hand, when the dominant land flows do not reach 50%, there might be two or three classes being used for conversion to energy crops without a significant dominant pattern.

3.2. National and regional analysis of dedicated energy crops (2020-2050)

The absolute area of cultivated ENCR are projected to increase across Europe. In Figure 8, the land occupied by ENCR is expressed in hectares (ha), for the years 2020 and 2050. In 2020, Germany (1,486,745 ha), France (1,463,875 ha) and Poland (987,881 ha) are by far the European countries that count the vastest surface dedicated to energy crop production. In some regions, the land dedicated to energy cropping is very large: more than 125,000 ha in the French Pays de la Loire, followed by Poland's Mazowieckie region with 116,000 ha , and the Brandenburg region in Germany with approximately 108,000 ha . Many of remaining countries show a quite homogeneous pattern at NUTS2 level, with most of their regions falling into the first group of the ranking (up to 25,000 ha), like Italy, Spain, Slovenia, Austria, Luxembourg, Belgium, the Netherlands and Sweden.

In 2050, the highest amount of land allocated to ENCR can be found not only in Poland (3,126,669 ha), France (2,740,414 ha) and Germany (2,448,470 ha), but also in Spain (1,453,497 ha) and Romania (1,376,573 ha) and the United kingdom (986,990 ha).

The comparison between absolute figures and shares offer a different picture since the shares do not reach, for most of the countries, more than 5% of the total available land in 2020. **The European average is approximately 3.2% and 7.5% in 2020 and 2050, respectively**. However, some regions have, in 2050, a share of ENCR in the available land that exceeds 20%: this is the case of the regions of Düsseldorf and Köln in Germany, with near 27% and 26%, and also Cheshire in the United Kingdom, which reaches 24% in 2050. Most of the regions with a higher than 10% share in 2050, belong to Poland, but other can also be found in the United Kingdom and Germany.

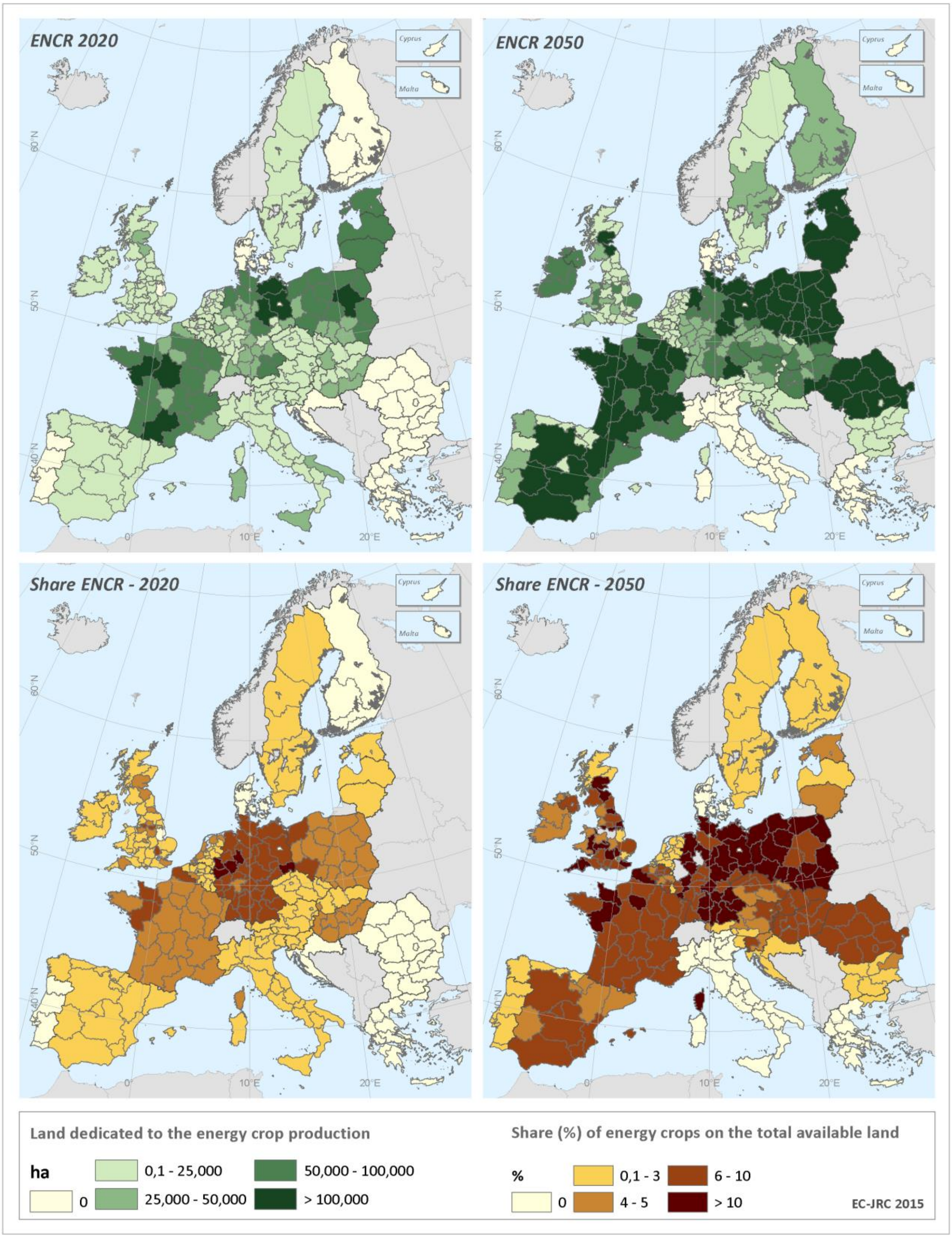


Figure 8. Expansion of dedicated energy crops between 2020 and 2050 at NUTS 2 level in the EU28. The first-upper two maps (green colours) represent the ENCR allocation measured in ha while the bottom two maps (orange colours) report the percentage of energy crop on the total available land.

A more comprehensive representation of local differences regarding the allocation patterns of ENCR is given in Figure 10, where results are aggregated at NUTS3 level for the years 2020, 2030, 2040 and 2050. Between 2020 and 2030, France and Poland show the highest number of provinces with substantial ENCR expansion while regions belonging to other countries undergo a more modest increase. On the other hand, from 2040 onwards, regions of Spain, the United Kingdom and Romania begin a considerable expansion of dedicated ENCR. German provinces keep a stable growth during the whole simulation period and in Italy energy crops disappear from 2040 onward, in compliance with the energy-shares projections of the Energy Reference Scenario 2013 and as forecasted by the CAPRI model.

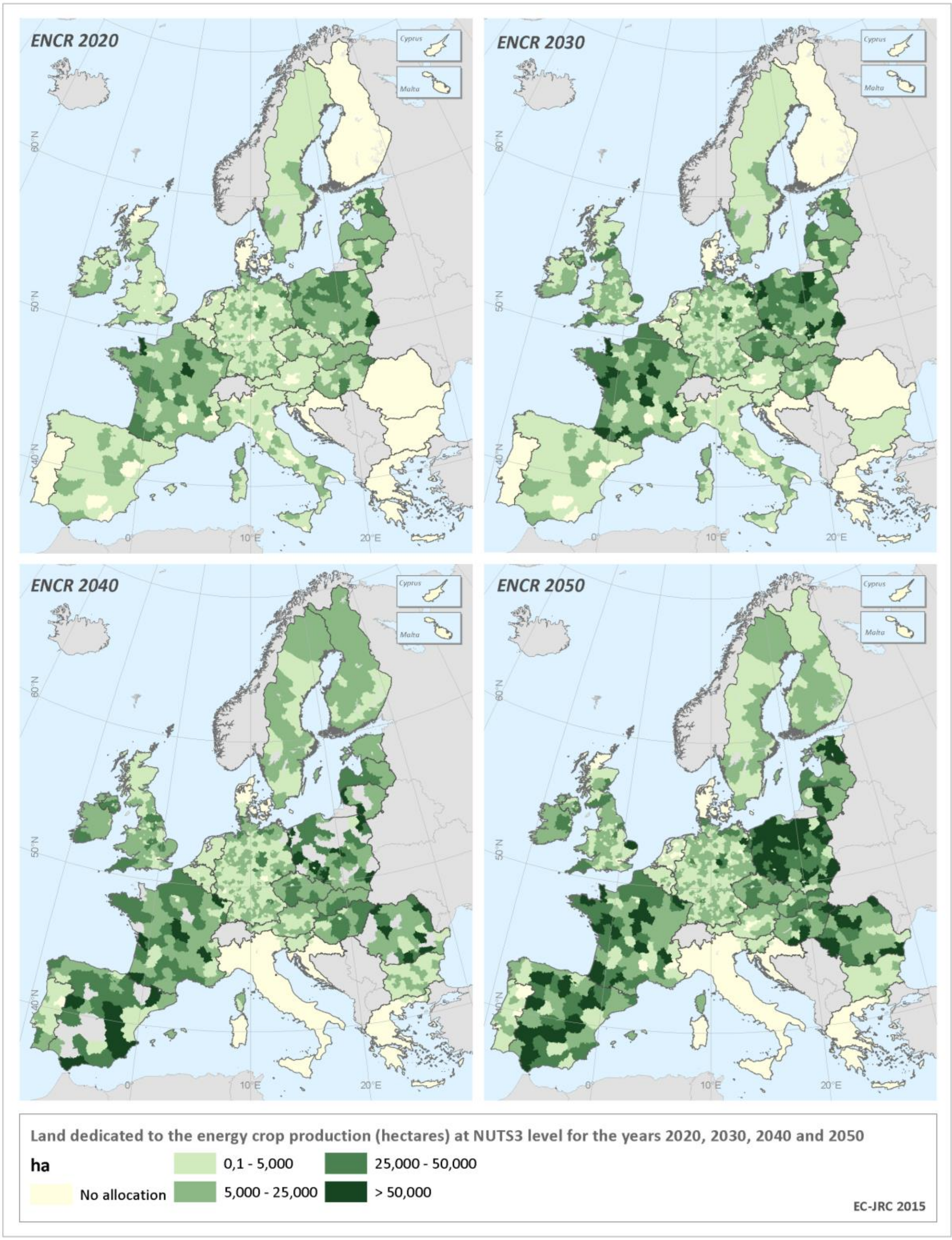


Figure 9. Expansion of dedicated energy crops per decades, between 2020 and 2050, at NUTS 3 level in the EU28.

Looking at Figure 10, some NUTS3 regions in Germany, the United Kingdom and Poland, ENCR are allocated on more than 50% of the available land in 2050. These local differences at NUTS3 level are mainly due to the total amount of available land within each province. In the second place, ENCR are encouraged to occupy areas with unfavourable soil characteristics for food and feed production, such as degraded and contaminated lands.

In Poland and Germany, the share of ENCR on the total land available , 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, ENCR are preferably allocated in the model in NUTS3 regions where erosion, contamination or salinity problems are present. This is particularly evident in Germany: In the most Southern NUTS3 regions, at the border with Austria, where the soil quality is higher than in the neighbouring regions, ENCR are scarcely present. Similarly, in Poland, ENCR are preferably allocated outside the eastern regions where agricultural land is of better quality. Nevertheless, the presence of protected areas in the south-western regions causes ENCR to be allocated also on the higher quality land in some NUTS3 in the east part of Poland.

In Romania, along the simulation period, ENCR are mainly allocated in the NUTS3 regions where the presence of forest is scarce and there is high presence of low quality soils. In Italy, the demand for ENCR is relatively low (around 1% of the total available land) 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.

The minimum production of ENCR is located in Sweden, Finland, Slovenia, Bulgaria, Latvia, Estonia, Austria and Portugal, where the share of allocated ENCR does not reach 1% in any province.

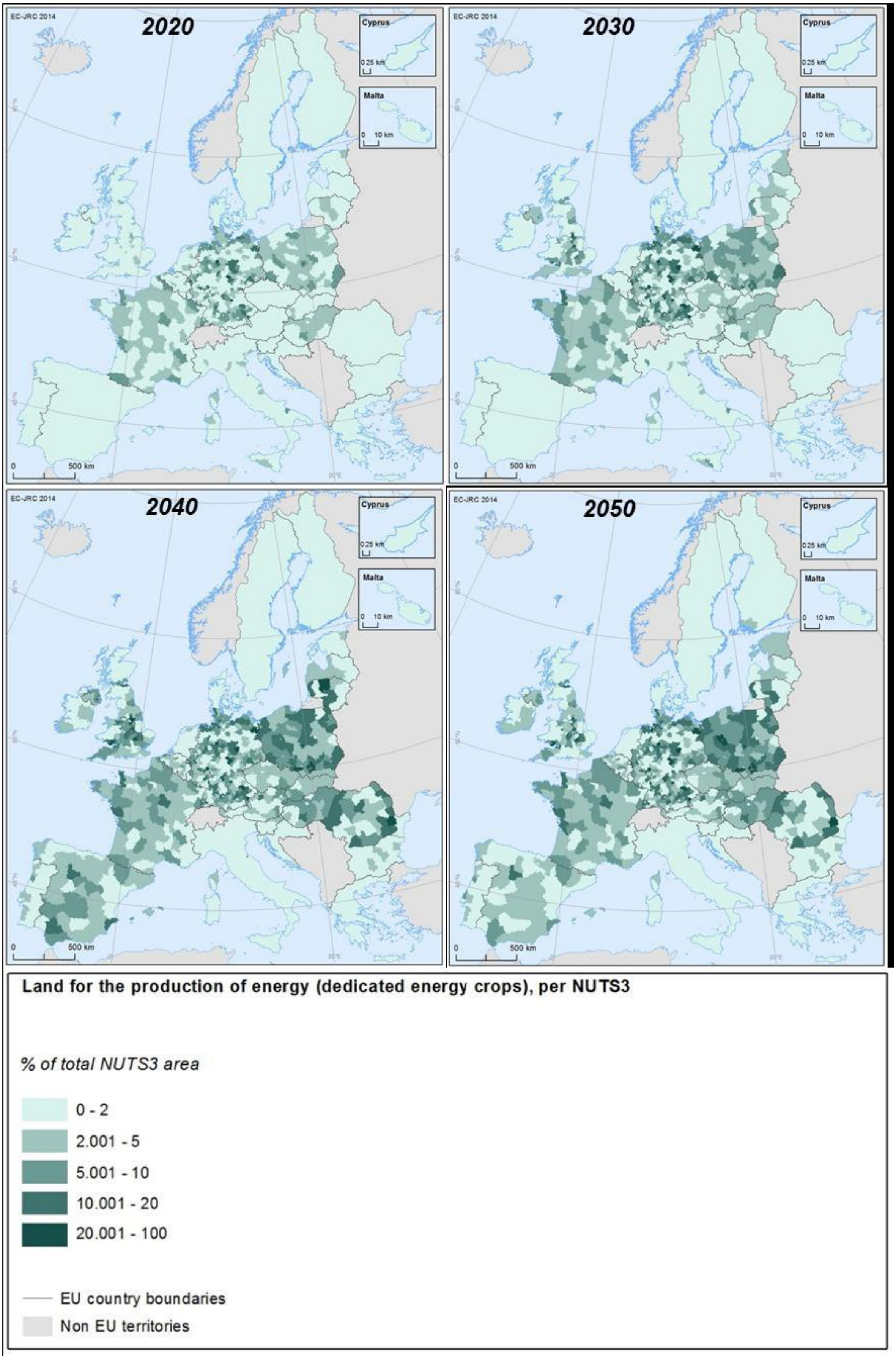


Figure 10. Allocated energy crops, represented as percentage of the total available land, for the years 2020, 2030, 2040 and 2050. Source: Baranzelli et al., 2014a.

3.2.1. Using degraded and contaminated lands for the energy crop production

In order to preserve agricultural and forest areas and participate to improving the environment, degraded and contaminated lands could be an interesting option for the cultivation of energy crops. Therefore, soils with high/medium saline concentration, soils affected by severe erosion, and soil contaminated by heavy metals could be suitable for the expansion of ENCR.

The total amount of degraded and contaminated lands re-used for energy crops production accounts for 1,965,497 ha in 2030 and 4,953,903 ha in 2050, across Europe. These figures represent respectively 24% and 36% of the total energy crop area for the same years, which reflects a recuperation of land with potential for energy crop growth.

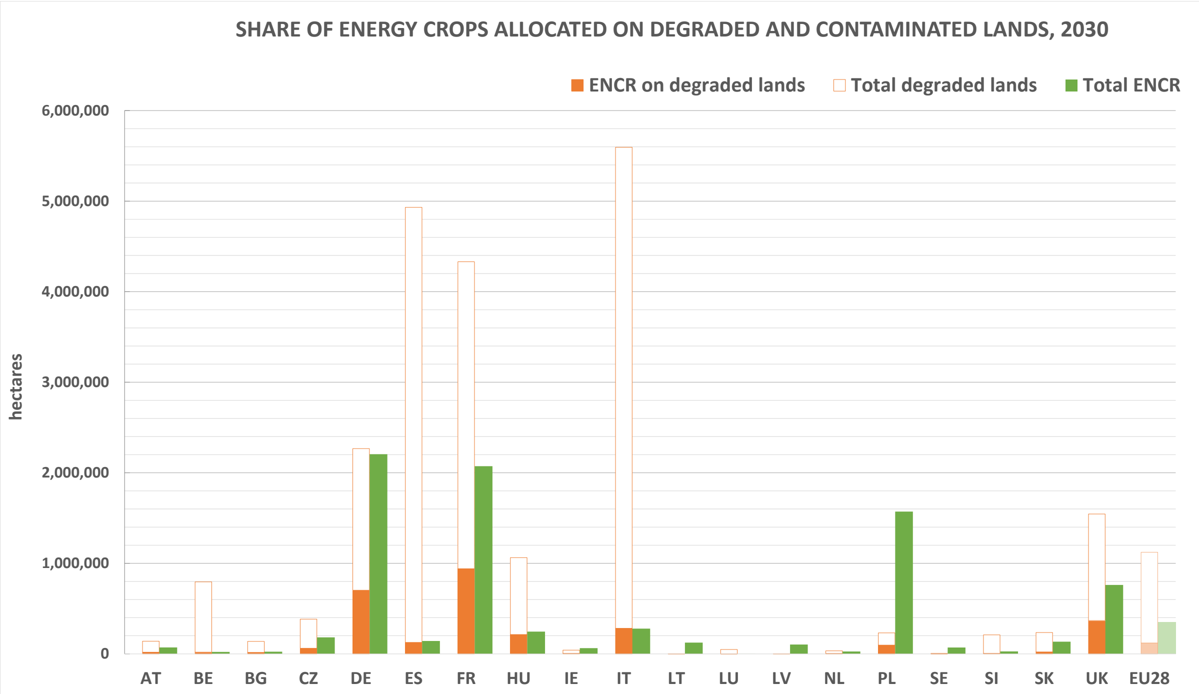


Figure 11. Dedicated energy crops allocated on degraded and contaminated lands (solid orange) compared to the total energy crop production in 2030. Additionally, the total amount of degraded lands are shown in order to complete the information (bars with orange line and solid white).

Some countries such as Hungary (86%), Belgium (88%), Spain (99%), Italy (99%) and Luxemburg (100%) have recovered almost the whole surface of degraded and contaminated lands to ENCR cultivation (Figure 11), unlike what happens in France and Germany. This situation therefore provides a double benefit. **First, the production of energy crops on less-competing areas, hence avoiding the massive displacement of agricultural land and forest. On the other hand, if carefully designed and regulated, ENCR in those areas might help to reduce soil erosion, improve soil structure and nutrients, clean water and soils (remediation)**.

The amount of land of each category (high salinity areas, severe erosion, highly contaminated areas by heavy metals) allocated to ENCR is aggregated at NUTS2 level, for the years 2030 and 2050 (Figure 12).

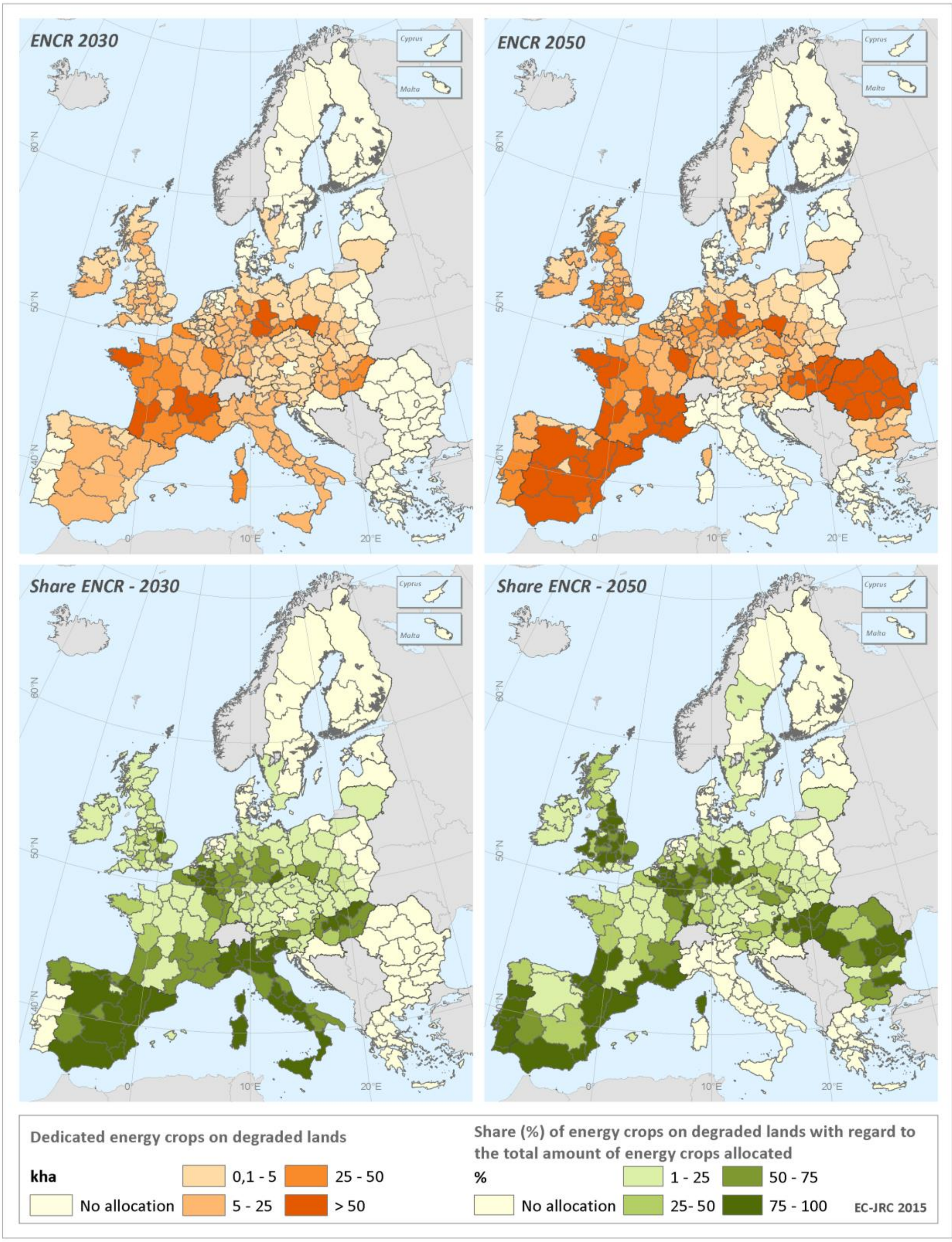


Figure 12. Expansion of ENCR on degraded and contaminated lands between 2020 and 2050 at NUTS 2 level in the EU28. The first-upper two maps (orange colours) represent the amount of ENCR on degraded lands measured in ha while the bottom two maps (green colours) report the percentage of energy crop on degraded lands over the total energy crop production.

The NUTS2 regions accumulating more ENCR on degraded and contaminated lands are coloured in a darker shade of orange representing regions with more than 25,000 ha (

Figure 12). In 2030, the share of ENCR allocated on degraded and contaminated lands varies strongly per NUTS2 regions across different MS. High proportions of ENCR allocated in these areas can be mostly found in some regions of France, Germany and the south of Hungary, reaching more than 60% in 2030.

In 2050, the overall picture for Europe is significant changing with regard to 2030. Most of the regions of Spain, Romania, the United Kingdom, France, Germany and Hungary allocate ENCR on degraded and contaminated lands. For instance, the region of Andalucía (Spain) reaches more than 286,000 ha, Sud-Est and Sud-Muntenia (Romania) nearby 190,000 ha, followed by Sachsen-Anhalt (Germany) amounting to nearly 145,000 ha. Main differences can be found in Portugal, which shows a high reconversion since it previously had no allocated ENCR; and Italy, whereby ENCR are no longer present in 2050, in compliance with the energy Reference Scenario 2013 and as forecasted by the CAPRI model.

Other perspective can be brought by the share of ENCR cultivated on degraded and contaminated lands over the total amount of ENCR. This is a way to measure the land efficiency of each region, when ENCR are allocated on these land categories. It is necessary to remind that **degraded and contaminated lands are static layer during the simulation**. As we can see from

Figure 12, there is a good balance in most of the regions of Spain, Italy and Hungary, between the ENCR allocated on degraded lands compared to the total production in 2030. In 2050, Romania, Bulgaria and United Kingdom present a good proportion, being on the class of 75-100%.

3.2.2. Suitability analysis

A spatially detailed analysis of the allocation of ENCR can identify regions where the pressure induced by the Reference Scenario (and in particular its economic and energy components) at European and country level could generate intense competition between different land uses. This situation might lead to highly fertile land being used either for urban and industry development or ENCR expansion, instead of being used for food and feed production.

Different drivers can cause the misplacement of food and feed crops from highly suitable land to lower levels of suitability. According to Baranzelli et al. (2014b), **in many regions in EU28, the demand for new built-up areas, either for residential or Industrial, Commercial and Service uses, together with the introduction of ENCR, can exacerbate the competition for land resources, potentially causing food and feed crops to be allocated on land not highly suitable for their growth**. Figure 13 illustrate the shares (%) of land that is particularly suitable for the allocation of food and feed crops (cereals, maize, root crops and other arable, respectively) that are indeed used to allocate ENCR.

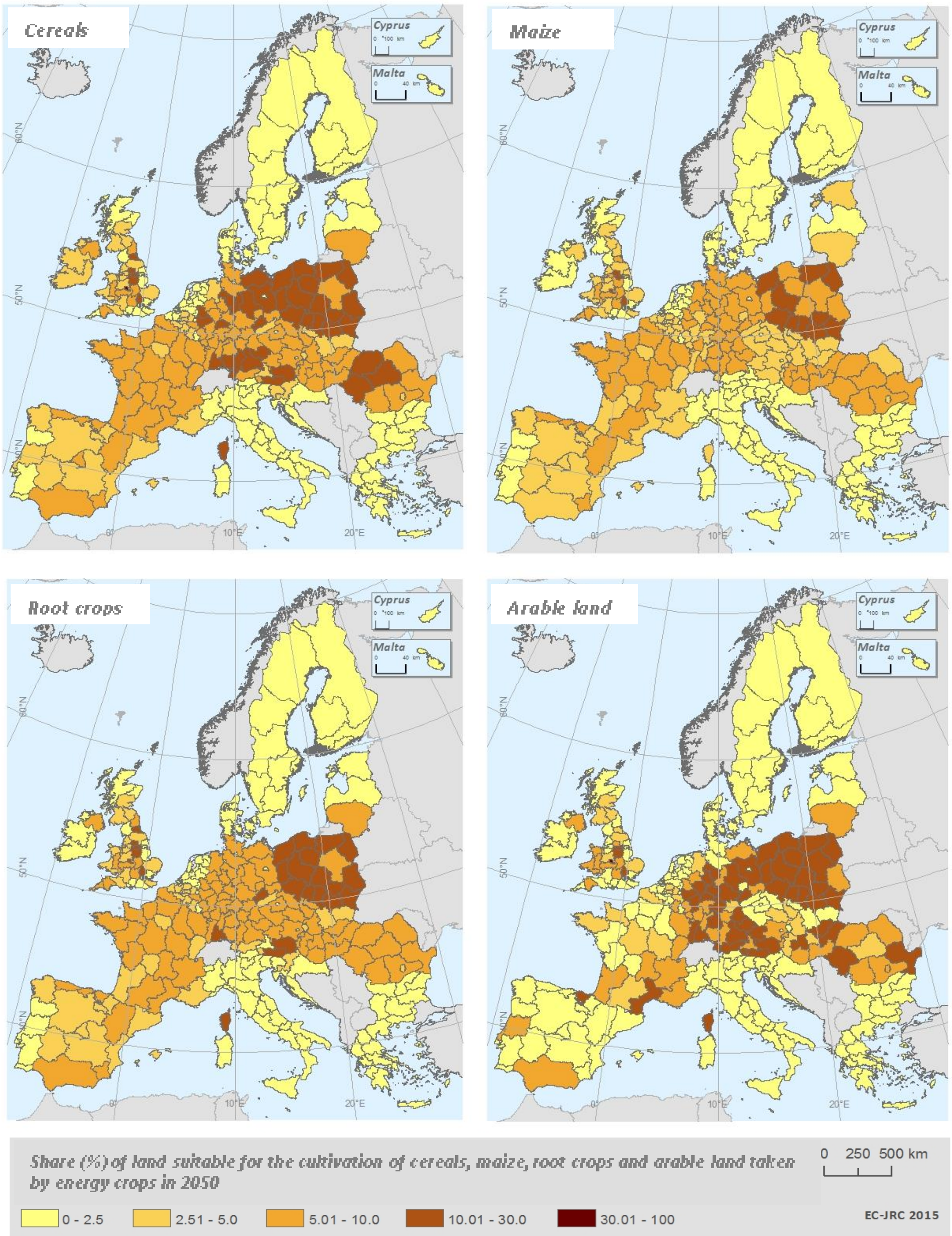


Figure 13. Share of land suitable for the allocation of cereals, maize, root crops and arable land that is used for ENCR in the year 2050. ***Source*****: Baranzelli et al., 2015.**

Figure 14 and Figure 15 provide an overview at European scale of the surfaces of ENCR allocated per suitability levels. For each MS, the total amount of land occupied by ENCR and the percentage allocated on each suitability class is reported for the years 2020 (when dedicated energy crops first appear, as forecasted by the CAPRI model) and 2050 (final year of the simulation).

In 2020, France (1,346 kha), Germany (1,316 kha) and Poland (900 kha) have the vastest surfaces dedicated to energy crop production. Most of the remaining countries contribute significantly less to the total energy crops production in Europe, ranging from 241 kha (Italy) to 6 kha (Slovenia). In particular, there are no ENCR in Romania, Luxemburg, Croatia, Denmark, Bulgaria, Cyprus, Finland, Greece, Malta and Portugal in 2020. The analysis of the distribution of ENCR within the five suitability levels reveals that, **for the largest producing countries, ENCR are allocated on the most fertile soils** (moderate, high and very high suitability levels). However, in Estonia, Sweden, Latvia, Lithuania, Slovakia and Hungary the dominant soils where ENCR are cultivated are the least suitable ones.

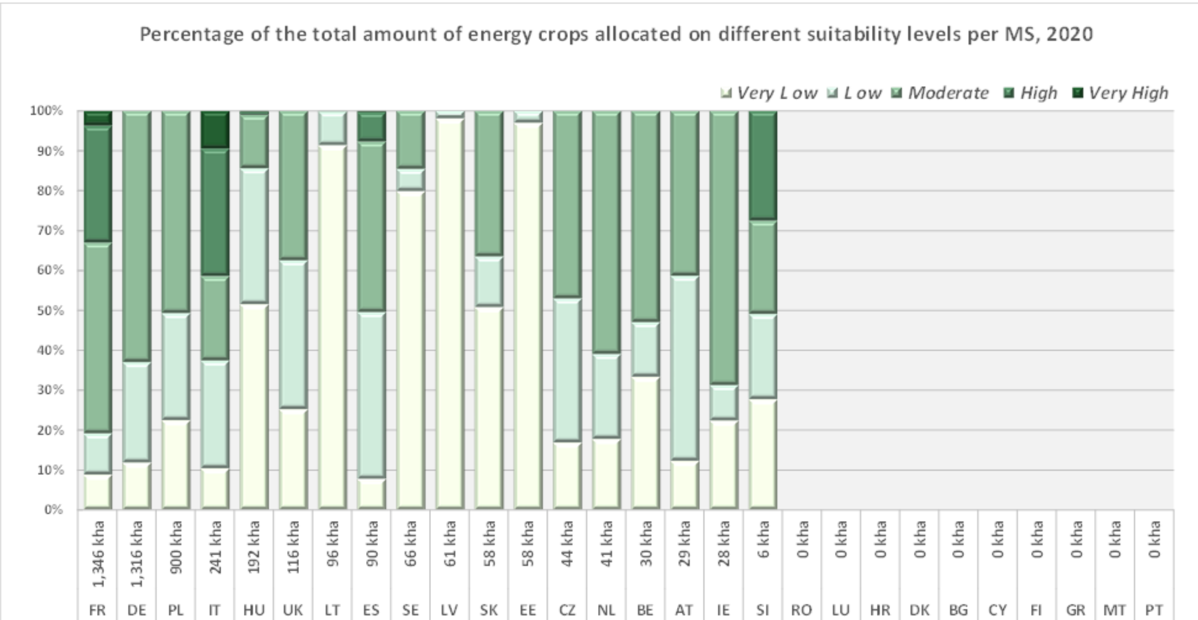


Figure 14. Percentage of the total amount (kha) of ENCR allocated per suitability level in 2020 for the EU28. *Source*: Baranzelli et al., 2015.

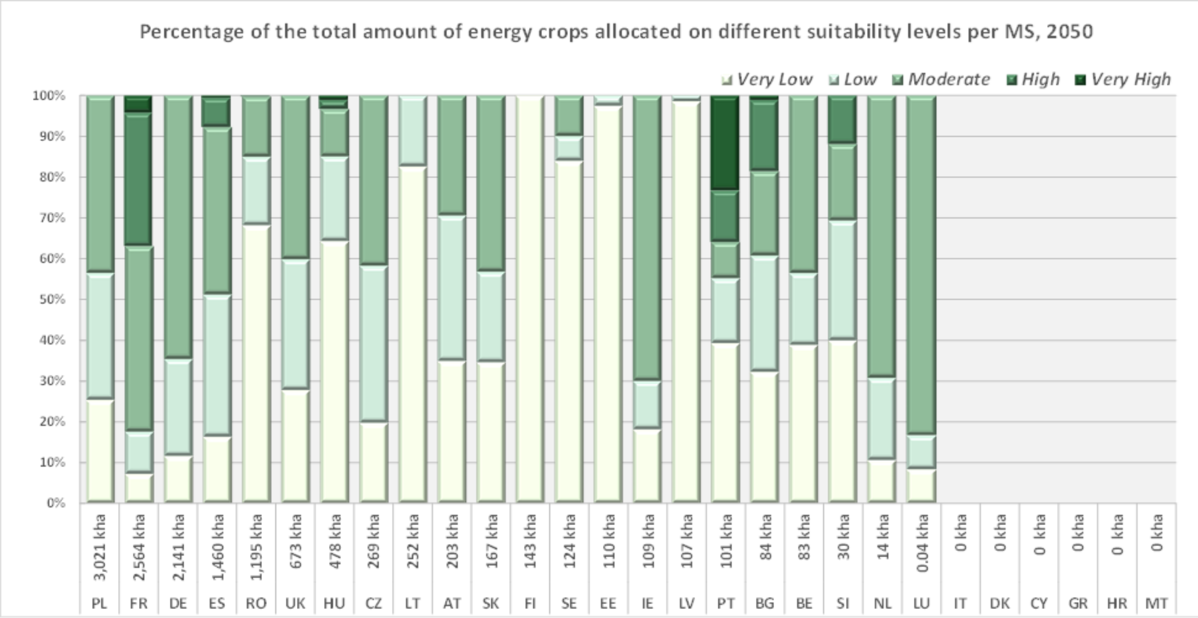


Figure 15. Percentage of the total amount (kha) of ENCR allocated per suitability level in 2050 for the EU28. ***Source*****: Baranzelli et al., 2015.**

The distribution of the allocated energy crop on the dominant suitability levels of the land at NUTS2 level is given in Figure 16. In 2020, ENCR are predominantly allocated on land with very high and high suitability levels in the central-west and south part of France, north of Spain, and central Italy. In whole countries like the Netherlands, Belgium, Luxembourg and Ireland, and numerous regions in the United Kingdom, Spain, Bulgaria and Germany, ENCR are mainly allocated on moderately suitable land. Allocation on low and very low suitability levels is predominant in regions of the central-eastern part of Europe, central-eastern Spain, Finland, and the eastern European countries. In 2050, no substantial changes are observed, except for (1) Portugal, where ENCR were not allocated in 2020 and are now grown on very high suitability level land in the north, (2) Romania (allocation on predominantly low levels), and (3) Italy, where ENCR will no longer be cultivated (in accordance with CAPRI’s projections).

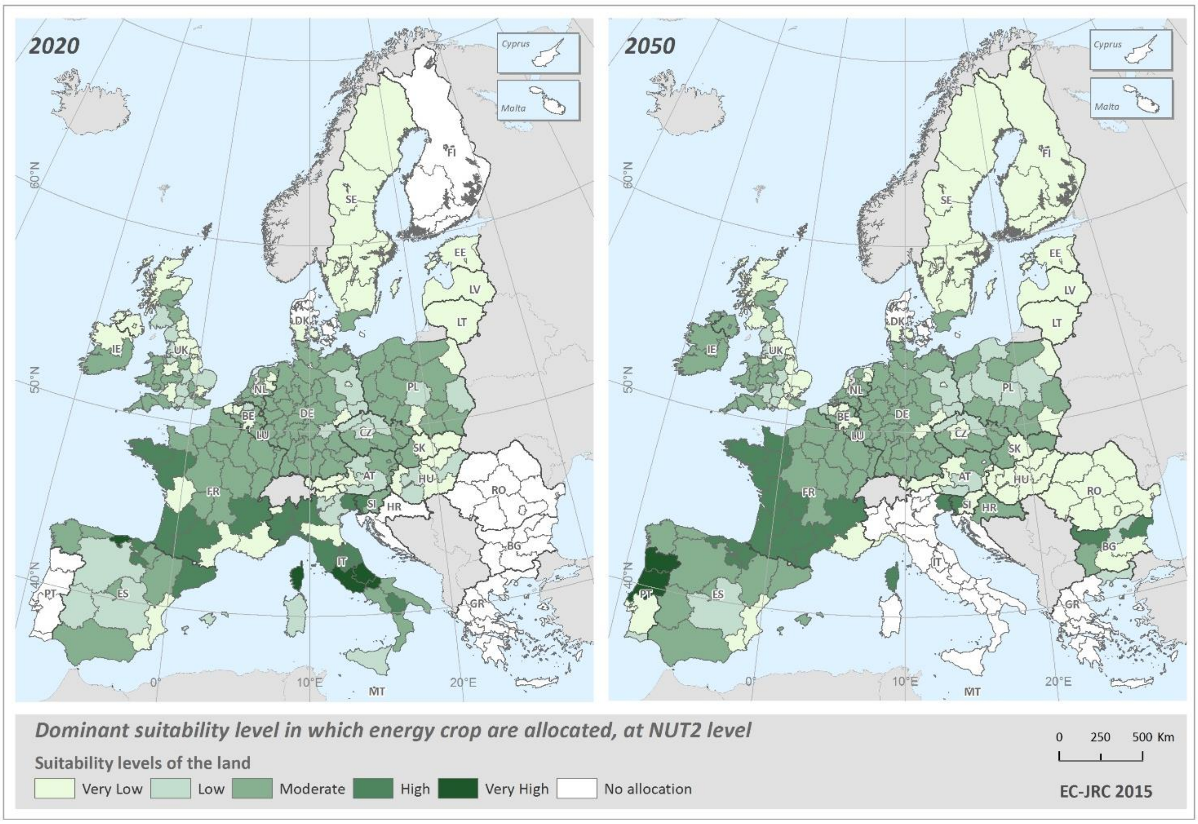


Figure 16. Suitability level of the land on which the majority of ENCR are allocated at NUTS 2 level in the EU28. ***Source*****: Baranzelli et al., 2015.**

The expansion of urban fabric and economic activities related to ICS is foreseen to also have environmental impacts on the land most suitable for energy crop production[9].

As can be seen from Figure 17 and Figure 18, especially in France, Italy, Portugal and Ireland, new urban and industry areas are allocated on land with moderate, high and very high suitability levels for energy crop production in 2020. The situation in France and Italy is particularly negative owing to the high share of built-up areas with respect to the total country extent: 5.6% and 5.5% respectively. These results are mainly due to a particularly high urbanisation pressure, which is the consequence of the population changes projected by DG ECFIN in some French and Italian regions (Baranzelli et al. 2014b). On the contrary, the United Kingdom, Poland, Romania, the Netherlands, Finland, Austria, Latvia, Estonia and Luxemburg are using land of very low and low suitability levels for the expansion of urban and other economic activities.

[9] It is worth mentioning that in some regions, land suitable for energy crops can be similarly suitable for food and feed crops: as the focus of this chapter is on environmental impacts on energy crops, the reader is further referred to Baranzelli et al., 2015 for a comprehensive explanation dedicated to land allocation and suitability analysis applied to both food and feed, and energy crops.

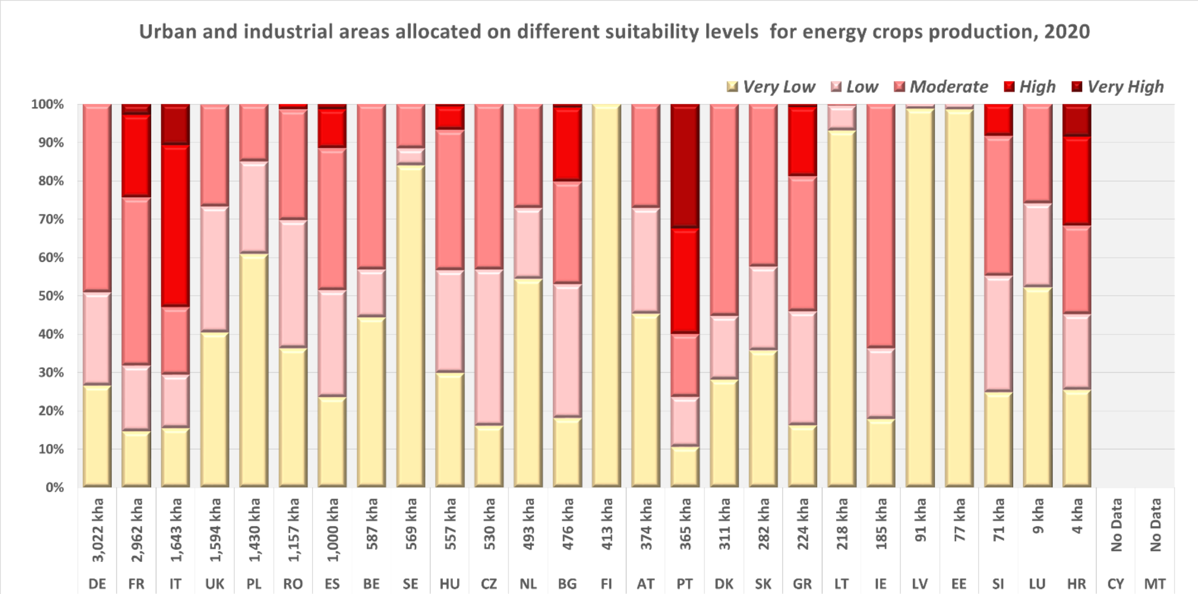


Figure 17. Suitability level (for ENCR) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28, in the year 2020. *Source*: Baranzelli et al., 2015.

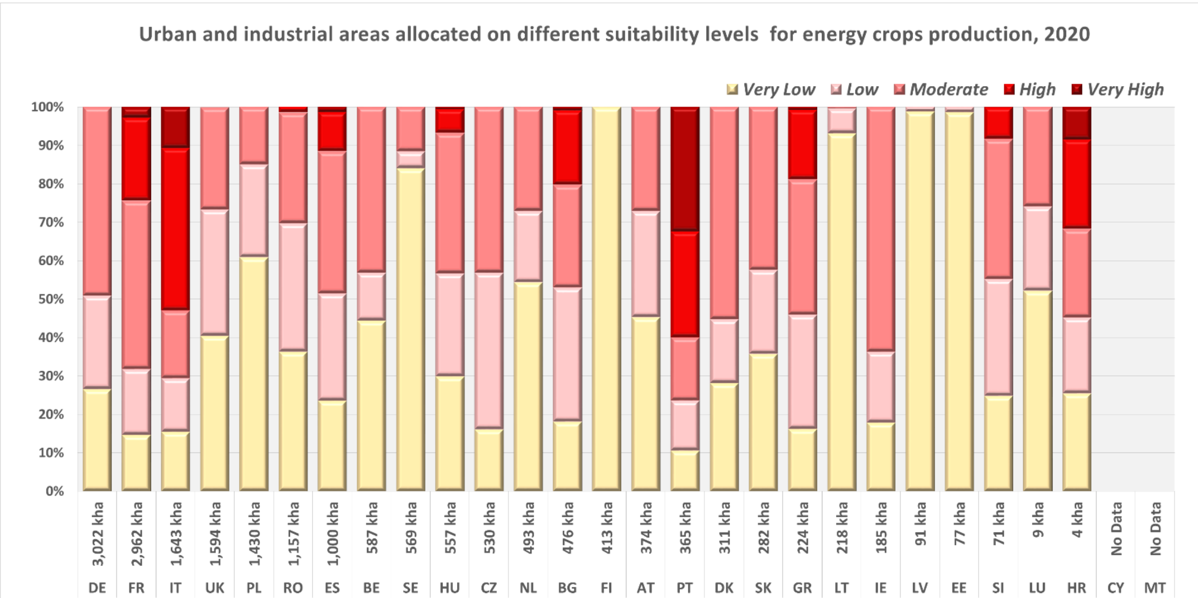


Figure 18. Suitability level (for ENCR) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28, in the year 2050. *Source*: Baranzelli et al., 2015.

At regional level, Figure 19 highlights that trends and patterns remain rather stable between 2020 and 2050. Countries such as Italy, France, Portugal, Spain and Greece are losing the most fertile land for energy production in favour of new built-up areas. Particularly Italy, followed by Portugal, shows an extremely negative trend, with almost all the regions using highly suitable land for ENCR to allocate urban and industrial areas. Central, eastern and northern parts of Europe preserve more the highest suitability land, while urban and industrial expansion takes place on lower quality soils for ENCR.

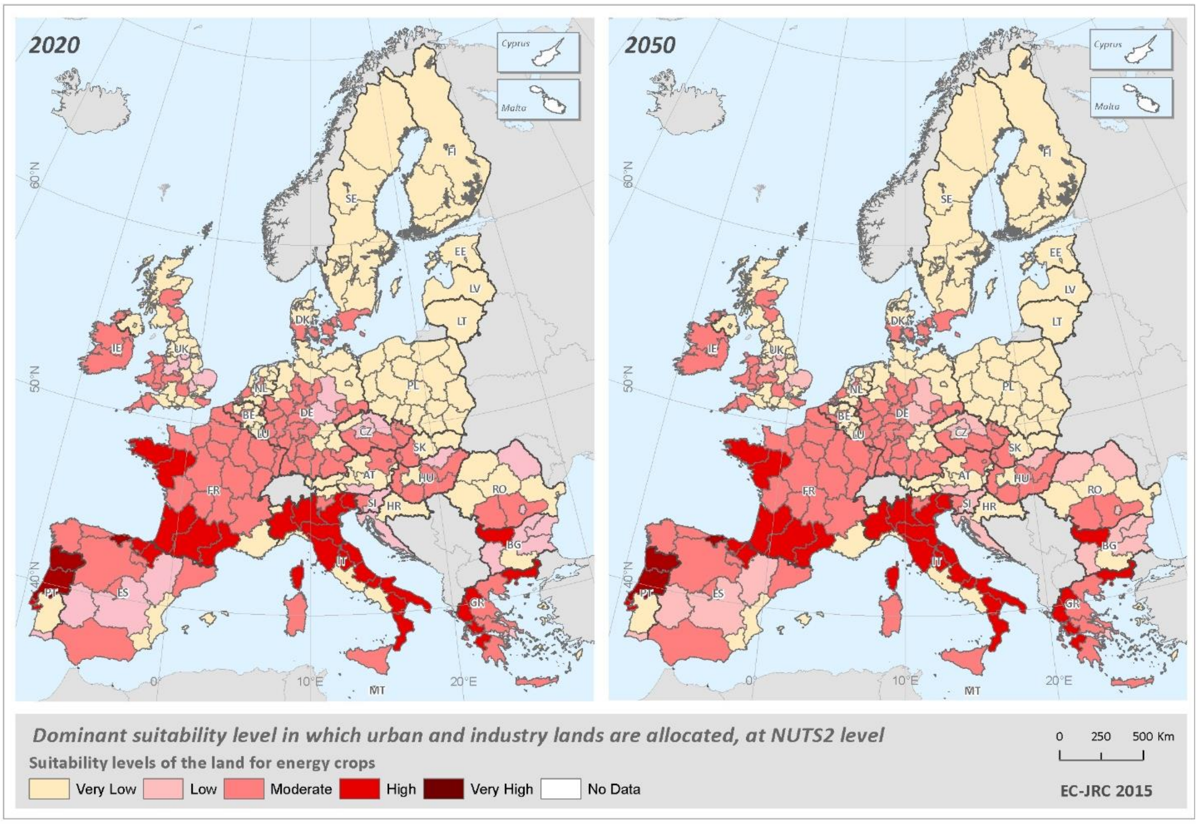


Figure 19. Suitability level (for ENCR) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28. *Source*: Baranzelli et al., 2015.

3.2.3. Factsheet at Member State level: summary of the energy crop allocation

The analysis of the allocation of ENCR, hereby presented at European level, is further developed at regional level (NUTS2) in Annex IV. Factsheets are there presented for each MS, according to the following structure:

At the top of the factsheets, a header summarises the main figures for each country:

- Total amount of ENCR at country level for the years 2030 and 2050, and the respective share with respect to the total available land;
- Amount of ENCR allocated on the different suitability levels, expressed by percentage over the total available land;
- Identification of the land uses that have been converted to ENCR.

After this introduction, two maps represent the availability of ENCR classified by suitability levels in 2030 and 2050, per NUTS2. Each region is shaded in green, according to the amount of allocated ENCR, measured in hectares: the darker the shade of green, the more ENCR are allocated. For each NUTS2, a pie chart expresses the proportion of ENCR allocated on different suitability levels: light shade of brown corresponds to the proportion of ENCR allocated on low and very low local biophysically suitable land, whereas darker shade of brown corresponds to ENCR allocated on the highest suitability levels. The first bar chart on the right hand side of the factsheet represents the same information of the pie charts, aggregated at a country level.

The second bar chart reports the amount of land, per land-use/cover class, which is converted to ENCR in 2030 and 2050.

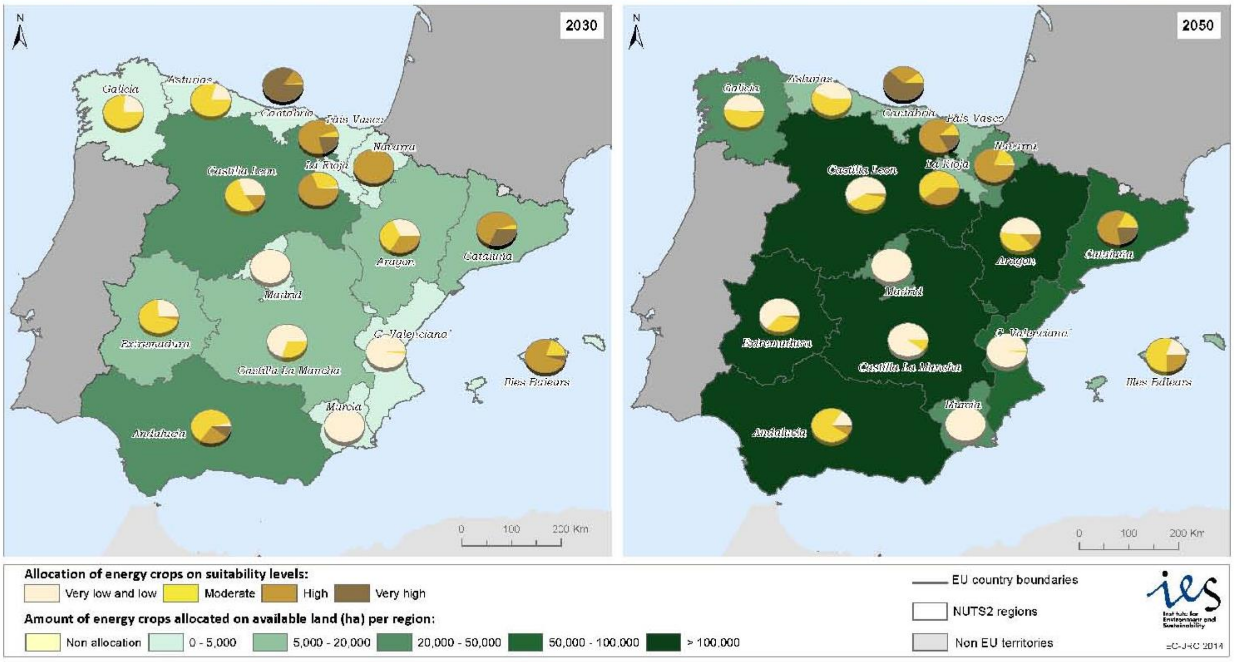
Finally, on the bottom left of the factsheet is displayed the allocation of ENCR on degraded and contaminated lands (ha) per NUTS2 in 2030. For each NUTS2, different shapes indicate the presence of different unfavourable agriculture soil conditions where ENCR have been allocated: black square for severe erosion, circle for highly contaminated lands by heavy metals, and star for highly saline soils. The size of each symbol is proportional to the quantity of ENCR allocated on the respective unfavourable soil condition.

An example of factsheet is represented in Figure 20, for Spain (ES).

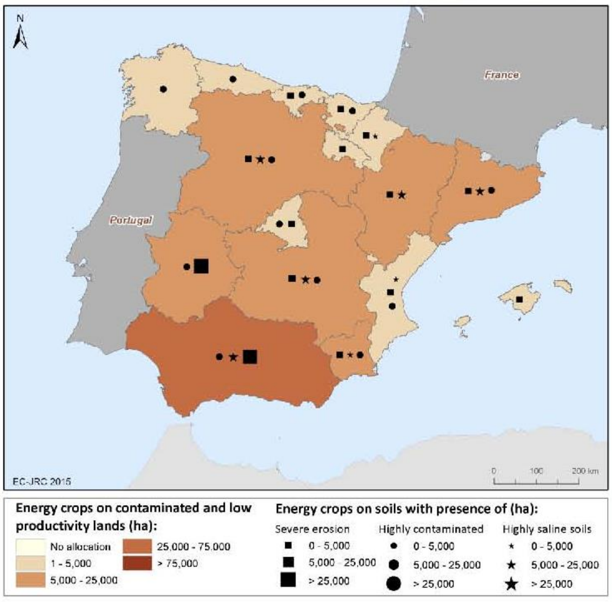
SPAIN (ES)

In Spain the allocation of energy crops reaches 102 and 1,454 Kha in 2030 and 2050 respectively. These figures represent a share of energy crops, on average, between 1% and 3,7% of the total available land within each region in 2050. Energy crops are not successfully allocated on the high local (biophysical) suitability lands (by 35% and 52% on low and very low for 2030 and 2050, respectively) except in the north-eastern part of Spain. The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (45%), cereals (26%) and forest and T.W. (21%) in 2050.

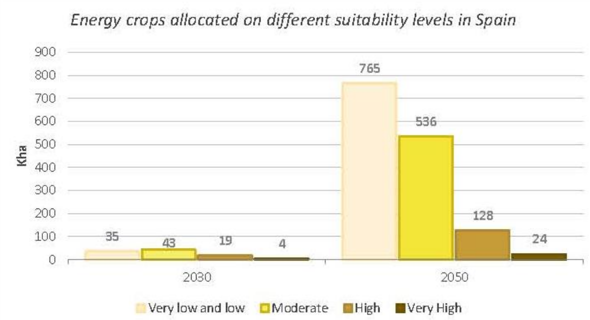
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions



Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 101,294 ha (3% of low productivity lands over available land) in 2030.



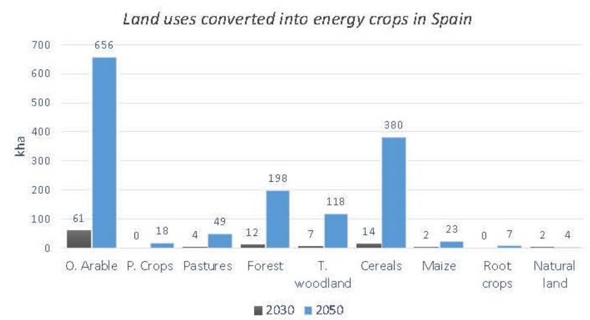


Figure 20. Example of factsheet for Spain, reporting the allocation of ENCR per suitability levels and on low productivity land. The black-and-blue chart reports the amount of land converted to ENCR in the whole country, per land-use/cover class, in the years 2030 and 2050.

Analysing the results of each factsheet presented in ANNEX IV, **it is possible to group MSs under two main profiles:**

Countries in which the production of energy crops is considerably high and the exploitation of degraded and contaminated lands might be high or low.

Italy, Spain, Hungary, the United Kingdom and France, with high energy crop production and high use of degraded and contaminated lands, belong to this first profile. In these countries, more than 50% of low productivity lands are used by energy crop cultivation. In the particular cases of Spain, Italy and Hungary, the figures show the best results: the allocation on these low productivity lands is about 100%, while France and the United Kingdom reach 50%. In addition, Spain, Hungary and the United Kingdom allocate ENCR on low, very low and moderate biophysical suitability levels, which means that more inputs might be needed for the production (the higher the suitability, the higher the potential productivity level with less additional inputs potentially harmful to the environment). On the contrary, France and Italy have a better distribution among the moderate, high and very high suitability levels. The projected allocation of ENCR implies the conversion from other land uses, and for these high producer countries, mainly other arable land and cereals suffer the higher losses, followed by pastures also in France and UK.

Germany and Poland, thought being part of the group of high producer countries of ENCR, do not practically make use of degraded and contaminated lands, for different reasons. In the case of Poland, it is due to the quasi-inexistence of land in these categories. In any case, just 6% of the dedicated energy crop have been allocated on degraded lands and basically on very low suitability levels. Concerning Germany, only 30% of the degraded and contaminated lands is used for energy crop production and, as Poland, allocated for half of it on low suitability levels. In Poland and Germany, like in the previous group of countries, the expansion of energy crop is produced mostly at expenses of arable and cereal land.

In this group of countries, degraded and contaminated land category can satisfactorily support the expansion of energy crop, except in Poland. However, as explained in the report, other components play an important role during the allocation mechanism, such as the competition between land-use classes by means of the suitability maps, land demand and EU policies.

Countries in which the availability of energy crops is moderate or considerably low and the exploitation of degraded and contaminated lands might be high or low.

In the first case, with moderate production and high use of degraded and contaminated lands, Austria and Czech Republic are the only countries with a reconversion of low productivity lands reaching nearly 30%. Both countries make use of the very low and low suitability levels of the land to allocate ENCR. Bulgaria, with more modest energy crop production, is the country that reuses degraded and contaminated lands in a better way, with a share near 65% of the energy crops total land.

In the particular case of Ireland, Sweden, the Netherlands, Lithuania, Slovakia and Slovenia, the figures show diffident results: the allocation on these land categories are below 20%, and even in some of these countries nearly 0% (Sweden and Lithuania). Luxemburg and Belgium, with very low energy crop production, uses efficiently the degraded and contaminated lands (100% and 88%, respectively). The remaining countries, i.e. Estonia, Finland, Latvia, and Portugal are low energy crop producers. In particular, for these countries, there is no energy crop allocated on degraded and contaminated lands in 2030.

With the exception of Bulgaria, Portugal, and Slovenia where ENCR have a better spreading among the moderate, high and very high suitability levels, the remaining countries allocated ENCR on low, very low and moderate biophysical suitability levels. This reflects that energy crops are not being cultivated on the better quality soils with regard to soil properties, but also climate conditions.

Arable land is the land-use class that is losing land surface the most in favour of the expansion of energy crop in Belgium, Bulgaria, Check Republic, Lithuania, Luxemburg, Slovenia, and Slovakia. In Finland, Sweden and Portugal forest is the dominant land use converted to ENCR. In the Netherlands and Ireland, pasture land is being converted to ENCR the most, and finally, Austria with a more heterogeneous land-use conversion.

4. Exploring the possible impact of an expansion of dedicated energy crops in Europe on the provision of ecosystem services

The results of the Reference Scenario presented in the earlier chapters are used to explore the relations between energy crops and the provision of a selection of ecosystem services at regional scale, through the land flows associated to energy crops development.

This analysis presents only a first stage of an assessment of environmental impacts, as a more in-depth assessment would require the use of detailed information of the different energy crop types and would also profit from ground-checking, in the form of local observations to study how expansion of different energy crops results in changes in the provision of multiple ecosystem services.

4.1. National and regional analysis of dedicated energy crops (2020-2050)

The EU Reference Scenario provides aggregated values of the expected areas of energy crops at NUTS3 scale for the period between 2010 and 2050. LUISA also provides projections for a selection of ecosystem services. In this chapter, this information is combined and presented in **correlation diagrams to give a preliminary indication of the expected impacts of an increase in energy crop on the provision of ecosystem services**.

The following ecosystem services were included in the analysis: pollination (relative pollination potential)**, water regulation** (water retention index)**, maintenance of habitat quality** (habitat quality index for farmland birds)**, and nature-based recreation opportunities** (recreation potential index). The indicators which are used to quantify these ecosystem services are mentioned between brackets and are modelled in LUISA at high resolution. The models used to calculate the in bold mentioned ecosystem services are in essence based on land cover and land use to which other input data is added. The models are briefly described in Maes et al. (2015), a JRC report which analyses the trends in ecosystem services between 2000 and 2010. Finally, also the extent of the Green Infrastructure network is included to the analysis.

The analysis of the impacts is based on the relation between changes in the areas of energy crops on the one hand and changes in the potential supply of ecosystem services on the other hand. The potential supply of ecosystem services refers to the capacity of ecosystems to provide certain services regardless their actual use, which depends on local, regional or even global demand.

The difference between the projected energy crops areas between 2050 and 2020 (when energy crops are projected to start) is computed at regional level. Similarly, the changes in ecosystem services were calculated for every NUTS3 region between 2020 and 2050. Regions without energy crops in 2020 or in 2050 were not considered when measuring the change, since this would result in infinities.

Change is always measured relative to the value in 2020 and expressed in percentage points over a period of 30 years. For instance, a positive change of 100% means that the yield of bio-energy crops has doubled over a time period of 30 years. In contrast, a negative change of -100% means that yield of energy crops has halved over the same time period.

Subsequently, the changes in ecosystem services are explained as a function of the land use changes. For every region, the land flow resulting from the conversion to energy crops is quantified.

Seven different land flows were considered: (1) from arable land to energy crops, (2) from cereals and maize to energy crops, (3) from permanent crops to energy crops, (4) from forest and transitional woodland to energy crops, (5) from pasture to energy crops, (6) from other energy crops to energy crops, and (7) from natural land to energy crops. These land flows were calculated for each NUTS 3 region and divided over the total land area which is available for potential conversion (so excluding urban and protected areas). Conversions of energy crops to forest or to other land uses were subtracted so that the final result is the net land flow from seven different land use types to energy crops. **These land flows were next used in a multiple regression models with each of the ecosystem services as the dependent variable**. **The purpose of these regression models is to understand what is the contribution of different land flows (towards energy crops) in explaining the change of ecosystem services.**

The impact of indirect land use changes on ecosystem services following an increased demand for energy crops were not addressed in this assessment. Higher demand for energy crops can result in a displacement of other crops, which, in turn, may impact the provision of certain ecosystem services.

4.2. General results: correlations and land flow analysis

The results of the correlation analysis are presented in Figure 29. The figures present the growth rate of energy crop area, over the 2020-2050 period, against the relative change of ecosystem services. Instead of plotting the results for all NUTS3 regions, they are grouped according to different growth intervals. This increases the interpretability of the figures. Table 4 puts these results in a perspective from land flows and as such the percentages reported in this table are useful to understand better the correlations between the growth in energy crops and ecosystem services (or the lack of a linear correlation between them).

Two main findings emerge from Figure 29:

A first, important observation relates to the distribution range of growth in energy crops over the 2020-2050 period. Changes at regional scale vary from a reduction of 100% in energy crop areas to a growth of 5000 % over the 30 years period. A second observation is that all ecosystem services which are considered in the analysis show a correlation to the expected change in energy crop production.

Before analysing the individual results, it is useful to understand what happens for regions where there is no change in the production of energy crops between 2020 and 2050. In Figure 21, these correspond to a 0% growth rate in the X-axis. The corresponding values on the Y-axis suggest the expected trend of ecosystem services regardless the production of energy crops. Under this particular condition (0% change in energy crop area between 2020 and 2050), pollination potential is expected to decrease, on average, with 13% (due to other factors). Habitat quality for farmland birds, green infrastructure and water retention would undergo moderate changes between 2020 and 2050 (less than 2 percent points). Recreation potential is expected to increase by about 3% under a scenario of no regional change in energy crop production. It is useful to compare the changes in ecosystem services and Green Infrastructures relative to energy crop production to these values of no growth in energy crops.

Figure 29 presents three types of information: the total explained variance of each regression model, with the change of an ecosystem service as a dependent variable, and the net land flows from different land uses to energy crops as predictor variables; the impact of a particular land flow on the service; and contribution of each land flow to the total explained variance. **The regression models were all statistically significant but the explained variance varied between only 9% for the model on water retention index and 61% for the model on habitat quality for farmland birds**. What this means for the different ecosystem services is discussed case by case in the following section.

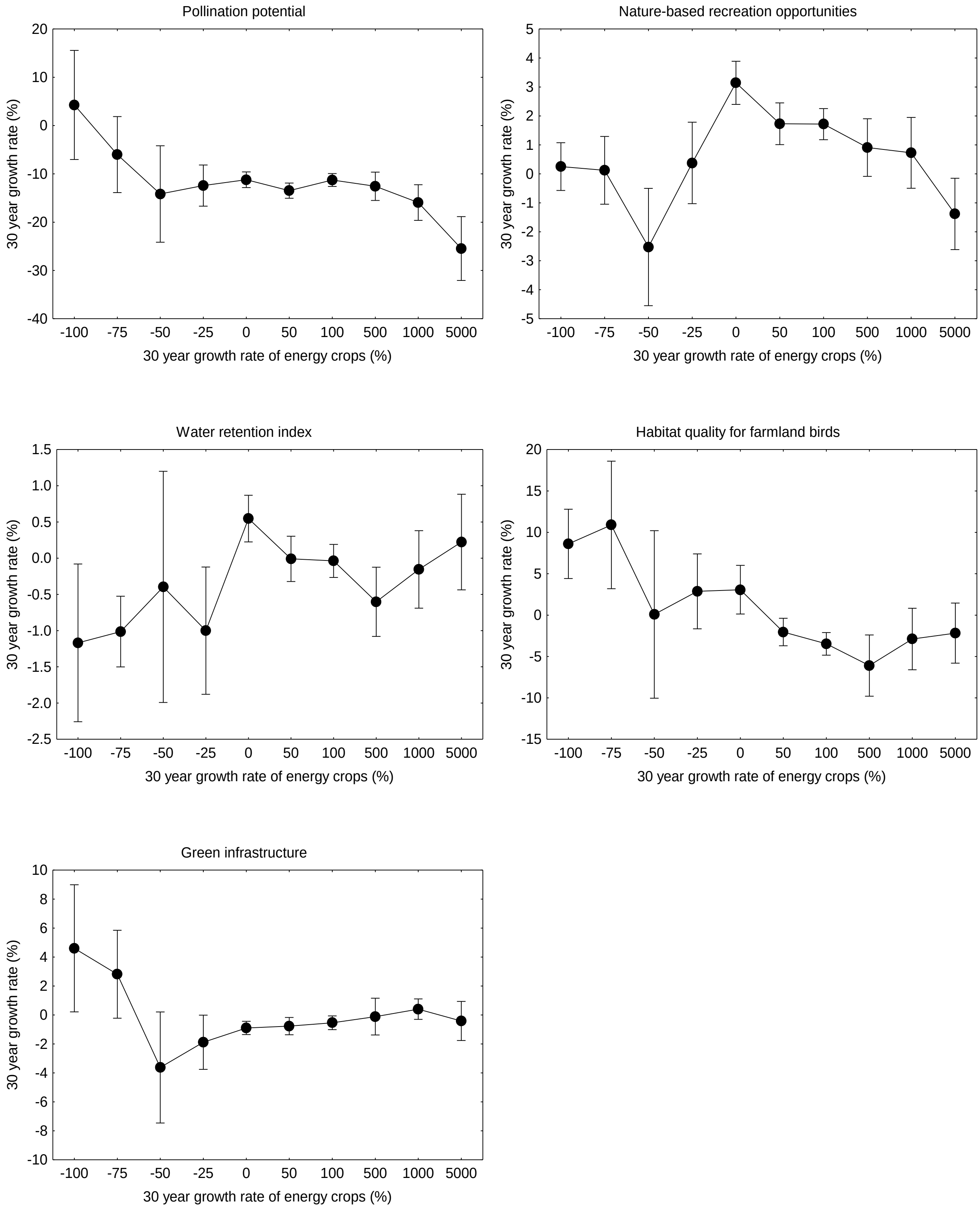


Figure 21. Relation between the growth in energy crop area (%) and the change in ecosystem services and green infrastructure (%). Error bars represent 95% confidence intervals.

Table 4. The impact of land conversion towards energy crops on ecosystem services and green infrastructure. The results in this table are based on a regression of the change in ecosystem services between 2020 and 2050 against different land flows.

Land flows (conversion to energy crops)	Pollination	Habitat quality for farmland birds	Nature-based recreation	Water retention index	Green infrastructure
Total explained variance	25%	61%	41%	9%	18%
From arable land	➔ 2%	↘ 81%	↗ 11%	➔ 7%	➔ 0.03%
From cereals and maize	↗ 2%	↘ 4%	↗ 57%	➔ 18%	➔ 7%
From permanent crops	↘ 2%	➔ 0.04%	➔ 1%	➔ 1%	➔ 2%
From forest and transitional woodland	↘ 14%	➔ 0.2%	↘ 10%	➔ 18%	↘ 46%
From pasture	➔ 0.04%	↘ 3%	↘ 6%	↘ 27%	➔ 0.02%
From natural land	➔0.13%	➔ 1%	➔ 3%	↘ 23%	↘ 35%
Other factors (model intercept)	↘ 74%	11%	↘ 10%	➔ 6%	➔ 1%

The total explained variance represents the variance explained by the regression model. The arrows indicate the change in the ecosystem service resulting from a specific land flow. The percentages behind each arrow correspond to the relative contribution of each land flow to the total explained variance.

↗: Land conversion to energy crops has a significantly positive impact on the service; Loss of this type of land results in an increase of the service.

↘: Land conversion to energy crops has a significantly negative impact on the service; Loss of this type of land results in a decrease of the service.

➔: Land conversion to energy crops has a no observed impact on the service; Loss of this type of land is not expected to result in a change of the service.

4.2.1. Pollination

Pollination is a regulating ecosystem services whereby insects, such as bees and bumblebees, contribute to the yield of crops which are dependent on them for pollination. Most fruit trees and vegetables need insect pollination. Pollination services are modelled using pollination potential as indicator, which expresses the capacity of land parcels to host pollinator populations considering also the distance to dependent crops.

Increasing regional growth rates of energy crop areas are related to regionally decreasing trends in pollination potential (Figure 29). Put another way, **regions with the highest growth rates of energy crop areas are losing land with the capacity**

to provide pollination. Regions with reductions in energy crop production are either gaining pollination capacity or, at least, the expected loss in capacity is lower than the trend observed when energy crop area is constant. **For pollination, these observed differences are high and significant.**

However, the overall loss of pollination which is expected between 2020 and 2050 can only be attributed to conversion to energy crops for a limited fraction (25% explained model variance,

Table 4). This means that **decline in pollination potential is expected to take place regardless of the expansion of energy crops**. **However,** Figure 29 makes clear that **growth in energy crops areas further enhances the loss of pollination potential**. A closer inspection of

Table 4 shows that conversion of forest, and permanent crops to energy crops has a negative impact on pollination potential while conversion of cropland for cereals and maize has a positive impact. This is evident since particularly patches of forest and woodland support pollinator habitats. However, afforestation can also negatively impact pollination potential. While forests support different bundles of ecosystem services, they are not necessarily good providers of pollination services. Pollinating insects such as bees and bumblebees are mostly absent from core forest but usually find suitable habitats on forest edges and grasslands rich in flowers. Patches of forest in an agricultural landscape thus support pollination, but land abandonment or land use change which enhances the development of core forest will negatively impact the total pollination potential of a region.

Figure 22 maps the changes in the suitability of land to support pollinator habitat. This map leaves out those regions (and countries) for which no change in bio-energy crops is expected between 2020 and 2050. The substantial losses in land pollination suitability expected for Spain, mid and northern Sweden and the Baltic States are very prominent but also most other regions are expected to lose suitable land to support pollinators. Note that this map presents the total change in pollination potential (not only the changes related to energy crop expansion, which would come on top of this already existing trend).

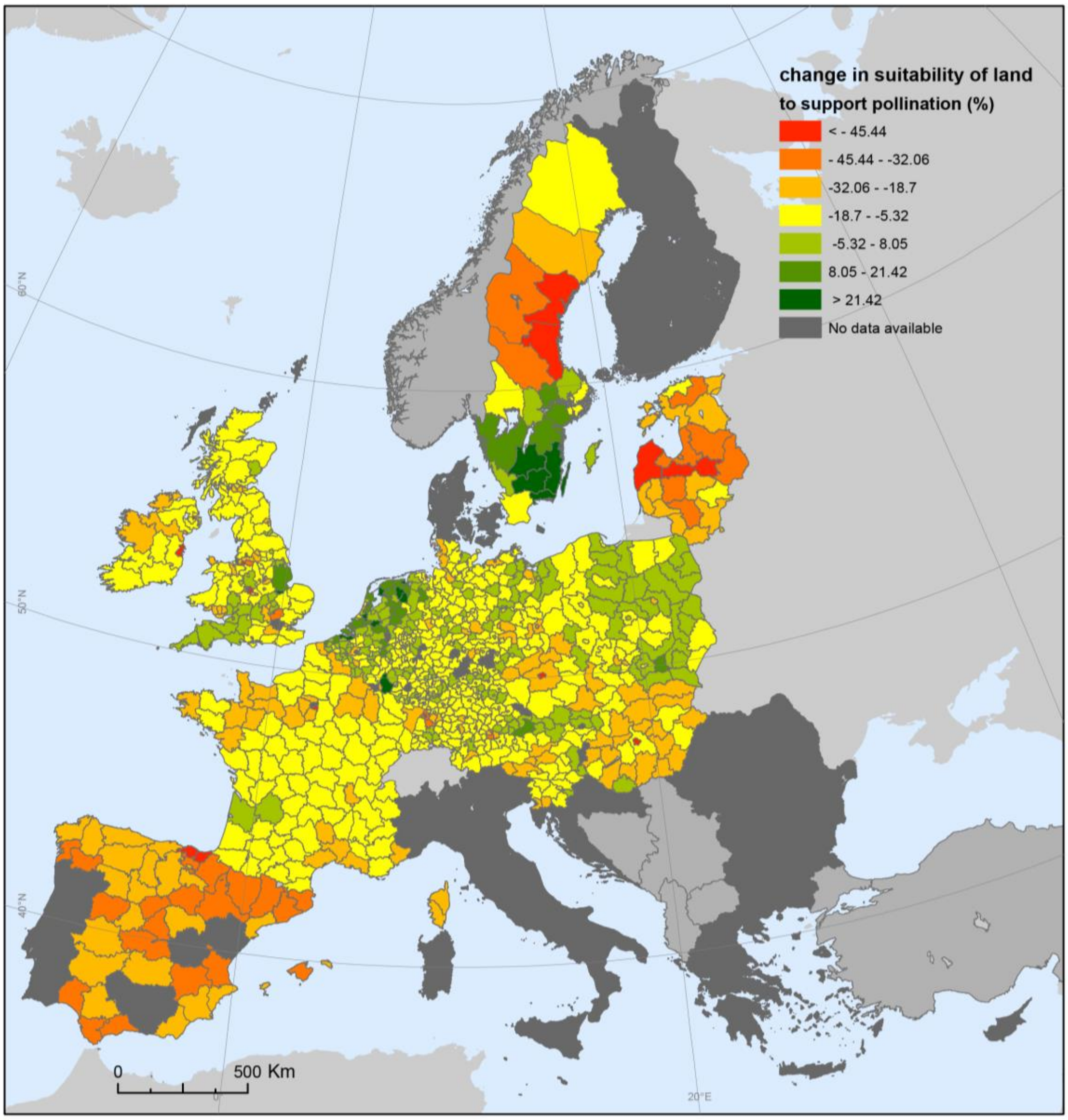


Figure 22. Relative change (%) in the suitability of ecosystems (based on land cover) in supporting pollination (regardless of the development of energy crops).

4.2.2. Habitat quality for birds

Habitat quality maintenance is considered in the TEEB (The Economics of Ecosystems and Biodiversity) and CICES (Common International Classification of Ecosystem Services) classification systems as a regulating ecosystem service. Habitat quality is modelled based on common bird species distribution. The indicator is a ratio between local species richness and regional species richness. Sub-indicators are available for farmland bird species (used here) and forest bird species.

As for pollination, habitat quality for farmland birds shows a generally negative response to energy crop production areas at regional scale (Figure 21). Regions with declining growth rates of energy crops are expected to observe increasing habitat quality for farmland birds. **Regions with rising energy crops production are associated to declining farmland birds habitat quality. These declines are almost entirely due to the conversion of arable land to energy crops** (

Table 4).

Also here, some nuance is needed. Not all arable land (or farmland in general) is equally important to support farmland birds. In Europe, farmland bird diversity continues to decline mainly because of agricultural intensification and land abandonment (Doxa et al. 2010). Low-intensity farmland, supporting or associated with a high rate of biodiversity, increases farmland bird abundances relative to intensively used arable land.

4.2.3. Nature-based recreation opportunities

Nature-based recreation includes activities such as walking, swimming or biking which people can do at a daily basis (for which they do not need to travel). So tourism is not included in the indicator which captures both the potential of land parcels to provide recreation as well as the proximity of these parcels for people.

The changes in nature-based opportunities relative to change in energy crop production are less evident than in the previous two examples. Changes range from -3% to +3% and do not follow a linear pattern.

Forests are important providers of nature-based recreation and the LUISA model is configured to acknowledge this. Cereal and maize fields have no value in supporting nature-based recreation and their conversion to energy crops is thus expected to enhance nature-based recreation (

Table 4). Evidently, a pan-European model can only indicate at coarse resolution where gains and losses of ecosystem services, in this case recreation, are to be expected. The actual supply of recreation services by ecosystems and the demand for recreation by the population depends on a range of local and regional factors: How are ecosystems locally managed; How will energy crops be implemented in the landscape, in such a way that they temporarily provide other ecosystem services as well (e.g., water retention). Also civil participation to nature-based recreation differs widely across Europe which will also affect outcomes of regional scale which go beyond the scope of this study.

4.2.4. Water retention

Water retention is a regulating ecosystem service. The corresponding indicator in LUISA is the water retention index which expresses the capacity of land parcels to store temporarily water before it runs off to downstream areas. **This function is important to prevent flooding and to maintain soil moisture**.

As a general observation, the water retention index (WRI) changes slowly in response to land use change. In regions with no growth of energy crops, the EU Reference Scenario predicts an increase of WRI of 0.5%. Regions with losses of energy crops areas are expected to lose water retention capacity. This difference is significant in regions where bioenergy crop changes with -25%, -75% or -100% (Figure 21). However, also regions with increasing production are expected to experience losses in water retention relative to the regions with no change in bio-energy crop production. Yet, **the general pattern suggests that increasing energy crop production areas is positively related to increasing water retention**, which is in line with the expectation that energy crops retain more surface water than annual crops on arable land.

The results of regression model which predicts the change in WRI using the land flows as predictors only resulted in an explained variance of 9% (

Table 4).

4.2.5. Green infrastructure

Green Infrastructure (GI) is modelled in LUISA as a network of particular land types including forests seminatural areas. Energy crops are not considered as green infrastructure in the present set-up of LUISA. So, in principle, **expansion of energy crops results in loss of green infrastructure**, which is evident from Figure 21 although losses are relatively small. In contrast, regions with declines in energy crops are expected to increase the GI-network but this pattern is not consistent. Land conversions from forest and woodland as well as from natural land to energy crops drive, obviously, the loss of GI (Table 4).

4.3. Case studies

This section illustrates the impact of increasing areas of energy crops on the selection of indicators, using five case studies. The case studies include regions from Estonia, Poland, UK, Netherlands and Spain. They are selected along a gradient in energy crop areas, from negative (a loss of 66% in 2050 relative to 2020) to positive growth (increment of more than 1000% corresponding to a substantial increase in area under energy crops; in the case of Todedo (Spain) from 377 ha in 2020 to over 65 thousand ha in 2050). Furthermore, each case study has different patterns in land conversions from different land use types to energy crops.

The results are summarised in Figure 23. The five regions are assorted according to the change in energy crop areas. For each region, the change in ecosystem service provision and green infrastructure is plotted. The correlation trends observed in Figure 21 are confirmed: a loss of pollination and habitat quality for farmland birds with increasing energy crops area; a mixed response for nature-based recreation; growth of the Green Infrastructure network in the regions with an outspoken loss of energy crops; and a moderate impact on water retention.

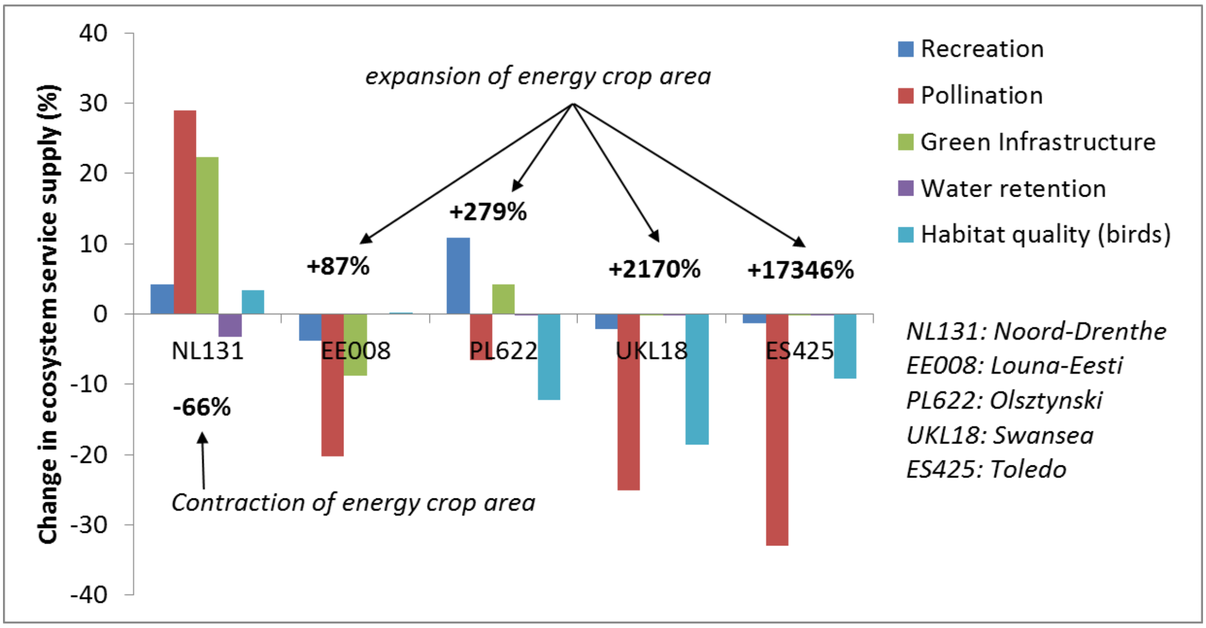


Figure 23. Relative change in ecosystem services and green infrastructure between 2020 and 2050 (%) for 5 regions in Europe with different changes in energy crop areas.

For each case, the land use in 2050 is mapped together with a bar diagram of the land flow between energy crops and other land types. The case for the Netherlands (Noord Drenthe) is given in Figure 24. This region contrasts with the other regions in that it is expected to undergo land conversion from energy crops to mainly forest and woodland (hence the negative land flow in the bar diagram). A total afforestation of 6000 ha is expected to increase the supply of most ecosystem services (Figure 23). The opposite pattern is expected for the case study in Estonia (Figure 25), with a predominant land flow from forest to energy crops (32 thousand ha) and an overall loss of ecosystem services.

Two case studies (one in Poland and one in the UK) are expected to undergo land conversions from farmland to energy crops, but their patterns differ. In the Polish region (Figure 26), arable land is lost towards energy crops, while in the British region (Figure 27, Swansea), mainly pasture will be turned into land for the production of energy crops. Note also the differences in absolute and relative magnitude of the changes in energy crop expansion. In the Polish region, as much as 100 000 ha are converted, which corresponds to a nearly 300% change over a 30 year time span, while in the UK region, a few thousands of ha are converted but it results in a much larger relative change. As a result, ecosystem services decline in both regions at different relative rates as well, with higher percent losses in the UK region.

Finally, the Spanish case (Figure 28) is very similar to the UK region in terms of impact, with losses in pollination and habitat quality for farmland birds due to the conversion of agricultural land to energy crop production.

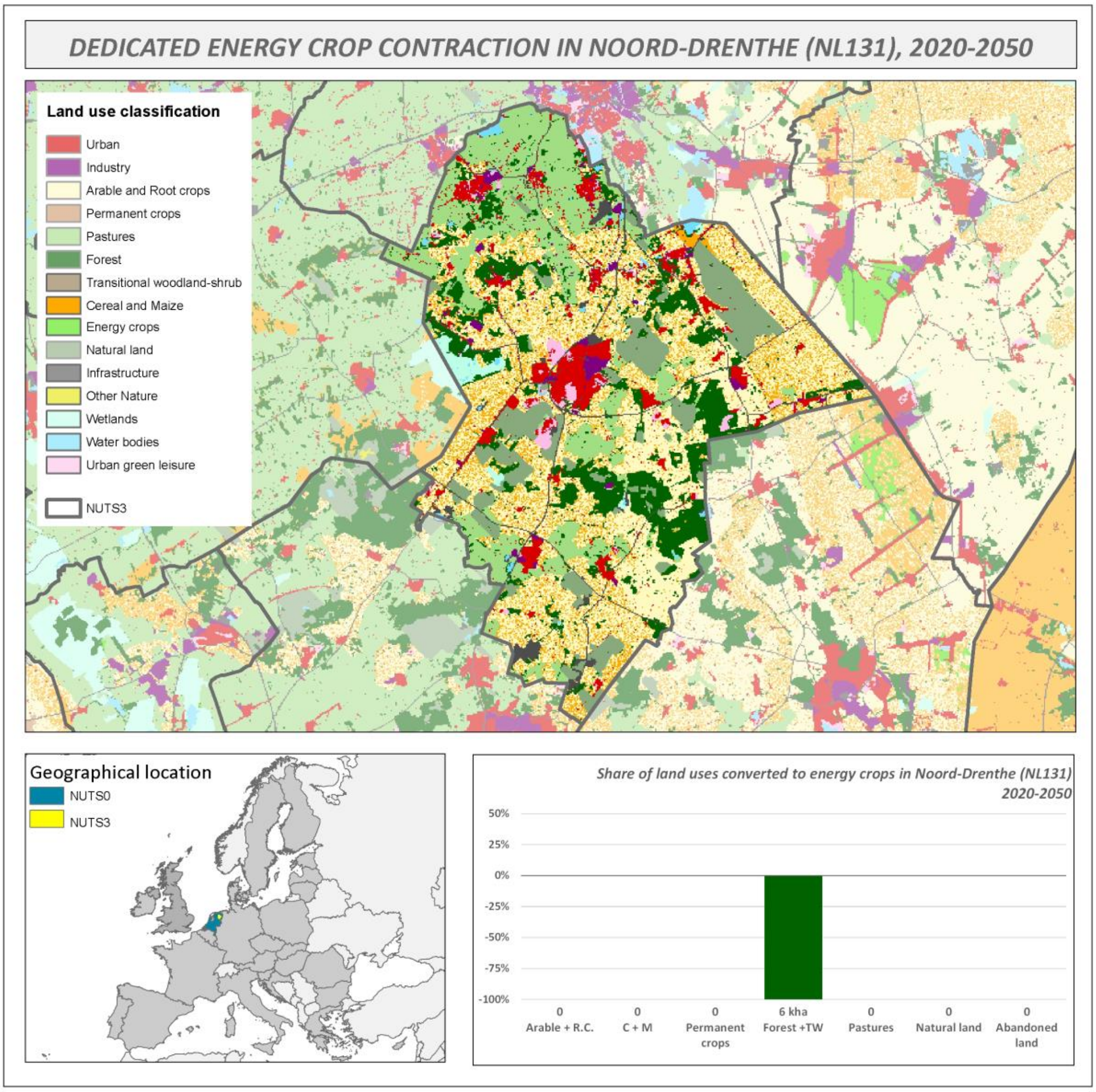


Figure 24. Land use in 2050 and land flows from energy crops to mainly forest expected for the Noord Drenthe region in the Netherlands. (R.C.: Root Crops; C+M: Cereals and Maize; TW: Transitional woodland).

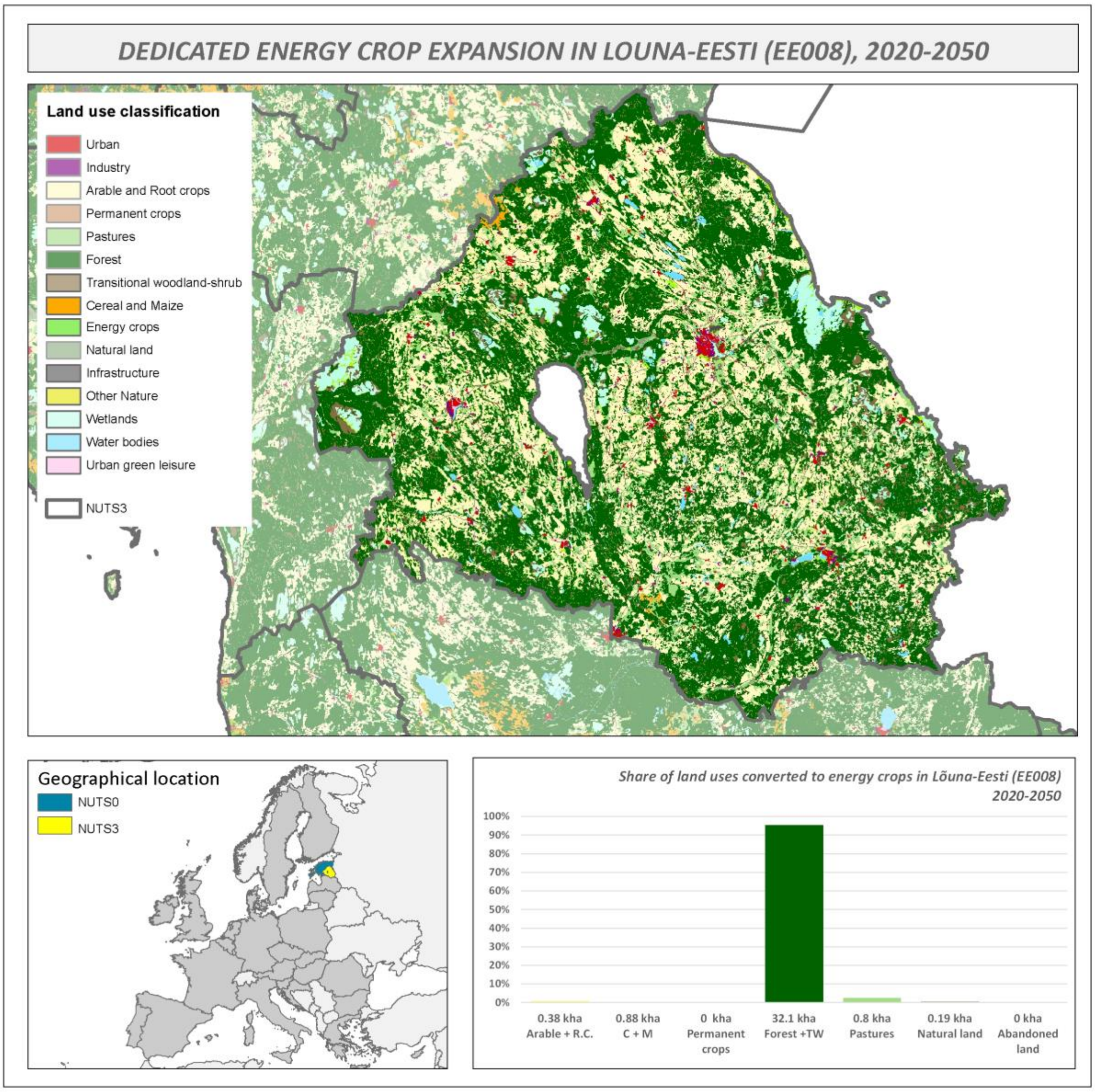


Figure 25. Land use in 2050 and land flows from mainly forest to energy crops expected for the Louna-Eesti region in Estonia. (R.C.: Root Crops; C+M: Cereals and Maize; TW: Transitional woodland).

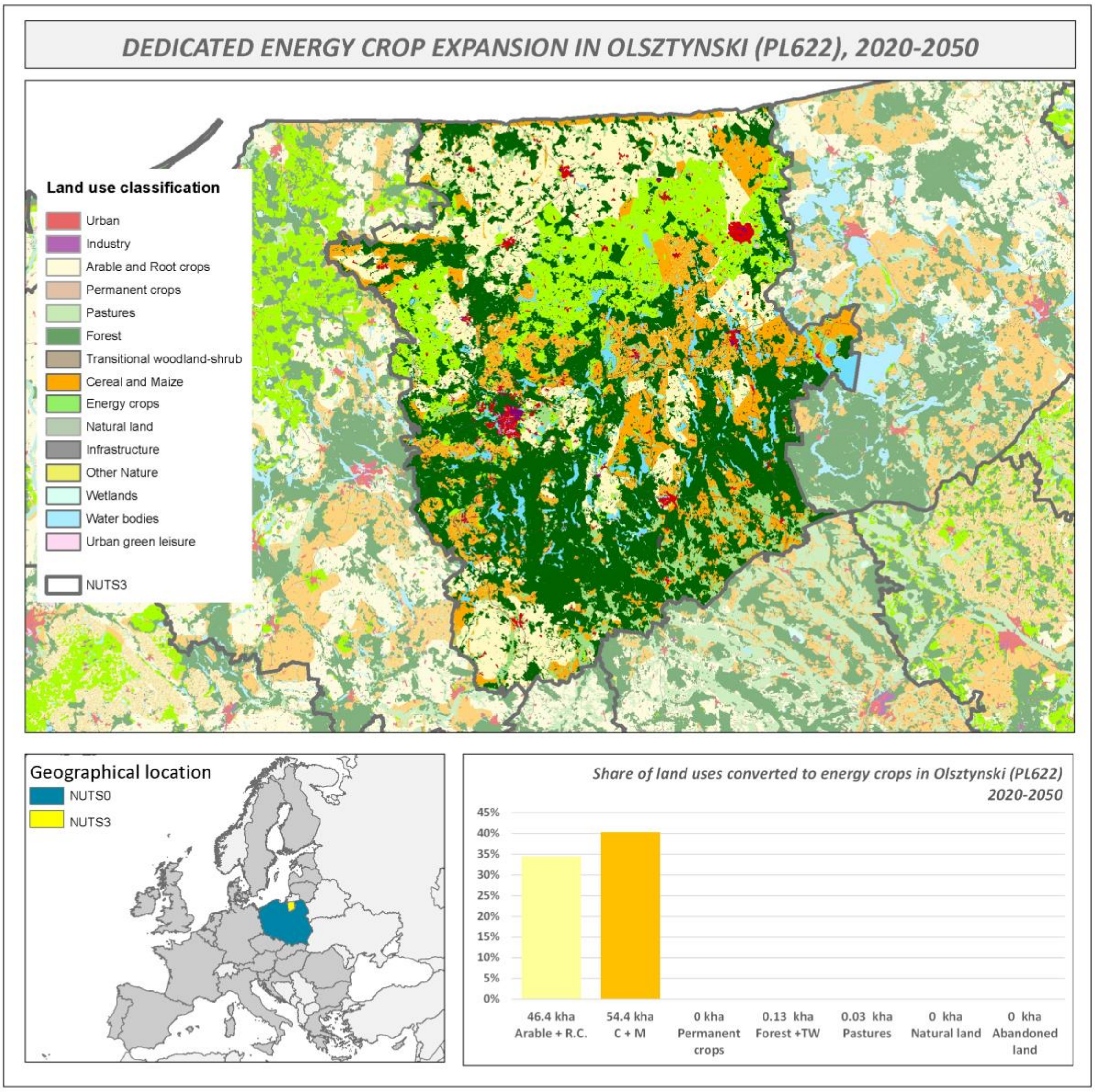


Figure 26. Land use in 2050 and land flows from mainly arable land to energy crops expected for the Olsztynski region in Poland. (R.C.: Root Crops; C+M: Cereals and Maize; TW: Transitional woodland).

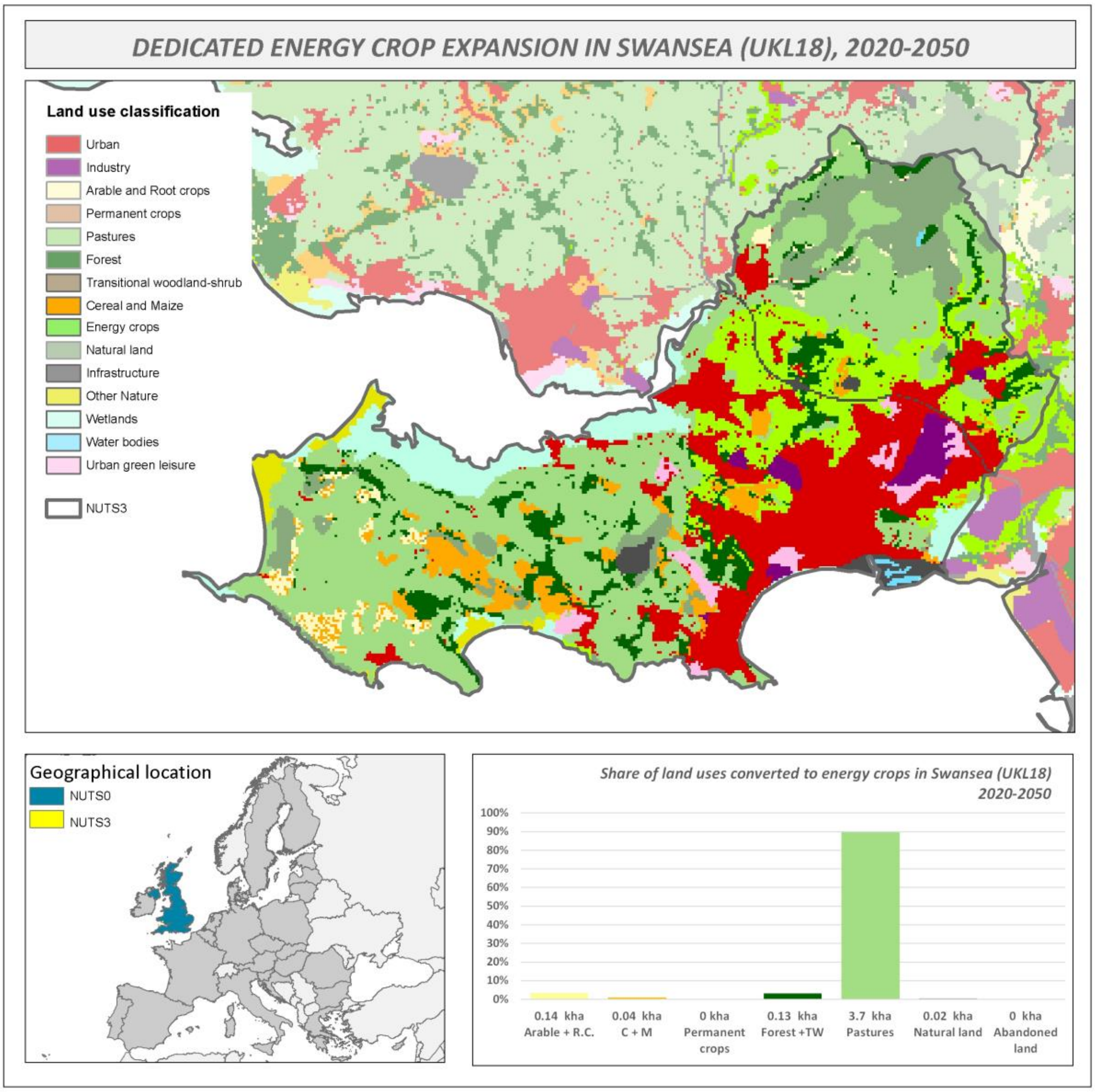


Figure 27. Land use in 2050 and land flows from mainly pasture to energy crops expected for the Swansea region in the UK. (R.C.: Root Crops; C+M: Cereals and Maize; TW: Transitional woodland).

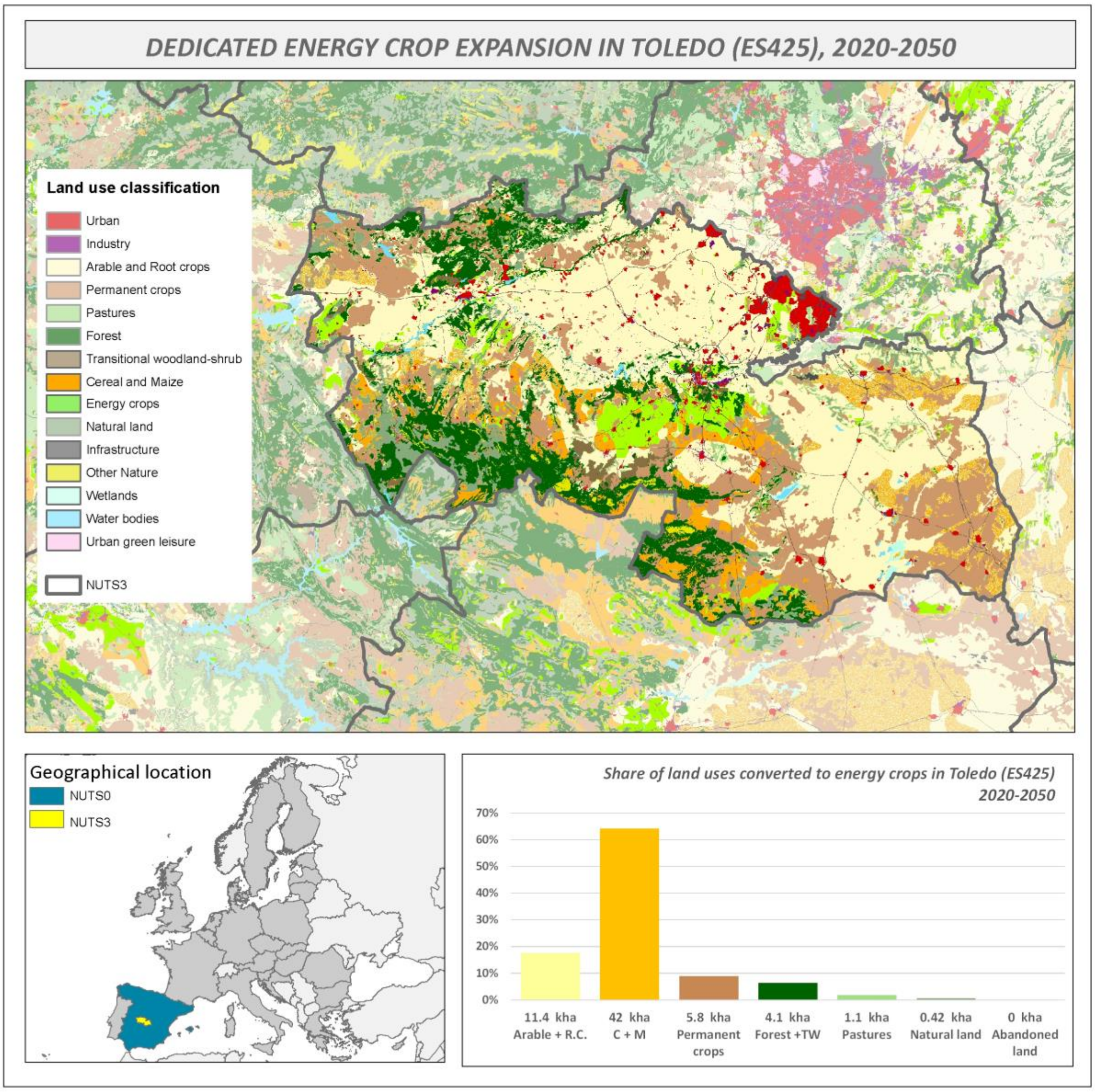


Figure 28. Land use in 2050 and land flows from different farmland types to energy crops expected for the Toledo region in Spain. (R.C.: Root Crops; C+M: Cereals and Maize; TW: Transitional woodland).

Conclusions

This report presents the results of the analysis of dedicated energy crops (ENCR) at European level under the EU Reference Scenario 2013, as implemented in the LUISA modelling platform (updated configuration 2014). The territorial assessment carried out by the LUISA platform highlights where in Europe the current macro-economic trends and 2020 climate and energy policy targets might impact our land resources in the mid-long term. This might happen, for instance, in regions where the demand for energy crops and the need for residential and industry/commerce/services areas are forecasted to increase.

The assessment of dedicated energy crops is presented in the report according to the total amount of ENCR aggregated at national and regional level with reference to: 1) the total available land and land demand, 2) the identification of the land uses that are converted to ENCR, 3) the use of degraded and contaminated lands as specific land with potential for energy cropping and 4) the amount of ENCR allocated on different suitability levels according to biophysical requirements. The following conclusions can thus be drawn:

- Land use changes due to the expansion of ENCR in the EU28 represent **17% of the total land use changes between 2020 and 2050**. In Sweden, Finland, Estonia, Latvia and Portugal, mainly natural lands are used for the expansion of ENCR. The remaining countries are predominantly losing agricultural lands
- **In 2020, the total area of energy crop in EU28 reaches 4,733 kha (1.3% of the total available land[10])**. France, Germany and Poland have the highest energy crop area in absolute figures. There is also ENCR in Romania, Luxemburg, Croatia, Denmark, Bulgaria, Cyprus, Finland, Greece, Malta and Portugal.
- **In 2050, the total production of ENCR in EU28 reaches 13,549 kha (3.6% of the total available land).** The trend substantially changes for Poland, Spain and Romania, which undergo a considerable energy crop expansion and become part of the group of main producers along with France and Germany. On the contrary, ENCR disappear altogether in Italy.
- **The significant expansion of ENCR in some countries** such as Poland, Spain, Germany, Romania, the United **Kingdom leads to a high competition for land**, since different alternative uses (food, forestry, urban, energy) compete for the same piece of land (further information in Baranzelli et al. (2014a).
- In the LUISA configuration herein adopted, food production is given priority in getting access to good quality soils, favouring degraded and contaminated lands to be reclaimed for planting ENCR. Soil salinity, severe erosion areas and contaminated lands are considered as unfavourable conditions for food and feed crops, but those lands are potentially suitable for cultivation of some energy species. **The total amount of degraded and contaminated lands reused for the conversion to energy accounts for respectively 1,965,497 ha and 4,953,903 ha in 2030 and 2050 across Europe**. These figures represent 24% and 36% of the total energy crop production for the same years, which reflects a certain recuperation of land with potential for energy crop growth. In the modelling, contaminated land is the group that contributes the most to produce energy crops (55%), followed by soils with high saline concentration (26%) and areas with severe erosion (19%). Italy, Spain, Hungary, the United Kingdom and France, with high energy crop production, are recovering efficiently degraded and contaminated lands (more than 50% in most of their regions) while Germany and Poland, though being part of the group of high producer countries of ENCR, do not practically make

[10] Total available land refers to all the simulated land-use classes with the exception of urban and industrial land (simulated land-use classes), infrastructures, other nature, wetlands and water bodies (non-simulated land-use classes).

use of those land categories lands. With a more modest energy crop production, Austria and Czech Republic are the only countries with a reconversion of degraded and contaminate lands reaching nearly 30%, and Belgium and Luxemburg 100%. A small proportion of degraded and contaminated lands (below 20%) is recuperated in Ireland, Sweden, the Netherlands, Lithuania, Slovakia and Slovenia. It is worth stressing that factors related to biophysical, accessibility and climate conditions are considered in LUISA for the allocation of all crops and indeed ENCR are a cost-effective choice in places where remediation or decontamination might be required for the cultivation of other crops.

- In some regions, displacement of food and feed crops is caused by the large increase of ENCR. It is the land suitable for the crops belonging to the LUISA class "Other Arable" (it includes: rape, sunflower, soya, pulses, tomatoes etc, see Table 6 in Annex II) that is mostly taken by energy crops, especially in Poland, Romania, Hungary, Germany and Austria, reaching nearly 30% in these countries. Land suitable for cereals undergoes a decline in the same countries, but affecting less regions than for the "Other Arable" land. Land highly suitable for maize and root crop is less used for energy purpose. The analysis of the distribution of ENCR within the five suitability levels of the land dedicated to ENCR reveals that, for the largest producing countries, ENCR are allocated on the most suitable soils for their growth (moderate, high and very high suitability levels), but less so in Poland, Romania and the United Kingdom. However, in Estonia, Sweden, Latvia, Lithuania, Slovakia and Hungary, ENCR are predomominantely cultivated on the least suitable soils. Due to the growth of residential and ICS (industry, commercial and services) sites, land highly suitable for the cultivation of food crops and feed crops is increasingly being used for artificial uses. In the case of energy crop production, the results are more heterogeneous across Europe. Countries such as Italy, France, Portugal, Spain and Greece are losing the most fertile lands for energy production in favour of urban fabric and other economic activities, while central, eastern and northern part of Europe preserve better the land highly suitable for the cultivation of ENCR.
- As result of the land competition, there is an increasing shift of food and feed crops towards low quality land, with environmental and economic impacts to be carefully evaluated.

The (statistical and spatially-explicit) impact analysis combined the changes in the total production for ENCR and the changes in the potential supply for a selection of ecosystem services (pollination, water regulation, habitat quality for farmland birds, nature-based recreation potential and also the Green infrastructure network) at NUTS3 scale for the period between 2020 and 2050[11] simulated in LUISA. In turn, the changes in ecosystem services depend directly on the land-use changes, being quantified in this study as land flows (conversion from any land use to energy crops).

The main findings of this analysis reflected a different response for each ecosystem services relative to a regional growth rate of ENCR production:

- Pollination potential is expected to decrease, on average by 13%, showing a loss of land with the capacity to provide pollination. The most affected areas in Europe are located in Spain, mid and northern Sweden and the Baltic States. However, there are evidences that other factors (such as afforestation) are also involved in the decrease of this service.
- Both habitat quality for farmland birds and water retention would undergo moderate changes between 2020 and 2050 (less than 2 percent points). Habitat quality declines in regions where ENCR production is expected to increase due to the conversion of arable land to ENCR plantations. In Europe, farmland bird diversity continues to decline also because of agricultural intensification and land

[11] Energy crops projections starts from 2020 onwards as derived by CAPRI model

abandonment. With regard to water retention, the general pattern suggests that increasing production is positively related to increasing water retention, which is in line with the expectation that ENCR retain more surface water than annual crops on arable land.

- The relationship between the changes in nature-based recreation opportunities and ENCR production is less obvious than for the previous ecosystem services, without a clear pattern. This is meanly due to the fact that cereals and maize fields have no value in supporting this service and their conversion to ENCR is thus expected to enhance nature-based recreation. On the other hand, the loss of green infrastructure is due to the land conversions from forest and woodland as well as from natural land to ENCR plantations.

Annex I. An overview of the Luisa modelling platform

The Land Use-based Integrated Sustainability Assessment modelling platform (LUISA) has been developed by the JRC and applied to address the competition for land arising from the energy, transport and climate dimensions of EU policies. This resulted in a high resolution land-use/cover simulation up to 2050, called the EU Energy Reference Scenario 2013 (updated configuration 2014 in LUISA).

LUISA is based on the principle that different land uses compete for the most suitable locations, given available land, assumed demand and policy constraints or incentives. The actual allocation of each land-use is governed by an optimization approach so that, given the modelling assumptions (Baranzelli et al., 2014), the resulting projected landscape represents the best spatial distribution. This implies that each land-use transition (change) causes trade-offs between different uses, both the two directly involved in the transition and possibly others (indirect impacts) affecting the society, environment and the capacity to provide ecosystem services.

Conceptually, LUISA is structured in three main modules: the 'demand module', the 'land use allocation module' and 'the indicator module'. The demand module takes into account sector specific land requirements. Macro-economic models are integrated in this module, specifically EUROSTAT for demographic projections, GEM-E3 for industry, commerce and services, CAPRI, for agricultural commodities (production of food, feed and energy crops), and official figures reported by UNFCCC for forestry, at large scale, country or macro-regional level. The allocation module spatially distributes the regional land use demands based on biophysical 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. Afterwards, 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 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). Concerning the land-use legend of the simulated classes within LUISA, the refined CLC2006 classes are aggregated as table X shows. Other classes are created to fulfil specific project requirement like abandoned classes.

Table 5. Land use legend in LUISA modelling platform

Land use classes	Land use / cover change
Urban (*active/abandoned*)	*Simulated*
Industry (*active/abandoned*)	*Simulated*
Other arable (*active/abandoned*)	*Simulated*
Permanent crops (*active/abandoned*)	*Simulated*
Cereals, Maize, root crops (*active/abandoned*)	*Simulated*
Pastures (*active/abandoned*)	*Simulated*
Forest *(active)*	*Simulated*
Transitional woodland shrub *(passive)*	*Simulated*
Scrub and/or herbaceous vegetation associations *(passive)*	*Simulated*
Energy crops *(active)*	*Simulated*

Infrastructure	*Not simulated*
Other nature	*Not simulated*
Wetlands	*Not simulated*
Water bodies	*Not simulated*

Annex II. Energy crop demand derived from the CAPRI model

The CAPRI (Common Agricultural Policy Regionalised Impact) model is a global agro-economic model of agricultural commodity markets with a focus on the European Union (Britz, 2012) which assesses the impacts of the Common Agricultural Policy (CAP) at NUTS 0 and NUTS 2 level. Besides, CAPRI also allows calculation of a wide range of economic and environmental indicators. Since CAPRI is primarily an economic model does not take explicitly into account the competition for land among different non-agricultural uses, and therefore it does not account for the availability of suitable land for growing agricultural commodities.

In LUISA, CAPRI model is the main driver to provide projections for agricultural commodities and dedicated energy crops. Each of the agricultural land-use classes corresponds to an aggregation of CAPRI commodities (Table 6).

Table 6. Correspondence table between CAPRI commodities and the seven agriculture land-use classes in LUISA

CAPRI commodity	LUISA 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]	
Table Grapes [TAGR]	
Olive plantations [OLIV]	
Table olives [TABO]	
Table wine [TWIN]	
Nursery plants [NURS]	
Flowers, ornam. plants, etc. [FLOW]	
Rape [RAPE]	Other Arable
Sunflower [SUNF]	
Soya [SOYA]	
Other oils [OOIL]	
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]	
Other crops [OCRO]	
Grassland extensive [GRAE]	Pastures
Grassland intensive [GRAI]	
Grassland set-aside [GSET]	
New Energy Crops [NECR]	New Energy Crops

In LUISA, lignocellulosic crops, both woody and herbaceous, used for the production of second generation biofuels, are simulated as one unique class (dedicated energy crops, ENCR). Land demand for this class is derived from the CAPRI model, and it corresponds to the CAPRI product aggregate "New Energy Crops - ligneous" which covers herbaceous and fast growing woody species (like poplar or willow).

The version of CAPRI currently used in LUISA corresponds to the Reference Scenario run in the context of the EUCLIMIT Project, developed in support of the European Commission and which was coordinated by the PRIMES team[12] in cooperation with IIASA, EuroCARE

[12] E3MLab: http://www.e3mlab.ntua.gr

and EXERGIA. The technical name of this CAPRI run is "PRIMESCOR". In this version currently used in LUISA (PRIMESCOR run), ENCR are not an explicit production activity, but they are exogenously fixed by the PRIMES model. Biofuels produced from ENCR are accounted for in CAPRI by reducing the agricultural land used for other agricultural production activities, in accordance with the yield information collected for these dedicated energy crops. In CAPRI, yield information for estimating land requirements of energy crops are derived also from Fisher et al., 2007[13]. As the yields of herbaceous and woody energy crops differ only moderately between the two categories, in CAPRI they were grouped using an average aggregated yield.

As a result of this configuration, energy crops are forecasted to appear not before the year 2020 in all EU28. For some countries, energy crops are absent for the whole simulation period (2020-2050), such as in Denmark, Greece, Malta, Cyprus and Croatia, while for others, as in Italy, Portugal, Romania, Bulgaria and Finland, fluctuations are forecasted.

[13] Fischer et al.: Assessment of biomass potentials for biofuel feedstock production in Europe: Methodology and results. REFUEL project report. Laxenburg, 2007.

Annex III. Suitability maps for energy crops

As was mentioned in section 2.4. eight suitability maps were generated for the selected crops: miscanthus, switchgrass, red canary grass, giant red, cardoon, willow, poplar and eucalyptus plantations. A GIS-multicriteria analysis was applied to define the most important biophysical factors determining the suitability of land to grow these crops (Perpiña et al., 2015).

Six suitability classes were defined to assigned numerical values to each class belonging to each factor map. The classes were classified as follows: Very suitable (highest adaptability), suitable, moderately suitable, low suitability, poorly suitable (low adaptability) and not suitable. The weighted linear addition (WLA) technique was applied in order to integrate all individual factors maps and to determine the overall suitability (appropriateness of the land to grow a specific energy crops) at each location. By integrating all biophysical factors map in one, it is possible to quantify the final suitability of each location (pixel) and per energy crop specie. The resulting suitability maps are shown in Figure 29 representing the degree of suitability of the land for each energy crop across Europe.

There is high variability in the resulting suitability maps for each energy crop, which reflects both the differences in adaptability between crops and the differences in physical characteristics of the land over Europe. The total suitable area varies strongly among the considered energy species. The herbaceous crops miscanthus, switchgrass and especially reed canary widely largely spread in Europe. Reed canary grass is adaptable to a wide range of temperature (from below 0°C to the warmest) and precipitation regimes, and can be grown from the south (Portugal, Spain, Italy, and Greece) to the north of Europe, including southern Finland and Sweden. Cardoon and giant reed are much less dispersed, and are adaptable mostly to Mediterranean regions and the north-western of France. With regards to woody crops, willow shows the highest adaptability, with highest suitability in central Europe, but covering even the eastern countries. As opposed to willow and poplar, eucalyptus is only adaptable to a limited range of possible sites in the Mediterranean regions since it requires warm temperatures (annual means between 12 - 23°C) in order to grow successfully.

In summary, the most suitable areas in Europe for dedicated energy crop are the north-western of France, north of Spain and the surrounding area of the strait of Gibraltar, from the north to the south of Italy except the Apennine Mountains, the central part of Portugal and Greece, the southern area of Romania and north of Bulgaria, and finally the western side of the United Kingdom and central and south-eastern side of Ireland. The remaining central European countries have moderately suitability and the eastern European countries have the lowest suitability for these energy crops.

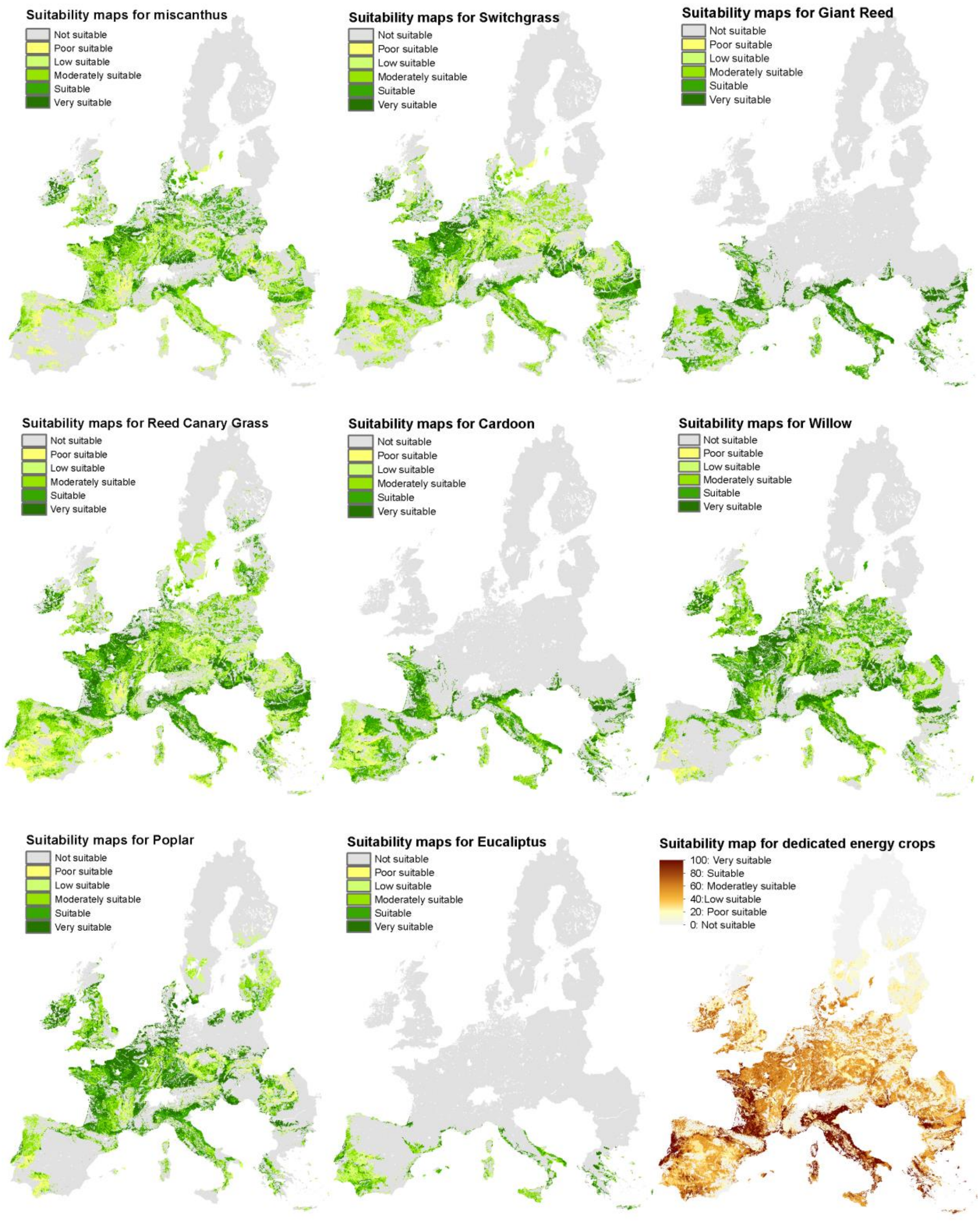


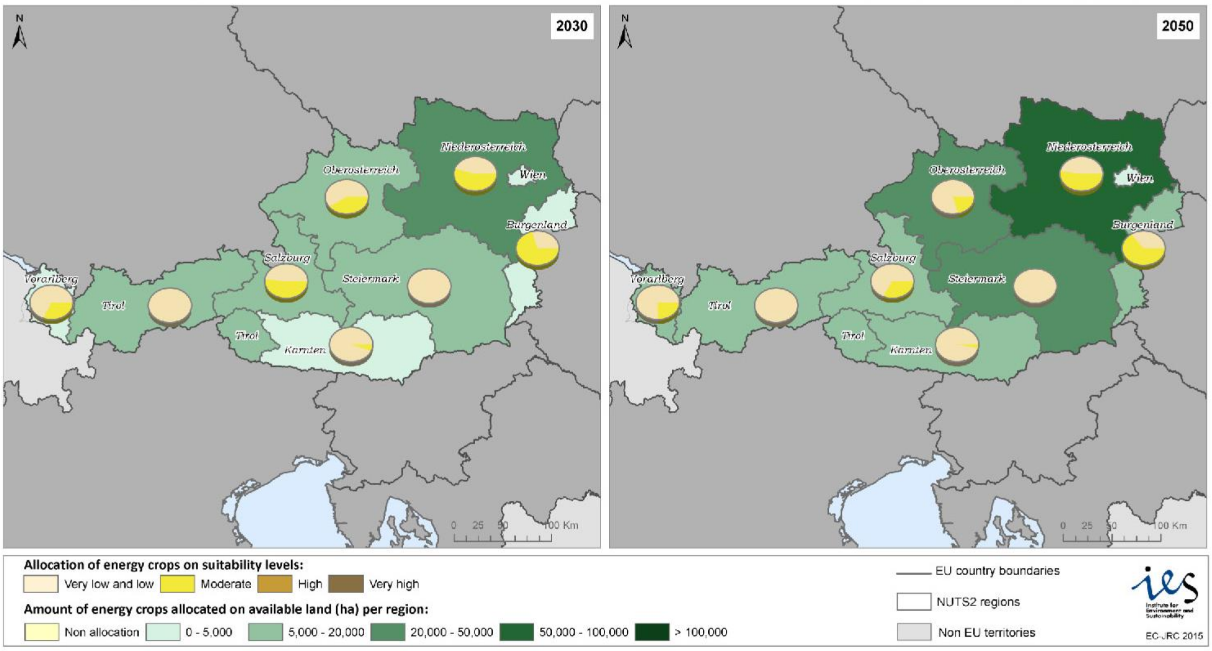
Figure 29. Suitability map for the individual energy crops (miscanthus, switchgrass, reed canary, giant reed, cardoon, willow, poplar and eucalyptus), with the last frame representing the overall suitability map for energy crops as a whole

Annex IV. Energy crop factsheets: analysis of the allocation of energy crops at Member State level

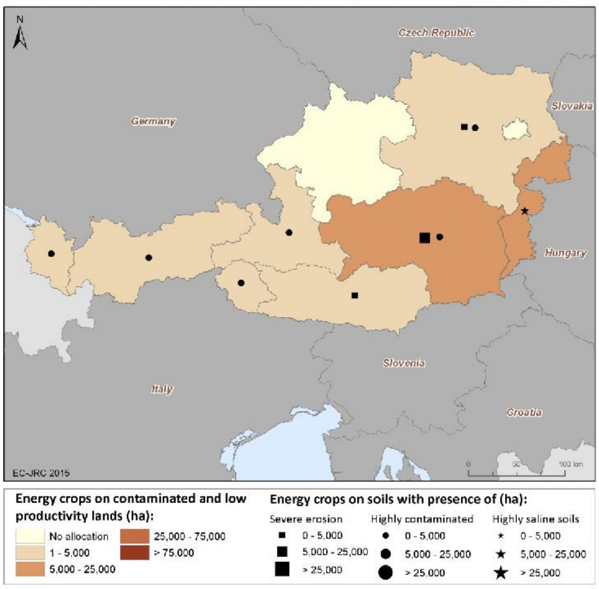
AUSTRIA (AT)

In Austria the allocation of energy crops reaches 71 and 189 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops , on average, between 1% and 3.4% of the total available land within each region in 2050. Broadly speaking, energy crops are allocated on low and very low local (biophysical) suitability lands (by 65% and 70% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly cereals and maize (46%), other arable land (26%), and pastures (14%) in 2050.

Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

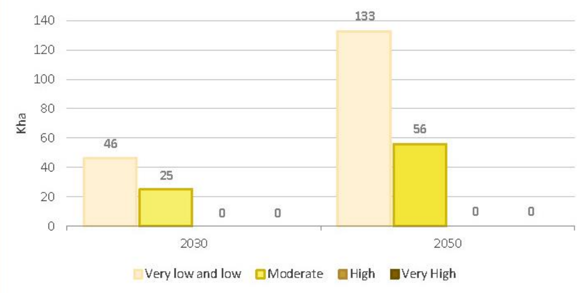


Energy crops on low productivity lands (2030)

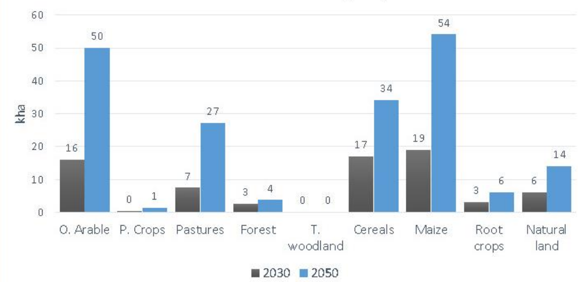


The allocation of energy crops on low productivity and contaminated lands reaches 18,285 ha (13% of low productivity lands over the total available land) in 2030.

Energy crops allocated on different suitability levels in Austria



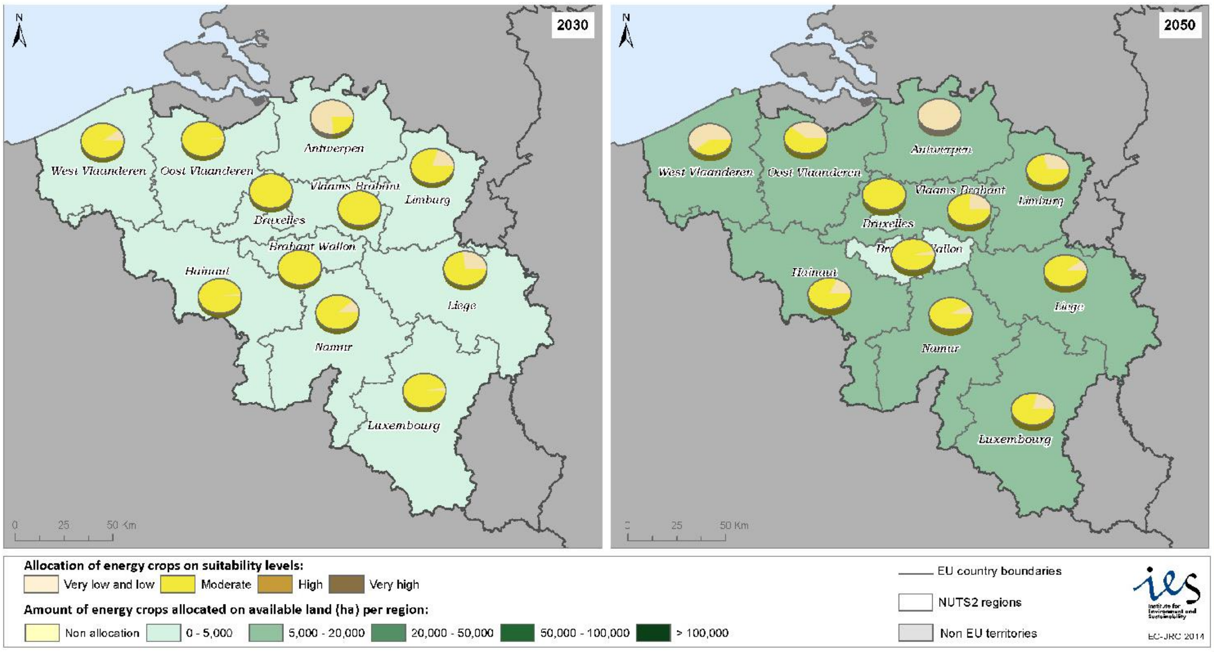
Land uses converted into energy crops in Austria



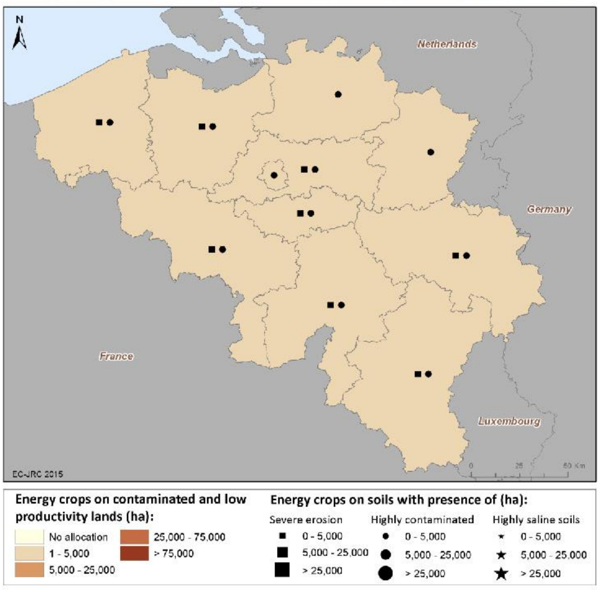
BELGIUM (BE)

In Belgium the allocation of energy crops reaches 22 and 85 Kha in 2030 and 2050 respectively. These figures represent a share of energy crops, on average, between 0.1% and 4.2% of the total available land within each region in 2050. Broadly speaking, energy crops are not successfully allocated on the high local (biophysical) suitability lands (by 35% and 52% on low and very low for 2030 and 2050, respectively) in Belgium. The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (35%) and cereals, maize and root crops (41%) in 2050.

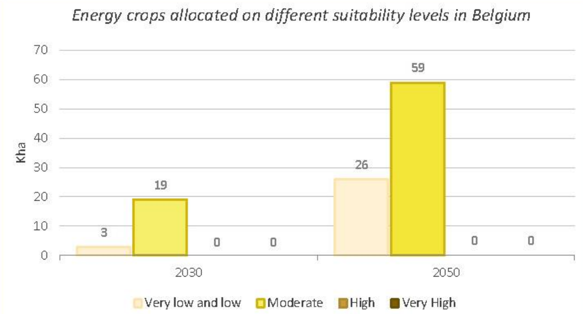
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

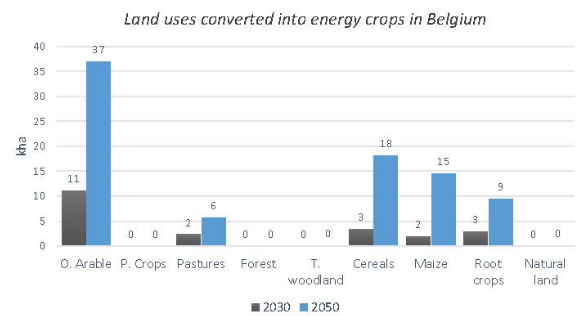


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 19,345 ha (2.5% of low productivity lands over the total available land) in 2030.

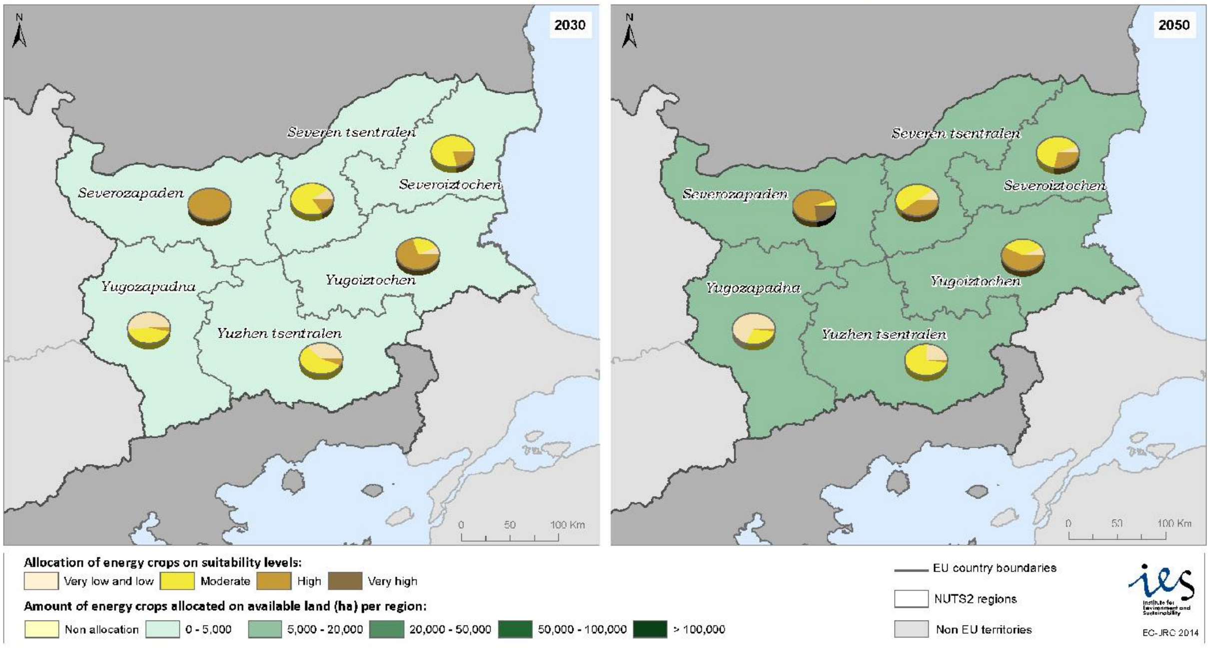




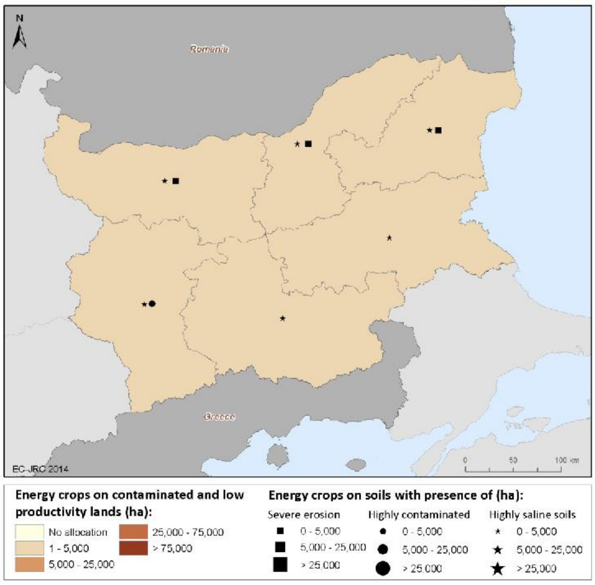
BULGARIA (BG)

In Bulgaria the allocation of energy crops reaches 24 and 91 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops between 0.6% and 1.3% of the total available land within each region in 2050. Broadly speaking, energy crops are successfully allocated on moderate and high local (biophysical) suitability lands (by 82% and 83% in 2030 and 2050, respectively) mostly in the north part of Bulgaria. The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (53%), cereals and maize (31%) and pastures (9%) in 2050.

Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

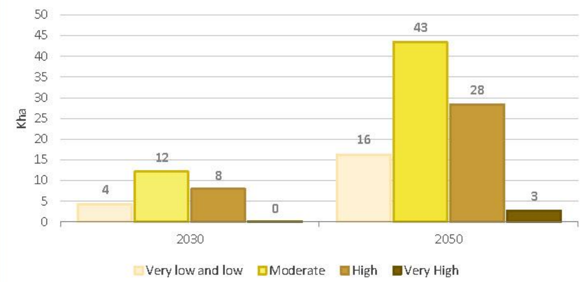


Energy crops on low productivity lands (2030)

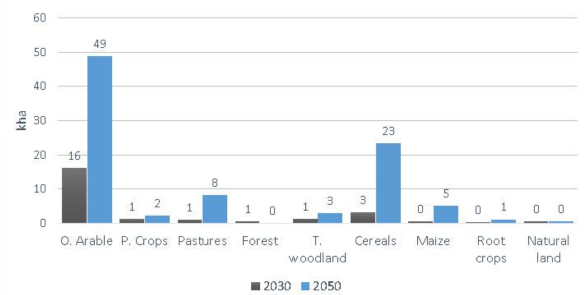


The allocation of energy crops on low productivity and contaminated lands reaches 15,824 ha (11.5% of low productivity lands over the total available land) in 2030.

Energy crops allocated on different suitability levels in Bulgaria



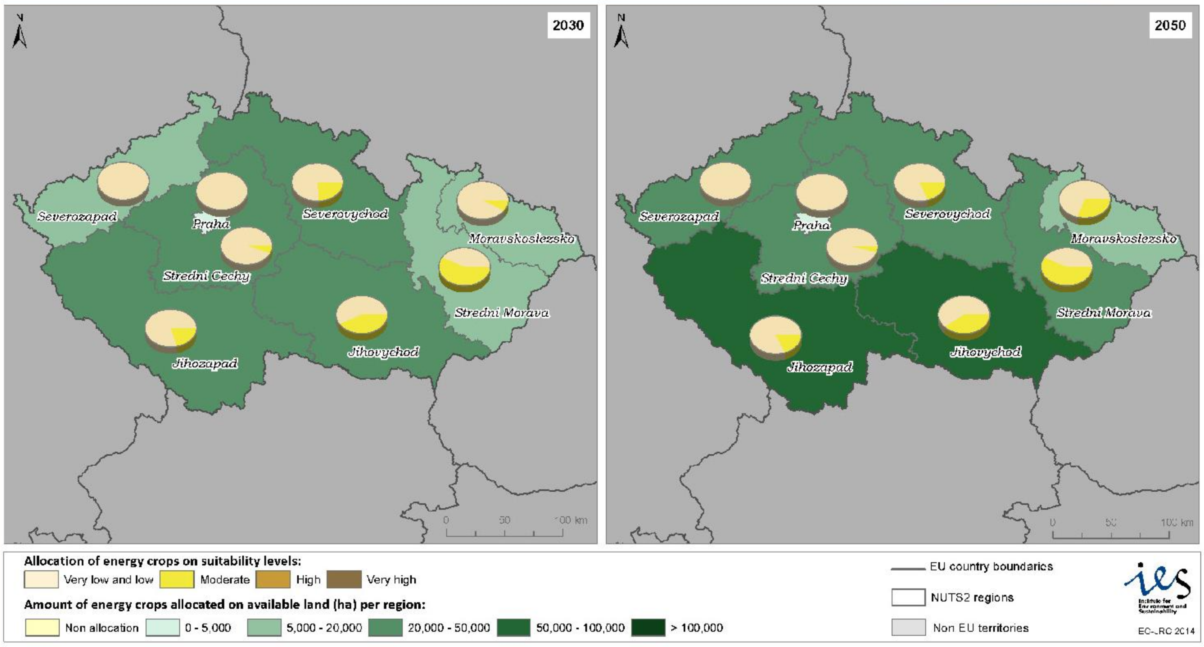
Land uses converted into energy crops in Bulgaria



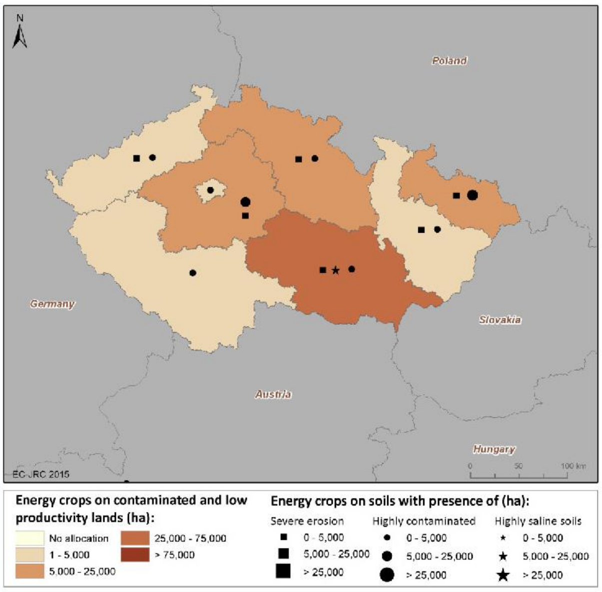
CZECH REPUBLIC (CZ)

In Czech Republic the allocation of energy crops reaches 182 and 274 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops between 0.6% and 1.3% of the total available land within each region in 2050. Broadly speaking, energy crops are successfully allocated on high local (biophysical) suitability lands (by 86% and 41% on moderate and high in 2030 and 2050, respectively) mostly in the north-eastern part. The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (55%), cereals and maize (24%) and forest (32%) In 2050.

Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

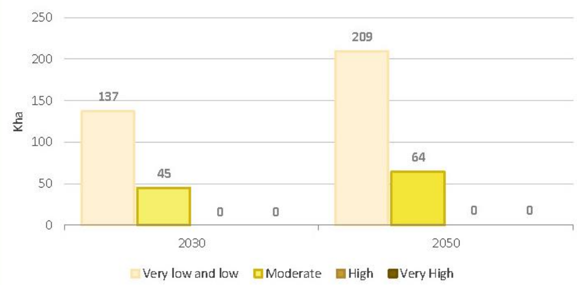


Energy crops on low productivity lands (2030)

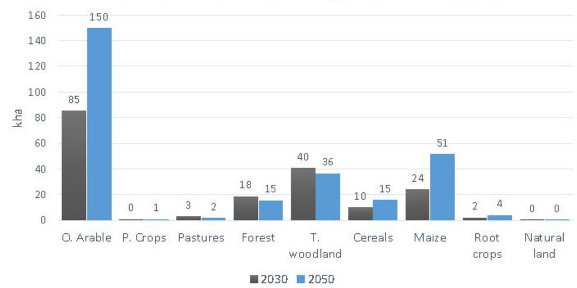


The allocation of energy crops on low productivity and contaminated lands reaches 62,253 ha (16% of low productivity lands over the total available land) in 2030.

Energy crops allocated on different suitability levels in Czech Republic



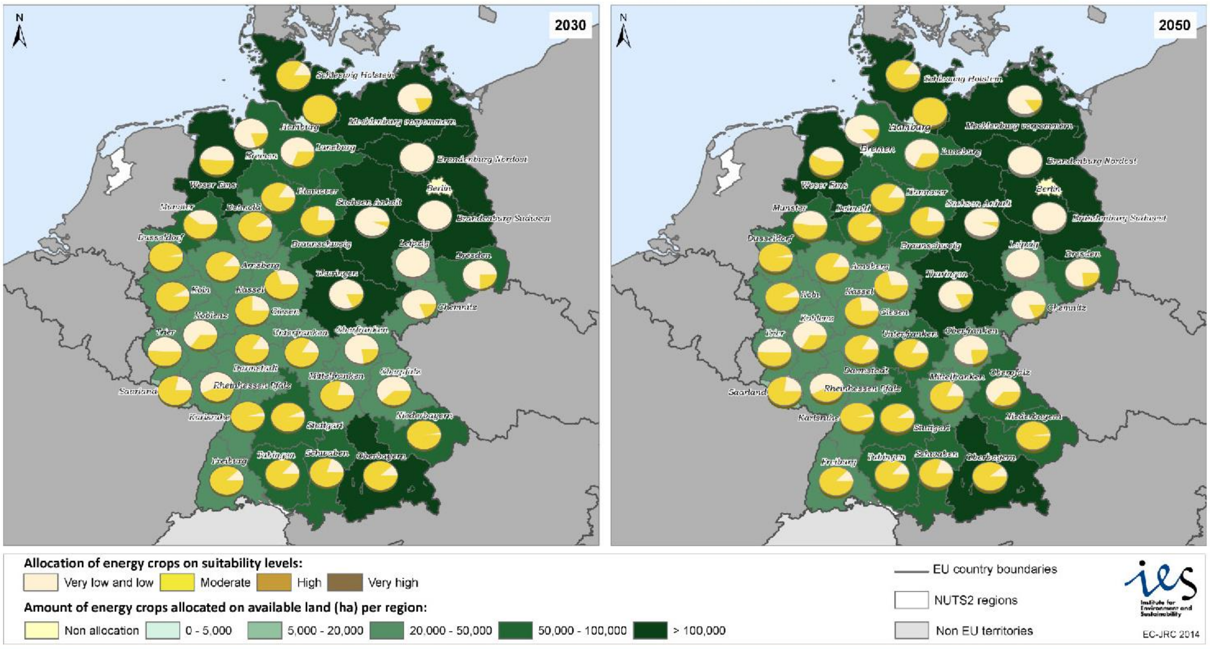
Land uses converted into energy crops in Czech Republic



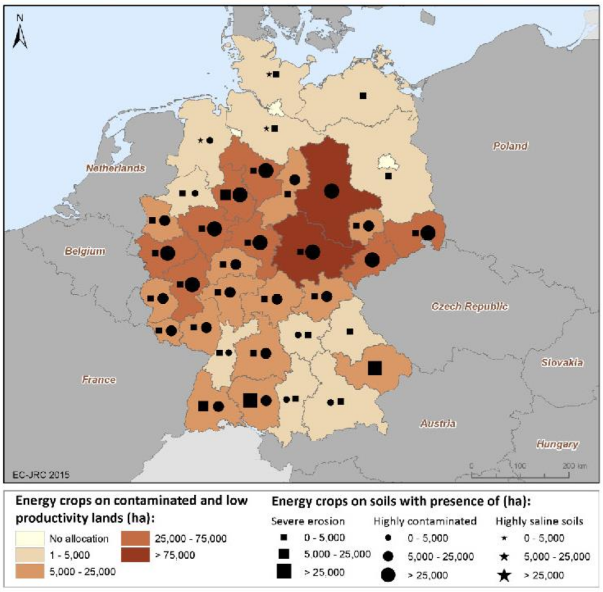
GERMANY (DE)

In Germany the allocation of energy crops reaches 2,205 and 2,448 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops, on average, between 4.5% and 9.2% of the total available land within each region in 2050. Broadly speaking, energy crops are half allocated on low and moderate local (biophysical) suitability lands (by 47% and 43% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (41%) and cereals (38%) in 2050.

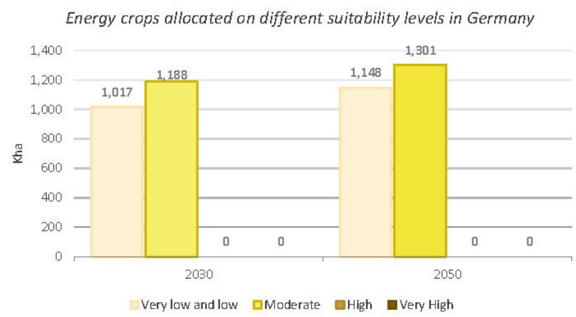
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

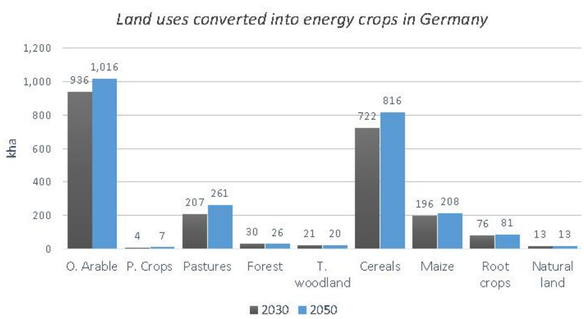


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 703,494 ha (31% of low productivity lands over available land) in 2030.

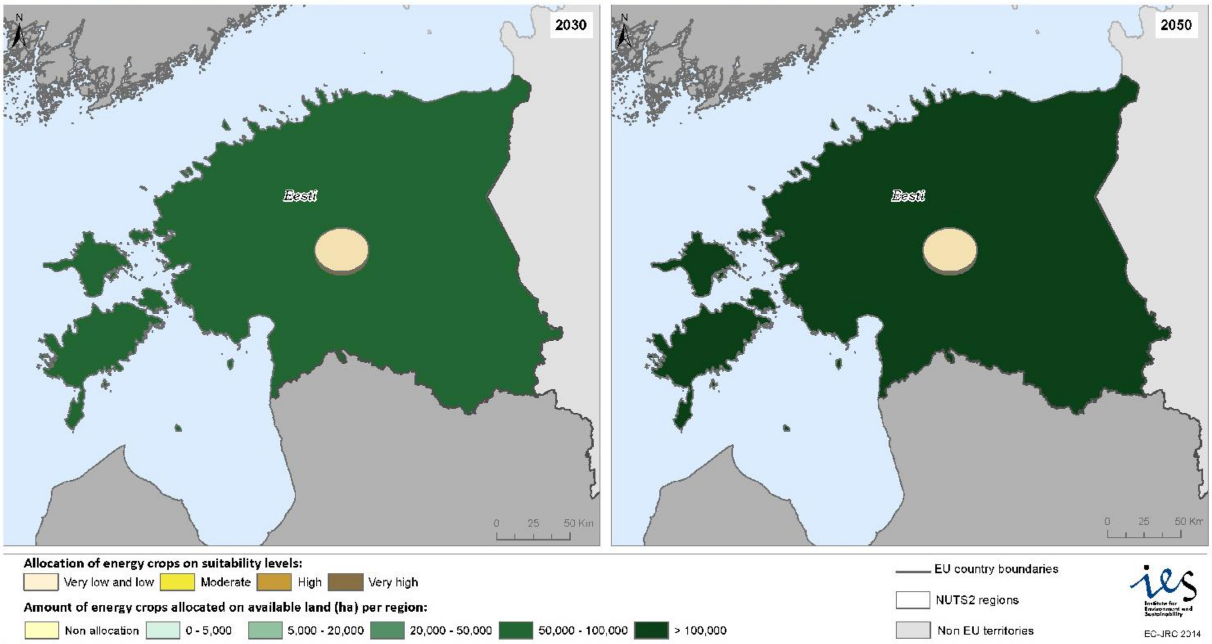




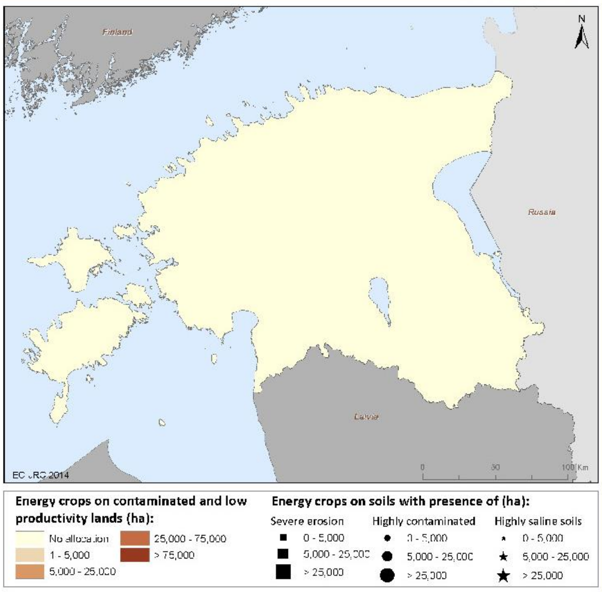
ESTONIA (EE)

In Estonia the allocation of energy crops reaches 83 and 126 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops near 2.8% of the total available land within the region in 2050. Broadly speaking, energy crops are unsuccessful allocated on low and very low local (biophysical) suitability lands (by 100% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, in this case more heterogeneously distributed between forest and T. Woodland (34%) and natural land (8%) in 2050.

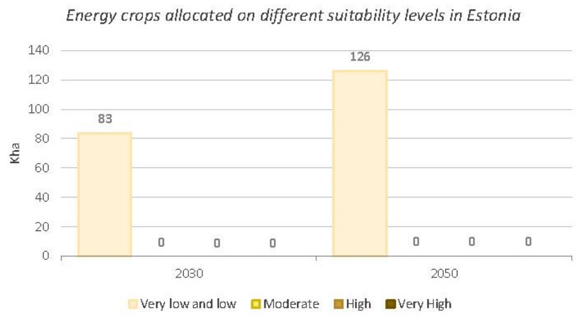
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

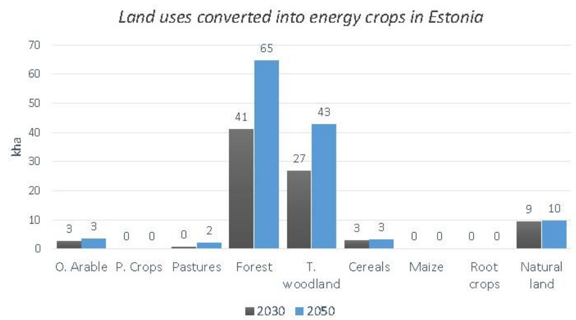


Energy crops on low productivity lands (2030)



There is no allocation of energy crops on low productivity and contaminated lands in 2030.

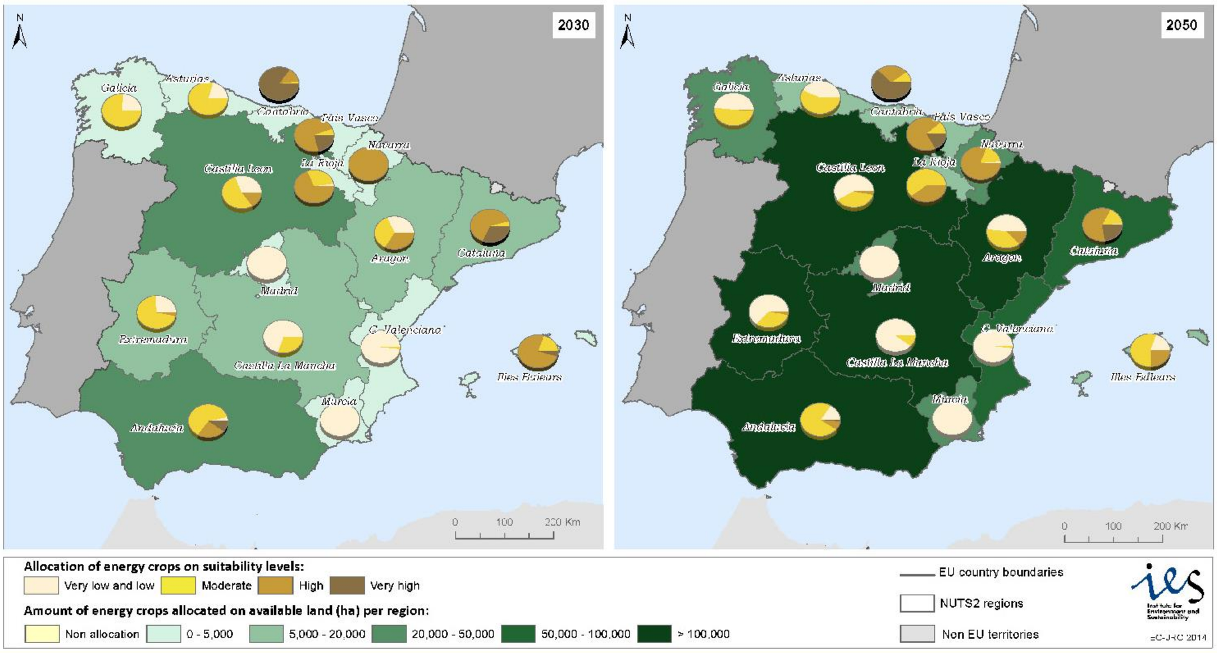




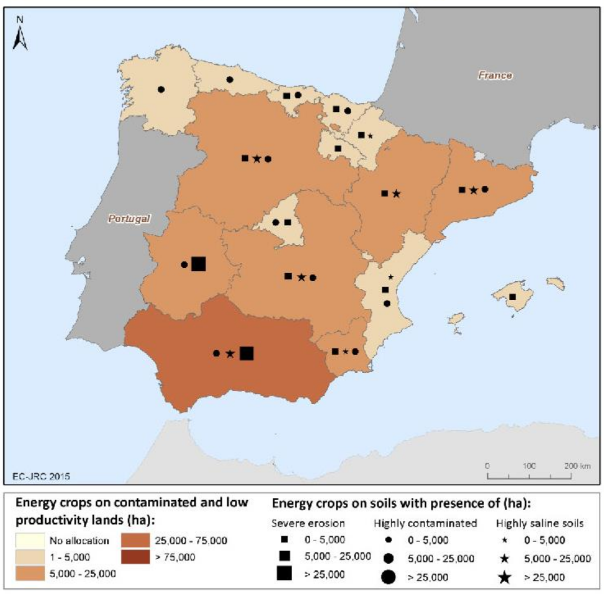
SPAIN (ES)

In Spain the allocation of energy crops reaches 102 and 1,454 Kha in 2030 and 2050 respectively. These figures represent a share of energy crops, on average, between 1% and 3,7% of the total available land within each region in 2050. Energy crops are not successfully allocated on the high local (biophysical) suitability lands (by 35% and 52% on low and very low for 2030 and 2050, respectively) except in the north-eastern part of Spain. The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (45%), cereals (26%) and forest and T.W. (21%) in 2050.

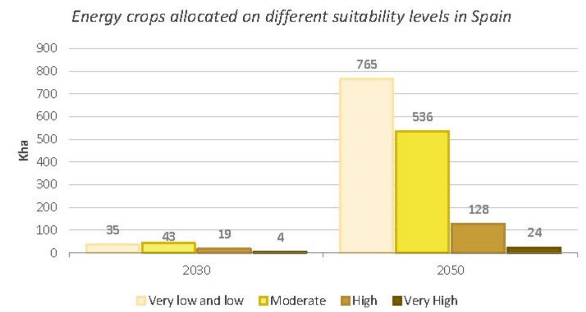
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

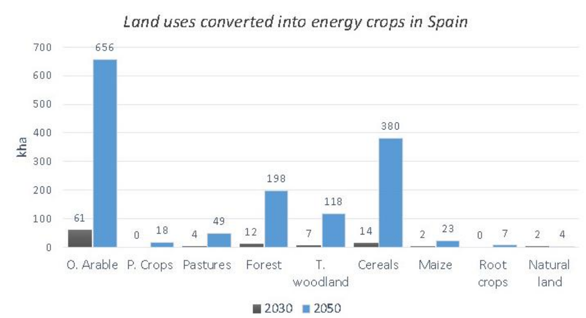


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 101,294 ha (3% of low productivity lands over available land) in 2030.

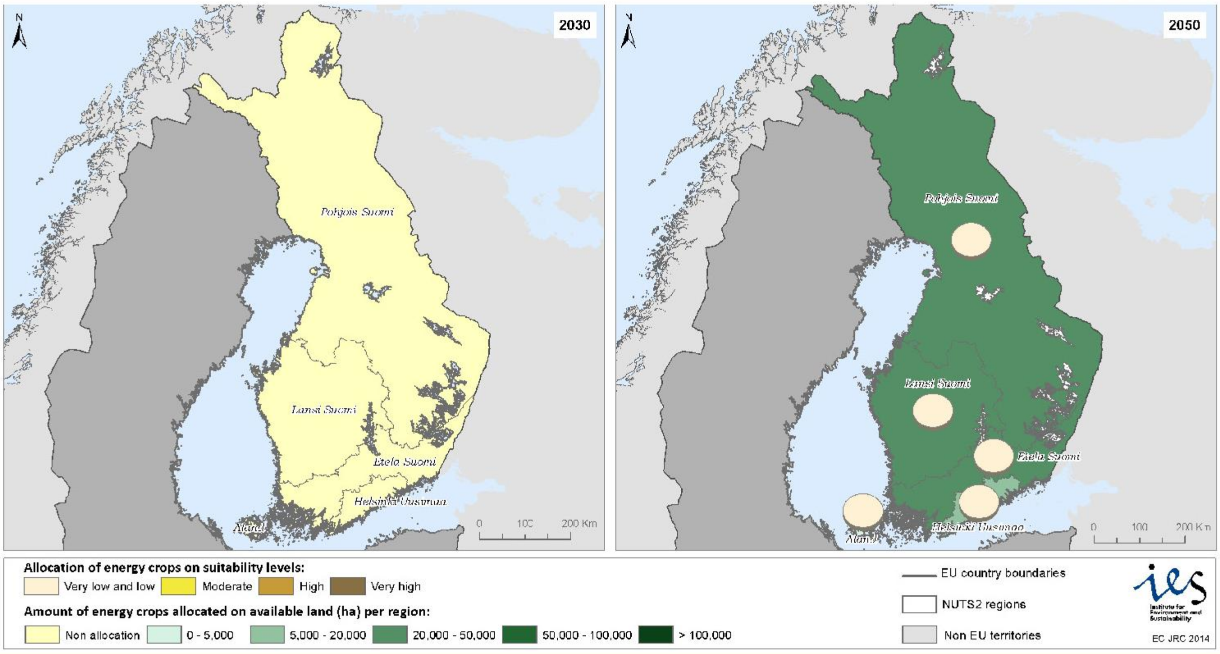




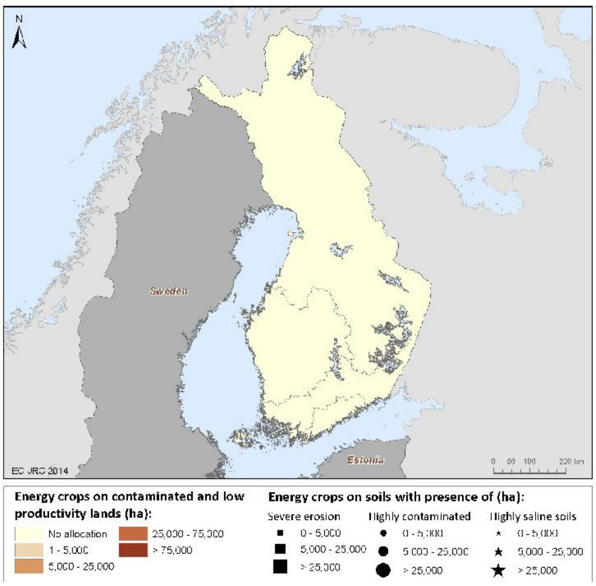
FINLAND (FI)

In Finland the allocation of energy crops reaches 138 kha in 2050 (there is not presence of energy crops in 2030). It represents a share of energy crops, on average, between 0.1% and 1.3% of the total available land within each region in 2050. Broadly speaking, energy crops are allocated on very low and low local (biophysical) suitability lands (100% in 2050). The projected allocation for energy crops implies the conversion from other land uses, mainly forest land (77%), Transitional woodland (21%) in 2050.

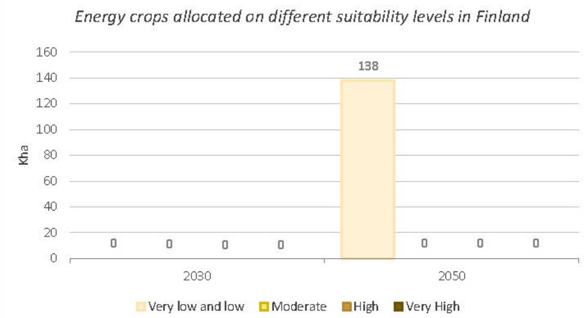
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

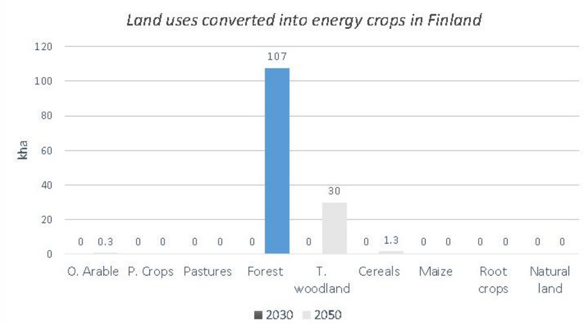


Energy crops on low productivity lands (2030)



There is no allocation of energy crops on low productivity and contaminated lands in 2030.

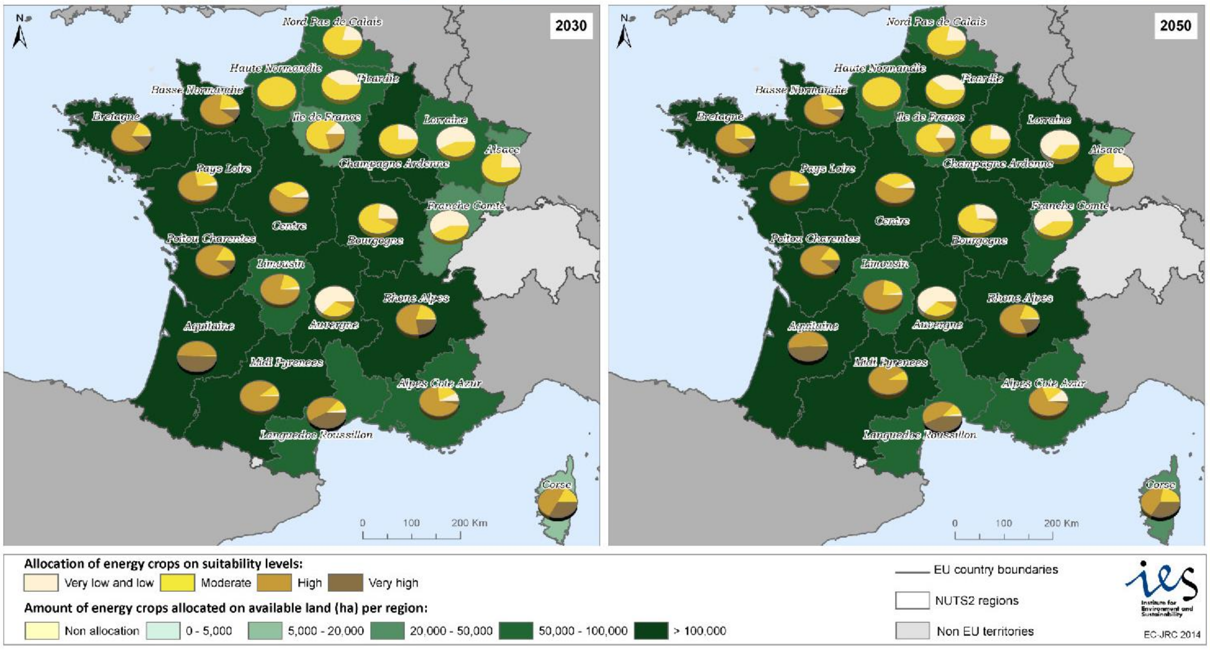




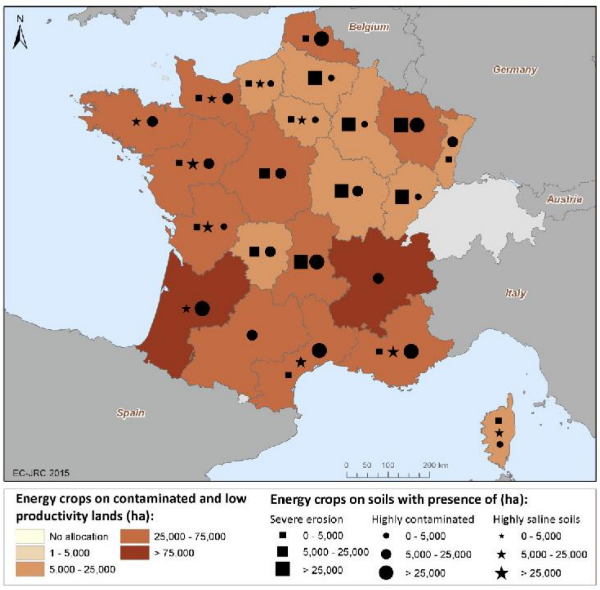
FRANCE (FR)

In France the allocation of energy crops reaches 2,073 and 2,740 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops between 2.5% and 7.6% of the total available land within each region. Broadly speaking, energy crops are successfully allocated on moderate and high local (biophysical) suitability lands (by 80% and 85% in 2030 and 2050, respectively) less in the north-eastern part of France. The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (32%) , cereals and maize(33%) and pastures (20%), in 2050.

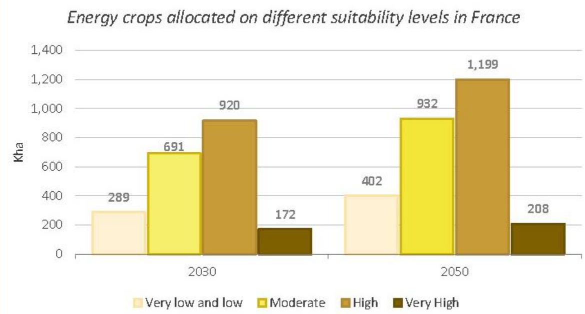
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

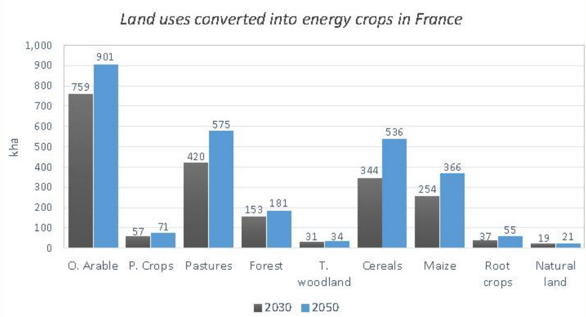


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 940,673 ha (22% of low productivity lands over the available land) in 2030.

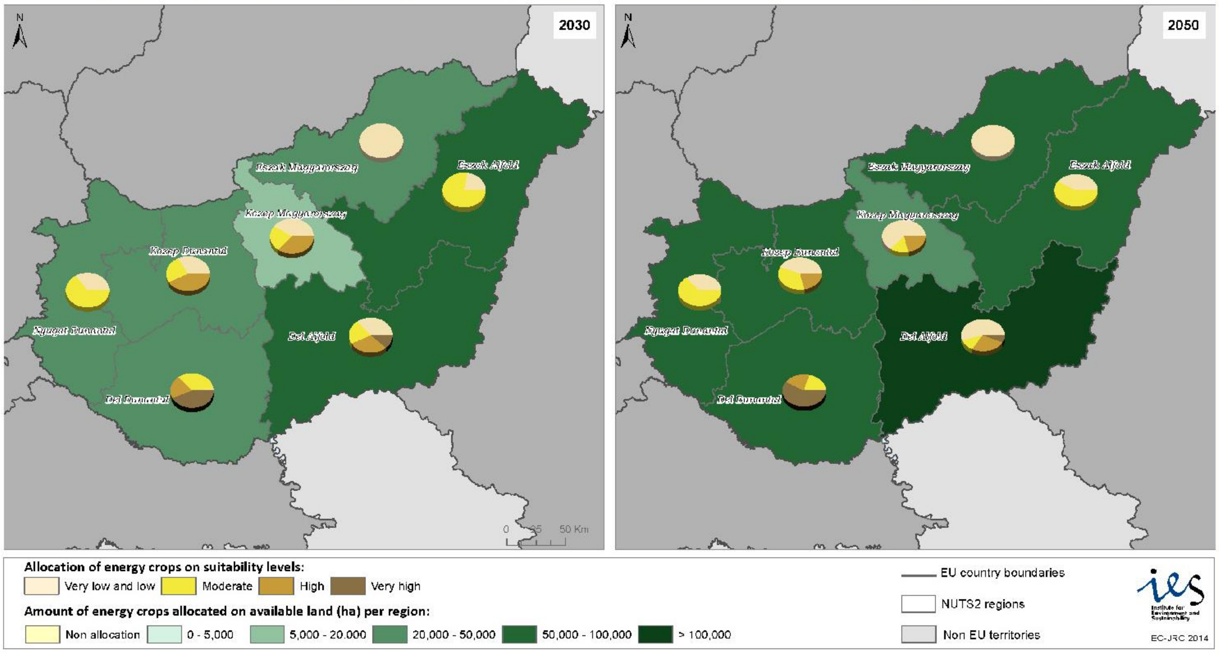




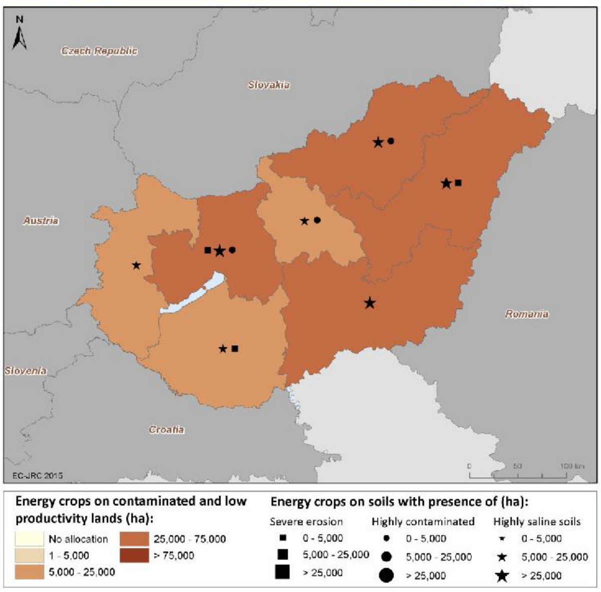
HUNGARY (HU)

In Hungary the allocation of energy crops reaches 246 and 490 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops between 4.4% and 6% of the total available land within each region in 2050. Broadly speaking, energy crops are allocated on moderate and high local (biophysical) suitability lands (by 64% and 53% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly other arable (39%), pastures (21%), cereals and maize (52%) and forest (5%) in 2050.

Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

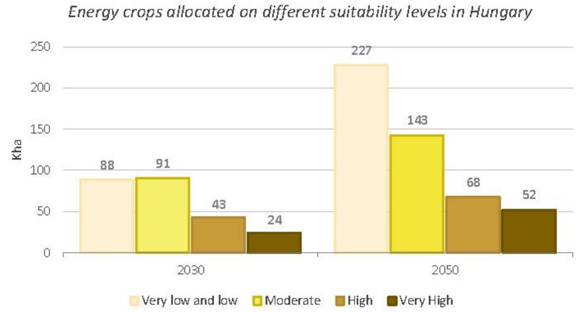


Energy crops on low productivity lands (2030)

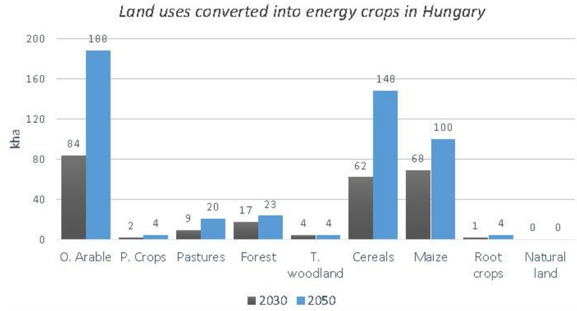


The allocation of energy crops on low productivity and contaminated lands reaches 213,670 ha (20% of low productivity lands over the total available land) in 2030.

Energy crops allocated on different suitability levels in Hungary



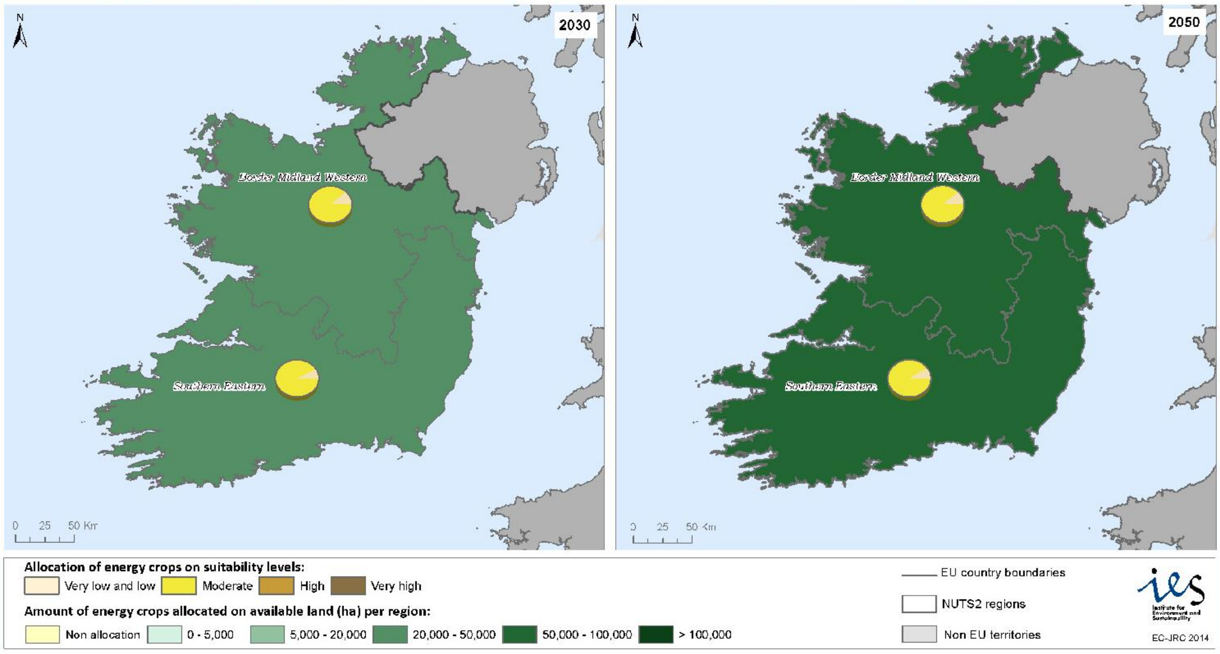
Land uses converted into energy crops in Hungary



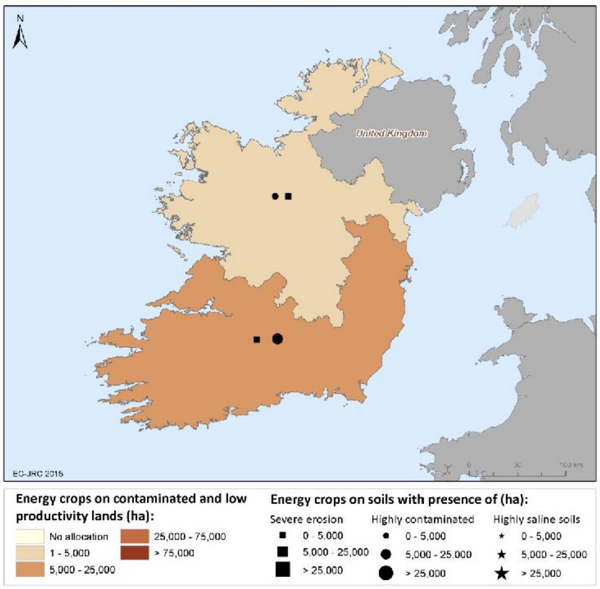
IRELAND (IE)

In Ireland the allocation of energy crops reaches 63 and 141 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops, on average, between 1.8 and 2.2% of the total available land within each region in 2050. Broadly speaking, energy crops are widely allocated on moderate local (biophysical) suitability lands (by 91% and 90% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly pastures (31%), other arable (20%), cereals (25%) and T. Woodland (16%) in 2050.

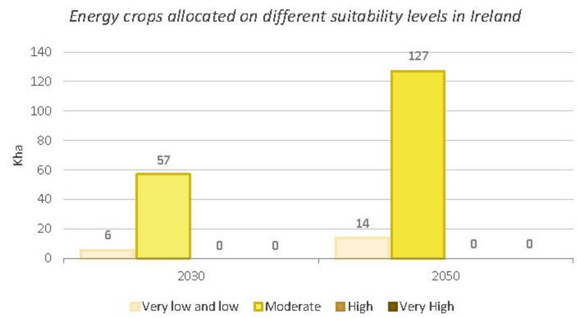
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

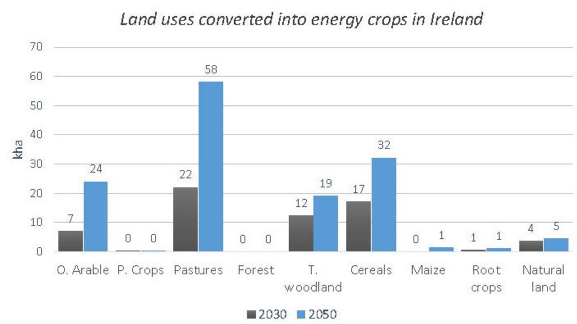


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 5,539 ha (13% of low productivity lands over the total available land) in 2030.

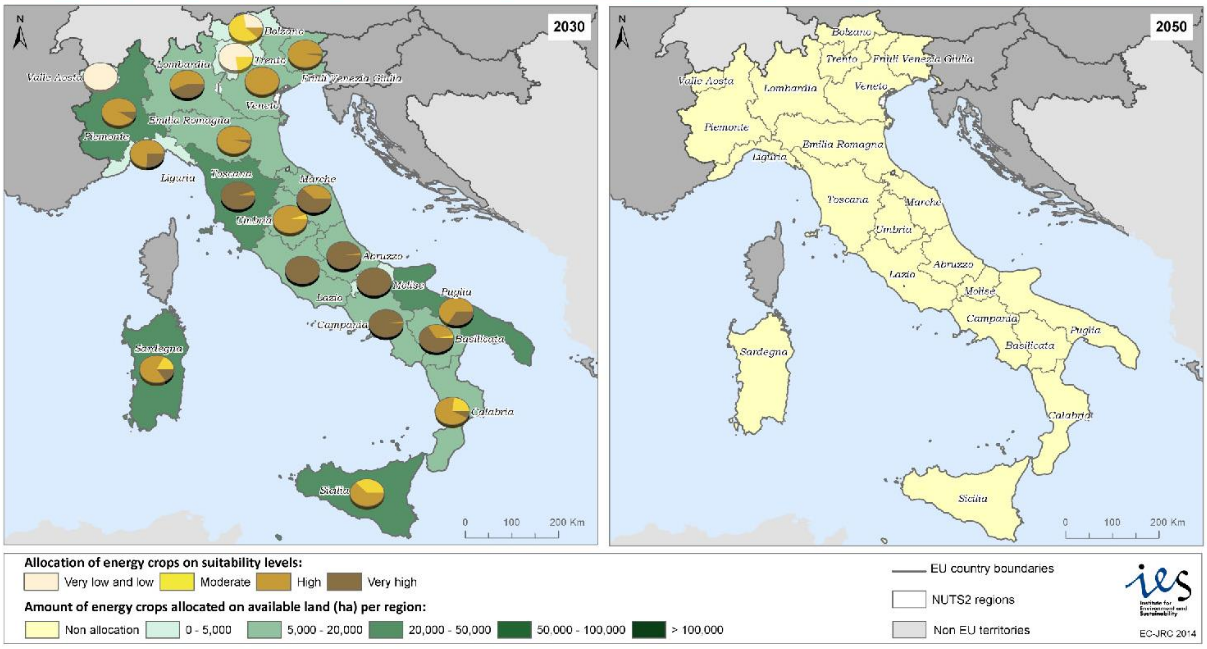




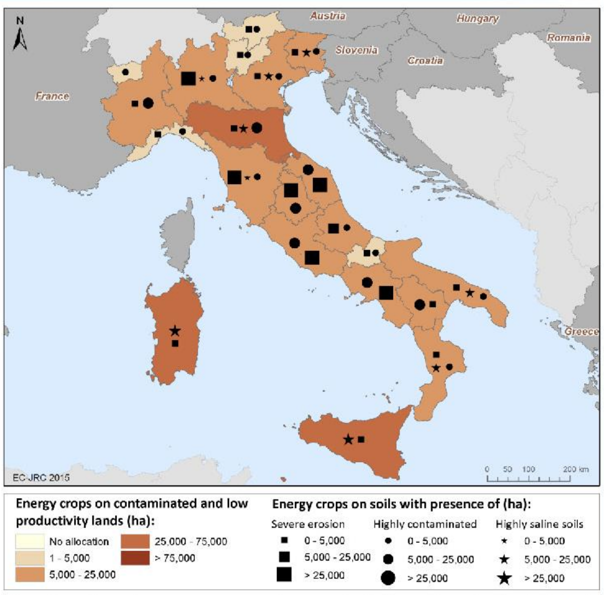
ITALY (IT)

In Italy the allocation of energy crops reaches 278 in 2030 . These figures represent a share of energy crops, on average, between 0.16% and 1.3% of the total available land within each region in 2030. Broadly speaking, energy crops are successfully allocated on moderate and the highest local (biophysical) suitability lands (by 98% in 2030) except in the north of Italy. The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (71%) and cereals (13%) in 2030.

Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

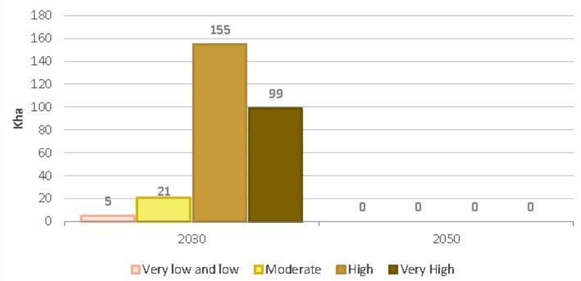


Energy crops on low productivity lands (2030)

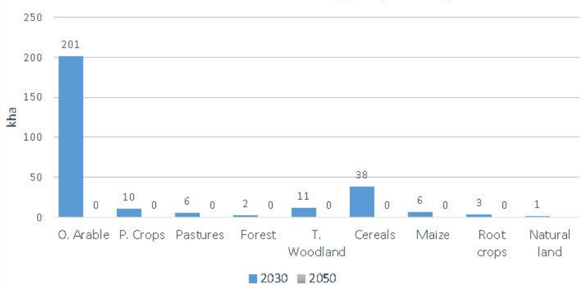


The allocation of energy crops on low productivity and contaminated lands reaches 282,395 ha (5% of low productivity land over available land) in 2030.

Energy crops allocated on different suitability levels in Italy



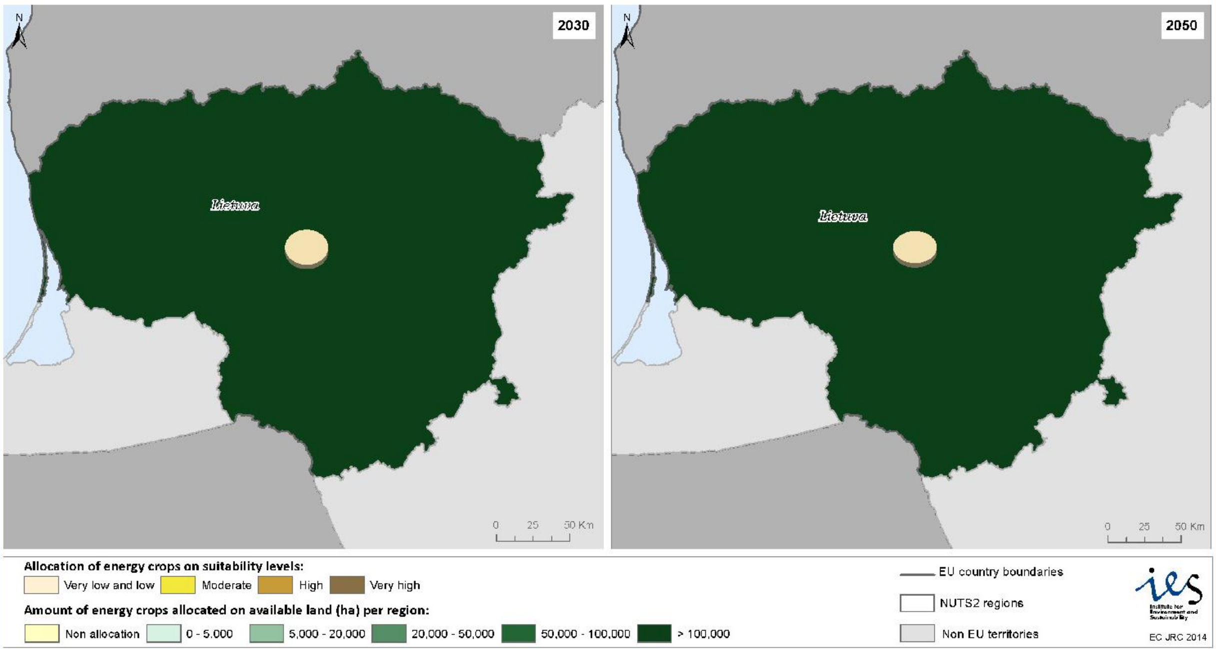
Land uses converted into energy crops in Italy



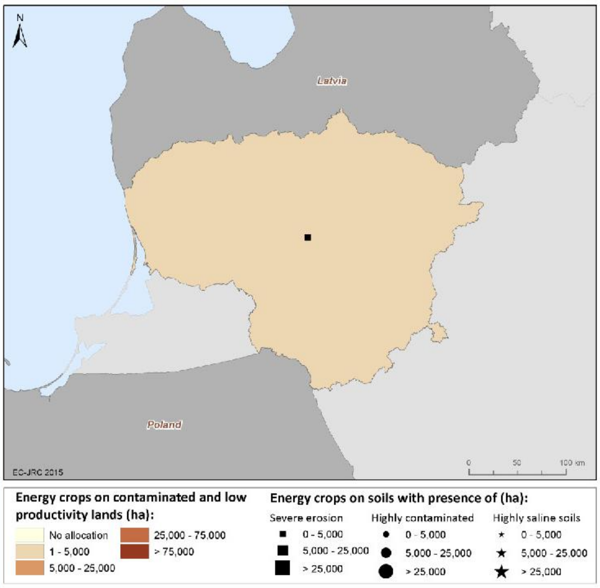
LITHUANIA (LT)

In Lithuania the allocation of energy crops reaches 124 and 254 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops near 4% of the total available land within the region in 2050. Broadly speaking, energy crops are unsuccessful allocated on low and very low local (biophysical) suitability lands (by 99% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly other arable (74%) and cereals (18%) in 2050.

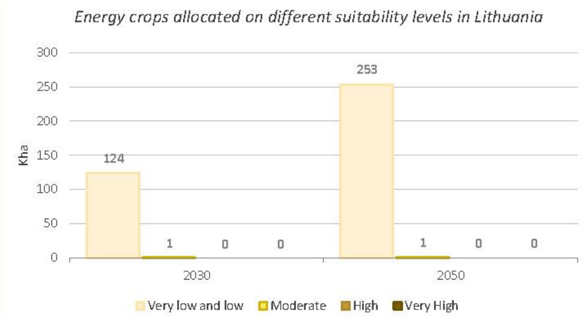
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

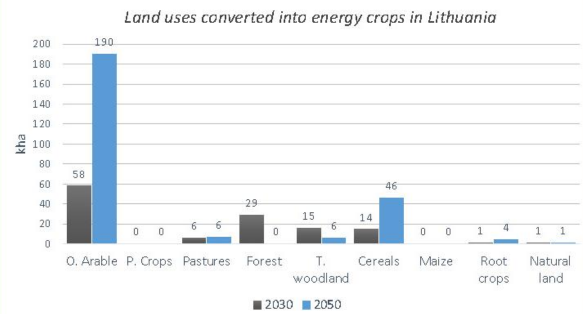


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 465 ha (42% of low productivity lands over the total available land) in 2030.

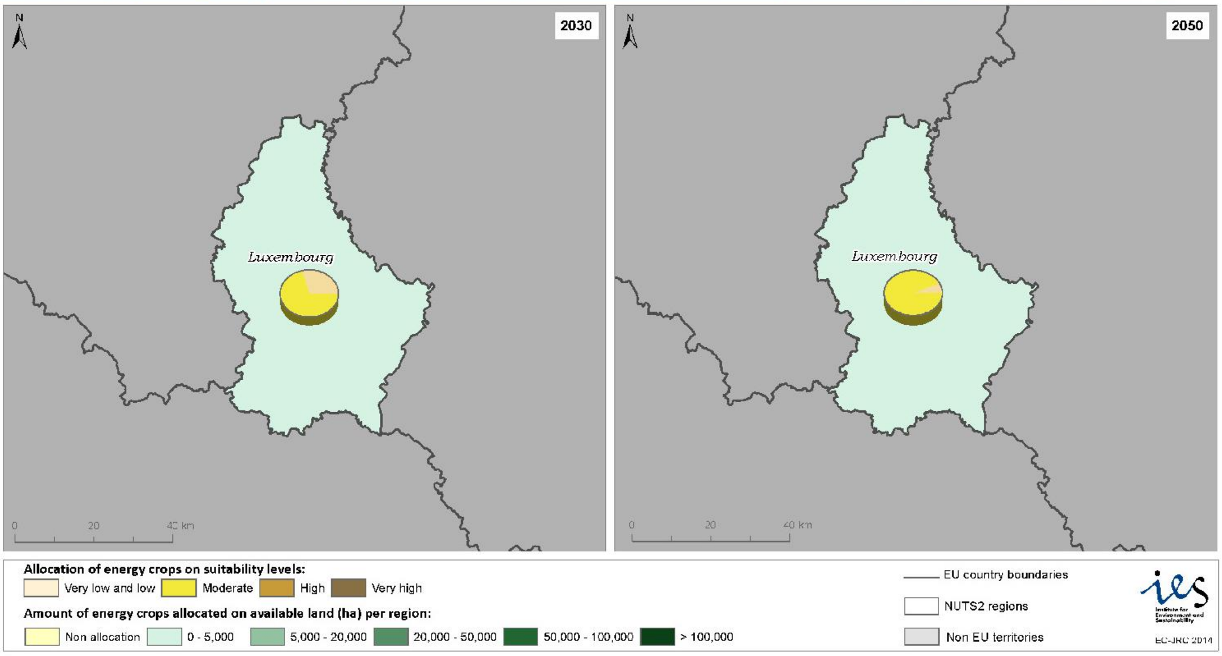




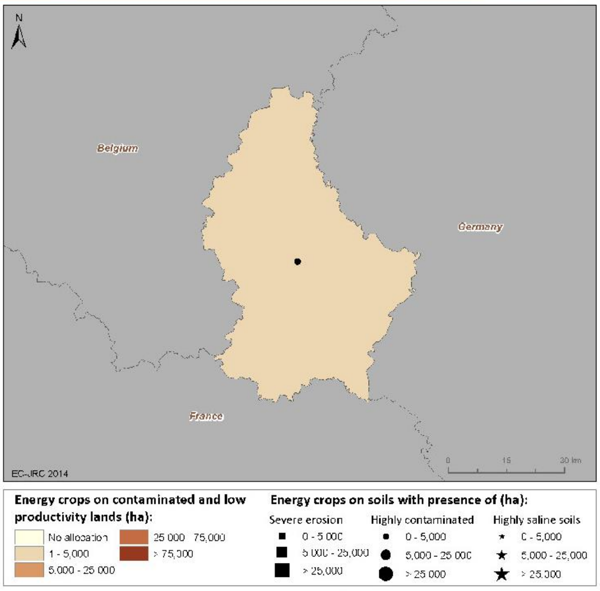
LUXEMBOURG (LU)

In Luxembourg the allocation of energy crops reaches 0.01 and 0.032 Kha in 2030 and 2050 respectively. These figures represent a share of energy crops between 0.002% and 0.01% of the total available land within each region in 2050. Broadly speaking, energy crops are successfully allocated on moderate local (biophysical) suitability lands (100% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (56%), cereals (21%) followed by forest (9%) in 2050.

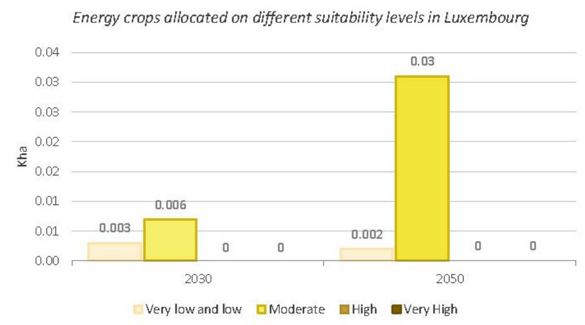
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

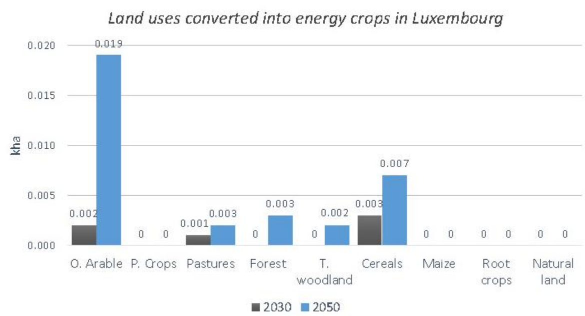


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 10 ha (0.2% of low productivity lands over the total available land) in 2030.

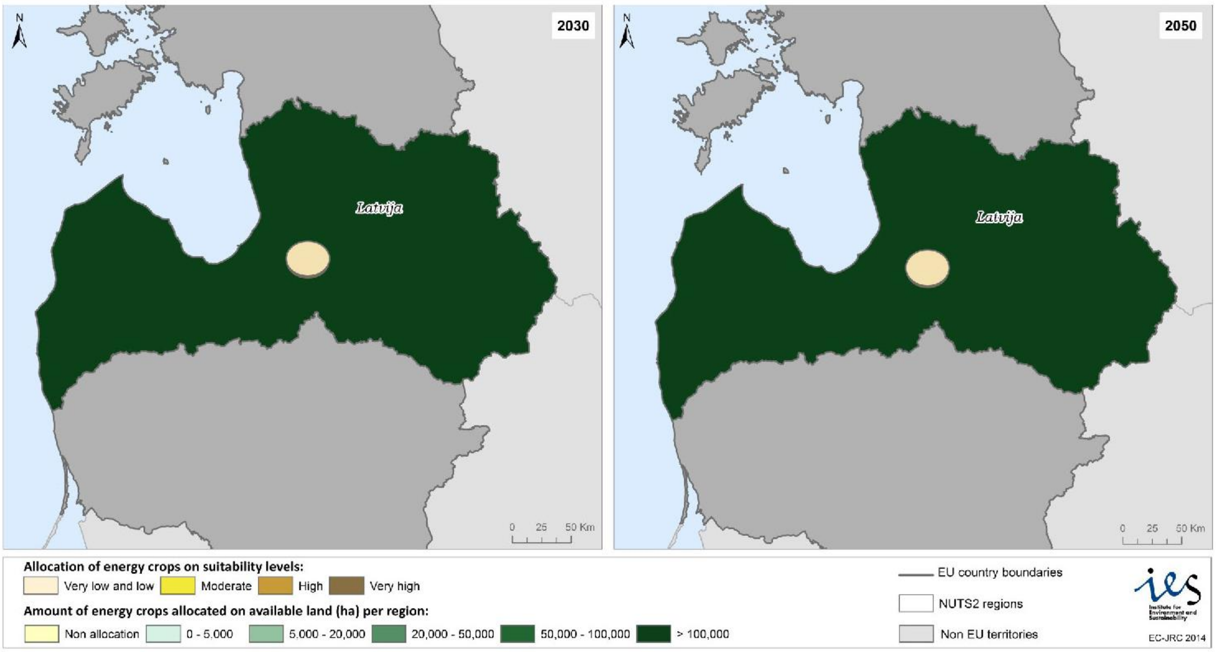




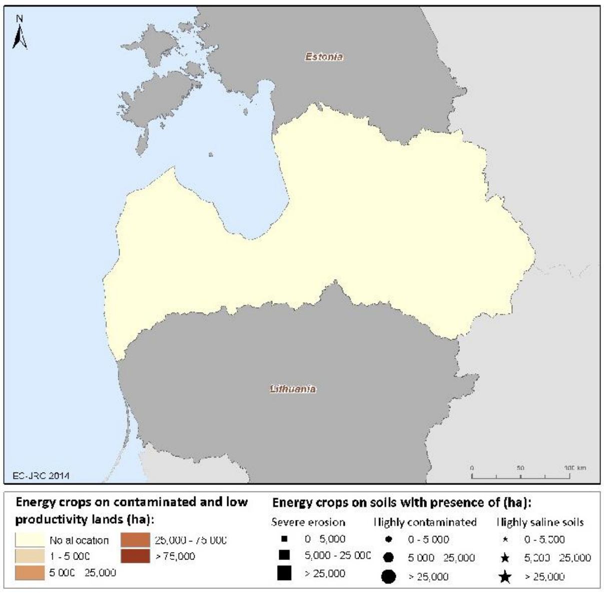
LATVIA (LV)

In Latvia the allocation of energy crops reaches 103 and 127 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops near 1.96% of the total available land within the region in 2050. Broadly speaking, energy crops are unsuccessfully allocated on low and very low local (biophysical) suitability lands (by 100% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, in mainly forest (28%), T. Woodland (32%) and pastures (33%) in 2050.

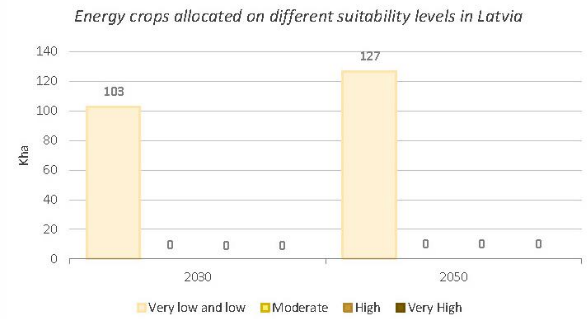
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

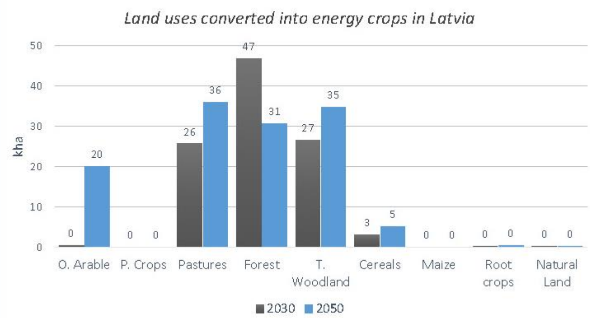


Energy crops on low productivity lands (2030)



There is no allocation of energy crops on low productivity and contaminated lands in 2030.

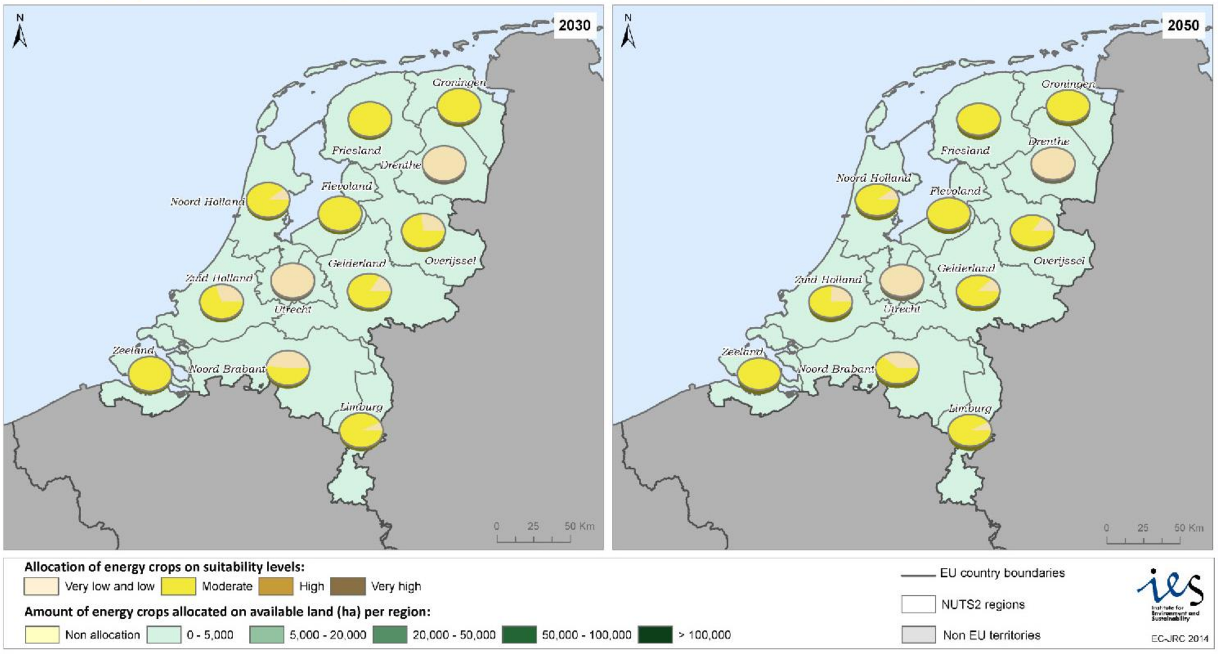




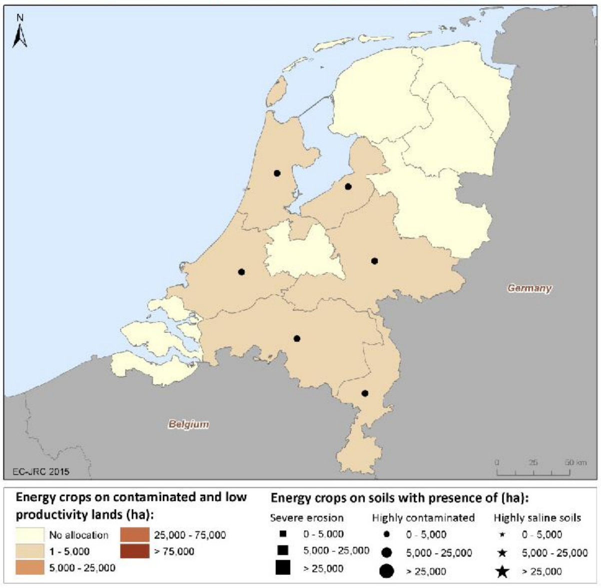
NETHERLANDS (NL)

In Netherlands the allocation of energy crops reaches 27 and 26 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops between 0.6% and 1.1% of the total available land within each region in 2050. Broadly speaking, energy crops are allocated on moderate local (biophysical) suitability lands (by 74% and 78% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly pastures (50%), cereals, maize and root crops (25%) and other arable land (22%) in 2050.

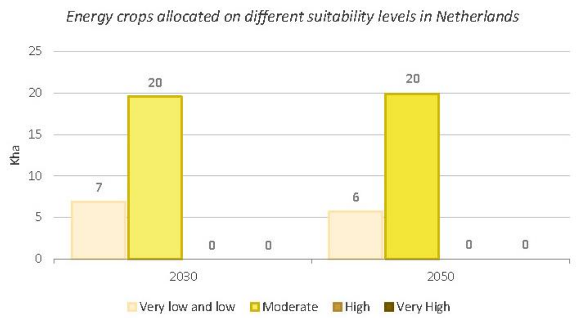
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

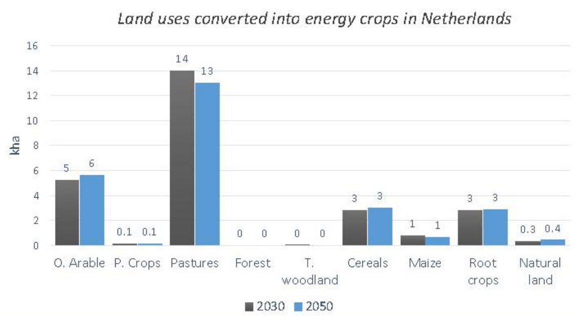


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 33,566 ha (14% of low productivity lands over the total available land) in 2030.

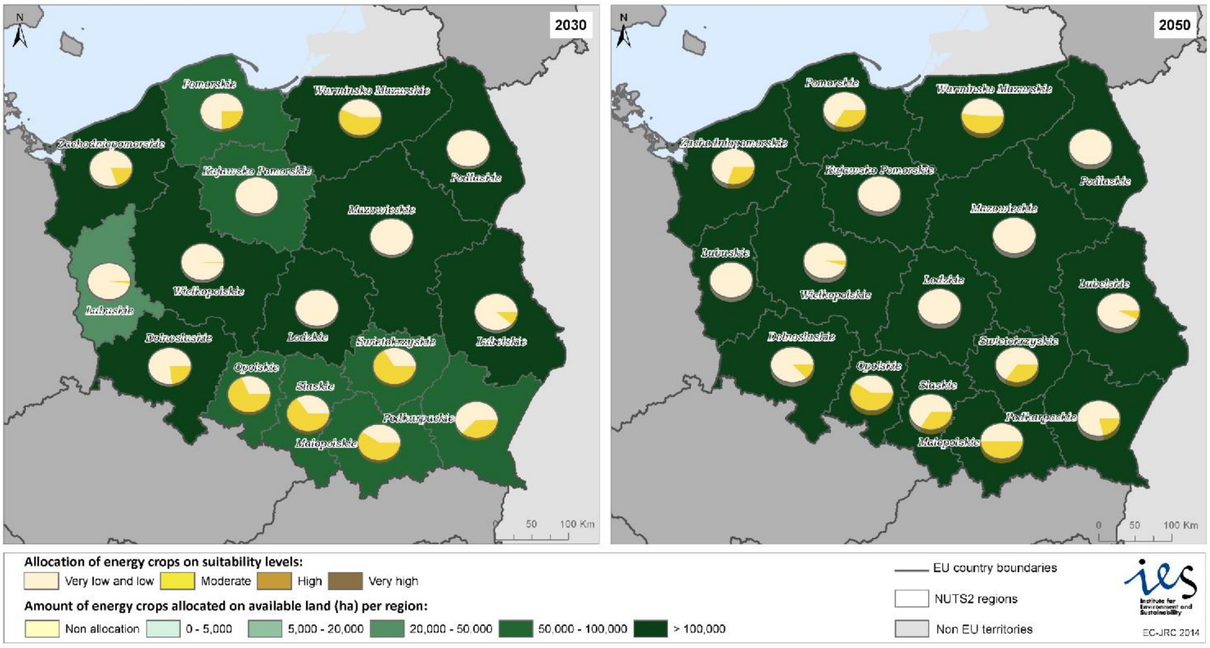




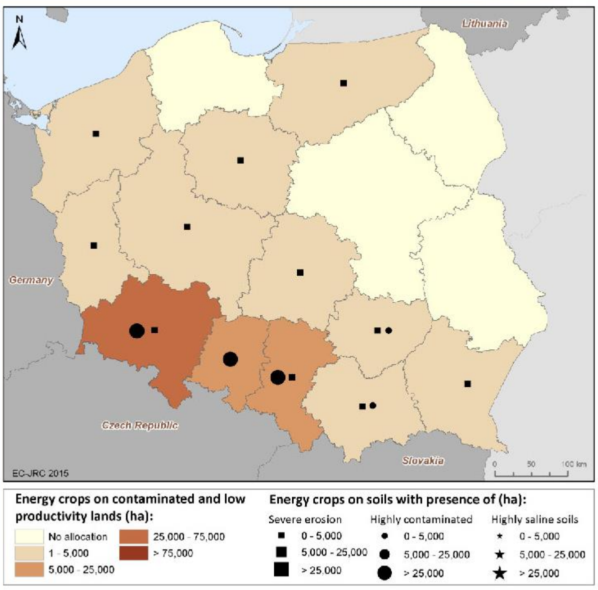
POLAND (PL)

In Poland the allocation of energy crops reaches 1,571 and 3,127 kha in 2030 and 2050, respectively. These figures represent a share of energy crops between 6.4% and 14.6% of the total available land within each region in 2050. Broadly speaking, energy crops are not successfully allocated on high local (biophysical) suitability lands (by 77% and 80% on low and very low levels in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly cereals, maize and root crops (49%) and other arable land (43%) in 2050.

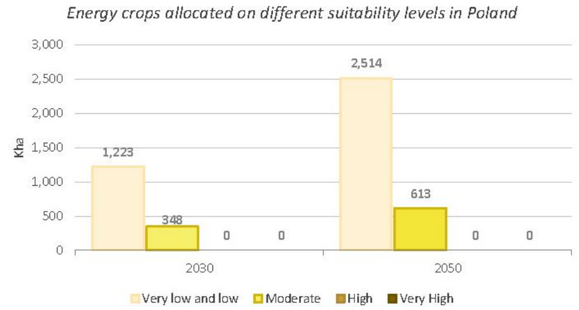
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

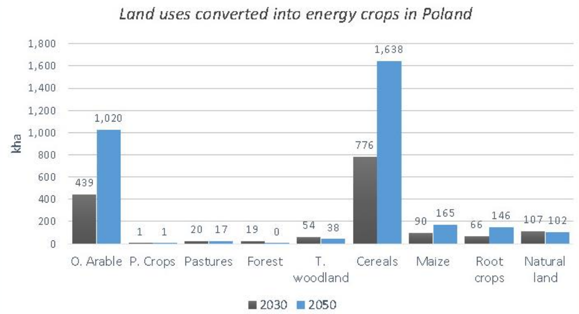


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 231,662 ha (42% of low productivity lands over available land) in 2030.

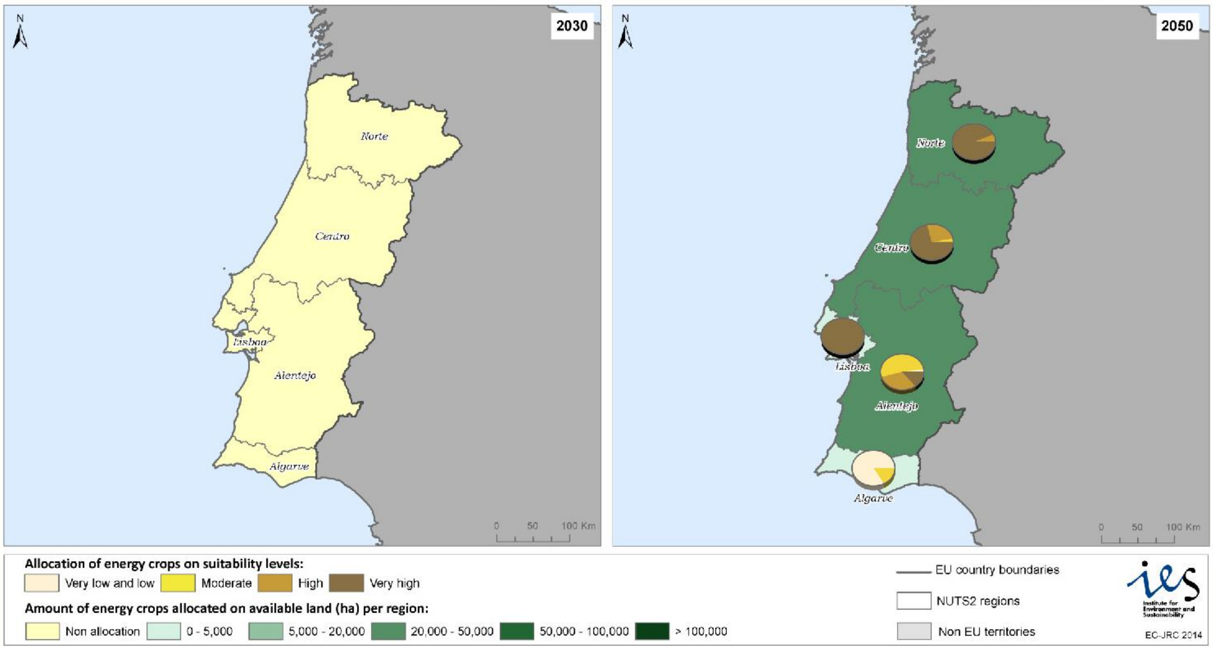




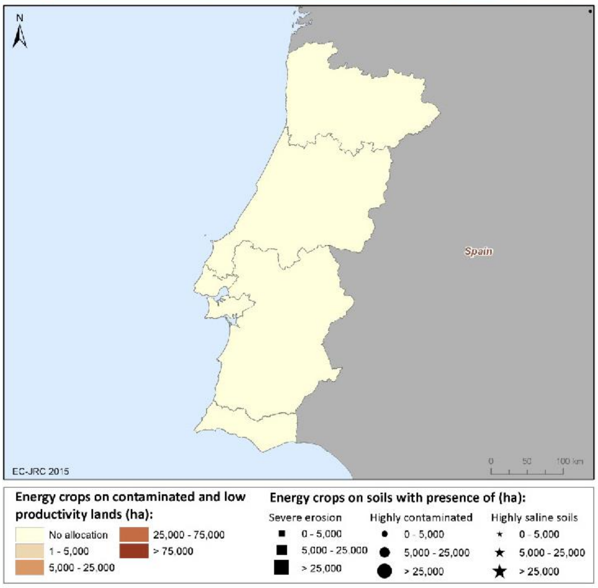
PORTUGAL (PT)

In Portugal the allocation of energy crops reaches 93 kha in 2050 (there is no presence of energy crops in 2030). It represents a share of energy crops near 1% of the total available land within each region in 2050. Broadly speaking, energy crops are successfully allocated on moderate, high and very high local (biophysical) suitability lands (by 95% in 2050). The projected allocation for energy crops implies the conversion from other land uses, mainly other forest (44%) and arable land (19%) in 2050.

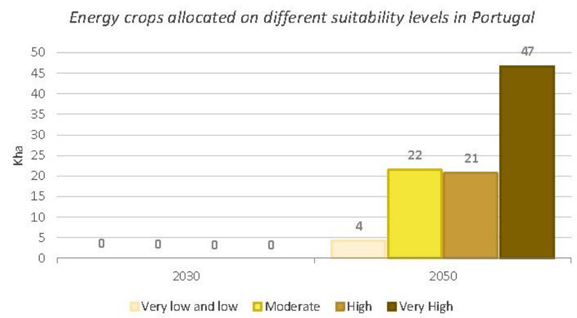
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

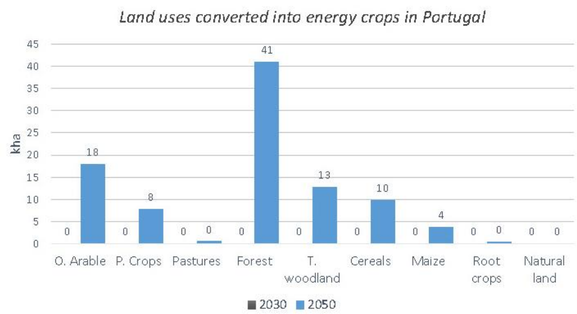


Energy crops on low productivity lands (2030)



There is no allocation of energy crops on low productivity and contaminated lands in 2030.

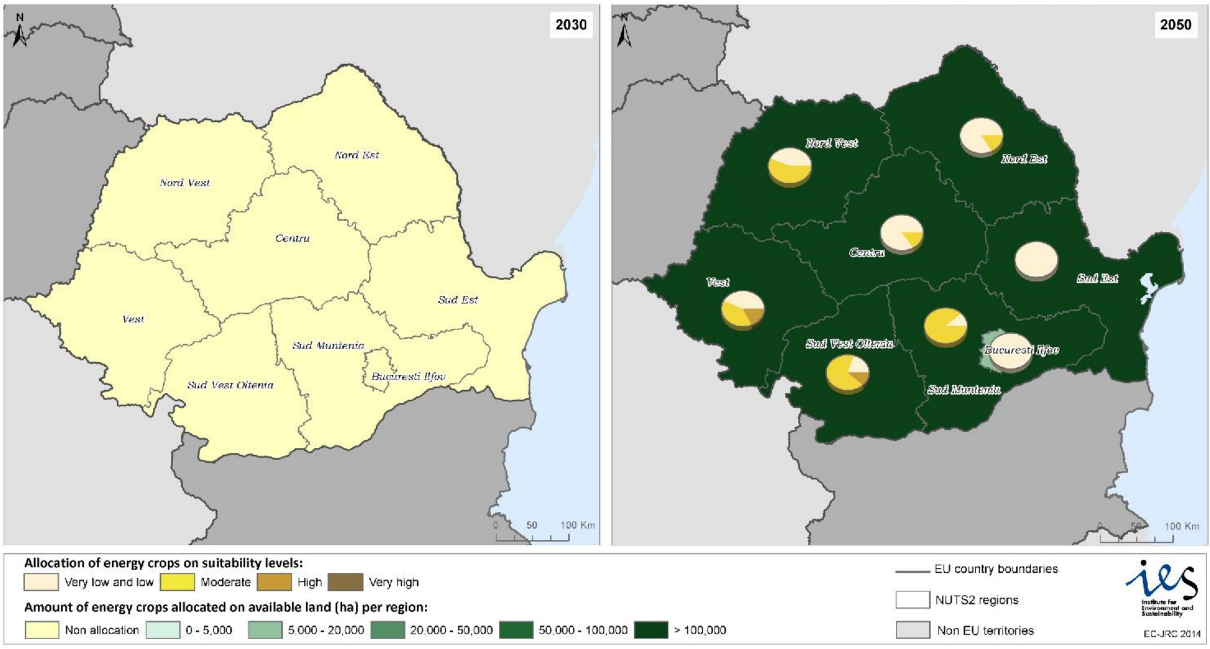




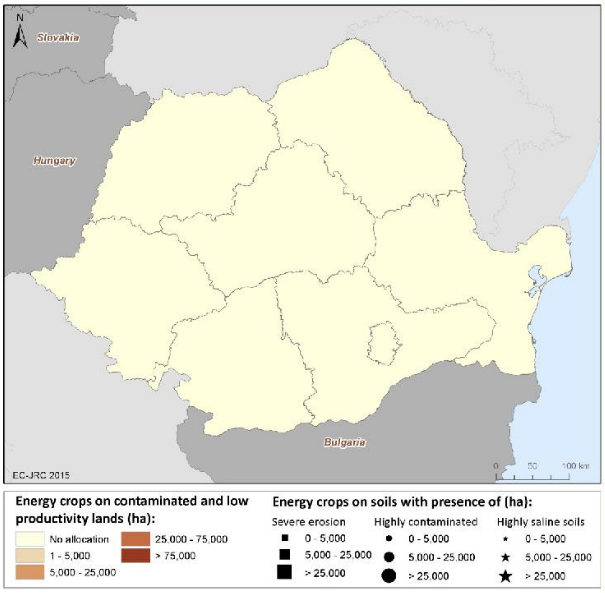
ROMANIA (RO)

In Romania the allocation of energy crops reaches 1,376 kha in 2050 (there is not presence of energy crops in 2030). It represents a share of energy crops, on average, between 4% and 7% of the total available land within each region in 2050. Broadly speaking, energy crops are half allocated on low and moderate local (biophysical) suitability lands (by 55% and 45% in 2050). The projected allocation for energy crops implies the conversion from other land uses, mainly cereals (52%), arable land (38%) maize and root crops (18%) and pasture land (5%) in 2050.

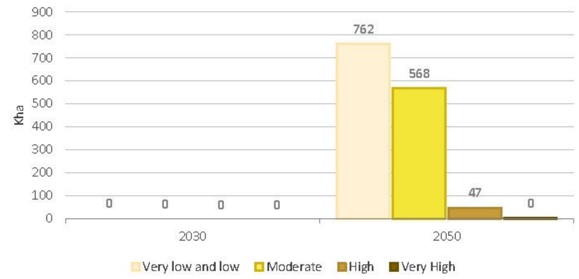
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

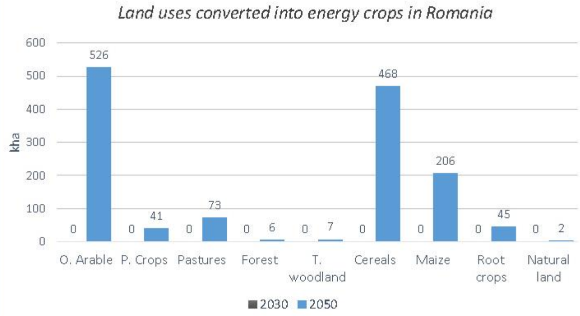


Energy crops on low productivity lands (2030)



There is no allocation of energy crops on low productivity and contaminated lands in 2030.

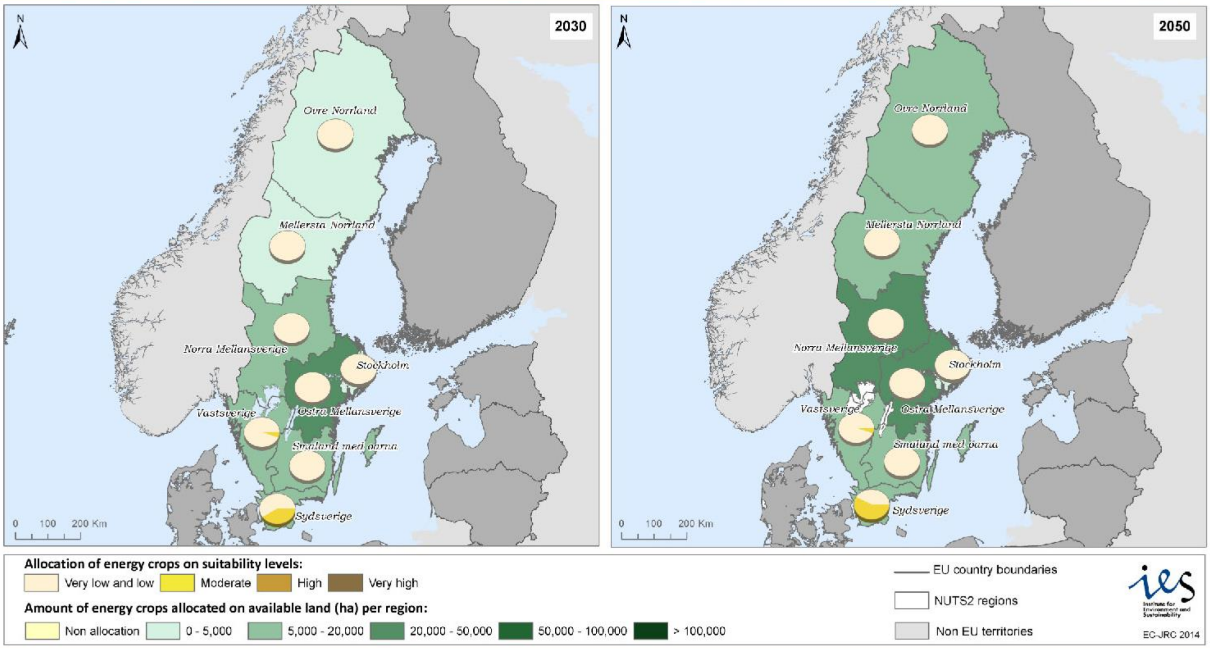




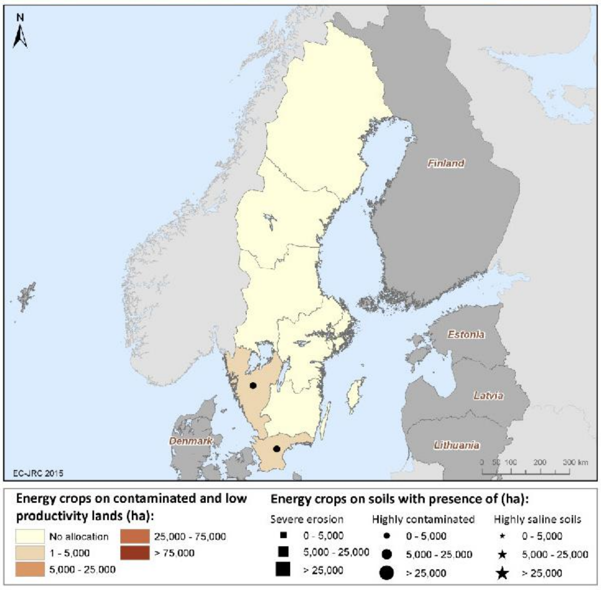
SWEDEN (SE)

In Sweden the allocation of energy crops reaches 70 and 115 kha in 2030 and 2050, respectively. These figures represent a share of energy crops, on average, between 0.1% and 1.1% of the total available land within each region in 2050. Broadly speaking, energy crops are not successfully allocated on high local (biophysical) suitability lands (by 92% and 93% on low and very low levels in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly forest (88%) in 2050.

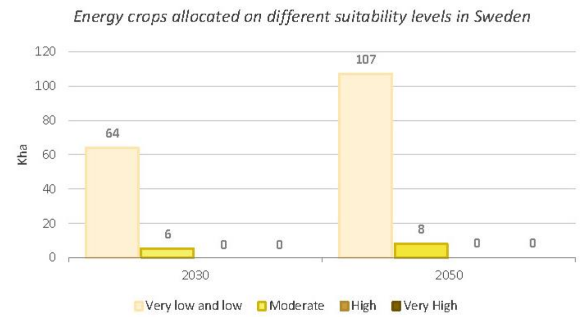
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

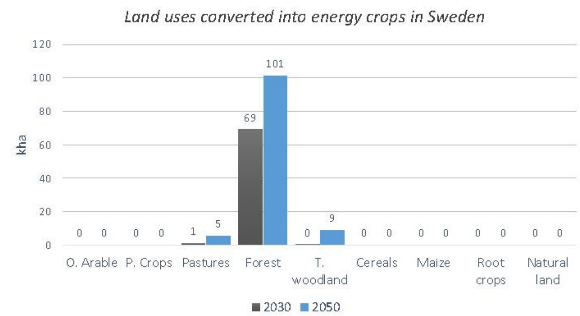


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 32 ha (0.6% of low productivity lands over available land) in 2030.

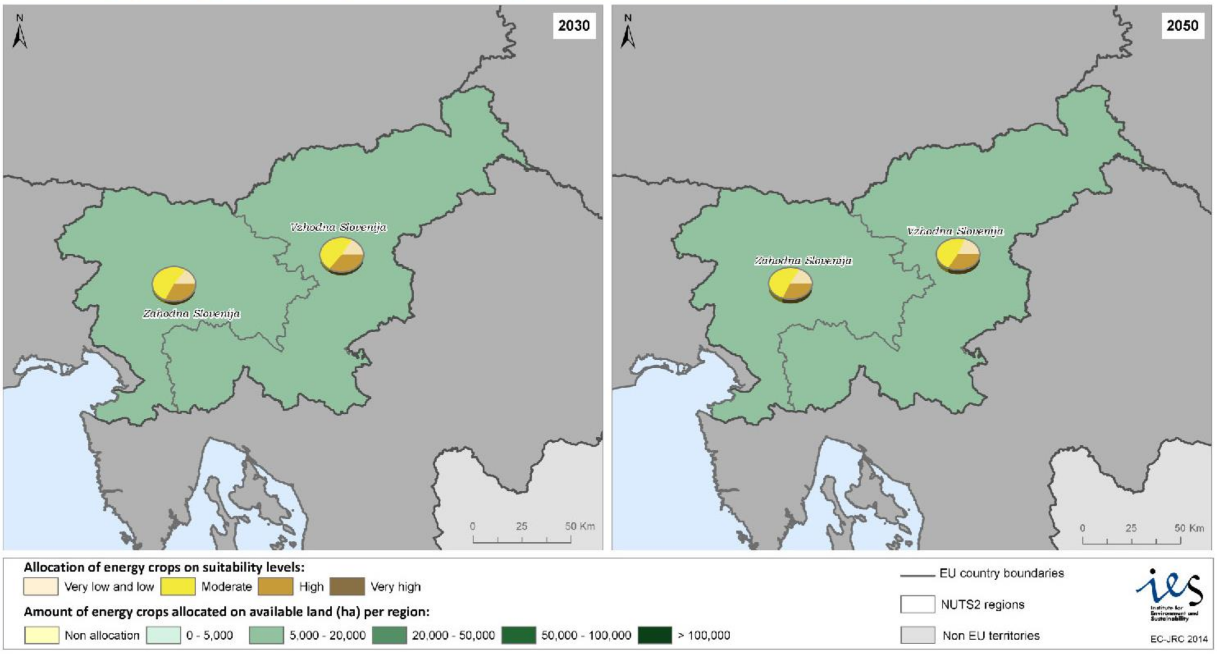




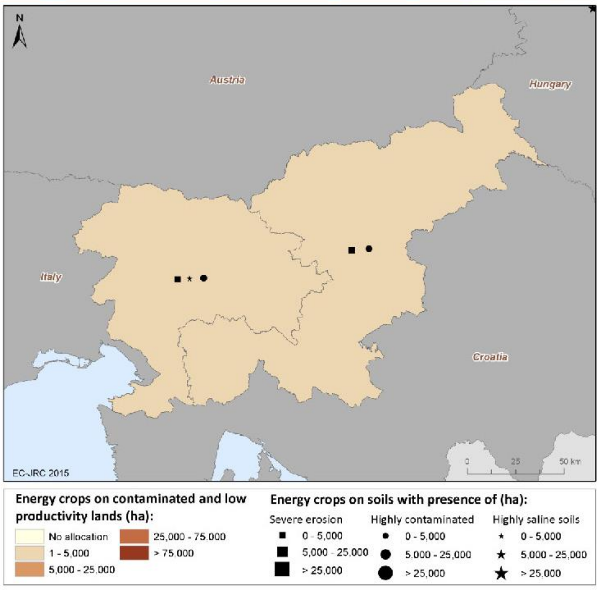
SLOVENIA(SI)

In Slovenia the allocation of energy crops reaches 27 and 30 kha in 2030 and 2050, respectively. These figures represent a share of energy crops of 1.1% and 2% of the total available land within each region in 2050. Broadly speaking, energy crops are successfully allocated on moderate and high local (biophysical) suitability lands (by 85% and 83% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (44%) and cereals and maize (20%) in 2050.

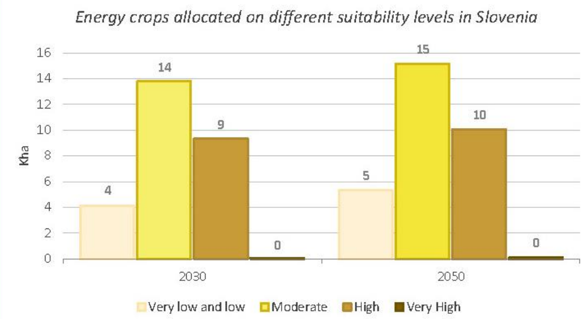
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

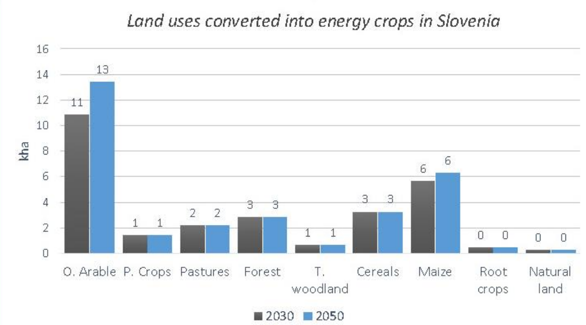


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 5,303 ha (2.5% of low productivity lands over the total available land) in 2030.

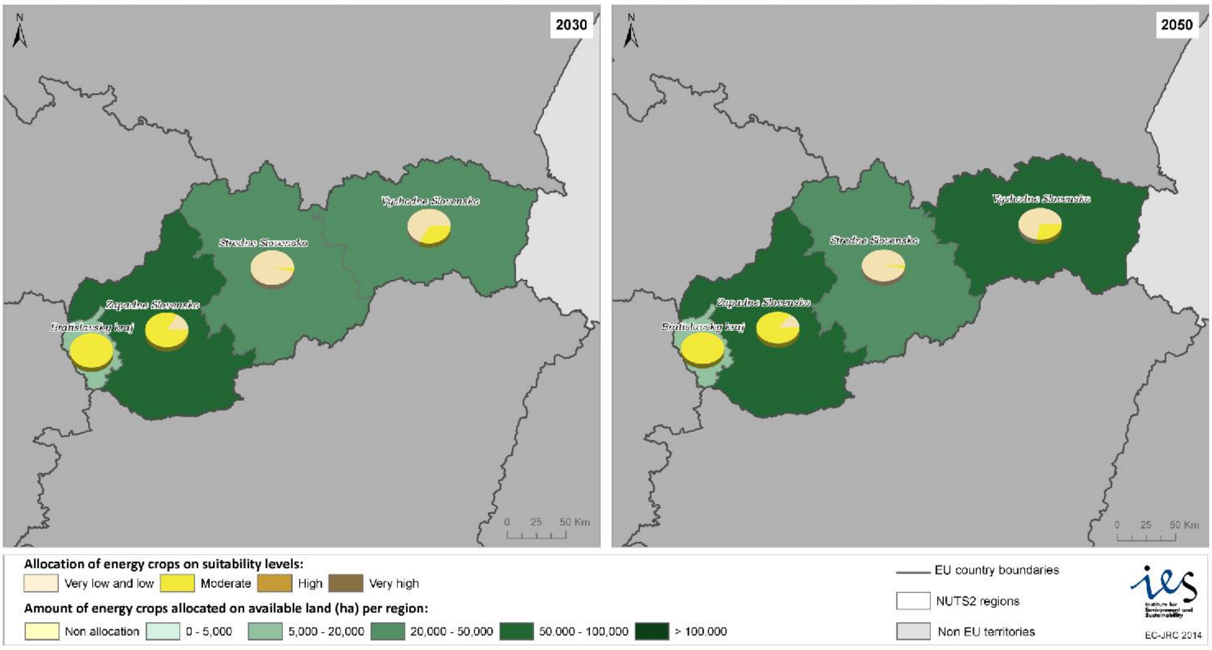




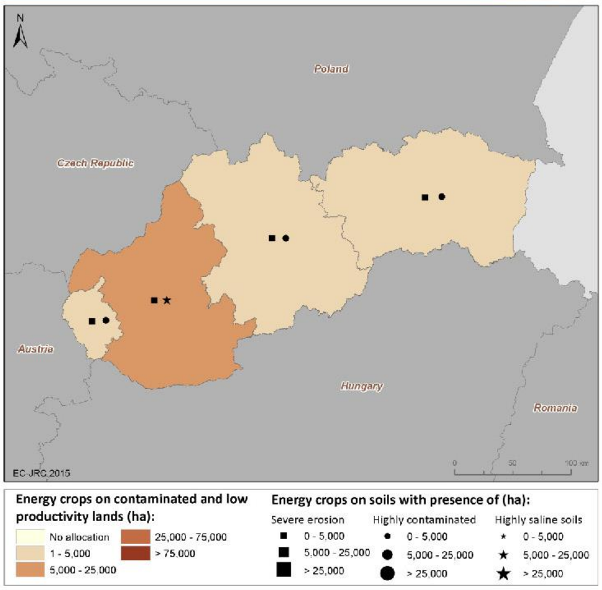
SLOVAKIA (SK)

In Slovakia the allocation of energy crops reaches 135 and 173 Kha in 2030 and 2050, respectively. These figures represent a share of energy crops between 2.4 and 4.7% of the total available land within each region in 2050. Broadly speaking, energy crops are half allocated on low and moderate local (biophysical) suitability lands (by 50% and 52% in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly other arable (42%), cereals and maize (24%) and forest and transitional woodland (25%) in 2050.

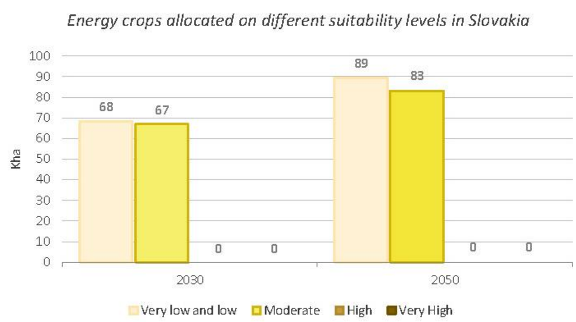
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

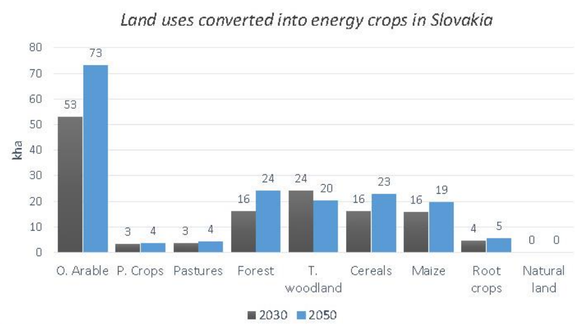


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 21,560 (9% of low productivity lands over the available land) in 2030.

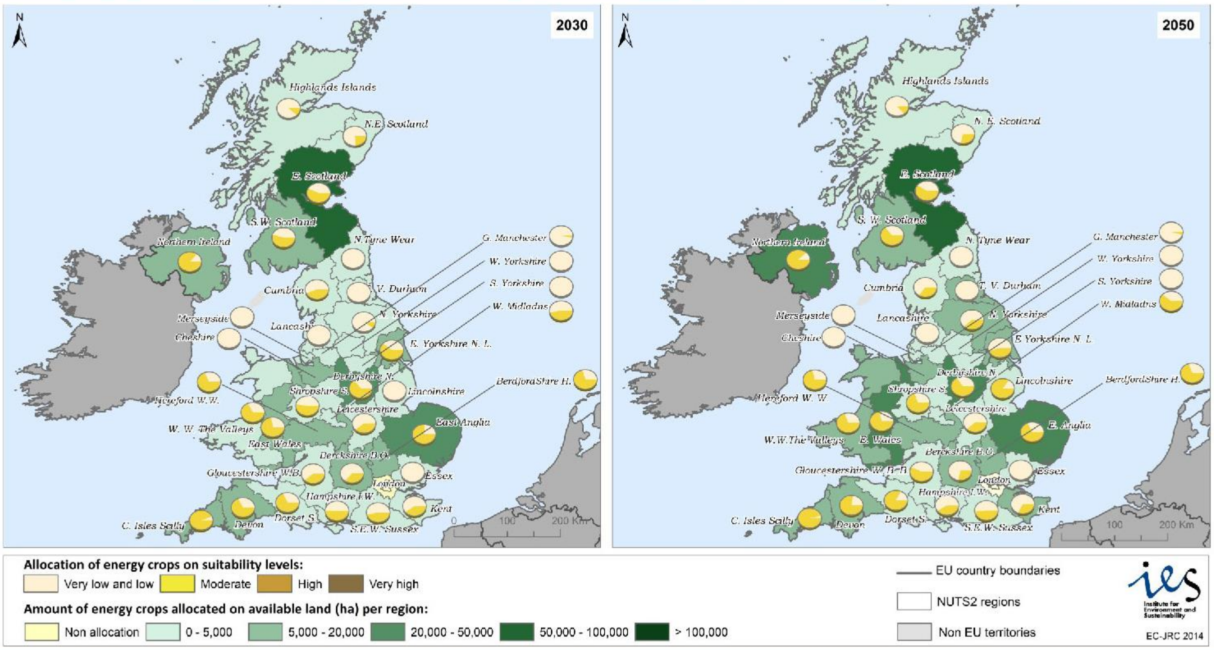




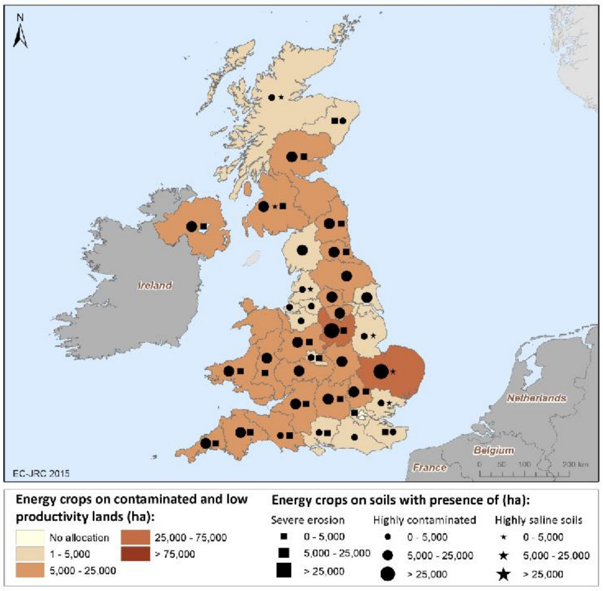
UNITED KINGDOM (UK)

In United Kingdom the allocation of energy crops reaches 761 and 978 kha in 2030 and 2050, respectively. These figures represent a share of energy crops between 0.5% and 17.7% of the total available land within each region in 2050. Broadly speaking, energy crops are half allocated on low and moderate local (biophysical) suitability lands (by 54% and 56% on moderate levels in 2030 and 2050, respectively). The projected allocation for energy crops implies the conversion from other land uses, mainly other arable land (48%), cereals (32%) and pasture lands (14%) in 2050.

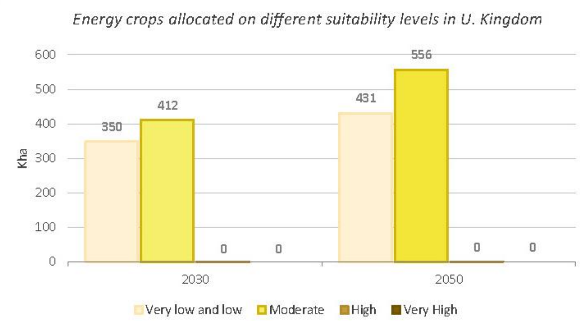
Availability of energy crops classified by suitability levels in 2030 and 2050 per NUTS2 regions

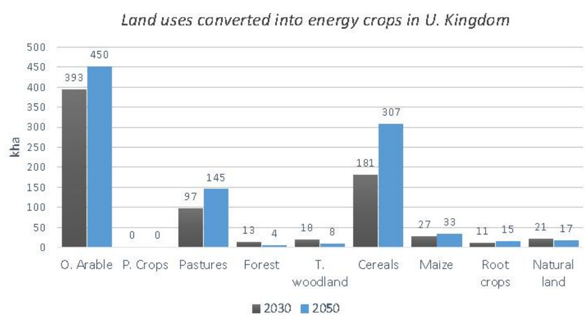


Energy crops on low productivity lands (2030)



The allocation of energy crops on low productivity and contaminated lands reaches 367,717 ha (24% of low productivity lands over available land) in 2030.





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