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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

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Executive summary

Background

The European Union is increasingly committed to accomplish the goal of a resilient Energy Union, by means of a governance process that shall ensure the coordination of different energy-related actions implemented across different spatial scales.

The analysis of potential impacts on the land-use system and the functions that it provides, such as production of food and provision of ecosystem services, is a crucial component contributing to the success of the Energy Union. The land-use system affects both the demand and the supply of energy. On the supply side, examples are the availability of feedstock for the provision of bioenergy and the availability of land for the installation of other renewables, such as solar energy. On the demand side, the spatial distribution of different users, such as industrial sites and residential buildings, also affects the final energy use of the whole system.

Both quantity and quality (suitability to specific uses or functions) of the land affect the capacity of the land itself to support not only productive systems, but also ecosystems and their services. In addition, the dynamic nature of the land system (resources can be degraded in quantity and quality at fast pace, while their recovery might take place on longer time scales) and the role of climate change, require a special effort in order to improve the resilience of the system itself.

The methodology

An integrated modelling framework has been applied to address at high spatial resolution the competition for land arising from the energy, transport and climate dimensions of EU policies, as included in the EU Energy Reference scenario 2013, with time horizon up to 2050.

The Reference scenario has been implemented in the Land Use-based Integrated Sustainability Assessment (LUISA) platform and - while primarily set around the assumptions on the achievement of the GHG and RES targets for 2020 and of related EU and national – includes other underlying important drivers for increased competition for land, such as detailed regional demographic and economic trends, investments in cohesion and infrastructural measures and environmental legislation. The developed approach would help understanding main sustainability 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.

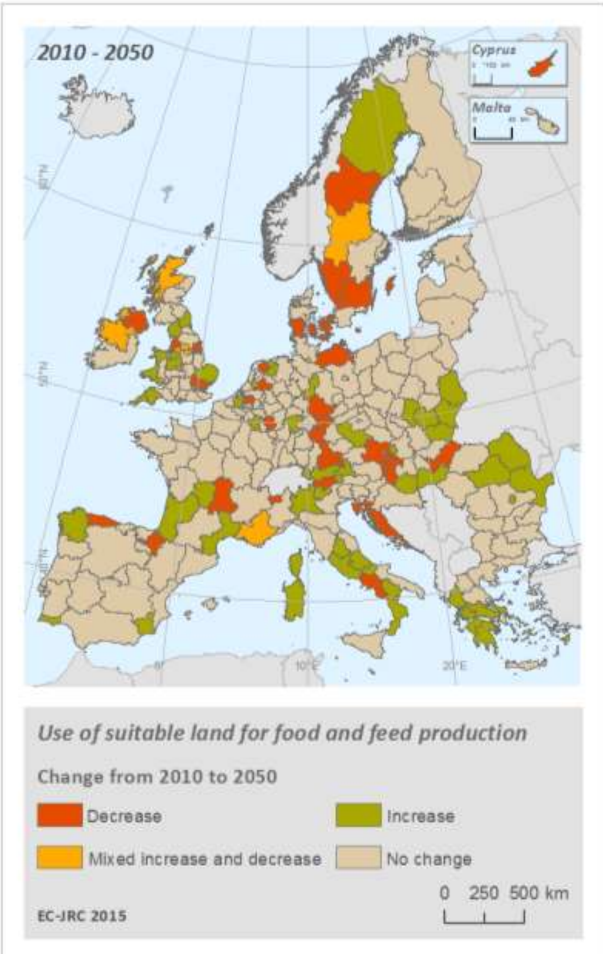
This report presents the quantitative analysis of the use of land suitable for the production of food, feed and energy and for the provision of services such as housing and infrastructure, as outcome of the modelling exercise over the time period 2020-2050. The analysis is performed at regional (NUTS2) scale. Previously published reports have described in detail – for the same reference scenario - the modelling framework, the demand for land originated by the socio-economic drivers and the transformations (allocations) from one land use class into another.

The quality of the land, in terms of biophysical soil characteristics and morphological and climatic suitability, is one of the key elements to consider when evaluating productivity level (yield) for the production of food, feed and energy. In an ideal case, the allocation of crop (and more generically any land use) follows strictly the criteria of highest overall suitability, since this would reduce the request for fertilizers and other inputs (e.g. water or labour). For example, building up should ideally occur only on totally unfertile lands since not requiring any specific soil condition. In the reality, in presence of market-driven demand, or because of population increase, or any social or policy drivers, the allocation of land use does not uniquely respect the criteria of maximum suitability, and competition for land occurs.

In the Energy Reference Scenario, the attainment of the energy targets forces the production of biomass for energy purposes, at cost and in place of other commodities. It is therefore of particular interest to evaluate, at local scale, the land resources necessary to support the production of land-based energy sources and the provision of other services, as demanded by the upstream economic and energy models.

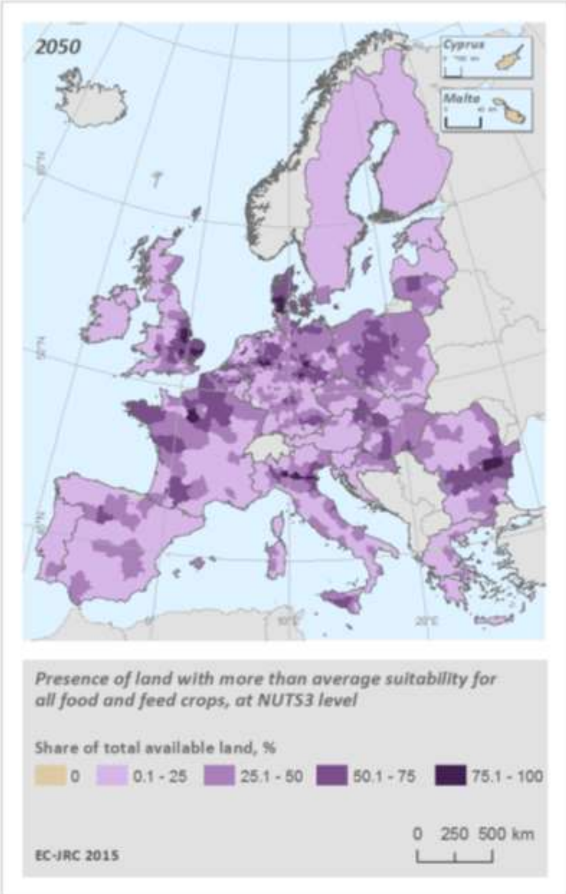
The results

Depending on the interplay among the different modelling factors affecting the allocation of uses and functions, factors such as driving macro-economic phenomena, biophysical characteristics of the land, neighbourhood interactions among different uses (repulsion/attraction effects) and policy-derived incentives and restrictions, the resulting projected landscape represents the best combination (i.e. a system optimum, see Lavalle et al., 2011) given the modelling assumptions. This implies that trade-offs between different uses take place: for instance, the allocation of each food and feed crop might not be optimal for the use taken alone.



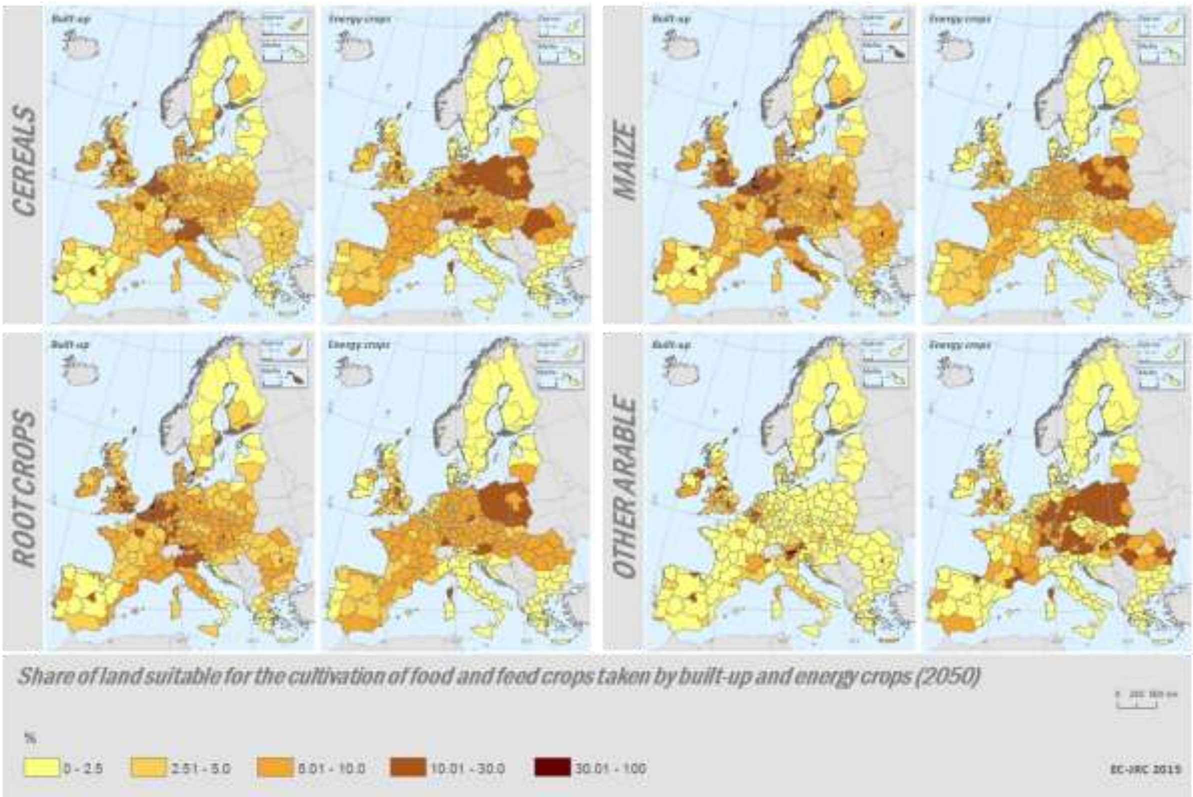
The modelling exercise has allowed to evaluate how the allocation of food and feed crops, energy crops and built-up unfolds under the Reference Scenario, in terms of use of land, suitable for the cultivation of food, feed and energy crops. A trend that emerges for several regions is the use of increasingly low suitable land for the production of food and feed (red in the figure on the left).

On the opposite, food and feed crops belonging to NUTS2 shaded in green are generally allocated on land of higher suitability levels; in the regions coloured in yellow some crop types are allocated on higher suitability levels, whereas others on lower levels; finally, in the regions shaded in light brown, no substantial changes are observed about the suitability levels used to allocate food and feed crops.



The allocation patterns of food and feed crops is also influenced by the competition among them. In some regions, the suitability of the land for growing these crops is quite similar among cereals, maize, root crops and other arable (NUTS3 shaded in darker colour in the figure on the left). This might further be the cause for some crops to be allocated on less suitable land, when the demand for competing food and feed types increases.

Among the drivers potentially causing the displacement of food and feed crops from highly suitable land to lower levels of suitability, is the increasing demand for new built-up areas, either for residential or ICS uses, together with the introduction of dedicated energy crops. These two phenomena can exacerbate the competition for land resources, potentially causing food and feed crops to be allocated on land not highly suitable for their growth. The figure below illustrates 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 either built-up or dedicated energy crops.



A detailed analysis of the allocation of food and feed, and energy crops, compared to the respective suitability of the land, has been carried out. The aim was to assess the potential impact (pressure) on cultivation patterns and landscapes in Europe, as of a reference scenario whereby legally binding energy-related targets are assumed to be met.

Energy Crops (ENCR)

A specific land use class is dedicated to the production of energy crops (non-food, lignocellulosic crops). According to the projections of the Reference Scenario, ENCR start to appear in Europe around the year 2020 and usually have a pick towards the end of the simulation period (2050).

Land use changes due to the expansion of ENCR in the EU28 represent 17% of the total land use changes between 2010 and 2050, reaching 30% in some countries such as France, Poland, Romania and Slovakia. This expansion takes place at the expenses of other agricultural land use classes, especially arable land and, within this category, cereals. In 2020, France (1,346 kha), Germany (1,316 kha) and Poland (900 kha) have the highest energy crop production in absolute figures. The other countries range from 241 kha (Italy) to 6 kha (Slovenia) and there is absence of ENCR in Romania, Luxemburg, Croatia, Denmark, Bulgaria, Cyprus, Finland, Greece, Malta and Portugal.

By 2050, Poland, Spain and Romania are projected to experience a considerable energy crop expansion and become part of the group of main producers along with France and Germany. On the contrary, in accordance with the implemented macro-economic settings of the reference scenario, ENCR disappear altogether in Italy. The expansion of ENCR on land characterised by low suitability is mainly taking place in the Nordic countries, eastern European countries and central-eastern part of Europe.

Production of food and feed

Overall, the production of food and feed takes place on land allocated to the following land use classes: cereals, maize, root crops, other arable, permanent crops and pasture. In the present report cereals, maize, root crops and other arable are especially investigated.

Cereals

In both 2020 and 2050, the majority of cereals in Europe are allocated on land classified as highly suitable for their production. Overall EU28, cereals decline by more than 15% with the exception of Bulgaria, Denmark, Croatia, Hungary, Malta, Portugal and Sweden, all other countries experience a decrease in the land allocated for cereals (on average higher than 10%). In this latter case, two different patterns can be seen. Firstly, in the majority of countries where cereals are decreasing, the proportion allocated on high quality land increases. This means that the first cereal farmland to be withdrawn is indeed that located on less suitable land. Among others, this is the case in Estonia, the United Kingdom, Slovakia and Slovenia. In other countries, such as Germany and Austria, notwithstanding the negative trend in cereals, the proportion of these crops allocated on lower quality land increases.

Maize

In both the years 2020 and 2050, maize is predominantly allocated on land that is highly suitable for this kind of crop. From 2020 to 2050, the overall quantity of maize allocated decreases in the majority of the MSs, with the exception of Germany, Denmark, Portugal, Sweden and Luxemburg. In the countries where the overall quantity of maize is increasing, the share of these crops allocated on very suitable land tends to increase; the only exception is Sweden, where the share of maize allocated on highly suitable land decreases in favour of land classified as moderately suitable. In countries where the overall quantity of maize decreases, the share allocated on highly suitable land tends to increase, with the exception of Croatia and Latvia. In Poland and Romania, the share of maize allocated on medium or high/very highly suitable land tends to change between 2020 and 2050, but without showing a clear pattern.

Root crops

In both 2020 and 2050, root crops are predominantly allocated on good quality land. Nevertheless, countries where a substantial share of root crops are allocated on moderately suitable land are: Spain, Greece, Poland, Austria, Estonia and the United Kingdom. These crops are allocated on particularly poor quality land in Malta and Cyprus, where the overall acreage of root crops is very limited. The majority of the MSs (18 out of 28) have less root crops allocated in 2050 than in 2020. Among these, Austria, Denmark, the United Kingdom and, to a lesser extent, Italy, experience an increase in the share of root crops allocated on highly suitable land.

On the other hand, in Cyprus, Latvia and Sweden, on the whole the land used for root crops decreases from 2020 to 2050, and the share allocated on low quality land increases. Among the countries where there is an increase of allocated root crops from the year 2020 to the year 2050, Estonia, Malta and Portugal experience an increase in the share of these crops allocated on poorly suitable land. A similar pattern can be seen in Ireland, but less pronounced.

Other arable land

From 2020 to 2050, the majority of European countries experience an increase in land cultivated for other arable crops. This increase is greater than 5% in Austria, Estonia, Spain, Finland, France, Greece, Hungary, Latvia, Malta, the Netherlands, Romania and Sweden. Overall, whether the total amount of allocated other arable land per country is increasing or decreasing, the general tendency is to shift these crops from moderately or highly suitable land to land with low suitability.

Suitable land lost because of urbanisation

The expansion of built-up areas, for residential and production uses, is one of the possible causes of loss of fertile and good quality land. Because of economic and demographic drivers, land highly suitable for the cultivation of food crops and non-food crops is being used for artificial uses, in particular for what concerns land with moderate suitability for cereal production. Maize and root crop cultivations are also affected, since built-up is predominantly allocated on land classified as moderately and highly suitable land for these types of crops.

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 residential and other economic activities, while central, eastern and northern parts of Europe better preserve better the land highly suitable for the cultivation of ENCR.

Conclusions

The production of energy from land resources is the issue of relevance when dealing with the analysis of the competition for land in the EU Energy Reference Scenario. The modelling exercise has allowed the evaluation of the trends in terms of allocation and use of fertile land for energy production and built up areas. The excessive exploitation of the land might, in turn, cause or exacerbate environmental problems at regional and local level. In the mid and long term, this might also bring negative economic repercussions, because the quality of the land is compromised and its recovery requires long-term and expensive investments.

Abstract

Since land is a finite resource, the competition for land among different uses has become a real problem. Competition for land takes place when different alternative uses (such as agriculture, forestry, energy or/and natural conservation) are competing for the same piece of land. When the competition for land is highly intense in a given territory, a specific land use/cover might cause the displacement of another one, leading to land-use conversion and, potential negative environmental, economic and social impacts. In the long term, this exacerbated competition might increase the pressure on the land and the impacts on the land capacity to support ecosystems and productive systems.

Methodologies and tools to assess the potential impacts of bioenergy development in the EU on land uses and functions provide useful insight to shed light on the environmental impacts of energy policies. The territorial assessment carried out by the Land Use-based Sustainability Assessment (LUISA) modelling platform highlights where in Europe the current macro-economic trends and energy policy targets might pose a threat to our land resources in the mid to long term. This might happen, for instance, in regions where the demand for energy crops and the need for residential and industry/commerce/services functions, is forecasted to increase. Essential land uses, such as agriculture for food and feed production, could therefore be transferred to less suitable lands at a regional or local scale.

The herein report explores in detail the land uses that are expected to be in direct competition for land (food, feed and energy) as a result of the EU bioenergy targets and considering the suitability characteristics of the land for these uses. The analysis is carried out per main crop group (cereals, maize, root crops, other arable crops and energy crops), as simulated by the LUISA modelling platform. The results presented highlight where and how the displacement of food and feed crops from highly suitable land to lower levels of suitability can be caused by different drivers, among which the expansion of built-up areas and dedicated energy crops.

In summary, the majority of cereal, maize and root crops in Europe are allocated on land classified as highly suitable (according to local biophysical conditions, possible fertiliser input and current cropping patterns) between 2020 and 2050. However, the amount of land cultivated with food crops (cereal, maize and root crop production) is shown to experience a substantial decrease in the majority of the MSs, on average higher than 10% across the entire simulation period. On the opposite, energy crop production increases at fast pace, at times doubling the amount of allocated land from the year 2020, when they first appears in the modelling, to 2050. Due to the growth of residential and ICS (industry, commercial and services) sites, land highly suitable for the cultivation of food crops and non-food crops is increasingly being used for artificial uses.

In general terms, growing crops on highly suitable land results in a cost reduction associated to inputs use, such as fertilizers, pesticides and water. However, as result of the competition, there is – in several areas in Europa - an increasing shift towards low quality land for growing food and feed crops, with environmental and economic impacts to be carefully evaluated.

1. Introduction

The European Union is increasingly committed to accomplish the goal of a resilient Energy Union, intended as a "sustainable, low-carbon and climate-friendly economy"[1]. In order to achieve this goal, an integrated governance and monitoring process1 is put forward as the essential instrument needed to integrate and coordinate energy-related actions at different levels. This governance process shall ensure integration across different spatial scales, from European to local, and promote coherence among different policy areas.

This strategy applies to all the five dimensions that the Energy Union is composed of: (1) Energy security, solidarity and trust; (2) A fully integrated European energy market; (3) Energy efficiency contributing to moderation of demand; (4) Decarbonising the economy; and (5) Research, Innovation and Competitiveness.

In particular, for the fourth dimension (decarbonisation), the integration of spatial dimensions and coordination of policy sectors is of utmost importance. The increasingly ambitious targets of domestic reduction in greenhouse gas emissions, together with the target on wanted shares of renewable energy consumption, commit the European Union to becoming the world leader in renewable energies. On the one hand, research and investment strategies play a fundamental role in this context; on the other hand, the framework strategy for a resilient energy union1 explicitly highlights that the EU "will also need to take into account the impact of bioenergy on the environment, land-use and food production".

In fact, the analysis of potential impacts on the land-use system and the functions that it provides, such as production of food and provision of ecosystem services, is a crucial component contributing to the success of the Energy Union. The land-use system affects both the demand and the supply of energy. On the supply side, examples are the availability of feedstock for the provision of bioenergy and the availability of land for the installation of other renewables, such as solar energy. On the demand side, the spatial distribution of different users, such as industrial sites and residential buildings, also affects the final energy use of the whole system.

Adding to the complexity is the fact that land is a finite resource, and considering all the possible uses it will be needed for besides energy production, the competition for land among different uses will become harsh. Examples of other land functions for which future demand will increase are production of food for people and feed for animals, provision of timber for material uses, need of urban areas for residential purposes and industrial sites for production activities.

Both quantity and quality (suitability to specific uses or functions) of the land affect the capacity of the land to support not only productive systems, but also ecosystems and their services. The dynamic nature of the land system (resources can be degraded in quantity and quality at fast pace, while their recovery might take place on longer time scales) and the role of climate change, require a special effort in order to improve the resilience of the system itself. The Paris Protocol[2] explicitly emphasises the pivotal role of

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[1] COM(2015) 80 final "ENERGY UNION PACKAGE - COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK. A Framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy".

[2] COM(2015) 81 final "ENERGY UNION PACKAGE COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL The Paris Protocol – A blueprint for tackling global climate change beyond 2020".

the "land use sector with regard to resilience of food security, and other environmental, social and economic benefits". As examples, the Protocol mentions the potential contribution of ecosystem-based adaptation in reducing flood risk and soil erosion, and improving water and air quality.

Aside from contributing to bioenergy production, affecting the energy demand, and overall guaranteeing food security and other functions, the land system and its changes (land-use changes) are also identified as a an important contributor to greenhouse gas emissions. In conclusion, the availability of methodologies and tools to assess the potential impacts of energy policies on land uses and functions is indeed required in order to fulfil the commitments put forward by the framework strategy for a resilient Energy Union.

In this context, an integrated modelling framework has been developed by JRC and applied to address, at high spatial resolution, the competition for land arising from the energy, transport and climate dimensions of EU policies, as included in the EU Energy Reference scenario 2013 (updated configuration 2014 in LUISA)[3], with time horizon up to 2050. Such a framework is based on the principle that different uses (or functions) compete for most suitable locations, given available land, and assumed demand and policy constraints or incentives. The actual allocation of each use is governed by an optimization approach, so that, given the modelling assumptions, the resulting projected landscape represents the best combination (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): both the two directly involved in the transition and possibly others (indirect impacts), ultimately affecting the society, environment and capacity to provide ecosystem services.

The first step of the methodology entails the analysis of the main macro drivers responsible for increasing pressure on the European land resources[4]. A particular focus has been dedicated to the land required and the land that is potentially available to accommodate the production of food and feed, and energy (bioenergy). At this stage of the analysis, it is possible to compare the availability of land that is suitable for the production of food and feed crops, or energy, and how it the availability of suitable land changed through time, mostly due to the expansion of competing uses such as residential and industrial areas.

The next step of the methodology focuses on the analysis of the allocation patterns resulting from the implementation of the reference scenario. In order to better highlight the two main objectives of the analysis, the results have been organized in two complementary reports. The first report[5] 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 of how the European landscape might change if the future happens according to a

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[3] 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 (EU Energy Reference scenario 2013).

[4] 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.

[5] Lopes Barbosa A, Perpiña Castillo C, Baranzelli C, Aurambout J, Batista E Silva F, Jacobs C, Vallecillo Rodriguez S, Vandecasteele I, Kompil M, Zulian G, Lavalle C. European landscape changes between 2010 and 2050 under the EU Reference Scenario. EU Reference Scenario 2013 LUISA platform – Updated Configuration 2014. EUR 27586. Luxembourg (Luxembourg): Publications Office of the European Union; 2015. JRC98696.

scenario consistent with the energy policy promoted by the European Union, especially in relation to the renewable targets.

This second report investigates in detail the land uses that are expected to be in direct competition for land (food, feed and energy) as a result of the EU bioenergy targets and considering the suitability characteristics of the land for these uses. The analysis is carried out per main crop group (cereals, maize, root crops, other arable crops and energy crops), as simulated by the LUISA modelling platform. The results presented highlight where and how the displacement of food and feed crops from highly suitable land to lower levels of suitability can be caused by different drivers, among which the expansion of built-up areas and dedicated energy crops.

Finally, the analysis of the modelling results from the EU Energy Reference scenario 2013 (updated configuration 2014 in LUISA), is complemented by the following two documents:

The main findings related to the demand and allocation of dedicated energy crops in EU28, are compiled in Perpiña Castillo et al. (2015), where detailed results are organised in factsheets per MS. In this report is described the performances of a selection of relevant indicators, related to the provision of ecosystem services when energy crop production considerably increase across Europe.

The present report is structured in four main chapters: Chapter 2 provides an overview of the shares of land suitable for the production of food and feed crops used for allocating built-up and energy crops. Chapter 3 analyses in detail where (on which level of suitable land) different types of crops are allocated. Chapter 4 focuses on the expansion of built-up as the main cause driving the loss of suitable land. Finally, Chapter 5 draws the main conclusions of the analysis presented in the report, also in relation to the main findings from Baranzelli et al. (2014b) and Lopes Barbosa et al. (2015).

2. Methodology

The main objective of the present report is to analyse the use of suitable land for the production of food and feed crops, as opposed to two main competing uses: dedicated energy crops (ENCR) and built-up.

According to the thematic detail of the LUISA platform, the main food and feed crop groups analysed are cereals, maize, root crops and other arable. The detailed crop types contributing to each group are listed in Table 1.

Table 1. Detailed crop types corresponding to the LUISA platform legend, as from the CAPRI model.

CAPRI activities	LUISA land-use class
Soft wheat Durum wheat Rye and Meslin Barley Oats Other cereals	Cereals
Potatoes Sugar beet Fodder root crops	Root crops
Grain maize Fodder maize	Maize
Paddy rice Oilseeds Pulses Flax and hemp Tobacco Other industrial crops Other crops Tomatoes Other vegetables Fodder other on arable land Set-aside voluntary Fallow land	Other arable

The analysis presented in the following chapters is based on the concept of land suitability. Together with policy-related layers and allocation rules based on neighbourhood relations between different land-uses/covers, suitability maps are one of the main components driving the allocation of crops in LUISA. Suitability layers represent the biophysical suitability of a parcel of land to be cultivated with food and feed crops, or ENCR. Each of these suitability layers is expressed on a scale from 0 (not suitable) to 1 (very suitable).

The suitability levels for food and feed crop production are defined according to local biophysical conditions, possible fertiliser input and current cropping patterns[6]. These levels

[6] It is assumed that farmers are rational agents and crops are currently cultivated on land that, on average, optimises the options available to the farmers.

are described as very low, low, moderate, high and very high. The higher the suitability, the higher the potential productivity level (yield), thus reducing the need for additional inputs potentially harmful to the environment.

Taking into consideration the different requirements of each different crop groups, a suitability layer has been computed separately for cereals, maize, root crops and other arable.

The main components contributing to the suitability of a parcel to be cultivated with a food and feed crop are the following[7]:

- Characteristics of the soil, such as soil texture and composition (Baruth et al., 2006);
- Biomass production potential, considering the potential application of fertilisers (Toth et al., 2011);
- Climate characteristics: the results of the AVEMAC project have been used in order to capture the yield variability due to the change in climate conditions, especially related to precipitation. For details, see Baranzelli et al. (2014a);
- Current agricultural use, as mapped in Corine Land Cover 2006 Refined (Batista e Silva et al., 2013). The assumption is that current (as from 2006) presence of a crop at a specific location can be interpreted as a proxy of how that location is suitable for that specific crop i.e. farmers tend to use the most suitable land for the most suitable cultivation.

Similarly, the suitability layer for ENCR is computed based on their ecological requirements. Due to the heterogeneity of this class, which covers lignocellulosic crops, both herbaceous and woody, the following approach has been applied. Eleven factors maps (biophysical variables) were identified as the most relevant: temperature, precipitation, length-growing period, frost-free days, soil pH, soil texture, soil drained, soil type, slope and salinity. Eight suitability layers have been thus compiled for each species comprised in the category "energy crop" (miscanthus, switchgrass, reed canary, giant reed, cardoon, willow, poplar and eucalyptus). The final suitability layer is a composition of these eight layers: at each location, the maximum suitability value among these layers is assumed, under the hypothesis that at each location the most suitable species would be planted.

Overall, the suitability layers constitute one component among many in the allocation mechanism of LUISA. In a region, within the policy-related constraints and incentives, each crop is not always allocated on the most suitable land, because of the competition with other uses for the same parcel of land. In Chapter 3, the allocation results of all food and feed crops is analysed for the period 2010 – 2050. The analysis is further detailed in Chapters 4 and 5, focusing on the period 2020-2050. The year 2020, instead of 2010, has been chosen in order to run a meaningful comparison with the allocation of ENCR, which are forecasted to appear in EU28 from 2020 onward.

[7] A more detailed description of how suitability maps were generated and used can be found in the EU Reference Scenario 2014 document (Baranzelli et al., 2014a).

3. Suitability analysis for food and feed production

This chapter provides an overview of how the allocation of food and feed crops changes over time under the simulated Reference scenario.

From Figure 1 to Figure 4, the trend, over the period 2010-2050, in the use of suitable land for the allocation of cereals, maize, root crops and other arable respectively, is compared to the corresponding crop demand. Demand trends are aggregated at NUTS1 level (from the original geography provided by the CAPRI model)[8], whereas the suitability analysis is detailed at NUTS2 level.

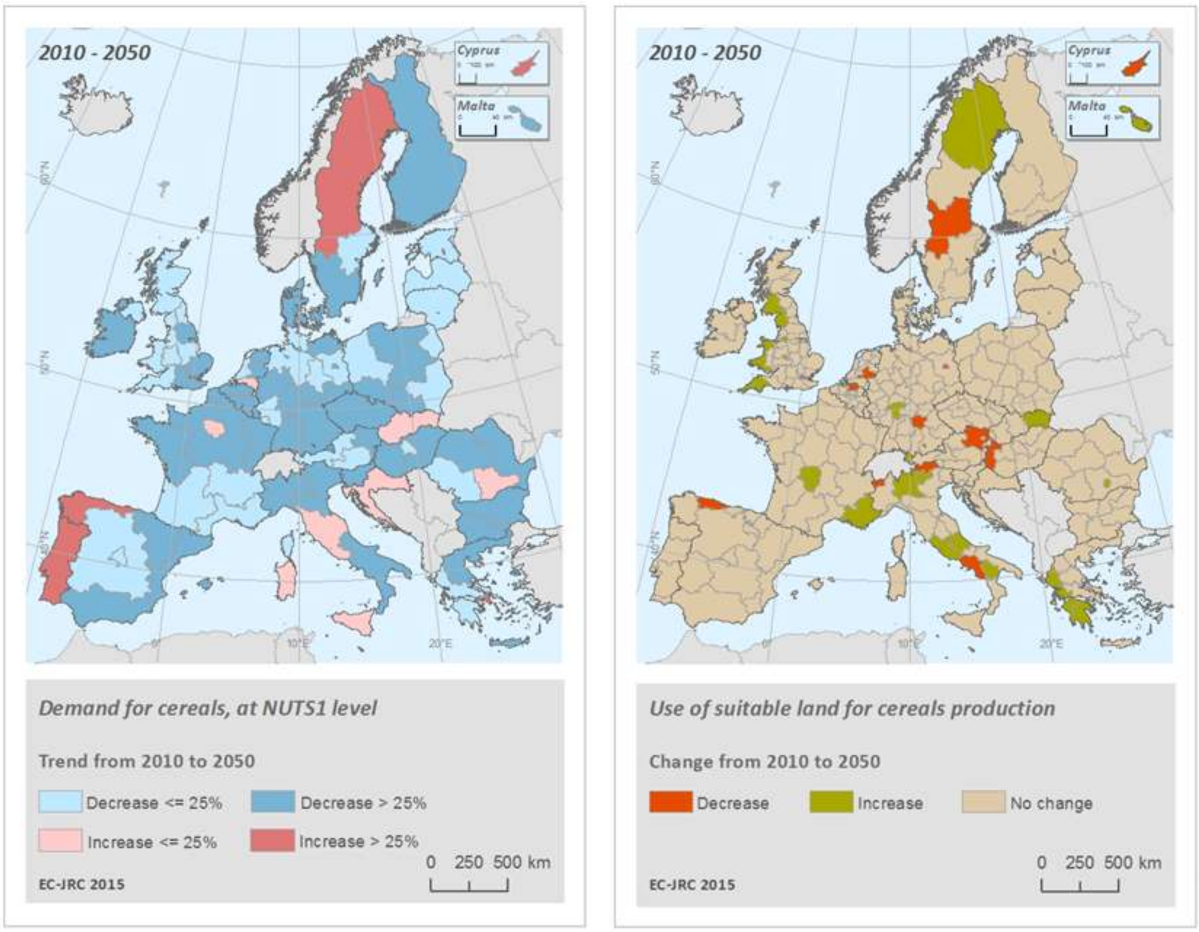

Figure 1. Demand for cereals (left-hand side map) and change in the suitability level that is used for cereals (right-hand side map), from the year 2010 to the year 2050.

[8] Land demand from the CAPRI model is originally provided at either NUTS1 or NUTS2 level, depending on the Member State. Hereinafter, in order to provide a homogenous representation of the demand trends, projections available from CAPRI at NUTS2 level have been aggregated at NUTS1 level.

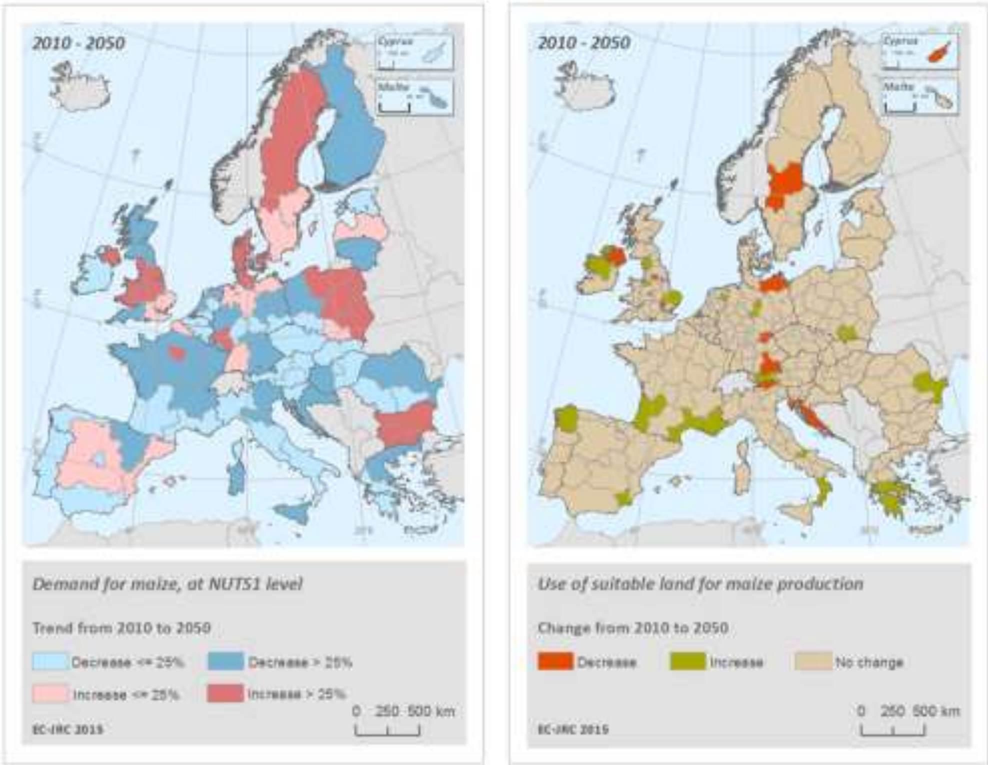

Figure 2. Demand for maize (left-hand side map) and change in the suitability level that is used for maize (right-hand side map), from the year 2010 to the year 2050.

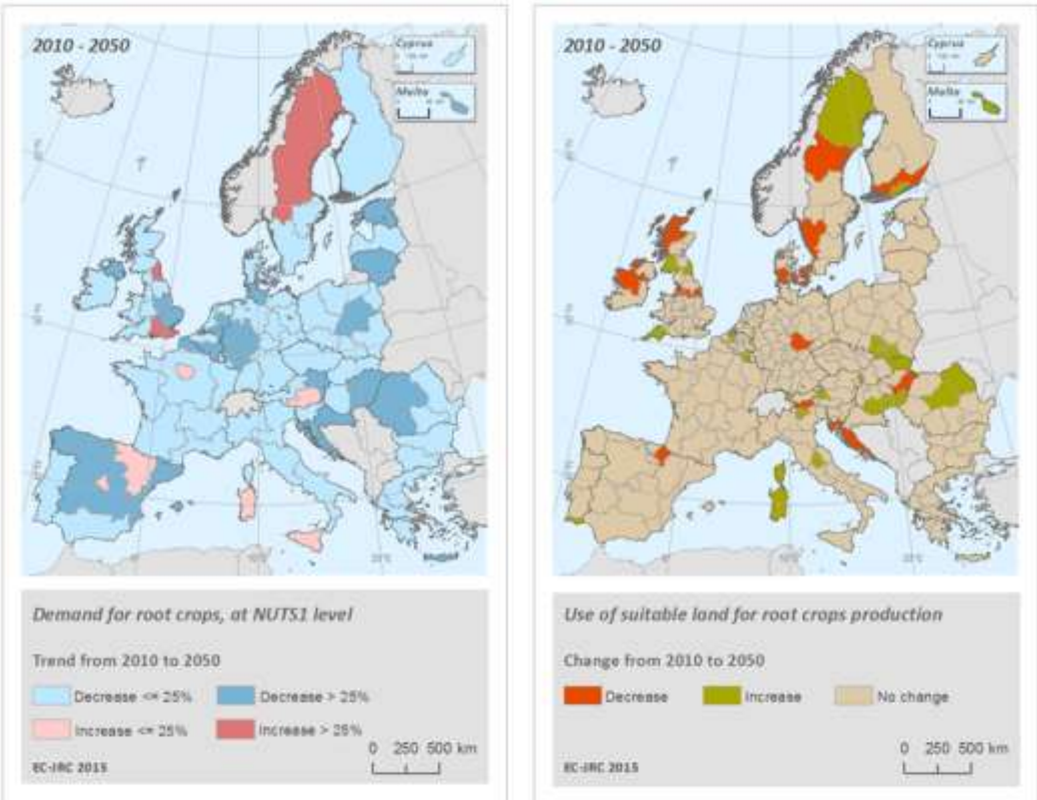

Figure 3. Demand for root crops (left-hand side map) and change in the suitability level that is used for root crops (right-hand side map), from the year 2010 to the year 2050.

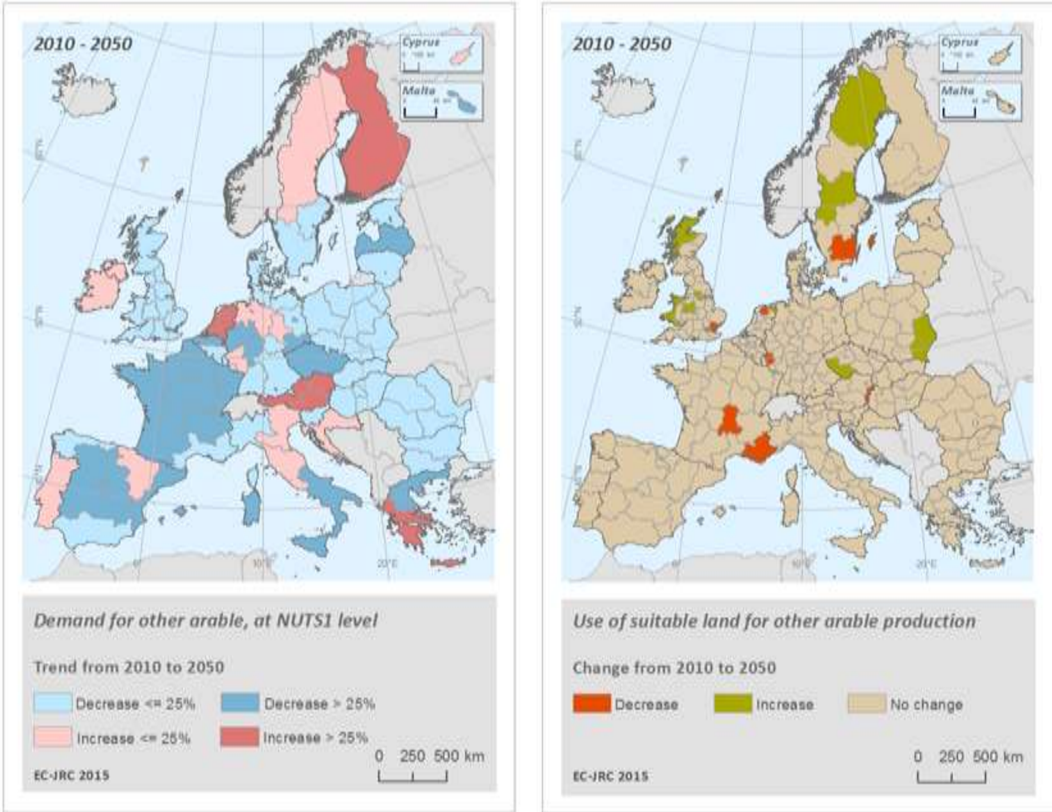

Figure 4. Demand for other arable (left-hand side map) and change in the suitability level that is used for other arable (right-hand side map), from the year 2010 to the year 2050.

Overall, in more than half of the regions the majority of the crops maintain the suitability level on which they are predominantly allocated. This can be observed for all the analysed crops (cereals, maize, root crops and other arable) and regardless of the trend in the demand for the respective crop.

In the remaining regions, it is possible to identify four different patterns, depending whether the demand for a crop is increasing/decreasing and the majority of it is allocated on land of lower/higher suitability in the year 2050, compared to 2010.

The NUTS2 regions where the demand is decreasing and the majority of crop is allocated, in 2050, on land of lower suitability are located in eastern Austria, north-western Hungary, Val d'Aosta, Südtirol and Campania in Italy, and across the border between the Netherlands and Belgium (cereals); south-eastern Germany and Croatia (maize); northern Ireland, the Highlands and part of East and West Midlands in the United Kingdom, east-southern Finland, southern Sweden, southern Denmark, Thuringia in Germany, eastern Hungary, Trentino-Alto Adige in Italy and Croatia (root crops); one region in South East England, and Auvergne and Provence-Alpes-Côte d'Azur in France (other arable).

This trend in the allocation of food and feed crops can be associated with the increasing pressure generated by the expansion of built-up (urban and ICS uses), often in combination with the relatively scarce availability of suitable land. Examples of this latter case are Südtirol and Val d'Aosta in Italy, and Antwerpen region in Belgium (cereals); Südtirol (maize); Greater Manchester, Lancashire and West Yorkshire in the United Kingdom (root crops). In addition to the pressure generated by the expansion of built-up, also the introduction of ENCR can combine with the scarce availability of suitable land and contribute to moving the cultivation of crops to less suitable areas e.g. in Auvergne and Provence-Alpes-Côte d'Azur in France (other arable).

On the opposite, regions where the demand for crops is decreasing and the majority of these crops are allocated on land of higher suitability manage to use the available land resources so to keep the remaining cultivated crops on the most suitable land, while accommodating the expansion of built-up and/or ENCR on lower quality land, even when the pressure from these two are high. One example is, for instance South Western Scotland for the cultivation of cereals.

Few regions across Europe are located in NUTS1 where the crop demand is forecasted to increase, whereas the majority of the crops are allocated on less suitable land. In some cases, this is due to the combination of high demand with scarce availability of suitable land. Examples are the region of Västsverige (cultivation of cereals) and Mellersta Norrland (cultivation of root crops) in Sweden, and Friesland in the Netherlands (other arable).

In other cases, also the pressure from built-up and ENCR expansion contribute to exacerbate the land competition. Two examples can be found in Spain: in the region of Asturias, the demand for cereals increases, but these crops are allocated on less suitable land, while the cultivation of ENCR increasingly uses land suitable for cereals; the region of Navarre presents a similar pattern, but for the cultivation of root crops. Similarly, in the Trier region in Germany the land suitable for the cultivation of other arable represents a very low share of the total available land and, instead of being allocated to satisfy the high demand for these crops, it is increasingly used for other uses, in particular ENCR. An analogous pattern for other arable can be found in Burgenland (Austria), where the competition with both ENCR and built-up is high.

Finally, in few regions crop demands are increasing and the crops are allocated on higher suitable land. Examples are regions in central Italy (cereals), two NUTS2 in the United Kingdom and one in southern Poland (maize), Sardinia in Italy (root crops) and northern and central Sweden (other arable).

Generally, this pattern is also due to the relatively abundant availability of suitable land. This is the case of the region of Malopolskie (Poland), where the presence of land suitable for the cultivation of maize is so abundant, that notwithstanding the large share of energy crops allocated on this type of land, maize is predominantly allocated on suitable land.

When analysing the allocation patterns of food and feed crops in comparison to the corresponding trend in land demand, it is also useful to highlight that in some regions, the suitability of the land for growing these crops is quite similar among cereals, maize, root crops and other arable. This might further be the cause for some crops to be allocated on less suitable land. This information is reported in Figure 5, in terms of share of available land that is suitable (average or higher level) for the cultivation of all food and feed crops, at NUTS3 level. Few NUTS3 where the share of land suitable for all food and feed crops is the highest (above 50% of total available land), are located in regions where the demand for at least one crop is increasing and crops are allocated on lower suitability levels. Examples are areas in central and eastern United Kingdom, northern and southern Germany, and eastern Hungary.

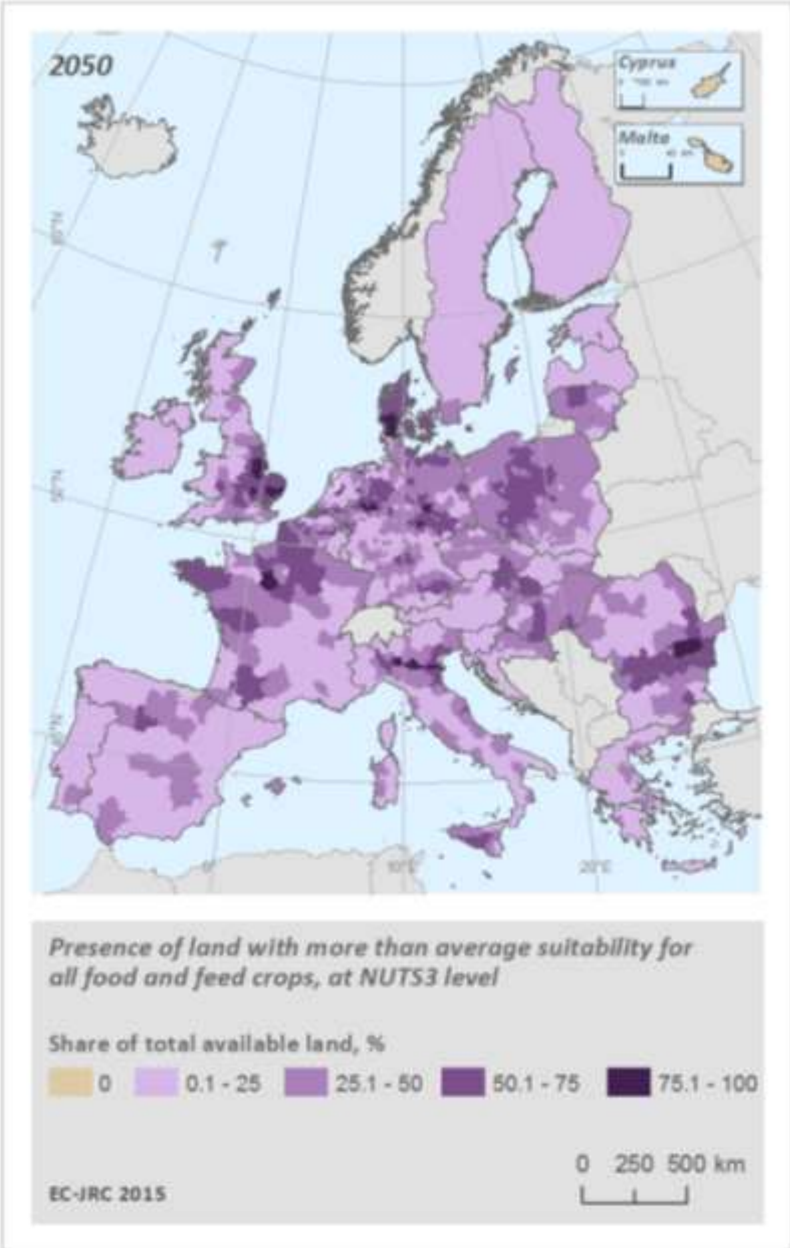

Figure 5. Presence of land suitable for the cultivation of all food and feed crops, at NUTS3 level, for the year 2050.

In order to summarise the main trends in the allocation of food and feed crops across Europe, as projected over the period 2010-2050, Figure 6 identifies regions where food and feed crops, considered altogether, are increasingly allocated on land characterised by lower suitability levels (red colour). The majority of these regions belong to France, north Italy, Germany and eastern countries, such as Romania and Hungary. On the opposite, food and feed crops belonging to NUTS2 shaded in green are increasingly allocated on land of higher suitability levels. In the regions coloured in yellow some crop types are allocated on higher suitability levels, whereas others on lower levels. Finally, in the regions shaded in light brown, no substantial changes are observed about the suitability levels used to allocate food and feed crops.

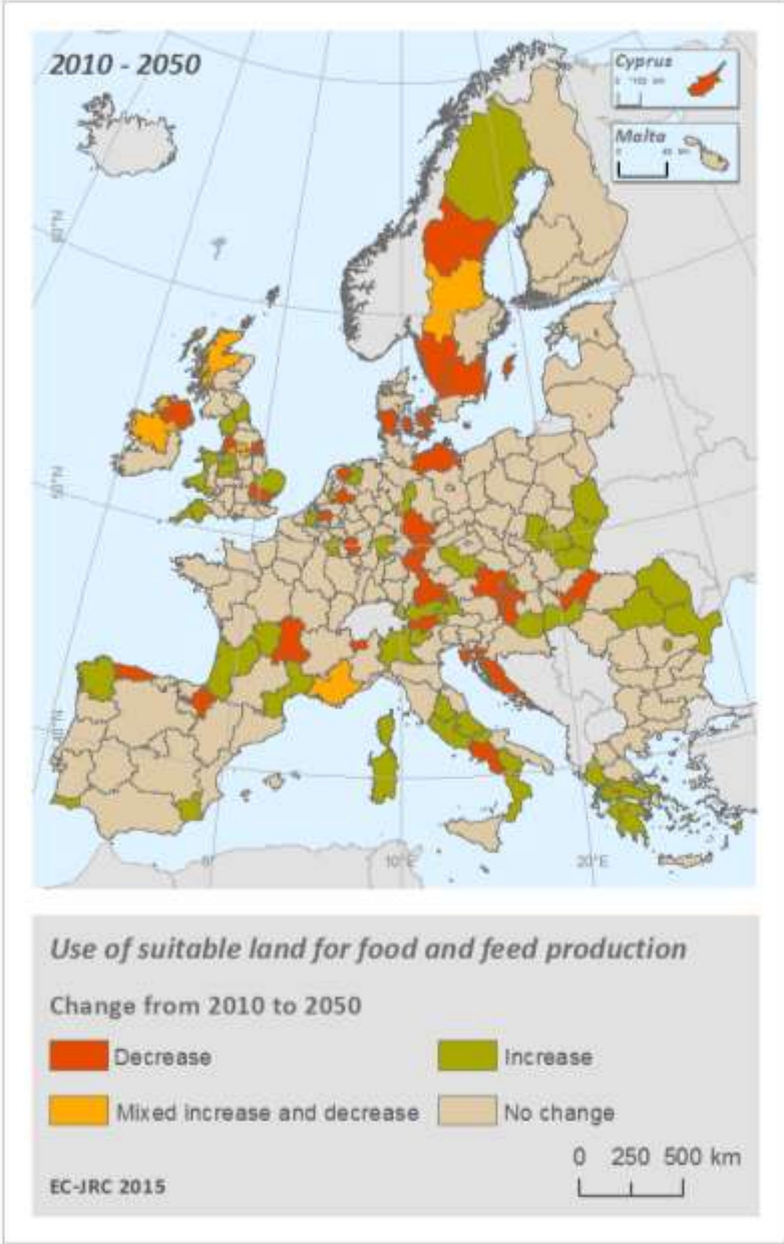

Figure 6. Change in the suitability level that is used for the growing food and feed crops, from 2010 to 2050.

The displacement of food and feed crops from highly suitable land to lower levels of suitability can be caused by different drivers. According to Baranzelli et al. (2014b), in many regions in EU28 the demand for new built-up areas, either for residential or ICS 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 7, Figure 8, Figure 9 and Figure 10 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 either built-up or ENCR.

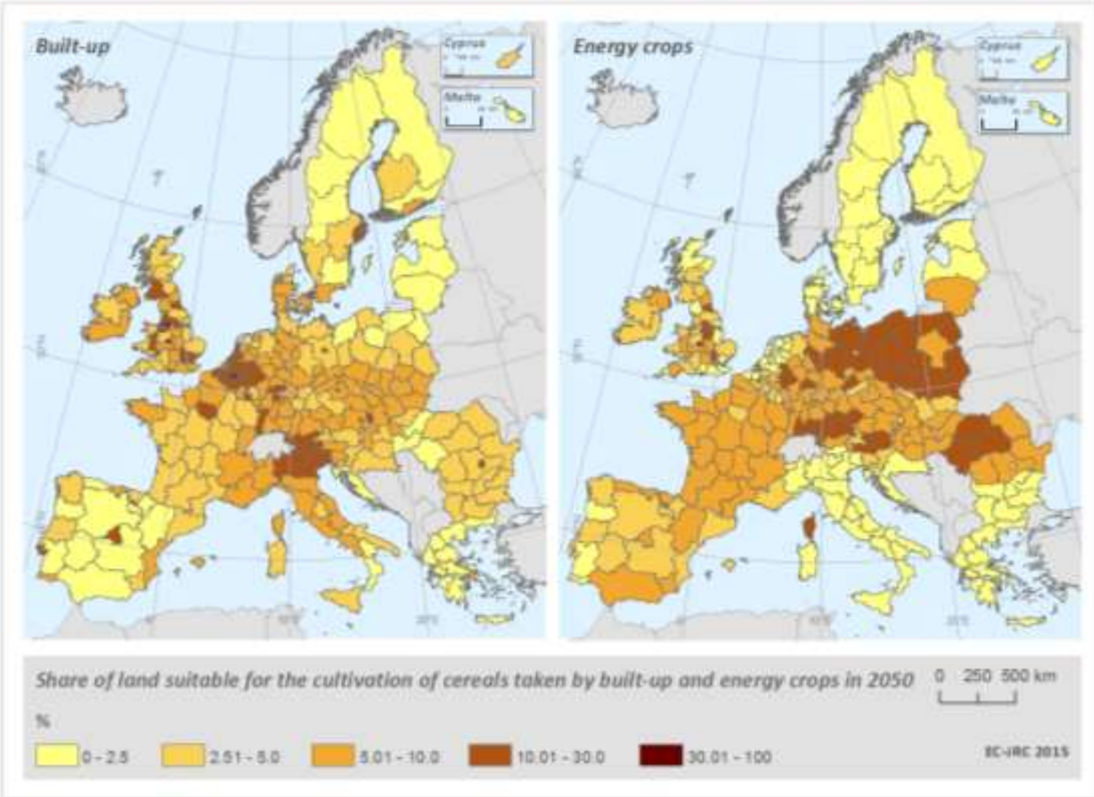

Figure 7. Share of land suitable for the allocation of cereals, that is used for built-up (left-hand side map) and energy crops (right-hand side map) in the year 2050.

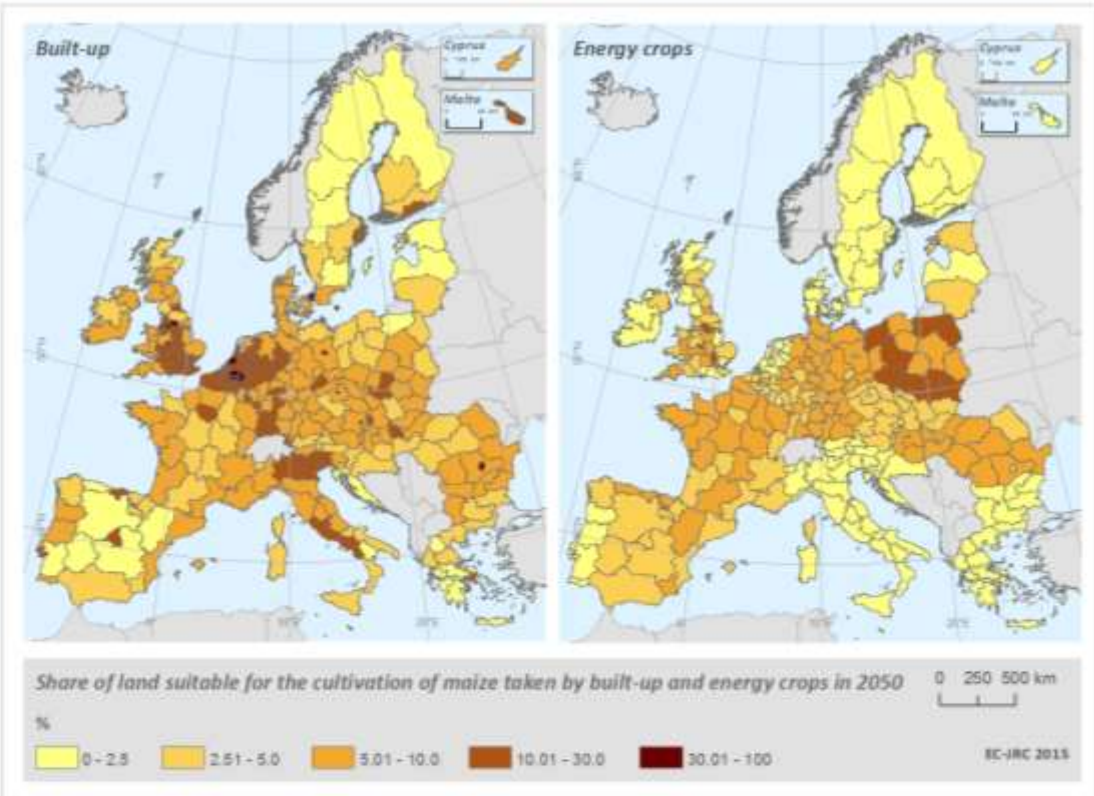

Figure 8. Share of land suitable for the allocation of maize, that is used for built-up (left-hand side map) and energy crops (right-hand side map) in the year 2050.

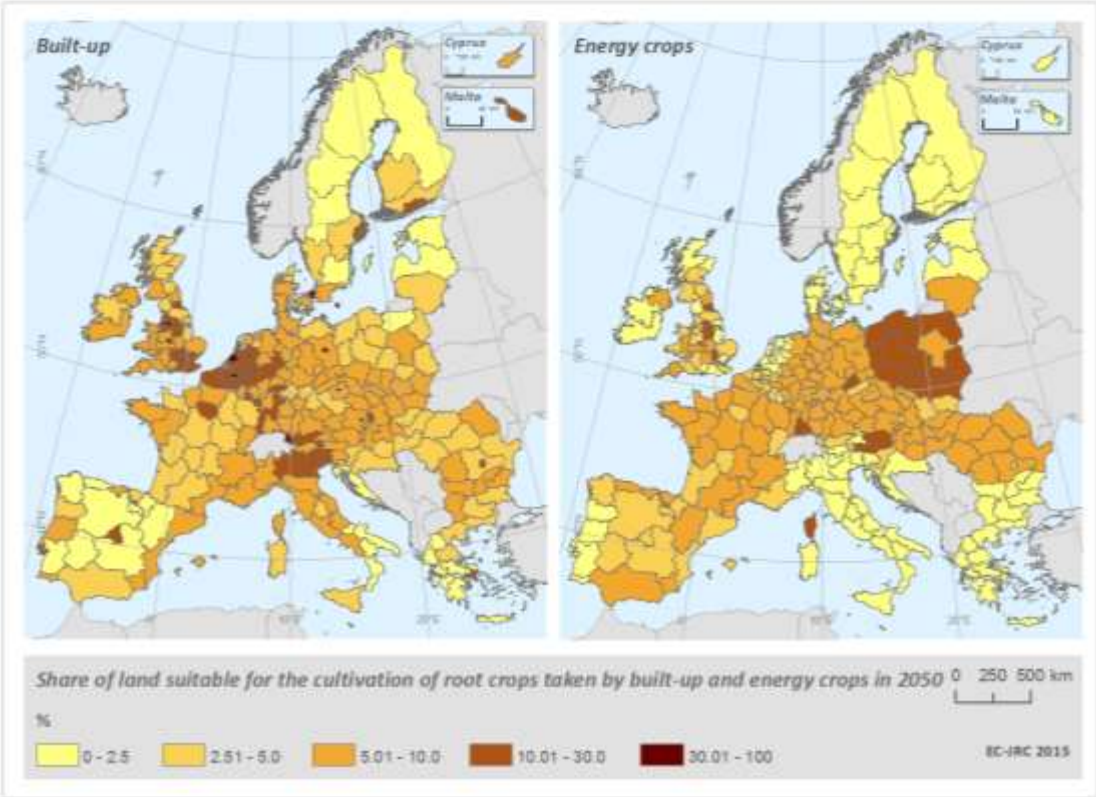

Figure 9. Share of land suitable for the allocation of root crops, that is used for built-up (left-hand side map) and energy crops (right-hand side map) in the year 2050.

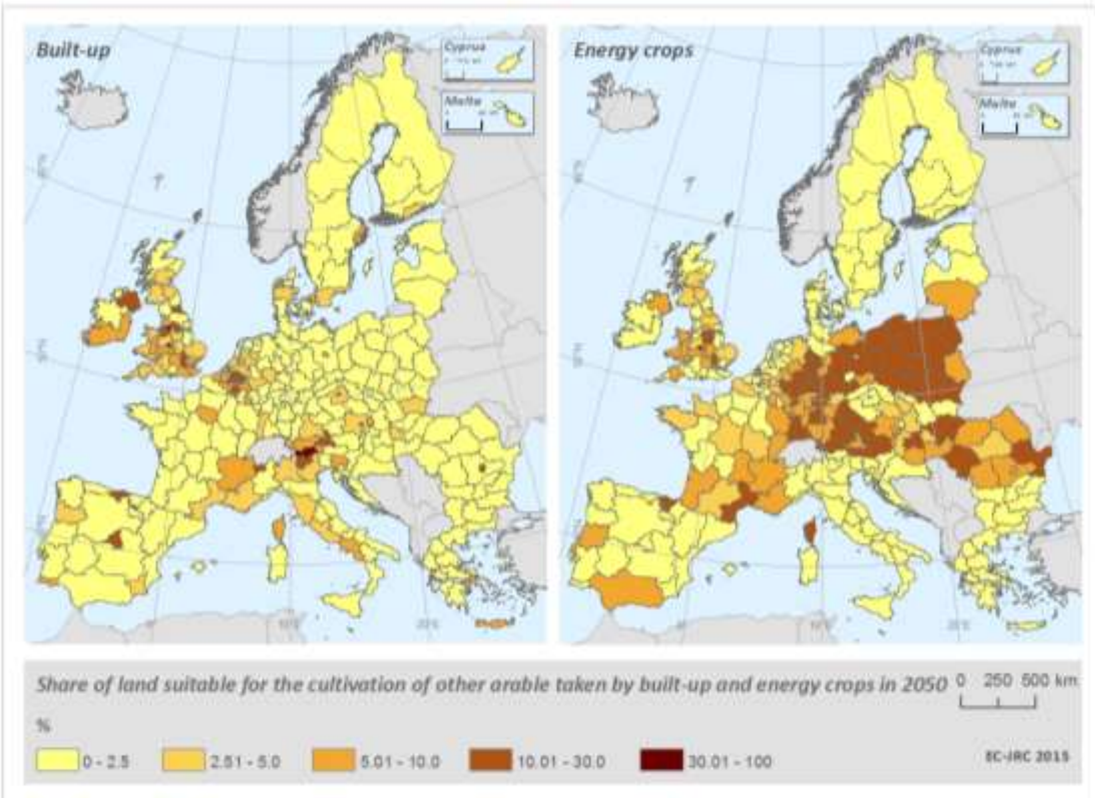

Figure 10. Share of land suitable for the allocation of other arable, that is used for built-up (left-hand side map) and energy crops (right-hand side map) in the year 2050.

In particular, the impact of ENCR expansion on the EU agricultural landscape can be detected not only in regions where the demand for ENCR is the highest, such as in Poland, but also in NUTS2 where their demand is relatively low or moderate (e.g. the United Kingdom)[9].

The potentially most critical situation regards regions where the competition for both artificial uses (residential and ICS) and ENCR is high (e.g. south Poland): in these cases, the probability that food and feed crops are forced to be allocated on less suitable land, increases. In the remainder of the report, Chapter 4 will further analyse these allocation patterns, for each crop group separately: cereals, maize, root crops and other arable.

[9] The demand for dedicated energy crops given in output by the CAPRI model and used in input by LUISA, is ultimately determined by the energy model PRIMES.

4. Allocation of food, feed and energy crops

This section juxtaposes levels of soil fertility in Europe with the projected changes in energy crops (ENCR) and agricultural land used for the production of food and feed. The aim of this analysis is to assess the potential impact (pressure) on cultivation patterns and landscapes in Europe, as of a reference scenario whereby legally binding energy-related targets are assumed to be met.

Across Europe, soils greatly differ from place to place, especially with respect to the type of soil, its origin, depth and organic content. Organic content differs considerably across soils, ranging from high organic soils in the North, through productive loams, shallow mountains soils and more arid soils in the Mediterranean region. Each type of soil has its own set of mechanical and chemical characteristics. In addition, climate conditions strongly vary across Europe from North to South. The main limitations for crop growth in Europe are cold temperatures and short vegetation period (Northern regions), and limited water supply during the vegetation period (Southern and South-Eastern regions).

A spatially detailed analysis of the allocation of food/feed and ENCR can identify regions where the pressure induced by the economic and energy scenario at European and country level could generate intense competition between different land uses. This situation might lead to: highly fertile land being used for urban and industry expansion instead of food crops; and ENCR replacing food crops.

In the remainder of this chapter, Figure 11, Figure 12, Figure 14, Figure 15, Figure 17, Figure 18, Figure 20 and Figure 21 report the shares of cereals, maize, root crops and other arable land respectively, for the years 2020 and 2050, allocated on different levels of land suitability, at MS level. Countries are ordered based on the total acreage of the analysed crop allocated in the given year.

4.1. Cereals

In both 2020 and 2050 (Figure 11 and Figure 12), the majority of cereals in Europe are allocated on land classified as highly suitable for their production. With the exception of Bulgaria, Denmark, Croatia, Hungary, Malta, Portugal and Sweden, all the other MSs experience a decrease in the amount of land allocated to cereals. Two patterns can be described. In Estonia, the United Kingdom, Slovakia and Slovenia more cereals are grown on land of high suitability. This means that the first farmland to be withdrawn from production is located on the less suitable land. In Germany and Austria the proportion of these crops allocated on lower quality land increases. This might be explained considering the competition for land with other uses, such as forest and built-up (Lopes Barbosa et al., 2015).

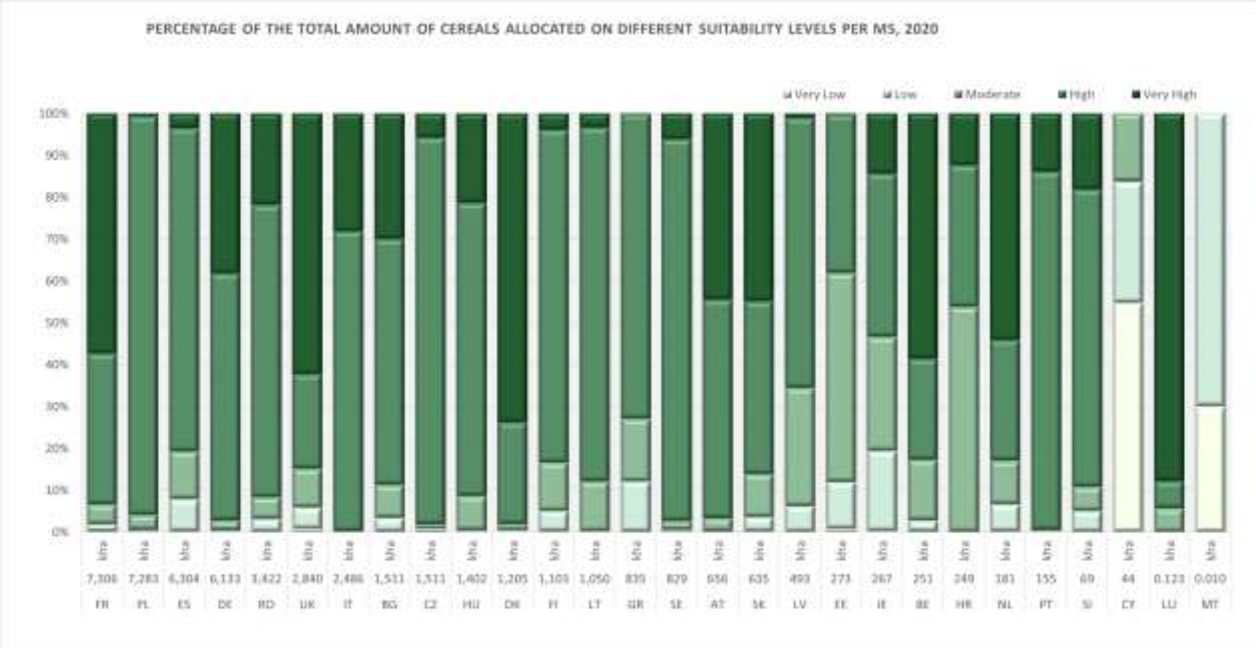

Figure 11. Percentage of the total amount (kha) of cereals allocated per suitability level in 2020 for the EU28 countries.

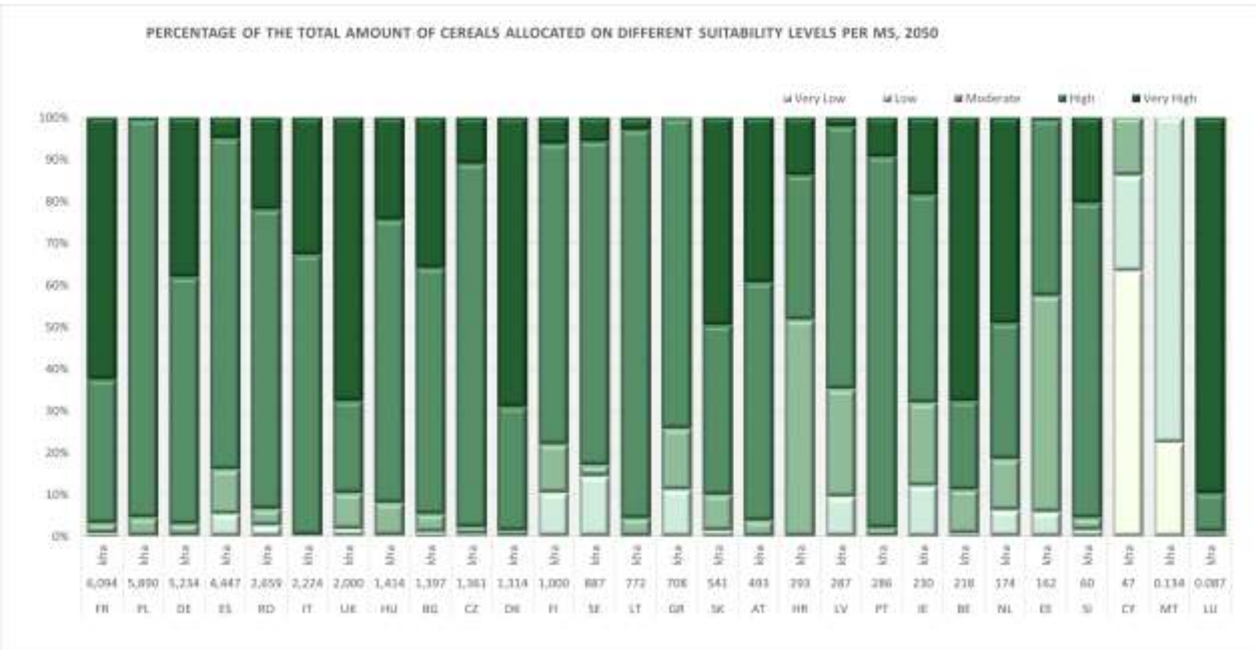

Figure 12. Percentage of the total amount (kha) of cereals allocated per suitability level in 2050 for the EU28 countries.

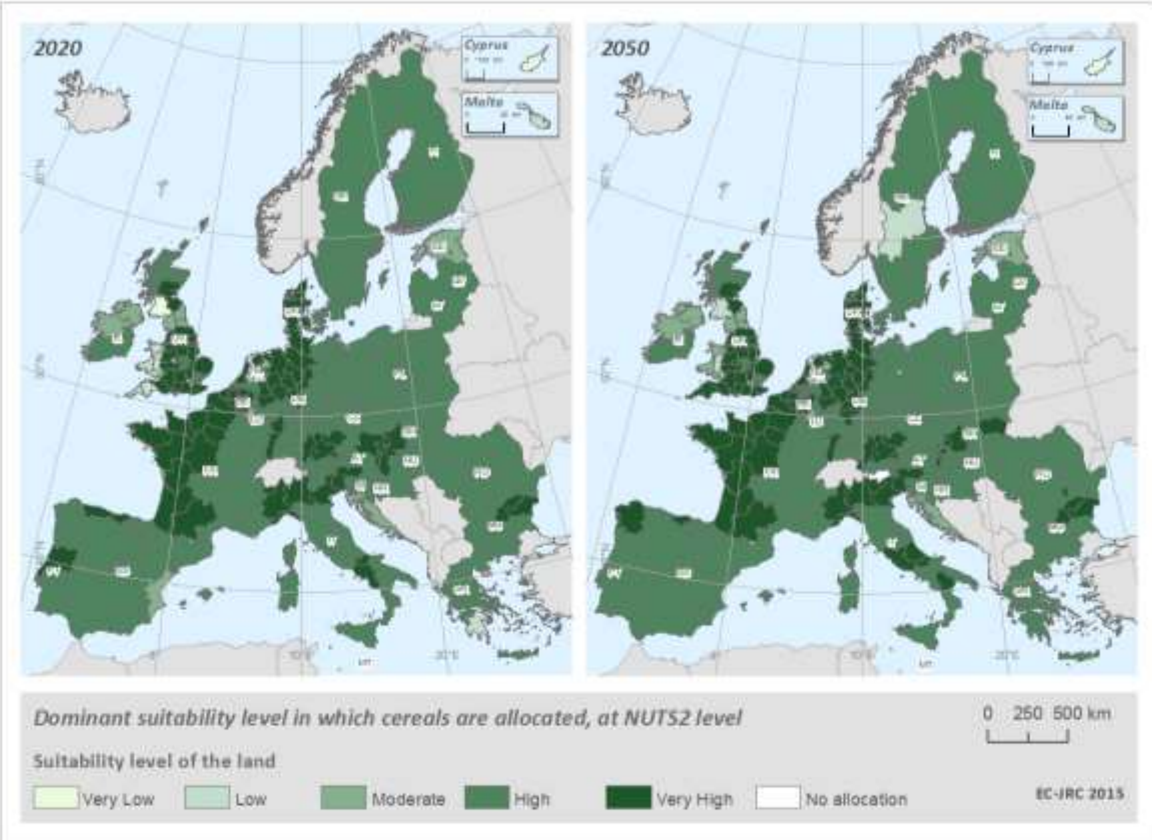

Figure 13. Suitability level of the land on which the majority of the cereals are allocated at NUTS 2 level in the EU28.

The dominant land suitability level on which cereals are allocated changes between the years 2020 and 2050 in few regions (Figure 13). Cereals are allocated on lower quality land in central Portugal, nord-west Spain, Campania region (Italy), northern Hungary and a few regions between Austria and Slovakia. On the other hand, in other NUTS2 regions cereals are predominately allocated on better quality land in Valencian region, north-east Italy, west and south-west Great Britain.

4.2. Maize

In both the years 2020 and 2050, maize is predominantly allocated on land that is highly suitable for this kind of crop (see Figure 14 and Figure 15).

From 2020 to 2050, the overall quantity of maize allocated decreases in the majority of the MSs, with the exception of Germany, Denmark, Portugal, Sweden and Luxemburg. In the countries where maize surface is increasing, the share of these crops allocated on very suitable land tends to increase; the only exception is Sweden, where the share land allocated to maize allocated on highly suitable land decreases in favour of land classified as moderately suitable.

In countries where the overall surfaces of maize decreases, the share allocated on highly suitable land tends to increase, with the exception of Croatia and Latvia. In Poland

and Romania, the share of land allocated to maize on medium or high/very highly suitable land tends to change between 2020 and 2050, but without showing a clear pattern.

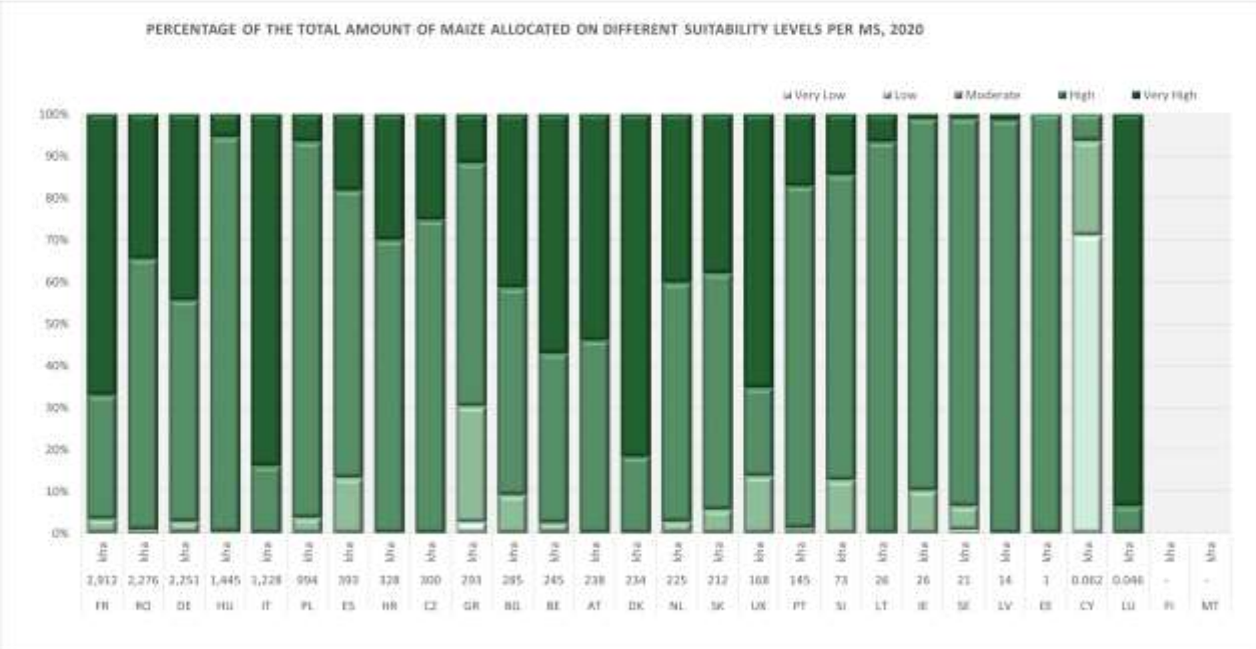

Figure 14. Percentage of the total amount (kha) of maize allocated per suitability level in 2020 for the EU28 countries.

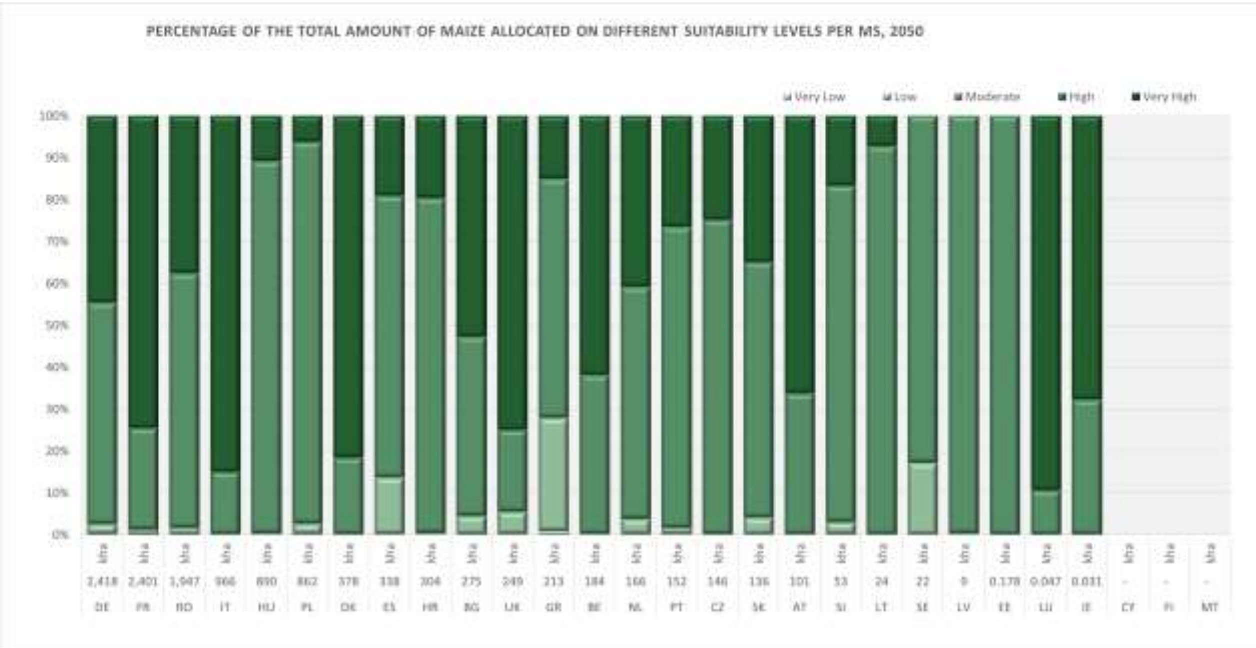

Figure 15. Percentage of the total amount (kha) of maize allocated per suitability level in 2050 for the EU28 countries.

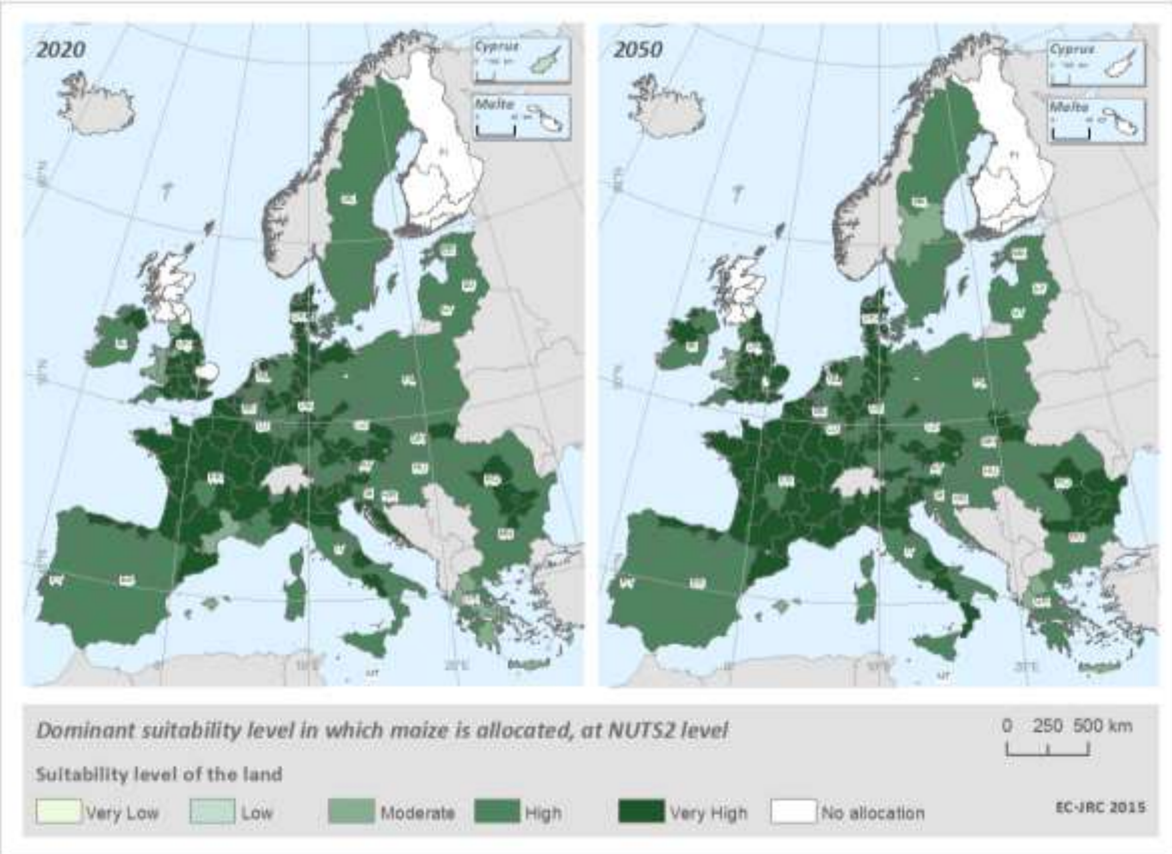

Figure 16. Suitability level of the land on which the majority of maize is allocated at NUTS2 level in the EU28.

Figure 16 displays the suitability level on which maize is predominantly allocated at regional level. In the majority of NUTS2 regions throughout Europe, maize is allocated on highly suitable land. Regions where maize is allocated on the best quality land are in France, the United Kingdom (Central and Southern regions), Italy (North), Denmark, Germany, Austria and Romania.

From 2020 to 2050 the dominant suitability level on which maize is allocated decreases in quality in just a few regions, such as Northern Ireland, Trentino-Alto Adige (Italy) and Norra Mellansverige (Sweden).

4.3. Root crops

In both 2020 and 2050 (Figure 17 and Figure 18), root crops are predominantly allocated on good quality land. Countries where a substantial share of root crops are allocated on moderately suitable land are: Spain, Greece, Poland, Austria, Estonia and the United Kingdom. These crops are allocated on particularly poor quality land in Malta and Cyprus, where their overall acreage is nevertheless very limited.

The majority of the MSs (18 out of 28) have less land allocated to root crops in 2050 than in 2020. Among these, Austria, Denmark, the United Kingdom and, to a lesser extent, Italy, experience an increase in the share of root crops allocated on highly suitable land. On the other hand, in Cyprus, Latvia and Sweden, root crop surfaces decrease from 2020 to 2050, and the share allocated on low quality land increases.

In countries where there is an increase of root crops surfaces (Estonia, Malta and Portugal) this increase occurs on poorly suitable land. A similar but less pronounced patterns can be detected in Ireland.

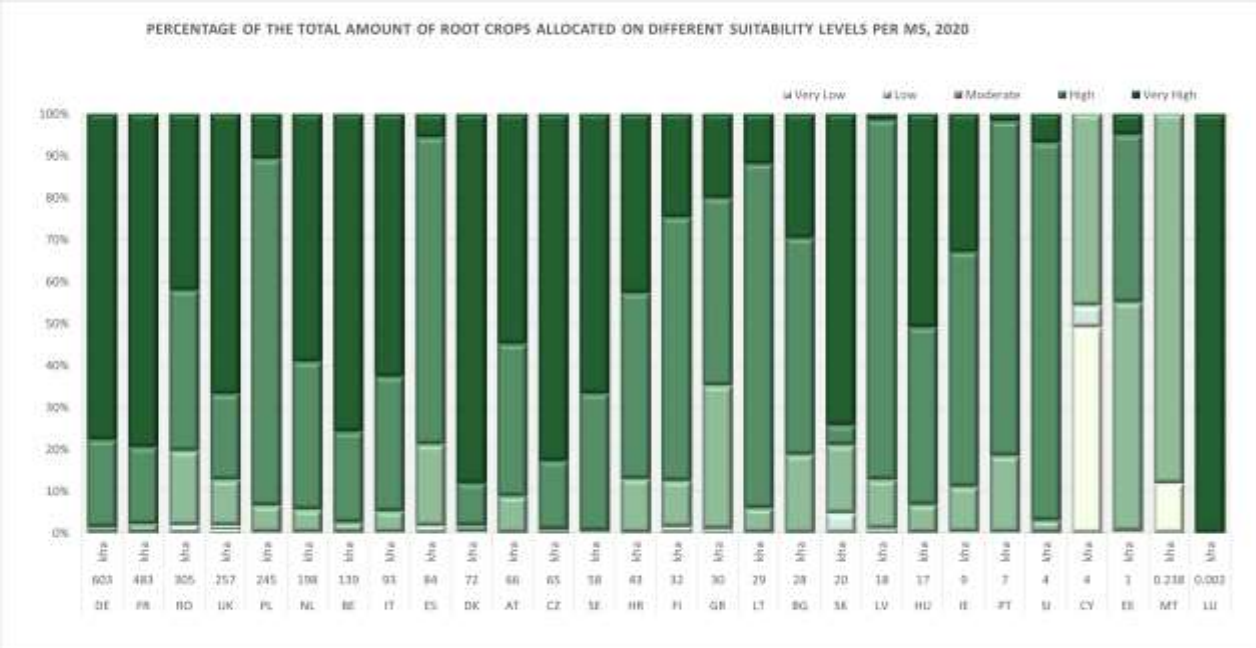

Figure 17. Percentage of the total amount (kha) of root crops allocated per suitability level in 2020 for the EU28 countries.

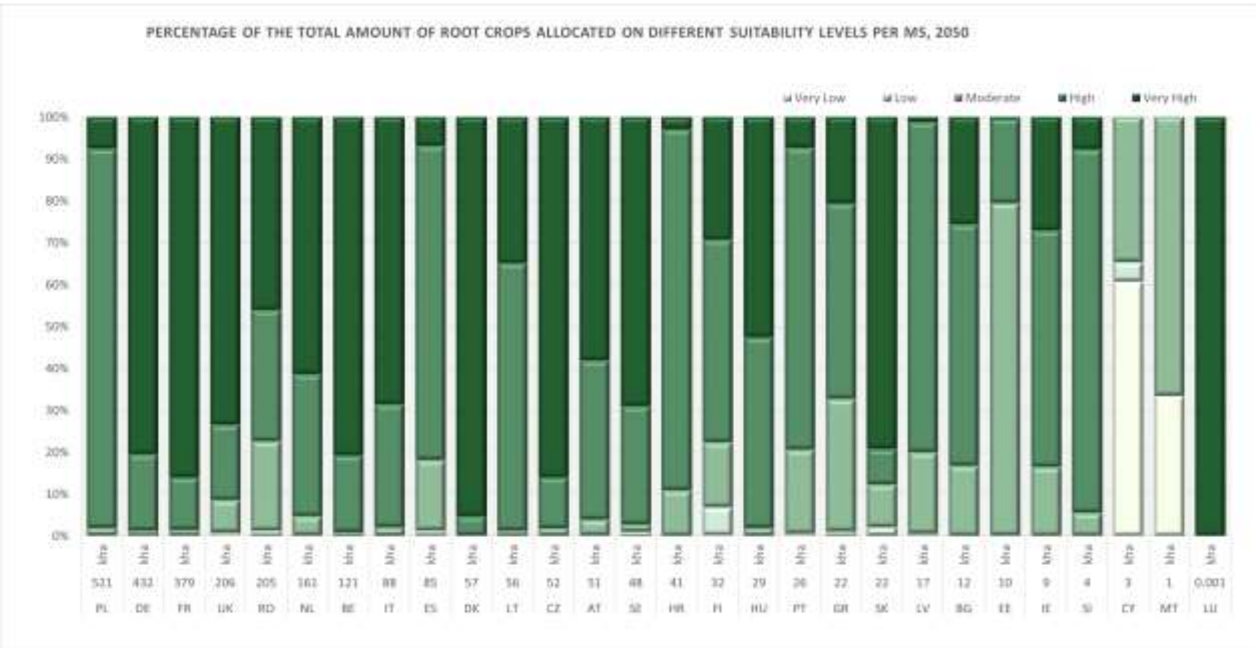

Figure 18. Percentage of the total amount (kha) of root crops allocated per suitability level in 2050 for the EU28 countries.

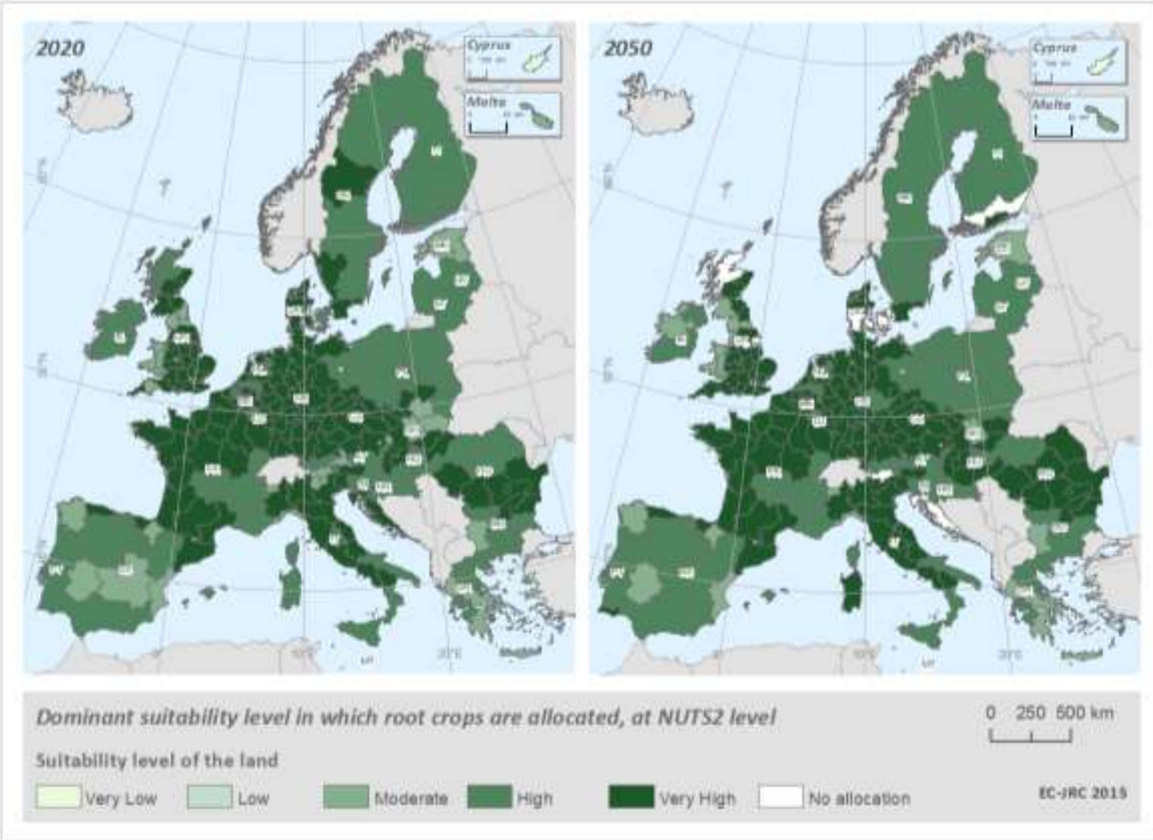

Figure 19. Suitability level of the land on which the majority of root crops are allocated at NUTS 2 level in the EU28.

Figure 18 highlights the allocation of root crops at regional level. The NUTS2 regions performing the worst are located in Eastern England, the Baltics, the Iberian Peninsula and Greece. In 2050, the regions where the majority of the root crops are allocated on land of lower quality than in 2020, are: Ireland (North), Northern Ireland, North West England, Yorkshire, Middle Norrland and South Sweden and the Southern regions of Poland.

4.4. Other arable land

Across Europe, crops belonging to the other arable class are predominantly allocated on land classified as having moderate or low suitability for these cultivations. Figure 20 and Figure 21 display this pattern for both the years 2020 and 2050 respectively. From 2020 to 2050, the majority of European countries experience an increase in land cultivated for other arable crops. This increase is greater than 5% in Austria, Estonia, Spain, Finland, France, Greece, Hungary, Latvia, Malta, the Netherlands, Romania and Sweden.

The general tendency is rather constant across Member States, though some areas shift these crops from very low and low suitability to moderately suitable land.

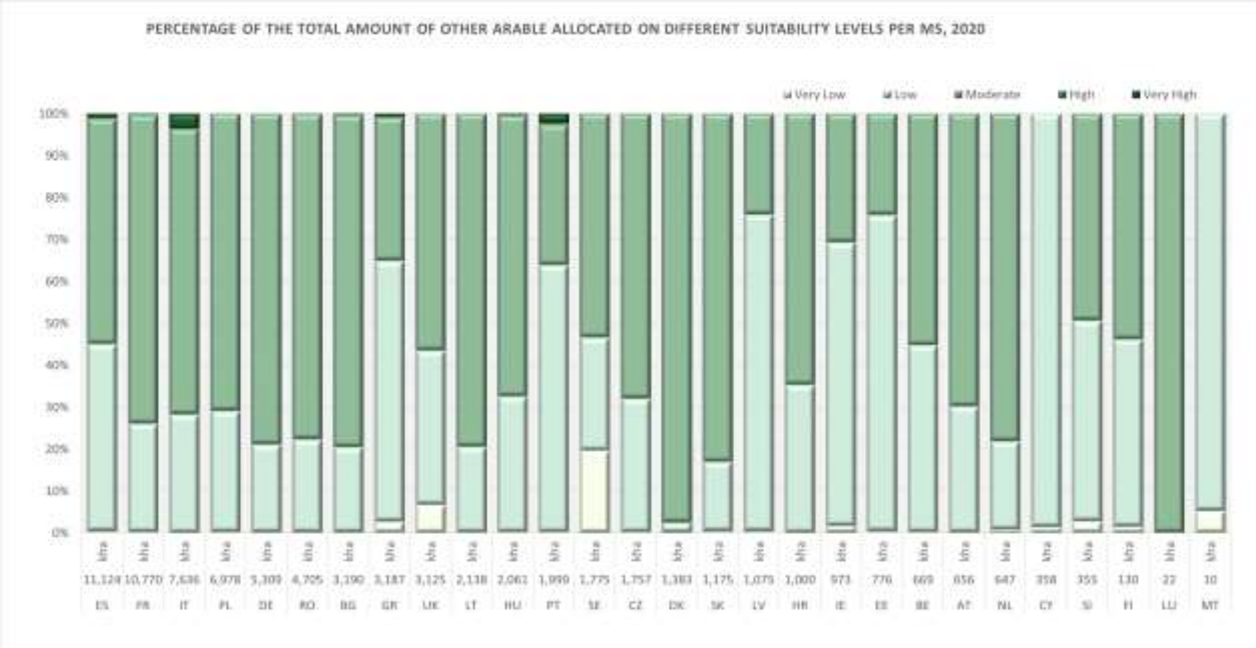

Figure 20. Percentage of the total amount (kha) of other arable land allocated per suitability level in 2020 for the EU28 countries.

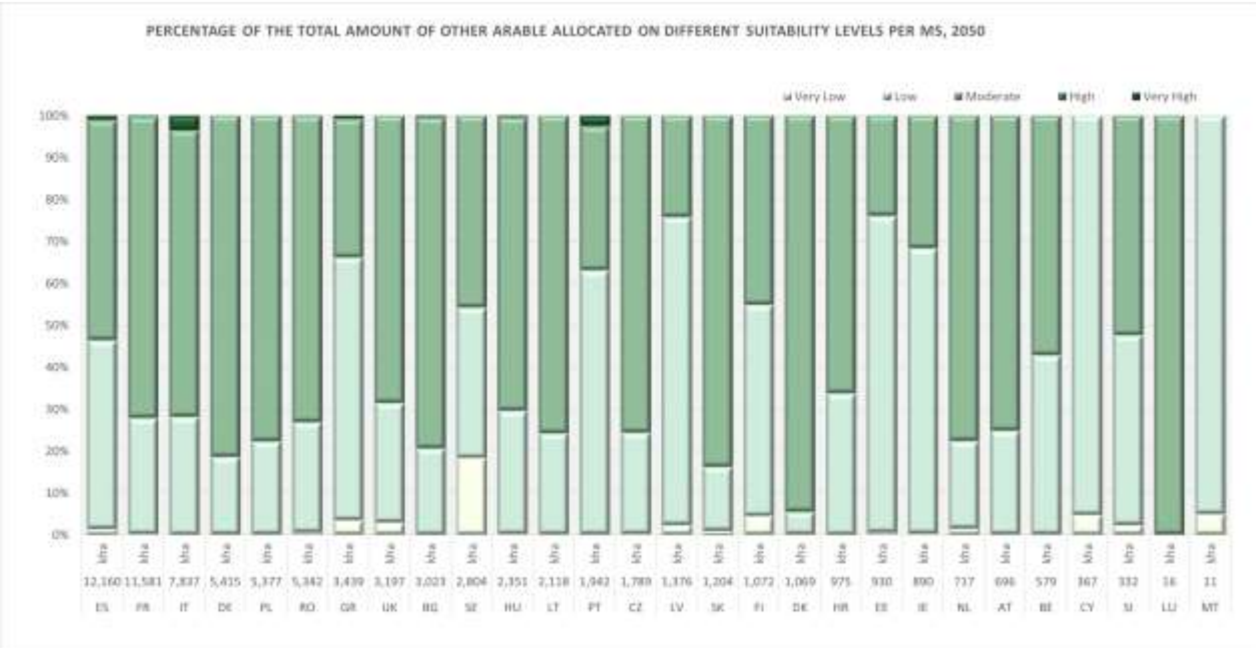

Figure 21. Percentage of the total amount (kha) of other arable land allocated per suitability level in 2050 for the EU28 countries.

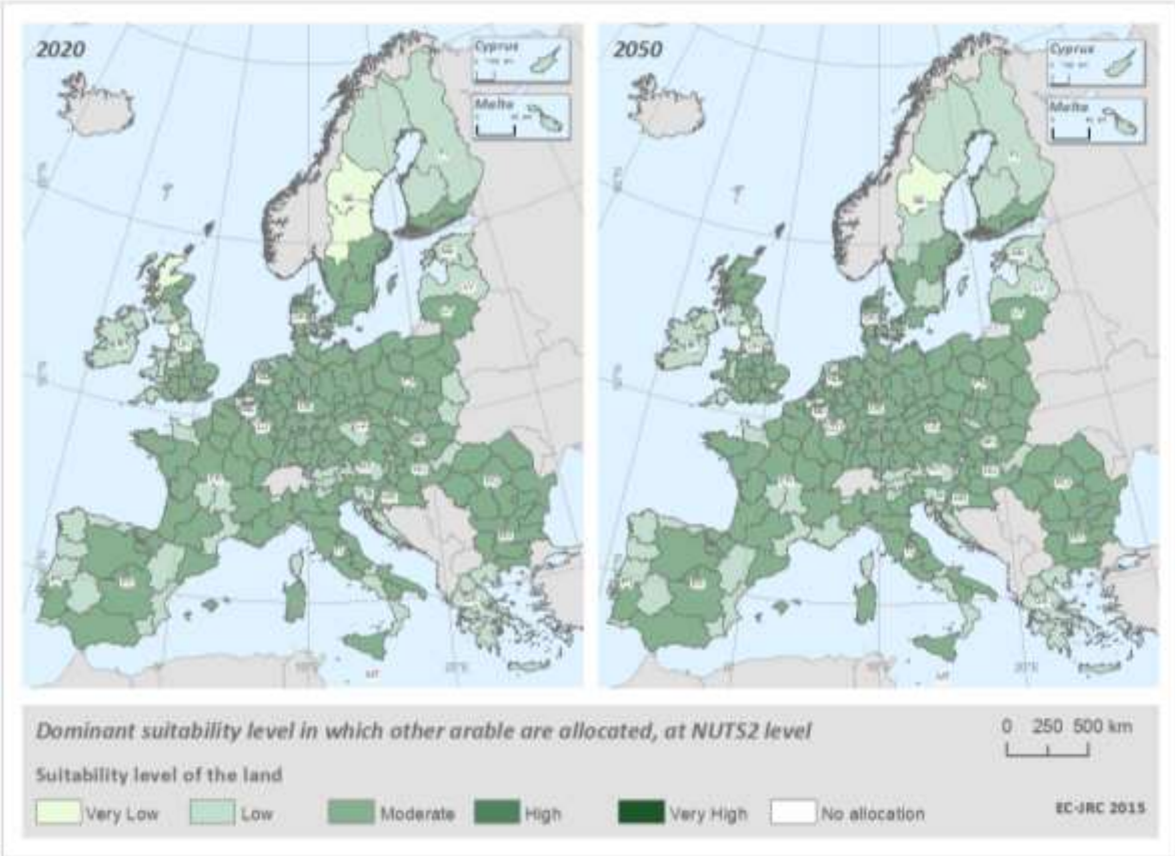

Figure 22. Suitability level of the land on which the majority of the other arable crops are allocated at NUTS 2 level in the EU28.

Figure 22 shows the regional distribution of other arable crops, highlighting the dominant suitability level where they are allocated on. Between the years 2020 and 2050 the only NUTS2 regions where the dominant suitability level worsens are Provence-Alpes-Côte d'Azur (France), southwest Czech Republic and Småland and the islands in Sweden.

4.5. Energy crops (ENCR)

As was reported in Lopes Barbosa et al. (2015), 17% of land use changes between 2010 and 2050 are due to the expansion of ENCR in the EU28. This number reaches 30% in some countries such as France, Poland, Romania and Slovakia.

Figure 23 and Figure 24 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 and 2050.

In 2020, France (1,346 kha), Germany (1,316 kha) and Poland (900 kha) have the highest surfaces dedicated to energy crop production. Most of the remaining countries contribute significantly less to the total energy production from these crops in Europe, ranging from 241 kha (Italy) to 6 kha (Slovenia). In particular, the modelling results show 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, all smaller producers, the dominant soils where ENCR are cultivated are the least suitable.

In 2050, the European trend substantially changed for some MSs. Poland, Spain and Romania, undergo a considerable expansion of energy crop and become part of the main producers along with France and Germany. On the contrary, ENCR disappear altogether in Italy. The suitability levels of the land are widely spread without any clear pattern, however it is possible to identify the expansion of ENCR on soils with low fertility in the Nordic countries, eastern European countries and central-eastern part of Europe.

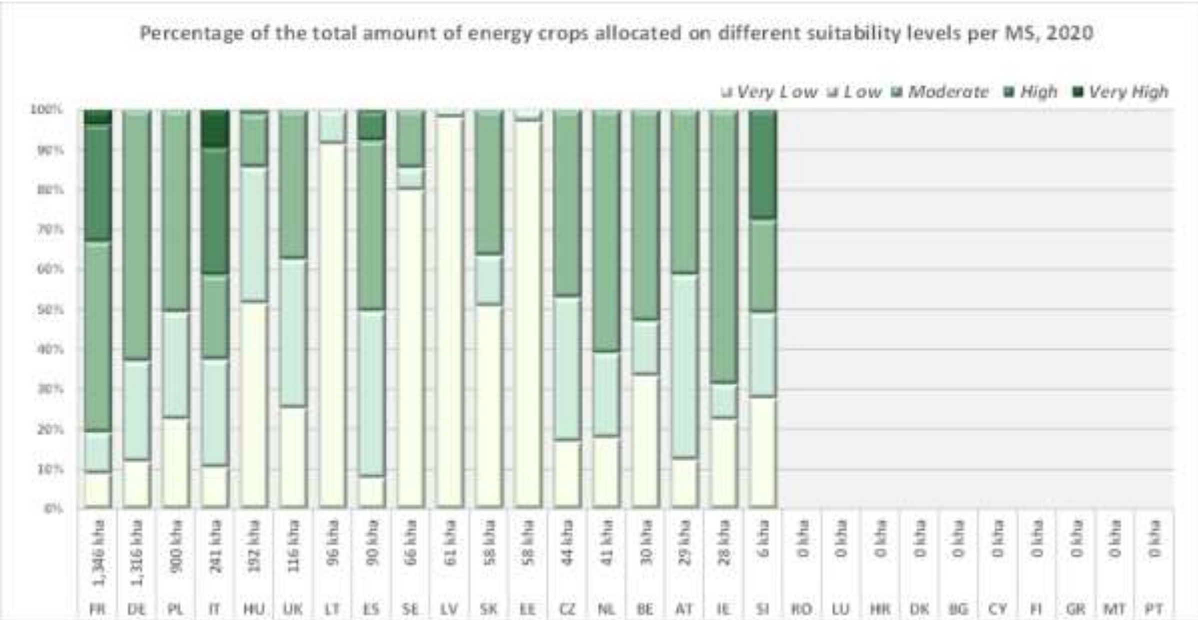

Figure 23. Percentage of the total amount (kha) of ENCR allocated per suitability level in 2020 for the EU28 countries.

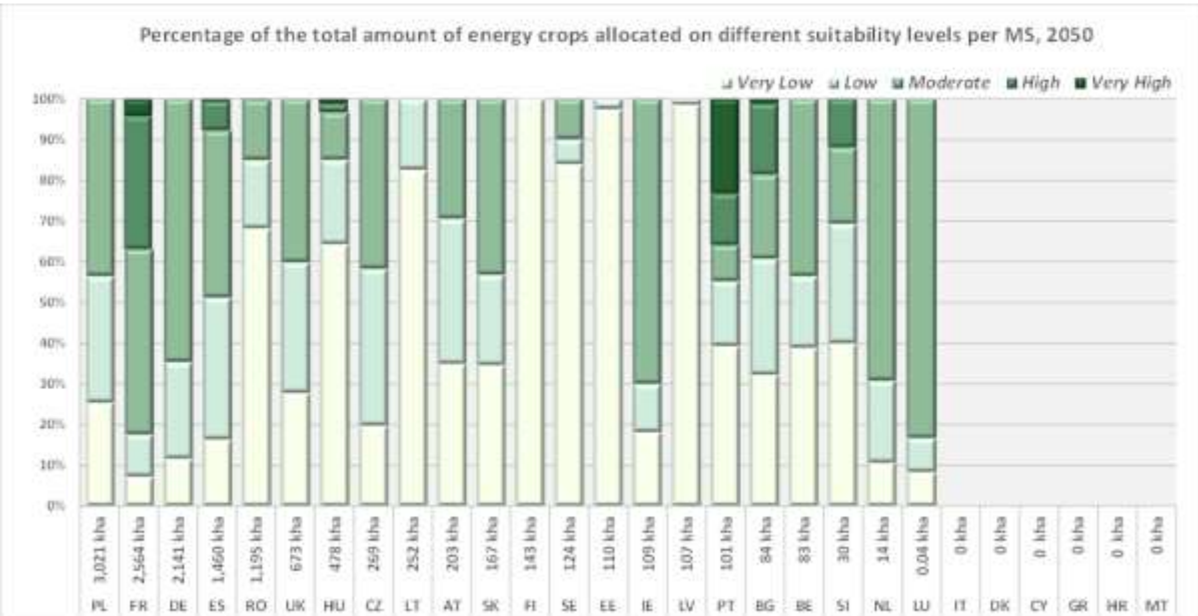

Figure 24. Percentage of the total amount (kha) of ENCR allocated per suitability level in 2050 for the EU28 countries.

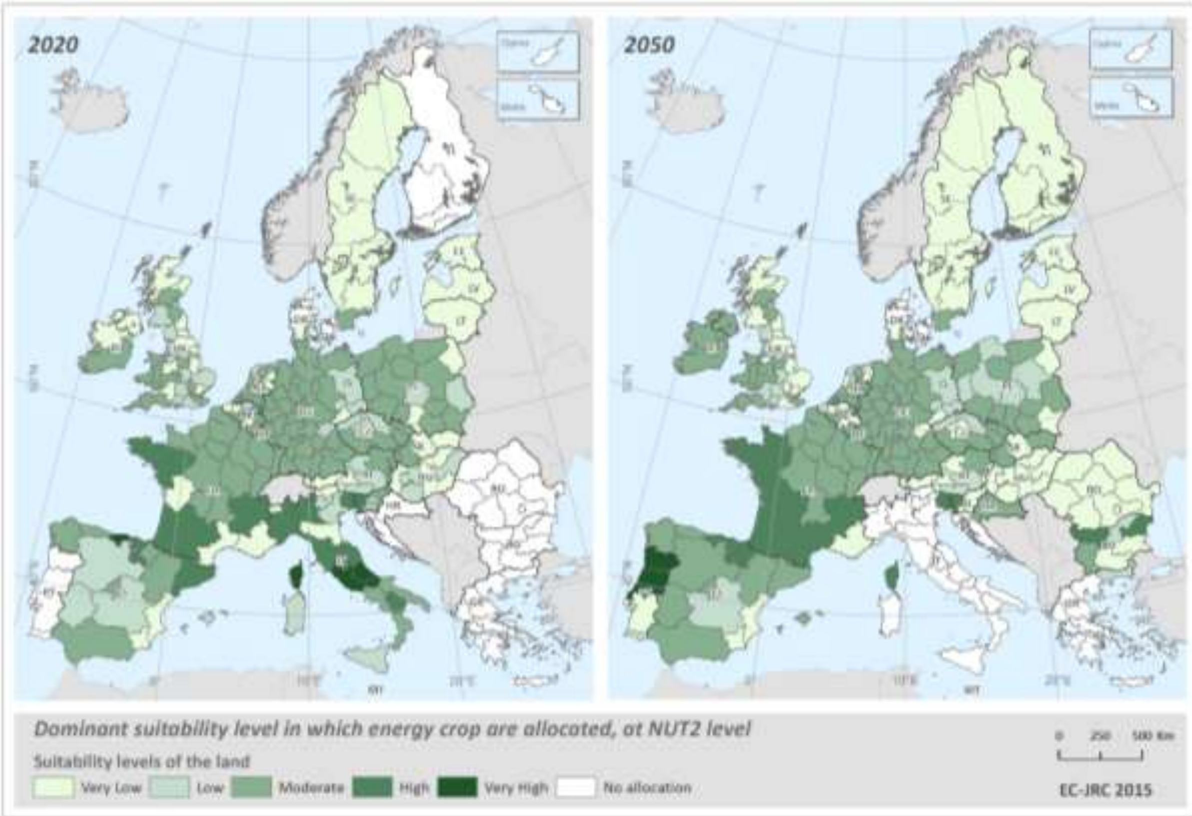

Figure 25. Suitability level of the land on which the majority of ENCR are allocated at NUTS 2 level in the EU28.

The distribution of the allocated energy crop on the dominant suitability levels of the land at NUTS2 level is given in Figure 25. 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.

5. Loss of land suitable for agriculture due to the expansion of built-up areas

The expansion of artificial areas, for residential and production uses (i.e. industry/commerce/services uses, ICS uses from here onwards), is one of the possible causes of loss of fertile and good quality land. The aim of this chapter is to illustrate how the expansion of land used for residential and industry/commerce/services uses unfolds in Europe under the Reference Scenario 2013 (updated configuration 2014 in LUISA). In this exercise, we focus on the suitability characteristics of the land that is converted to artificial uses.

In Figure 32, Figure 26, Figure 28 and Figure 30 the percentage of land suitable for the cultivation of crops, from moderate to very high suitability level, that is used for the allocation of urban or ICS uses, is reported at country level. Suitable land for cereals, maize, root crops and other arable, is analysed, respectively. In the graphs, countries are ordered based on the total availability of land suitable for the considered crop group (moderate, high and very high suitability levels).

Each crop group is thus analysed separately. However, it is worth reiterating that, as highlighted in Chapter 3, land suitable for a crop can be similarly suitable for other crops as well. This implies that the shares displayed in the graphs can partially account for the same land that is suitable for more than a crop simultaneously.

Figure 34 and Figure 35 indicate the shares of suitability levels on which ENCR are allocated, at European level, in the years 2020 and 2050 respectively.

5.1. Cereals

As reported in Figure 26, the national average share of land suitable for the cultivation of cereals taken by built-up area (from medium to very high suitability levels), is 3.9% in 2020 and 5% in 2050. Among the MSs with less than the European average availability of land suitable for cereals (6,797 kha), the ones with more than 5% of urban and ICS land allocated on these categories of land are Germany, Italy and the United Kingdom. Among the rest of the countries, Denmark, Slovakia, Austria, Belgium, the Netherlands and Luxemburg are the ones with the highest shares, in both 2020 and 2050. Particularly high in 2050 are the shares in Belgium (almost 18%), Luxemburg (almost 12%) and the Netherlands (more than 9%).

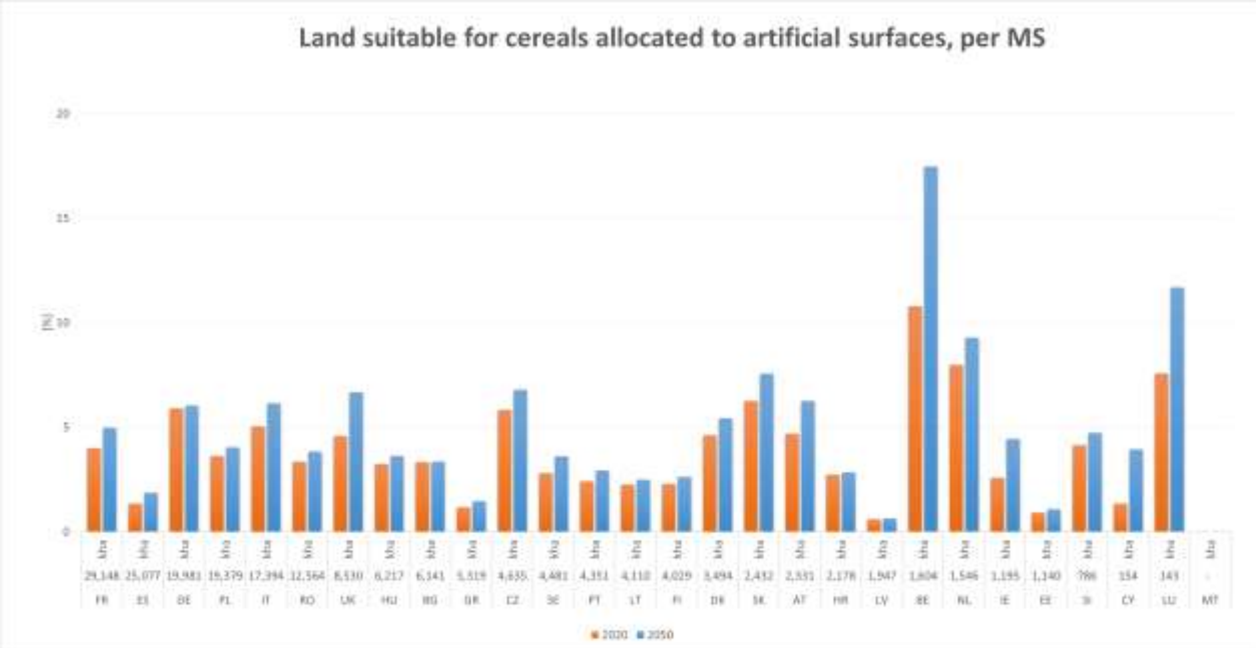

Figure 26. Share of land suitable for the cultivation of cereals that is taken by urban and industrial areas in the EU28.

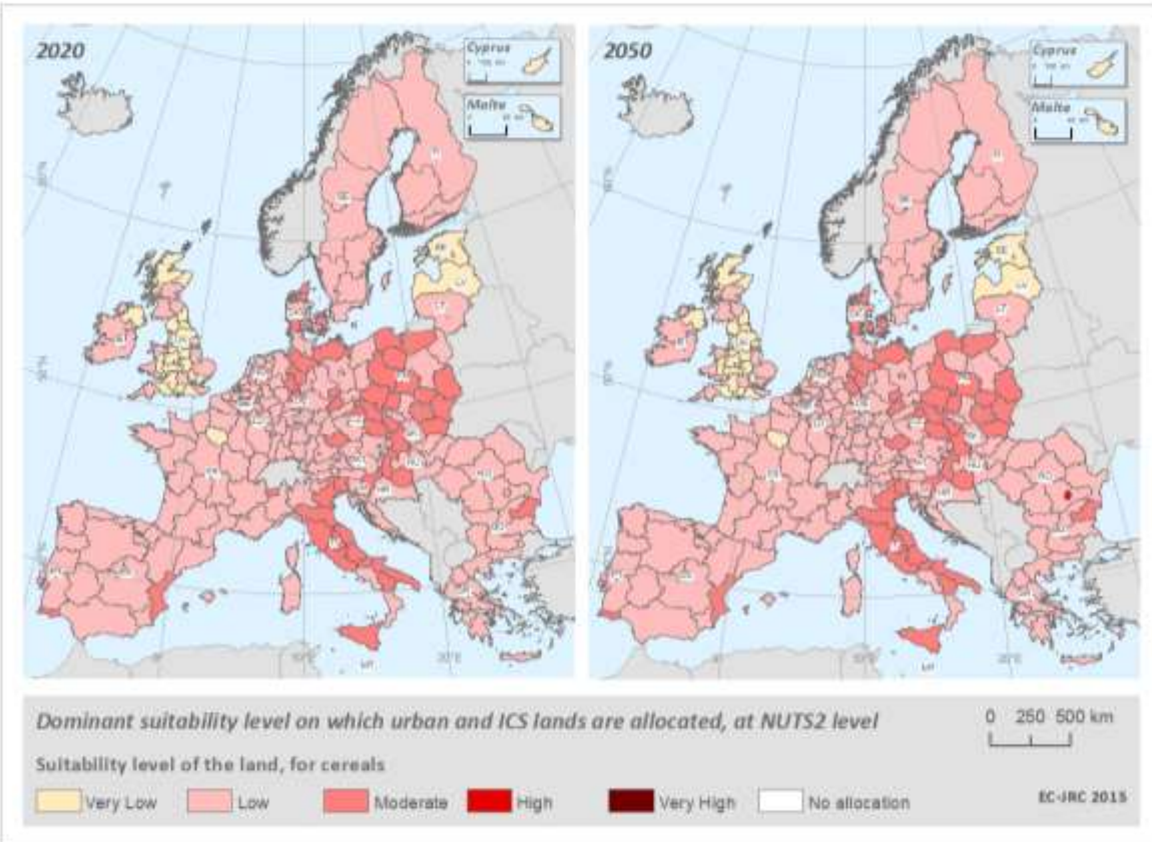

Figure 27. Suitability level (for cereals) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28.

The regional patterns reported in Figure 27 highlight that urban and ICS are predominantly allocated on land of moderate suitability level for cereals in regions of Italy, Hungary, Czech Republic, Slovakia, Poland, Germany and Denmark. Built-up is predominantly allocated on very low quality land for cereals in the majority of NUTS2 in the United Kingdom, Estonia and Latvia.

As in the case of other arable, the regional patterns remain rather stable from 2020 to 2050.

5.2. Maize

The average percentage of this land suitable for maize that is allocated for urban or ICS use is higher than in that for cereals (Figure 28). The average for all MSs is 5.66% in 2020 and 6.78% in 2050. If we consider just the countries with more than the European average availability of suitable land for maize (12,098 kha), the share decreases to 4.17 % in 2020 and 4.25% in 2050. In the case of the countries below the European average availability of suitable land for maize, the percentages rise to 6.15% (2020) and 7.53% (2050).

Among all the considered food and feed crop groups, maize is the one affected the most by the expansion of urban and ICS land uses. As depicted in Figure 29, for 2020 and 2050, in almost all NUTS2 in the EU28, built-up is predominantly allocated on land classified as moderately suitable for maize. In a few regions, especially in north-central Italy, northern and western France, Czech Republic and Denmark, residential and ICS uses are allocated on land highly suitable for maize.

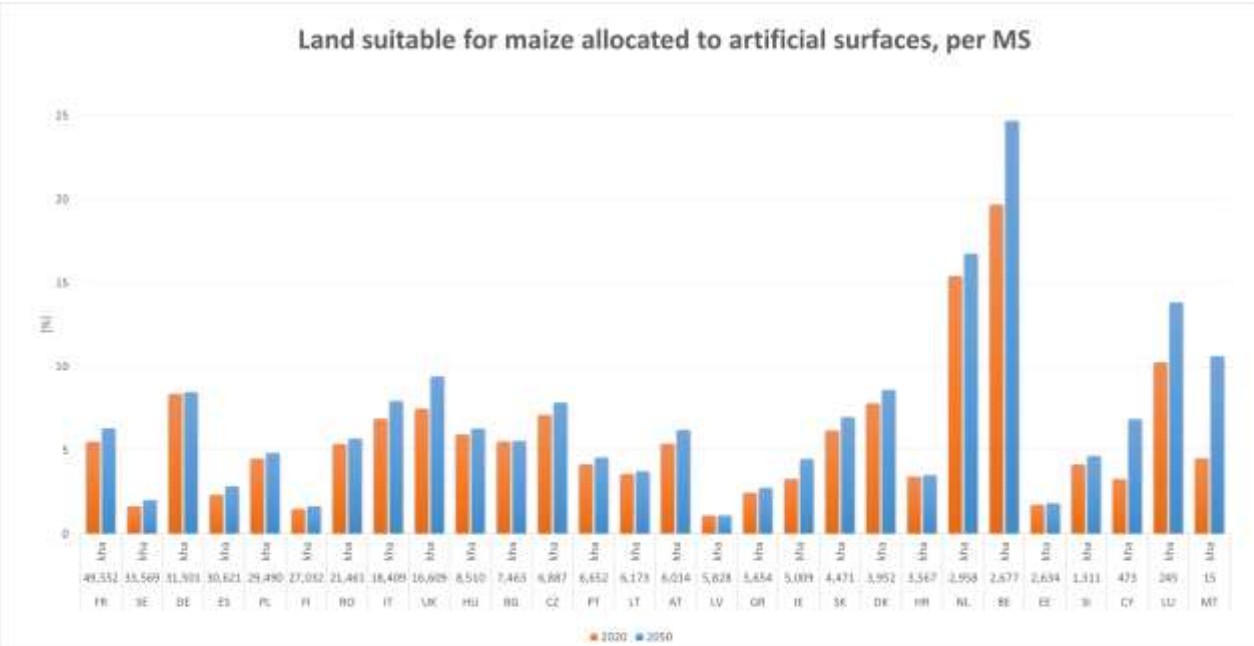

Figure 28. Share of land suitable for the cultivation of maize that is taken by urban and industrial areas in the EU28.

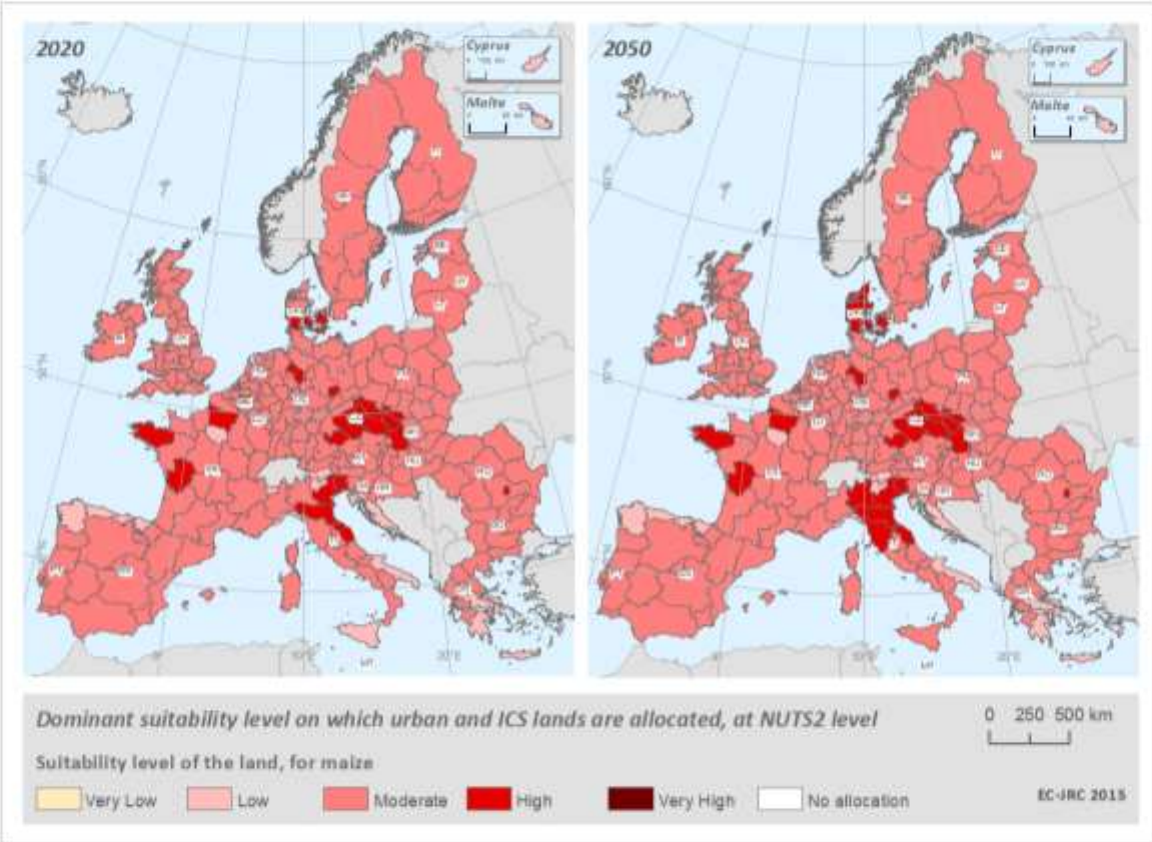

Figure 29. Suitability level (for maize) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28.

5.3. Root crops

The EU28 average percentage of medium or high quality land suitable for growing root crops, consumed by urban or ICS uses, is 5.19% in 2020 and 6.48% in 2050 (Figure 30).

The European average availability of good quality land suitable for root crops is 8,409 kha. Among the countries above this average value, France, Germany, Italy and the United Kingdom have the highest percentages (between 5 and 10 %). Among the rest of the MSs, especially high percentages can be found in the Netherlands (almost 15% in 2020 and 16% in 2050) and Belgium (almost 16% in 2020 and more than 22% in 2050).

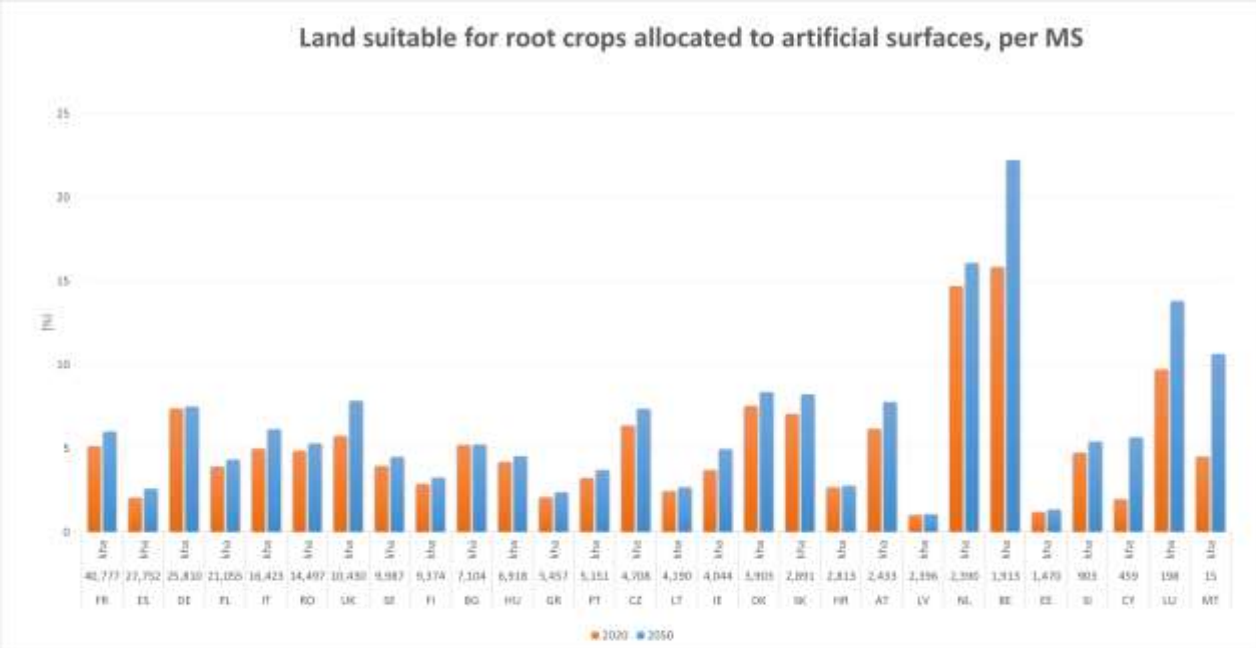

Figure 30. Share of land suitable for the cultivation of root crops that is taken by urban and industrial areas in the EU28.

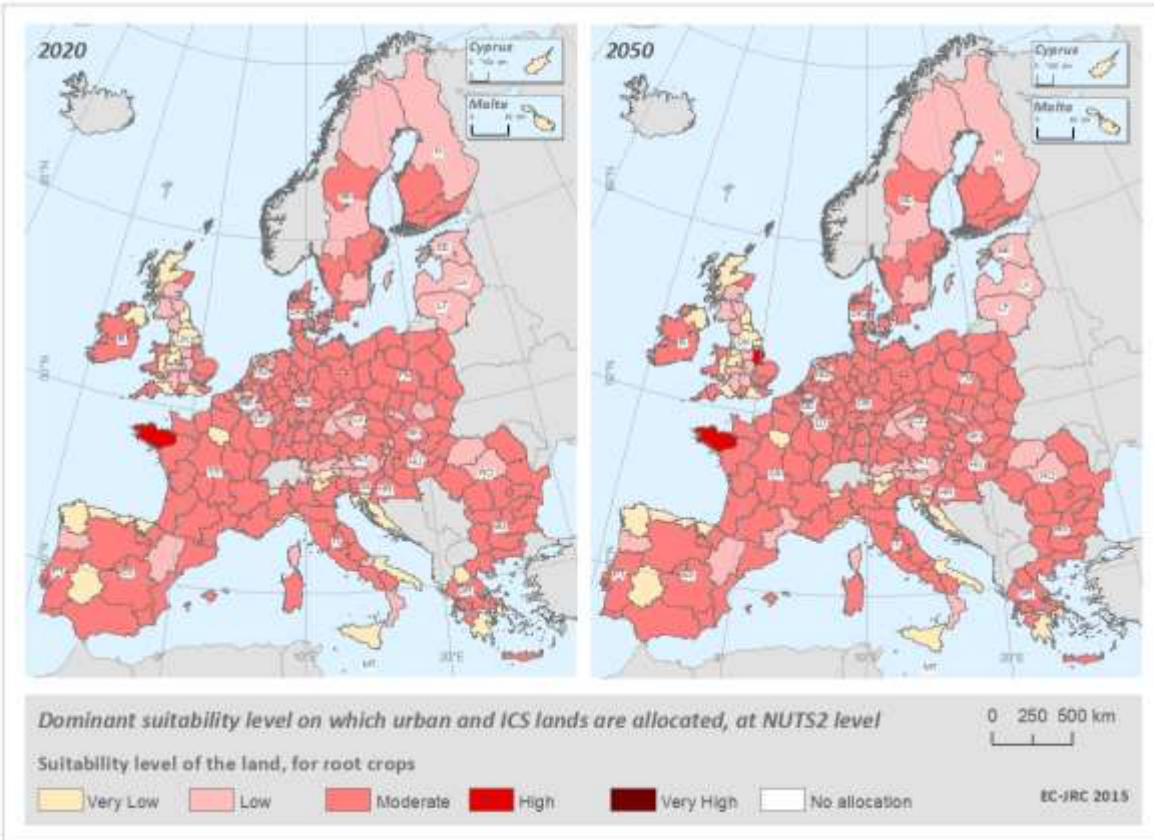

Figure 31. Suitability level (for root crops) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28.

Figure 31 reports the suitability level for root crops on which residential and ICS uses are predominantly allocated at NUTS2 level. In the vast majority of the regions, the dominant suitability class reported is moderate. Only in two regions in France and the United Kingdom is the dominant suitability level high. On the contrary, the expansion of urban and ICS land predominantly affects low or very low quality land in the majority of the United Kingdom, Sweden, Finland, the Baltic countries (Estonia, Latvia and Lithuania), two western regions in Romania, southern Croatia, northern Spain and southern Italy.

5.4. Other arable land

In Figure 32, the percentage of land suitable for the cultivation of other arable, from moderate to very high suitability level, that is used for the allocation of urban or ICS uses, is reported.

In all MSs, this percentage increases more than double in most of the countries from the year 2020 to 2050, with the exception of Germany, the United Kingdom, Bulgaria, Belgium, Estonia and Slovenia. Among the countries where the availability of land suitable for the cultivation of other arable is above the European average (3,353 kha), those with the highest shares are Italy and the United Kingdom, with more than 2% and 4% respectively of this land being used for built-up purposes in 2050. Among the countries with low availability of land suitable for other arable, Belgium, Ireland and Luxemburg are the ones with the highest shares of this category of land which is used for built-up: almost 10%, 4.4% and more than 8% respectively in 2050.

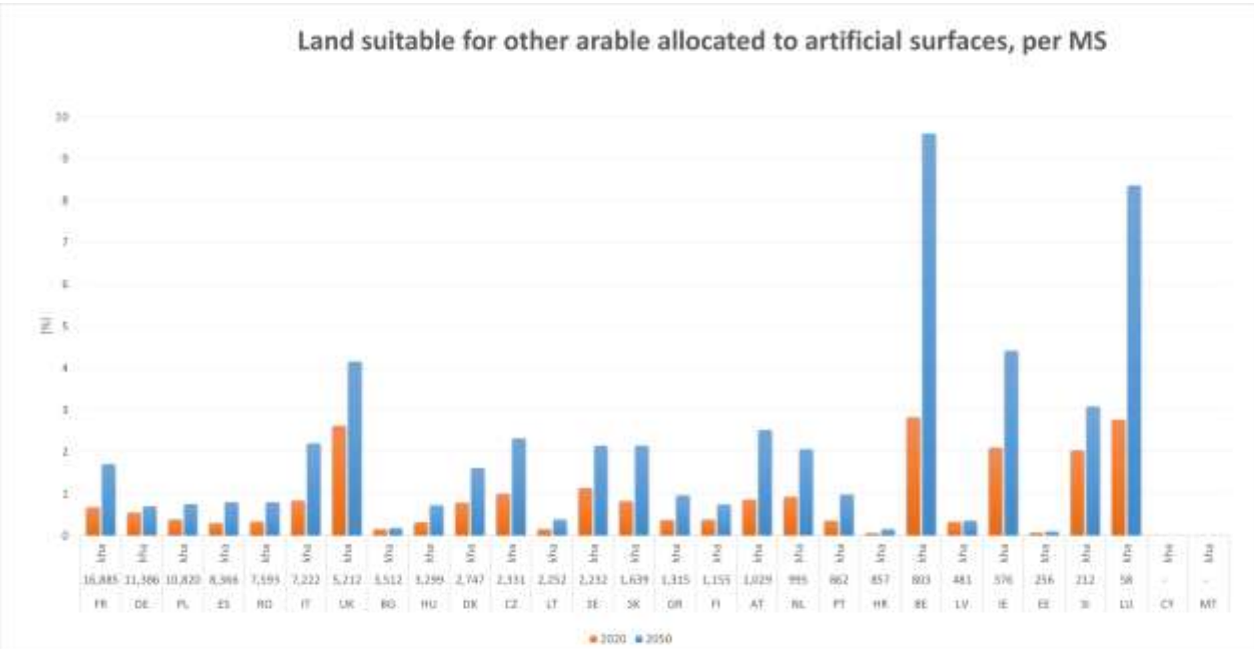

Figure 32. Share of land suitable for the cultivation of other arable that is taken by urban and industrial areas in the EU28.

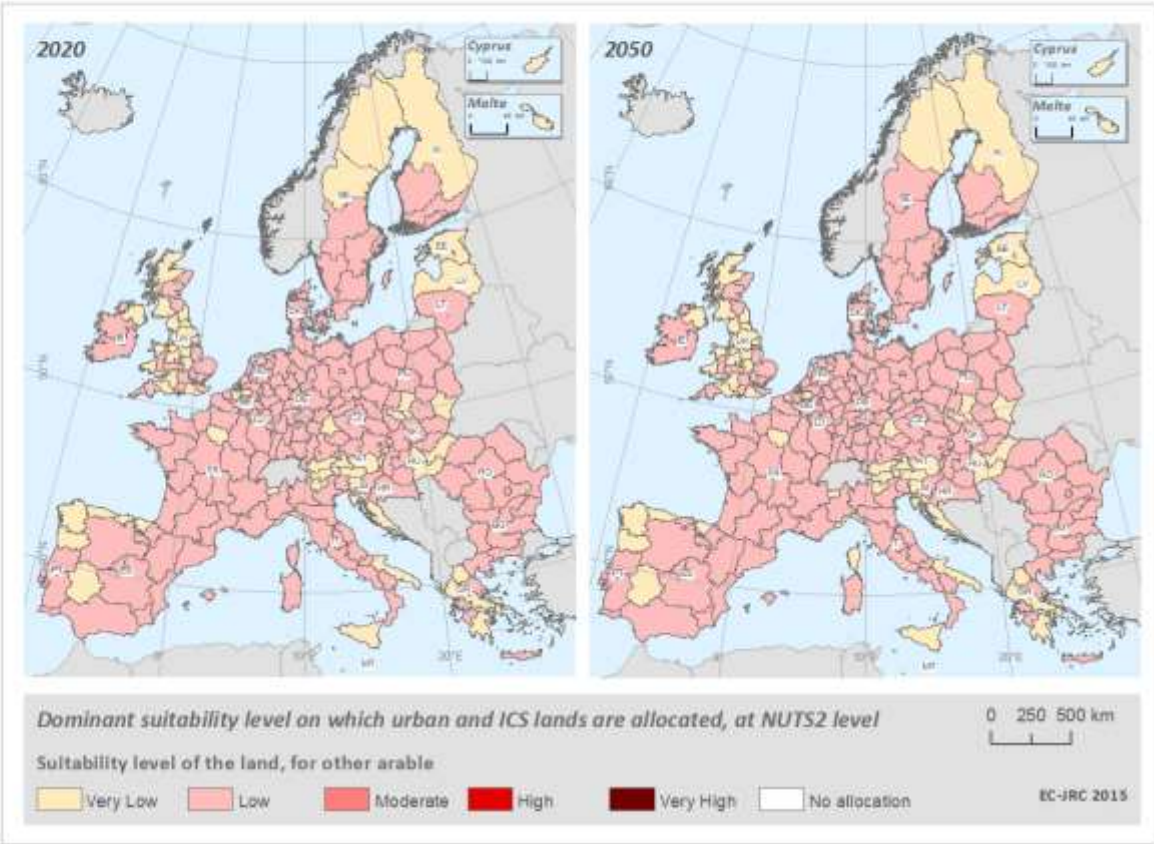

Figure 33. Suitability level (for other arable) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28.

Figure 33 reports the regional distribution of suitability category of land suitable for other arable taken by residential and ICS land in EU28. In the year 2020, all across Europe, urban and ICS land are allocated predominantly on land with low suitability for other arable. In particular built-up is predominantly allocated on land characterised by very low suitability levels for other arable in a few regions in northern Portugal and Spain, southern Italy, northern Sweden and Finland, throughout the United Kingdom and Greece, and in Estonia and Latvia. From 2020 to 2050 these patterns remain rather stable.

5.5. Energy crops (ENCR)

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 build-up areas with respect to the total country extent: 5.6% and 5.5% respectively. 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.

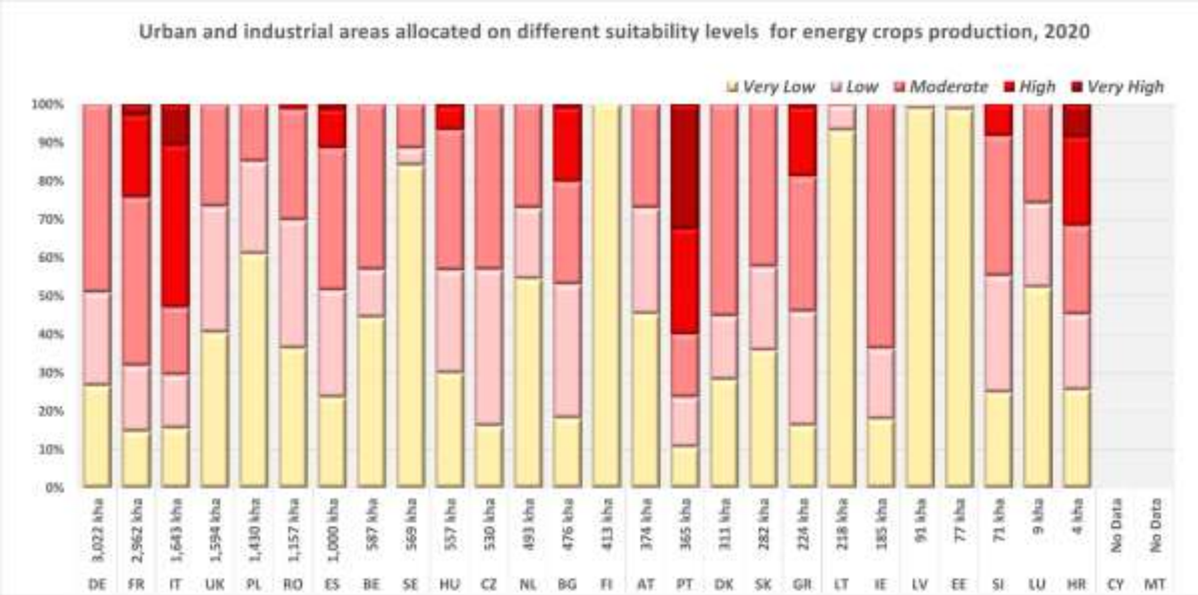

Figure 34. Suitability level (for ENCR) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28, in the year 2020.

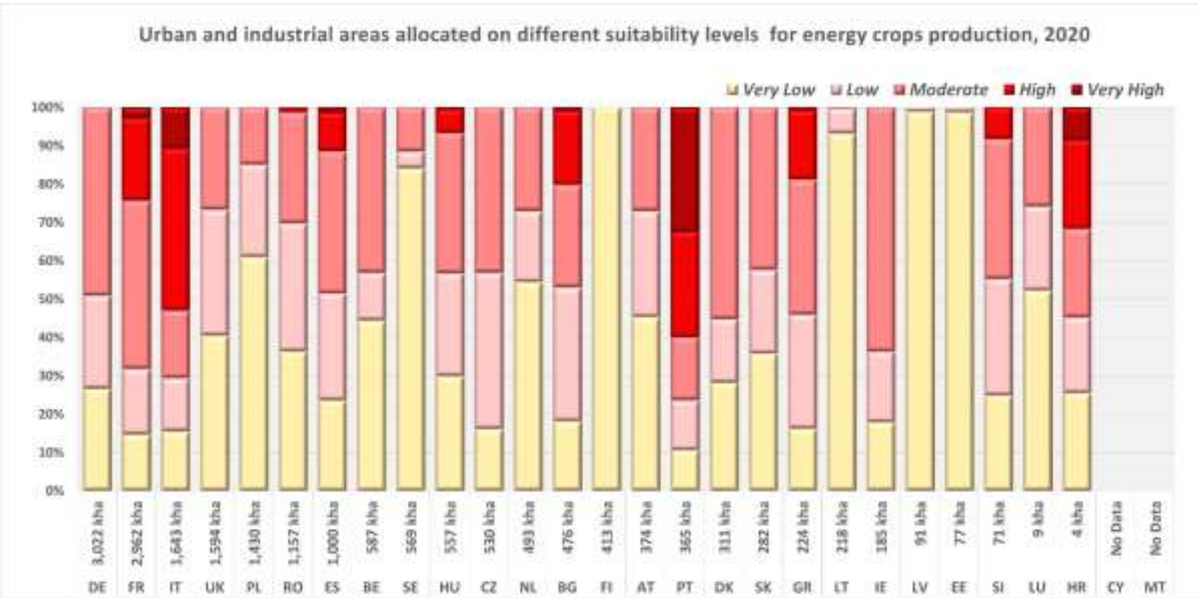

Figure 35. Suitability level (for ENCR) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28, in the year 2050.

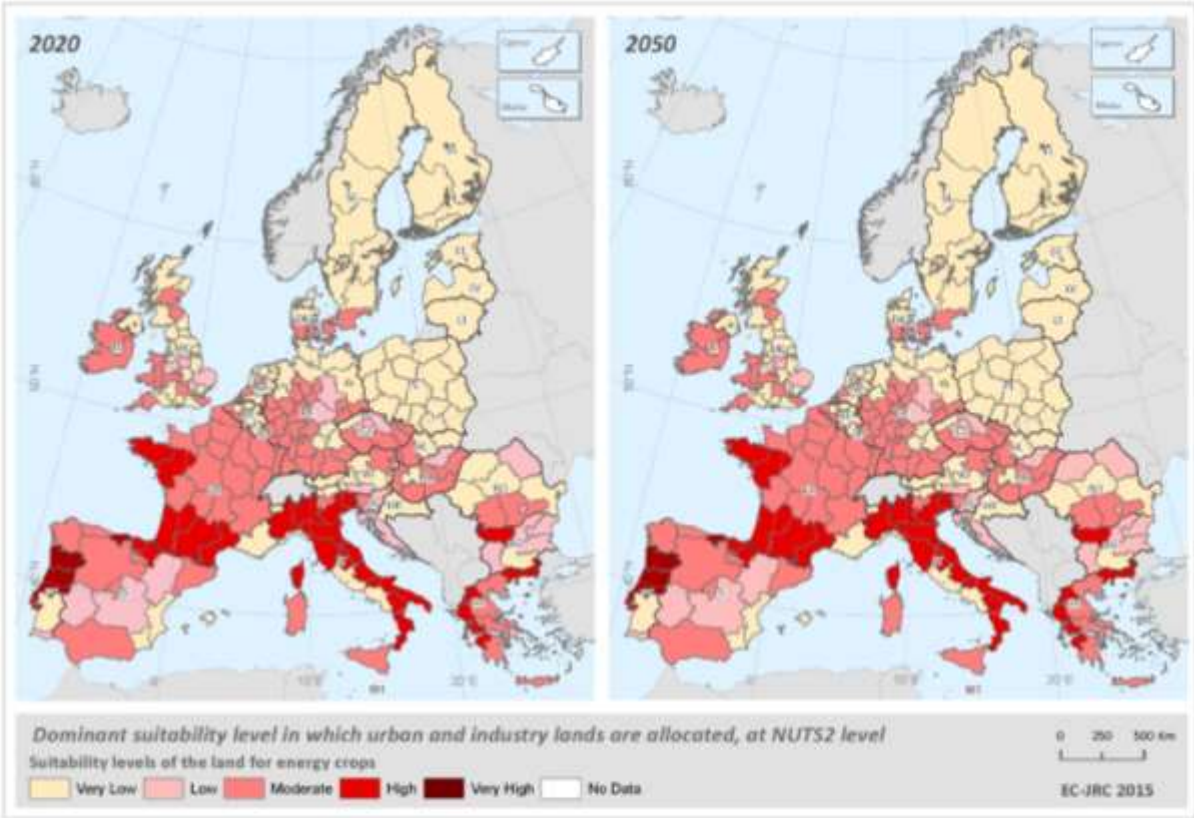

Figure 36. Suitability level (for ENCR) on which the majority of the artificial areas are allocated at NUTS 2 level in the EU28.

At regional level, Figure 36 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.

6. Conclusions

Competition for land takes place when different alternative uses (such as agriculture, forestry, energy or/and natural conservation) are competing for the same piece of land. When the competition for land is highly intense in a given territory, a specific land use/cover might cause the displacement of another one, leading to land-use conversion and, potential negative environmental, economic and social impacts. The competition for land between food and bio-fuel production has become a well-known example. In the long term, this exacerbated competition might increase the pressure on the land and the impacts on the land capacity to support ecosystems and productive systems deserve to be in-depth investigated.

The territorial assessment carried out by the LUISA platform highlights where in Europe the current macro-economic trends and energy policy targets might pose a threat to our land resources in the mid to long term. This might happen, for instance, in regions where the demand for energy crops and the need for residential and industry/commerce/services functions, is forecasted to increase. Essential land uses, such as agriculture for food and feed production, can therefore be transferred to less suitable lands at a regional or local scale.

The majority of cereal, maize and root crops in Europe are allocated on land classified as highly suitable (high and very high levels). In Europe, the allocation of crops belonging to the other arable class predominantly takes place on land classified as having moderate or low suitability suitable, with an increase of 5% on average between 2020 and 2050. However, the amount of land cultivated with cereal, maize and root crop production is experiencing a substantial decrease in the majority of the MSs, on average higher than 10% across the entire simulation period. On the opposite, energy crop production increases at fast pace, at times doubling the amount of allocated land from the year 2020, when they are first introduced, to 2050. The suitability levels of the land are widely spread without any clear pattern for these crops, however it is possible to identify the predominant expansion of energy crops on soils with moderate, low and very low fertility.

Due to the growth of residential and ICS (industry, commercial and services) sites, land highly suitable for the cultivation of food crops and non-food crops is increasingly being used for artificial uses. In 2020 and 2050, built-up areas are allocated predominantly on land scarcely suitable (low and very low) for crops belonging to the other arable category. On the contrary, land taken by artificial areas is predominantly characterised by moderate suitability levels for cereal production. Maize and root crop are the crops most affected by the expansion of urban and ICS land uses, since built-up is predominantly allocated on land classified as moderately and highly suitable land for both crops. 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 energy crops.

In general terms, growing crops on highly suitable land results in a cost reduction associated to inputs use, such as fertilizers, pesticides and water. However, as result of the competition, there is – in several areas in Europa - an increasing shift towards low quality land for growing food and feed crops, with environmental and economic impacts to be carefully evaluated.

The viability of compensation mechanisms, such as the application of additional fertilisers, are very site-specific and have to be evaluated against their potential environmental impacts, and according to the current policy provisions (Nitrates Directive, Water Framework Directive, CAP).

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List of abbreviations and definitions

CAP	Common Agricultural Policy of the European Union
EU28	European Union (28 countries)
ENCR	(Dedicated) Energy Crops
GDP	Gross Domestic Product
GHG	Green House Gases
GVA	Gross Value Added
ha	Hectares
kha	Thousands of hectares
ICS	Industry, Commerce and Services
LCF	Land Cover/use Flows
LUISA	Land Use-based Integrated Sustainability Assessment modelling platform
MS	Member State
NUTS	Nomenclature of Territorial Units for Statistics

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

Lopes Barbosa A, Perpiña Castillo C, Baranzelli C, Aurambout J, Batista E Silva F, Jacobs C, Vallecillo Rodriguez S, Vandecasteele I, Kompil M, Zulian G, Lavalle C. European landscape changes between 2010 and 2050 under the EU Reference Scenario. EU Reference Scenario 2013 LUISA platform – Updated Configuration 2014. EUR 27586. Luxembourg (Luxembourg): Publications Office of the European Union; 2015. JRC98696

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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 allocation of other arable land, permanent crops, pastures and energy crops.

Available land

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.

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 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.

Each 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.

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.

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