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Assessment of capacity for ecosystem services in agricultural areas, focusing on areas with natural constraints (ANC)

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Abstract/Executive summary

Introduction

Areas with Natural Constraints (ANC, previously referred as 'less favoured areas', LFA) designates areas where agricultural production or activity is more difficult because of natural handicaps and therefore there is a significant risk of agricultural land abandonment. The scheme compensates for the natural disadvantage.

Ecosystem services are the benefits people obtain from ecosystems (MA, 2005). They are derived from ecosystem functions and represent the realized flow of services for which there is demand ((Maes, 2013)MAES, 2013). Ecosystem functions/capacities are defined as the capacity to deliver ecosystem services (MAES, 2013).

The ANC scheme aims at maintaining the countryside and maintaining and promoting sustainable farming systems. Therefore it can help to maintain or improve certain ecosystem services and ecosystem services can increase agricultural productivity, which can be important particularly in marginal areas.

Furthermore, it contributes to the fourth priority of the rural development policy: restoring, preserving and enhancing ecosystems dependent on agriculture and forestry.

Beyond these aims, the demand for a better targeting of areas with natural constraints calls for the assessment of ecosystem services of these areas.

Objectives

The aim of the ecosystem service assessment of 'Areas with natural constraints' (ANC, Articles 31 & 32 of Council Regulation (EU) 1305/2013) at European level is to gain insight into the current status of ecosystem services (ES) supply, to develop a classification system based on ES supply, and to evaluate the performance of the ANC scheme. It can contribute to the better targeting of areas with natural constraints.

Methods

The report presents the proposed methodology for the assessment of ecosystem capacities in less favoured areas. Ecosystem capacity refers to the potential of ecosystems to provide services and it is an element of the ecosystem service cascade in the conceptual framework for ecosystem service mapping and assessment (Maes et al., 2013).

The methodology was tested for nine ecosystem services, including services from all of the three main groups of services (provisioning, regulating and maintenance, cultural; Maes et al., 2013). The report shows the actual status of the ecosystem capacities in less favoured agricultural areas compared to non-LFA agricultural areas. The assessment was elaborated for less favoured areas (LFA) delineated in 2008/2009 as the new delineation of ANC is currently under progress, covering 25 Member States of the EU.

The methodology includes two main analysis: (1) comparison of LFA and non-less favoured agricultural areas and (2) classification of areas within LFA.

The comparison of LFA and non-LFA covers three aspects of ecosystem capacities: (1) quantitative levels, (2) relationships (spatial trade-offs and synergies) among capacities and (3) multifunctionality. Some possible examples are presented for the evaluation, comparison and classification of administrative units regarding to the ecosystem capacities of their less favoured areas, testing them at NUTS2 level. These methods are based on the comparison of the administrative unit level average/median values of each

service separately or taking into account all services at the same time. The latter can be obtained by

(1) statistical method: cluster analysis or

(2) by classifying all ecosystem capacity values in three classes as low, medium and high, and then calculating the spatial extension of low, medium and high capacity areas within the selected administrative units or

(3) by calculating the number of services potentially delivered at a minimum level at a certain spatial resolution, in our case at 1km level, and then using this to calculate a multifunctionality index at administrative unit level.

The ecosystem services included in the analysis are (1) provisioning services: cultivated crops, reared animals, water provisioning for drinking and for non-drinking purposes; (2) regulating and maintenance services: mass stabilization and control of erosion rates (erosion control), hydrological cycle and water flow maintenance (water regulation), maintaining nursery populations and habitats, pollination, global climate regulation and (3) cultural service: physical and intellectual interactions with ecosystems.

The capacities of agro-ecosystems to deliver the above mentioned services were approximated by the following indicators/proxies, respectively: (1) provisioning services: cropland soil productivity (Toth et al., 2013) and crop production capacity, grassland soil productivity (Toth et al., 2013) and grass production capacity, hydrological excess water (mm) (Wriedt and Bouraoui, 2009); (2) regulating and maintenance services: erosion control index (1 – C-factor), water content at field capacity (cm3 cm-3), semi-natural vegetation abundance (number of 25 m cells in 1km2 specified as semi-natural vegetation) (Garcia-Feced et al, 2014), pollination potential index (Zulian et al., 2013), carbon stock in the topsoil (t/ha in 0-30 cm depth) (Lugato et al., 2014) and (3) recreation potential index (Paracchini et al., 2014).

Results

The study revealed that all of the studied ecosystem capacities are significantly different in LFA and in non-LFA at EU level. Biomass provisioning capacities, i.e. capacity for cultivated crops and for reared animals are the services most directly related to agricultural production. Both are higher in non-LFA than in non-LFA. The only exception is the actual set of potential supply for reared animals provision that is higher in LFA due to the higher share of grasslands. On the other side LFA has higher capacity for all of the studied regulating, maintenance and cultural services.

Most of the studied ecosystem services can be classified in three groups based on the share of low, medium and high capacity areas in LFA and in non-LFA:

1. Mainly low capacity in LFA and high capacity in non-LFA: capacity for crop provision, potential supply for reared animals provision, water provision.

2. Mainly high capacity in LFA and low capacity in non-LFA: capacity for erosion control, habitat maintenance, pollination and recreation.

3. The capacity is mainly medium in both LFA and non-LFA, and the share of medium capacity is higher in non-LFA than in LFA: capacity for water regulation and for global climate regulation.

The capacity for reared animals provision was assessed in another way as well, considering not only the soil productivity but also the spatial extent of land actually used for grazing. This actual capacity for reared animals is mainly low in both LFA and non-

LFA. Nevertheless, there are more low capacity areas in non-LFA and more medium and high capacity areas in LFA.

The spatial trade-offs and synergies among ecosystem capacities are similar in LFA and in non-LFA at EU level, as it was concluded from the principal component analyses.
In both LFA and non-LFA three bundles of capacities were observed showing spatial trade-offs between them and synergies among the capacities within the bundles: (1) cultivated crops, (2) habitat maintenance, pollination, recreation, (3) reared animals, global climate regulation.
However, the synergies were rather weak, which means that there are no strong spatial overlaps between the capacities.
At Member State level, the differences between LFA and non-LFA concerning the quantitative level of ecosystem capacities vary greatly. The trade-offs and synergies show moderate differences. The variability of natural conditions and the agricultural systems throughout the studied area can be drivers for the differences, as well as the variability of the national delineation of less favoured areas.

In order to evaluate and classify areas within less favoured agricultural areas more methods were tested and presented through some examples in the report.

1. Spider diagrams are proposed as a simple tool for the visualisation and comparison of ecosystem services (capacities) of NUTS2 regions.

2. The cluster analysis classified the NUTS2 regions in three groups. The interpretation of the resulted classes was supported by the hotspot- and cold-spot maps of the ecosystem capacities. The bundles

3. Maps are shown classifying NUTS2 regions in five groups based on the multifunctionality index in their less favoured and non-less favoured areas, respectively. Comparing the two maps, it can be seen that there are more NUTS2 regions with relatively high multifunctionality in LFA than in non-LFA, whereas there are less NUTS2 regions with low scores in LFA. There are a number of NUTS2 regions that scores higher in LFA than in non-LFA. Comparing the multifunctionality index calculated separately for provisioning and for regulating services, it was revealed that in LFA it is higher for regulating services than for provisioning services in most of the NUTS2 regions, except some regions in Northern Europe. In non-LFA the relation between multifunctionality for regulating and for provisioning services varies from region to region without trends at continental level.

Conclusions

The directions of the detected differences in ecosystem capacities between LFA and non-LFA at EU level are in line with the aims of the ANC scheme. The size of the differences, greatly varying at Member State level, could be increased with a better targeting.

The developed methodology is flexible, it can be repeated for the assessment of ecosystem services of less favoured areas for all elements of the MAES conceptual framework (Mapping and Assessment of Ecosystems and their Services, Maes et al., 2013): function, ecosystem service, benefit, value.

It allows for the classification of less favoured agricultural areas concerning their ecosystem services, likely with more precision if at country or regional level.

It can be applied at any suitable scales, administrative unit levels, as well as including more ecosystem services, depending on data availability. It is important to highlight that the selection of ecosystem services and their indicators can have crucial effect on the outputs.

The output maps can be used to locate and identify promising places, hotspots and cold-spots as well. Beyond the quantitative assessment of ecosystem services it can help to explore conflicts and synergies among them.

The methodology allows for the screening and identification of Member States/regions that (1) have greatly smaller or higher capacity for one or more ecosystem services compared to the EU level and (2) in which the difference between less favoured and non-less favoured areas is much smaller or even it is the opposite direction compared to the EU level.

The analyses can be repeated for the areas with natural constraints when their delineation will be ready and use the results for the evaluation of the performance of the newly delineated areas as well as for comparing them with the currently delineated areas. It can contribute to the better targeting of the ANC scheme.

1 Introduction

Ecosystem functions are defined as the capacity to deliver ecosystem services (MAES, 2013). Ecosystem services are the benefits people obtain from ecosystems (MA, 2005). They are derived from ecosystem functions and represent the realized flow of services for which there is demand (MAES, 2013). The Common International Classification of Ecosystem Services (CICES Classification) Version 4.3 (MAES, 2013) distinguishes three main categories of ecosystem services: provisioning, regulating and maintenance, and cultural services (Table 1).

Table 1 Common International Classification of Ecosystem Services (CICES Classification) Version 4.3. Source: MAES, 2013.

CICES for ecosystem service mapping and assessment				
CICES for ecosystem accounting				
Section	**Division**	**Group**	**Class**	**Class type**
Provisioning	Nutrition	Biomass	Cultivated crops	*Crops by amount, type*
			Reared animals and their outputs	*Animals, products by*
			Wild plants, algae and their outputs	*Plants, algae by amount, type*
			Wild animals and their outputs	*Animals by amount, type*
			Plants and algae from in-situ aquaculture	*Plants, algae by amount, type*
			Animals from in-situ aquaculture	*Animals by amount, type*
		Water	Surface water for drinking	*By amount, type*
			Ground water for drinking	
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	*Material by amount, type, use, media (land, soil, freshwater, marine)*
			Materials from plants, algae and animals for agricultural use	
			Genetic materials from all biota	
		Water	Surface water for non-drinking purposes	*By amount, type and use*
			Ground water for non-drinking purposes	
	Energy	Biomass-based energy sources	Plant-based resources	*By amount, type, source*
			Animal-based resources	
		Mechanical energy	Animal-based energy	*By amount, type, source*

CICES for ecosystem service mapping and assessment				
CICES for ecosystem accounting				
Section	**Division**	**Group**	**Class**	**Class type**
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	*By amount, type, use, media (land, soil, freshwater, marine)*
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	*By amount, type, use, media (land, soil, freshwater, marine)*
			Dilution by atmosphere, freshwater and marine ecosystems	
			Mediation of smell/noise/visual impacts	
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	*By reduction in risk, area protected*
			Buffering and attenuation of mass flows	
		Liquid flows	Hydrological cycle and water flow maintenance	*By depth/volumes*
			Flood protection	*By reduction in risk, area protected*
		Gaseous / air flows	Storm protection	*By reduction in risk, area protected*
			Ventilation and transpiration	*By change in temperature/humidity*
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	*By amount and source*
			Maintaining nursery populations and habitats	*By amount and source*
		Pest and disease control	Pest control	*By reduction in incidence, risk, area protected*
			Disease control	
		Soil formation and composition	Weathering processes	*By amount/concentration and source*
			Decomposition and fixing processes	
		Water conditions	Chemical condition of freshwaters	*By amount/concentration*
			Chemical condition of salt waters	
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	*By amount, concentration or climatic*
			Micro and regional climate regulation	

CICES for ecosystem service mapping and assessment				
CICES for ecosystem accounting				
Section	**Division**	**Group**	**Class**	**Class type**
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	*By visits/use data, plants, animals, ecosystem type*
			Physical use of land-/seascapes in different environmental settings	
		Intellectual and representative	Scientific	*By use/citation, plants,*
			Educational	
			Heritage, cultural	
			Entertainment	
			Aesthetic	
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	*By use, plants, animals, ecosystem type*
			Sacred and/or religious	
		Other cultural outputs	Existence	*By plants, animals, feature/ecosystem type*
			Bequest	

Areas with natural constraints (ANC, previously referred as 'less favoured areas', LFA) designates areas where agricultural production or activity is more difficult because of natural handicaps and therefore there is a significant risk of agricultural land abandonment, and compensates for the natural disadvantage. Areas are classified in three categories (Article 32, Council Regulation (EC) 1305/2013):

(1) Mountain areas handicapped by short growing season due to high altitude or to steep slopes or to both;

(2) Areas facing significant natural constraints;

(3) Areas affected by specific constraints (areas where farming should be continued in order to conserve or improve the environment, maintain the countryside, preserve the tourist potential of the areas or protect the coastline).

Despite ANC scheme is structurally distinct from the agri-environment measure, it clearly contributes to environmental objectives. It supports continued agricultural management in areas where farming is important from an environmental perspective, promoting sustainable land management. It aims at the maintenance of valued open landscapes, semi-natural habitats and biodiversity. It contributes to the fourth priority of the six Union priorities for rural development (Article 5, REGULATION (EU) No 1305/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL), to "restoring, preserving and enhancing ecosystems dependent on agriculture and forestry". Moreover it is denominated in Focus Area 4a of the regulation as the following: "restoring, preserving and enhancing biodiversity, including in Natura 2000 areas, and in areas facing natural or other specific constraints, and high nature value farming, as well as the state of European landscapes".

The incorporation of ecosystem protection and restoration into the Common Agricultural Policy was further endorsed by the EU Biodiversity Strategy (European Commission, 2011) (Maes et al., 2013). It aims to halt the loss of biodiversity and also the degradation of ecosystem services in the EU by 2020. It assumes that the protection of ecosystems and their services results in favourable effects on habitats and species conservation status. As it has been proved that focusing only at protected areas and species is not enough, semi-natural and agricultural land, moreover sustainable agriculture are also targeted in the strategy (Maes et al., 2011).

Therefore, the assessment and monitoring of the performance of agricultural areas and in particular areas facing natural or other specific constraints is essential to support the evaluation of the rural development policy.

The maintenance of extensive agricultural activity in rural landscapes is important for biodiversity, which is confirmed by the high number of species closely associated with farmlands and grasslands in agricultural use (Tucker and Heath, 1994; Delbaere et al., 2002). It is particularly true for High Nature Value farmlands (Paracchini et al., 2008). Both intensive land use and abandonment of agricultural land management can lead to loss of biodiversity (Marshall et al., 2003;Berendse et al., 2004, Deguine et al., 2014). In marginal agricultural areas the extreme biophysical conditions and their specific agricultural management can create higher landscape diversity and provide habitat for specialized species (Berger et al., 2006). Capacity for regulating services can be higher due to the significant amount of plots without cultivation in most marginal parts, variable timing of the farming activities from plot to plot and higher crop diversity driven by unfavourable conditions.

There are less studies about the effects of conversion to intensive production and/or land abandonment on ecosystem services and especially for multiple services (e.g. Ford et al., 2012, Gómez et al., 2005). However, it is well known that the service flow of agro-ecosystems depends on the applied agricultural practices and on the intensity of land management (Watson et al., 2000, Sandhu et al., 2008, Lipper et al., 2006). For example in croplands, the regular ploughing, planting, and harvesting lead to loss of organic matter, emitting carbon dioxide into the atmosphere. However, low carbon farming practices (residue management, reduced tillage, ley cropping systems, etc.) can contribute to the stabilization or increase in soil organic carbon (Lal, 2004).

Less favoured areas are expected to have lower capacity for biomass provisioning services and higher capacity for various regulating and cultural services than more favourable land. Therefore they can have high potential and demand for ecological intensification (Doré et al., 2011) that means to increase the productivity of extensive farming systems while maintaining sustainability by enhancing the regulating and maintenance services delivered by agro-ecosystems. Also, the multifunctional management could increase the sustainability of these areas (Palese et al., 2013). This emphasizes the need for a comprehensive ecosystem service assessment including trade-offs and synergies among services. Mapping of the ecosystem services, identifying hotspots and cold spots can help to better target the scheme.

The methodology proposed in present report for the assessment of the contribution of ANC to restoring, preserving and enhancing biodiversity and ecosystem services contains

(1) the mapping of their ecosystem services (capacities and actual flow) at different spatial levels,

(2) their classification and evaluation regarding to ecosystem services (capacities and actual flow),

(3) their comparison with agricultural areas out of the scheme.

It allows for analysing spatial differences from three aspects: quantitative level, (2) relationships (trade-offs and synergies) among services and (3) level of multifunctionality. The assessment based on this methodology can answer the following questions:

(1) What is the quantitative level and spatial distribution of ecosystem services in ANC at different spatial levels?

(2) Are there spatial differences within ANC concerning certain services and the overall performance? Where are the hotspots and cold spots?

(3) Do ANC perform differently from other agricultural areas (have higher or lower capacities and/or actual flows)?

A new ANC delineation is not yet adopted in all Member States (current process until 2017), so the assessment was performed for the LFA delineation used at present. It can be repeated for the new ANC when it will be finalised.
The method was applied to ecosystem capacities as a first step, and it can be expanded to actual service flows as a next step. This approach follows the recommendation of Hansen and Pauleit (2014), i. e. important capacities (functions) of agro-ecosystems not covered by actual (demand and) supply of ES should be included in a multifunctionality assessment, otherwise some potential but important services can be left out.
The methodology contains already introduced indicators, data and follows recommendations from EU wide assessments (Maes et al., 2011, , Paracchini et al., 2012, 2015, Toth et al., 2013, Zulian et al., 2013a, 2013b, Egoh et al, 2014., Dick et al., 2014). Most of the ecosystem service assessments at EU level covers all land uses but there are some specifically focusing on agro-ecosystems (Paracchini et al., 2012, Garcia-Feced et al., 2015, Paracchini et al., 2015), and Maes et al. (2013) gives specific recommendations for ecosystem mapping and assessment for croplands and grasslands.

The objective of this report is to assess the capacities of less favoured areas for ecosystem services, to propose a replicable methodology to classify agricultural areas based on their ecosystem services and to evaluate the performance of the ANC scheme. It can contribute to the better targeting of the ANC.

2 Data

2.1 Agricultural area, less favoured areas

The agricultural area in EU27 was mapped by

- the 1ha-resolution Corine Land Cover 2006 Version 17 (12/2013) (and Corine Land Cover 2000 for Greece - missing in CLC2006) database (European Environment Agency),
- the spatial database of high nature value farmland (Paracchini et al., 2008) and
- the utilized agricultural area (UAA, Source: CAPRI, reference year 2004).

The less favoured areas (LFA) correspond to the delineation used in 2008/2009 (article 18, article 19, and article 20 of Council Regulation (EC) 1257/1999, DG AGRI internal dataset).

2.2 Ecosystem service indicators

The denomination of the ecosystem services is based on the classes of CICES Classification Version 4.3 (MAES, 2013). The selection of ecosystem services was done based on the following criteria:

- the relevance from the aspect of maintenance of extensive farming, beneficial for the environment,

- data availability.

The relevance from the aspect of extensive farming means that the ecosystem service can be delivered and used by humans along with maintaining farming. Therefore for example, using soil as raw material is not relevant.
Data availability is important as we should obtain a comparable and transparent system. Therefore we need common indicators for which data is available for the whole area.
The indicators and data used for evaluating the capacity of ecosystems to deliver services are summarized in Table 2.

Table 2 Ecosystem services and the indicators for the capacity of ecosystems in less favoured areas to deliver the services, with the data used for the indicator and the sources of data indicated.

Ecosystem service section	Ecosystem service	Indicator for capacity	Data (source)
Provisioning	Cultivated crops	Cropland soil productivity (dimensionless index) and Crop production capacity	Cropland soil productivity index (Tóth et al., 2013) Cropland share (CLC 2006 and 2000)
	Reared animals and their outputs	Grassland soil productivity (dimensionless index) and Grass production capacity	Grassland soil productivity index (Tóth et al., 2013) Grassland share (CLC 2006 and 2000)
	Ground water for drinking and for non-drinking purposes	Hydrological excess water (mm)	Hydrological excess water (Wriedt and Bouraoui, 2009)
Regulating and Maintenance	Mass stabilization and control of erosion rates	Erosion control index (1 – C-factor) (dimensionless)	C-factor, share of crops (CAPRI, Terres et al., 2013)
	Hydrological cycle and water flow maintenance	Water content at field capacity (cm^3 cm^{-3})	Topsoil texture (European Soil Database, derived data, Hiederer, R. 2013a,b)
	Pollination	Pollination potential (dimensionless)	Relative Pollination Potential (RPP) (Zulian et al., 2013a)
	Maintaining nursery populations and habitats	Semi-natural vegetation abundance	Semi-natural vegetation spatial database (Garcia-Feced et al, 2015)
	Global climate regulation	Carbon stock in the topsoil (t/ha in 0-30 cm depth)	Soil organic carbon stock (Lugato et al., 2014)
Cultural	Physical and intellectual interactions with ecosystems	Recreation potential index (dimensionless)	Recreation potential indicator (RPI) (Paracchini et al., 2014)

The selected indicators and the pros and cons for their selection are described below by ecosystem services. (P): provisioning, (R): regulating and maintenance, (C): cultural ecosystem services. For some indicators more detailed information can be found in Annex I, II. III. IV. and V.

1. ECOSYSTEM SERVICE: Cultivated crops (P)

Definition: Cultivated crops service includes the provision of all crops that are used directly or indirectly as foodstuffs and energy production.

Indicator: *cropland soil productivity index.* Spatial resolution: 1km.

The cropland productivity index (Tóth et al., 2013) is a dimensionless index that can be used as an indicator for the capacity of the soil for crop production in croplands. Soil productivity refers to the capacity to supply nutrients and water and thus produce plant biomass at a given quantity. The model includes soil, climate and topographic factors (Annex I.). It was built to reflect for rain-fed conditions. The index is created by assessing the inherent soil productivity and then extending it with a management factor (fertilization). Inherent productivity in this context means soil productivity before human interference.

Source: Tóth et al., 2013

Strenghts and limitations: the cropland soil productivity gives information about the soil productivity of all land, despite of current land use, i.e. the capacity of the land for crop production when it is used for that. This can be used as an indicator for potential supply. It is usable in case of potential land use changes, for land planning purposes for example.

Soil productivity index is mainly determined by expert judgement. Various factors, such as climate, soil water storage capacity, topography (slope and aspect) effects and the expected productivity increase due to fertilization were taken into account. The output was validated with NPP (net primary production) data derived from remote sensing.

2. ECOSYSTEM SERVICE: Reared animals and their outputs (P)

Definition: Livestock services refer to animals raised for domestic or commercial consumption or use.

Indicator: *grassland soil productivity index.* Spatial resolution: 1km.

The grassland productivity index (Tóth et al., 2013) is a dimensionless index that can be used as an indicator of the capacity of the soil to supply nutrients and water and thus produce grass. It is developed in parallel with the soil biomass productivity of croplands but without fertilizer response factor. The other difference is that both are based on the ranking of soils regarding to their long-term average inherent productivity, but the ranking was done differently for croplands and grasslands.
Source: Tóth et al., 2013

3. ECOSYSTEM SERVICE: Water provision for drinking and for non-drinking purposes (P)

Definition: The combined ecosystem service refers to the water available for drinking and for other use such as domestic use, irrigation, livestock consumption and industrial use.

Indicator: *Hydrological excess water*.

Hydrological excess water is the amount of water available for surface and groundwater runoff calculated using a generic monthly rainfall-runoff model at sub catchment level (Wriedt and Bouraoui, 2009).

$HXS(t) = P^*(t) - ETA(t),$ where

$P(^*)$ = (effective) Precipitation (mm), ETA = actual evapotranspiration (mm).

$ETA(t) = P^*(t) / [\alpha + (P^*(t)/ETP(t)^{\beta}]^{1/\beta},$ where

P(*) = (effective) Precipitation (mm), ETP = potential evapotranspiration (mm), $\alpha = 1$, $\beta=1.5$.

Climatic data were taken from the MARS climatic database (Micale and Genovese 2004) developed by MARS/AGRIFISH Unit of the Joint Research Centre. The database was created by interpolating observations of meteorological stations across Europe to a 50 km square grid. Daily rainfall, potential evapotranspiration and snow depth are included in the database for the time period 1990 – 2003.

Source: Wriedt and Bouraoui (2009)

4. ECOSYSTEM SERVICE: Mass stabilization and control of erosion rates (R)

Definition: The capacity of ecosystems to control soil erosion.

It is based on the ability of vegetation (i.e. the root systems) to bind soil particles thus preventing the fertile topsoil from being blown or washed away by water or wind (Maes et al., 2011). Land use, topography, soil properties and climate (wind and precipitation) are the predominant variables determining the magnitude of erosion. Vegetation helps conserving soils and prevent the siltation of waterways and landslides.

Indicator: *erosion control index.*

The C-*factor* of the RUSLE model substracted from 1 is used as a proxy for erosion control. The RUSLE model estimates soil erosion by water by means of an empirical equation:

$$A = R\ K\ L\ S\ C\ St\ P, \qquad (Eq1)$$ where

A = (annual) soil loss ($t\ ha^{-1}\ yr^{-1}$), R = rainfall erosivity factor ($MJ\ mm\ ha^{-1}\ h^{-1}\ yr^{-1}$), K = soil erodibility factor ($t\ ha\ h\ ha^{-1}\ MJ^{-1}\ mm^{-1}$), L = slope length factor (dimensionless), S = slope factor (dimensionless), C = cover management factor (dimensionless), St = stoniness correction factor (dimensionless), P = human practices aimed at erosion control (dimensionless).

The C factor represents the influence of land cover and cropping on soil erosion by water.

C-factor data was obtained from CAPRI model, in which it was calculated on the basis of the HSMU crops share and their respective crop-specific factors. Crop system factors have been specified for all of the 41 crops types included in CAPRI, depending on their physical and phenological features which can increase or decrease soil erosion (i.e. soil coverage, root structure, phenological stages, etc.). Some more information about the indicator can be found in Annex II.

Source: CAPRI model (Terres et al., 2013)

Limitations, further work: the crop-specific c-factor for some cultivated crops can be refined and differentiated more by member states for some crops, adjusting it to local conditions. The effect of small-scale patches of semi-natural vegetation on erosion control is not considered.

5. ECOSYSTEM SERVICE: Hydrological cycle and water flow maintenance (R)

Definition: Hydrological cycle and water flow maintenance refers to the influence ecosystems have on the timing and magnitude of water runoff, flooding and aquifer recharge, particularly in terms of water storage potential of the ecosystem. We refer to it also as water regulating services (Maes et al., 2011.)

Indicator: *water content at field capacity.* Spatial resolution: 1 km.

Water content at field capacity is the amount of water that remains in the soil after excess water drained away by gravity. It is considered as the water retention capacity of the soil. It was calculated from the soil texture data of the European Soil Database (Hiederer, 2013a,b)

Limitation and further work: soil organic carbon content of the soil was not taken into account, nevertheless it can influence water retention capacity. Water infiltration capacity and water retention capacity of vegetation are not taken into account.

Source: European Soil Database, derived data. Hiederer, R. (2013a,b).

6. ECOSYSTEM SERVICE: Pollination (R)

Definition: Pollination services refer to the role ecosystems play in supporting the transfer of pollen between flower parts.

Indicator: *Pollination potential of agro-ecosystems.* Spatial resolution: 1km.

The pollination potential index (Zulian et al., 2013a) is the potential capacity of ecosystems to provide pollination so refers to the ecosystem function. The applied methodology was derived from the InVEST model (Kareiva et al., 2011) and it was adapted to fit the continental scaled mapping. The short description of the model can be found in Annex III.

Source: Zulian et al (2013a).

Strengths and limitations:

It is the only one comprehensive database at EU level regarding to capacity for pollination.
Its strength is that it combines the pollinator abundance and the floral resources information and it takes into account flight distances and pollinator activity as well.
Its main limitation is that natural, semi-natural vegetation and landscape elements at fine scale (hedges, ponds, ditches, etc.) hence also the pollination potential is underestimated in agricultural areas, because of lack of data on these micro-features. Furthermore, it is largely based on expert knowledge, and its validation is missing because of poor data coverage with respect to the abundance of pollinator species at European level.

7. ECOSYSTEM SERVICE: Maintaining nursery populations and habitats (R)

Definition: maintaining habitats for plant and animal nursery and reproduction

Indicator: semi-natural vegetation abundance in agricultural land. Spatial resolution: 1km.

Abundance of semi-natural vegetation is the number of 25m cells in 1km^2 specified as semi-natural vegetation (García-Feced et al., 2015). It is obtained by satellite image classification, using various spatial databases for creating matching rules, for exclusion of intensive agricultural vegetation and for validation (CLC2006, High Nature Value farmlands, European Forest Map 2006, Riparian vegetation 2006, Energy Input indicator based on CAPRI model, Areas with high seasonal variability in vegetation, LUCAS 2006). Both large (extensive, semi-natural grasslands, agroforestry areas, traditional orchards) and small (hedgerows, buffer strips, field margins, scattered trees or woodlots) patches of perennial vegetation and woody vegetation are identified.

Source: García-Feced et al., 2015

Strengths and limitations:

this is the first EU wide geospatial layer of semi-natural vegetation in agricultural lands. Given the resolution of input data the main limitation is that, among small size elements, it contains information on spatial distribution of macro-features (hedgerows or woodlots) but not of micro-features (field margins and flower strips).

8. ECOSYSTEM SERVICE: Global climate regulation (R)

Definition: Global climate regulation services are defined as the influence that ecosystems have on the global climate by emitting greenhouse gasses to the atmosphere or by extracting carbon from the atmosphere (Maes et al., 2011).

Indicator: *Carbon stock in the topsoil* (t/ha in 0-30 cm depth) (Lugato et al., 2014).

Soil organic stock (t C ha^{-1}) in the 0-30 cm soil layer is calculated for agricultural land, for a baseline year (2010), using the agro-ecosystem SOC submodel of CENTURY (Parton et al., 1988) (Annex IV.).

The spatial extension of agricultural land use was derived from the Corine Land Cover (CLC) 2000–2006 databases (http://www.eea.europa.eu/ publications/COR0-landcover), including the thirteen classes defined as 'agricultural areas'.

Source: Lugato et al., 2014.

Strengths and weaknesses: Data is coming from a database calculated by a pan-European simulation platform with high spatial resolution and harmonized data sets. It has been validated against measured carbon sequestration data derived from long-term experiments (LTE).

The indicator could be supplemented with the estimated carbon content stored in the above- and below-ground vegetation, calculated from the crop shares (Data source: CAPRI model) and from the estimated carbon content of each crop. However, in agricultural ecosystems below-ground carbon stock dominates (Marland et al., 2003).

9. ECOSYSTEM SERVICE: Physical and intellectual interactions with ecosystems (C)

Definition: Cultural ecosystem services are defined as the nonmaterial benefits obtained from ecosystems. The recreational pleasure that people derive from natural or managed ecosystems is defined as recreation service.

Natural and semi natural ecosystems, as well as cultural landscapes, provide a source of recreation for mankind. People enjoy forests, lakes or mountains for hiking, camping, hunting, fishing or bird watching, or just for being there. Recreation is also supplied by managed ecosystems, such as agricultural lands.

Indicator: *Recreation potential index of agro-ecosystems*. Spatial resolution: 1km.

Recreation potential index (RPI) is an indicator for the capacity of ecosystems to provide recreational services. It was calculated by aggregating the following variables:

- hemeroby or degree of naturalness,

- presence of protected areas,
- presence of coastlines,
- quality of bathing water and accessibility.

Hemeroby, or degree of naturalness is an index that measures the human influence on landscapes and flora. According to the assessment in Paracchini et al. (2014), all CLC classes but artificial land use contribute to the potential of nature for recreation. Data sources used in the model are listed in Annex V.

Source: Paracchini et al., 2014.

3 Methods

3.1 Derivation of ecosystem service indicators in cases when data was calculated or the original database was modified

1. ECOSYSTEM SERVICE: Cultivated crops (P)

The cropland productivity index (Tóth et al., 2013) was used as indicator for the potential supply (section 1). To obtain the actually used set of supply (capacity with the current land use) it was multiplied with the spatial extension of croplands (classes 12-17, 19-21 of CORINE). The resulted indicator is called crop production capacity. It includes the actual land use information, approximating the potential provided by biophysical conditions in croplands. It increases with increase in soil productivity and/or share of croplands. It is not restricted to food production, but includes all biomass production in arable lands.

2. ECOSYSTEM SERVICE: Reared animals and their outputs (P)

The grassland productivity index (Tóth et al., 2013) was used as indicator for the potential supply of the areas (section 2). To obtain the actually used set of supply (capacity with the current land use) it was multiplied with the spatial extension of grassland (and other land use classes, potentially used for grazing; classes 18; 26 - 29; 35 of CORINE). The derived indicator is called grass production capacity. It increases with increase in soil productivity and/or share of grasslands.

3. ECOSYSTEM SERVICE: Mass stabilization and control of erosion rates (R)

The value of C-factor decreases with increase in the protective influence of the crops, therefore it is necessary to subtract it from 1 to express the capacity for erosion control. Accordingly, the c-factor values (CAPRI, Terres et al., 2013) were substracted from 1, obtaining a proxy for erosion control.

4. ECOSYSTEM SERVICE: Hydrological cycle and water flow maintenance (R)

Water content at field capacity was calculated from the texture class of the topsoil (Hiederer, R. 2013a) with the pedotransfer function nr 7 in Tóth et al. (2015):

Texture	θ_{FC}
Coarse	0.199
Medium:	0.308
Medium fine	0.326
Fine	0.362
Very fine	0.362
Peat soils	0.575

5. ECOSYSTEM SERVICE: Pollination (R)

Pollination potential of agro-ecosystems is calculated from the 100m spatial resolution pollination potential database (Zulian et al., 2013a) for the purpose of present study, according to the followings. The original 100 m database was upscaled at 1 km by extracting the 100 m cells covered by agricultural land and calculating the mean pollination potential value of these cells in each 1 km cell. Agricultural land use was defined by the CLC2006 map (European Environment Agency) and by high nature value farmland database (Paracchini et al., 2008). In this way data for non-agricultural land were excluded from the upscaled database.

6. **ECOSYSTEM SERVICE: Global climate regulation (R)**

As the study area contains high nature value farmlands out of the agricultural classes of CLC, and the original dataset (Lugato et al., 2014) was calculated only for agricultural areas delineated by CLC, data gaps had to be filled up. For missing data imputation, data calculated for extensive pasture land use was used from the same database, assuming that the relevant areas are extensive pastures.

7. **ECOSYSTEM SERVICE: Physical and intellectual interactions with ecosystems**

Recreation potential index of agro-ecosystems was calculated from the 100 m spatial resolution recreation potential index (RPI) database (Paracchini et al., 2014) for the purpose of present study, according to the followings (similarly as pollination potential). The original 100 m database was upscaled at 1 km by extracting the 100 m cells covered by agricultural land and calculating the mean recreation potential value of these cells in each 1 km cell. Agricultural land use was defined by the CLC2006 map (European Environment Agency) and by high nature value farmland database (Paracchini et al., 2008). In this way data for non-agricultural land were excluded from the upscaled database.

3.2 Delineation of agricultural areas

Agricultural areas, being the study area of the whole assessment, were mapped (Figure 1). The exercise was implemented for 25 Member States of the EU. Croatia is missing as it was not a member of the EU at the time of the LFA delineation. Cyprus and Malta are absent due to lacking data.

As the delineation of LFA and data for most of the indicators are available at 1 km spatial resolution, agricultural land is also mapped at 1 km spatial resolution. Agricultural land was defined by areas with a share of agricultural land above 50%.

The share of agricultural land was calculated as the share of 100 m cells in 1 km2 area covered by agricultural land (class 2 at Level 1, 12-22) defined by CLC2006 (and by CLC2000 for areas missing from CLC2006) and high nature value farmlands (HNV).

By applying the 50 % threshold on the share of agricultural land two types of error were minimized:

1. the exclusion of agricultural areas and

2. the inclusion of non-agricultural areas (number of 100m cells).

Three scenarios (share of agricultural land above 25%, 33% and 50%) were tested (Table 3). With the chosen threshold 10.9 % of the 100m agricultural cells and 13.7 % of the 100m agricultural cells that are in LFA are excluded. 12.7 % of the non-agricultural cells and 13.8 % of the non-agricultural cells that are in LFA are included. This way the agricultural area is defined by 1km cells dominated by agriculture and the delineation has an error of similar magnitude for both directions.

Finally, we excluded areas not having utilized agricultural area (1 km cells with UAA = 0, data source: CAPRI). The resulted final agricultural mask was used then for extracting agricultural areas from the less favoured and non-less favoured areas layers. It resulted in two layers:

(1) less favoured agricultural areas,

(2) non-less favoured agricultural areas.

Furthermore, each ecosystem capacity indicator map was masked with the agricultural layer in order to obtain databases for agricultural areas. To obtain databases for less favoured and for non-less favoured agricultural areas, all indicator databases were masked with the less favoured and non-less favoured agricultural areas masks, respectively.

Table 3 The extent of two types of error in case of three options for delineating agricultural land: including all 1km cells with agricultural land above (1) 25%, (2) 33% and (3) 50%. *: 1. Exclusion of agricultural areas, 2. Inclusion of non-agricultural areas (expressed by the percentage of 100m cells).*

Type of error	Studied area	>25%	>33%	>50%
Agricultural cells excluded (% of all 100m agricultural cells)	Whole area of EU27	2.8	4.5	10.9
	LFA in EU27	3.7	5.9	13.7
Non-agricultural cells included (% of all 100m agricultural cells)	Whole area of EU27	25.7	21.6	12.7
	LFA in EU27	30.1	24.8	13.8

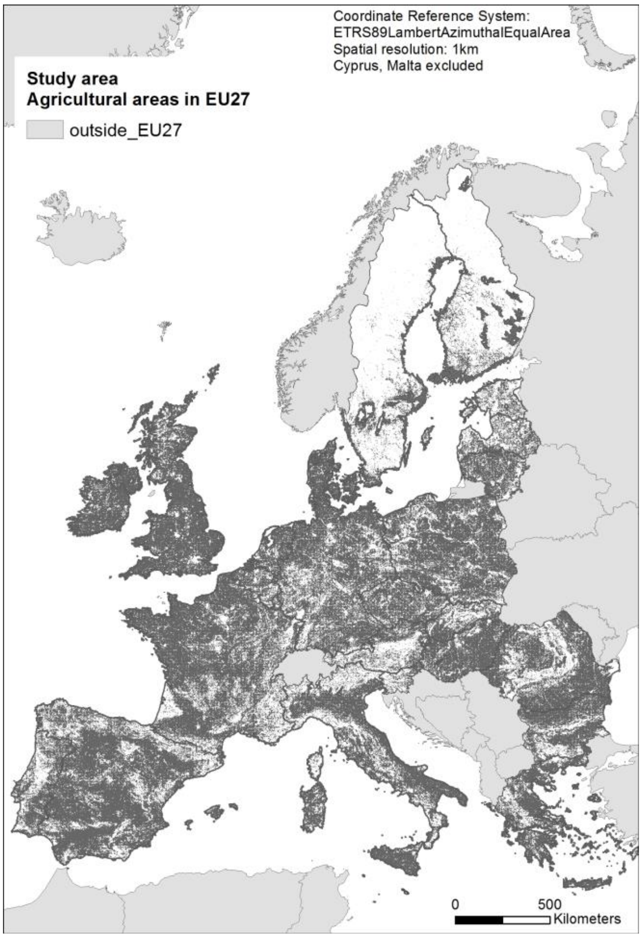


Figure 1 Agricultural areas defined by the agricultural classes in CLC2000 and high nature value farmlands, excluding areas without utilized agricultural area (UAA).

3.3 Data Normalization

Normalisation is calculated prior to trade-off analysis in order to obtain comparable indicators. It was done for each ecosystem capacity indicators already extracted with the agricultural mask presented above (see section 3.2). Four normalization methods were selected and tested taking into account the theoretical framework and the data properties.

a. Min-max normalization:

$$y_i = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

Where x_i is the value of indicator *i*, x_{max} *is the highest value of* x_i at any site, and x_{min} is the lowest value of x_i at any site in the study area, representing the ends of the normalisation range.

With this method the standardised scores for all indicators have an identical range (0-1). This makes

this method more robust when there are outliers. However, the range for indicators with very little variation is increased, therefore these indicators will contribute more to the composite indicator (Saisana and Tarantola, 2002).

b. Standardization:

$$\frac{x_i - x_{mean}}{6},$$

where y_i is the standardized value of indicator *i*, x_i is the actual value and x_{mean} is the mean value of indicator *i*, and *6* is the standard error.

This method is more robust when dealing with outliers than the calculation of the ratio or percentage differences from the mean. However, it does not entirely solve the problem (Saisana and Tarantola, 2002). This is because the range between the minimum and maximum observed standardised scores will vary for each indicator. The method gives greater weight to an indicator in those areas with extreme values. This is desirable if the aim is to reward exceptional behaviour, for example if we believe that a few exceptional indicators are worth more than a lot of average scores. On the other hand, it can be avoided if we create consistent classes for all indicators.

The method is presented on one example map for recreation potential. The standardized values of the indicators are grouped in four classes (Table 4), which can be interpreted along the followings:

- The standardized value is negative when the actual (original) value at a given place is lower than the mean value
- It is positive when the actual (original) value at a given place is higher than the mean value.
- It is below -1, when the actual (original) value at a given place is lower than the mean value, and the difference between them (in absolute value) is higher than the standard deviation.
- It is above 1, when the actual (original) value at a given place is higher than the mean value, and the difference between them (in absolute value) is higher than the standard deviation.
- It is 0 when the actual (original) value at a given place is equal to the mean value.

Table 4 Classes created based on standardized values of the capacity indicators.

Classes	Ranges of standardized values
1	< -1
2	-1 – 0
3	0 – 1
4	> 1

c. Creating classes and assigning scores to them

We can lose information with this method (the original precision of the values of indicators), and it is often hard to find appropriate thresholds for classes. But when there are well-defined classes (based on meaningful thresholds, sustainability levels or predefined target/desirable levels) we can obtain well interpretable results. Another advantage is that it is not sensitive for outliers. Moreover, it makes the treatment of non-linear relationship between the indicator and the ecosystem service.

In our assessment values of each indicator were classified into three qualitative groups as low, medium and high. In most cases, in absence of other thresholds, the classes are limited by the 33rd and 66th percentiles (Table 5).

The classes for carbon stock in the topsoil (t/ha in 0-30 cm depth) follow the classification of Lugato et al. (2014).

Water content at field capacity (cm^3 cm^{-3}), derived from soil texture information, assigning certain values to texture classes, was classified based on expert judgement, considering the water regime of different soil textures. Values of coarse textured soils are grouped into the low capacity class, medium and medium fine textured soils' values into the medium capacity class, while fine and very fine textured soils' values (and peat) into the high capacity class (Table 5).

Table 5 The ranges of the "low" (1) ,"medium" (2) and "high" (3) classes created for the capacity indicators.

Indicator	Classification
Hydrological excess water (mm)	1: 0 – 260 2: 260 – 390 3: 390 - 2900 (33rd and 66th percentiles)
Cropland soil productivity	1: 0 – 0.55 2: 0.55 – 0.69 3: 0.69 - 1 (33rd and 66th percentiles)
Grassland soil productivity	1: 0 – 0.549 2: 0.55 – 0.686 3: 0.687 - 1 (33rd and 66th percentiles)
Crop production capacity	1: 0 – 0.302 2: 0.303-0.535 3: 0.536 – 1 (33rd and 66th percentiles)
Grass production capacity	1: 0 2: 0-0.216 3: 0.217-1 (33rd and 66th percentiles)
Erosion control	1: 0.29 – 0.797

	2: 0.798 – 0.880 3: 0.89 – 1 (33^{rd} and 66^{th} percentiles)
Water content at field capacity ($cm^3\ cm^{-3}$)	1: 0.199 2: 0. - 0.33 3: 0.33 - 0.575 (expert judgement)
Pollination potential	1: 0 – 0.04 2: 0.04 – 0.096 3: 0.096 – 0.9 (33^{rd} and 66^{th} percentiles)
Carbon stock in the topsoil (t/ha in 0-30 cm depth)	1: 0-40 2: 40-80 3: >80 (based on Lugato et al., 2014)
Recreation potential	1: 0 – 0.16 2: 0.16 – 0.21 3: 0.21 – 0.88 (33^{rd} and 66^{th} percentiles)
Semi-natural vegetation abundance (number of 25m cells in $1km^2$ specified as semi-natural vegetation)	1: 0 – 200 2: 200 – 750 3: 750 – 1600 (33^{rd} and 66^{th} percentiles)

d. Creating two classes, above and below a given threshold

This method can be used if the aim is to distinguish two predefined classes for each indicator (e.g. based on a sustainability or target level, mean, median or other threshold). Its main advantages are simplicity and that it is not affected by outliers. However, information is lost with its use (the original precision of the values of indicators), and it is very sensitive to the fixed thresholds.
It was complemented in present study using the lower threshold of the medium (nr 2) class of the previous (c) method (Table 5). The resulted maps show the areas (1km cells) where each service is potentially delivered at least at medium level.

Further possibilities: Normalization can be calculated using a local maximum (and minimum) value, for example at NUTS0 level or for biogeographical regions, if the aim is to evaluate ecosystem services compared to a local maximum instead of a EU maximum. The result of this approach would highlight more the local heterogeneity. Thresholds for defining classes can also be determined at NUTS0 level.

3.4 Outliers treatment

As outliers can affect the normalization and the results and interpretation of statistical analysis, like principal component analysis (PCA), they may become unintended benchmarks (OECD Handbook on Composite Indicators, 2008). The presence of outliers was determined in the datasets of indicators. It was performed using a standard non-parametric method, the Interquartile Range.
In case of water content at field capacity the detection of outliers is not relevant as fixed values were assigned to the six soil texture classes. In case of erosion control, grassland and cropland soil productivity, pollination potential and recreation potential the outliers defined by the Interquartile Range were kept unchanged. This was motivated by the fact that the studied indicators can have naturally high spatial variability.
Outliers were transformed in case of the soil organic carbon stock despite heterogeneity exists due to the high difference between mineral and organic soils. The reason is that the upper outlier threshold is close to the lowest values of organic carbon content of organic soils and this threshold was considered as the maximum relevant capacity

(higher carbon content doesn't deliver higher service). Nevertheless the outlier transformation was used to truncate the indicator. Outliers were transformed by the values of the outlier thresholds defined as follows:

Lower outlier threshold = Q1 - 1.5*IQR
Upper outlier threshold = Q3 + 1.5*IQR,

where the Interquartile Range (IQR) is a measure of statistical dispersion, being equal to the difference between the upper and lower quartiles: IQR = Q3 – Q1.

3.5 Comparison of ecosystem capacities between LFA and non-LFA

Less favoured agricultural areas are heterogeneous concerning the biogeographical, climatic conditions as well as the agricultural system, and the intermediate LFA delineation was based on some 140, very different national criteria by Member States. Therefore, in order to explore the variability among Member States, the comparison of capacities at EU level was supplemented with Member State level analyses.

3.5.1 Comparison of the distributions

The distribution of each capacity indicator was compared between LFA and non-LFA with the sm.density.compare function in R. It was implemented for a random selection of 5000 grid cells from both less favoured and non-less favoured agricultural areas throughout the 25 studied Member States of the EU. The analysis provided the comparison of the density estimates graphically and formally in a permutation test of equality. It allowed to display the density estimates of the indicators in LFA and in non-LFA and an appropriate reference band in one joint plot. The number of samples generated in bootstraps was set to the default value (N = 100).
In addition, the Mann-Whitney - Wilcoxon-test was used to test if the population distributions are identical. The wilcox.test function in R was applied. The null hypothesis is that the capacity data from LFA and from non-LFA are identical populations.

3.5.2 Comparison of the medians

The differences between median values of LFA and non-LFA were calculated for each ecosystem capacities at EU and at Member State level. The difference was normalized with the median values in non-LFA at EU level, and the normalized difference was summed up for the 25 countries in order to quantify the overall Member State level difference between LFA and non-LFA.
The Member States were ranked based on the deviation of their median values in LFA from the EU LFA median for each ecosystem capacity.

3.5.3 Comparison of the average values

The size of the difference between LFA and non-LFA for all indicators was quantified by the effect size (*d* or *Cohen's d*) (Cohen, 1988):

$$d = \frac{M_{LFA} - M_{nonLFA}}{STD_{pooled}},$$

where

$$STD_{pooled} = \sqrt{\frac{{STD_{LFA}}^2 + {STD_{nonLFA}}^2}{2}}$$

Therefore a *d* of 1 means that the two groups' means differ by one standard deviation; a *d* of 0.5 reveals that the two groups' means differ by half a standard deviation; and so on.
Cohen suggested that *d*=0.2 be considered a 'small' effect size, 0.5 represents a 'medium' effect size and 0.8 a 'large' effect size (Cohen, 1988), but these thresholds are not recommended to be used blindly as the effect size always has to be judged based on the cost-benefit ratio. In Cohen's terminology, a small effect size is one which you can only see through careful study. A 'large' effect size is an effect which is very substantial, big enough, and/or consistent enough, that you may be able to see it 'with the naked eye'.
The effect size was considered to be large when it is equal or above 0.5 in present study in the absence of predefined objectives related to the differences. It's a lower threshold than Cohen's one, because the sample size is large and the variability at EU level is high even within the two groups. Nevertheless, this is not a significancy test, just a metric from which one can see how large is the difference between LFA and non-LFA compared to the standard deviation. The results were compared to those based on the distribution analysis.

An uncertainty analysis was performed to address the uncertainty coming from the EU scale databases. Two hundred grid points were randomly resampled out of 1000 random grid points for both LFA and non-LFA. The means and the standard deviations were calculated for all samples and this procedure was repeated 1000 times. This resulted in a set of means and standard deviations. The effect size was calculated from these statistics as well. In order to assess the reliability of the analysis, the results were then compared to the effect sizes calculated from the original datasets. Furthermore the number of runnings were counted in which the direction of the difference (i.e. the sign of the effect size) is the same as those from the analysis of the whole dataset.

3.6 Analysis of interactions (trade-offs and/or synergies) between ecosystem capacities

The goal of principle component analysis (PCA) is to reveal how the different variables change in relation to each other and how they are associated, and to identify their bundles. It can help to define the weights for aggregation of the indicators as well.
In order to explore spatial trade-offs and synergies among ecosystem capacities, PCA of the studied indicators was performed. It was applied for a random selection of 15000 grid cells from both less favoured and non-less favoured agricultural areas throughout the 25 studied Member States of the EU, respectively. It was implemented with normalized data with min-max re-scaling, after outlier transformation for soil organic carbon stock.

The same analysis was repeated at Member State level, for a random selection of 1000 grid cells from both less favoured and non-less favoured agricultural areas, respectively, from some selected countries (France, Poland, Romania, Italy).

3.7 Aggregating the indicators for ecosystem capacities

The mathematical combination (or aggregation) of the individual indicators (Saisana and Tarantola, 2002) can be used to summarise the complex and multi-dimensional issue of ecosystem capacity to deliver services, allowing for an easier interpretation and for comparison across places and classification of areas. However, to avoid misleading, non-robust messages and to draw sophisticated assessment conclusions, composite indicators should be constructed based on a sound methodology and used in combination with the sub-indicators (Saisana and Tarantola, 2002).
In case of the four tested data normalization methods the following aggregation methods are possible:

1. Re-scaled values of indicators

The rescaled values are multiplied with weights and are summed to obtain an overall indicator.

2. Standardized values of indicators

Similarly, the standardized values are multiplied with weights and are summed to obtain an overall indicator.

3. Scores assigned to classes

The sum or the mean of the scores can be calculated.

4. Binary data (above/below threshold)

In this case the number of indicators above or below the thresholds can be calculated as an overall indicator of multifunctionality.

The first three type of normalized data were not aggregated at this stage because there is no clear evidence for weights definition and this may produce misleading results. The fourth type of data was aggregated using the method described above. It resulted in the number of services potentially delivered at least at medium level at 1km spatial resolution. It can be used as an indicator , however, for its evaluation, the quantitative values, trade-offs and synergies of subcomponents has to be taken into account (Hansen and Pauleit, 2014).

3.8 Evaluation and classification of areas based on ecosystem capacities

Some examples for data evaluation at NUTS2/NUTS3 level are shown in present report, which can be used in the future also at LAU2 level supported by more accurate, higher spatial resolution, local data or using other/more indicators. The standard NUTS2/NUTS3 established by EUROSTAT were used.

a. The average and median of normalized values (with min-max method, 0-1) for each indicator were calculated for NUTS2 regions. Spider charts were created to visualize all capacities simultaneously. NUTS2 regions were classified based on their mean and median capacities, respectively, with K-means cluster analysis. The nine studied capacities were taken into account. The biomass provisioning capacities were approximated with the actually used set of supply. The clustering was carried out with the cascadeKM function in package *vegan* in R. It creates several partitions forming a cascade from a small to a large number of groups minimising the sum of squares within the clusters. The values of the criterion Calinski-Harabasz (1974) were used to select the best partition (the correct number of groups). It is used to find the optimum number of groups, minimizing the sum of squares within the clusters and maximizing the sum of squares among the clusters. In order to help the interpretation of the cluster analysis, hotspot analyses were complemented for bundles of ecosystem services identified by the principle component analysis. They were conducted with the Hot Spot Analysis (Getis-Ord Gi*) function in ArcGIS 10.1 for a random selection of 15000 1km cells in less favoured areas.

b. The less favoured agricultural areas in administrative units can be evaluated based on the spatial rate of the high/medium or high capacity areas. The number of ecosystem services for which more than 50% of the agricultural area in a given unit has high (or medium/high) capacity was determined. An indicator obtained with similar calculation by Egoh et al. (2008) is called service richness. Some examples are shown for NUTS3 regions.

   From this analysis the following indicators can be determined: For how many (and for which) ecosystem services has a certain region high (or medium/high) capacity in more than 50% of its agricultural area? Alternatively, if the aim is to evaluate the administrative units based on selected services, the spatial rate of low/medium/high classes can be determined for those services in interest.

c. A multifunctionality indicator was calculated from the number of services potentially delivered at least at medium level (at $1km^2$ spatial level) separately for LFA and for non-LFA in NUTS2 regions following the next equation:

$$MF_{NUTS2} = \frac{1 * R1 + 2 * R2 + 3 * R3 + 4 * R4 + 5 * R5 + 6 * R6 + 7 * R7 + 8 * R8 + 9 * R9}{9}$$

Where: MF_{NUTS2} is the multifunctionality indicator, and

$$R_n = \frac{N_{SERVn}}{N_{LFA\ or\ non-LFA}}$$

Where

- N_{SERVn} is the number of 1km cells in the NUTS2 region with n number of services potentially delivered at least at medium level, n = 1, 2, …., total number of studied services;
- $N_{LFA\ or\ non\text{-}LFA}$ is the number of 1km cells classified as less favoured agricultural area (or non-less favoured area) in the NUTS2 region.

The multifunctionality indicator was calculated on the basis of all nine ecosystem services included in present study and also on the basis of only provisioning and only regulating and maintenance services. It was not calculated for cultural services as for that group of services only one indicator is available. For the biomass production capacities the actual set of potential supply indicators were used.

4 Results

4.1 Indicators

The statistics of the selected indicators for ecosystem capacities are presented in Table 6. Note that all indicators and therefore all results concern ecosystem capacities instead of actual flows of services.

Table 6 Statistics of the capacity indicators in the study area, agricultural land in the 25 Member States.

Ecosystem service	min	max	mean	STD
Water provision	79.68	2907.08	351.81	173.88
Crop provision – potential	0	1	0.61	0.17
Crop provision – actual set of supply	0	1	0.401	0.251
Reared animals provision – potential	0	1	0.59	0.18
Reared animals provision – actual set of supply	0	1	0.146	0.210
Erosion control	0.29	1	0.84	0.09
Water regulation	0.199	0.575	0.31	0.07
Pollination	0	0.90	0.11	0.12
Habitat maintenance	0	1600	570.21	499.71
Global climate regulation	0	1390.3	93.68	107.36
Global climate regulation (after outlier transformation)	0	179.92	78.92	42.98
Recreation	0.06	0.88	0.24	0.13

4.2 Maps of capacity indicators for LFA and for non-LFA

The spatial distribution of the capacity indicators for nine ecosystem services in LFA and in non-LFA can be seen in the following maps, showing the original values of all indicators classified in four groups by quantiles. Percentage distributions of low – medium – high capacity areas in LFA and in non-LFA (for the methodology see section 3.3.c.) help to interpret the differences between LFA and non-LFA quantitatively.
At EU level, most of the ecosystem services can be classified in three groups based on the percentage distribution of low, medium and high capacity areas in LFA and in non-LFA.

4. Mainly low capacity in LFA and high capacity in non-LFA: capacity for crop provision, potential supply for reared animals provision, water provision.

5. Mainly high capacity in LFA and low capacity in non-LFA: capacity for erosion control, habitat maintenance, pollination and recreation.

6. The capacity is mainly medium in both LFA and non-LFA, and the share of medium capacity is higher in non-LFA than in LFA: capacity for water regulation and for global climate regulation. However, for water regulation there are more low capacity areas in LFA than in non-LFA, and on the contrary, there are more high capacity areas in non-LFA than in LFA, whereas for global climate regulation both low and high capacity areas have higher share in LFA than in non-LFA.

The actually used potential supply for reared animals is mainly low in both LFA and non-LFA. Nevertheless, there are more low capacity areas in non-LFA and more medium and high capacity areas in LFA.

4.2.1 Provisioning services

1 - Cultivated crops

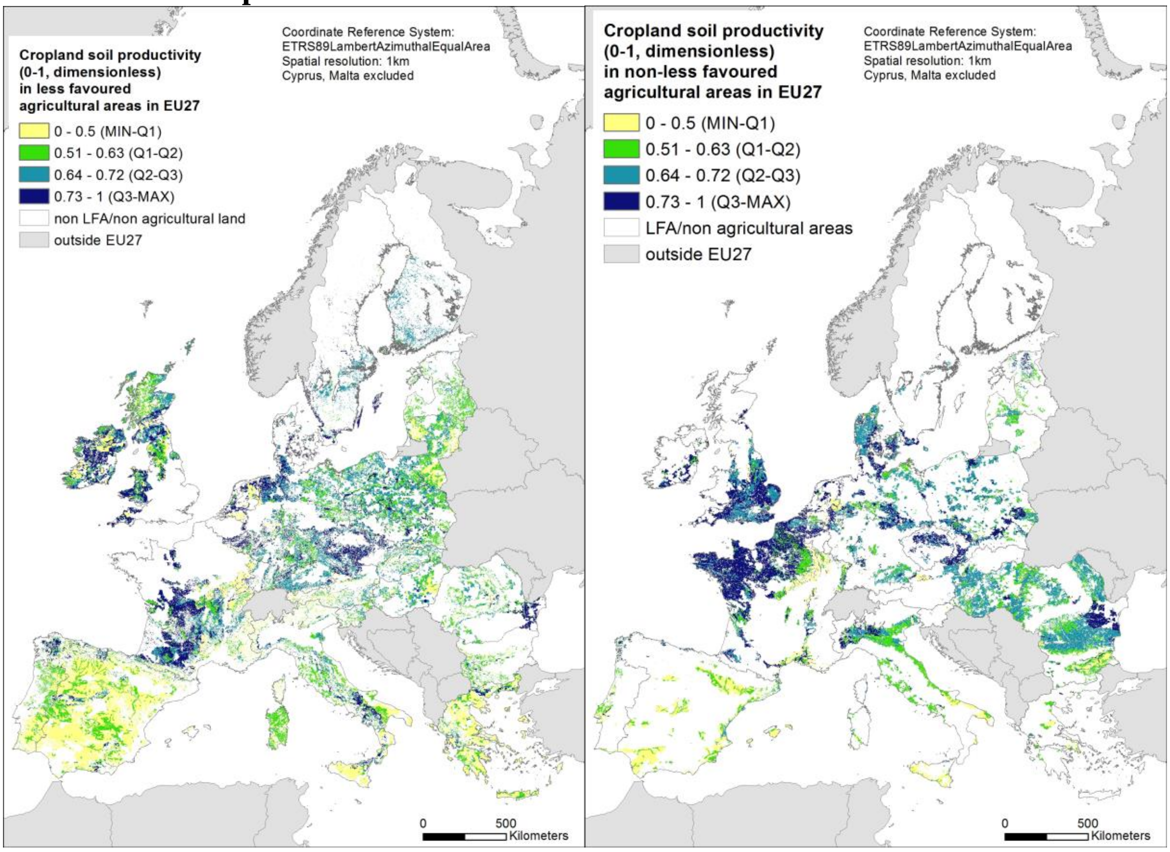


Figure 2 Cropland soil productivity in (left) less favoured and in (right) non-less favoured agricultural areas of EU27 as an indicator for the ecosystem capacity (potential supply) for the service of cultivated crops. Data source: Tóth et al., 2013.

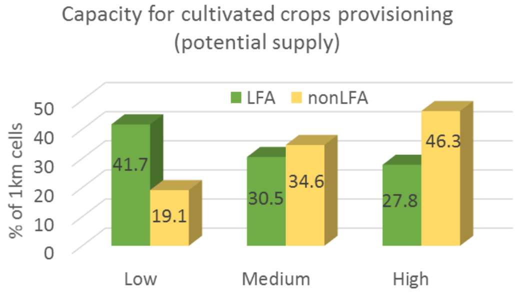


Figure 3 Percentage distribution of low, medium and high potential supply for cultivated crops provisioning. N_{LFA} = 1276559, $N_{non\text{-}LFA}$ = 898850.

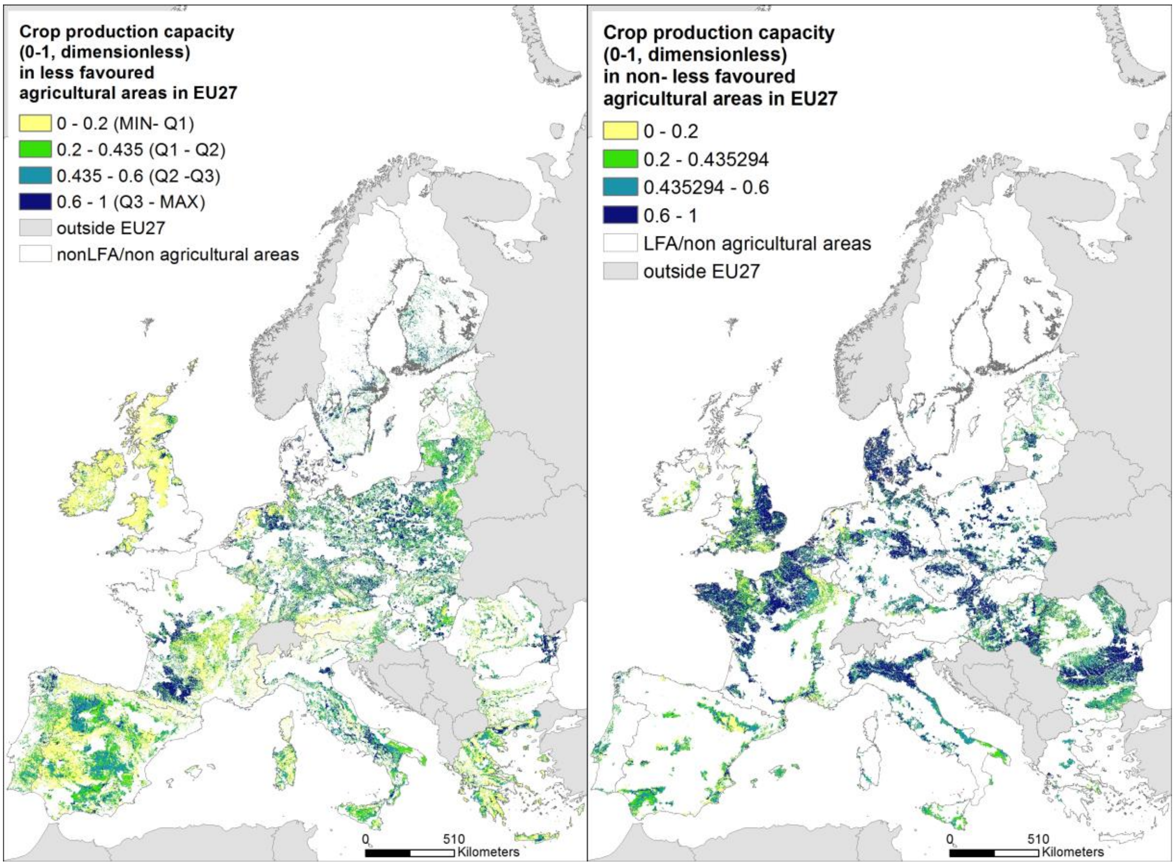


Figure 4 Crop production capacity (share of cropland (from CLC2006, and CLC2000 for Greece) weighted with the cropland soil productivity index (Source: Tóth et al., 2013)) in (left) less favoured and in (right) non-less favoured agricultural areas, as an indicator for the actually used set of supply for cultivated crops provisioning service.

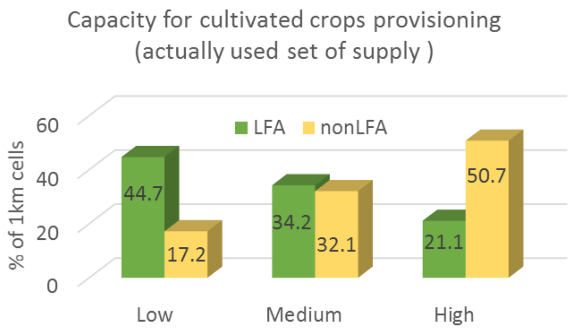


Figure 5 Percentage distribution of low, medium and high actually used set of supply for cultivated crops provisioning. N_{LFA} = 1275159, $N_{non\text{-}LFA}$ = 897602.

2- Reared animals and their outputs

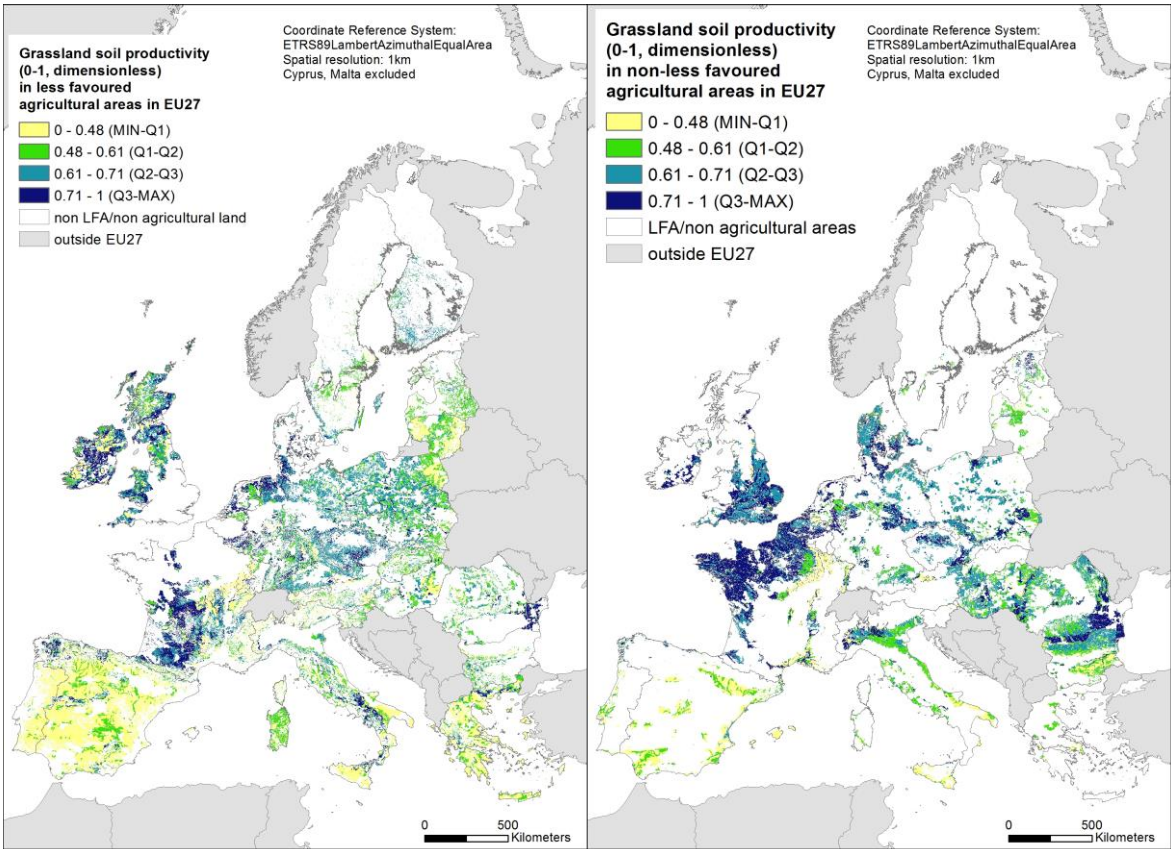


Figure 6 Grassland soil productivity in (left) less favoured and in (right) non-less favoured agricultural areas of EU27 as an indicator for the capacity (potential supply) to deliver the ecosystem service of reared animals and their outputs. Data source: Toth et al., 2013.

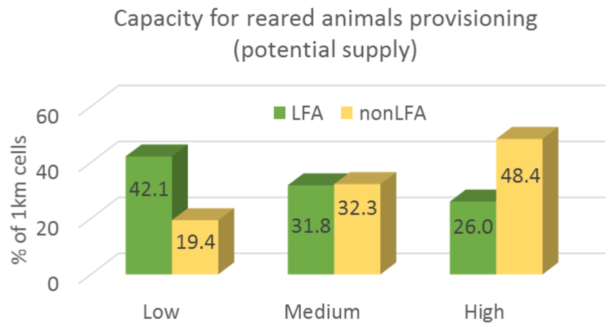


Figure 7 Percentage distribution of low, medium and high potential supply for reared animals provisioning. N_{LFA} = 1276559, $N_{non\text{-}LFA}$ = 898850.

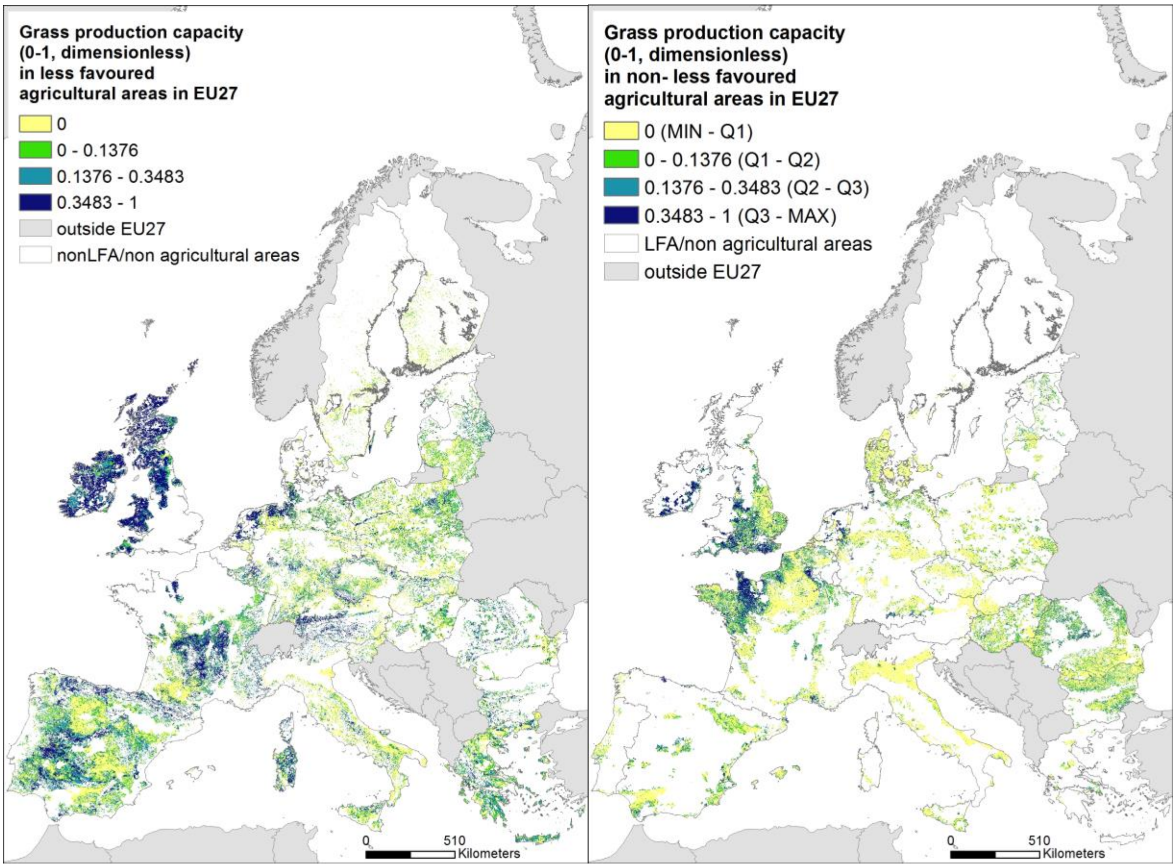


Figure 8 Grass production capacity (share of grassland (from CLC2006, and CLC2000 for Greece) weighted with the grassland soil productivity index (Source: Tóth et al., 2013)) in (left) less favoured and in (right) non-less favoured agricultural areas of EU27 as a proxy for the ecosystem capacity for reared animals provisioning service.

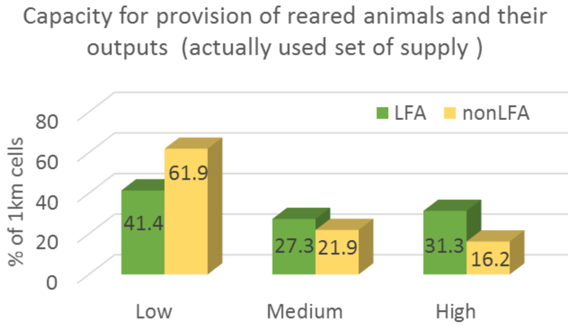


Figure 9 Percentage distribution of low, medium and high actually used set of supply for reared animals provision. N_{LFA} = 1 275 159, $N_{non\text{-}LFA}$ = 897 602.

3 - Water provision for drinking and for non-drinking purposes

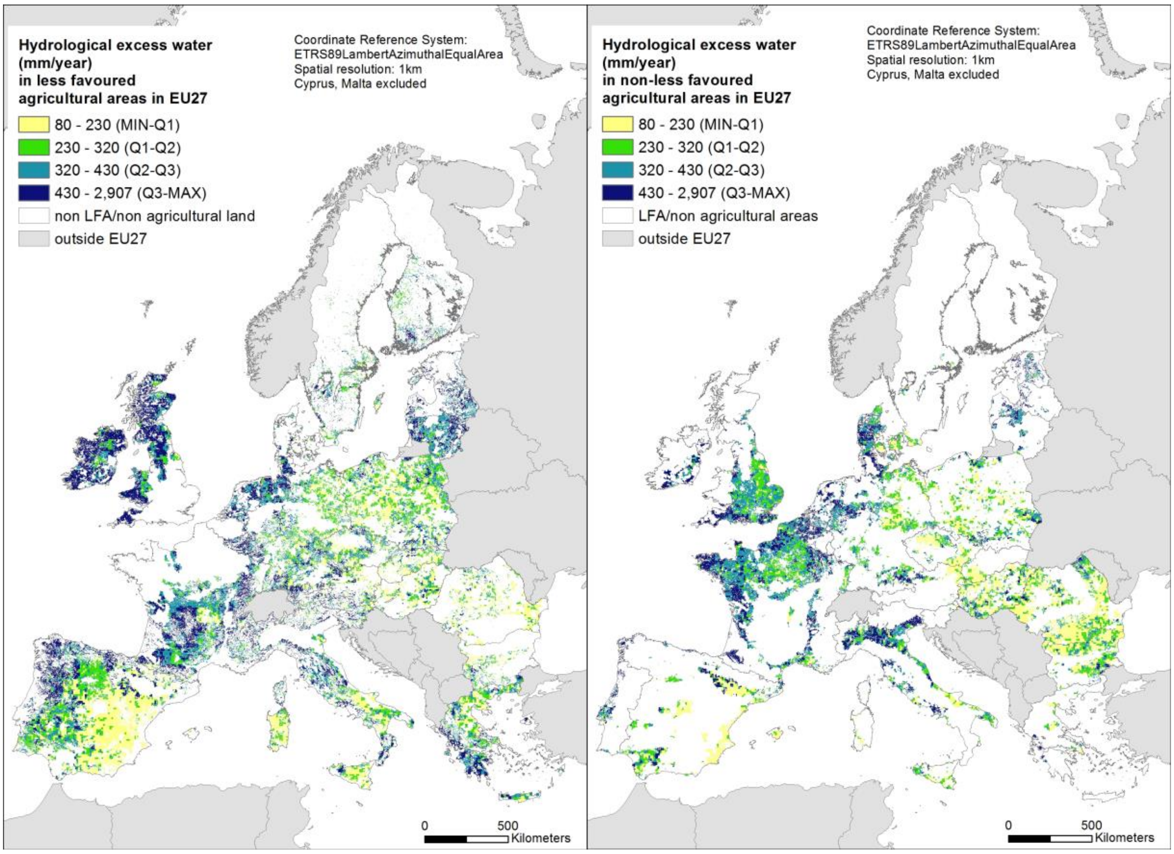


Figure 10 Hydrological excess water in (left) less favoured and in (right) non-less favoured agricultural areas of EU27 as a proxy for the ecosystem capacity for water provision. Data source: Wriedt and Bouraoui (2009)

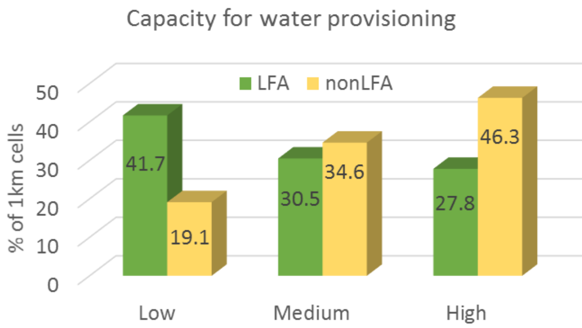


Figure 11 Percentage distribution of low, medium and high capacity for water provision. N_{LFA} = 1248769, $N_{non-LFA}$ = 887327.

4.2.2 Regulating and maintenance services

1 - Mass stabilisation and control of erosion rates

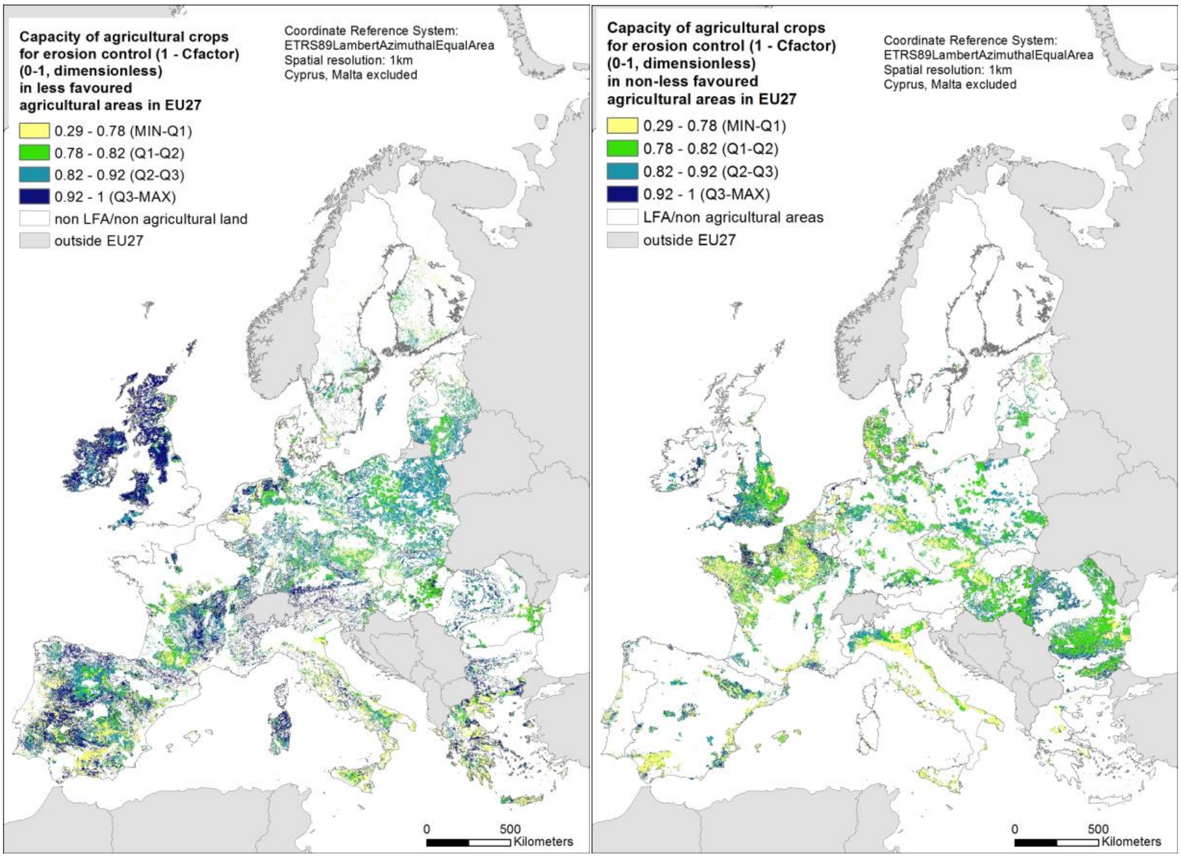


Figure 12 Erosion control indicator (1 – C-factor) in (left) less favoured and in (right) non-less favoured agricultural areas of EU27 as an indicator for the capacity of agro-ecosystems for erosion control. Data source: CAPRI model (Terres et al., 2013.).

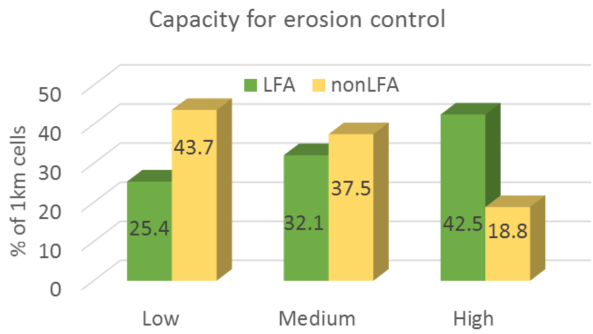


Figure 13 Percentage distribution of low, medium and high capacity for erosion control. N_{LFA} = 1284127, $N_{non\text{-}LFA}$ = 902475.

2 - Hydrological cycle and water flow maintenance

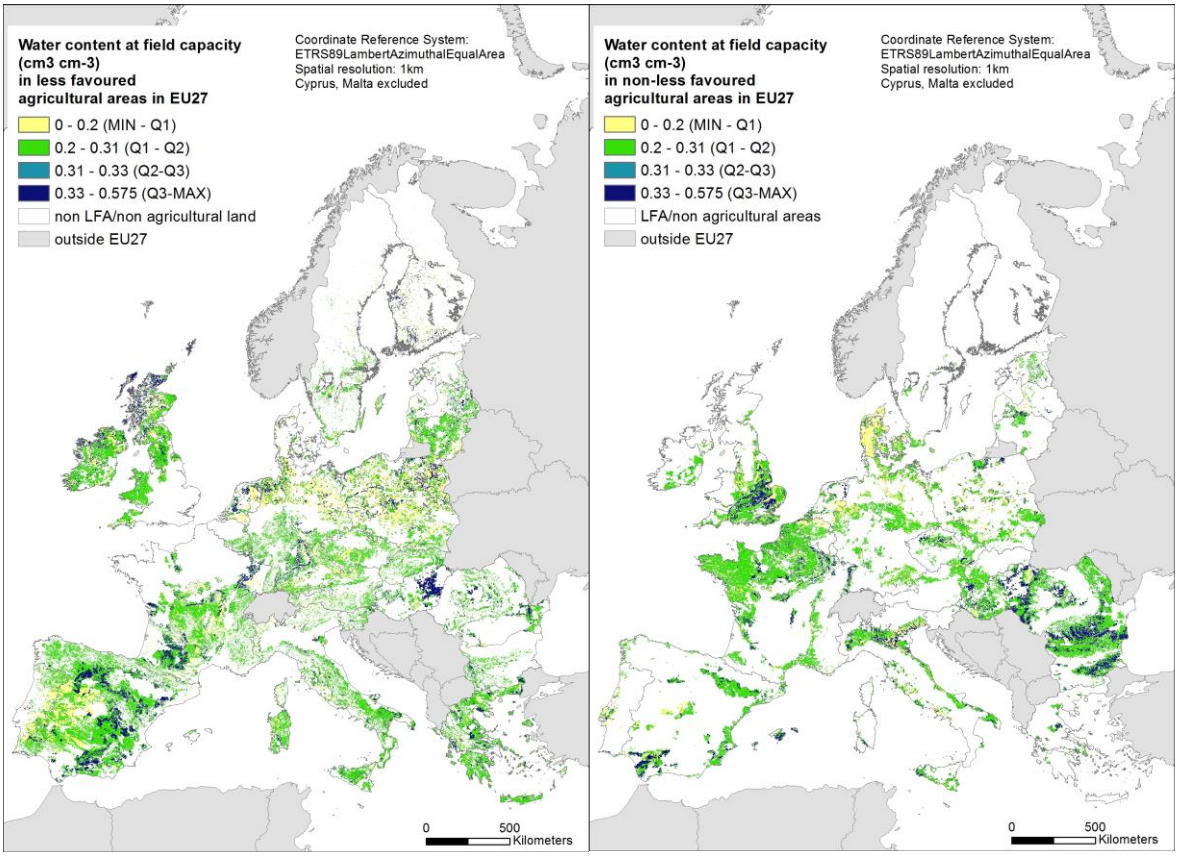


Figure 14 Topsoil water content at field capacity (cm3 cm-3) in (left) less favoured and in (right) non-less favoured agricultural areas of EU27 as an indicator of the ecosystem capacity to deliver water regulation. Data source: European Soil Database, derived data, Hiederer, R. (2013a,b).

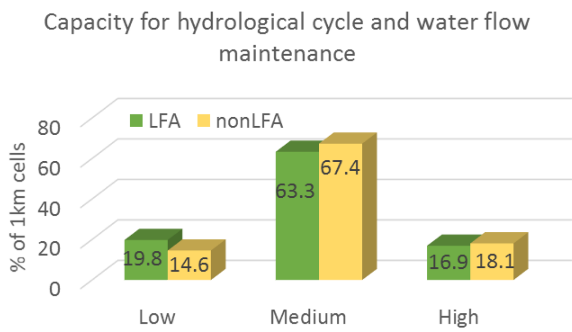


Figure 15 Percentage distribution of low, medium and high capacity for hydrological cycle and water flow maintenance. N_{LFA} = 1270586, $N_{non\text{-}LFA}$ = 900673.

3 - Pollination

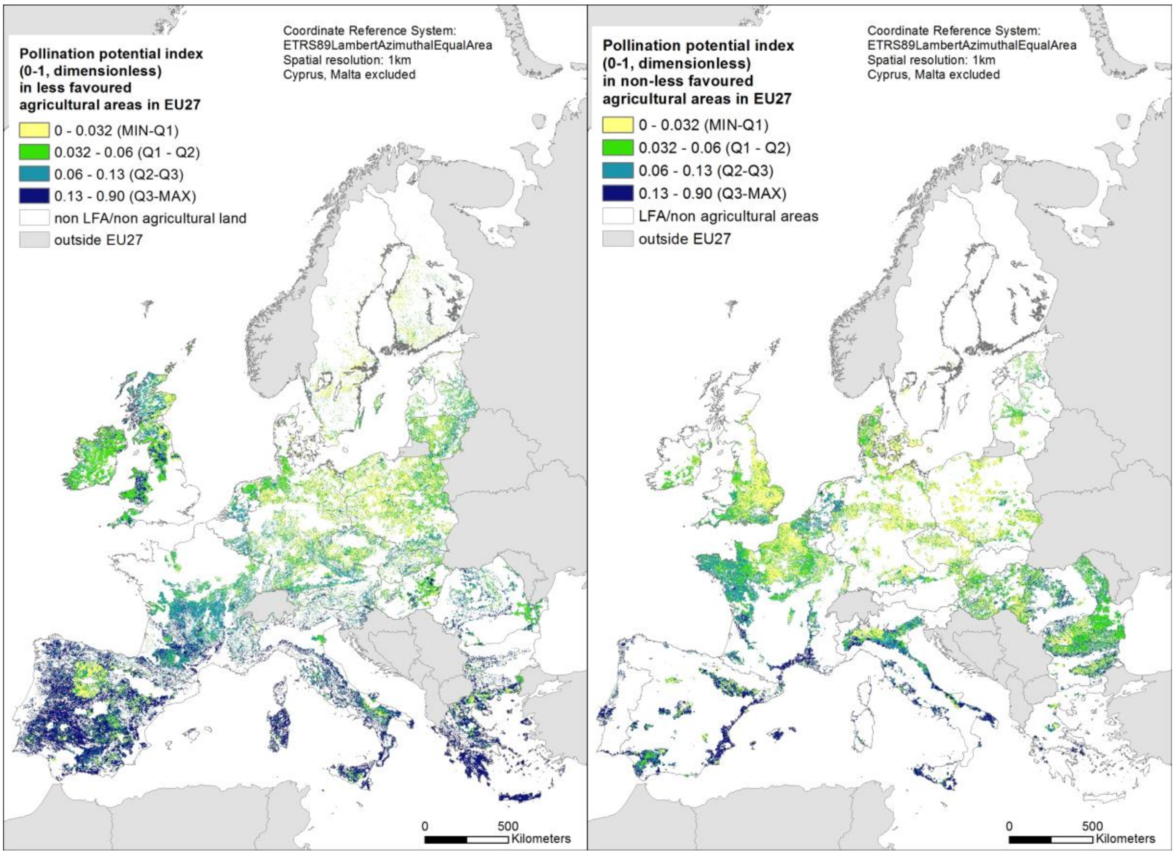


Figure 16 Pollination potential in (left) less favoured and (right) in non-less favoured agricultural areas of EU27 as an indicator for the capacity of ecosystems for maintaining pollination. Data source: Zulian et al., 2013a.

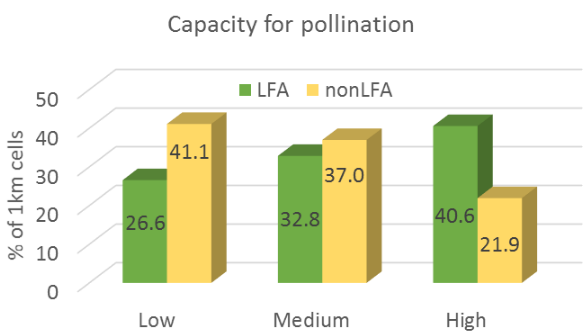


Figure 17 Percentage distribution of low, medium and high capacity for pollination. N_{LFA} = 1283505, $N_{non\text{-}LFA}$ = 902215.

4 - Maintaining nursery populations and habitats

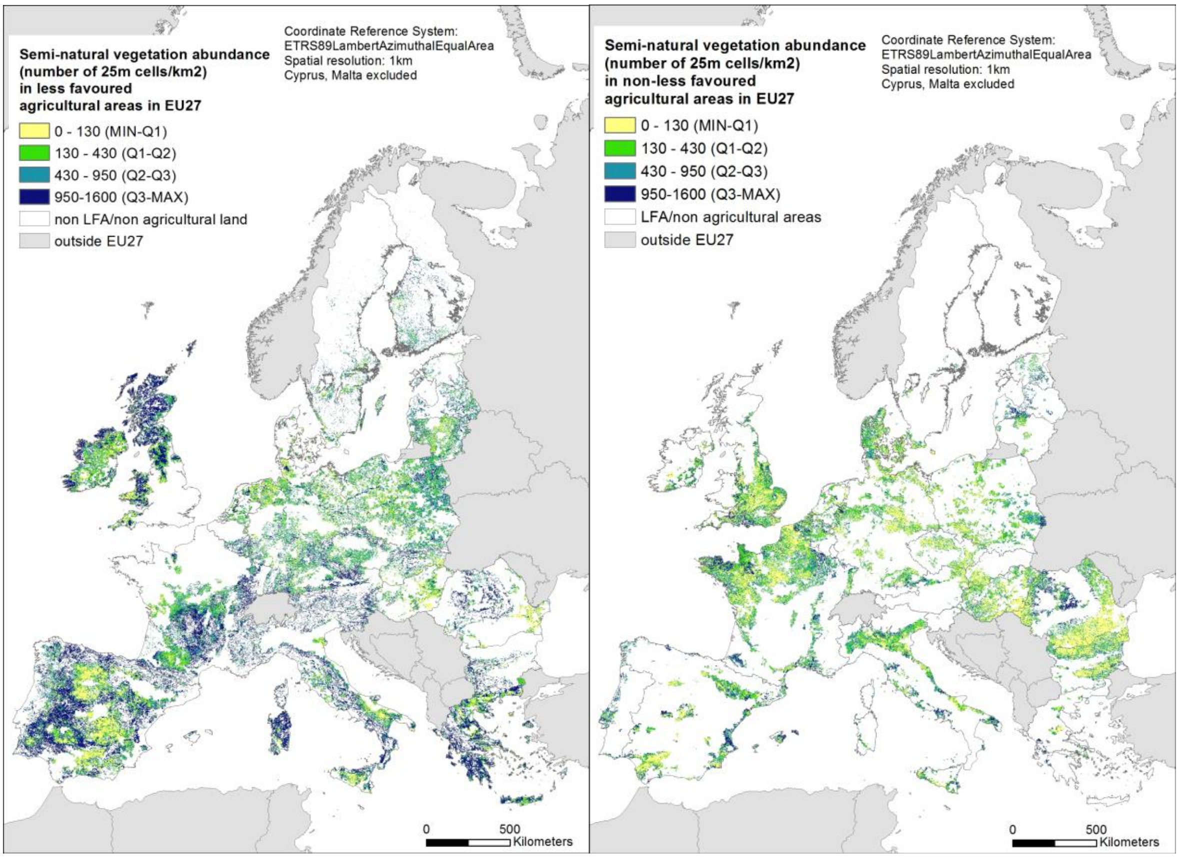


Figure 18 Share of semi-natural vegetation (number of 25 m cells covered by semi-natural vegetation) in (left) less favoured and in (right) non-less favoured agricultural areas of EU27 as a proxy for the capacity to maintain nursery populations and habitats. Data source: Garcia-Feced et al, 2015.

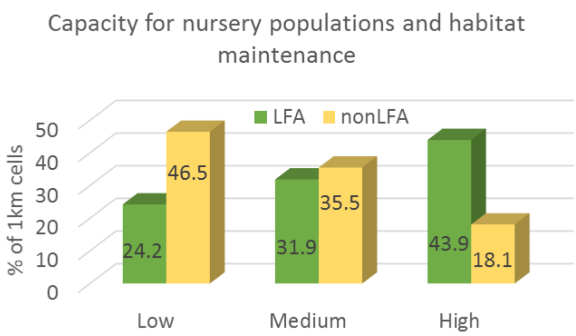


Figure 19 Percentage distribution of low, medium and high capacity for maintaining nursery populations and habitats. N_{LFA} = 1284127, $N_{non\text{-}LFA}$ = 902475.

5 - Global climate regulation by reduction of greenhouse gas concentrations

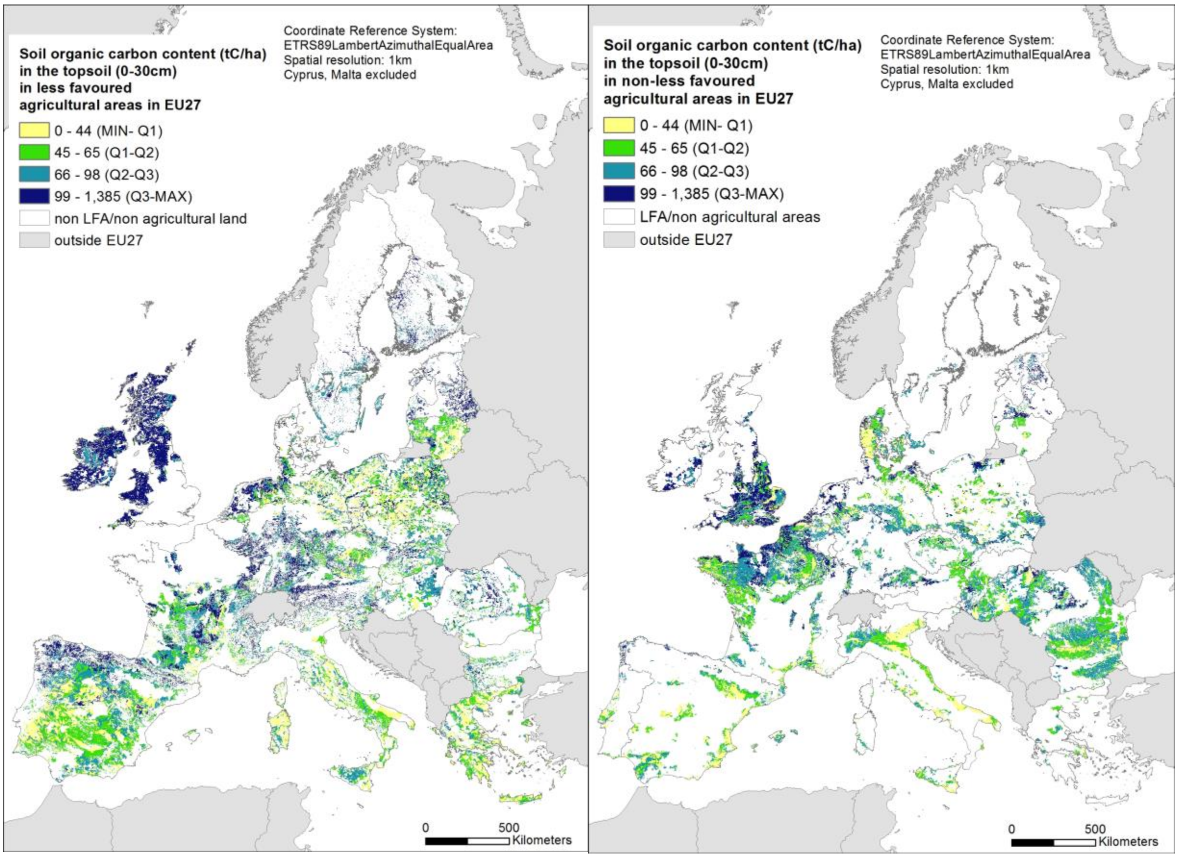


Figure 20 Organic carbon content in the topsoil (0-30 cm) (t C/ ha agricultural area) in (left) less favoured and in (right) non-less favoured agricultural areas of EU27 as an indicator of the ecosystem capacity to deliver climate regulation. Data source: Lugato et al., 2014

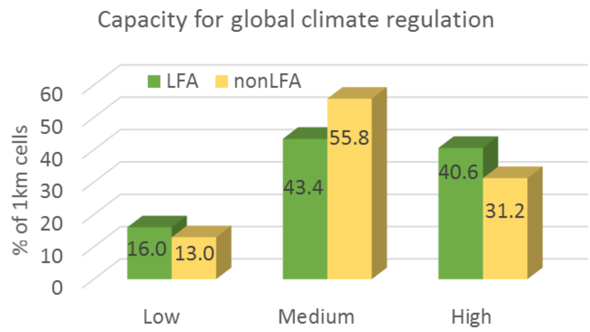


Figure 21 Percentage distribution of low, medium and high capacity for global climate regulation. N_{LFA} = 1278162, $N_{non\text{-}LFA}$ = 901887.

4.2.3 Cultural services

Physical and intellectual interactions with ecosystems

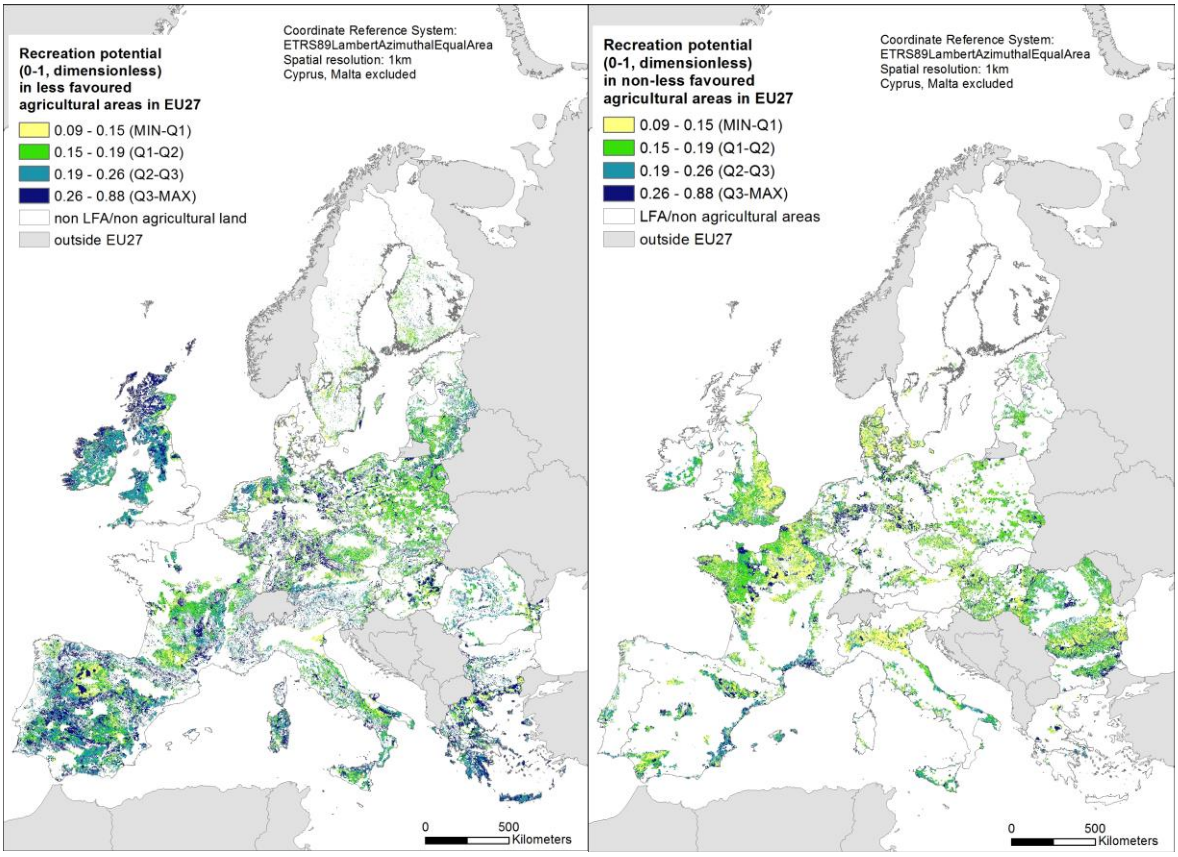


Figure 22 Recreation potential of ecosystems in (left) less favoured and in (right) non-less favoured agricultural areas of EU27. Data source: Paracchini et al., 2014.

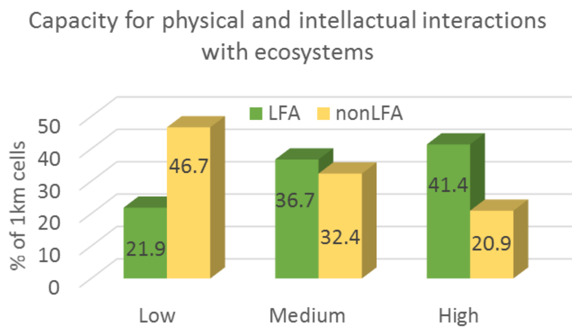


Figure 23 Percentage distribution of low, medium and high capacity for physical and intellectual interactions with ecosystems. N_{LFA} = 1284123, $N_{non\text{-}LFA}$ = 902473.

4.3 Maps of standardized values

The standardized values of indicators can be used for further analysis, similarly as normalized values. They are suitable for identifying areas with very high and/or very low ecosystem capacities. Maps of standardized recreation potential values are presented (Figure 24) here, as examples.

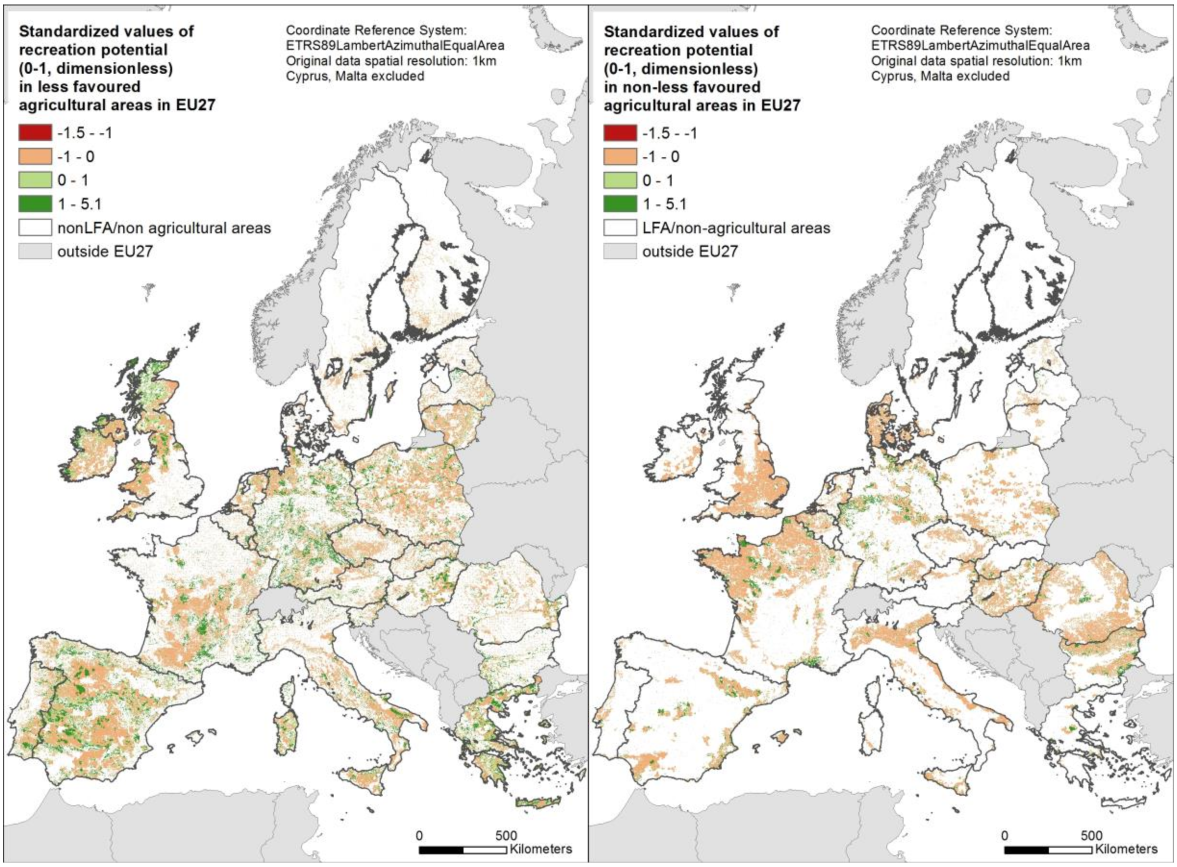
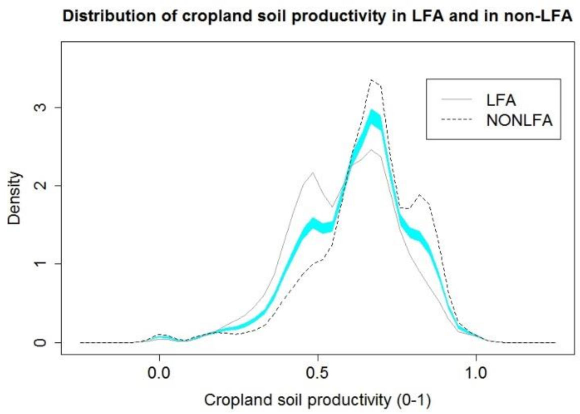


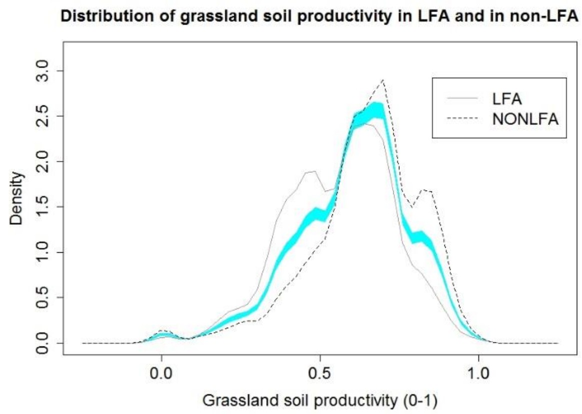
Figure 24 Standardized values of recreation potential in (left) less favoured and in (right) non-less favoured agricultural areas.

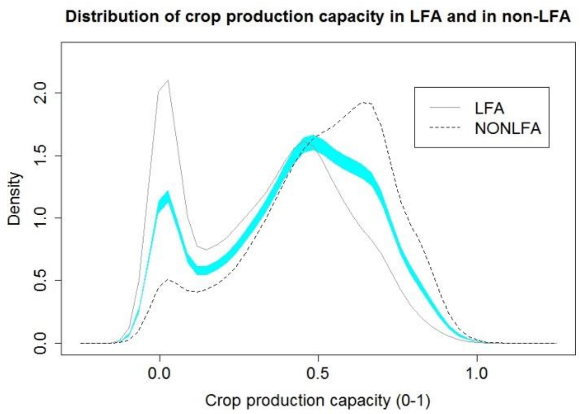
4.4 Comparison of ecosystem capacities between LFA and non-LFA

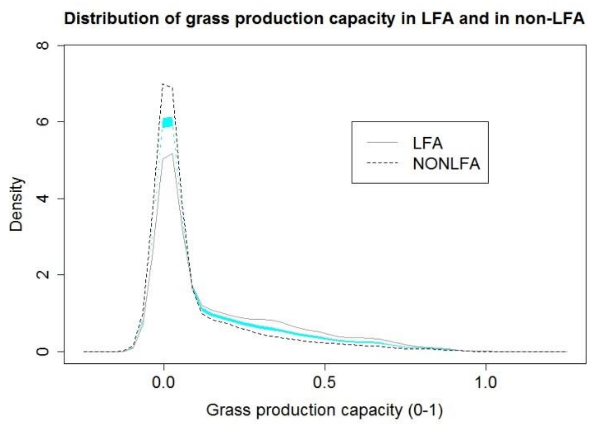
4.4.1 Comparing the distributions of capacity indicators

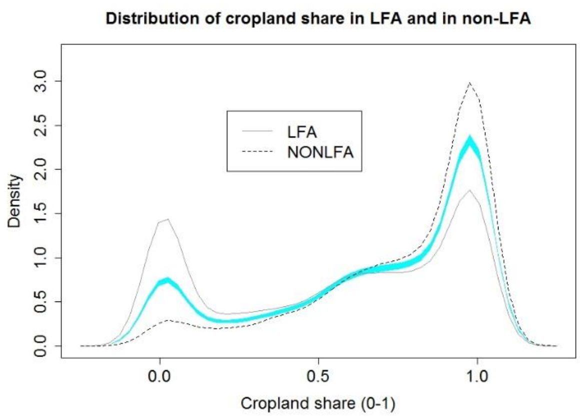
The calculated reference bands are narrow (Figure 25), which shows that the estimations of the distributions are very precise. Both LFA and non-LFA curves are mainly out of it in all cases, which shows that they differ. The bootstrap hypothesis test of equality confirmed the difference for each indicator (N = 5000, p = 0).

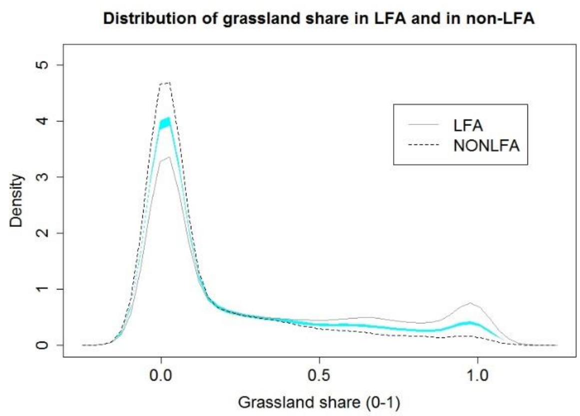

Distribution of cropland soil productivity in LFA and in non-LFA
LFA
NONLFA
Density
Cropland soil productivity (0-1)

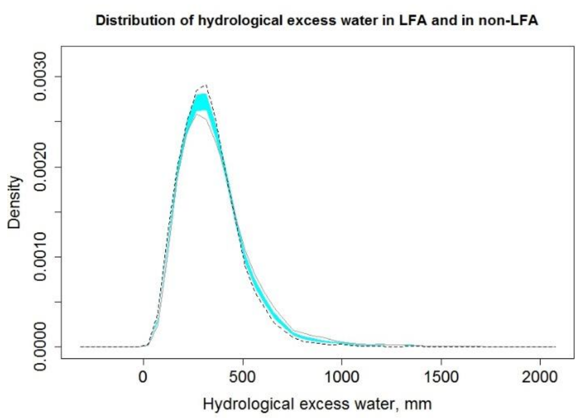

Distribution of grassland soil productivity in LFA and in non-LFA
LFA
NONLFA
Density
Grassland soil productivity (0-1)


Distribution of crop production capacity in LFA and in non-LFA
LFA
NONLFA
Density
Crop production capacity (0-1)


Distribution of grass production capacity in LFA and in non-LFA
LFA
NONLFA
Density
Grass production capacity (0-1)


Distribution of cropland share in LFA and in non-LFA
LFA
NONLFA
Density
Cropland share (0-1)


Distribution of grassland share in LFA and in non-LFA
LFA
NONLFA
Density
Grassland share (0-1)


Distribution of hydrological excess water in LFA and in non-LFA
Density
Hydrological excess water, mm

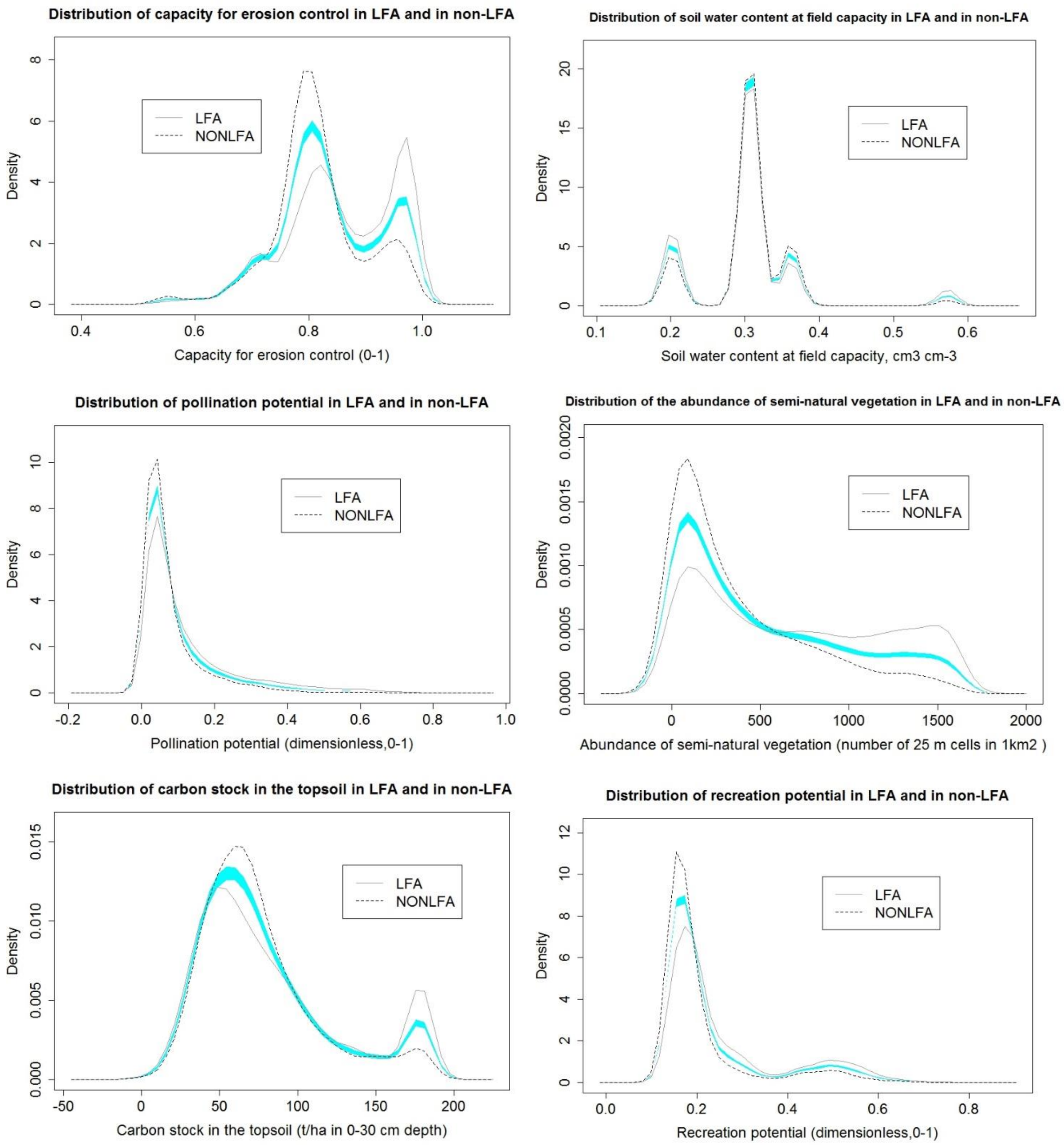


Figure 25 Distribution of each ecosystem capacity indicators in LFA and in non-LFA (N = 5000 for both). Blue line is the appropriate reference band calculated by the sm.density.compare function in R.

The distribution of each capacity is similar shape in LFA and in non-LFA (Figure 25), only the distribution of crop production capacity is slightly different. The Wilcoxon rank sum test confirmed that the distributions are shifted up or down relative to each other significantly for each ecosystem capacity (Table 7). The null hypothesis was rejected at 0.05 significance level in all cases as all p values are below 0.05. There are more than one peaks in the distribution of more indicators. In all cases, one peak is higher in LFA, whereas the other(s) are higher in non-LFA.

Table 7 The test statistic (W) and the p-values of the Wilcoxon rank sum test for each ecosystem service.

Ecosystem service	W	P
Water provision	13.660.904	8.797e-16
Crop provision – actually used supply	7.406.513	< 2.2e-16
Crop provision – potential	9.092.352	< 2.2e-16
Reared animals provision - actually used supply	15.394.398	< 2.2e-16
Reared animals provision - potential	8.819.993	< 2.2e-16
Erosion control	16.084.817	< 2.2e-16
Water regulation	11.670.071	8.54e-12
Pollination	15.561.379	< 2.2e-16
Habitat maintenance	17.028.121	< 2.2e-16
Global climate regulation	13.140.635	9.042e-06
Physical and intellectual interactions with ecosystems	16.789.460	< 2.2e-16

4.4.2 Comparison of median values

The difference between median values of LFA and non-LFA (in % of the median in non-LFA) at EU level is the highest for habitat maintenance, then for pollination and thirdly for the actually used set of supply for crop provision (Table 8). The biomass provisioning capacities are higher in non-LFA except the actual set of potential supply for reared animals provision. LFA has higher capacity for all of the other studied services at EU level.

The median values of some capacities only slightly differ between LFA and non-LFA, which shows that it is not enough to compare medians, and confirms the necessity of the analysis of whole distributions.

Table 8 The median of each indicator in less favoured (LFA) and in non-less favoured agricultural areas (non-LFA), and the difference between them in the study area. $Median_{LFA}$ is the median value in LFA, $Median_{nonLFA}$ is the median value in non-LFA, DIFF = $Median_{LFA}$ - $Median_{non\ LFA}$, DIFF (%) = $|(Median_{LFA} - Median_{non\ LFA}) / Median_{non\ LFA}| *100$. The services are in decreasing order concerning the DIFF (%).

Type of the ecosystem service	Ecosystem service	Median $_{LFA}$	Median $_{non-LFA}$	DIFF	DIFF (%)
Regulating	Habitat maintenance	636	231	405	175
Regulating	Pollination	0.0724	0.0468	0.0256	55
Provisioning	Crop provision – actually used supply	0.35	0.54	-0.19	35
Cultural	Physical and intellectual interactions with ecosystems	0.2	0.164	0.036	22
Provisioning	Crop provision – potential	0.59	0.68	-0.09	13
Provisioning	Reared animals - potential	0.58	0.67	-0.09	13
Provisioning	Water provision	331.6	311.5	20.1	6
Regulating	Erosion control	0.851	0.804	0.05	6
Regulating	Global climate regulation	68.99	65.81	3.18	5
Regulating	Water regulation	0.308	0.308	0	0
Provisioning	Reared animals provision - actually used supply	0.0527	0	0.0527	-

The size of the difference between median values in LFA and in non-LFA greatly varies among Member States (Annex VI.). The normalized difference (with the non-LFA EU median) summed up for the 25 countries is highest for habitat maintenance, then for pollination and thirdly for actually used supply for crop provision (Table 9), similarly as the differences at EU level (Table 8).

Table 9 Sum of normalized differences in Member States between the median values in LFA and in non-LFA. N = 25.

	Sum of differences (LFA - non-FA/non-LFA)
Habitat maintenance	42.7
Pollination potential	13.5
Crop provision – actually used supply	9.3
Global climate regulation	5.7
Physical and intellectual interactions with ecosystems	4.8
Reared animals - potential	4.1
Water provision	4.1
Crop provision – potential	3.3
Erosion control	1.9
Water regulation	0.9

In order to explore the deviations of Member States from the EU level assessment, Member States were ordered according to the deviations between

(1) the MS and EU level median values and

(2) the MS and EU level difference between LFA and non-LFA

for each ecosystem capacity.

The ranking of Member States according to the deviation of their LFA median values from the EU LFA median (Figure 26) shows that the deviation can be quite high in many cases and it varies notably among Member States. Note, that where the shown difference (MS LFA – EU LFA) is positive, the MS LFA median is higher than the EU LFA median and vice versa. The variabilities of cropland and grassland soil productivity, erosion control and physical and intellectual interactions with ecosystems in LFA among MSs are rather low, while the other capacities varies more.

Note, that all values refer to less favoured agricultural areas.

Both cropland and grassland soil productivity MS LFA medians differ most strongly (being higher) from the EU LFA median in Belgium.

The median of grass production capacity is quite low at EU level. The countries can be grouped in three types according to the capacity in the less favoured areas, (1) having very low capacity, lower or slightly higher than the EU median, (2) having zero capacity and (3) having higher capacity than the EU median.

The median of crop production capacity is higher than the EU LFA median mainly in some northern European countries.

Water provision capacity is lower in some Central and Southern European countries and higher in some Atlantic and Northern European countries.

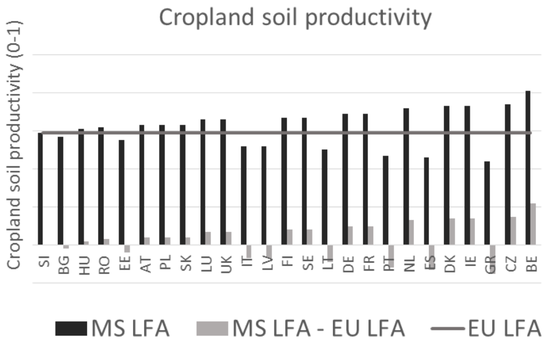
Pollination capacity is lower in some Central and Eastern European countries and higher in Southern European countries compared to the EU LFA median.

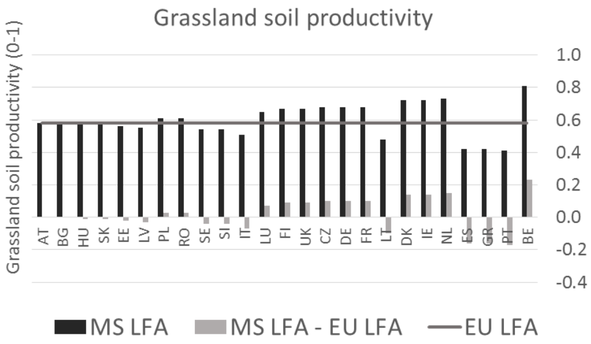
The difference is the highest for habitat maintenance in two Member States containing mainly mountain areas (LFA article 18), in Austria and in Slovenia, where the capacity is higher than the EU median. They are followed by two countries, Denmark and Hungary, without mountain areas, in which the median capacity is lower than the EU median.

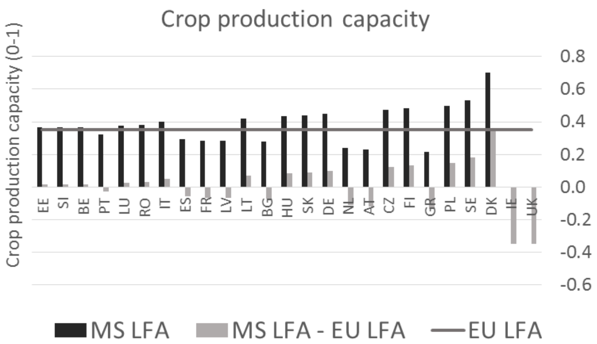
Most Member States with higher pollination and habitat maintenance show relatively higher capacity for the cultural service as well.

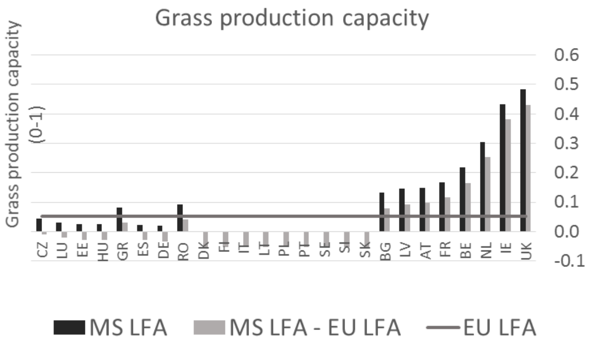
The capacity for global climate regulation is similar or slightly lower than the EU level in less favoured areas of many Member States, while it is higher principally in some Northern European countries.

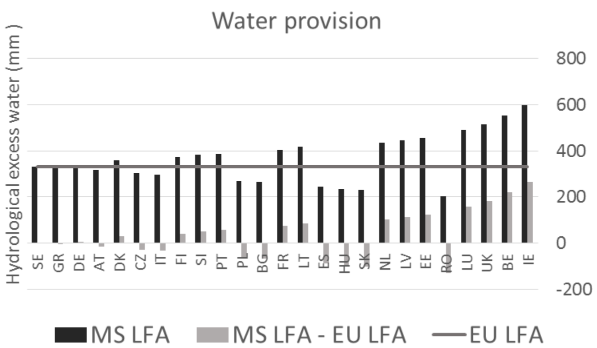
The variability of natural conditions and the agricultural systems and that of the national delineation of less favoured areas can be drivers of the differences.











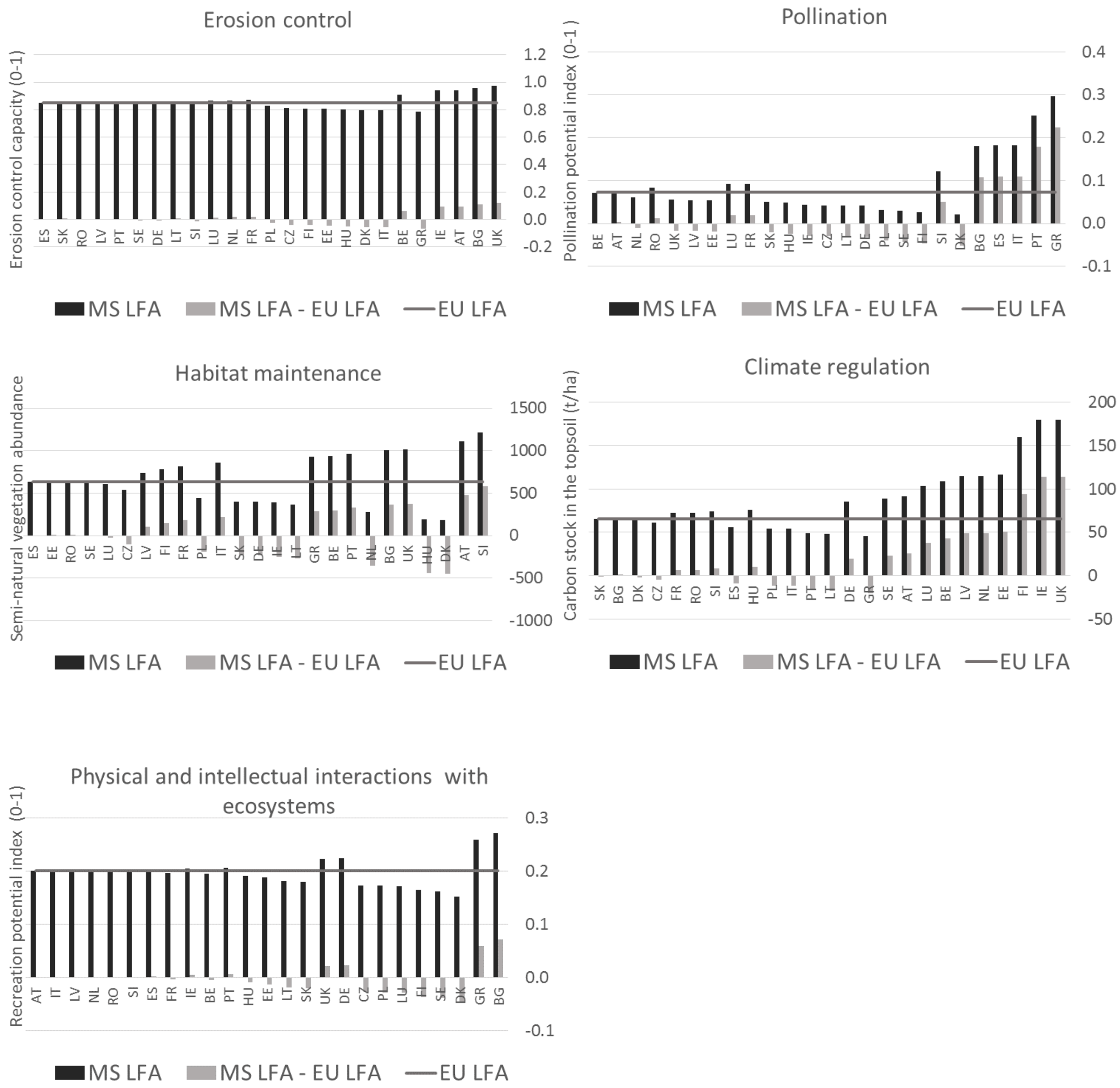


Figure 26 Median values of each ecosystem capacity indicator in 25 Member State (MS) and at EU level, and the differences between MS LFA medians and the EU LFA median. The Member States are lined in decreasing order according to the deviation (in absolute value). LFA: less favoured areas. NONLFA: non-less favoured areas.

Ranking the Member States according to the deviation of the MS level difference between LFA and non-LFA from the EU level difference (Figure 27) helps to identify Member States with lower or higher or even opposite direction difference compared to the EU difference.

Opposite direction differences compared to the EU level difference occur in one or few Member States for each service.

The difference between LFA and non-LFA highly varies both for actually used set of potential supply for cultivated crops and reared animals. The main driver for this can be the differences in the agricultural structure of the countries, i. e. the differences in share of grasslands and croplands at 1km level (Figure 28).

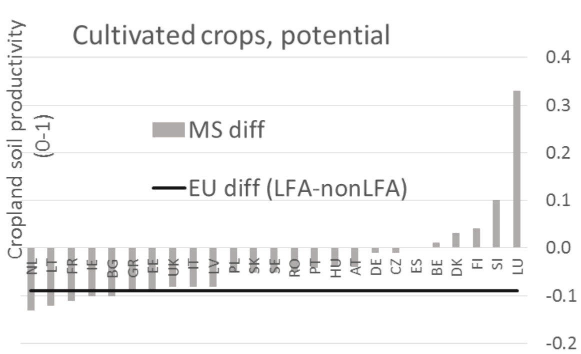
The difference concerning water provision highly varies, too, and in some countries it has opposite direction. It was expected as LFA includes heterogeneous areas and it depends on the natural conditions of the countries.

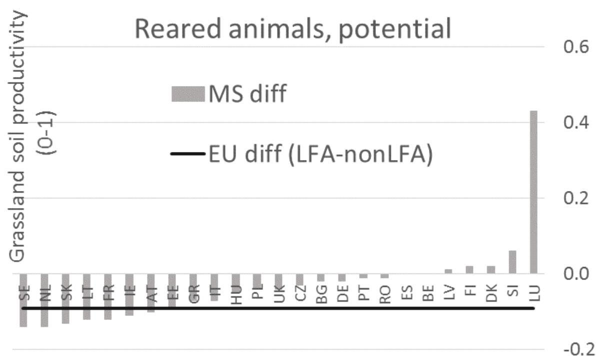
The difference for erosion control is higher in general mainly in countries having more grasslands in LFA.

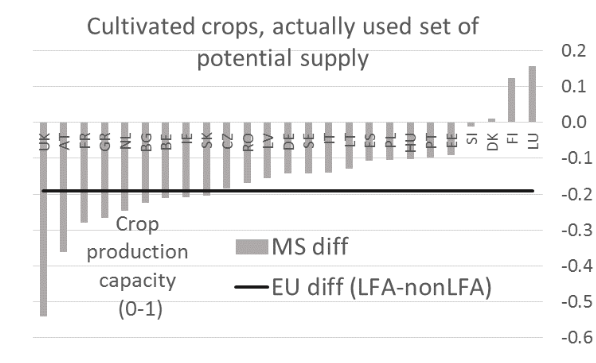
Pollination potential is quite low in all agricultural land at EU level compared to semi-natural areas. The difference for pollination is higher than the EU level difference in some Southern European countries having relatively higher pollination potential in LFA. These countries show higher difference for habitat maintenance, too (Greece, Bulgaria, Italy, Slovenia).

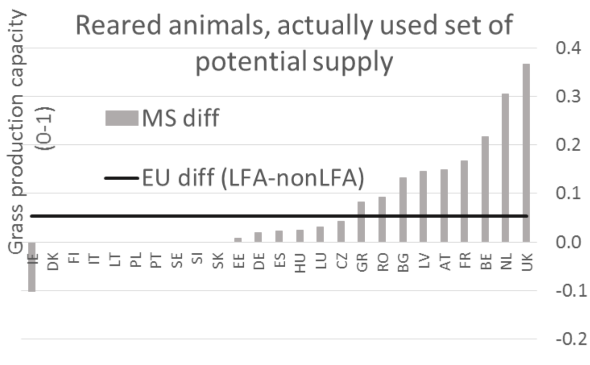
Capacity for global climate regulation is slightly lower in LFA than in non-LFA at EU level, but in most of the Member States it is the opposite. The difference in most of these countries is low, but there are some with a quite high difference, mainly Northern European Member States. The reason behind is that areas with organic soils, where the capacity indicator values are high, are included in LFA and they are mainly located in Northern Europe (Jones et al., 2005).

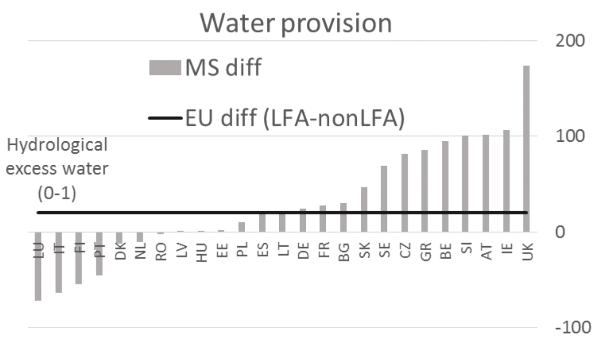
The difference in physical and intellectual interactions with ecosystems is similar in most Member States. In most of the countries it is higher in LFA than in non-LFA and the difference is highest in Bulgaria. The exception is Finland (and Luxembourg with a slight difference) where this capacity is higher in non-LFA than in LFA. The Member States with higher difference for pollination and habitat maintenance show relatively higher difference for the cultural service as well.











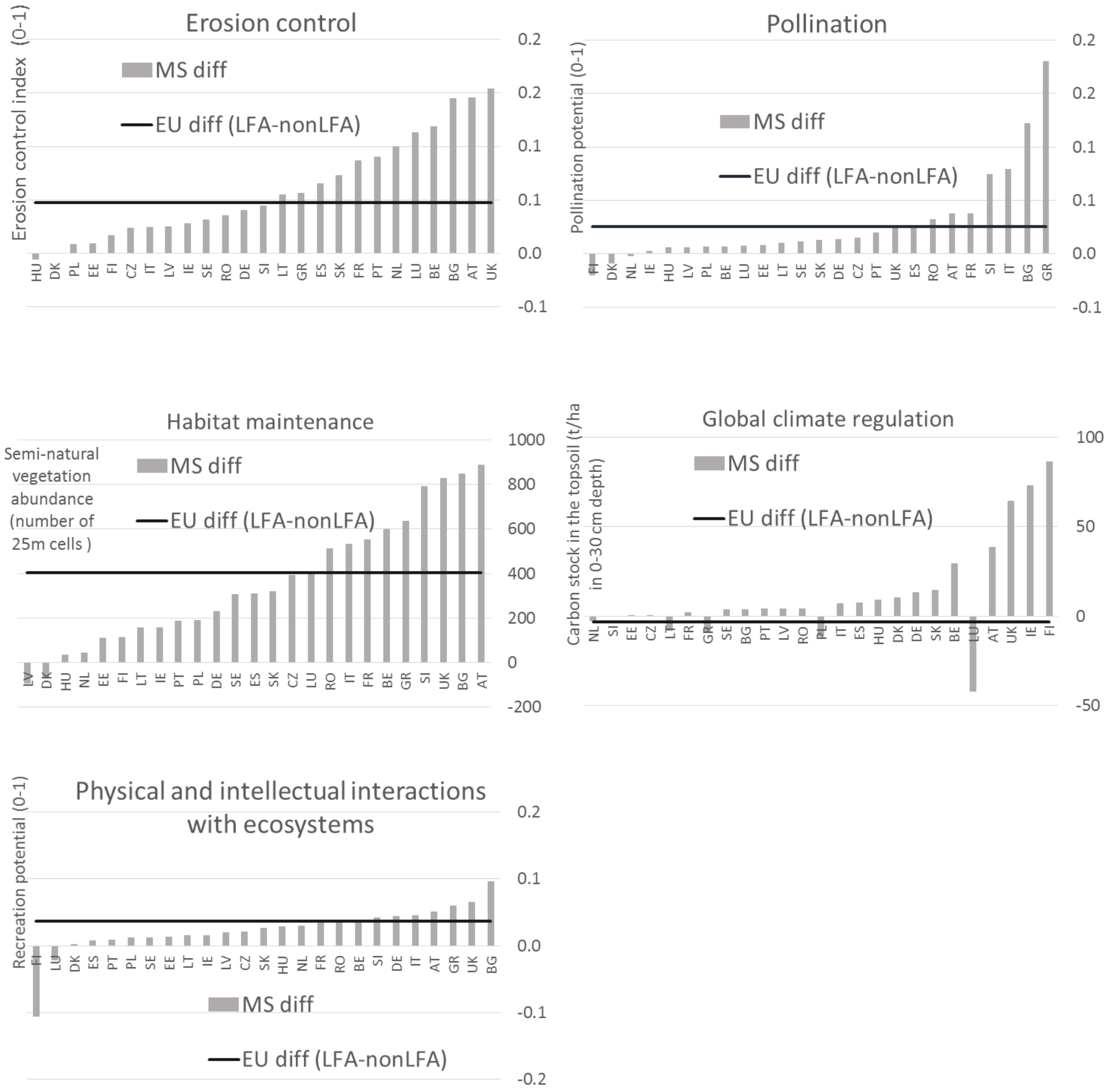


Figure 27 The difference between the median values of each capacity indicator in LFA and in non-LFA at EU level (EU diff, LFA-nonLFA) and in the 25 Member States (MS diff).

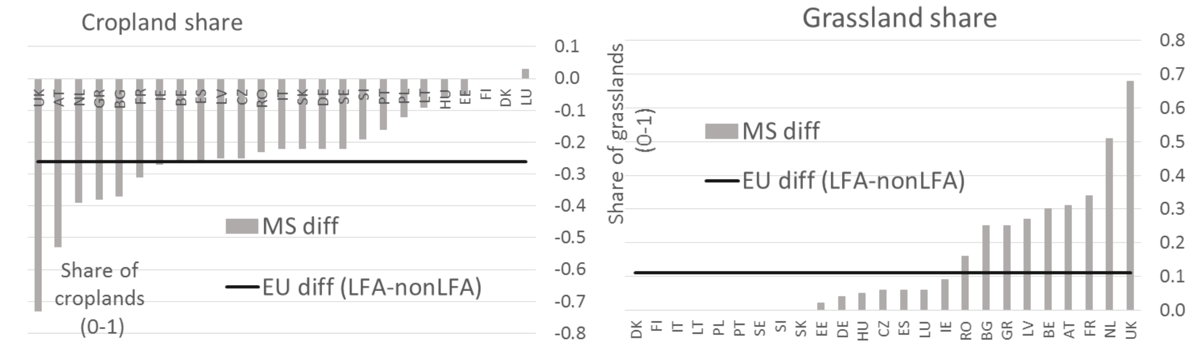


Figure 28 The difference between the median values of cropland and grassland share in LFA and in non-LFA at EU level (EU diff, LFA-non-LFA) and in the 25 Member States (MS diff).

4.4.3 Comparing the mean values of the capacity indicators

The statistics used for the comparison of the average capacities in LFA and in non-LFA in the agricultural area in 25 Member States can be seen in Table 8. The potential supply for biomass provisioning services (cropland and grassland soil productivity) are lower in LFA. The actually used set of supply (capacity with the current land use) for crop production (crop production capacity) is also lower in LFA than in non-LFA. The grass production capacity is already higher in LFA due to the higher share of land currently available for grass production. The capacities for most of the regulating and maintenance services (except for water regulation for which there is no difference) and for recreation are higher in LFA.

The effect size is the highest for crop production capacity. It is high for habitat maintenance, as well. Beyond these two indicators the effect size is above 0.5 (the difference is higher than half of the standard deviation) for grassland soil productivity, equal to 0.5 for erosion control and approximates 0.5 for cropland soil productivity, pollination potential and recreation.

Table 10 The effect size, mean and standard deviation of all used indicators in less favoured (LFA) and in non-less favoured agricultural areas (non-LFA) in the study area. $Mean_{LFA}$ is the mean value for LFA, $Mean_{nonLFA}$ is the mean value for non-LFA, DIFF = $Mean_{LFA}$ - $Mean_{non\ LFA}$, STD_{LFA} is the standard deviation for LFA, STD_{nonLFA} is the standard deviation for non- LFA, STD pooled is the pooled standard deviation (for the calculation method see chapter 3.5). P: provisioning services, R: regulating and maintenance services, C: cultural services.

	Ecosystem service	$Mean_{LFA}$	$Mean_{non\ LFA}$	DIFF	STD_{LFA}	STD_{nonLFA}	STD pooled	Effect Size
P	Water provision	367.3	323	44.3	189.4	146.6	169.4	0.262
	Crop provision – actually used supply	0.322	0.509	-0.187	0.243	0.219	0.231	-0.808
	Crop provision – potential	0.579	0.659	-0.08	0.164	0.159	0.162	-0.495
	Reared animals provision - actually used supply	0.165	0.088	0.077	0.216	0.168	0.193	0.398
	Reared animals provision – potential	0.555	0.646	-0.091	0.17	0.17	0.17	-0.535
R	Pollination	0.128	0.076	0.052	0.137	0.084	0.114	0.458
	Global climate regulation	82.69	73.57	9.12	47.14	35.62	41.78	0.218
	Erosion control	0.857	0.814	0.043	0.0907	0.081	0.086	0.500
	Habitat maintenance	702.2	382.3	319.9	522	396.3	463.4	0.690
	Water regulation	0.305266	0.30499	0.0003	0.077	0.057	0.068	0.004
C	Physical and intellectual interactions with ecosystems	0.26	0.207	0.053	0.135	0.104	0.121	0.440

The effect sizes obtained with resampling of a subset of the database and iteration were all very similar to the original ones (Table 10 and Table 11). The high number of runnings with the same direction of the difference also strengthen the differences, except for water regulation.

Table 11 Results of the Monte-Carlo simulations ($N_{subsample}$ = 200, N_{rep} = 1000). The mean values of the means and standard deviations of the 1000 runnings for all indicators in less favoured (LFA) and in non-less favoured agricultural areas (non-LFA). $Mean_{LFA}$ is the mean value for LFA, $Mean_{non-LFA}$ is the mean value for non-LFA, DIFF = $Mean_{LFA}$ - $Mean_{non-LFA}$, STD_{LFA} is the standard deviation for LFA, $STD_{non-LFA}$ is the standard deviation for non-LFA, STD pooled is the pooled standard deviation (for the calculation method see chapter 3.5). N with the same sign (+/-): the number of runnings resulted in the same direction of the difference as in the original analysis (Table 8). P: provisioning services, R: regulating and maintenance services, C: cultural services.

	Ecosystem service	$Mean_{LFA}$	$Mean_{non\ LFA}$	DIFF	STD_{LFA}	STD_{nonLFA}	STD pooled	Effect Size	N with same

									sign (+/-)
P	Water provision	363.9	332.7	31.2	183.6	149.2	167.3	0.187	975
	Crop provision – actually used supply	0.327	0.513	-0.187	0.241	0.217	0.229	-0.816	1000
	Crop provision – potential	0.579	0.660	-0.081	0.153	0.160	0.157	-0.514	1000
	Reared animals provision - actually used supply	0.182	0.088	0.094	0.220	0.171	0.197	0.476	1000
	Reared animals provision – potential	0.554	0.646	-0.092	0.158	0.171	0.165	-0.560	1000
R	Pollination	0.127	0.078	0.050	0.132	0.084	0.111	0.450	1000
	Global climate regulation	80.5	72.9	7.6	44.3	34.6	39.7	0.191	984
	Erosion control	0.859	0.817	0.042	0.094	0.080	0.087	0.481	1000
	Habitat maintenance	682.2	383.7	298.5	513.3	394.4	457.7	0.652	1000
	Water regulation	0.302	0.303	-0.001	0.075	0.058	0.067	-0.014	444
C	Physical and intellectual interactions with ecosystems	0.261	0.207	0.054	0.134	0.106	0.121	0.443	1000

The mean values and the effect sizes were calculated for all indicators by Member States (Annex VII) as well. At Member State level the differences between the capacities of LFA and non-LFA are variable, e.g. capacity for maintaining nursery populations and habitats differs considerably at EU level but despite it differs significantly between LFA and non-LFA in many Member States as well, there are Member States where the difference is minor (and it can even have opposite direction).

4.5 Trade-offs and synergies among capacities

4.5.1 EU level

Beyond the quantitative comparison of ecosystem capacities between LFA and non-LFA, the spatial trade-offs and synergies among ecosystem capacities were compared as well. According to the PCA results there are only very slight differences between LFA and non-LFA (Figure 29 and Figure 30).

Both in LFA and in non-LFA, besides the isolated capacity for cultivated crops, two bundles of capacities can be detected:

1. Habitat maintenance, pollination and recreation – all related to semi-natural vegetation.

2. Capacity for reared animals provision and climate regulation (water regulation, water provision, and erosion control can be grouped in this bundle but they are poorly correlated to the principle components) – related to soil functions, climate and land use, high values are expected in grasslands having high productivity.

The results revealed that the spatial relationships among ecosystem capacities are mainly determined by the spatial variability of the capacity indicators of cultivated crops, habitat maintenance and climate regulation.

The interrelatedness of the services in the first bundle were observed by the quantitative analyses of the capacities at Member State level (chapter 5.4, comparison of median values).

The hotspots and cold-spots of capacity for cultivated crops and that of the two bundles can be seen next to the PCA results in order to visualize the spatial trade-offs. Differences between LFA and non-LFA:

1. Cultivated crop provision is slightly more strongly correlated to the first two axis in non-LFA than in LFA.
2. Pollination is slightly more strongly correlated to the second component in LFA than in non-LFA.
3. Climate regulation is more strongly correlated to the first component. Therefore these two capacities are closer to each other in non-LFA than in LFA.

However, all these differences are minor.

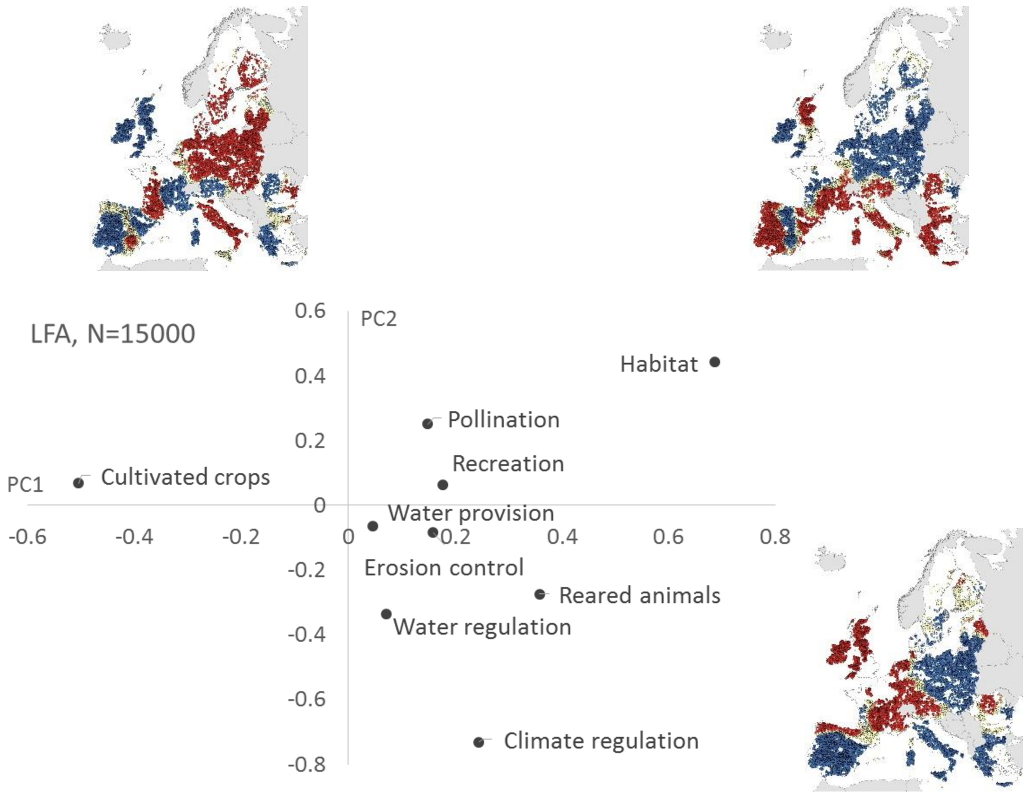


Figure 29 Principle component analysis of capacities for ecosystem services in less favoured areas in EU (N = 15000 grid cells, total explained variance by the first two principal components is 64%). Each dot represents the correlation between normalized capacity indicators and the two first principle components.

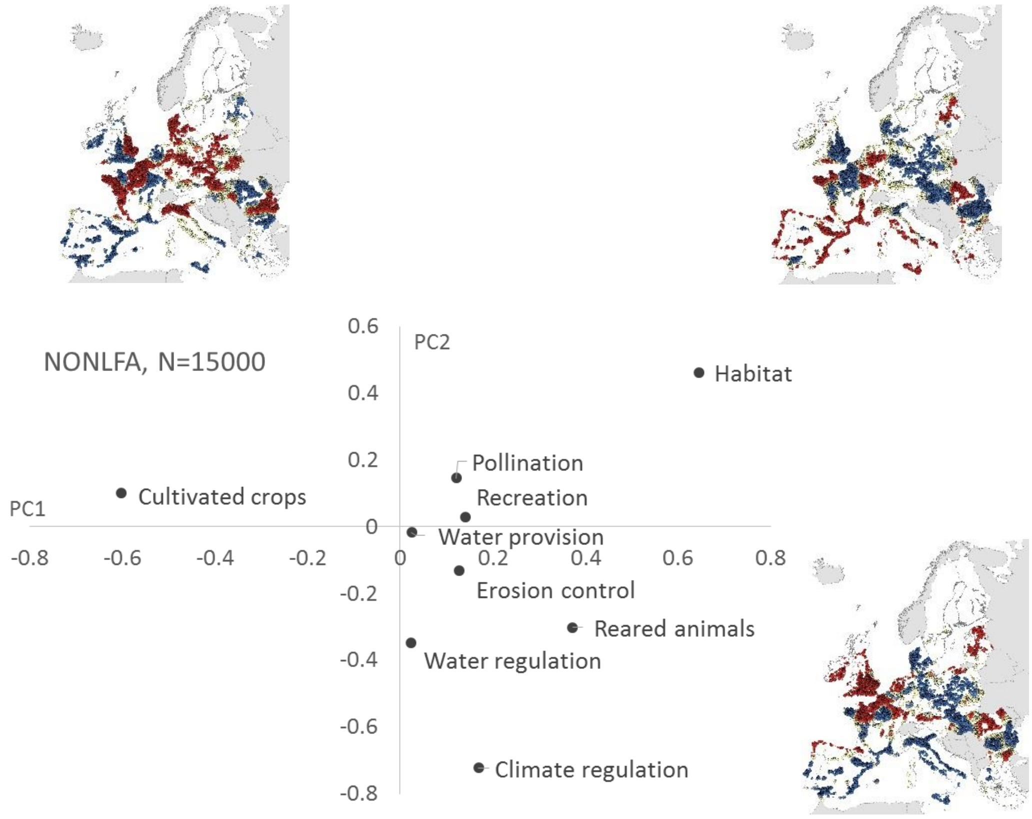


Figure 30 Principle component analysis of capacities for ecosystem services in non-less favoured areas in EU (N = 15000grid cells, total explained variance by the first two principal components is 59%). Each dot represents the correlation between normalized capacity indicators and the two first principle components.

4.5.2 Member State level

The PCA of some countries selected to represent some different biogeographic regions and agricultural systems are shown in this section. Some differences can be observed in their PCA, especially concerning recreation, pollination and climate regulation.

For example, recreation shows trade-off with capacity for cultivated crops in general, but in France (Figure 31) they are not negatively correlated in LFA, while in non-LFA they are.
At EU level, capacity for cultivated crops shows trade-off with climate regulation, while in Romania (Figure 32) it is true only in non-LFA. In Italy there is no strong trade-off between them, moreover, they show synergy in non-LFA (climate regulation correlates with the third principle component).

The synergy between pollination and habitat maintenance is much weaker in three Member States (out of the four examples) than at EU level or even doesn't exist. However, in Italy pollination correlates more strongly with the first three principle components than in the other three countries. The reason behind this can be that the variance of pollination at EU level is higher than at MS level due to the north-south trend in the EU, and this trend can be observed also within Italy. It means that the geographical position has stronger influence on the indicator than the local ecosystem status. In order to focus on the local (Member State or regional) differences, pollination could be mapped normalizing the index with a local maximum.

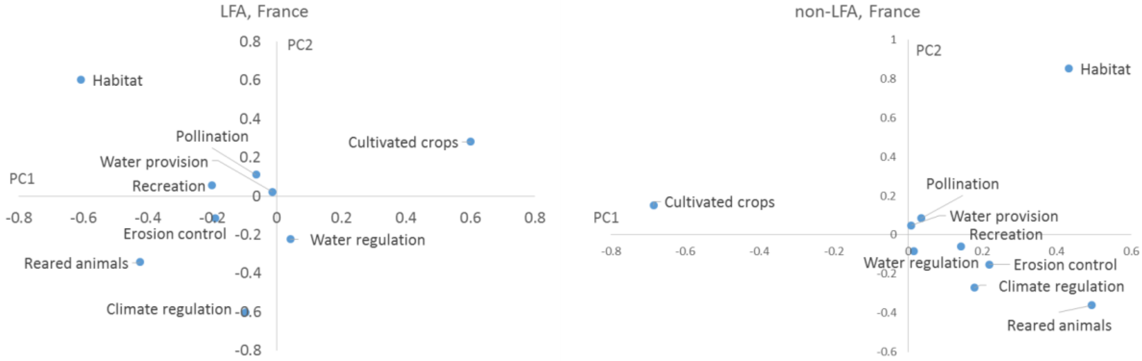


Figure 31 Principle component analysis of ecosystem capacities in less favoured areas (N = 1000grid cells, total explained variance by the first two principal components is 66%) and in non-less favoured areas (N = 1000grid cells, total explained variance by the first two principal components is 63%) in France. Each dot represents the correlation between normalized capacity indicators and the two first principle components.

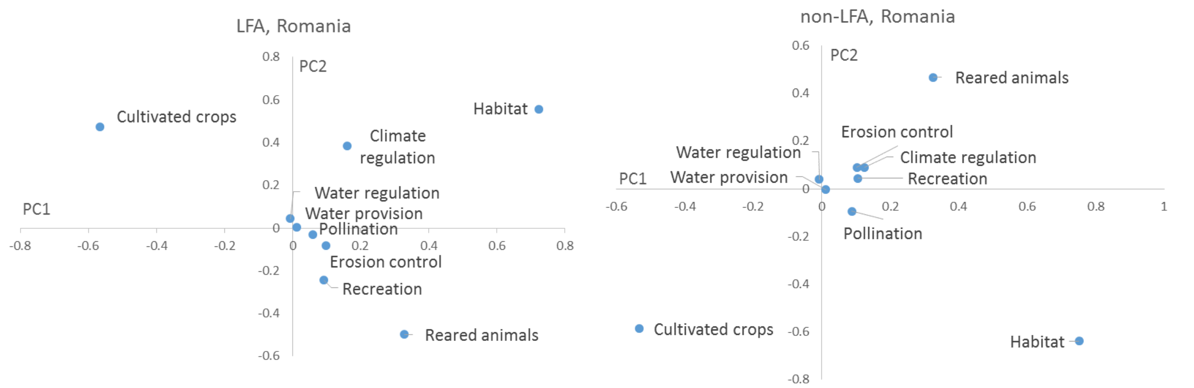


Figure 32 Principle component analysis of ecosystem capacities in less favoured areas (N = 1000grid cells, total explained variance by the first two principal components is 80%) and in non-less favoured areas (N = 1000grid cells, total explained variance by the first two principal components is 83%) in Romania. Each dot represents the correlation between normalized capacity indicators and the two first principle components.

In Poland (Figure 33) in LFA the common trade-offs are present, but in non-LFA the capacity for cultivated crops negatively correlates along only one axis with the other capacities, so the trade-off between them is not so strong.

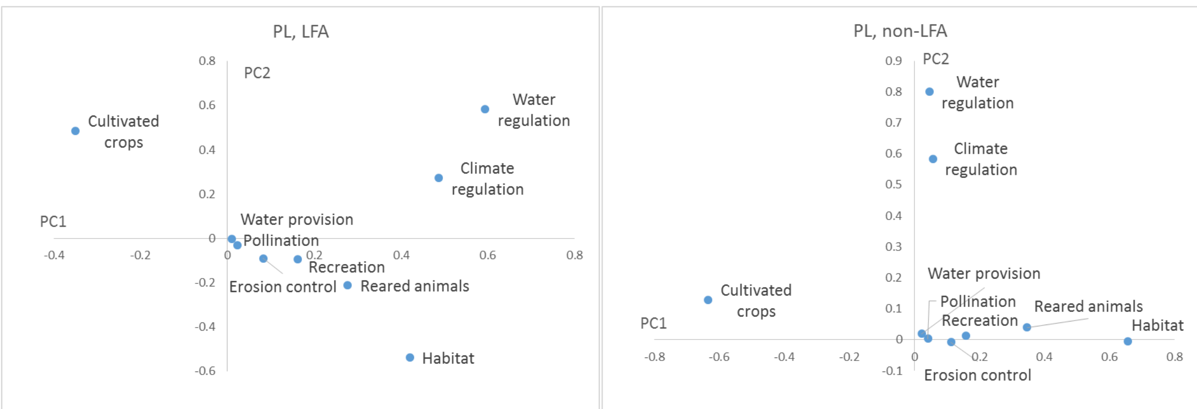


Figure 33 Principle component analysis of ecosystem capacities in less favoured areas (N = 1000grid cells, total explained variance by the first two principal components is 75%) and in non-less favoured areas (N = 1000grid cells, total explained

variance by the first two principal components is 67%) in Poland. Each dot represents the correlation between normalized capacity indicators and the two first principle components.

In Italy the most important difference between LFA and non-LFA (Figure 34) is that there is a bundle of capacities containing pollination, recreation and reared animals, and in LFA erosion control belongs to this bundle, whereas in non-LFA it shows trade-off with them, though it is slight.

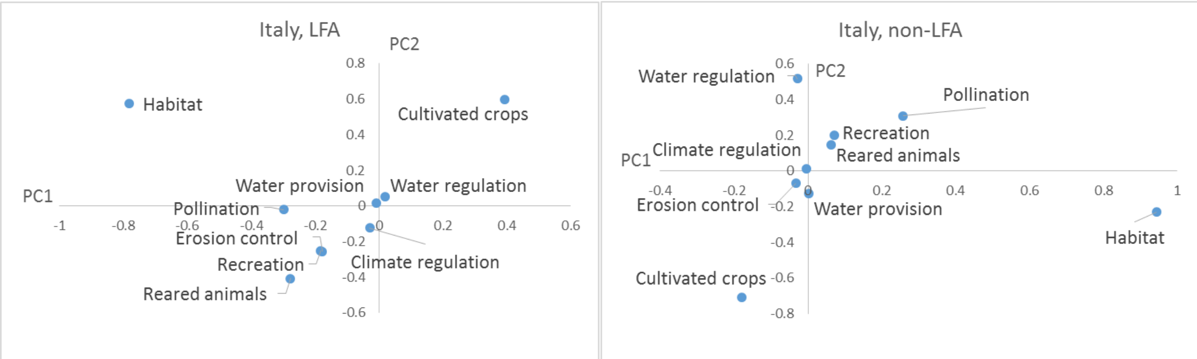


Figure 34 Principle component analysis of ecosystem capacities in less favoured areas (N = 1000grid cells, total explained variance by the first two principal components is 77%) and in non-less favoured areas (N = 1000grid cells, total explained variance by the first two principal components is 75%) in Italy. Each dot represents the correlation between normalized capacity indicators and the two first principle components.

4.6 Evaluation and classification of administrative units based on ecosystem capacities

4.6.1 Evaluation of administrative units comparing the averages and/or medians of each normalized indicator value

The easiest way to assess administrative units concerning the overall capacity of their less favoured agro-ecosystems to deliver services, is to compare the mean or median capacities expressed in normalized indicators (Figure 35). The figure shows that in certain cases (depending on the distribution of the data) the choice between mean and median can have great impact on the outcome.

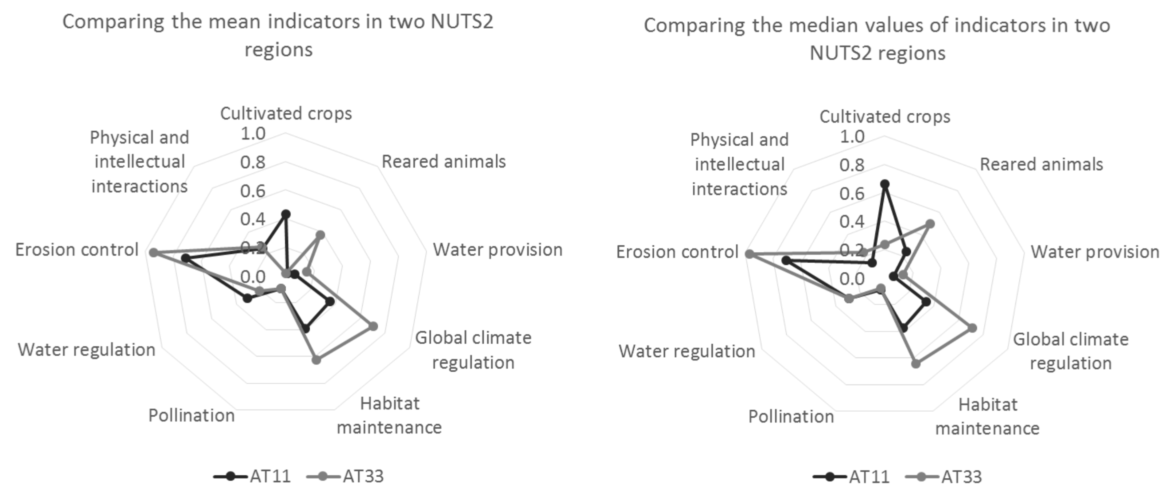


Figure 35 Mean and median values of capacity indicators (normalized values, 0-1) in two NUTS2 regions for nine ecosystem services. AT11 and AT33 are the codes of the NUTS2 regions.

The advantage of this method is that all individual services can be seen simultaneously. However, the comparison of administrative units and the interpretation is not easy in the absence of a single summarizing, composite indicator. The indicators can be aggregated in order to obtain a joint indicator but for this the weights of each ecosystem service have to be defined based on an agreed methodology in compliance with the characteristics of each indicator and with the objectives of the evaluation. The composite indicator always has to be used and interpreted in combination with its sub-indicators.

The NUTS2 mean indicator values, calculated from normalized values in LFA are shown in Annex VIII.

4.6.2 Classification of administrative units taking into account all capacities

A possible method for classification of administrative units is cluster analysis that allows for taking into account multiple indicators.

The NUTS2 regions were classified based on their average ecosystem capacities, using the k-means cluster analysis (Figure 36a). According to the clustering, the optimum number of groups is three (the Kalinski criterion is highest for 3 groups, it is 130.44). The number of regions in the three groups are 63, 47 and 118. The resulted groups can be interpreted analysing the individual capacities (

Table 12) and the following general descriptions can be given for them:

- Class1: higher capacity for pollination and habitat maintenance; medium capacity for cultivated crops; lower capacity for climate regulation;
- Class2: higher capacity for reared animals, for climate regulation and for erosion control, medium-high capacity for habitat maintenance
- Class 3: higher capacity for cultivated crops, low capacity for reared animals and for habitat maintenance.

Capacities for water provision and regulation and for recreation are similar in the three groups.

Testing the clustering based on the median values instead of averages resulted in a similar outcome, which shows that the choice between them has moderate impact in this case (Figure 36b).

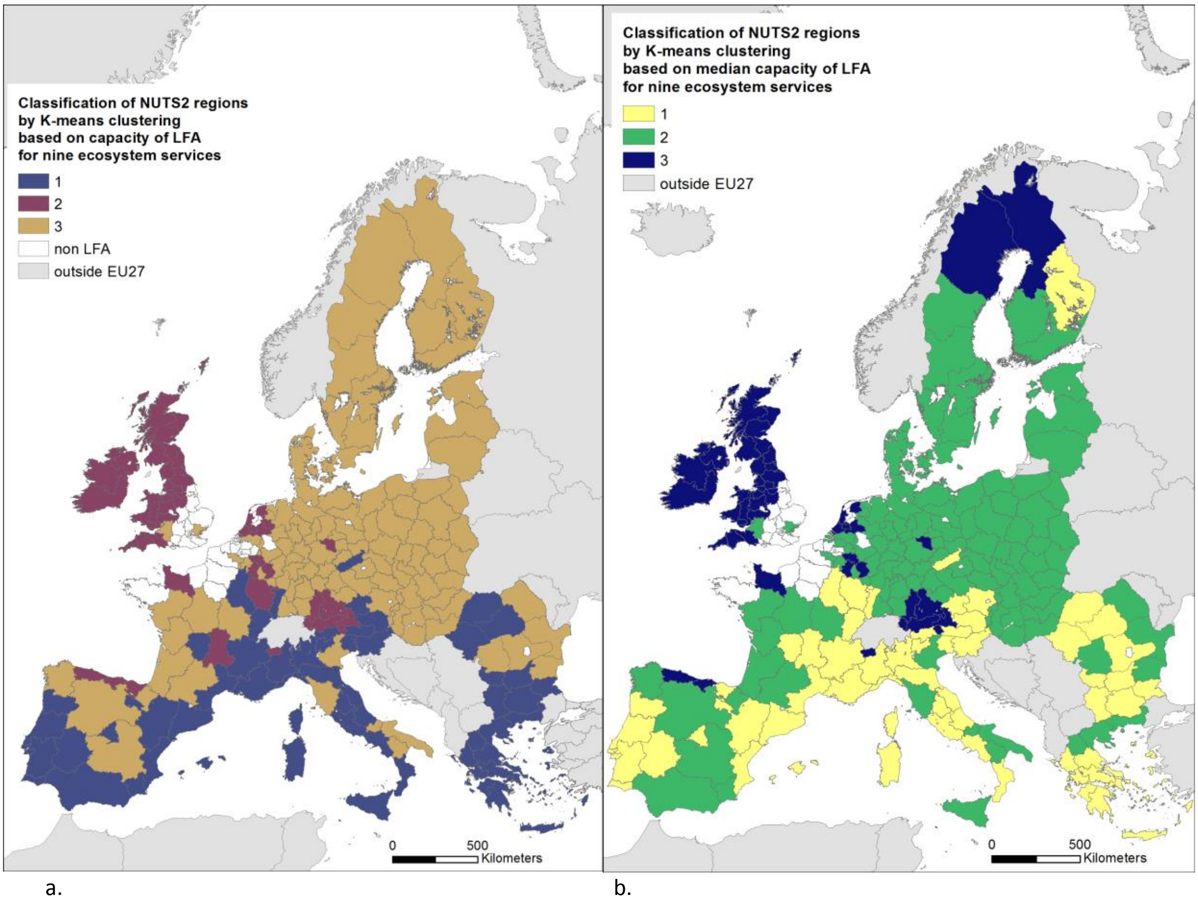


Figure 36 Classification of NUTS2 regions with the k-means clustering based on the (a.) average and (b.) median capacities of less favoured areas for nine ecosystem services (cultivated crops, reared animals, water provision, climate regulation, habitat maintenance, physical and intellectual relationships with ecosystems, pollination, water regulation, erosion control). The number of groups is predefined to be 3.

Table 12 Mean values of the nine ecosystem capacity indicators in the three classes obtained by the k-means clustering.

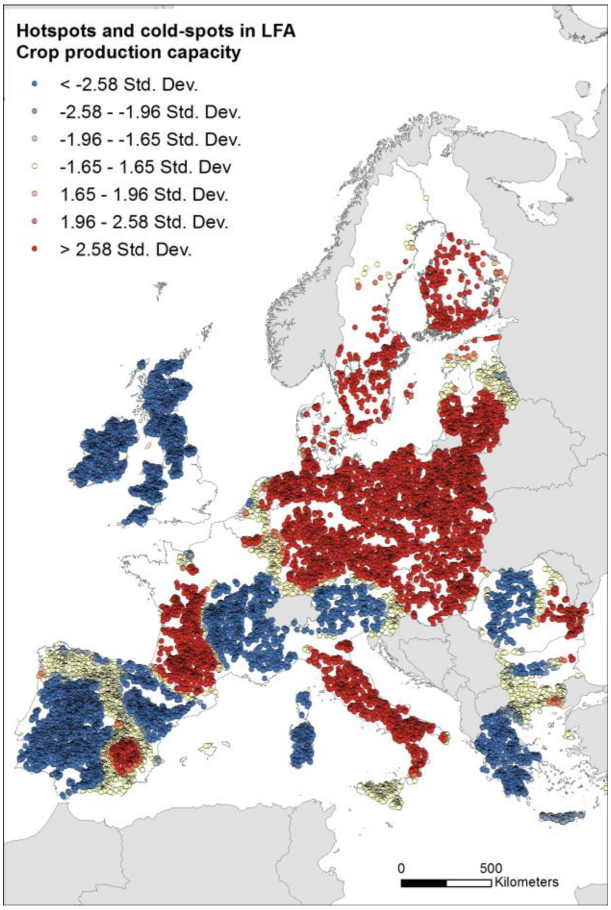
	Class1	Class2	Class3
Cultivated crops	0.26	0.14	0.45
Reared animals	0.16	0.43	0.11
Water provision	0.10	0.15	0.09
Climate regulation	0.36	0.80	0.47
Habitat maintenance	0.59	0.48	0.34
Recreation	0.28	0.26	0.24
Pollination	0.25	0.08	0.07
Water regulation	0.27	0.31	0.27
Erosion control	0.79	0.88	0.77

The classes can be related to differences in spatial extension of land use categories as well as in cropland and grassland soil productivities (Table 13). The average share of grasslands is the highest in Class 2, that of croplands is the highest in Class3.

Table 13 Mean values of cropland and grassland spatial rate (%), and of cropland and grassland soil productivity in the three classes obtained by the k-means clustering.

	Class1	Class2	Class3
Cropland (%)	47.55	29.18	59.00
Grassland (%)	24.36	43.15	12.66
Cropland soil productivity	0.50	0.63	0.64
Grassland soil productivity	0.63	0.56	0.57

The maps presenting the hotspots and cold-spots of bundles of ecosystem capacities can also help to evaluate the classification (Figure 37).



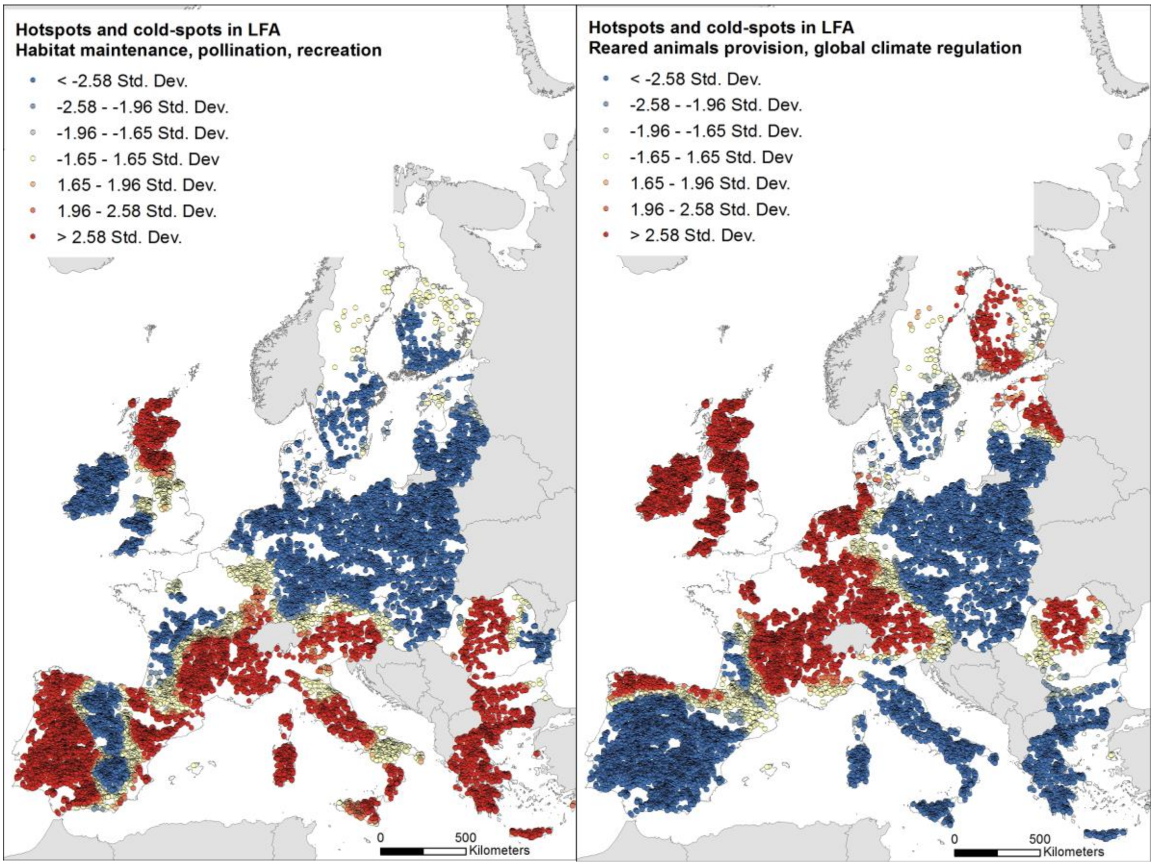


Figure 37 Hotspots (red dots)and cold-spots (blue dots) of three ecosystem capacity bundles in less favoured agricultural areas in the EU (25 countries). The bundles were determined with principle component analysis (see Figure 28).

4.6.3 Evaluation of administrative units based on the spatial extension of the high/medium and/or high capacity areas

Administrative units can be evaluated and compared based on the spatial extension of high/medium and/or high capacity areas using the low, medium and high capacity classes created from the original values for each indicator.

The tested indicator for this type of evaluation is the number of ecosystem services for which more than 50% of the agricultural area in the given unit has high (or medium/high) capacity. The spatial rate of medium and high and that of high capacity areas for nine ecosystem services is presented for one NUTS3 region as an example in Figure 38. The spatial rate of low capacity areas can be seen in Figure 39.

From this analysis the following questions can be answered concerning ecosystem services:

- For how many (and for which) ecosystem services has the certain region high or medium/high capacity in more than 50% of its agricultural area?
- For how many (and for which) ecosystem services has the certain region low capacity in more than 50% of its agricultural area?

The region in the example has high capacity for one service in more than 50% of the agricultural area. It has medium or high capacity for six services, and low capacity for three services in more than 50% of the agricultural area.

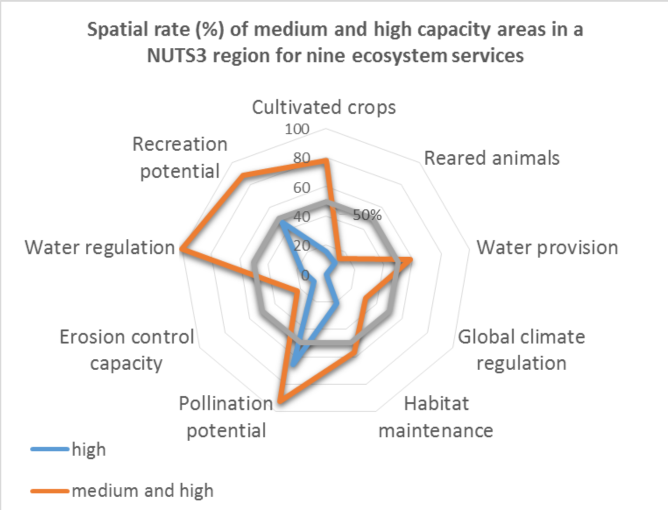


Figure 38 The spatial rate (%) of medium and high (2nd and 3rd class) and that of only high (3rd class) capacity areas in a NUTS3 region for nine ecosystem services as an example for the use of the evaluation of administrative units based on the spatial rate of medium and/or high capacity areas..

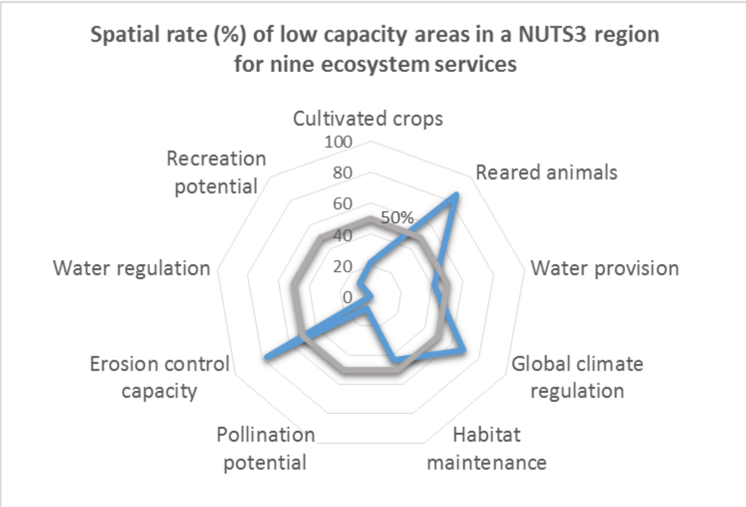


Figure 39 The spatial rate (%) of low (1st class) capacity areas in a NUTS3 region for nine ecosystem services as an example.

If the objective is the evaluation of individual ecosystem services, the spatial rate (%) of low, medium and high capacity areas for the certain ecosystem service can be determined in each region and these rates can be used for the comparison (Figure 40).

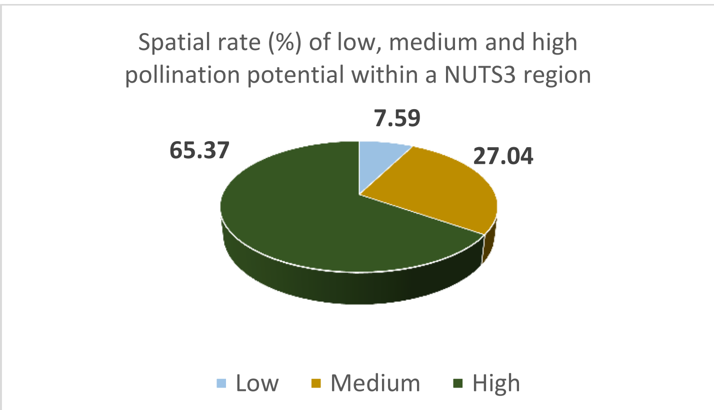


Figure 40 Spatial rate (%) of low, medium and high pollination potential within a NUTS3 region as an example for the assessment of individual services.

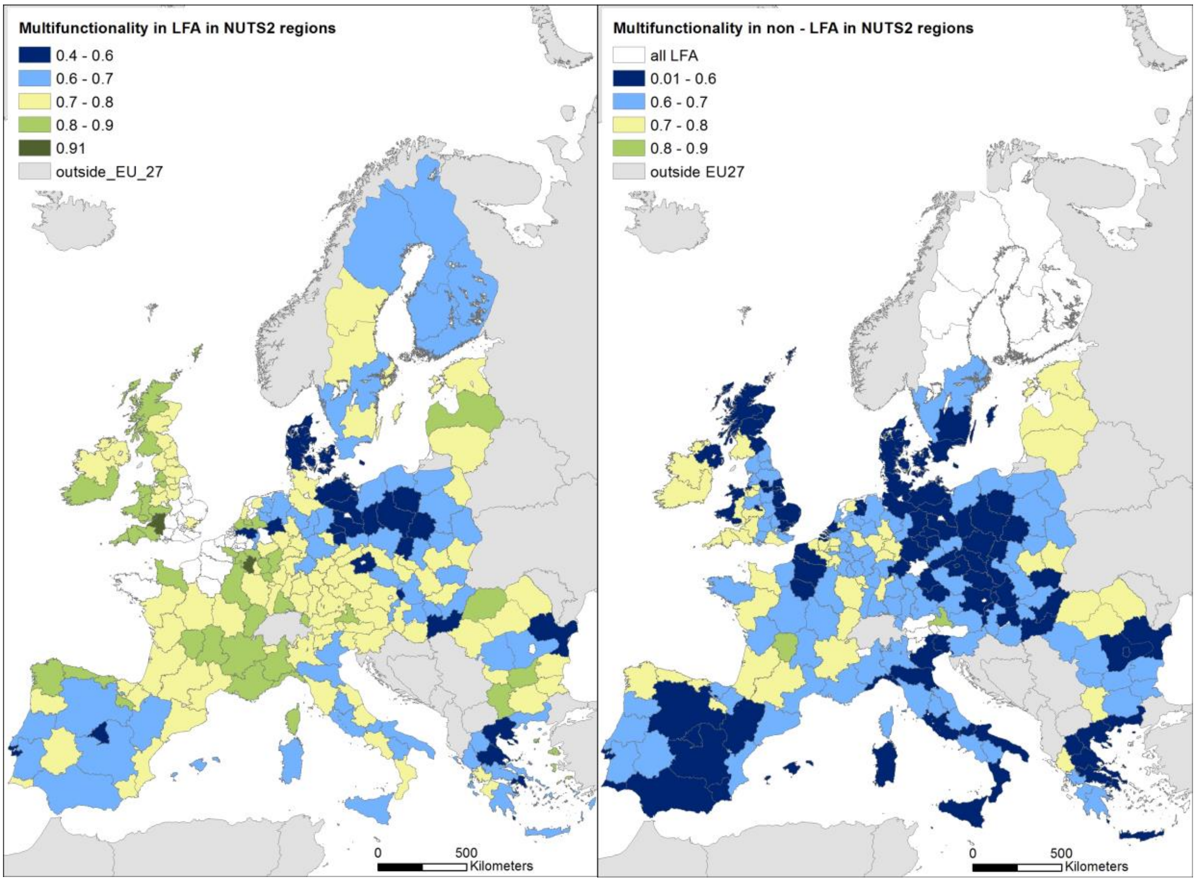
4.6.4 Evaluation of administrative units based on their multifunctionality

The means and standard deviations of the number of services potentially delivered at least at medium level (from the nine studied services) in LFA and in non-LFA at EU level are summarized in Table 14 The statistics of the number of services potentially delivered at least at medium level (from the nine studied services), using (A.) the potential supply indicator and (B.) the actual set of potential supply indicator for the biomass provisioning capacities.

Table 14 The statistics of the number of services potentially delivered at least at medium level (from the nine studied services), using (A.) the potential supply indicator and (B.) the actual set of potential supply indicator for the biomass provisioning capacities.

	Mean		STD		STD pooled	Effect size
	LFA	Non-LFA	LFA	Non-LFA		
A	6.472	6.181	1.676	1.593	1.64	0.18
B	6.660	5.979	1.379	1.534	1.46	0.47

The multifunctionality indicator of NUTS2 regions is presented in Figure 41 (for the calculation method see chapter 3.8, c.). It shows regions having higher multifunctionality with green colours, and regions with low multifunctionality with blue. It can be seen that there are more highly multifunctional (green) NUTS2 regions on the LFA map than on the non-LFA map, whereas there are less NUTS2 regions with low multifunctionality in LFA. There are a number of NUTS2 regions where the multifunctionality is higher in LFA than in non-LFA.



a. b.

Figure 41 Multifunctionality indicator (normalized weighted sum of the number of services potentially delivered at least at medium level) in (a) less favoured agricultural areas and in (b) non-less favoured agricultural areas in NUTS2 regions of 25 Member States in EU. The maximum number of services is 9.

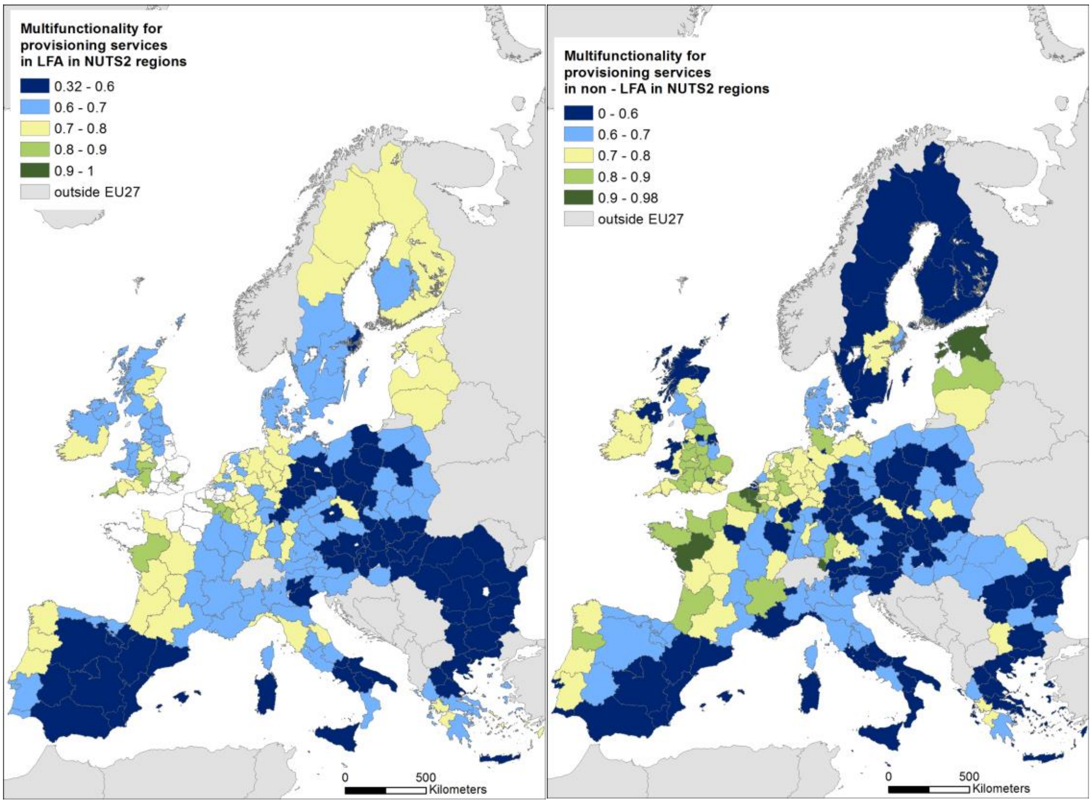
In order to see the components of the total indicator, the multifunctionality indicators calculated separately for provisioning and for regulating and maintenance services are also presented (Figure 42 and Figure 43).

Note that provisioning services include three services: cultivated crop, reared animals and water provision. Capacity for reared animals and crop provision are spatially linked to grasslands and croplands, respectively, therefore two mutually exclusive capacities are counted for biomass capacity. However, at 1 km spatial level, both land use can be present. It’s also important to note that grass production was considered to be potentially delivered at least at medium level in all 1km cells in which there is any grassland, as the threshold for medium level capacity for grass production was 0 (median), while the threshold (median) for crop production capacity was 0.303.

The multifunctionality for the three studied provisioning services can be lower due to low soil productivity, low water provisioning capacity, or low share or absence of grasslands or croplands, or both. Therefore, it is not expected to be always lower in LFA. However, there are more NUTS2 regions with high multifunctionality for provisioning services in non-LFA than in LFA. On the other hand, there are more NUTS2 regions with high multifunctionality for regulating and maintenance services in LFA. The difference is more significant in the latter case.

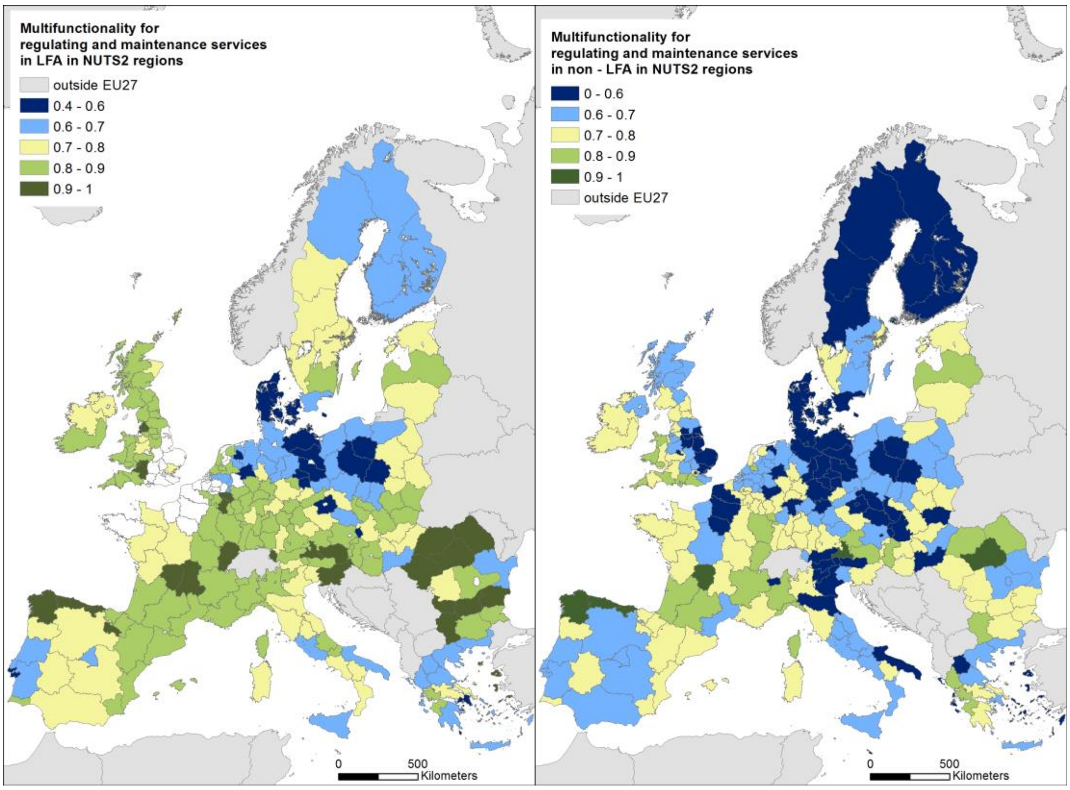
The indicator for multifunctionality could be the average number of services potentially delivered at least at medium level as well. Instead of this, the normalized weighted sum is proposed to be used in order to obtain comparable indicators for different groups of services (even with different number of studied services, e.g. for provisioning services and regulating services in our case). Comparing the multifunctionality for the two studied groups of services, it can be seen that:

1. in LFA the multifunctionality for regulating and maintenance services is higher than that for provisioning services in most of the NUTS2 regions, except some regions in Northern Europe.
2. In non-LFA the relation between multifunctionality for regulating and maintenance services and that for provisioning services varies from region to region.



a. b.

Figure 42 Multifunctionality indicator for provisioning services (normalized weighted sum of the number of provisioning services potentially delivered at least at medium level) in (a) less favoured agricultural areas and in (b) non-less favoured agricultural areas in NUTS2 regions of 25 Member States in EU. The number of studied provisioning services is 3.



a. b.

Figure 43 Multifunctionality indicator for regulating and maintenance services (normalized weighted sum of the number of regulating and maintenance services potentially delivered at least at medium level) in (a) less favoured- and in (b) non-less favoured agricultural areas in NUTS2 regions of 25 Member States in EU. The number of studied services is 5.

5 Discussion

5.1 Capacity of LFA and non-LFA for delivering ecosystem services

The analysis revealed that LFA and non-LFA are significantly different concerning the distributions of each ecosystem capacity. Capacities for cultivated crops and reared animals are lower, whereas the studied capacities for regulating, maintenance and cultural services are higher in LFA than in non-LFA.

The directions of the detected differences between LFA and non-LFA concerning ecosystem capacities at EU level are in line with the aims of the ANC scheme, however the size of the differences that is greatly variable at Member State level, could be increased with a better targeting.

The observed trade-offs and synergies are not surprising. García-Feced et al. (2015) already have shown that the indicator used for habitat maintenance has no negative correlation with provisioning services in agricultural land, and it has positive correlations with the following regulating and maintenance services from present analysis: pollination, global climate regulation, water regulation.

Some of the relationships between services have been shown already for the study area of EU including all land cover types (Maes, 2011, Maes et al., 2012), for example (1) the synergies between pollination and recreation, (2) between water provision, water regulation and erosion control, and (3) trade-off between these latter services (water provision, water regulation and erosion control) and crop provision.

Our study confirmed the existence of these relationships within agricultural land, within LFA and within non-LFA as well. On the other hand, there are also some differences. For example, global climate regulation showed synergy with recreation potential and pollination potential at EU level (Maes, 2011) whereas it belongs to another bundle of services in agricultural land according to our analysis at EU level. One of the reasons behind can be that considering all land cover areas the main factor is the tree/forest cover for the capacity for global climate regulation, whereas in agricultural land it is more the soil carbon storage, and also because of this reason different indicators were used in the two analyses. However, it can change at Member State level, as for example in LFA in Italy they show synergies.

Another difference that was found is the strength of some relationships. Due to that some regulating and cultural services have mainly lower capacities (those related to semi-natural vegetation, like physical and intellectual interactions with ecosystems), therefore also lower variability within agricultural land than considering all areas, their relationships with provisioning services are weaker.

The trade-offs and synergies between ecosystem capacities are similar in LFA and in non-LFA at EU level, despite some small differences could be detected. Analysing the relationships at Member State level, some slight differences can be observed, varying between Member States.

Therefore, the study revealed that despite there are quantitative differences regarding to ecosystem capacities between LFA and non-LFA at EU level, the relationships among ecosystem capacities are similar in the two areas. Similar statement was concluded from an analysis by Dick et al (2014).

As ecosystem capacities are provided by ecosystems including vegetation and the abiotic environment, they are strongly related to land cover/land use and influenced by biophysical factors. Therefore, the variability of natural conditions and the agricultural systems throughout the studied area can be drivers for the differences among Member States, as well as the variability of the national delineation of less favoured areas.

The cluster analysis based on nine ecosystem capacities grouped NUTS2 regions into three classes. The classification is highly related to land use (grassland-cropland share) and to biomass provisioning capacities. The variability within NUTS2 regions can be high, in order to take it into account, the normalization can be done using the local maximum values of the indicators. Further differentiation can be achieved with more precise data.

The multifunctionality of agro-ecosystems was higher in many NUTS2 regions in LFA than in non-LFA. The difference is even sharper considering multifunctionality for only regulating and maintenance services. In LFA there is a sharp difference between multifunctionality for the studied provisioning and that for the studied regulating and maintenance services, which cannot be observed in non-LFA.

All the statements can change at Member State or regional level, but the same methodology can be applied efficiently.

5.2 The methodology and its application

The presented assessment

- gives comprehensive information on the spatial distribution and quantitative level of ecosystem capacities in - less favoured and non-less favoured – agricultural areas at EU and at Member State level
- identifies hotspots and cold-spots for the provision of ecosystem services
- evaluates spatial differences within less favoured areas for each service and for the overall performance, which allows for classification of the areas
- evaluates the performance of less favoured areas compared to other agricultural areas at EU and at Member State level regarding to capacities for ecosystem services from three aspects: (1) quantitative level, (2) relationships (trade-offs and synergies) among services and (3) level of multifunctionality.

The comprehensive comparison of LFA and non-LFA at EU level has shown that the most accurate method is to compare the distributions. The choice between the comparison of average or median values can notably influence the outcome in certain cases. The ranking of capacities is also different at EU level using the two methods, however the actually used set of supply for crop provision and habitat maintenance are both in the first three capacities.

The spatial distribution of capacities for ecosystem services in less favoured and in non-less favoured agricultural areas are presented on separate maps in the report. The percentage distributions of low, medium and high capacity areas provide a clear-cut EU level assessment.

Beyond the visual interpretation of the presented maps with the original indicator values and the standardized values, hot-spot analysis is proposed for exploring the variability of the ecosystem capacities within less favoured areas.

Four different types of evaluation methods are described in the report:

1. Evaluation based on the average/median of each normalized indicator;
2. Cluster analysis of the spatial units based on the average/median of the normalized indicators;
3. Evaluation based on the spatial extension of low, medium and high capacity areas;
4. Evaluation based on the number of services potentially delivered at a minimum level (multifunctionality analysis).

The first method contains the most precise information on each individual service.

The second method is a multivariate statistical method which aims to classify a sample of subjects (or objects) on the basis of a set of variables into a number of different groups such that similar subjects are placed in the same group. Its interpretation has to involve the separate indicators.

The outputs of the third and fourth methods contain less information but seem to be more straightforward. The second method differentiates three levels of capacity (low, medium, high). It can be used for evaluating different ecosystem services simultaneously in regions or administrative units and it gives a quantitative indicator suitable for comparison of areas. The third method gives the most simple, easily comparable quantitative information, however its interpretation also has to include the sub-indicators.

The second and third method 2 using the classes based on standardized values can be used for indicate areas where the capacity for particular ecosystem services is very high (or where it is very low).

The fourth method can be used to select areas with higher or lower multifunctionality and to classify areas according to their multifunctionality.

The choice between the four methods can be decided based on the objective of the evaluation. The first method can be used for the interpretation of the other three methods as supporting information.

The described methodology can support the performance evaluation and the better targeting of the ANC policy scheme based on ecosystem services delivery. The EU level assessment allows for the identification of regions/Member States in which the performance of LFA highly differ from those assessed at EU level.

Maps can be used to locate and identify promising places, hotspots and cold-spots as well. They can help to explore conflicts and synergies between ecosystem services. The presented methods can be used for the classification and evaluation of less favoured agricultural areas concerning their ecosystem services, likely with more precision if at country or regional level.

The developed methodology can be applied at any suitable scales, administrative unit levels, as well as including more ecosystem services.

It is important to highlight that the selection of ecosystem services and their indicators can have crucial effect on the outputs as it has been already concluded by several authors (e.g. Dick et al., 2014).

5.3 Difficulties and further work

A new delineation of the areas with natural constraints is ongoing and have to be finished by December 2017 by Member States. After that the ecosystem service assessment can be implemented on the newly delineated areas using the same methodology.

The described methodology were tested with nine ecosystem services and it can be expanded with more. However, it is constrained by available EU level data. The most recent EU wide ecosystem service assessment (Maes et al., 2015) provides some newly developed indicators for this purpose. Another source can be the ongoing mapping and assessment of the state of ecosystems and their services in the Member States required by Action 5 of the EU Biodiversity Strategy to 2020.

Principle component analysis was used in present report for the comparison of LFA vs. non-LFA at EU and Member State level but it can be used at any spatial level/administrative unit.

Ecosystem services are perceived differently by various groups of people or stakeholders (e.g. for some citrus tree farmers pollination by bees is undesirable, Sagoff (2011)), which also has to be considered (Hauck et al., 2012). The aggregation of services has to be adapted to the aim of particular assessments. In case of less favoured areas it can be implemented assigning different weights to services or to focus on a number of selected ecosystem services, and/or all services can be considered to be equally important. The variation of ecosystem capacities due to the bioclimatic conditions and to agricultural land use types should be taken into account at EU level assessments. Multi-scale mapping can help to solve the issue of interrelatedness of ecosystem services and the divergent needs of stakeholders at different levels (Hauck et al., 2012).

The presented methodology is tested with capacity indicators. The actual services/service flows can be assessed similarly, but data availability issues and varying stakeholder approaches makes it more difficult. The used indicators should be sensitive to changes in land management practices having impact on actual services/service flows. The results can provide basis for the analysis of the threatening effects of land abandonment and agricultural intensification on ecosystem services in areas with natural constraints.

After the assessment of both ecosystem capacities and actual services/service flows with the same method the relationships between them can be analysed. Modelling the potential impacts of land abandonment and agricultural intensification on biodiversity and ecosystem services, and performing scenario analyses can help to identify regions where it is important to maintain extensive agricultural activity in order to maintain (one or more) ecosystem services.

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List of Abbreviations

ANC: areas with natural constraints

CAPRI: Common Agricultural Policy Regionalised Impact Modelling System

CICES: Common International Classification of Ecosystem services

CLC: CORINE Land Cover

DG AGRI: Directorate-General for Agriculture and Rural Development

EC: European Commission

ES: ecosystem service

EU: European Union

HNV: high nature value farmlands

LAU2: Local administrative unit (level2)

LFA: less favoured areas

MAES: Mapping and Assessment of Ecosystems and their Services, Working Group of the European Commission

MARS: Monitoring Agricultural Resources Unit (Joint Research Centre, Institute for Environment and Sustainability, European Commission)

MS: Member State

non-LFA: non-less favoured areas

NUTS2: Nomenclature of Territorial Units for Statistics (EUROSTAT, European Commission)

OECD: Organisation for Economic Co-operation and Development

PCA: principle component analysis

STD: standard deviation

UAA: Utilized agricultural area

AT	Austria	ES	Spain	LV	Latvia
BE	Belgium	FI	Finland	MT	Malta
BG	Bulgaria	FR	France	NL	Netherland
CY	Cyprus	HR	Croatia	PL	Poland
CZ	Czech Republic	HU	Hungary	PT	Portugal
DE	Germany	IE	Ireland	RO	Romania
DK	Denmark	IT	Italy	SE	Sweden
EE	Estonia	LT	Lithuania	SI	Slovenia
EL	Greece	LU	Luxembourg	SK	Slovakia
				UK	United Kingdom

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Annex I. Cultivated crops – cropland soil productivity

The modelling steps are the following:

1. Eight characteristic climate systems were identified classifying the 35 climatic areas of Europe (Hartwich et al., 2005) based on the complex effects of water availability and thermal regime for soil processes and plant growth. Second-level taxonomic soil units (WRB) were grouped into five inherent capability classes based on their relative productivity in each climatic zone, separately. In parallel, STUs were rated according to the available water capacities of topsoil and subsoil. Soils were grouped into four classes based on water-storing capacity.
2. Productivity scores (1-8) were assigned to each cell of the matrix of the eight climatic regions and the five inherent capability classes. These scores were multiplied with the multiplication factor (0.75-1) based on the water-storing capacity classes. The result of this procedure is the inherent soil productivity index. Scores were assigned to each STU in the SGDBE and a spatially weighted average of the score was calculated for each soil mapping unit.
3. Second-level taxonomic soil units (WRB) were grouped into five classes in each climatic zone according to their expected productivity increase due to fertilization. Then a fertilizer response score was assigned to each soil unit in the eight climatic zones (1-8). To calculate the soil productivity the inherent soil productivity and the fertilizer response scores were aggregated, assigning a mechanical weight to the fertilizer response indices. Only those STUs were included in the calculations which had cultivated land as the primary or secondary land use type in the SGDBE. Finally, a correction coefficient was applied to evaluate the effect of the topography (slope and aspect) on the soil productivity.
4. The model was validated with a remote sensing-derived indicator. Net primary production (NPP) was estimated from Normalized Difference Vegetation Index (NDVI) data and used as a proxy for the aboveground biomass production.

Data sources:

1. Soil: European Soil Database (ESDB, EC 2003). Soil Geographical Database of Eurasia (SGDBE), PedoTransfer Rules Database (PTRDB).
2. Land use: SGDBE, dominant and secondary land use types. To present the results: CORINE.
3. Climate: Climatic zonation of Hartwich et al., 2005.
4. Topography: digital elevation model (DEM) from the Shuttle Radar Topography Mission (SRTM, Rabus et al., 2003), resolution: 90 m (grid cell).
5. Validation datasets: SPOT VEGETATIONa decadal data, 10 day synthesis or the maximum Normalized Difference Vegetation Index (NDVI) composite.

Source: Toth et al., 2013

Annex II. Mass stabilization and control of erosion rates - Erosion control

The C-factor value in the CAPRI model is a weighted average of the Crop System factor on the Utilised Agricultural Area (UAA) of the HSMU (Terres et al., 2103). It considers only cultivated crops in agricultural land.
It can be considered as the factor expressing the capacity of ecosystems to influence soil erosion risk. By definition, C = 1 under standard fallow conditions (bare soil). As surface cover is added to the soil, the C factor value approaches zero. C-factor values are equal to the reduction in soil loss for a specific-erosion control system when compared to the bare soil (control) condition.
HSMU (homogeneous Spatial Mapping Unit) is the unit of CAPRI model. HSMUs are homogeneous clusters of 1 km2 pixels, identified on the basis of the Farm Structure Survey regions (NUTS 2 or 3, depending on the Member State, EUROSTAT 2003), land cover (CLC2000), soil mapping units (European Soil Database V2.0, European Commission, 2004) and slope (Britz and Witzke, 2008).

Annex III. Pollination – Pollination potential index

The possible foraging sites were mapped by an expert based assessment of the availability of floral resources and foraging ranges based on various types of land cover information. Then this data was combined with the available nesting sites to obtain the relative pollinator abundance. This map was corrected with the activity of pollinators that was estimated from temperature and solar irradiation data. The flight range was used again to estimate the relative pollination potential from the updated (by activity correction) relative pollinator abundance. The areas where pollinators physically cannot exist were masked out (high altitudes, open water).

The relative pollination potential can be calculated for any pollinator species. It was yet calculated for a single ecological guild of pollinators with a relatively short flight distance (solitary bees).

For cropland the spatial data of land use from the CAPRI model (crop shares for HSMUs) was used to assign weights for nesting suitability and floral availability for each crop type. The CLC2000 arable land cover was replaced with the HSMU crop type data and scores for the nesting suitability and floral availability were calculated as weighted zonal average. The scores were increased in agricultural areas under extensive farming (data is available only for Olive farming) and under High Natural Value Farmland, and in agricultural areas with higher habitat heterogeneity, having semi-natural habitats in the landscape (intersecting with a map of semi-natural habitats based on CLC2000).

Annex IV. Global climate regulation – soil organic content in the topsoil

SOC stocks were calculated for approximately 164 000 combinations of soil–climate–land use. The CENTURY model was especially developed to deal with a wide range of cropping system rotations and tillage practices for system analysis of the effects of management and global change on productivity and sustainability of agroecosystems. Its crop growth routines are integrated for both herbaceous and trees crops (e.g. orchard, vineyard), including the possibility to simulate mixed systems. It works with monthly time step. The SOC submodel includes three soil organic matter pools (active, slow and passive) with different potential decomposition rates, above and belowground litter pools and a surface microbial pool which is associated with decomposing surface litter.

Unique homogenous territorial units (Soil and Climate Unit – SCU) were identified by the overlay of soil polygons with a climatic data grid. Within each SCU, the land use was defined by either the Corine Land Cover (CLC) 2006 database or CLC2000 in areas where the 2006 data were not available. The original CLC classes were aggregated into seven classes and the area (ha) for the following new categories was calculated for each SCU: arable, rice, vineyard, olive, orchard, pasture and complex system. This information was complemented by statistics on crop production area for NUTS2 regions, from the EU Statistical Office (EUROSTAT) (http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database) to implement the modelling of crop rotations for arable lands.

The model was implemented with the main management practices (irrigation, mineral and organic fertilization, tillage, etc.) derived from official statistics maintained by EUROSTAT (the statistical office of the European Union) and tested with the EIONET-SOIL inventory (Panagos et al., 2013) and the soil sample from 2009 LUCAS survey (Land Use/Cover statistical Area frame Survey) (EUROSTAT, 2011), providing SOC measured data.

Annex V. Entertainment & Aesthetic (cultural) ecosystem services - Recreation potential

Data sources used in the model are the following:

1. hemeroby: CLC land cover data; CAPRI: disaggregated data on nitrogen input and livestock density (at HSMU scale); AFOLU tree species database (1 km2 grid; distribution data of the 26 most abundant species in Europe and of 9 introduced species were used);
2. presence of protected areas: Natura 2000, CDDA database (European inventory of nationally designated areas);
3. presence of coastlines (sea and lakes): CLC2000;
4. bathing water quality: EU Bathing Waters Directive, annually collected data by EEA;
5. bathing water accessibility: European road network, TeleAtlas;
6. distance from urban centers: CORINE urban classes.

Annex VI. Ranking of Member States by the normalized difference between the median values in LFA and in non-LFA.

The tables contains the Member States following each other in decreasing order, and the normalized differences between the median values in LFA and in non-LFA ((Median $_{LFA}$ – Median $_{non\text{-}LFA}$)*100/Median $_{non\text{-}LFA}$, difference expressed in percentage of the non-LFA median) for each indicators/services in the tables.

a. Provisioning services

Cropland soil productivity		Grassland soil productivity		Crop production capacity		Grass production capacity		Water provision	
LU	100	LU	195	IE	100	UK	0.37	UK	50.9
SI	20.4	SE	20.6	UK	100	NL	0.30	AT	47.2
LT	19.4	LT	20.0	LU	70.6	BE	0.22	CZ	36.9
GR	17.0	SK	18.6	AT	61.1	FR	0.17	SI	35.6
NL	15.3	NL	16.1	GR	55.4	AT	0.15	GR	35.3
BG	14.9	FR	15.0	NL	50.5	LV	0.15	SE	26.3
EE	14.1	AT	14.7	FR	49.4	BG	0.13	SK	25.1
FR	13.8	GR	14.3	BG	44.4	IE	0.10	IE	21.7
IT	13.3	EE	13.8	BE	36.3	RO	0.09	BE	20.7
LV	13.3	IE	13.3	LV	35.1	GR	0.08	IT	17.6
IE	12.0	SI	12.5	FI	34.4	CZ	0.04	BG	12.9
UK	10.8	IT	12.1	SK	31.6	LU	0.03	LU	12.8
PT	7.9	HU	8.1	RO	30.4	HU	0.02	FI	12.8
RO	7.4	PL	6.2	CZ	28.1	ES	0.02	PT	10.4
PL	7.4	UK	5.6	ES	26.5	DE	0.02	ES	8.0
SK	7.4	CZ	4.2	IT	25.6	EE	0.01	DE	7.7
SE	6.9	BG	3.3	DE	23.9	DK	0	FR	7.3
FI	6.3	FI	3.1	LT	23.4	FI	0	LT	5.6
HU	6.2	DK	2.9	PT	23.2	IT	0	PL	3.8
AT	6.0	DE	2.9	SE	21.0	LT	0	DK	3.4
DK	4.3	PT	2.4	EE	19.6	PL	0	NL	2.3
DE	1.4	LV	1.9	HU	18.8	PT	0	RO	1.3
CZ	1.3	RO	1.6	PL	17.3	SE	0	HU	0.47
BE	1.3	ES	0	SI	3.0	SI	0	EE	0.46
ES	0	BE	0	DK	1.4	SK	0	LV	0.07

b. Regulating and maintenance services and one cultural service

Erosion control		Water regulation		Habitat maintenance		Pollination		Climate regulation		Recreation	
UK	18.8	DK	54.8	BG	546.5	BG	210.2	FI	117.3	BG	54.8
AT	18.2	HU	17.5	UK	447.6	SI	158.5	AT	72.6	UK	41.0
BG	17.8	LU	14.9	SK	390.2	GR	154.8	IE	68.0	FI	39.1
LU	15.0	AT	0	AT	388.6	AT	97.4	UK	55.5	AT	33.4
BE	14.9	BE	0	RO	380.0	UK	78.8	BE	36.9	GR	29.5

NL	13.0	BG	0	CZ	278.7	IT	77.8	LU	28.7	IT	29.1
PT	11.9	CZ	0	GR	216.0	FR	71.0	SK	27.8	SI	26.0
FR	11.0	DE	0	FR	207.9	SE	67.6	DK	19.0	DE	24.5
SK	9.3	EE	0	LU	203.0	RO	62.2	DE	18.2	BE	22.9
ES	8.3	ES	0	SI	187.2	CZ	55.4	PL	17.5	FR	21.1
GR	7.7	FR	0	BE	178.0	DE	49.8	GR	16.7	RO	20.6
LT	6.7	GR	0	IT	165.5	FI	43.2	IT	15.3	HU	17.8
SI	5.6	IE	0	DE	131.8	SK	33.9	ES	15.2	NL	17.3
DE	5.0	IT	0	ES	95.7	LT	31.8	LT	14.3	SK	17.1
RO	4.3	LT	0	SE	95.6	DK	30.6	HU	13.6	CZ	13.5
SE	3.8	LV	0	LT	75.5	PL	25.7	PT	8.9	LV	11.0
IT	3.2	NL	0	PL	74.7	EE	18.1	RO	6.1	LU	10.9
IE	3.0	PL	0	IE	67.7	ES	17.4	BG	5.7	LT	9.2
LV	3.0	PT	0	DK	27.2	HU	14.5	SE	4.0	IE	8.2
CZ	3.0	RO	0	PT	23.8	LV	13.1	LV	3.7	SE	7.8
FI	2.1	SE	0	HU	22.2	BE	11.1	FR	3.0	PL	7.2
EE	1.2	SI	0	EE	20.5	LU	9.0	NL	2.3	EE	7.1
PL	1.00	SK	0	NL	19.1	PT	8.6	CZ	0.8	PT	4.5
HU	0.67	UK	0	FI	16.8	IE	6.7	EE	0.2	ES	3.6
DK	0.00	FI	0	LV	11.3	NL	3.3	SI	0	DK	1.0

Annex VII. Statistics for comparison of LFA versus non-LFA according to average capacity by Member States.

Statistics of capacity indicators in LFA and in non-LFA by Member States. LFA: mean values for LFA, NON LFA : mean values for non-LFA, DIFF: the difference between the values of LFA and non-LFA, STD_{pooled}: pooled standard deviation, Effect size: difference between the values of LFA and non-LFA normalized with the pooled standard deviation. Indicators: cropland soil productivity (dimensionless, 0-1), crop production capacity (dimensionless, 0-1) , grassland soil productivity (dimensionless, 0-1), grass production capacity (dimensionless, 0-1), hydrological excess water (dimensionless, mm), erosion control (dimensionless, 0-1), pollination potential (dimensionless, 0-1), semi-natural vegetation (number of 25m cells with semi-natural vegetation in 1km^2), soil organic content in the topsoil (tC/ha) and recreation potential (dimensionless, 0-1).

1. Indicators for provisioning services

	Cropland soil productivity					Crop production capacity				
MS	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**
AT	0.574	0.629	-0.056	0.128	-0.435	0.251	0.542	-0.291	0.209	-1.392
BE	0.768	0.763	0.005	0.115	0.042	0.362	0.560	-0.199	0.214	-0.929
BG	0.563	0.606	-0.043	0.111	-0.384	0.277	0.487	-0.210	0.202	-1.043
CZ	0.723	0.743	-0.020	0.060	-0.332	0.439	0.625	-0.186	0.188	-0.989
DE	0.670	0.688	-0.018	0.114	-0.154	0.415	0.561	-0.147	0.209	-0.700
DK	0.726	0.708	0.019	0.057	0.328	0.663	0.643	0.020	0.120	0.163
EE	0.561	0.660	-0.099	0.107	-0.923	0.354	0.448	-0.094	0.178	-0.525
ES	0.461	0.445	0.016	0.132	0.119	0.268	0.346	-0.079	0.196	-0.401
FI	0.661	0.564	0.097	0.165	0.588	0.493	0.409	0.084	0.093	0.908
FR	0.644	0.726	-0.082	0.179	-0.462	0.323	0.541	-0.218	0.255	-0.855
GR	0.421	0.502	-0.081	0.152	-0.533	0.250	0.423	-0.173	0.215	-0.807
HU	0.558	0.627	-0.069	0.118	-0.587	0.402	0.496	-0.095	0.194	-0.488
IE	0.658	0.781	-0.124	0.181	-0.682	0.096	0.249	-0.153	0.201	-0.763
IT	0.537	0.579	-0.043	0.130	-0.328	0.369	0.527	-0.158	0.183	-0.863
LT	0.540	0.606	-0.066	0.076	-0.869	0.415	0.504	-0.089	0.142	-0.622
LU	0.646	0.432	0.213	0.175	1.219	0.377	0.240	0.137	0.205	0.668
LV	0.542	0.570	-0.028	0.086	-0.326	0.276	0.417	-0.141	0.178	-0.792
NL	0.683	0.708	-0.025	0.191	-0.130	0.289	0.446	-0.156	0.315	-0.496
PL	0.637	0.682	-0.045	0.105	-0.432	0.469	0.569	-0.100	0.184	-0.543
PT	0.483	0.516	-0.033	0.095	-0.352	0.298	0.413	-0.115	0.161	-0.716
RO	0.630	0.663	-0.033	0.118	-0.277	0.381	0.515	-0.134	0.244	-0.550
SE	0.708	0.720	-0.012	0.098	-0.119	0.520	0.620	-0.101	0.166	-0.607
SI	0.554	0.510	0.044	0.122	0.361	0.358	0.410	-0.052	0.145	-0.357
SK	0.592	0.666	-0.075	0.089	-0.840	0.423	0.615	-0.191	0.151	-1.262
UK	0.642	0.740	-0.098	0.176	-0.557	0.085	0.493	-0.408	0.232	-1.759

	Grassland soil productivity					Grass production capacity				
MS	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**
AT	0.559	0.619	-0.061	0.128	-0.472	0.197	0.019	0.178	0.157	1.130
BE	0.761	0.760	0.001	0.131	0.008	0.244	0.085	0.158	0.172	0.923
BG	0.569	0.600	-0.031	0.116	-0.272	0.183	0.066	0.117	0.155	0.757
CZ	0.682	0.731	-0.050	0.071	-0.699	0.134	0.022	0.112	0.133	0.843

DE	0.651	0.685	-0.034	0.124	-0.271	0.157	0.062	0.095	0.185	0.516
DK	0.708	0.692	0.016	0.057	0.273	0.018	0.022	-0.004	0.073	-0.054
EE	0.557	0.659	-0.102	0.106	-0.958	0.100	0.103	-0.003	0.143	-0.018
ES	0.431	0.423	0.008	0.135	0.059	0.157	0.069	0.088	0.157	0.559
FI	0.658	0.548	0.110	0.170	0.650	0.021	0.009	0.012	0.041	0.291
FR	0.626	0.714	-0.088	0.203	-0.435	0.225	0.120	0.106	0.210	0.503
GR	0.407	0.490	-0.084	0.153	-0.544	0.131	0.056	0.076	0.131	0.577
HU	0.533	0.608	-0.075	0.128	-0.584	0.106	0.066	0.041	0.133	0.306
IE	0.647	0.790	-0.143	0.201	-0.712	0.534	0.514	0.020	0.247	0.083
IT	0.522	0.561	-0.038	0.133	-0.289	0.104	0.014	0.091	0.123	0.735
LT	0.503	0.576	-0.073	0.077	-0.948	0.053	0.038	0.015	0.091	0.164
LU	0.617	0.344	0.272	0.213	1.276	0.126	0.046	0.080	0.129	0.615
LV	0.550	0.537	0.013	0.080	0.164	0.177	0.077	0.100	0.144	0.694
NL	0.690	0.718	-0.028	0.192	-0.149	0.348	0.220	0.128	0.317	0.404
PL	0.609	0.654	-0.045	0.094	-0.477	0.085	0.050	0.035	0.130	0.273
PT	0.413	0.462	-0.049	0.090	-0.541	0.126	0.031	0.095	0.109	0.868
RO	0.633	0.666	-0.032	0.137	-0.237	0.169	0.088	0.081	0.168	0.480
SE	0.564	0.634	-0.070	0.091	-0.768	0.039	0.028	0.012	0.090	0.130
SI	0.528	0.482	0.046	0.112	0.408	0.064	0.019	0.045	0.087	0.524
SK	0.568	0.659	-0.091	0.090	-1.014	0.074	0.007	0.067	0.098	0.690
UK	0.615	0.723	-0.108	0.170	-0.632	0.504	0.205	0.299	0.224	1.334

	Hydrological excess water				
MS	**LFA**	**NON LFA**	**DIFF**	**STDpooled**	**Effect Size**
AT	384.7	251.5	133.2	190.8	0.70
BE	539.9	467.8	72.1	92.9	0.78
BG	273.6	248.2	25.4	93.6	0.27
CZ	303.8	238.6	65.2	99.9	0.65
DE	358.9	335.4	23.5	127.3	0.18
DK	353.3	369.5	-16.2	124.3	-0.13
EE	460.9	461.5	-0.6	82.8	-0.01
ES	293.4	288.8	4.6	187.4	0.02
FI	385.0	431.3	-46.3	92.0	-0.50
FR	438.9	394.3	44.6	136.3	0.33
GR	338.2	286.2	52.0	113.8	0.46
HU	254.1	257.4	-3.3	110.0	-0.03
IE	619.1	559.6	59.5	221.1	0.27
IT	333.3	383.9	-50.5	157.9	-0.32
LT	428.1	400.7	27.4	79.1	0.35
LU	488.3	548.1	-59.9	76.0	-0.79
LV	450.4	453.5	-3.1	78.0	-0.04
NL	454.2	470.5	-16.3	84.8	-0.19
PL	276.3	269.1	7.2	96.5	0.07
PT	444.7	482.1	-37.5	221.9	-0.17

RO	220.8	222.1	-1.4	92.5	-0.01
SE	359.7	273.1	86.5	118.0	0.73
SI	405.7	327.0	78.7	188.2	0.42
SK	251.0	189.8	61.3	89.5	0.68
UK	581.7	374.0	207.8	209.5	0.99

2. Indicators for regulating and maintenance services

	Erosion control					**Pollination potential**				
MS	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**
AT	0.906	0.811	0.095	0.077	1.24	0.082	0.051	0.031	0.039	0.78
BE	0.887	0.811	0.076	0.074	1.03	0.073	0.069	0.004	0.031	0.14
BG	0.922	0.841	0.081	0.071	1.13	0.183	0.087	0.096	0.093	1.03
CZ	0.828	0.794	0.034	0.042	0.81	0.052	0.036	0.016	0.031	0.52
DE	0.856	0.819	0.038	0.069	0.55	0.048	0.036	0.012	0.028	0.43
DK	0.799	0.803	-0.003	0.054	-0.06	0.030	0.037	-0.006	0.028	-0.23
EE	0.800	0.804	-0.004	0.083	-0.05	0.059	0.051	0.008	0.026	0.32
ES	0.850	0.799	0.052	0.112	0.46	0.220	0.187	0.033	0.163	0.20
FI	0.795	0.823	-0.028	0.088	-0.32	0.035	0.051	-0.016	0.030	-0.53
FR	0.864	0.804	0.060	0.092	0.65	0.110	0.070	0.040	0.066	0.60
GR	0.812	0.732	0.080	0.132	0.60	0.284	0.185	0.100	0.166	0.60
HU	0.834	0.819	0.014	0.062	0.23	0.077	0.058	0.019	0.061	0.31
IE	0.922	0.869	0.052	0.089	0.59	0.050	0.043	0.008	0.022	0.35
IT	0.820	0.766	0.054	0.100	0.54	0.214	0.133	0.081	0.130	0.62
LT	0.858	0.832	0.026	0.047	0.55	0.048	0.037	0.012	0.024	0.50
LU	0.846	0.778	0.068	0.084	0.81	0.098	0.085	0.013	0.029	0.46
LV	0.843	0.830	0.013	0.068	0.19	0.059	0.050	0.009	0.021	0.41
NL	0.847	0.800	0.047	0.093	0.50	0.071	0.075	-0.005	0.036	-0.13
PL	0.845	0.831	0.014	0.040	0.36	0.039	0.033	0.006	0.025	0.25
PT	0.827	0.772	0.054	0.120	0.45	0.275	0.238	0.037	0.137	0.27
RO	0.862	0.835	0.027	0.068	0.40	0.103	0.071	0.032	0.062	0.52
SE	0.845	0.819	0.026	0.082	0.32	0.035	0.022	0.013	0.022	0.59
SI	0.858	0.819	0.039	0.088	0.45	0.126	0.065	0.061	0.054	1.13
SK	0.856	0.789	0.067	0.044	1.52	0.065	0.048	0.017	0.037	0.45
UK	0.937	0.842	0.095	0.071	1.35	0.072	0.038	0.034	0.037	0.91

	Habitat maintenance					**Soil organic content in the topsoil (tC/ha)**				
MS	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**

AT	1019.3	364.6	654.7	379.8	1.72	96.1	71.6	24.5	37.5	0.65
BE	924.1	519.3	404.7	386.9	1.05	110.8	77.9	32.9	31.8	1.03
BG	924.3	302.1	622.2	436.1	1.43	74.2	62.2	12.0	23.5	0.51
CZ	605.9	243.0	362.9	349.3	1.04	69.9	64.7	5.2	26.6	0.20
DE	510.4	288.4	222.0	363.0	0.61	92.1	75.5	16.6	38.2	0.43
DK	297.8	367.8	-70.0	309.5	-0.23	58.0	54.2	3.8	24.0	0.16
EE	669.3	572.1	97.1	369.9	0.26	116.4	119.1	-2.7	33.9	-0.08
ES	705.8	487.9	218.0	535.5	0.41	64.4	54.3	10.1	28.3	0.36
FI	764.0	754.4	9.6	334.1	0.03	130.6	80.6	50.1	51.3	0.98
FR	808.2	407.7	400.5	437.6	0.92	81.7	76.2	5.5	34.8	0.16
GR	871.1	498.4	372.7	538.4	0.69	47.5	55.7	-8.2	15.4	-0.53
HU	333.3	282.2	51.1	345.4	0.15	75.2	70.3	4.8	23.7	0.20
IE	641.6	455.9	185.7	506.0	0.37	145.0	129.3	15.7	44.5	0.35
IT	816.8	449.0	367.7	468.0	0.79	55.2	50.4	4.8	20.9	0.23
LT	454.9	309.6	145.3	342.2	0.42	54.4	55.4	-0.9	17.6	-0.05
LU	655.5	238.9	416.6	321.2	1.30	115.5	136.2	-20.6	31.3	-0.66
LV	733.7	827.0	-93.3	366.4	-0.25	119.6	113.3	6.3	34.4	0.18
NL	463.7	415.2	48.6	429.1	0.11	119.3	116.2	3.1	45.3	0.07
PL	497.8	344.6	153.2	337.0	0.45	67.1	71.1	-4.0	36.5	-0.11
PT	903.8	747.9	155.9	446.9	0.35	51.9	45.7	6.3	29.4	0.21
RO	682.6	345.5	337.1	501.2	0.67	79.6	69.7	9.8	26.7	0.37
SE	645.8	411.1	234.7	380.6	0.62	92.3	84.2	8.1	16.2	0.50
SI	1099.4	506.7	592.7	373.4	1.59	84.2	94.8	-10.6	39.8	-0.27
SK	519.1	152.8	366.2	351.3	1.04	73.0	57.0	16.1	21.8	0.74
UK	901.4	369.9	531.5	507.5	1.05	161.7	114.4	47.3	46.2	1.02

	Soil water content at field capacity				
MS	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**
AT	0.294	0.307	-0.014	0.032868	-0.419
BE	0.309	0.282	0.027	0.04526	0.600
BG	0.314	0.327	-0.013	0.027632	-0.453
CZ	0.293	0.306	-0.013	0.044956	-0.295
DE	0.297	0.290	0.007	0.080695	0.084
DK	0.259	0.244	0.016	0.069986	0.225
EE	0.322	0.341	-0.019	0.099633	-0.194
ES	0.304	0.310	-0.005	0.0439	-0.123
FI	0.305	0.219	0.085	0.104708	0.813
FR	0.303	0.308	-0.005	0.045679	-0.116
GR	0.309	0.319	-0.010	0.040297	-0.244
HU	0.337	0.324	0.012	0.060524	0.206
IE	0.335	0.313	0.023	0.086929	0.260
IT	0.301	0.297	0.005	0.050043	0.092
LT	0.317	0.322	-0.005	0.08279	-0.065

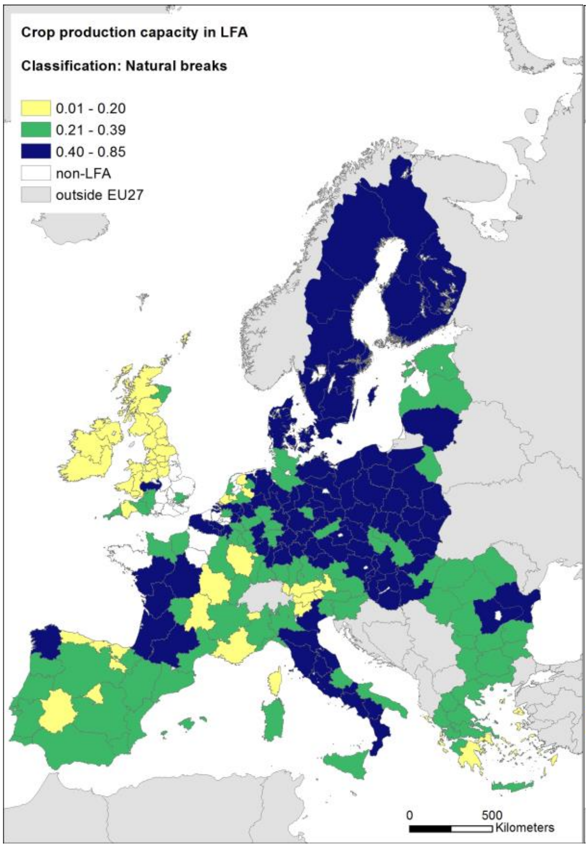
LU	0.312	0.338	-0.026	0.037782	-0.688
LV	0.324	0.311	0.013	0.090368	0.147
NL	0.312	0.291	0.021	0.120115	0.174
PL	0.283	0.294	-0.010	0.08936	-0.117
PT	0.272	0.266	0.007	0.062612	0.107
RO	0.312	0.322	-0.009	0.03494	-0.270
SE	0.310	0.304	0.007	0.075698	0.090
SI	0.317	0.322	-0.005	0.028626	-0.164
SK	0.304	0.305	-0.001	0.022884	-0.033
UK	0.334	0.303	0.032	0.092256	0.344

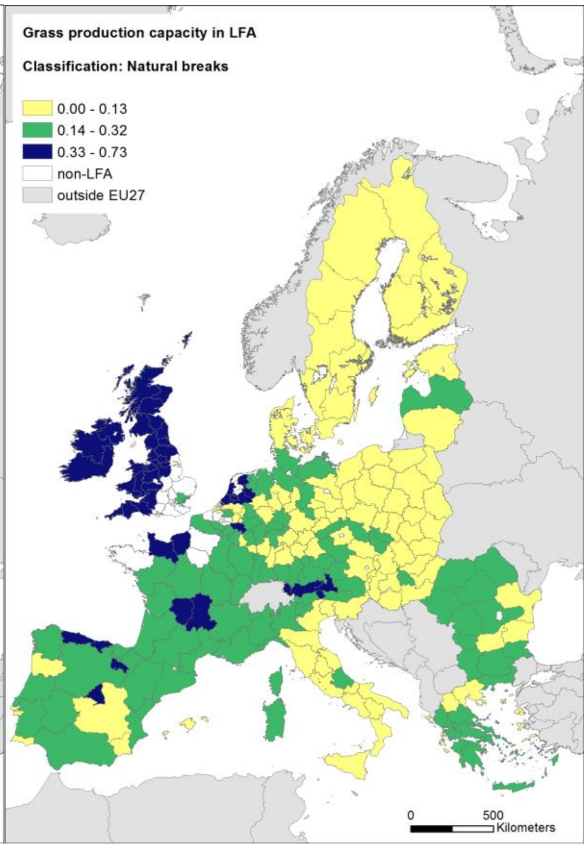
3. Indicator for cultural services

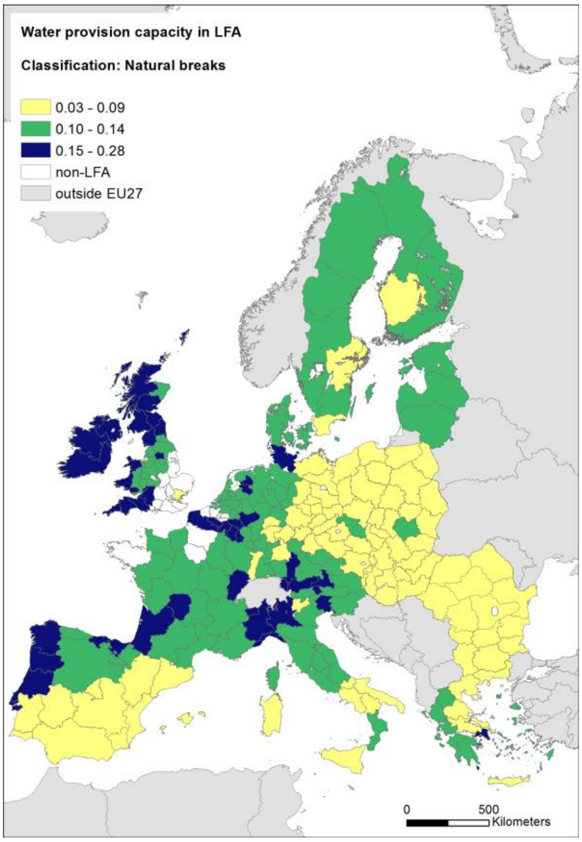
	Recreation pontential				
MS	**LFA**	**NON LFA**	**DIFF**	**STD_{pooled}**	**Effect Size**
AT	0.234	0.180	0.054	0.089	0.61
BE	0.268	0.203	0.065	0.123	0.53
BG	0.333	0.232	0.101	0.134	0.76
CZ	0.207	0.177	0.030	0.080	0.38
DE	0.310	0.267	0.043	0.155	0.28
DK	0.199	0.183	0.016	0.088	0.19
EE	0.209	0.189	0.019	0.073	0.26
ES	0.269	0.230	0.039	0.125	0.31
FI	0.191	0.301	-0.110	0.061	-1.81
FR	0.259	0.210	0.048	0.130	0.37
GR	0.312	0.260	0.052	0.146	0.35
HU	0.266	0.204	0.062	0.122	0.51
IE	0.268	0.194	0.074	0.094	0.79
IT	0.250	0.189	0.061	0.106	0.58
LT	0.213	0.195	0.018	0.087	0.21
LU	0.197	0.210	-0.013	0.071	-0.18
LV	0.240	0.222	0.018	0.112	0.16
NL	0.217	0.197	0.020	0.091	0.22
PL	0.227	0.193	0.034	0.107	0.32
PT	0.274	0.214	0.060	0.117	0.51
RO	0.253	0.192	0.060	0.104	0.58
SE	0.202	0.181	0.021	0.081	0.26
SI	0.255	0.223	0.032	0.119	0.27
SK	0.244	0.197	0.048	0.110	0.43
UK	0.276	0.178	0.098	0.095	1.04

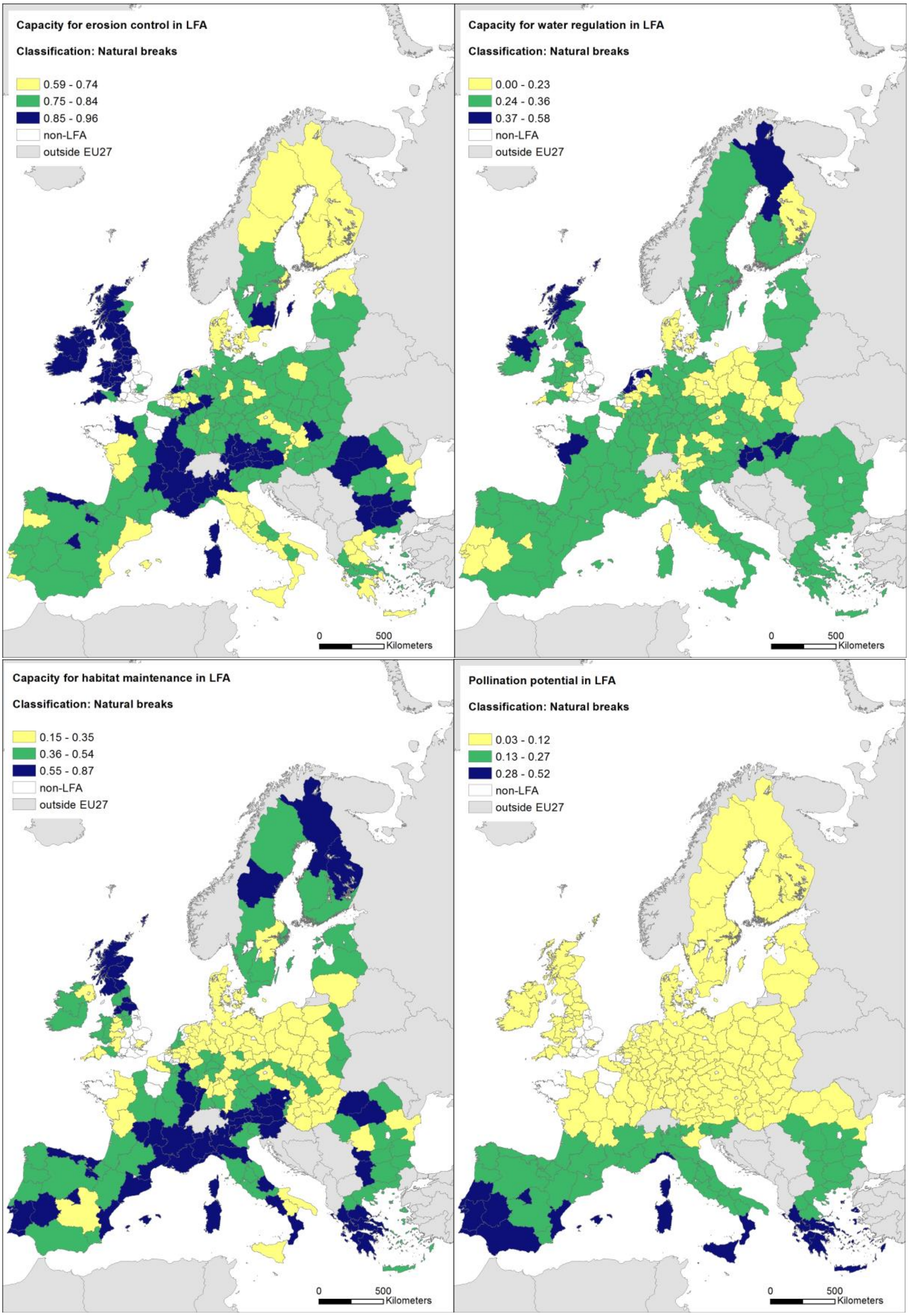
Annex VIII. Capacity for nine ecosystem services in LFA in EU27 (except Malta and Cyprus)

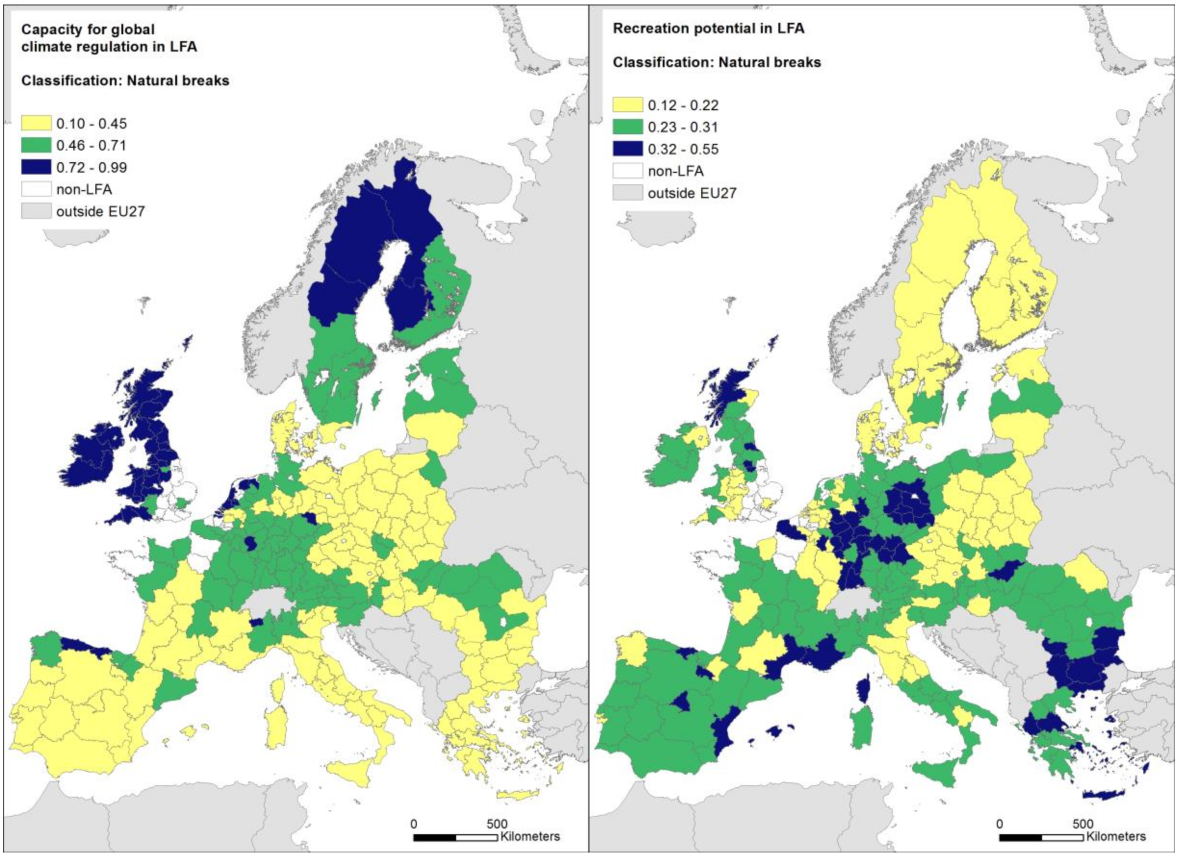
Average indicator values at NUTS2 level, classification method: natural breaks (ArcGIS 10.1).








Capacity for erosion control in LFA
Classification: Natural breaks
0.59 - 0.74
0.75 - 0.84
0.85 - 0.96
non-LFA
outside EU27
0
500
Kilometers
Capacity for water regulation in LFA
Classification: Natural breaks
0.00 - 0.23
0.24 - 0.36
0.37 - 0.58
non-LFA
outside EU27
0
500
Kilometers
Capacity for habitat maintenance in LFA
Classification: Natural breaks
0.15 - 0.35
0.36 - 0.54
0.55 - 0.87
non-LFA
outside EU27
0
500
Kilometers
Pollination potential in LFA
Classification: Natural breaks
0.03 - 0.12
0.13 - 0.27
0.28 - 0.52
non-LFA
outside EU27
0
500
Kilometers


Capacity for global
climate regulation in LFA
Classification: Natural breaks
0.10 - 0.45
0.46 - 0.71
0.72 - 0.99
non-LFA
outside EU27
0 500 Kilometers
Recreation potential in LFA
Classification: Natural breaks
0.12 - 0.22
0.23 - 0.31
0.32 - 0.55
non-LFA
outside EU27
0 500 Kilometers

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