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Land Productivity Dynamics in Europe

Towards a Valuation of Land Degradation in the EU

Cherlet M., Ivits E., Sommer S., Tóth G., Jones A., Montanarella L., Belward A.

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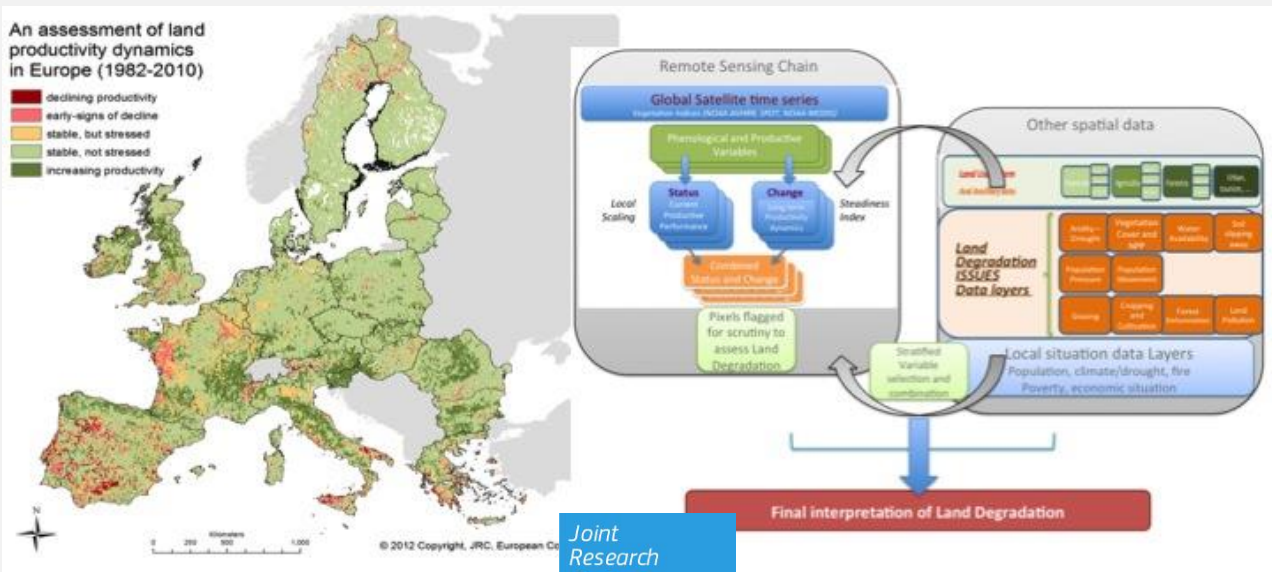

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Joint Research Centre

Contact information
Name: Michael Cherlet
Address: Joint Research Centre, Via Enrico Fermi 2749, TP 440, 21027 Ispra (VA), Italy
E-mail: michael.cherlet@jrc.ec.europa.eu
Tel.: +39 0332789982

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Title Land productivity dynamics in Europe – towards valuation of land degradation in the EU

Abstract
This document reported first results on the assessment and evaluation of land- productivity dynamics and showed initial examples on the added value of integrating contextual information. Such information that is needed to derive final judgments related to the land degradation situation in contribution to the implementation of the RIO+20 target of a 'land degradation neutral world'. We documented that, based on satellite time-series observations; the dynamics of the land-productivity can be mapped for the EU27. Using this basis information to analyze incidence with potential drivers of land degradation, such as unsustainable exploitation or e.g. soil erosion, to compile convergence of evidence allows interpreting the land- productivity dynamics in the light of identifying and mapping on-going land degradation. This spatial evaluation also highlighted that, in the frame of the 'neutral land degradation world' discussion, area percentages of decline and increase
In land-productivity cannot straightforwardly be counterbalanced as these areas can have totally different actual and optional Land uses as well as economic and cultural values.

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Joint Research Centre
Institute for Environment and Sustainability
Land Resource Management Unit

Table of Contents

EXECUTIVE SUMMARY

Land degradation and desertification adversely affect food production and security, water security, energy security, biodiversity, and many ecosystem services. Land degradation is the persistent reduction or loss of the biological and economic productivity of land. Causes and consequences of land degradation have multiple characteristics and vary within space, scale and context; hence measuring land degradation is a very complex and multifaceted problem that needs to address biophysical and societal processes.

In the context of this study, land productivity is calculated by combining long-term changes with the current levels of efficiency of factors that define standing biomass conditions. Derived from satellite observations between 1982 and 2010, land productivity is a good reflection of the status of the supporting and main regulating ecosystem services on which provisioning and cultural services are based. This report introduces a regional land productivity dynamics map which can serve as a basis for analysing issues that influence the condition of biomass, such as land use, climate and soil characteristics. This process of further integrating thematic and/or area-specific information, including societal aspects, will ultimately lead to a comprehensive land degradation assessment.

This report illustrates the first steps of integrating global layers with adapted local knowledge, based on a concept which was developed for the new World Atlas of Desertification.

What causes land degradation in Europe?

Key causes of land degradation in the European Union (EU) include inappropriate agricultural intensification, soil sealing, agro-silvo-pastoral land abandonment, loss of productive land, ecosystem fragmentation, pollution and increased frequency of climatic extremes that affect the condition and functioning of soil and vegetation.

Agricultural intensification does not always lead to land degradation. But pressure on land can engender degradation processes that can negatively impact the functioning of ecosystems and provoke soil erosion, salinisation, soil carbon content depletion, soil compaction and even the collapse of grazing and/or crop productivity.

Land covered by concrete, tarmacadam and other elements of our expanding human infrastructures prevents productive land from delivering provisioning ecosystem services. Soil sealing cuts off the land’s supporting ecosystem service potential and degrades the productive capacity of the landmass. This is an increasingly pressing issue, as the demands for food, fuel and fibre are increasing. It also compromises other natural land functions, such as surface-atmosphere gas, water and energy exchanges, and negatively affects soil conditions and overall biodiversity.

When used for forestry, grazing or growing crops, land is usually carefully managed, although a decline in land productivity can occur due to a range of stresses at the local or landscape level. When land is abandoned, factors such as reduced spatial complexity, soil erosion or shrub encroachment, along with the associated increase in the frequency and intensity of fires and changes in nutrient input, can decrease the agro-silvo-pastoral value of the land.

Climate variability exacerbates the human impacts described above and exerts its own pressure on the natural system. Extreme meteorological events (e.g. drought, intense rains, windstorms) are likely to increase in frequency and intensity. Vegetation productivity and soil stability and health are directly affected by these extremes, thus magnifying, accelerating and even driving land degradation.

Where in Europe is land degradation a problem?

10% (about 2 million ha) of the EU's most productive soils show early signs of a decline in land productivity

Nowhere in Europe is fully immune to land degradation, but some regions are more susceptible than others. As noted above, land degradation is caused by interconnected biological, physical, social and economic drivers; these complex interactions present significant challenges to measuring land degradation. Because land productivity - the measure of the dynamics and efficiency of standing biomass - is exploited for biological products of economic value and is influenced by human-environment interactions, this study uses change patterns in land productivity as a base upon which biophysical and societal information is added in order to deduce ongoing land degradation.

A decline in land productivity can be a first indication of ongoing land degradation processes - but stable or even increasing land productivity is not necessarily an indication of the absence of land degradation. Using a range of daily observations from Earth observing satellites (between 1982 and 2010), the JRC has developed a standardised methodology for mapping land productivity dynamics capable of delivering comparable results across Europe.

The drivers (e.g. the effects of agricultural intensification, extreme meteorological events, and soil erosion) can have both positive and negative changes, as can be deduced by combining the abovementioned remote-sensing analysis with socio-economic and other physical data such as meteorological measurements, soil surveys, land cover, land use, yield and demographic data. This allows for the identification of where and why land productivity is changing, where threats are greatest and where conditions are improving.

The study confirms that land productivity is declining in some locations across almost all EU Member States; the hot, dry Mediterranean countries are undoubtedly highly susceptible, but so too are the colder, wetter northern and eastern parts of Europe to some degree. We estimate that 85.1% of the total EU area is currently unaffected by land productivity decline, 7.9% shows a land productivity that is stable but stressed, 5.6% shows early signs of land productivity decline, and 1.5% (6,037,500 ha) is in decline (table 1, figures 3 and 4).

Focusing on agricultural areas, a more diverse picture emerges: less than 1% (112,500 ha) of EU arable land, and even less of EU pastureland (0.2%), is in decline (tables 2a and 2b). Arable land in the EU contains soils of widely different quality. About 10% of the EU's most productive soils show early signs of land productivity decline, whilst 15% of the least productive soils fall into this category (table 3).

In contrast, the study has also found an almost 15% increase in land productivity for the EU as a whole (table 1), with forests and semi-natural areas accounting for almost half of this.

It must be noted that this study's mapping and assessment of land productivity dynamics focuses on ongoing processes. Land productivity dynamics are therefore only depicted with respect to change since 1982, when daily satellite observations began. Knowledge about actual ongoing processes is more relevant to mitigation and adaptation decision making than to strategies aimed at the restoration of degraded lands. Furthermore, at the spatial resolution of the satellite observations used to calculate land productivity (5 km by 5 km), land cover often appears to be heterogeneous, even though it may include different land cover types. This integrates combined productivity in blocks of 2,500 ha. This resolution cannot capture individual field- or plot-level processes, such as erosion, organic matter decline, etc., or provide the detail needed to study localised situations, such as small Natura 2000 sites. However, the satellite observation data are unique in providing continuous, repetitive and synoptic landscape information on the actual status of and changes in the standing biomass, which reflects the functioning of the ecosystem for the entire EU from 1982 to date.

What are the consequences of land degradation?

Productive land is effectively a non-renewable resource on human time scales

Degraded land has less capacity to provide food, fuel and fibre than unaffected areas. In general, degraded land has reduced biodiversity and changed (though not necessarily reduced) biophysical attributes – the roles of degraded and unaffected land in the climate system can be quite different as a result of changed albedo, water and gas-cycling properties and even surface roughness. Degraded land could turn into a source of carbon emissions and thereby contribute to global warming. One of the prime consequences is that the natural productivity of the land decreases – sometimes to such an extent that recovery is constrained by physical/chemical conditions and/or beyond economic feasibility. Global estimates quote economic losses of 7-12% of agricultural production due to land degradation. Losing land and land productivity can be disastrous as land is effectively a non-renewable resource on human time scales. With the exception of the occasional volcanic island and land reclaimed from water bodies, the land area is fixed. As it can take well over 100 years to generate a single centimetre of soil in temperate grasslands, soil lost to erosion (figures 19 to 22) or sealing cannot be easily replaced within a human lifespan. Secondary effects, such as the collapse of rural communities, migration, and feedback on the climate system are felt far beyond the directly affected areas and people. Off-site impacts are not negligible and land degradation must not be considered a localised problem.

The RIO+20 Conference committed to strive for a land degradation neutral world, but is European land degradation neutral?

The United Nations Conference on Sustainable Development (RIO+20) target of 'neutrality' aims to prevent land degradation and restore degraded lands. Recognising that some land degradation is probably inevitable, the RIO+20 target allows for land restoration to compensate for land degradation. This first evaluation suggests that almost all EU Member States are affected by declining land productivity to some degree. Yet, without a fully accepted indicator, we cannot definitively confirm whether or not the EU is land degradation neutral.

A reduction in land degradation will lead to increased productivity and new economic opportunities, help secure rural labour markets through alternative and sustainable land use options, and help safeguard ecosystem services, including the land's climate system, water-regulation capacity and biodiversity functions. The degradation of ecosystems is – to a large extent – induced by unsustainable human activities. This puts people at the very centre of the issue and requires them to take responsibility and action. Understanding the value of ecosystems and their services is essential in order to construct preventative solutions and conservation methodologies that deliver socio-economic benefits. Sustainable land management is a viable option for prevention and conservation and has been implemented in a wide diversity of geographical and economic contexts. Achieving land-degradation neutrality is not so much desirable as essential.

By avoiding the pitfalls of unsustainable agricultural intensification (figures 24 and 25), by improving spatial planning, in particular infrastructure and housing (to make maximum use of brownfield sites, cut back on the sealing of productive soils, etc.), by encouraging rural communities to develop sustainable practices and by pursuing an effective fight against climate change, Europe could reach a land degradation neutral state.

What can be done?

Efficient use of the land means managing trade-offs between human needs and the long-term capacity of the ecosystem to provide goods and services.

Systematic information gathering (mapping, measuring and monitoring) provides scientific evidence, such as that outlined in this report, on which to build and implement policies to reduce land degradation and improve rehabilitation in priority areas. Our capacity for such information gathering is improving; new satellite observations are available with improved spatial resolution over those used in this study, and repeatable methodologies can process these into meaningful products as illustrated in this report. Well-established and functioning global networks of land degradation experts are

in place in the framework of the World Atlas of Desertification and the European Soil Bureau Network, and archives of validated information are growing.

Efficient use of the land should be based on managing trade-offs between human needs and the long-term capacity of the ecosystem to provide goods and services. Unsustainable land management has visible and measurable negative outcomes, beyond productivity loss, which can be mapped. The effects of land management practices can be quantified by adding the economic valuation of land and its associated ecosystem services. Such holistic assessment will facilitate more informed decision making and encourage the development of sustainable solutions, in line with the transition to a green economy and resource efficiency. Land degradation science provides a basis for these evidence-based policies.

Though no specific land degradation legislation is in place at the EU level, policies such as the Soil Thematic Strategy, regional development, the Common Agricultural Policy (CAP) reform, the Water Framework Directive, the EU 2020 Biodiversity Strategy and the Economics of Land Degradation (ELD) initiative increasingly consider the abovementioned approach and acknowledge the need for cross-sectorial integration.

This document is based on the initial results of ongoing scientific research. It should not be considered as definitive or exhaustive.

1 POLICY DEMAND REGARDING LAND DEGRADATION IN EUROPE

In its final document entitled "The future we want", the delegations to the United Nations Conference on Sustainable Development (RIO+20, held in Rio de Janeiro, Brazil, 20-22 June 2012) recognised the need for urgent action to reverse global land degradation. It set a target of striving for a land-degradation neutral world in the context of sustainable development.

This involves being aware of where and at what intensity land degradation occurs, and the location of areas that should be conserved, protected or restored, in order to assess and manage trade-offs between direct human/social needs and continental/global equilibrium, in view of maintaining sufficient ecosystem productivity.

Systematic mapping, measuring and monitoring, based on a robust scientific and technical knowledge base such as that outlined in this report, are needed to provide evidence on land degradation. Such information is needed to develop and implement policies to reduce land degradation and improve rehabilitation. The European capacity for such information gathering is improving through the development of long-term archives of validated thematic information and new high-resolution satellite observations.

The efficient use and preservation of land should be based on managing trade-offs between human needs and the long-term capacity of the ecosystem to provide necessary goods and services. Unsustainable land management has visible and measurable negative outcomes which go beyond agricultural productivity losses. The effects of land management practices can be quantified by adding an economic valuation of land to a valuation of the associated ecosystem services that land provides. Such holistic assessments of costs and benefits will facilitate more informed decision making and encourage the development of sustainable solutions, thus making it an integral element of policy and planning processes in line with the transition of the private and public sectors to a green economy.

In a Communication published at the onset of the Year of Biodiversity (Comm (2011)244), European Union (EU), Member States committed to develop, with the assistance of the European Commission, a set of biophysical maps of ecosystem services of key importance at the EU level by the end of 2020. These maps should identify the spatial differences in ecosystem services supplied by all ecosystems in the EU, including semi-natural and agricultural systems which fall outside the Natura 2000 network but which contribute to green infrastructure.

Although there is currently no specific land degradation legislation within the EU, policies such as the Soil Thematic Strategy, regional development, the Common Agricultural Policy (CAP) reform, the Water Framework Directive, the EU 2020 Biodiversity Strategy and the Economics of Land Degradation (ELD) initiative increasingly consider the abovementioned approach, acknowledging the need for cross-sectorial integration. Although final solutions still need to be found, land-degradation science, such as that provided in this report, provides a sound basis for evidence-based policies.

2 LAND DEGRADATION – DEFINITION FRAMEWORK

Land

This study investigates land under the perspective of the United Nations Convention to Combat Desertification (UNCCD) definition which refers to land as "*the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system*" (Article 1 of the UNCCD). Of course, this includes all human interactions with the environment.

Land Degradation

The complex interactions alluded to above are reflected in the UNCCD convention text (1994), which defines land degradation in drylands as the "*reduction or loss of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as:*

(i) soil erosion caused by wind and/or water;
(ii) deterioration of the physical, chemical and biological or economic properties of soil; and
(iii) long-term loss of natural vegetation".

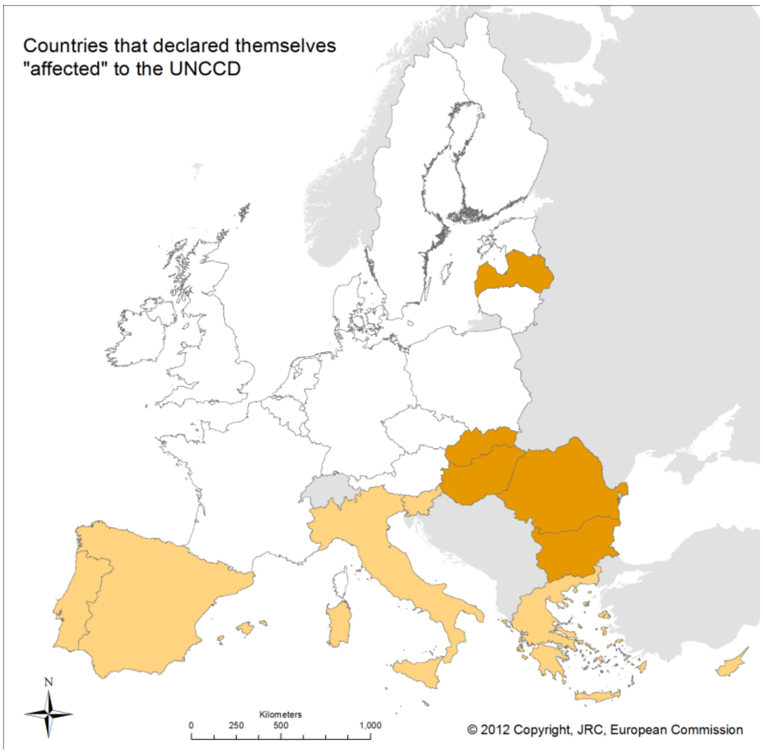


Figure 1: EU countries that declared themselves to the UNCCD as being 'affected' by land degradation (under Annex 4 in light shade and Annex 5 in darker shade)

While the abovementioned UNCCD definition contains geographical restrictions, effectively limiting areas under consideration to 'drylands', there has been much argument in recent years to favour the global dimension of land degradation. The first scientific conference of the UNCCD Committee on Science and Technology (held in 2010 in Buenos Aires, and co-organised by the European Commission's Joint Research Centre) reconfirmed the fact that land degradation and desertification adversely affect global food production and security, water security, energy security, global biodiversity, and many ecosystem services. Land degradation and desertification also compromise associated recreational, world heritage and cultural values. In preparation for the conference, a group of experts (Dryland Science for Development, WG1, http://dsd-consortium.jrc.ec.europa.eu) revisited and reformulated the UNCCD definition and recommended the following:

> ***(a) Desertification is an end state of the process of land degradation; this process is expressed by a persistent reduction or loss of biological and economic productivity of lands that are under uses by people whose livelihoods depend, at least partly, on this productivity, yet the reduction or loss of this productivity is driven by that use.***
>
> ***(b) Combating desertification means addressing all stages of land degradation including those that precede the level of productivity loss specific to desertification, the one for which reclamation, rather than***

rehabilitation measures are required for restoring the persistently lost productivity of the land.

(c) Land degradation and desertification, as described in (a) and (b), require attention in all lands, with special concern directed to all drylands, namely those of climate yielding an aridity index ≤ 0.65, whether based on 1950-1980 prevailing climate, and/or on more recent climate data.

Whilst reaffirming that drylands are deserving of 'special concern', this revisited definition recognises land degradation as a truly global problem and provides a basis for global and continental assessments. Consequently, this study covers the whole of the EU.

3 ASSESSING LAND DEGRADATION

Land degradation and desertification are complex phenomena. Land degradation is driven by multiple factors[6,7,8,9]. Causes and consequences of land degradation have manifold interacting characteristics that vary within space, scale and context. Hence, the measurement of land degradation is a very complex multifaceted task that needs to address both biophysical and societal processes. Such considerations have been clearly asserted in recent science-based paradigms such as the Dryland Development Paradigm (DDP[8]).

In past decades, EU-funded research has addressed many of the abovementioned issues, focusing on developing methodologies for monitoring and assessing land degradation processes (e.g. MEDALUS, LADAMER, DESURVEY) as well as approaches to map and evaluate sustainability options, ecosystem services and sustainable land management techniques that prevent and mitigate land degradation and desertification (e.g. IP SENSOR, MEDACTION, DESIRE).

The work presented in this report builds on key findings of the abovementioned research and on scientific collaboration in the compilation of the new World Atlas of Desertification (WAD), which was initiated and is coordinated by JRC in partnership with the United Nations Environment Programme. The WAD assessment and mapping methodologies are adapted for global scale studies, expanding from dryland areas only, as described in the 1994 UNCCD definition. The report documents the application of the first steps of the WAD assessment framework and provides a baseline information layer for further EU-wide assessment.

Addressing the abovementioned definition and conceptual discussion, this report introduces a spatial continuous base layer of 'land productivity

dynamics'. 'Land productivity' in this context is defined as an expression of the bio-productivity resulting from all land components and their interactions, and is not only related to human activities and direct land use. Land productivity is therefore not to be confused with agricultural productivity. The report illustrates that, in order to identify and attribute land degradation 'causes' and 'effects', further biophysical and societal information is needed from multiple ancillary data sources. Integration analysis is outlined in some examples.

The low- and medium-resolution satellite remote sensing imagery used for this study cannot capture single field-level processes, but it is unique in providing repetitive and synoptic information and in observing 'land' at kilometre scales. This intrinsically allows 'land' to be perceived as a functional unit. The satellite measurement is therefore an expression of all climate-soil-water-human interactions that condition the functioning and status of the heterogeneous land cover observed. 'Land' is considered in its most holistic sense. This study builds on this basic concept.

Against this background, the 'land-degradation neutrality' target set at the RIO+20 Conference in June 2012 would be achieved if persistent reduction or loss of the land's biological and economic productivity were matched by persistent increases or gains in the land's biological and economic productivity. But what exactly can be balanced against what? Can a productivity decrease in one area be balanced by an increase elsewhere? This report seeks to contribute to this discussion.

4 TOWARDS A SYNOPTIC ASSESSMENT OF LAND DEGRADATION IN EUROPE

4.1 Introduction

Land degradation is a complex and dynamic phenomenon and is therefore difficult to monitor and assess[1]. Regional assessment approaches have so far been largely empirical with a focus on biophysical symptoms[2]. However, recent scientific advances suggest that assessments need to integrate biophysical and social sciences, address multi-scale aspects and integrate various indicators that reflect slow and fast processes. The basic assessment and mapping concept that was developed for compiling a new World Atlas of Desertification[3] (WAD) is based on these approaches. The current report applies the methods developed for the production of the WAD, as shown in figure 2.

Firstly, the state of ecosystem productivity related to land degradation and desertification is mapped through satellite observations gathered over a twenty-nine year period. Relevant satellite observations started in 1982, and observations up to 2010 were available by the time this research activity got underway. This provides roughly 35 million observations of 5 km x 5 km cells of the entire EU for this period. At this spatial resolution (25 km^2) the satellite observations, from which land productivity is calculated, effectively comprise a mix of land use and cover types, including agriculture, urban, forest, water, etc. This integration captures the productivity of all these surfaces conditioned by humans and the environment in blocks of 2,500 ha. This level of resolution cannot capture individual field- or plot-level processes, such as erosion, organic matter decline, soil sealing, etc., nor is it appropriate for studying localised situations, such as small Natura 2000 reserves. However, the data are unique in providing continuous, repetitive and synoptic observed information on the status and changes of the vegetative cover for the entire EU.

The condition and dynamics of vegetation are also a good proxy for the structure and functioning of the ecosystem[4], for example, by measuring its response to variations in soil quality, climate influence or human-induced land use and land use changes. For each satellite-based observation point, the standing biomass, which is the total biomass of a given area at a given moment in time, is calculated every year for the entire 1982 to 2010 observation period. Long-term changes and fluctuations in the standing biomass are calculated[5] and combined with measures of deviations from current locally defined maximum productivity levels, which are in turn derived from a higher spatial resolution (1 x 1 km) dataset compiled from observations of the 'Vegetation' sensors on Europe's SPOT satellites, spanning the period 2006 to 2010. This combination is the basis for determining land productivity dynamics[6]. For each 5 km by 5 km square we can measure whether stable, declining or improving standing biomass dynamics have led to land productivity conditions that are at or below the current local potential. The latter is either a natural potential, a potential determined by human land use, or a combination of both. Whilst not an absolute measure of land productivity, this robust approach does provide a consistent, uniform and repeatable index that can be used to flag areas of concern and identify areas of improvement.

The revisited UNCCD definition of land degradation centres on the notion of a persistent reduction or loss of biological and economic productivity of lands used by people whose livelihoods, in general, depend on this productivity[7]. To capture this land use aspect, the satellite-derived evidence is combined with other data and information layers to address land change and land management processes. This convergence of evidence allows for a more complete interpretation of observed land productivity dynamics in terms of land degradation or improvement. Initial results for the EU are presented in this report.

4.2 Assessment of land productivity dynamics in Europe

4.2.1 Introduction

According to the concept of interacting human-environment systems[8], 'ecosystem services' are created by human activity and demands. Anthropogenic impacts, and changes over time, define the trends and the current potential of any ecosystem to supply these services. These demand-driven services tap into available ecosystem structures, which represent a vital natural resource, and affect the functioning of the ecosystem. The dynamics of the Earth's biomass cover, or standing biomass, is a good expression of the general level of the potential of land to supply, or keep on supplying, ecosystem services. Assessing vegetative-cover dynamics approximates a measure of general productivity levels of the land or human-environment system. Land users exploit this land productivity to produce biological products of economic value[9]. Land productivity reflects climatic constraints, the overall quality of the land, and how efficiently the soil and other resources were used, and indirectly indicates the level at which these resources are appropriated for human use, i.e. is the land used for intensive/extensive agriculture, for grazing, forestry or urban development? Hence, land productivity dynamics can indicate levels of sustained land quality and are therefore used as first step in the assessment of land degradation. For example, a decrease in overall land productivity could be expected to indicate a decline in or degradation of land quality (e.g. vegetation, soil and water quality and/or quantity, crop production levels). Whether this is related to land degradation or, for example, land use change, would then need to be further explored.

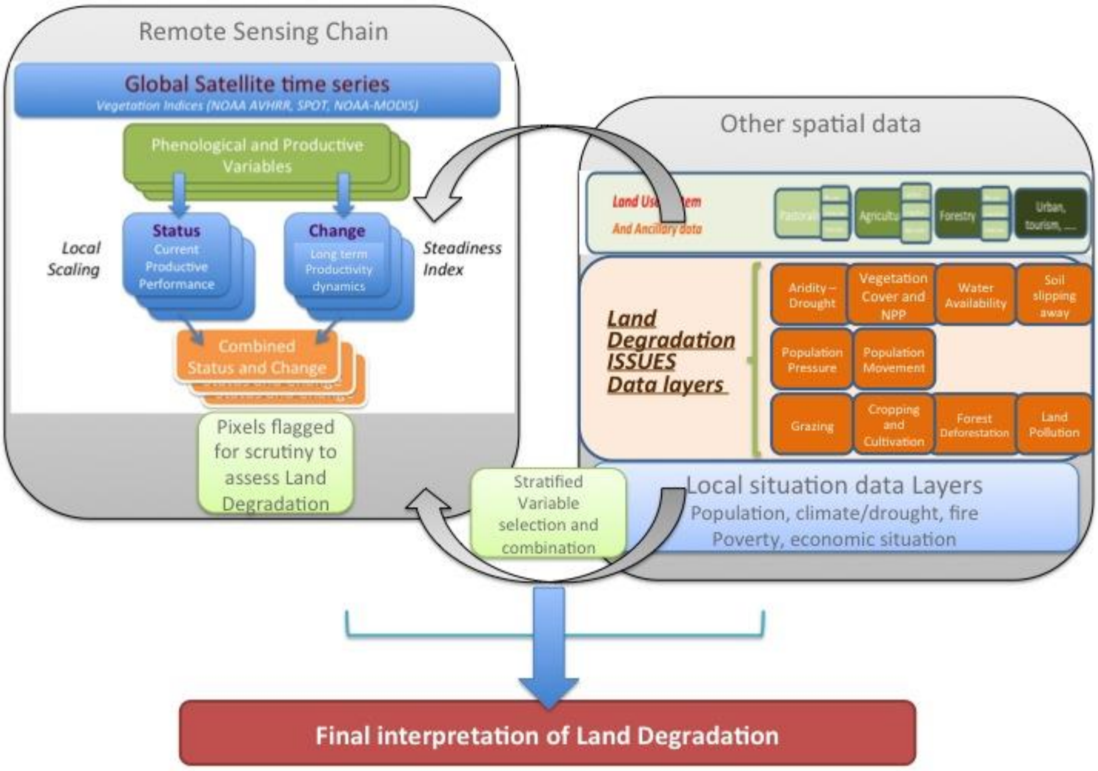


Figure 2: Simplified schematic overview of the processing and interpretation scheme for assessing and mapping land degradation at regional and global scales[4, 5] (based on the WAD Implementation Plan [3])

This assessment of the loss in overall productivity conforms to the abovementioned definitions of land degradation. However, analysis of long-term changes and current efficiency levels of vegetative or standing biomass combined into a land productivity dynamics product is only a first step. The results need to be further integrated with more detailed additional information that reflects climatic and/or societal information such as local land use processes, changes in land use practices and/or yield outputs, population movements, etc. This integrative analysis is needed to obtain a holistic interpretation of possible ongoing land degradation that explains the biophysical dynamics in relation to anthropogenic activities. This section presents the first step, the assessment of land productivity dynamics. The following sections will integrate other critical factors at play when analysing the various situations.

4.2.2 Land productivity dynamics in Europe

Figure 3 shows the land productivity dynamics for the EU as calculated from satellite observations. The term 'land productivity' effectively refers to

variations in the rate, quantity and timing of the standing biomass production of an ecosystem. Factors that influence ecosystem biomass production include climate and climate variation, ecosystem structural elements (such as altitude, slope, soil and all the life-supporting characteristics of the soil), type of biomass and of course human interaction (such as urban, forest, agriculture or pastoral activities).

The map shows changing dynamics over the period 1982 to 2010 as a combination of long-term change and short-term evaluation of the efficiency of an area that produces sustained levels of standing biomass, compared to average conditions. The starting point is thus the state of the ecosystem in 1982. The level of detail of the satellite-based information introduces advantages, such as landscape-scale approaches, and some limitations that need to be considered during further interpretation, such as the impossibility of directly observing field-level processes.

Satellite observations are based on 5 km by 5 km squares. In the European context, a 25 km^2 area (2,500 ha) will, in all likelihood, be heterogeneous in terms of land cover types. Even in regions with dense agriculture, forest or pasture, such an area will contain combinations of land cover, including housing, infrastructure and sometimes water, bare rock and ice surfaces. Hence, land productivity is an expression of the combined changes that occur in such area in terms of overall standing biomass production. Care must be exercised in interpreting this new metric. It provides a consistent overview but, given the measurement scale, cannot be used for highly localised decision making. Land productivity is an indication of the level of sustainable land use, calculated as the relationship between land quality in general productive terms and what is obtained as output.

Figure 3 shows five classes of land productivity levels. For example, the class: "declining productivity" is assigned to areas that (a) have shown evidence of prevailing downward trends in standing biomass over the twenty-nine-year observation period and (b) show a current production efficiency that is below their potential. The latter is calculated by determining the deviation of its Cyclic Fraction metric (which expresses the net biomass production of a growing season) from a maximum production level for a growing season (established within contextual homogeneous ecosystem units using higher-resolution data for a baseline window of five years).

Although signs of declines and increases in land productivity are found throughout the EU territory, this does not necessarily indicate land-degradation neutrality. To establish this condition, an assessment by contextual analysis in relation to the major land degradation issues in Europe is required. Key land degradation issues in Europe include inappropriate agricultural or pastoral intensification, soil sealing, soil erosion, agro-silvo-pastoral land abandonment and increased frequency of climatic extremes that impact the vegetation and/or condition and functioning of the soil. Therefore, the signs of declines and increases in land productivity need to be

evaluated with respect to their association to one or more of these land degradation issues. Ecosystem types and related land use options need to be included in the trade-offs.

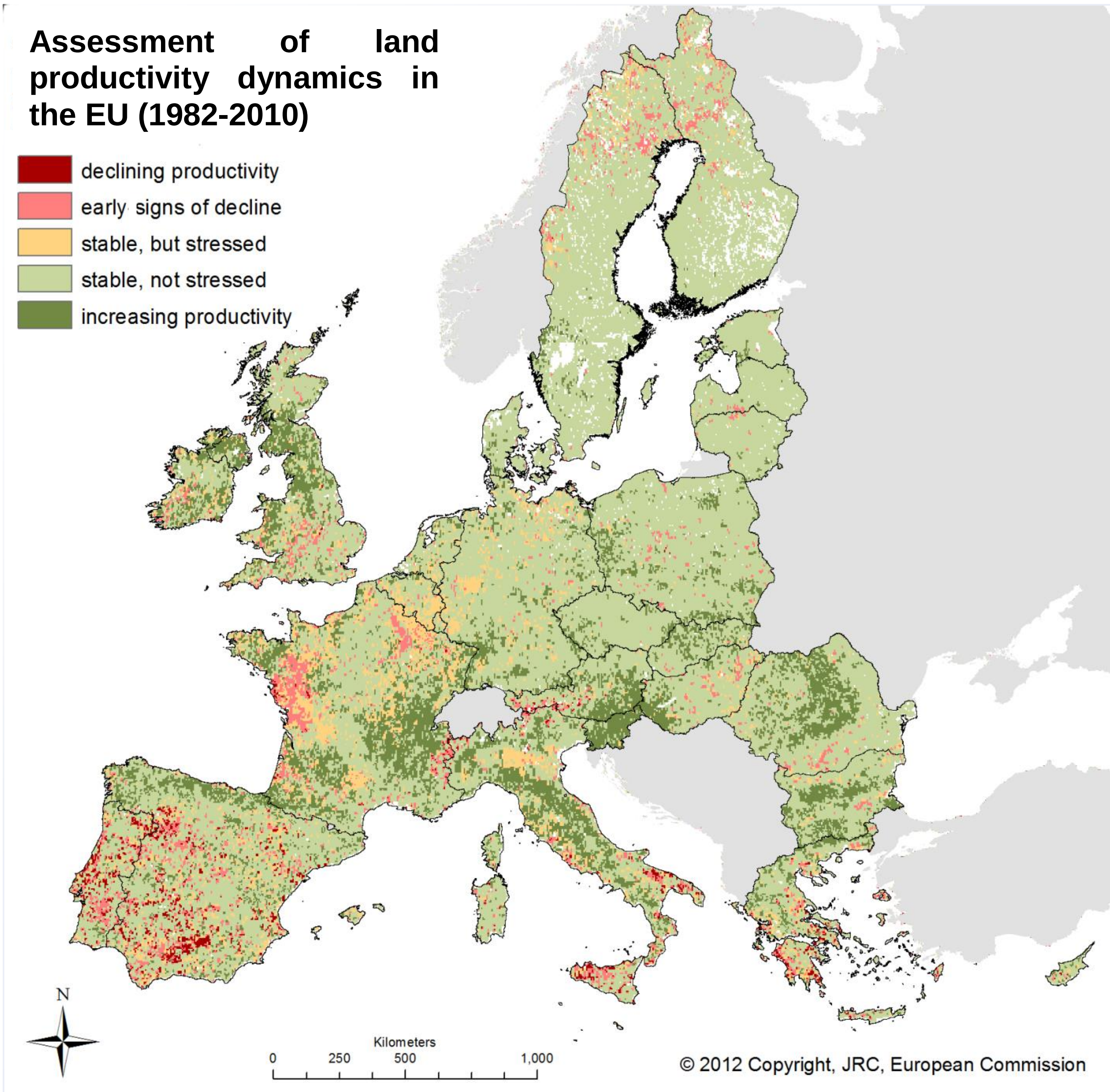


Figure 3: Land productivity dynamics as calculated from long-term satellite-derived observations of land productivity combined with current levels of productivity performance. This map is a base layer that indicates areas with declining, stable or improving land productivity dynamics that can/need to be further scrutinised to get insight into the possible causes and effects of land degradation processes.

Decline, or its early signs, in land productivity can be caused by processes such as meteorological extremes such as droughts (and the related increased fires risk), or floods, by climate variability resulting in changes to the start and/or end of the growing season, or abnormally warmer or colder periods

that cause plant stress. In densely populated areas, a decline in land productivity may be due to loss of soil or productive land that is caused by expanding infrastructure rather than lower biomass production per surface area unit. In agricultural areas (croplands and pasture), land productivity decline may be attributed to the loss of semi-natural vegetation converted into agriculture or other land use changes. Overgrazing may be a factor, and other changes in land management can also cause a decline in production (e.g. cultivated varieties producing less biomass, changes in fertiliser regime, irrigation and land drainage). It is possible that some approaches to crop production that may result in lower biomass can, in the longer term, contribute to improving soil conditions, e.g. organic farming. When opposite processes are present (e.g. wetter periods, regeneration of semi-natural vegetation, expansion of forests or crop varieties that produce more biomass, such as maize compared to wheat), an increase in land productivity can be observed. All variations between the above mentioned situations are observed over Europe and are mapped accordingly, as shown in figure 3.

Examples are given in this report but these do not yet constitute the exhaustive analysis required to come to a final conclusion on land-degradation neutrality in Europe. First statistical results of a pan-European assessment of land productivity dynamics, mapped in figure 3, are listed in table 1.

Land productivity dynamics in the European Union (as % of the area)				
Declining productivity	**Early signs of decline**	**Stable but stressed**	**Stable, not stressed**	**Increasing productivity**
1.5	**5.6**	**7.9**	**70.2**	**14.9**

Table 1: Percentage of area of the EU belonging to the five land productivity dynamics classes represented in in figure 3.

70.2% of the EU territory shows stable land productivity dynamics. In these areas, productivity can fluctuate according to land cover and land use variations, but the overall level of productivity has remained stable throughout the observation period. Appropriate levels of management and economic sustainability are assumed. Some 14.9% of the EU (an area slightly more than twice the size of Italy) showed an observable increase in land productivity during the 1982-2010 period. However, it is important to remember that this land productivity dynamics assessment focuses on mapping ongoing processes. Thus, land that was degraded or in very poor condition prior to the 1980s (the start of measurements) may well appear as being stable or even improving – the 14.9% improvement (in area) also

includes locations that effectively started from a very low level of productive standing biomass.

The land productivity of 15% of EU territory (an area of about 620,000 km^2 – equivalent to that with improving land productivity) is found to be stable but with some signs of stress or showing early signs of decline or is in decline. These areas have markedly different ecosystem characteristics, different actual land use, and diverse land use potential and options. All of these areas might be cause for concern. Within this category, 7.9% of the EU is observed to have had a stable situation for the twenty-nine years until 2010, but for the 2006-2010 period, land productivity was observed to be substantially below its natural potential. These areas were marked as being 'stable but stressed'. Further analyses will be necessary to identify and qualify the stress factors.

Some 5.6% of the EU area shows early signs of decline in land productivity, for which the contextual analysis will result in an estimated impact in terms of land degradation. For a small area (1.5% of the EU – only slightly smaller than Latvia, but still representing some 6 million hectares), a clear long-term land productivity decline was observed. The importance of this 1.5% will be clarified further in the document by establishing where this actually occurs.

Figure 4 shows that areas in western Europe where intensive agriculture traditionally has been a major land use have relatively more territory under stress or showing early signs of decline than most of the areas in eastern Europe. Areas where land productivity is in decline are mostly (but not exclusively) to be found in the Mediterranean region.

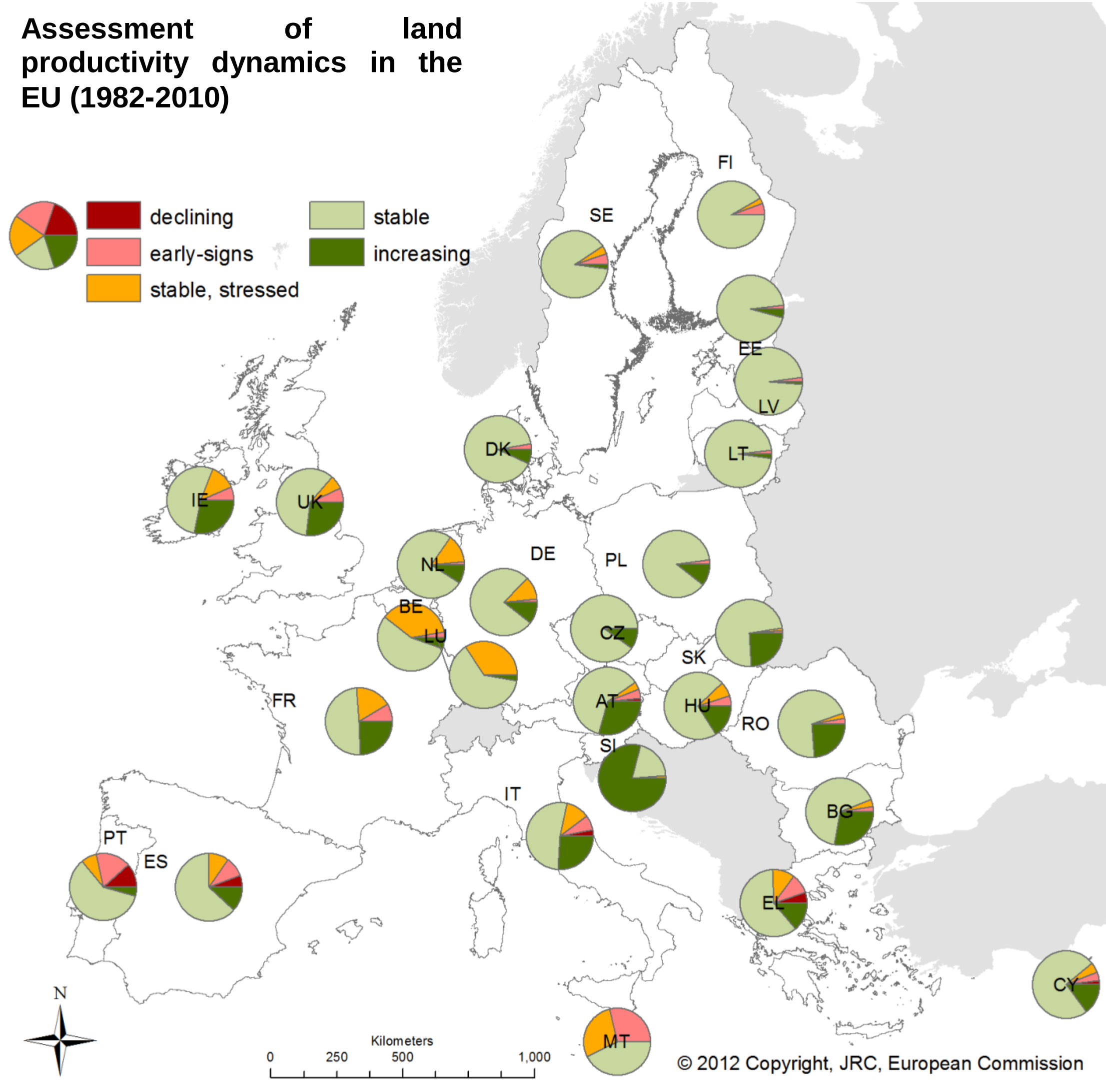


Figure 4: Assessment of land productivity dynamics as a share of EU Member States' size. Land productivity dynamics are calculated from satellite observations of long-term changes of land productivity (1982-2010) combined with current levels of performance (2006-2010)

In terms of land-degradation neutrality, the RIO+20 target of 'neutrality' aims at keeping productive land stable with sustained, or even increasing, economic production. Looking only at land surfaces percentages, the land productivity budget for the EU seems neutral, but considering that the decrease or increase in land productivity occurs in distinct human-environment systems with diverse land uses and geographical locations, these differences cannot be cancel each other out. The next chapter documents this in more detail. However, this first evaluation suggests that Europe is not land-degradation neutral.

Analysis indicates that 15% of the EU land area is showing increased land productivity. An area of 7.1% shows early signs of decline or actual decline in land productivity. As mentioned above, the land use options and related trade-off values for food production or economic produce are not always

comparable. Data on agricultural areas (cropland and pasture) tell a different story: less than 1% of EU arable land and even less of EU pastureland (0.2%) is coincident with declining land productivity, but more than 11% of permanent crops (mainly tree crops) fall into the declining land productivity category (tables 2a and 2b).

The difference in land cover types where decline and/or increase in land productivity occurs is very visually apparent in figures 5 and 7 below.

4.3 Evaluating land productivity dynamics in the context of land degradation

4.3.1 Integrating explanatory information

Complex processing of regular space-based observations provides an assessment of the land productivity dynamics that is a proxy expression of the sustained land quality status. This substantially advances assessments as to whether, and where, potential land degradation processes are ongoing. Research outcomes of the past decade[10] indicate that further contextual information is needed on the various issues at play in order to interpret land degradation processes. In other words, more understanding has to be sought on where and why the assessed change in land productivity is really critical in terms of land degradation. Once this is known, trade-offs can be evaluated on which to base mitigation strategy planning.

Within the Human-Environment (H-E) system, components interact and their transitions, such as land use change, can create pressures that drive the H-E system into less desired states, leading to land degradation. These forces are limited[11] and can be grouped into a number of global scale 'issues' which include:

Aridity and drought
Biomass production
Water availability
Soil related aspects (erosion, salinisation, sealing, contamination, etc.)
Changing population densities and movements
Urban sprawl
Grazing mismanagement

Inappropriate/unsustainable agricultural practices

This report addresses a limited number of prevailing issues that are important to land degradation in Europe. For example, readily available datasets are integrated with the synoptic assessment for further evaluation.

Multiple issues need to be analysed when evaluating land productivity dynamics in the light of assessing land degradation or desertification. This is true when evaluating local areas of interest, but also when carrying out Europe-wide evaluations of land-degradation neutrality. Area statistics cannot always be directly compared nor combined. For example, it is important to know whether areas showing early signs of decline are in or outside both High Nature Value farmland areas and high productive soil areas in order to value these signs in terms of land-degradation neutrality.

It should be stressed again that the mere extent of areas within different land productivity dynamics classes cannot be compared in a straightforward manner as their ecosystems can be completely dissimilar and their land use potential or value can be very different.

The sections below provide a first contextual analysis with some example datasets.

4.3.2 Land productivity dynamics in relation to principal European land cover types/uses

In the EU, land showing a decline in land productivity, early signs of decline or that is 'stable but stressed', can be associated with intensive or intensified land use systems such as arable land, permanent crops or intensively managed pasturelands.

Agricultural areas constitute about 40% of the EU land surface, and some of these areas are showing signs of stress or decline.

The same land productivity dynamics classes can represent completely different situations in different parts of Europe in terms of the importance and potential of the ecosystem as related to food production capacity, soil quality, economic potential conservation efforts or cultural aspects. For the evaluation of land-degradation neutrality it is essential to distinguish land productivity situations for the various types of European land cover. The Corine2000[12] land cover map was used to examine areas that are more or less affected by a decline in land productivity or land cover types for which an increase in productivity is observed. The share of each land productivity dynamics class by land cover type in the EU is listed in table 2a. The portion of each land cover type within the respective land productivity dynamics class in listed in table 2b.

Percentage distributions of land productivity dynamics show a comparable pattern within all land cover type classes (table 2a). A stable productivity situation is predominant for all land cover types. Permanent crops and pastures are slightly less dominant in the 'stable, not stressed' class, at around 58%. Permanent crops are significantly more prominent in the 'declining' class, at 11.8%. A significant share (25.2%) of pastures fall within the 'increasing productivity' class.

For the arable land of the EU, some 83% fall under the 'stable, not stressed' (73.3%) or increasing (9.6%) land productivity dynamics classes. Some signs of stress are apparent in 9.2% of the EU arable area while 7.3% show early signs of decline. A decline in land productivity is observed in 0.7% of the arable area. This is half the surface where productivity decline was estimated EU-wide (see table 1), but still represents an area of about 4.5 times the size of Luxembourg.

Note that land productivity is not conceptually the same as, and is not necessarily directly related to, agricultural production. Low-resolution imagery introduces a considerable amount of heterogeneity, and standing biomass production is not to be equalled with crop production.

Permanent crops, tree crops and vines, are the land cover types for which the largest portion is in decline, at 11.8%. This is notably higher than the EU average for all classes of 1.5% under decline (table 1). During the 1982-2010 period, intensification of olive and citrus cultivation with little or no undercover (as practiced in the Mediterranean area) certainly influences this figure. Furthermore, early signs of decline are observed over another 9.2% of the permanent crop area while over 9.6% fall under the 'stable but stressed' land productivity class.

72.1% of the EU's forests and semi-natural areas (including natural grasslands) show 'stable, not stressed' land productivity, while for 16.6%, land productivity is increasing.

Figures 5, 6 and 7 show the share of land productivity dynamics types per country using Corine Land Cover classes: early signs of decline (figure 5), 'stable but stressed' (figure 6) and increasing land productivity (figure 7). In most EU countries, the areas showing the largest observed decline in land productivity are found under managed lands (i.e. arable and pastures). The pie charts indicate that countries such as Ireland, the UK and France have extensive areas of pastures that show a decline in or stress on land productivity.

Figures 5 and 7 illustrate that the typology of areas showing improved land productivity dynamics are, or can be, completely different from areas where land productivity is in decline. Most of the improvement is observed over semi-natural areas while the declining areas correspond mostly to agriculture productive area. The latter are areas that are critical for food production. These lands should be kept very productive. Hence, a direct comparison of area statistics in view of evaluation 'land degradation neutrality' can be misleading and typology needs to be considered.

Lands under forest and semi-natural land cover show the largest observed signs of decline or stress in countries with less arable and pasture lands. In such countries, the total area of these land productivity classes can be relatively small (see figure 4). A total of 9.4% and 8.2% of the territories of Sweden and Finland respectively show signs of decline or with 'stable, stressed' land productivity, while these figures are 26.7% and 36% for the territories of France and Portugal respectively. For analysis purposes, the Corine forest class was aggregated to include the semi-natural and natural grasslands, which are spatially a major class in northern and Mediterranean countries.

	Land cover types				
Land productivity dynamics	**Arable land**	**Permanent crops**	**Pastures**	**Forests and semi-natural areas**	**other**
declining	**0.7**	**11.8**	**0.2**	**1.4**	**2.5**
early signs of decline	**7.3**	**9.2**	**4.1**	**4.1**	**7.1**
stable but stressed	**9.2**	**9.6**	**12.1**	**5.8**	**8.3**
stable, not stressed	**73.3**	**58.7**	**58.4**	**72.1**	**66.2**
increasing productivity	**9.6**	**10.7**	**25.2**	**16.6**	**15.9**

Table 2a: EU land productivity dynamics within different land cover types (as % of the EU land surface; based on Corine2000)

	Land productivity class				
Land cover types	**declining**	**Early signs of decline**	**stable but stressed**	**stable, not stressed**	**increasing productivity**
Arable land	**13.9**	**38.4**	**34.2**	**30.6**	**18.8**
Permanent crops	**19.7**	**4.0**	**3.0**	**2.0**	**1.7**
Pastures	**1.4**	**6.3**	**13.1**	**7.1**	**14.4**
Forests and semi-natural areas	**40.7**	**31.2**	**31.8**	**44.1**	**47.6**
Other	**24.3**	**20.1**	**17.9**	**16.2**	**17.5**

Table 2b: EU land cover types within the land productivity dynamics classes (as % of the EU land surface; based on Corine2000)

Selected classes from the Corine2000 database are: Arable land, permanent crops, pastures, forests and semi-natural areas; Other = heterogeneous agricultural areas, open spaces, water and artificial surfaces

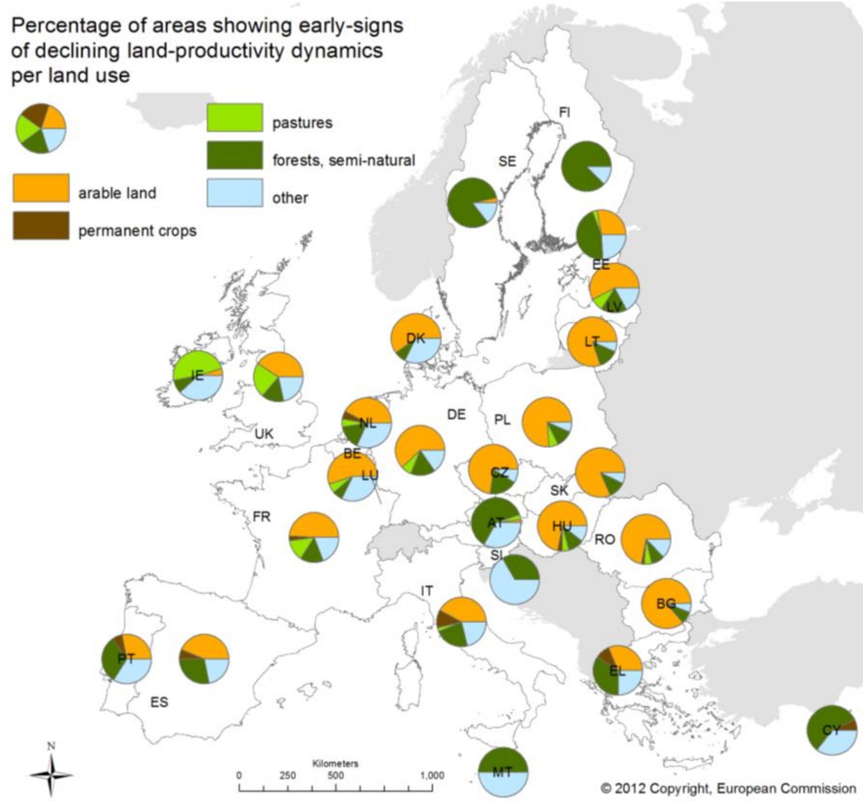


Figure 5: Land cover types (grouped) showing <u>early -signs of declining land productivity dynamics</u> in the EU Member States (the pie charts indicate the land cover types that show early signs of land productivity decline as a % of the total area of each country)

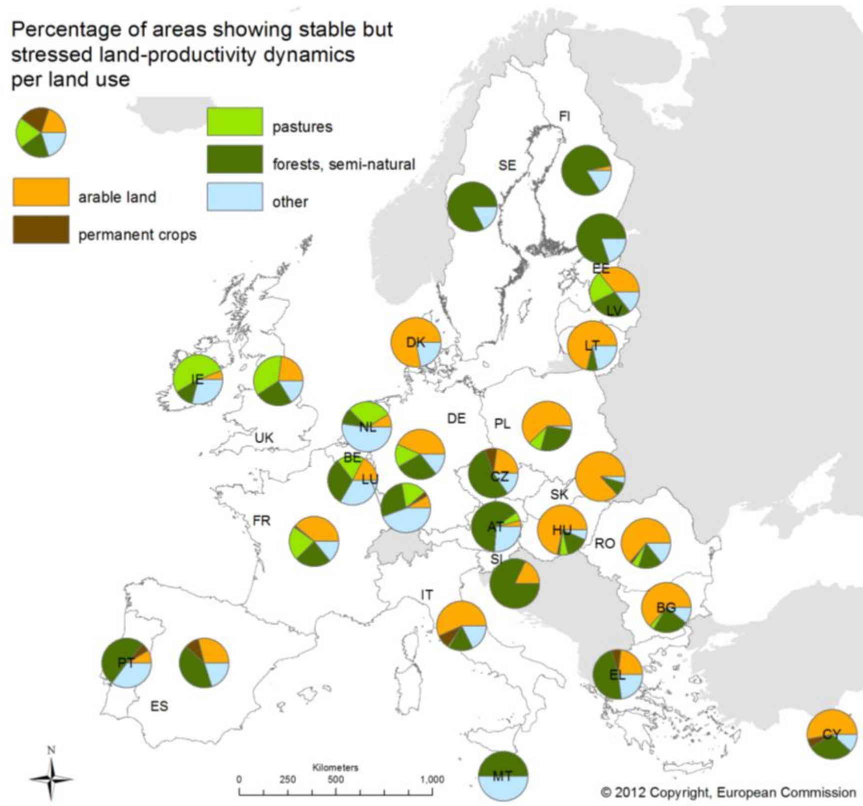


Figure 6: Land cover types (grouped) showing <u>stable but stressed land productivity dynamics</u> in the EU Member States (the pie charts indicate the land cover types under <u>stable but stressed</u> land productivity decline as a % of the total area of each country)

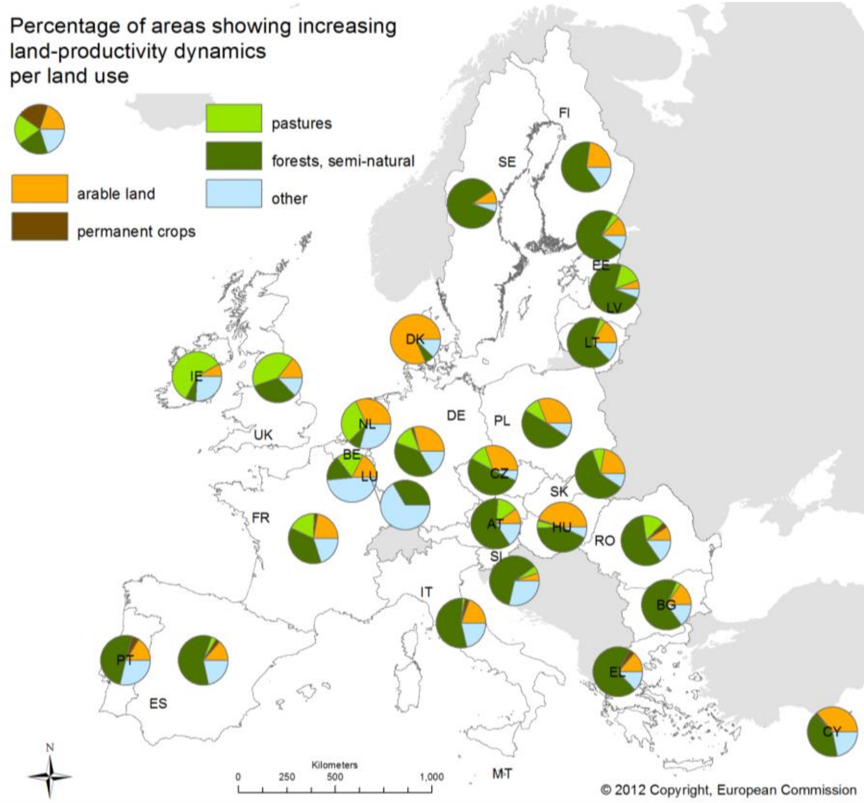


Figure 7: Land cover types (grouped) showing <u>increasing land productivity dynamics</u> in the EU Member States (the pie charts indicate the land cover types showing <u>increasing land productivity dynamics</u> as a % of the total area of each country)

4.3.3 Land productivity dynamics in relation to soil productivity levels in croplands

10.2% of the <u>most productive cropland soils</u> in the EU show a decline, or early signs of decline, in land productivity, while 14.2% show 'stable but stressed' land productivity.

Around 7% of <u>average productive cropland soils</u> and around 15% of the <u>least productive cropland soils</u> show a decline, or early signs of decline, in land productivity.

(Considering an EU-wide classified range of soil productivity for croplands).

In general, the good soils of Western European and Mediterranean countries are more affected than are those of Northern or Eastern European countries.

(Considering a country-based scaling of soil productivity for croplands)

Land is a finite resource. Adequate food production mainly relies on agriculture achieving better production rates and more sustainable yields from better soils. Soil is one of the many ecosystem structures that can provide essential ecosystem services for human benefit. Therefore, land productivity dynamics have been analysed for cropland areas with different levels of soil productivity.

Soil-forming processes are a consequence of climatic, mineral and biological processes conditioned by parent material, topography and other factors. Hence, soil characteristics vary geographically. The efficiency of soil productivity is highly dependent on the land use to which it is subjected. Agriculture is the optimal land use of more productive soils whereas forestry can be productive on soils that are not optimal for crop growth. Soil sealing poses a challenge to all soils.

Productive soils are a restricted resource that needs to be protected through adapted sustainable land use and land management. It is critical to evaluate the land productivity dynamics for the cropland soils in Europe. Figure 8 shows the distribution of soil productivity for croplands[12] under rainfed conditions. The limited availability of highly productive soils is clearly observable.

Around 63% and 73% of Europe's most productive and averagely productive croplands respectively are completely stable, while around 12% show increasing land productivity.

Declining land productivity is observed in only 0.5% of highly productive cropland soils (equal to 112,500 hectares). However, about 9.7% (around 2 million hectares) of highly productive cropland soils show early signs of land productivity decline, while 'stable but stressed' land productivity is observed in a considerable area, 14.2%. The EU's marginal cropland soils show a decline in 4.7% of the cropland area.

Land productivity dynamics	**Cropland soil productivity classes**		
	low	**medium**	**high**
declining	**4.7**	**0.9**	**0.5**
early signs of decline	**10.3**	**6.0**	**9.7**
stable but stressed	**14.4**	**7.8**	**14.2**
stable, not stressed	**59.1**	**73.4**	**63.4**
increasing productivity	**11.6**	**11.8**	**12.3**

Table 3: Land productivity dynamics for European classes of soil productivity for croplands (as % of cropland productivity classes).

The map shown in figure 8 and its related statistics in table 3 are based on a re-grouped ten-class ranking of soil productivity called the Cropland Productivity Index (CPI[13]) combined with the land productivity dynamics index[14]. They are valid for the EU as a whole, where the productivity of marginally, average and most productive cropland reflects the EU-wide range of soil quality levels.

There is regional variation within the EU-wide soil productivity classes. The relative importance of soils for crop growth and food production is most evident at the national level. The soil productivity of croplands was therefore scaled per country in figures 12-14, which illustrate the land productivity dynamics for each country's least, average and most productive cropland soils.

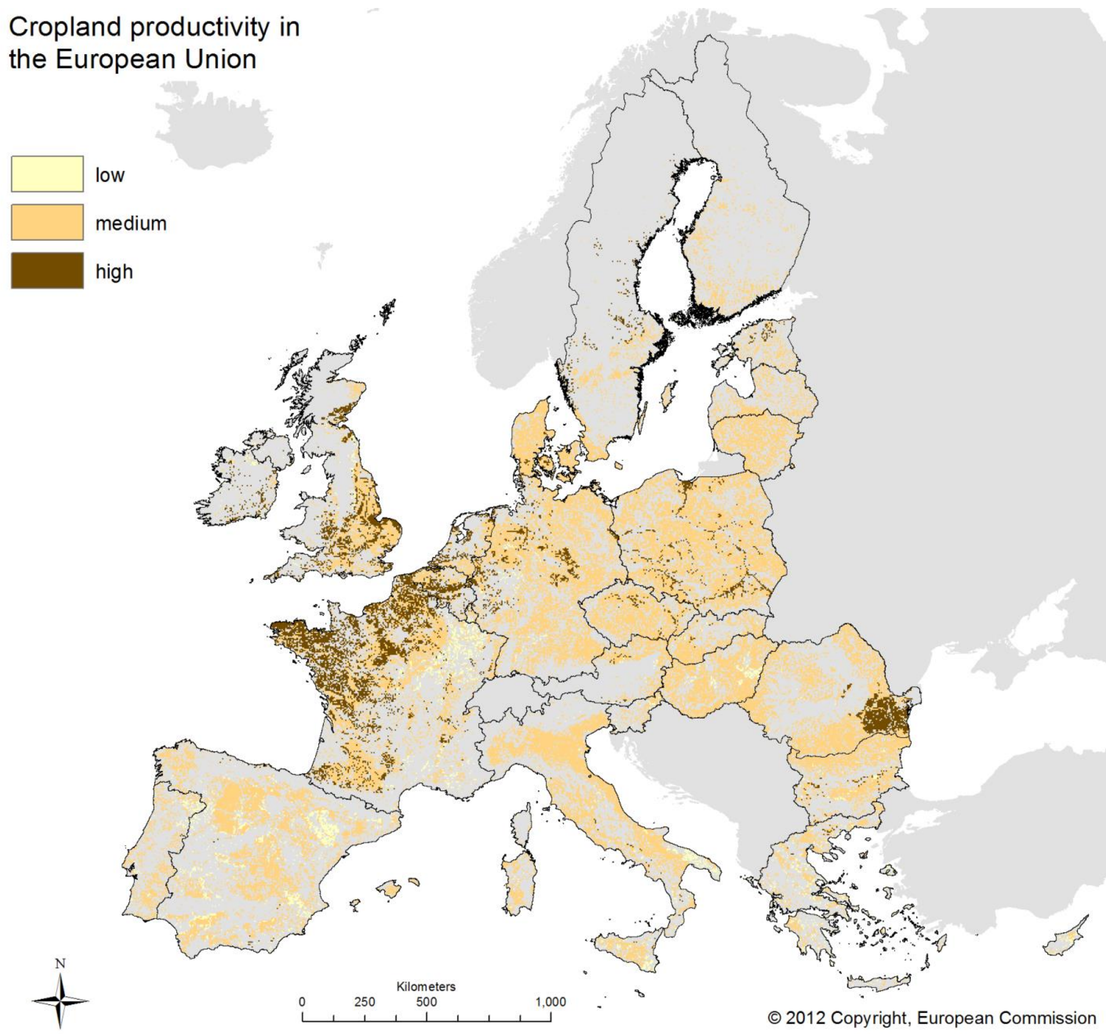


Figure 8: Soil productivity of rainfed croplands at the EU level. (grey is either no cropland or outside the EU)

Whilst on the European scale practically none (only 0.5%) of the most productive cropland soils show a decline in land productivity, this does not hold entirely true for individual Member States when soil productivity is assessed per country (figures 12-14).

Over 9.4% of the most productive area in Spain shows declining land productivity. Early signs of decline are observed in 50% of the most productive soils in Portugal, and in 14.7% and 9% of such soils in France and Hungary respectively. 'Stable but stressed' land productivity is observed in around 30%, 21.5% and 25% of the best cropland soils of Belgium, France and Italy respectively. The land productivity has remained completely stable in all the most productive cropland soils of Latvia and Finland, and most of those of Germany (83%), Romania (86.8) and most other countries during the twenty-nine year period. 71.4% of Slovenia's best soils show increasing land productivity.

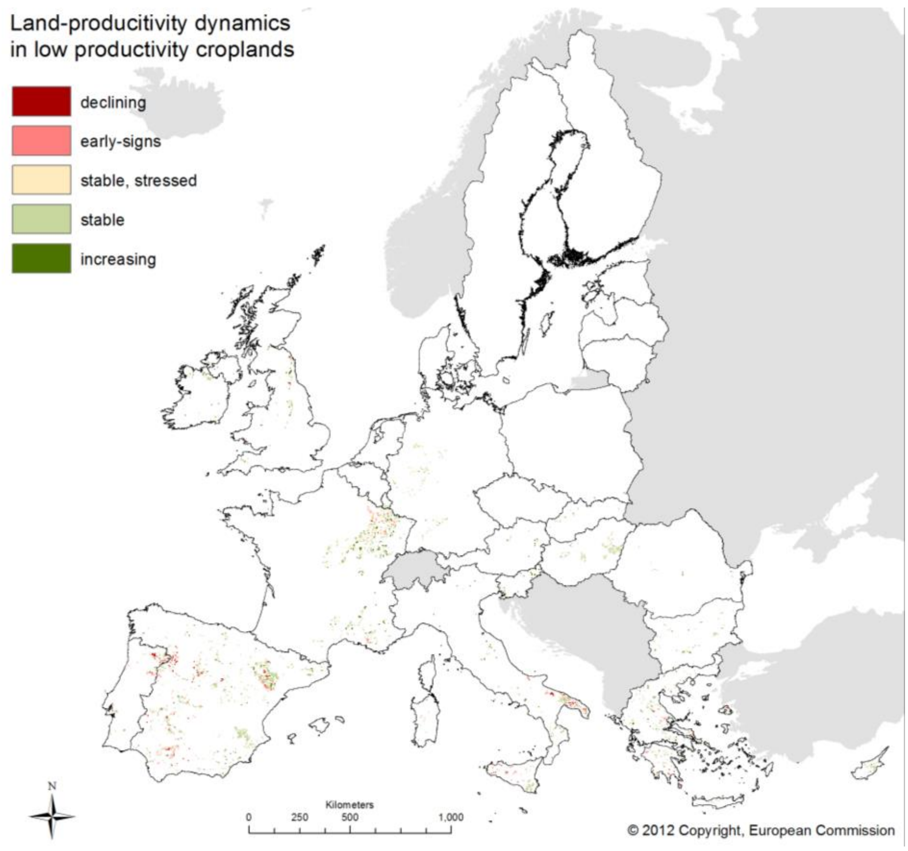


Figure 9: Incidence of land productivity dynamics with <u>low soil productivity</u> for croplands at the EU level

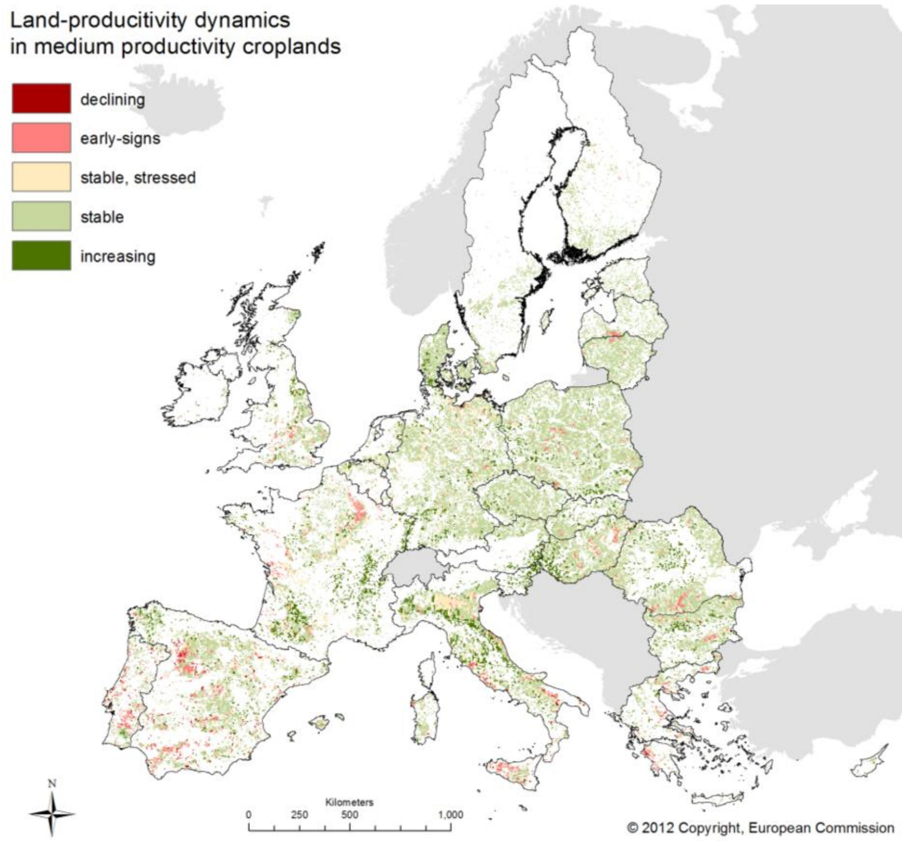


Figure 10: Incidence of land productivity dynamics with <u>medium soil productivity</u> for croplands at the EU level

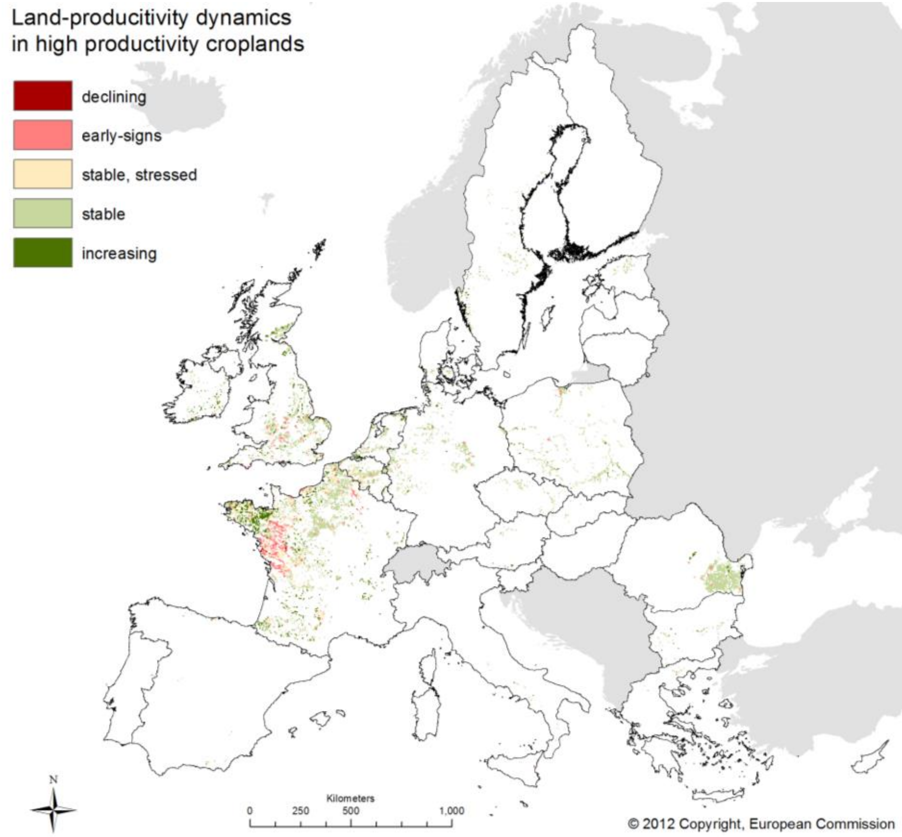


Figure 11: Land productivity dynamics with <u>high soil productivity</u> for croplands at the EU level

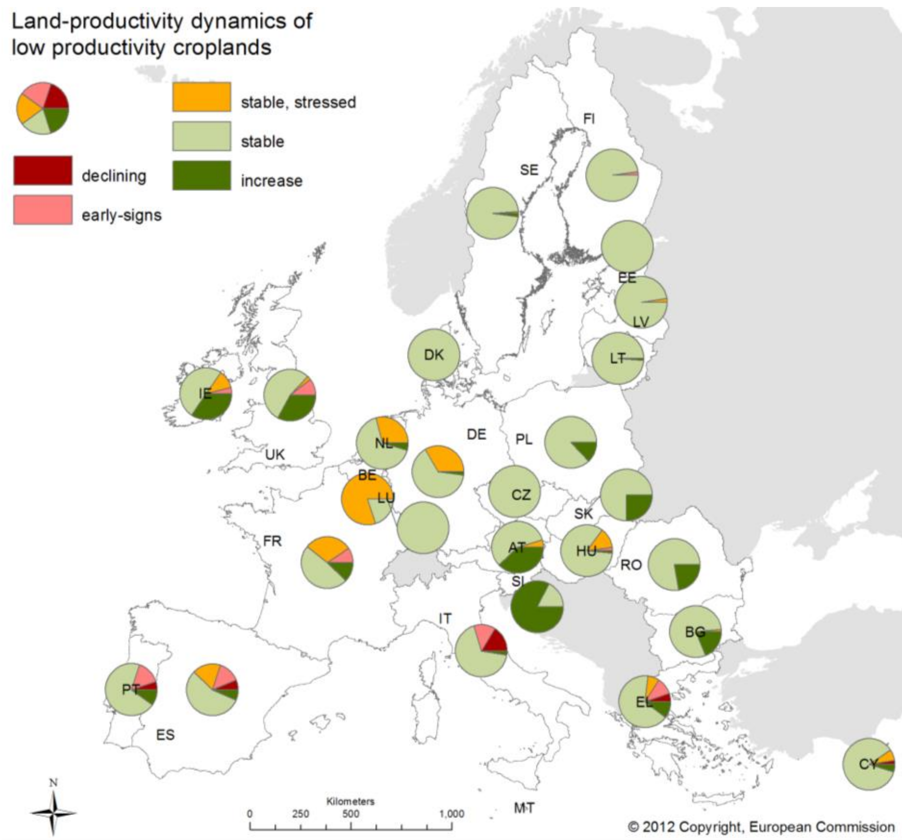


Figure 12: Land productivity dynamics of croplands in EU Member States with LOW soil productivity

(defined relative to the range within each separate Member State)

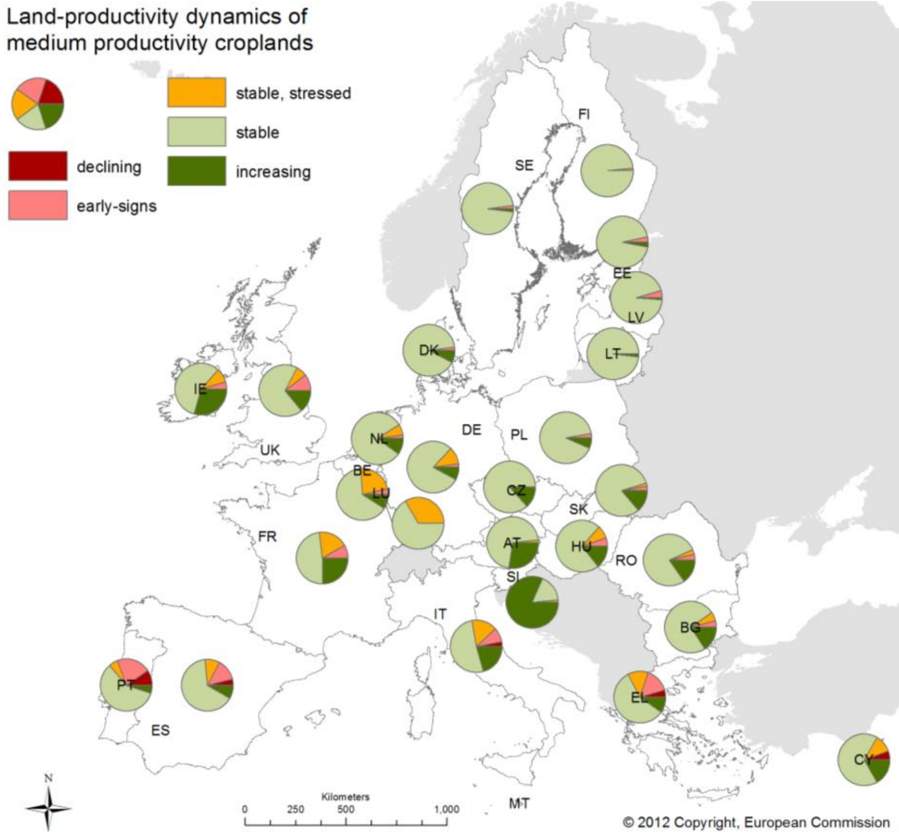


Figure 13: Land productivity dynamics of croplands in EU Member States with MEDIUM soil productivity (defined relative to the range within each separate Member State)

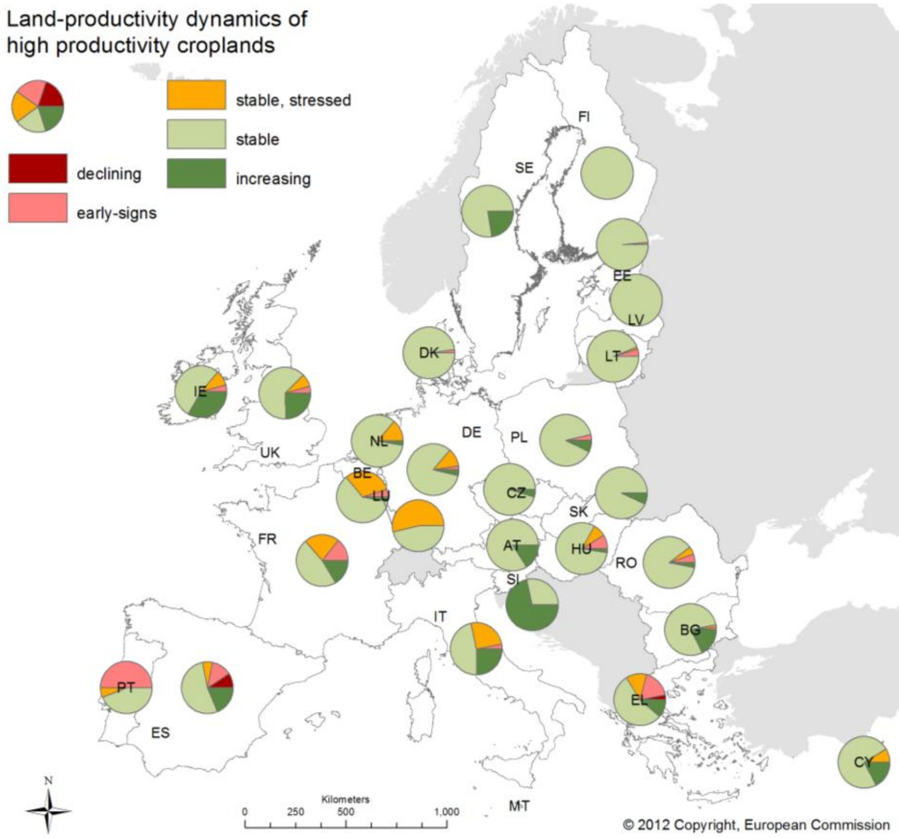


Figure 14: Land productivity dynamics of cropland sin EU Member States with HIGH soil productivity (defined relative to the range within each separate Member State)

4.3.4 Examples of cause-effect relationships in Europe

The previous sections investigate the land productivity dynamics in Europe as first level information within the analytical framework of an evaluation of land degradation. This explores, although not yet exhaustively, where specific dynamics take place in the EU and what ecosystem structures are affected in terms of land cover and cropland soils. In order to complete this valuable overview, contextual information is needed to appraise possible causes of land degradation.

Many factors play a role in the complexity of 'land degradation', especially where biophysical and socio-economic aspects interact. Climatic, meteorological, anthropogenic and biophysical processes are all potential causes or effects, but they all interact very differently at regional and local scales.

The following section evaluates a few examples of potential causal factors at EU level and illustrates a few local examples.

4.3.4.1 Meteorological events

4.3.4.1.1 Drought

During the past decade, drought events are likely to have accelerated the reduction in land productivity in areas of the EU with intensified agriculture.

More intense land use could affect the natural resilience of ecosystems.

Drought could have a more persistent impact over areas in Western Europe where the ecosystem is less drought resistant, especially when combined with intensified land use.

Drought is one of the major global weather-related disasters and can have devastating impacts on the environment, agriculture, economy, and society[15]. Medium- and long-term effects of repeated drought events, combined with non-adapted land management, can trigger land degradation and, in extreme cases, desertification. Drought impacts depend on the duration, severity and spatial extent of the precipitation deficit, and to a large extent on the environmental and socio-economic vulnerability of affected regions. The costs resulting from droughts in Europe over the past thirty years have been estimated to be at least 100 billion Euros[16].

Temporal patterns and the spatial representation of rainfall anomalies indicate where and when precipitation deficits occurred in Europe. The land productivity combined with variations in the growing season for these areas can be analysed.

It is estimated that the heat wave and drought that occurred in Europe in 2003 resulted in a 30% decrease in Europe's gross primary production[16]. Figures 15 and 16 illustrate that persistent drought and recurrent drought events during the past decade are likely to have affected large areas in Europe. Further research suggests that areas whose natural ecosystem resilience was altered by human activity (e.g. through the introduction of intensified agricultural systems) remain more vulnerable to drought[17].

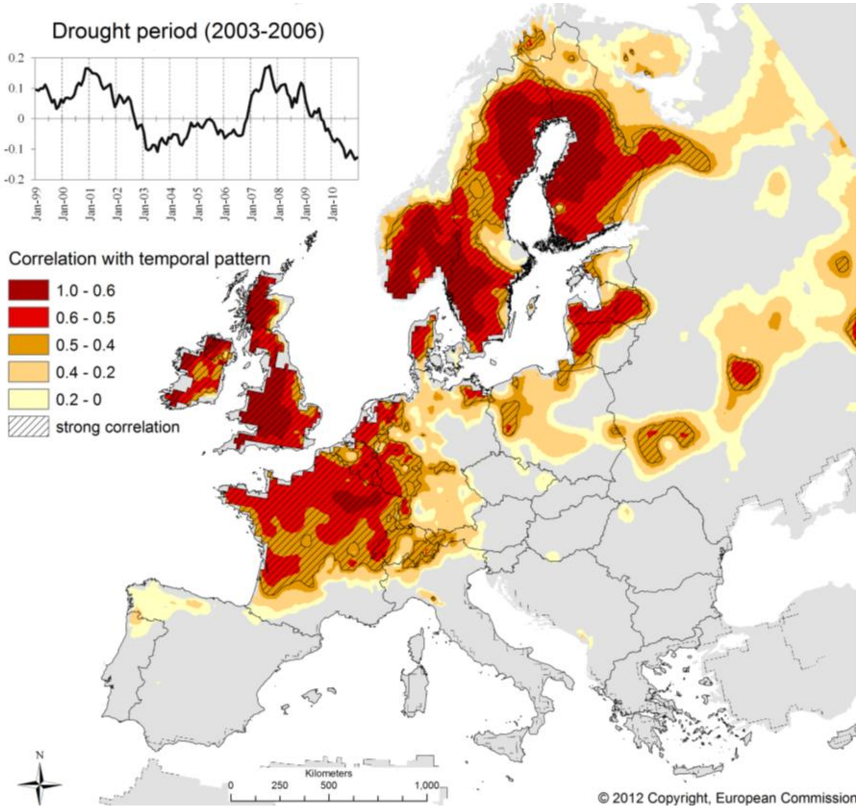


Figure 15: Spatial (map) and temporal (graph) patterns of drought events during the period 2003-2006. Shades of red indicate the degree of certainty of the occurrence of the drought event (dark red indicates certainty of the drought event).

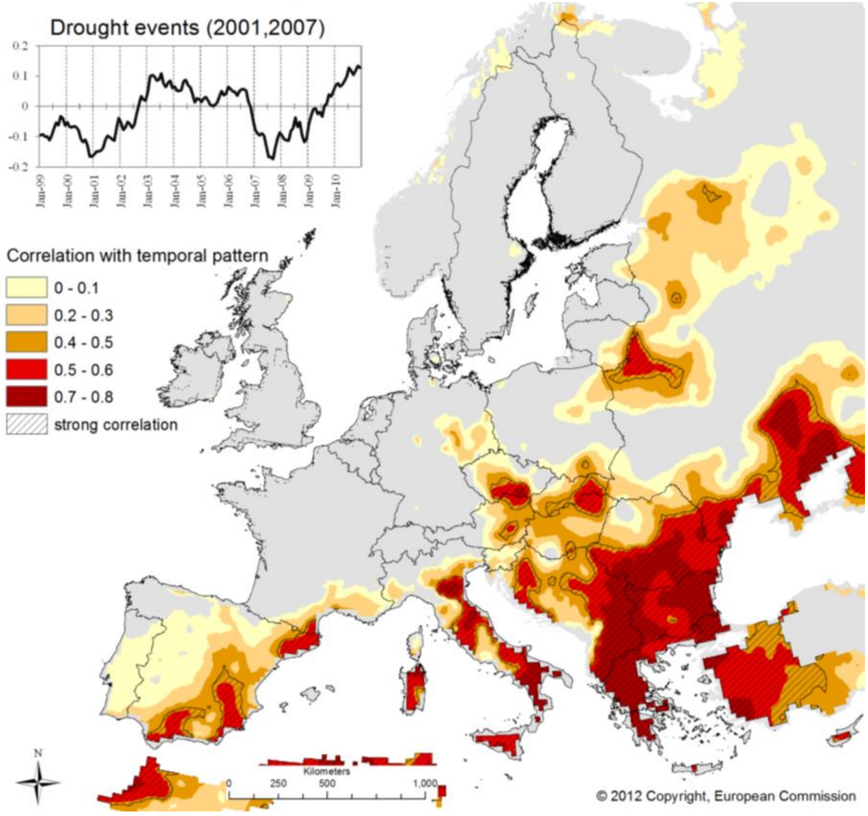


Figure 16: Spatial (map) and temporal (graph) patterns of drought events in early 2001 and mid-2007. Shades of red indicate the degree of certainty of the occurrence of the event (dark red indicates certainty of the drought event).

4.3.4.1.2 Extreme meteorological events

***Ad hoc* extreme meteorological events can play an important role, provoking catalysing situations that worsen exposure to land degradation processes. Excess rain can cause flooding which can have negative (outwash) or positive (deposition) effects on the usable land resource.**

Excess wind, such as the Klaus windstorm that passed over France in 2009 (see figure 17), can have drastic effects on natural resources. Scientific reports[18] and citations in Wikipedia indicate that some 60% of the Forêt des Landes was partly or totally destroyed. First devastated by the Klaus windstorm 2009, then infested by bark beetle (*Ips sexdentatus*) in 2010, some 220,000 hectares of forest in Forêt Les Landes will need to be repopulated between now and 2017.[1]" This equates to around 88 satellite observation points or mapped pixels.

A decrease in land productivity has been observed over the Forêt Les Landes area since the Klaus windstorm event. Reduced vegetation cover could increase the vulnerability of the area to degrading processes. As this is an intensively managed forest and reforestation is planned or already implemented, little or no effects in the way of land degradation are to be

[1] http://www.guardian.co.uk/environment/2012/jul/31/france-landes-forest-replanting-scheme

expected. However, the example illustrates the sensitivity of the land productivity assessments to changes in biomass on the ground (figure 18).

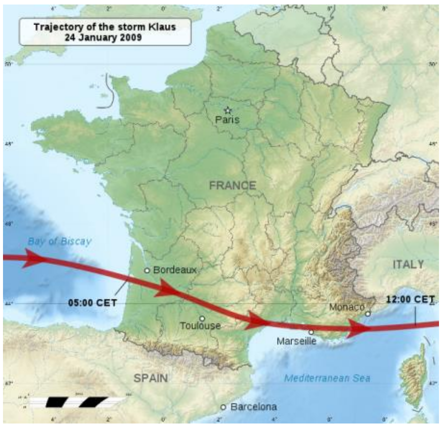


Figure 17: Trajectory of the Klaus Windstorm in 2009
(source: http://en.wikipedia.org/w/index.php?title=File:Klaus_storm_track_-_20090124_-_map-en.svg&page=1)

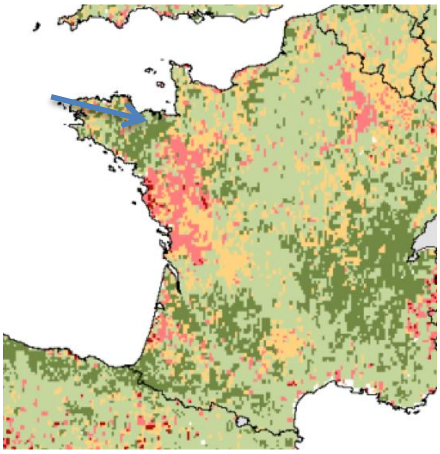


Figure 18 (Extracted from Figure 3): Shades of red indicate decline and early signs of decline in the area of the Forêt des Landes through which the "Klaus" windstorm swept in 2009 (see arrow).

4.3.4.2 Soil processes: e.g. soil erosion

In the EU, 38.3% of areas showing a decline in land productivity are coincident with estimated soil erosion on cultivated land. More than half of the areas showing early signs of decline or 'stable but stressed' land productivity could be linked to soil erosion.

Soil erosion is an important causal issue of decline in land productivity over the whole of the EU.

The Earth's soil layer produces around 99% of human necessities in the way of food, fibre, fodder and many other needs such as biofuel, sand, and renewable energy. As the soil is both an abiotic and biotic ecosystem structure, it also provides other crucial basic functions such as filtering and recharging aquifers, buffering pollutants and regulating gas and nutrient exchanges. Soil forms very slowly and it takes millennia to develop through rock weathering and interactive processes with the environment, climate and life forms. Soil loss through degradation processes (such as the loss of soil structure and chemical characteristics) or by erosion (i.e. the physical loss of topsoil, which includes most of the soil's organic matter) takes several human generations to replenish.

Erosion is the wearing away of the land surface by water and wind. It occurs primarily due to inappropriate land management: deforestation, overgrazing, forest fires, loss of vegetation cover and impact of rainfall. The JRC report on the State of Soil in Europe[19] documents the state of soil erosion in the EU. As documented in the report, any soil loss of more than 1 tonne per hectare per year can be considered as being irreversible within the time span of 50-100 years. Figure 19 reproduces the report's map of soil erosion by water as was estimated spatially for EU cultivated land using the RUSLE model and CORINE2006 Land Cover database.

The EU Thematic Strategy for Soil Protection of the European Commission[18/2] has identified eight principal soil degradation threats that affect European soils: erosion, organic matter decline, compaction, salinisation, landslides, contamination, sealing (and/or urbanisation), and biodiversity decline. These degradation processes have impacts on both the environment and productivity. Their impact on land productivity can be assessed through the land productivity dynamics (see figure 3). Soil loss can result in lower land productivity. Feedback mechanisms are complex; soil erosion can lead to lower land productivity, and lower land productivity can trigger accelerated erosion. Land productivity dynamics classes were calculated within the low, medium and high classes of the EU-24 soil erosion map (shown in figure 19) (table 4).

Land productivity dynamics	Estimated soil erosion		
	low	medium	high
declining	1.3	1.8	3.8
early signs of decline	6.7	7.5	7.4
stable but stressed	8.2	10.2	9.6
stable, not stressed	76.8	65.1	53.2
increasing productivity	7.0	15.3	26.0

Table 4: Share of land productivity dynamics classes in the EU per estimated soil erosion class

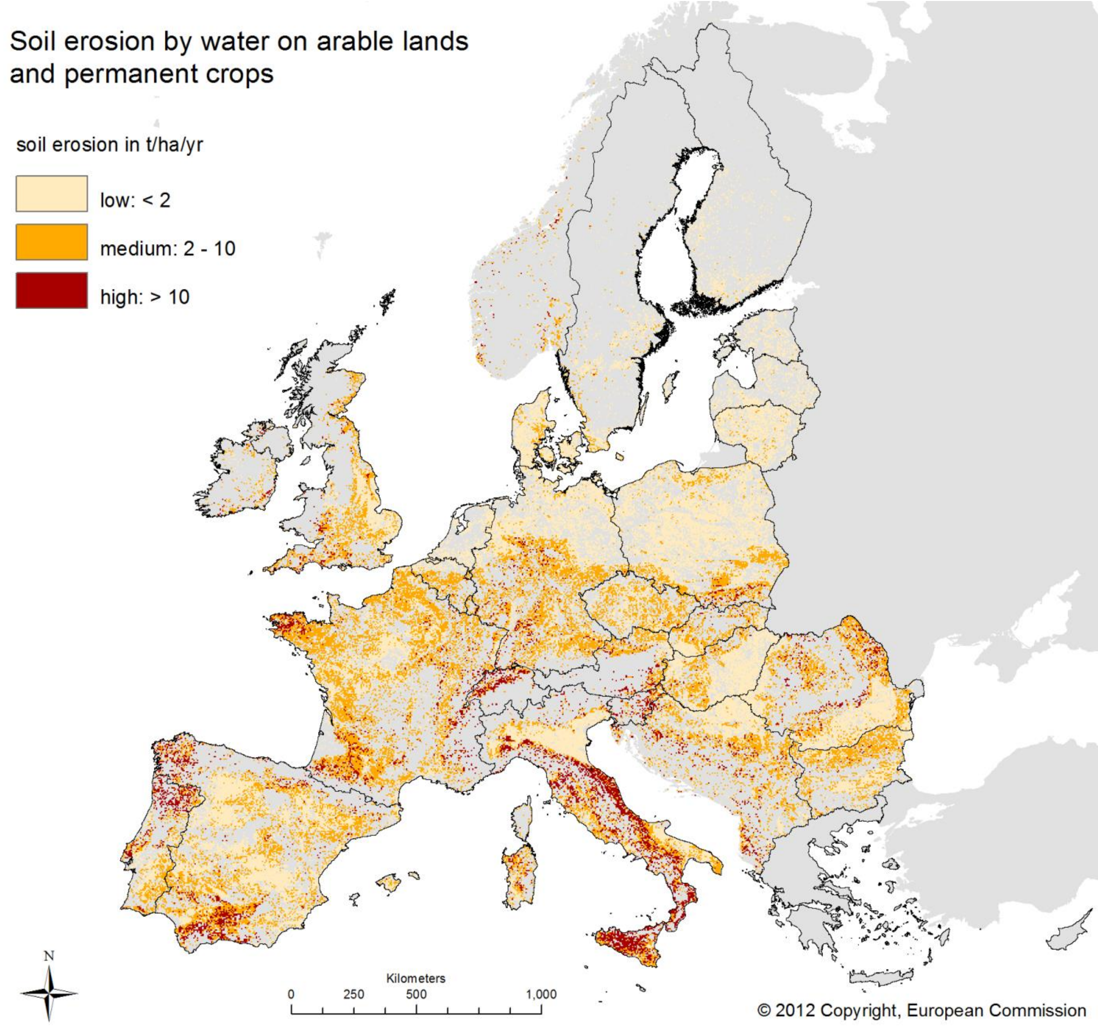


Figure 19: Estimation of soil erosion on EU cultivated lands through rainsplash, sheetwash and rill erosion as calculated using the RUSLE model (2006) and the CORINE2006 Land Cover Database.[20]

The high erosion class has the highest share of declining land productivity (as expected), but also has the highest share of increasing land productivity. Figures 20, 21 and 22 illustrate the incidence of land productivity dynamics within the three erosion classes. These maps indicate that the estimated increased risk of erosion on cultivated land has not led to widespread decline in land productivity over the past thirty years.

These seemingly contradictory results of increased land productivity in areas at high risk of erosion may be explained by a number of factors. Firstly, the 25 km² cell of the satellite observations from which the land productivity is calculated can contain a mixture of agricultural and semi-natural land cover types. While this can reflect landscape-scale functioning, it cannot capture ongoing plot-level processes, such as splash, rill or sheet erosion. Secondly, erosion risk depends on the actual cover and/or land management practices. While slope is an important factor in estimating erosion risk, semi-natural vegetation can be proportionally more abundant then the actual field surface in more hilly or mountainous areas (such as central Italy, which is mapped as being prone to erosion). At the level of detail of this study, the stable land productivity dynamics of such vegetation can mask ongoing field-level erosion. On the other hand, land abandonment in areas mapped as having high erosion potential can lead to an increase in the standing biomass. This would have the effect of increasing land productivity but also by decreasing in-situ risk of erosion, which would improve the functional conditions of the land. Also, EU farmers may have successfully adapted their management practices in line with the agri-environmental measures (AEM) contained within Pillar 2 of the CAP. Earlier studies indicated that the ratio of AEM/Used Agricultural Area is a good indicator of pressure on land productivity, with the smaller the ratio the higher the pressure[21].

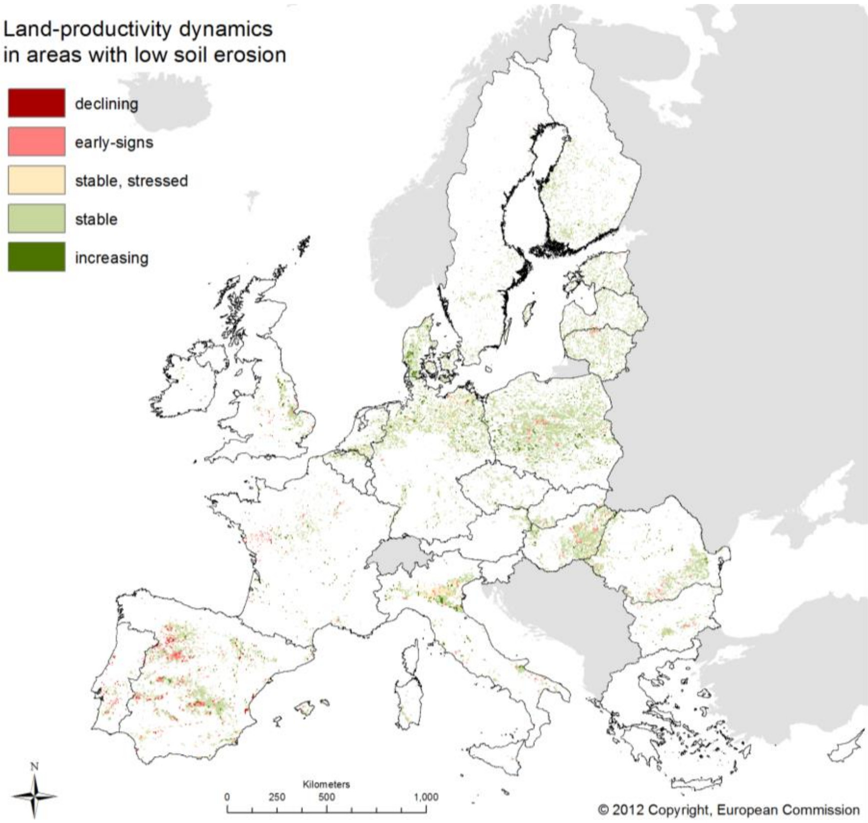


Figure 20: Incidence of land productivity dynamics within the areas of LOW estimated erosion

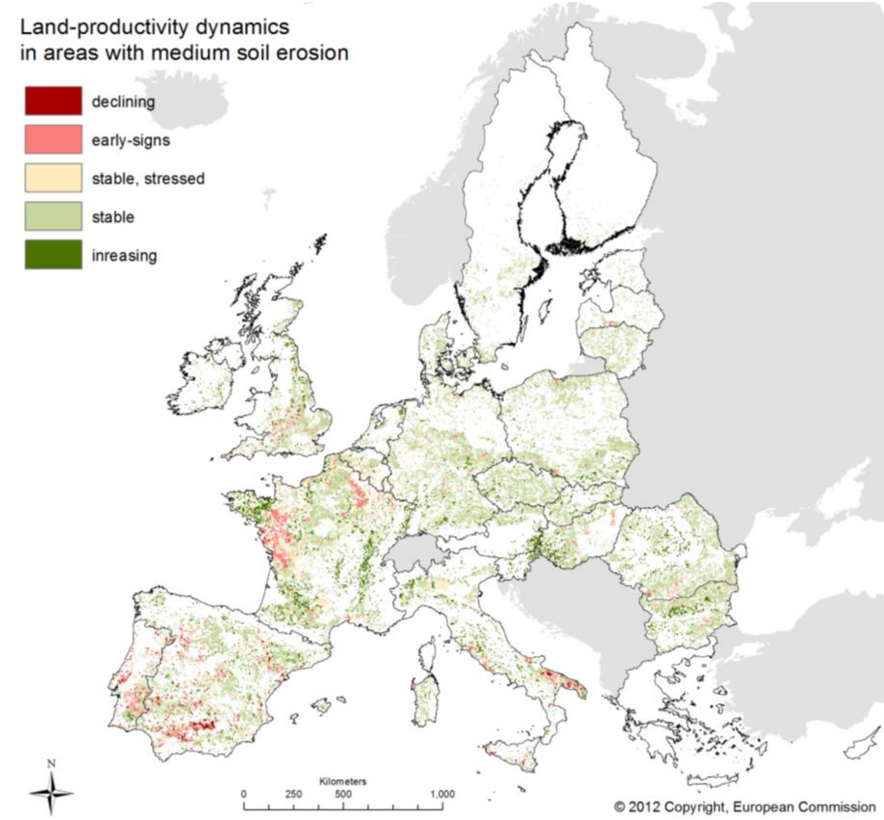


Figure 21: Incidence of land productivity dynamics within the areas of MEDIUM estimated erosion.

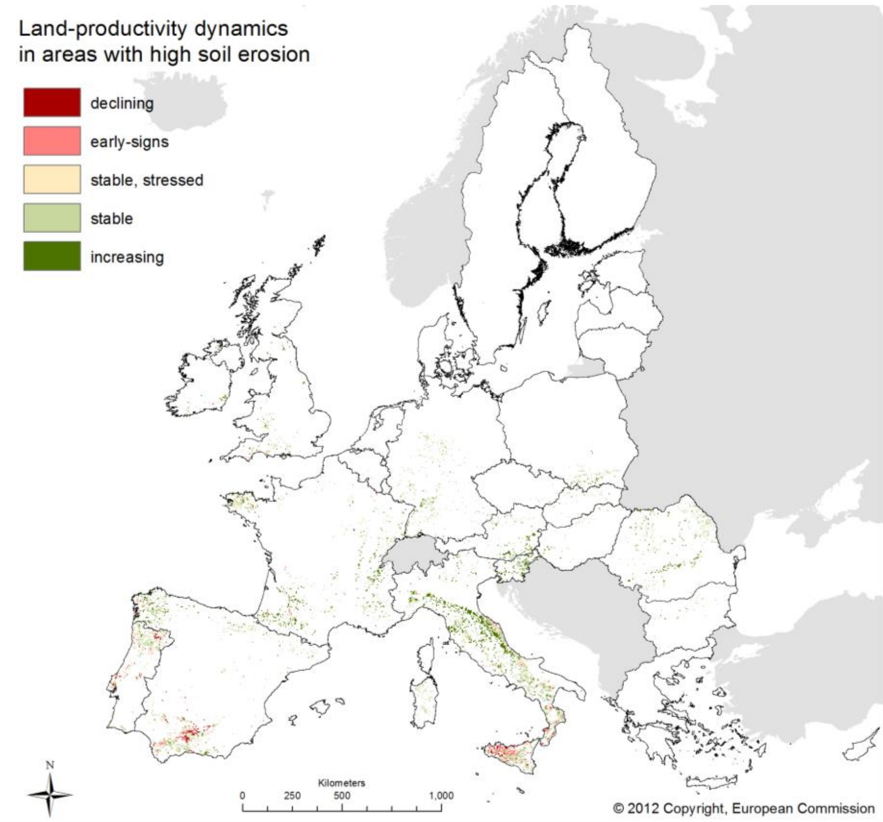


Figure 22: Incidence of land productivity dynamics within the areas of HIGH estimated erosion.

Soil loss in the EU of more than 1 t/ha/yr is considered to be an irreversible loss. Figure 23 maps cultivated areas where the incidence of land productivity dynamics that are in decline, showing early signs of decline and are 'stable but stressed' coincide with estimated irreversible soil erosion (based on data from figure 19).

Considering the complexity of the human-environment interactions contributing to land degradation, soil erosion has been clearly identified as one of the causes, and is probably the most visible process. Loss of land productivity in cultivated areas, however, may be due to erosion caused by land management. The direct loss of standing biomass due to erosion would be more likely to occur in natural and semi-natural environments. However, the real cause-effect relationship for this range of situations has not been analysed in this report. Table 5 documents the coincidence of negative land productivity dynamics in cultivated areas of the EU that are estimated to have irreversible levels of soil erosion.

As can be seen in figure 23, the observed incidence of soil erosion as a probable, if not only, cause of certain levels of decline of land productivity is an EU-wide phenomenon that is definitely not confined to Mediterranean areas only.

	Land productivity dynamics		
	declining	early-signs	stable, stressed
EU	38.3	60.5	54.5

Table 5: Share of the land productivity dynamics classes coinciding with erosion of more than 1 t/ha/yr (as % of the land productivity dynamics class)

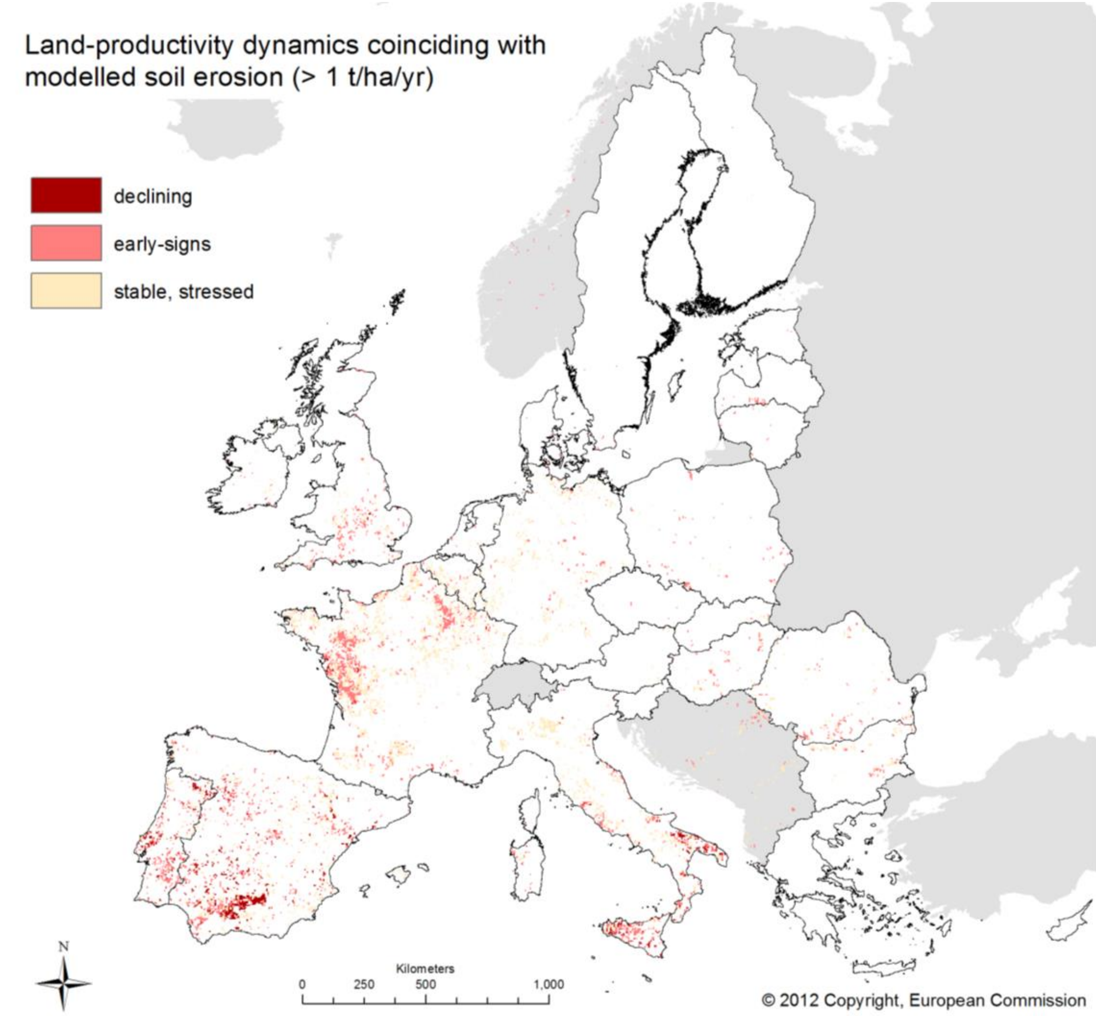


Figure 23: Spatial incidence of negative land productivity dynamics within areas where estimated erosion is greater than 1 t/ha/yr.

4.3.4.3 Land management intensity: measured using N surplus

The use of nitrogen surplus as a surrogate indicator of land management intensity shows correspondence between declining land productivity and increasing land management intensity.

Other aspects of land management need to be considered to explain the cause-effect chain of land degradation or improvement.

For several decades, the EU's Common Agricultural Policy (CAP) had the objective of increasing food production. This increasing efficiency and productivity resulted in intensification of farming methods, which have had significant impacts on the environment. This evolution has been marked by a growing reliance on non-renewable fertiliser and pesticide inputs and higher stocking densities[21].

Land management intensity is certainly conditioning land productivity levels. Land-use intensification could jeopardise land functions and deplete the soil, compromising continued sustainable production.

***Manure distribution in the Odense** (in 21)*

The estimated level of nutrient losses, provoked by the extensive use of inorganic fertilisers or the application of organic inputs such as slurry, can provide a first indication of land management intensity. Figure 24 gives a representation of such intensity in the EU as reflected in measured nitrogen surplus[19]. Table 6 lists the share of the land productivity dynamics classes within areas of low, medium and high nitrogen surplus.

Areas with medium nitrogen surplus levels show a decline in land productivity in only a few specific regions, as shown in figure 25. Areas with medium and high N surplus show substantial expanses where land productivity is stable but stressed; 12.7 and 17.3% respectively. Areas with a high nitrogen surplus show a lower percentage of increasing productivity (9.5%), with most of the land productivity dynamics falling under the 'stable, not stressed' class. Areas showing high nitrogen surplus coincide with densely populated regions in Europe. A considerable amount of the productive land in these areas is being lost to urban sprawl, with the result that it contributes to the 'stable but stressed' land productivity class. Areas showing low nitrogen surplus correspond to the remaining the EU agricultural land, showing a similar distribution of percentages to that of table 1 (percentage of the total EU area belonging to the five land productivity classes).

Land productivity dynamics	Estimated nitrogen surplus		
	low	medium	high

declining	**1.7**	**0.4**	**0.0**
early signs of decline	**5.5**	**5.7**	**1.1**
stable but stressed	**5.9**	**12.7**	**17.3**
stable, not stressed	**71.4**	**66.7**	**72.1**
increasing productivity	**15.5**	**14.5**	**9.5**

Table 6: Share the land productivity dynamics classes within areas of low, medium and high nitrogen surplus (N surplus class values are low: < 30 kg/ha; medium: 30-80 kg/ha; high: > 80 kg/h, see Bouraoui et al., 2009[22])

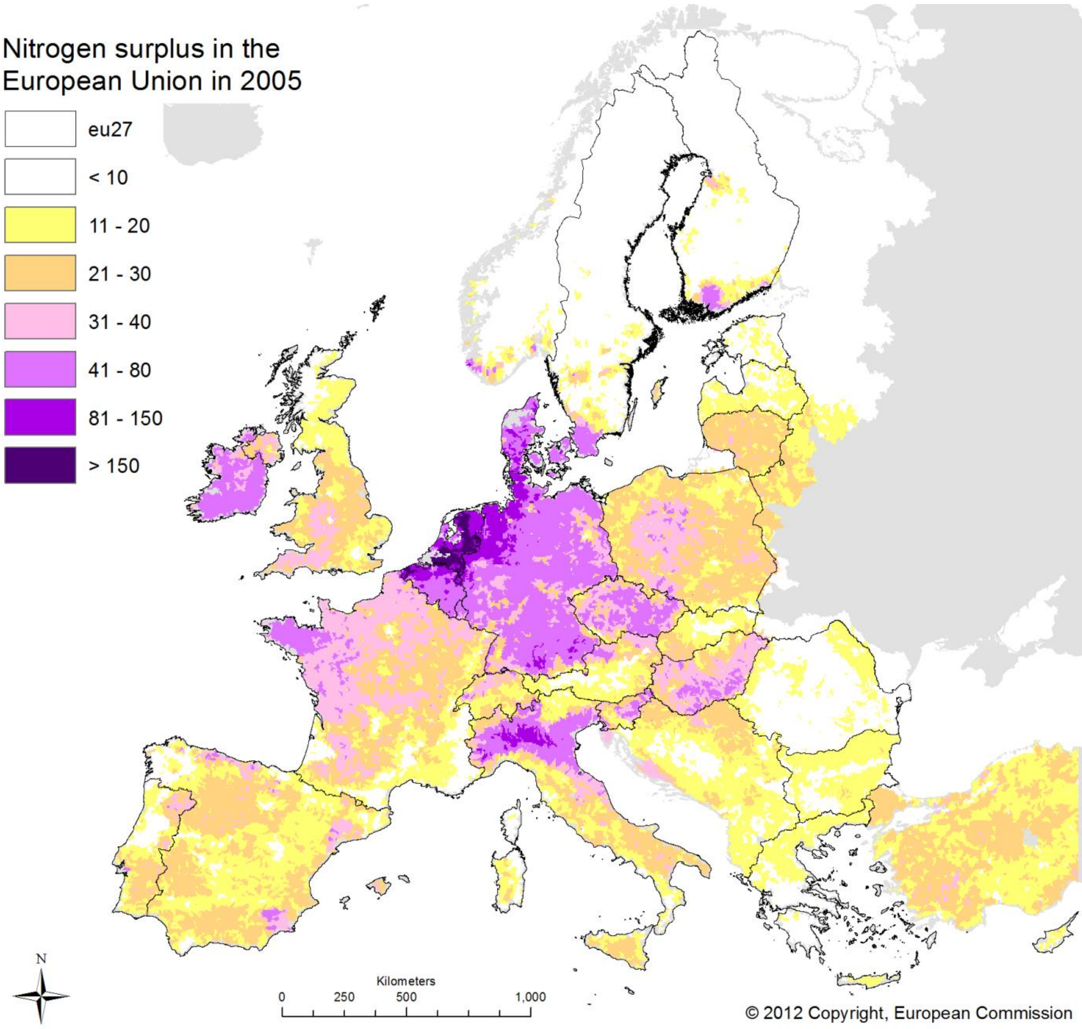
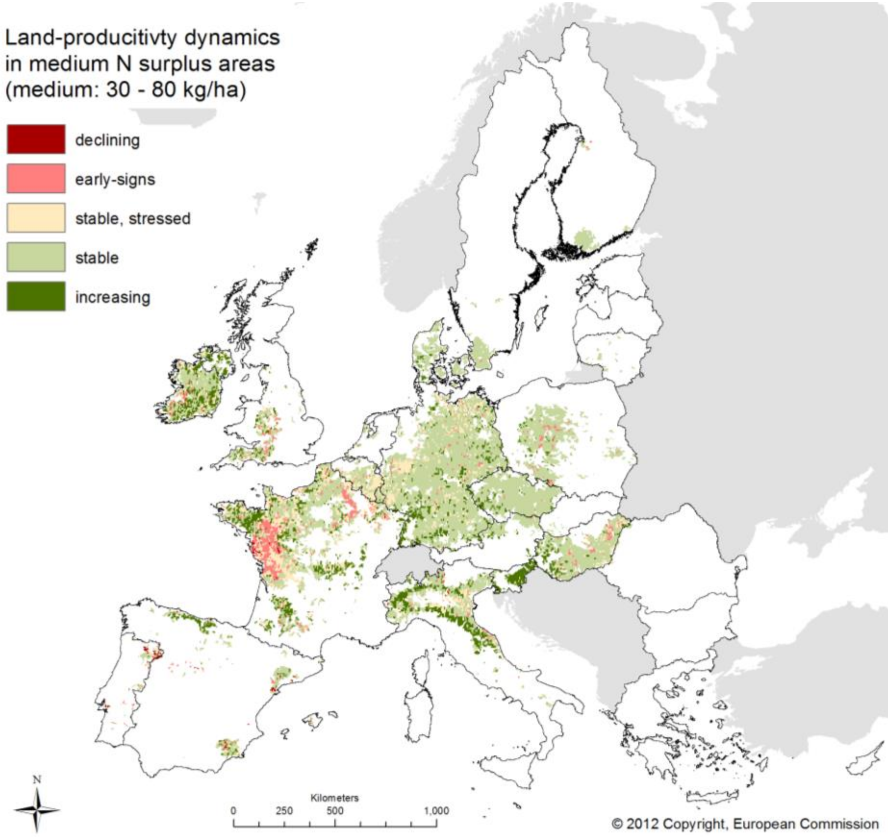


Figure 24: Estimated nitrogen surplus in the European Union (Source: Jones et al., 2012[19])



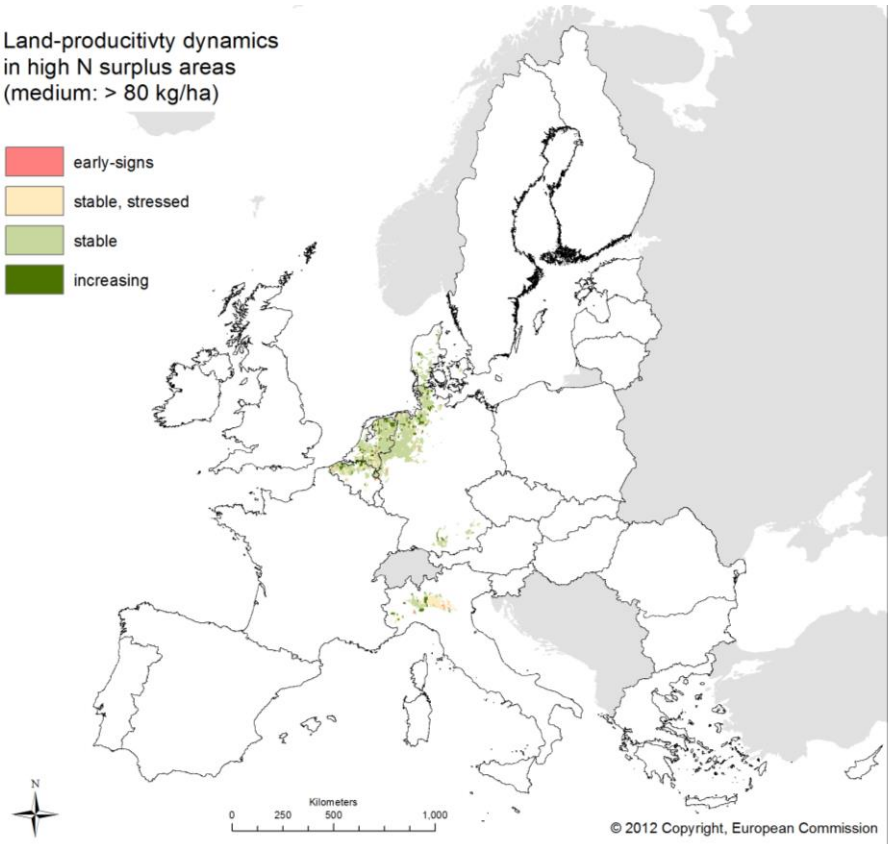


Figure 25: Land productivity dynamics within areas with (a) medium (top) and (b) high (bottom) nitrogen surplus

Land use change and agricultural intensification potentially play a role in the land productivity dynamics in an area in mid-western France, see figure 26 and figure 27.

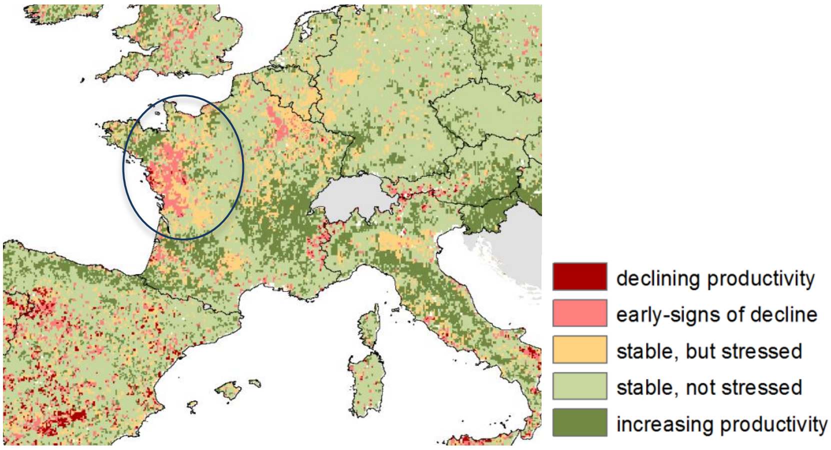


Figure 26: Area in mid-western France where early signs of declining land productivity dynamics can be observed.

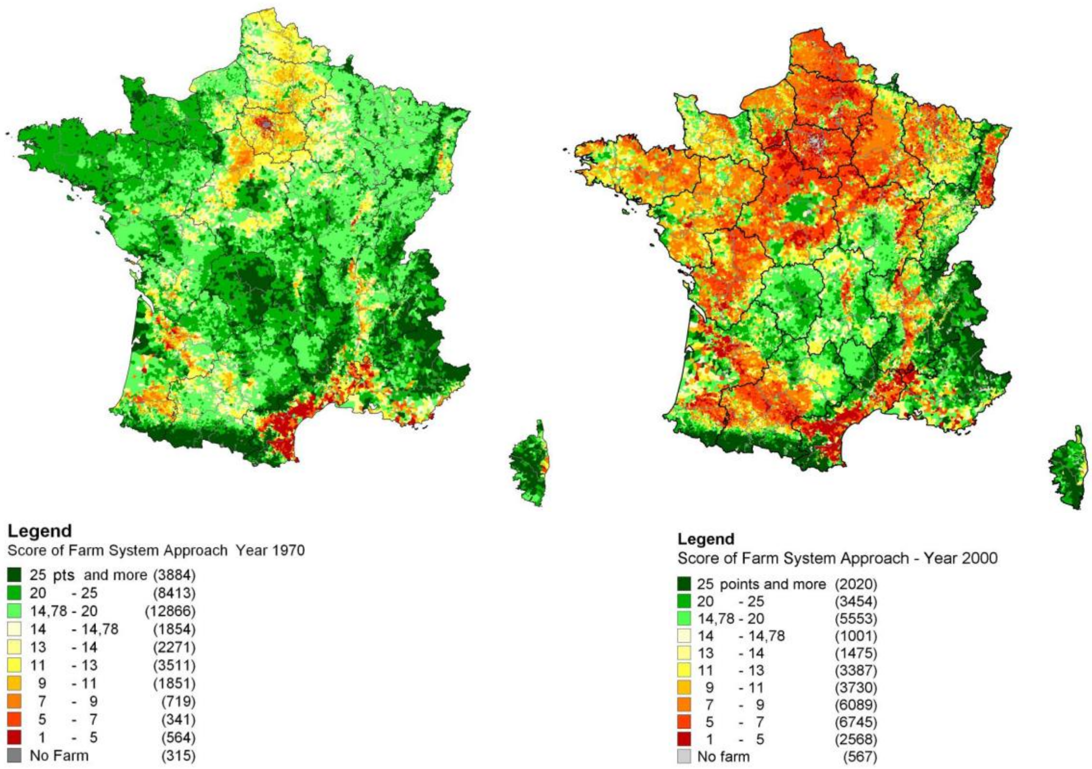


Figure 27: Intensification of land use from 1970 (left) to 2000 (right). Darker shades of red indicate more intense land use.

The indicator for intensification (figure 27) is based on three sub-indicators as proxies for the main characteristics of High Nature Value farmland in France: (1) crop rotations, (2) extensive land-use practices and (3) presence of landscape elements. Each sub-indicator scores a value from 0-10 (except for crop rotations, where the minimum is 1) according to its contribution to the nature value of a municipality. The final score ranges from 1 to 30. The scoring system rates the main components of each sub-indicator (i.e. extensive practices are calculated separately for crops and grasslands; landscape elements comprising hedgerows, forest edges, traditional orchards, fishing ponds or wetlands, are weighted separately[23]). Areas evolving from green (higher score) to red (lower score) are areas that have undergone agricultural intensification during the 1970-2000 period. Other sources, such as the average annual water irrigation requirements (shown in figure 28) confirm this evolution.

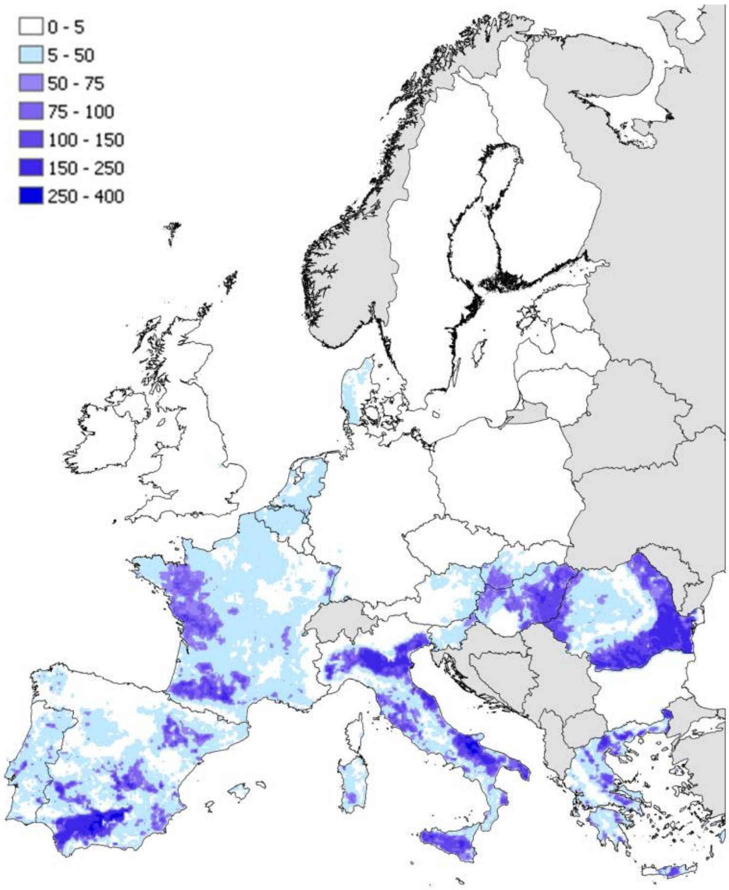


Figure 28: Average annual water irrigation requirements for Europe (mm per 25 km² grid)[24]

4.3.4.4 Land take and soil sealing

Proper soil functioning can also be influenced or even completely hampered by other aspects of land management. Soil sealing, by converting land into artificial surfaces, is an increasing threat to land productivity. The loss of productive or agricultural land to artificial surfaces is a common problem in the European Union, of which all regions are affected to a greater or lesser extent. Simultaneously, there are also considerable differences between EU Member States in terms of the speed of land take and in the quality of the land taken away from crop production in favour of artificial surfaces[12, 25]. In terms of ecosystem services, soil sealing causes a 100% loss of land productivity. Bearing in mind that productive land is a limited resource that is vital for feeding humanity, trade-offs need to be very carefully studied when deciding whether or not to cede productive land to other, e.g. urban or industrial, human use.

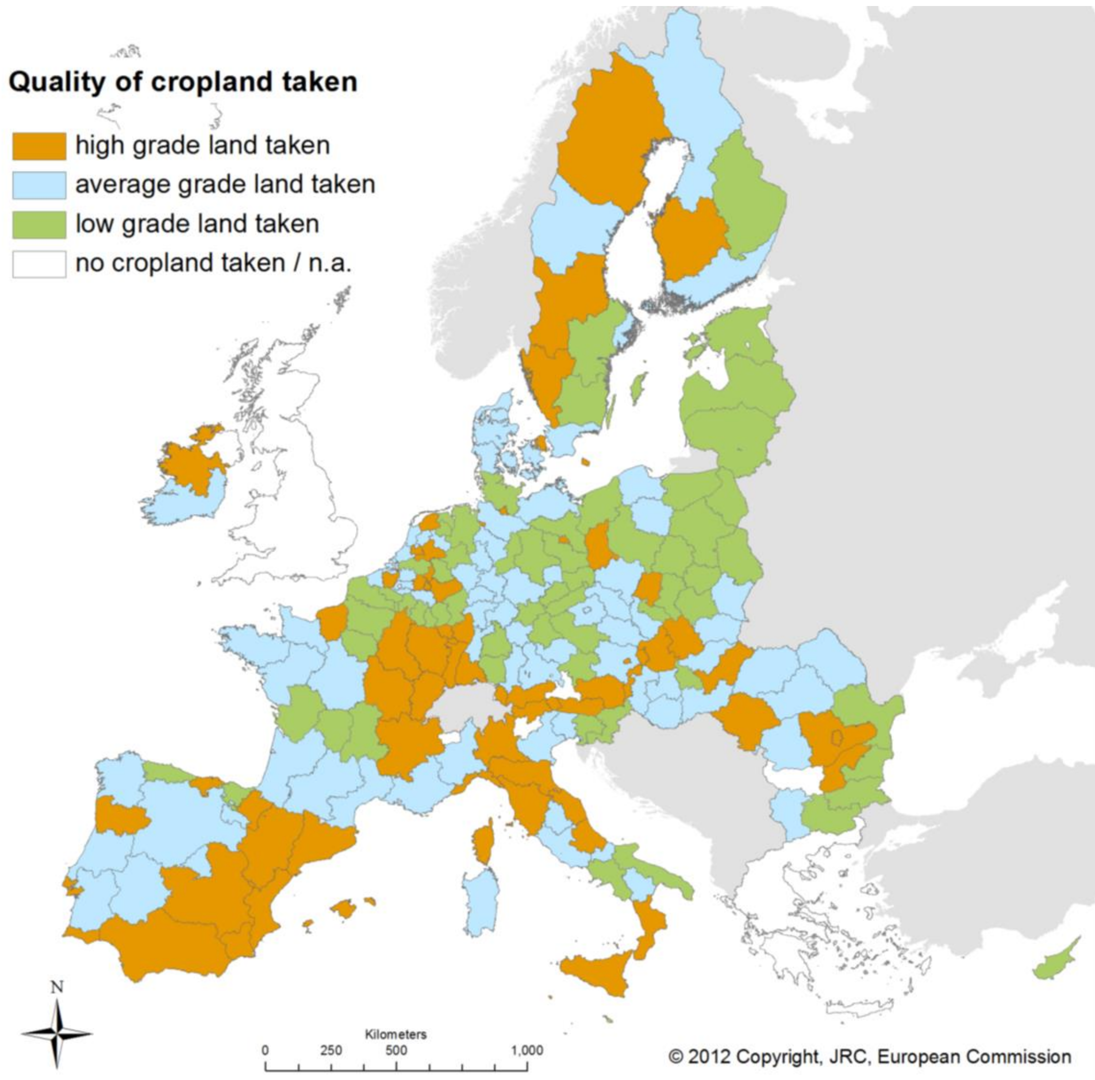


Figure 29: Quality of cropland taken by soil sealing/artificial use in NUTS regions of the EU

country	conversion to artificial land from:						
	cropland (ha)	cropland (% of country total surface area)	cropland (% of land surface area†)	cropland (% of cropland area in 2000)	grassland (% of grassland area in 2000)	plantations (% of plantation area in 2000)	forests (% of forest area in 2000)
Austria	4,457	0.10	0.12	0.26	0.16	0.06	0.05
Belgium	2,208	0.12	0.15	0.18	0.07	0.05	0.15
Bulgaria	1,858	0.04	0.04	0.05	0.14	0.06	0.01
Cyprus	6,703	1.09	1.28	1.83	2.35	1.31	0.58
Czech Republic	7,710	0.17	0.18	0.23	0.65	0.10	0.04
Denmark	9,727	0.25	0.28	0.34	0.10	0.15	0.06
Estonia	1,522	0.10	0.11	0.18	0.14	0.07	0.08
Finland	2,122	0.03	0.04	0.13	0.40	0.00	0.04
France	56,140	0.13	0.17	0.26	0.14	0.22	0.06
Germany	49,473	0.19	0.21	0.31	0.17	0.12	0.07
Hungary	11,574	0.17	0.19	0.22	0.33	0.18	0.05
Ireland	5,680	0.29	0.37	0.86	0.35	0.24	0.11
Italy	40,509	0.16	0.18	0.37	0.07	0.12	0.02
Latvia	335	0.02	0.02	0.02	0.03	0.01	0.01
Lithuania	2,609	0.05	0.06	0.09	0.07	0.07	0.01
Luxembourg	67	0.16	0.17	0.08	0.98	0.00	0.04
Netherlands	20,531	1.07	1.25	1.55	1.23	1.16	0.22
Poland	14,133	0.06	0.07	0.09	0.08	0.06	0.03
Portugal	7,497	0.29	0.32	0.31	0.52	0.18	0.38
Romania	6,177	0.04	0.04	0.07	0.04	0.05	0.01
Slovakia	2,791	0.08	0.07	0.16	0.02	0.06	0.01
Slovenia	350	0.05	0.06	0.09	0.01	0.03	0.05
Spain	78,342	0.27	0.29	0.48	0.37	0.28	0.12
Sweden	5,903	0.04	0.05	0.19	0.19	0.01	0.03
EU-24	338,418	0.14	0.16	0.27	0.21	0.16	0.06

Table 7: Extent of land take from main land cover types (to artificial land) in the EU between 2000-2006[25]

† *With reference to the total land surface area (excluding waters and wetlands)*

4.4 Effects of policy strategies and future options

In general, High Nature Value (HNV) farmland areas seem to have a larger share of stable or increasing land productivity than those with low, or no, nature value. Natura 2000 areas show a larger share of increasing land productivity.

Further analysis is needed, but first indications are that it can be worthwhile to further optimise EU agri-environmental policy strategies to mitigate land degradation in HNV farmland areas.

While the CAP aimed to increase food production, the improvement of agri-environmental aspects was dealt with by specific incentive measures within Rural Development Plans. High Nature Value (HNV) farmlands have been mapped in the EU to indicate areas under cultivation for which there is a specific interest in, or potential for, keeping natural diversity. In many of these areas, agri-environmental measures were undertaken[26]. Other EU strategies aimed to maintain environmental diversity by protecting certain areas, such as those under the Natura 2000 policy.

A harmonised dataset for the EU on which and where agri-environmental measures have been implemented during the past ten years would offer an excellent basis on which to evaluate their effect on overall land productivity dynamics. As a first step in understanding the effect that recent policy strategies have had on land productivity dynamics, we evaluate the land productivity of HNV farmland and Natura 2000 areas on the assumption that such areas should show more stable or improving land productivity dynamics.

4.4.1 High Nature Value (HNV) farmland

Areas showing levels of likelihood[26] of HNV farmland presence are mapped in figure 30. For the EU, this map shows the spatial distribution of HNV farmland, reclassified based on the original map produced by the JRC and the European Environment Agency (EEA). HNV farmland areas are regrouped for our analysis into four classes of likelihood (low 1-25%; medium 26-50%, high 51-75%, very high 76-100%). The share of land productivity dynamics within each of these classes is presented in table 8.

Land productivity dynamics	HNV probability classes			
	low	medium	high	very high

declining	**1.4**	**1.9**	**2.2**	**3.6**
early signs of decline	**4.1**	**4.5**	**5.8**	**8.1**
stable but stressed	**5.6**	**6.5**	**7.4**	**8.1**
stable, not stressed	**71.7**	**66.8**	**63.4**	**63.4**
increasing productivity	**17.2**	**20.3**	**21.1**	**16.8**
	% of EU Area			
	19.7	**10.2**	**6.4**	**8.0**

Table 8: Share of land productivity dynamics within High Nature Value farmlands in the EU

Although HNV farmland covers a large part of the EU and the distribution of its share of land productivity dynamics is very similar to the distribution for the EU as a whole (see table 1), there are some observable differences. The share of increasing land productivity is higher in all HNV probability classes than the EU average (of 14.9%), particularly in medium and high HNV probability classes. Perhaps surprisingly, the greatest percentage of areas under decline are found to be in the 'very high' HNV probability class. This class also shows higher percentages of areas in the declining, 'early signs of decline' and in the 'stable but stressed' land productivity classes than in the overall EU distribution.

The substantial coincidence of declining and stressed land productivity dynamics with the 'very high' HNV probability class in the Mediterranean area can be observed in figure 31. Over such areas, the observation area of 25 km^2 contains semi-natural areas together with highly productive agricultural systems, such as permanent crops or irrigation systems. Proportions between these land uses may have changed during the past decennium.

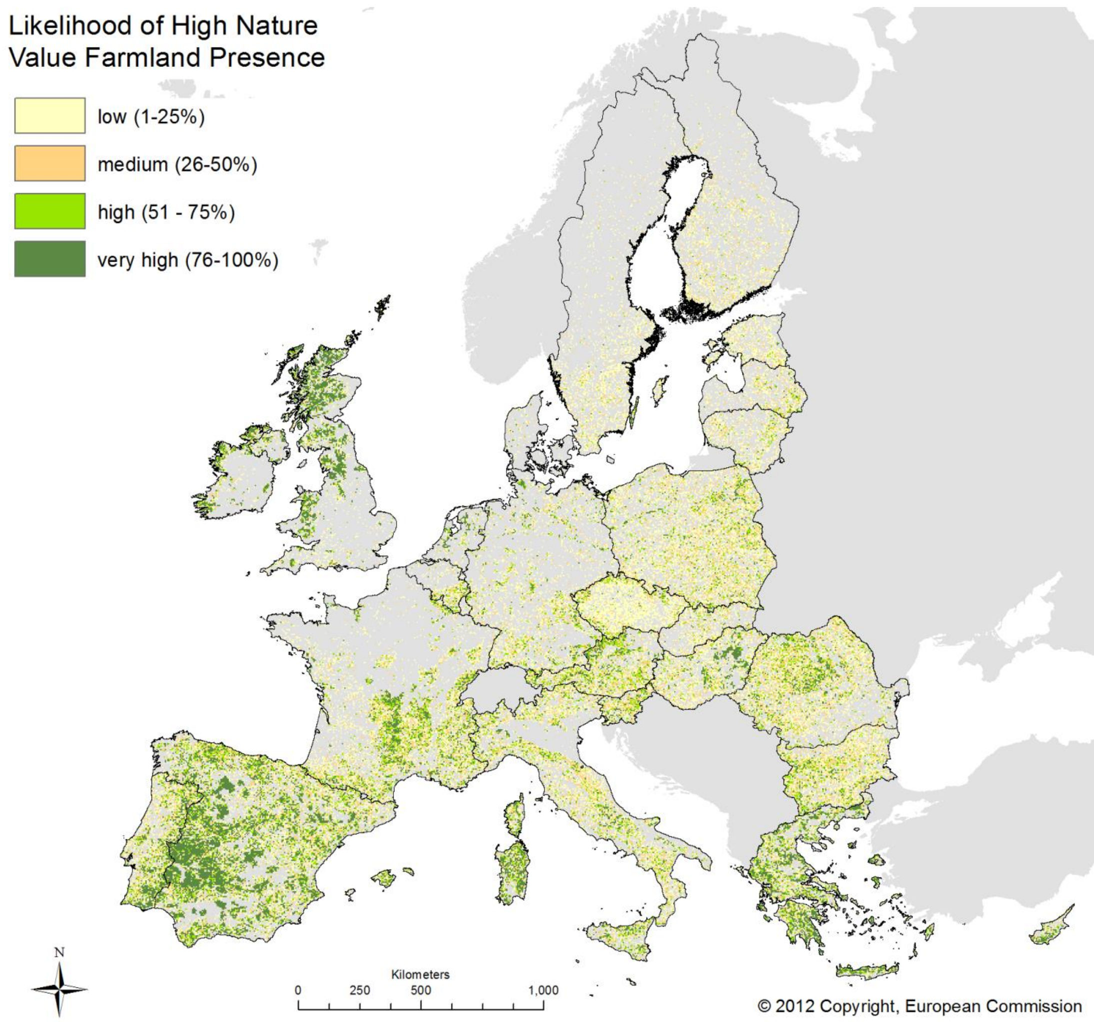


Figure 30: Spatial distribution of High Nature Value (HNV) farmland areas in the EU (regrouped based on JRC-EEA[22]).

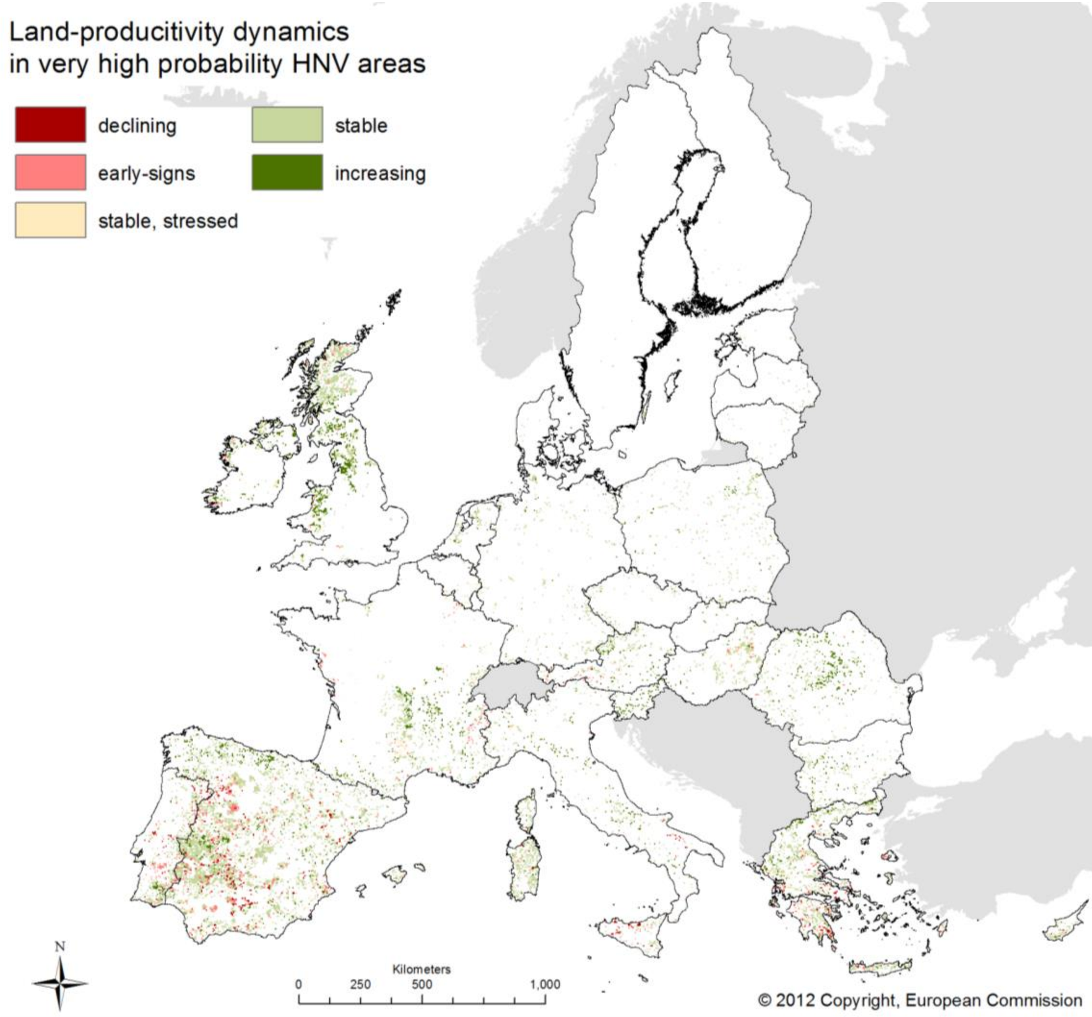


Figure 31: Correspondence of land productivity dynamics within the 'very high' probability class of High Nature Value (HNV) farmland areas.

4.4.2 Natura 2000

Natura 2000 supports the EU's nature and biodiversity policy. It is an EU-wide network of nature protection areas established under the 1992 Habitats Directive. The aim of the network is to assure the long-term survival of Europe's most valuable and threatened species and habitats[27]. Natura 2000 sites cover over 17% of the EU area and are distributed all over Europe. Figure 32 presents the distribution of the sites and their corresponding land productivity dynamics.

Table 9 shows that, similarly to HNV areas, the percentage distribution of land productivity dynamics in the Natura 2000 sites is comparable to that of the overall EU sample. However, compared to the EU or HNV areas, a slightly higher percentage of increasing land productivity is noticeable. 17.8% of the land within Natura 2000 sites shows increasing land productivity as compared to 14.9% for the whole EU. The Natura 2000 network is not a system of strict nature reserves that exclude all human activities. In

addition, the observation resolution of 25 km² used to calculate the land productivity dynamics can give rather coarse measurements of land productivity for the smaller areas within the network. Such measurements would be best made with higher-resolution information, for which however, long-term time series data are not yet available.

Land productivity dynamics				
declining	**early signs of decline**	**stable, but stressed**	**stable**	**increasing**
1.8	**5.7**	**7.3**	**67.3**	**17.8**

Table 9: Assessment of land productivity dynamics of Natura 2000 sites in the European Union. Values are expressed as % of the Natura 2000 sites

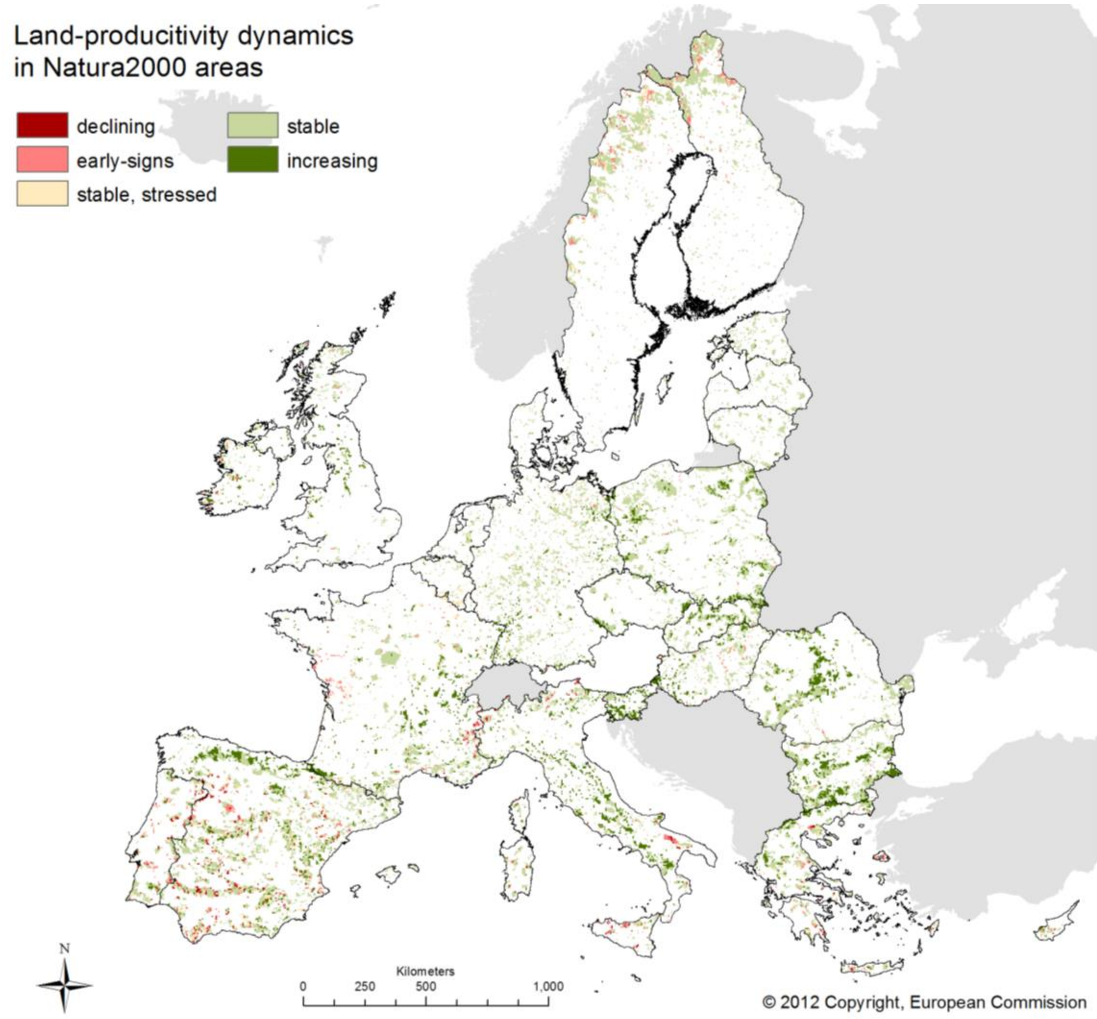


Figure 32: Land productivity dynamics in Natura 2000 areas (coloured areas represent Natura 2000 areas – white areas are not part of Natura 2000).

5 CONCLUSIONS

Land degradation is a complex phenomenon caused by interacting biophysical and societal factors. No agreed scientific assessment and measurement protocols or complementing indicators currently exist. However, long-term satellite-based observations offer considerable potential as a source of information on land productivity dynamics, which offers potential as a baseline on which to further integrate contextual information in order to assess land degradation. This is still subject to further verification and research to understand the complex social, economic and biophysical processes that drive local (positive and negative) changes in land productivity dynamics.

This study shows that land productivity dynamics can be mapped for the EU based on satellite time series observations. This information can be used to analyse the incidence of potential drivers of land degradation, such as unsustainable land use or soil erosion, and to interpret land productivity dynamics in the light of ongoing land degradation.

Land productivity is observed to be in decline in 1.5% (around 6 million hectares) of the EU territory, with another 5.6% showing early signs of decline. Some of these areas are being cultivated for agricultural production and, in some cases, correspondence to mapped drought events, significant soil erosion risk and land use intensification. Convergence of such evidence can prove useful for improved assessment of ongoing land degradation.

Land productivity dynamics are found to have been stable in most of the EU during the 1982-2010 period. Increases in land productivity were found in semi-natural land cover types, and a higher coincidence was observed in HNV farmland and Natura 2000 sites.

This spatial evaluation also highlighted the fact that, in the frame of the 'neutral land degradation world' discussion, area percentages of declines and increases in land productivity cannot be counterbalanced in a straightforward manner, as these areas can have totally different actual and potential land uses, and economic and cultural values. Therefore, discussions on land-degradation neutrality must consider trade-offs with regard to the impacts of different land use or management strategies.

This document reports the first results of an assessment and evaluation of EU land productivity dynamics, and gives examples of the added value of integrating contextual information when making final judgements on land degradation. These findings constitute a valuable contribution to land degradation assessments in general and, specifically, to the implementation of the RIO+20 target of a 'land degradation neutral world'.

6 OUTLOOK – RIO+20

An assessment of land productivity dynamics, combined with further explanatory biophysical and societal data, has potential value as an indicator with which to measure progress towards the RIO+20 target of land-degradation neutrality.

The Parties to the RIO+20 Conference decided "to strive to achieve a land-degradation neutral world in the context of sustainable development". This is a noble but controversial target in that it is not clear what, and where, land degradation is taking place. There are also no agreed methodologies to assess land degradation at regional, continental or global scales. The research documented in this report aims to address this issue. The notion of 'neutral' is also debatable as many interpretations are still open; is it restoration versus degradation, or is it 'maintaining and improving' versus degradation?

Reduced land degradation will lead to increased productivity and new economic opportunities, help secure rural labour markets through alternative and sustainable land use options, and help safeguard environmental services of the land, including the land's climate system, water regulation capacity and biodiversity functions. The degradation of ecosystems is, to a large extent, induced by unsustainable human activities. This puts people at the very centre of the issue and requires them to take responsibility and action. Understanding the value of ecosystems and their services is essential to construct preventative solutions and conservation methodologies that deliver socio-economic benefits. Sustainable land management provides viable alternatives for prevention and conservation and has been implemented in a wide diversity of geographical and economic contexts. Thus, achieving land-degradation neutrality is not so much desirable as essential.

It should be obvious that, when cultivated or intensively used lands show indications of ongoing degrading processes, strategies should be implemented to mitigate these processes through adapted land management techniques that maintain adequate levels of food production. Also, intensifying mitigation and protection strategies could prove to be valuable in areas of high nature value interest or conservation sites.

By avoiding the pitfalls of unsustainable agricultural intensification (figures 24 and 25), improving spatial planning, in particular infrastructure and housing (to make maximum use of brownfield sites, cut back on the sealing of productive soils, etc.), encouraging rural communities to develop sustainable practices and pursuing an effective fight against climate change, Europe might reach a land-degradation neutral state.

This report shows that, based on satellite time-series observations, land productivity dynamics can be mapped for the EU. This can be used as a basis on which to identify and map ongoing land degradation by analysing the incidence of potential drivers (such as unsustainable exploitation or soil erosion) and compiling evidence to interpret land productivity dynamics.

Building on these initial results, the next steps for a European land degradation assessment and contribution to the RIO+20 target are to improve analytical schemes (including the compilation of further and more detailed contextual data), fine-tune models to better understand cause-and-effect relationships, and provide more detailed scenario analyses.

References

[1] S. Sommer, C. Zucca, A. Grainger, M. Cherlet, R. Zougmore, Y. Sokona, J. Hill, R. Della Peruta, J. Roehrig, G. Wang (2011): Application of indicator systems for monitoring and assessment of desertification from national to global scales. Land Degrad. Develop. 22: 184–197. Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/ldr.1084

[2] Oldeman LR, Hakkeling RTA, Sombroek WG. (1991): World map of the status of human-induced soil degradation: an explanatory note. Second Edition. Wageningen, The Netherlands and Nairobi, Kenya: International Soil Reference and Information Centre/United Nations Environment Programme

[3] Cherlet M and Sommer S. (2009): WAD Implementation Plan. Roadmap towards a new World Atlas on Desertification, Land Degradation and Drought. Joint Research Centre, Institute for Environment and Sustainability. JRC Action DESERT (22008), WP 2009, Deliverable 2.2.
http://desert.jrc.ec.europa.eu/action/php/index.php?action=view&id=105

[4] Ivits, E., Cherlet, M., Mehl, W., Sommer, S. (2012a): Ecosystem Functional Units characterized by satellite observed phenology and productivity gradients: a case study for Europe. *Ecological Indicators*, pp. 17-28. 10.1016/j.ecolind.2012.11.010

Hill J, Stellmes M, Udelhoven T, Roeder A, Sommer S. (2008): Mediterranean Desertification and Land Degradation - Mapping Related Land Use Change Syndromes Based on Satellite Observations. GLOBAL AND PLANETARY CHANGE 64 (3-4); p. 146-157. JRC45576

[5] Ivits, E., Cherlet, M., Sommer, S., Mehl, W. (2012): Addressing the complexity in non-linear evolution of vegetation phenological change with time-series of remote sensing images. *Ecological Indicators,* 26, 49–60. 10.1016/j.ecolind.2012.10.012.

[7] Ivits, E., Cherlet, M., Sommer, S., Mehl, W. Conti M. (2012): An integrated assessment framework for land degradation at global scales, JRC Action DESERT (22008), WP2012, Deliverable 1.4

[7] DSD WG1 White Paper (2010):
(http://dsd-consortium.jrc.ec.europa.eu/documents/WG1_White-Paper_Draft-2_20090818.pdf)

[8] Reynolds J F, Stafford Smith DM, Lambin EF, Turner BL, Mortimore IM, Batterbury SPJ, Downing TE, Dowlatabadi H, Fernandez RJ, Herrick JE, Huber-Sannwald E, Jiang H, Leemans R, Lynam T, Maestre FT, Ayarza M, Walker B. (2007): Global desertification: Building a science for dryland development. Science 316:847-851.

[9] Lal R., Safriel U. and Boer b., (2012): Zero Net Land Degradation, A New Sustainbale Development Goal for RIO+20; a report prepared for the Secretariat of the UNCCD, May 2012.
http://www.unccd.int/Lists/SiteDocumentLibrary/secretariat/2012/Zero%20Net%20Land%20Degradation%20Report%20UNCCD%20May%202012%20background.pdf

[10] Winslow M. D., J. V. Vogt, R. J. Thomas, S. Sommer, C. Martius and M. Akhtar-Schuster (2011): Science for improving the monitoring and assessment of dryland degradation. Land Degrad. Develop. 22: 145–149 (2011). Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/ldr.1044. JRC59301

[11] Geist HJ and Lambin EF. (2004): Dynamic Causal Patterns of Desertification, Bioscience, Vol.54No.9, pp.817-829

[12] CLC2000 (EEA, 2000) [http://www.eea.europa.eu/data-and-maps/data/corine-land cover-2000-raster](http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster)

[13] Tóth G, Bódis K, Ivits É, Máté F, Montanarella L. (2011): Productivity component of the proposed new European agri-environmental soil quality indicator. In: Tóth G, Németh T, editors. Land quality and land use information in the European Union. Luxembourg: Publication Office of the European Union. p. 297–308.

[14] Kurnik B. and Niemeyer S., 2008, Drought forecasting in Europe with Standardized Precipitation Index using ECMWF monthly forecasts, EMS2008-A-00384, 2008, 8th Annual Meeting of the EMS / 7th ECAC

[15] European Commission (2007): Water Scarcity and Droughts, Second Interim Report.
http://ec.europa.eu/environment/water/quantity/pdf/comm_droughts/2nd_int_report.pdf

[16] Ciais, Ph., Reichstein, M., Viovy, N., Granier, A., Ogee, A., Allard, V., Aubinet, M., Buchmann, N., Bernhofer, C., Carrara, A., Chevallier, F., De Noblet, N., Friend, A. D., Friedlingstein, P., Grunwald, T., Heinesch, B., Keronen, P., Knohl, A., Krinner, G., Loustau, D., Manca, G., Matteucci, G., Miglietta, F., Ourcival, J.M., Papale, D., Pilegaard, K., Rambal, S., Seufert, G., Soussana, J.F:, Sanz, M.J., Schulze, E.D:, Vesala, T., Valentitni, R. (2005): Europe-wide reduction in primary productivity caused by the heat and drought in 2003. Nature, Vol. 437, 529-533.

[17] Ivits, E., Horion, S., Fensholt, R., Cherlet, M., (2013): Drought footprint on European ecosystems between 1999 and 2010 assessed by remote sensing observed vegetation phenology and productivity. *Global Change Biology*, at second review

[18] Danjon F. et al. (2009): Genetic variability in 3D coarse root architecture in Pinus pinaster, in Proceedings of the 2nd International Conference on Wind Effects on Trees, Freiburg, October 2009

[18/2] Commision of the European Communities, 2006, Brussels, 22.9.2006, Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, Thematic Strategy for Soil Protection, COM(2006)231Final

[19] Jones A., Panagos P., Barcelo F., Bouraoui F., Bosco C., Dewitte O.,Gardi C., Erhard M., Hervás J., Hiederer R., Jeffrey S., Lükewille A., Marmo L., Montanarella L.,

Olazábal C., Petersen J-E., Penizek V., Strassburger T., Tóth G., Van Den Eeckhout M., Van Liedekerke M., Verheijen F., Viestova E., Yigini Y. (2012): The State of Soil in Europe – A contribution of the JRC to the European Environment Agency's Environment State and Outlook Report – SOER 2010, EUR – Scientific and Technical Research series – ISSN1831-9424(online), ISSN101-5593 (print), ISBN 978-9279-22806-3 (pdf), ISBN 978-92-79-22805-6 (print)

[20] **Bosco et al. (2012) from the "State of Soil in Europe, JRC Reference Report 2012**

[21] **Cherlet M. (2007): Experiences and Analysis of Pressures and Impacts from Agriculture on Water Resources and Developing an related Programme of Measures – Report of the Pilot River Basin Group of Agriculture, EUR ISSN1018-5593, ISBN 978-92-79-06228-5**

[22] **Bouraoui F., Grizetti B., Aloe A. (2009): Nutrient Discharge from Rivers to Seas for year 2000, EUR24002EN, European Commission, Office for Official Publications of the European Communities, Luxemburg, pp.79**

[23] **Philippe Pointereau, Maria Luisa Paracchini, Jean-Michel Terres, Frédéric Jiguet, Yves Bas, Katarzyna Biala (2007): Identification of High Nature Value Farmland in France through Statistical Information and Farm Practices Surveys. EUR 22786 EN – Joint Research Centre – Institute for Environment and Sustainability. Office for Official Publications of the European Communities Luxembourg 2007 – 65 pp. – 27.9 x 21 cm, EUR – Scientific and Technical Research series – ISSN 1018-5593 ISBN 978-92-79-06475-3**

[24] **de Roo A. et al., 2012, Water resources in Europe and Africa: matching water supply and water demand, EUR25247EN, European Commission, Office for Official Publications of the European Communities, Luxemburg, pp.40, ISBN 1018-5593 (print)//1831-9424 (online)**

[25] **Tóth G. (2012): Impact of land take on the land resource base for crop production in the European Union. Science of the Total Environment 435-436: 202–214**

26 Maria Luisa Paracchini, Jan-Erik Petersen, Ybele Hoogeveen, Catharina Bamps, Ian Burfield, Chris van Swaay (2008): High Nature Value Farmland in Europe - An Estimate of the Distribution Patterns on the Basis of Land Cover and Biodiversity Data. EUR 23480 EN, Luxembourg: Office for Official Publications of the European Communities 2008, 87 pp. – 21 x 29.7 cm, EUR – Scientific and Technical Research series – ISSN 1018-5593, ISBN 978-92-79-09568-9

27 http://ec.europa.eu/environment/nature/natura2000/index_en.htm

ANNEX

Table A.1: Land productivity dynamics of low productivity croplands in the Member States of the European Union (in % of the low productivity croplands).

Countries	declining	early signs	stable, stressed	stable	increasing
Austria	0.0	0.0	4.8	57.1	38.1
Belgium	0.0	0.0	80.0	20.0	0.0
Bulgaria	0.0	0.0	1.6	79.7	18.8

Cyprus	**2.3**	**0.0**	**7.0**	**86.0**	**4.7**
Czech Republic	**0.0**	**0.0**	**0.0**	**100.0**	**0.0**
Denmark	**0.0**	**0.0**	**0.0**	**100.0**	**0.0**
Estonia	**0.0**	**0.0**	**0.0**	**100.0**	**0.0**
Finland	**0.0**	**2.4**	**0.0**	**97.6**	**0.0**
France	**0.0**	**9.7**	**29.6**	**48.4**	**12.4**
Germany	**0.0**	**0.0**	**33.3**	**64.7**	**2.0**
Greece	**5.5**	**10.4**	**7.4**	**66.3**	**10.4**
Hungary	**0.0**	**2.3**	**12.8**	**83.5**	**1.5**
Irish Republic	**0.0**	**3.8**	**11.5**	**50.0**	**34.6**
Italy	**16.2**	**13.5**	**0.0**	**67.6**	**2.7**
Latvia	**0.0**	**0.0**	**2.4**	**97.6**	**0.0**
Lithuania	**0.0**	**0.7**	**0.0**	**98.2**	**1.1**
Luxembourg	**0.0**	**0.0**	**0.0**	**100.0**	**0.0**
Malta	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Netherlands	**0.0**	**0.0**	**28.9**	**66.5**	**4.6**
Poland	**0.0**	**0.4**	**0.0**	**86.7**	**12.9**
Portugal	**5.0**	**15.0**	**0.0**	**70.0**	**10.0**
Romania	**0.0**	**0.0**	**0.0**	**77.8**	**22.2**
Slovakia	**0.0**	**0.0**	**0.9**	**74.4**	**24.8**
Slovenia	**0.0**	**0.0**	**0.0**	**17.4**	**82.6**
Spain	**6.4**	**13.8**	**17.6**	**55.6**	**6.6**
Sweden	**0.0**	**0.0**	**1.1**	**96.8**	**2.2**
United Kingdom	**0.0**	**10.6**	**2.1**	**54.3**	**33.0**

Table A.2: Land productivity dynamics of <u>medium productivity croplands</u> in the Member States of the European Union (in % of medium productivity croplands).

Countries	**declining**	**early signs**	**stable, stressed**	**stable**	**increasing**
Austria	**0.0**	**0.4**	**2.0**	**70.4**	**27.2**
Belgium	**0.0**	**3.6**	**22.6**	**64.6**	**9.1**
Bulgaria	**0.2**	**4.3**	**5.5**	**74.5**	**15.6**
Cyprus	**5.6**	**0.0**	**11.1**	**66.7**	**16.7**
Czech Republic	**0.0**	**0.0**	**0.6**	**85.9**	**13.5**
Denmark	**0.0**	**1.9**	**0.6**	**89.8**	**7.7**
Estonia	**0.0**	**3.3**	**0.3**	**93.4**	**3.0**

Finland	**0.0**	**1.6**	**0.9**	**97.3**	**0.1**
France	**0.2**	**8.5**	**18.4**	**48.1**	**24.8**
Germany	**0.0**	**2.1**	**11.0**	**78.8**	**8.0**
Greece	**4.7**	**15.6**	**12.3**	**57.8**	**9.6**
Hungary	**0.0**	**5.4**	**8.1**	**72.2**	**14.3**
Irish Republic	**0.0**	**4.5**	**9.1**	**56.8**	**29.5**
Italy	**2.8**	**9.2**	**15.9**	**51.5**	**20.7**
Latvia	**0.0**	**4.8**	**0.1**	**94.0**	**1.1**
Lithuania	**0.0**	**0.7**	**0.7**	**96.7**	**1.8**
Luxembourg	**0.0**	**0.0**	**33.3**	**66.7**	**0.0**
Malta	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Netherlands	**0.3**	**2.2**	**6.9**	**80.5**	**10.1**
Poland	**0.0**	**3.0**	**0.7**	**89.7**	**6.5**
Portugal	**9.6**	**21.1**	**5.7**	**58.5**	**5.1**
Romania	**0.0**	**3.9**	**3.0**	**78.0**	**15.1**
Slovakia	**0.0**	**2.6**	**1.9**	**81.7**	**13.8**
Slovenia	**0.0**	**0.0**	**1.6**	**16.9**	**81.5**
Spain	**4.2**	**13.4**	**9.2**	**64.9**	**8.4**
Sweden	**0.0**	**2.1**	**0.2**	**95.7**	**1.9**
United Kingdom	**0.6**	**10.4**	**6.8**	**68.5**	**13.8**

Table A.3: Land productivity dynamics of high productivity croplands in the Member States of the European Union (in % of high productivity croplands).

Countries	declining	early signs	stable, stressed	stable	increasing
Austria	**0.0**	**0.0**	**0.0**	**84.0**	**16.0**
Belgium	**0.0**	**5.0**	**30.9**	**61.2**	**2.8**
Bulgaria	**0.0**	**1.7**	**1.7**	**79.2**	**17.5**
Cyprus	**0.0**	**0.0**	**8.7**	**73.9**	**17.4**
Czech Republic	**0.0**	**0.7**	**0.4**	**94.4**	**4.5**

Denmark	**0.0**	**1.9**	**0.0**	**98.1**	**0.0**
Estonia	**0.0**	**1.5**	**0.0**	**98.5**	**0.0**
Finland	**0.0**	**0.0**	**0.0**	**100.0**	**0.0**
France	**0.7**	**14.7**	**21.5**	**46.8**	**16.3**
Germany	**0.0**	**2.6**	**11.3**	**82.6**	**3.5**
Greece	**3.2**	**17.7**	**12.9**	**54.8**	**11.3**
Hungary	**0.0**	**8.9**	**8.1**	**80.7**	**2.2**
Irish Republic	**0.0**	**4.2**	**9.5**	**53.0**	**33.3**
Italy	**0.7**	**2.9**	**25.2**	**46.6**	**24.6**
Latvia	**0.0**	**0.0**	**0.0**	**100.0**	**0.0**
Lithuania	**0.0**	**4.5**	**1.4**	**94.1**	**0.0**
Luxembourg	**0.0**	**0.0**	**53.8**	**46.2**	**0.0**
Malta	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Netherlands	**0.0**	**0.0**	**13.9**	**83.3**	**2.8**
Poland	**0.0**	**3.7**	**0.7**	**88.4**	**7.1**
Portugal	**0.0**	**50.0**	**6.3**	**43.8**	**0.0**
Romania	**0.1**	**5.3**	**5.0**	**86.8**	**2.9**
Slovakia	**0.0**	**0.0**	**0.0**	**92.9**	**7.1**
Slovenia	**0.0**	**0.0**	**0.0**	**28.6**	**71.4**
Spain	**9.4**	**12.5**	**6.3**	**53.1**	**18.8**
Sweden	**0.0**	**0.0**	**0.0**	**77.6**	**22.4**
United Kingdom	**0.0**	**4.4**	**7.9**	**63.4**	**24.2**

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