Study supporting potential land targets under the 2014 land communication

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Study supporting potential land and soil targets under the 2015 Land Communication

Final Report

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Glossary

Bio-productivity footprint indicator: A variation of the land footprint indicator. Results from the land footprint indicator measured in actual hectares can either be normalised against a benchmark of global average productivity, or the bio-productivity indicator can be calculated as a mass indicator, illustrating the carbon content of the harvested biomass corresponding to the land footprint.

Brownfield: Derelict underused or abandoned land which has been previously developed for industrial, commercial or residential purposes, and which may have real or perceived contamination problems. Urban brownfield is limited to land within existing urban areas (definition adopted for the purpose of this study from the definition of brownfields used in the EC Guidelines on best practice to limit, mitigate or compensate soil sealing).

Brownfield redevelopment: Bringing brownfield land back into use. This involves one or more of the following: bringing the site back into market without change in land use, changing existing or past land use by integrating the site into planning strategy for the local or regional area (this includes also re-naturalisation and de-sealing of brownfield land) and cleaning up existing soil pollution.

Direct land use: Land use directly required for the provision of specific agricultural or forestry products or services.

Ecosystem function: The capacity of an ecosystem to provide ecosystem services.

Ecosystem service: The direct and indirect contributions of ecosystems to support the economy and human well-being including food, materials, clean water, clean air, climate regulation, flood prevention, pollination and recreation.

"Embodied", "embedded" or "virtual" land imports: Land areas that were appropriated in elsewhere to produce an imported good.

Environmental impacts: Changes to the environment, either adverse or beneficial, that result from external pressures. In this study, EU consumption is considered as an external pressure and the relationship between EU consumption and environmental impacts is one of cause and effect.

Erosion: Removal of soil material by water, wind or, to a lesser extent, tillage or harvesting (Joint Research Centre, 2012a)

Erodibility: Ease with which a particular soil can become detached and transported, related to its properties such as organic matter content, texture, structure and permeability (Panagos, Meusburger, Van Liedekerke, Alewell, Hiederer, & Montanarella, 2014) (Borrelli, Ballabio, Panagos, & Montanarelle, 2014)

Erosivity: Ability of natural force (water, wind) to erode (Joint Research Centre, 2012a)

Gap sites: Non built-up sites that offer potential for development (individual plots as well as several contiguous plots) which lie within established or newly built settlement areas (definition based on BBSR, 2011, provided through the call for evidence for this study).

Global impacts: In the context of this study, they encompass the environmental and social impacts related to the consumption of food, feed, bio-energy and other biomaterial products. The identified key global impacts are deforestation, soil degradation, nutrient pollution, biodiversity loss, GHG emissions and climate change and social impacts such as food availability, labour conditions and land tenure.

Global sustainable land use: A global land use system that allows natural and cultivated areas to sustain their respective ecosystem services while allowing a fair per capita resource distribution to fulfil basic and context specific needs.

Impact-oriented indicators: Indicators illustrating the various environmental and social pressures and impacts related to land use, most importantly deforestation, biodiversity loss, soil degradation and GHG emissions.

Indirect land use change (ILUC): Land use and corresponding land use changes, which are indirectly driven by direct land use change elsewhere (Plevin et al. 2010). For example, expansion of cropland production in Southern Brazil dislocates the former cattle production to Northern Brazil, thereby indirectly contributing to deforestation of the Amazon.

Land: The terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system" (UNCCD).

Land cover: Physical and biological cover of the Earth's surface (e.g. infrastructures, cropland, woodland, shrubland, grassland, bare land, wetlands and water bodies) (EEA).

Land degradation: Interaction of biophysical and socio-economic processes that negatively affect soil function and in particular land's productive capacity (UNEP, 2003).

Land displacement: Tendency of nations with rising affluence to 'outsource' a growing share of their cropland requirements to third countries and mainly involves leakage and indirect land use effects (Lambin and Meyfroidt, 2011a).

Land footprint indicator: An indicator to assess the total domestic and foreign land required to satisfy the final consumption of goods and services of a country or world region. The land footprint is an area-based indicator measured in area units (e.g. hectares). In other publications, the terms global land use (GLU) and actual land demand (ALD) where used synonymously (see UNEP 2014, Erb 2004).

Land recycling: Redevelopment of previously developed land (brownfield) for economic purpose, ecological upgrading of land for the purpose of soft-use (e.g. green areas in the urban centres) and re-naturalisation of land (bringing it back to nature) by removing existing structures and/or desealing surfaces.

Land take: The amount of agriculture, forest and (semi-)natural land taken by urban and other artificial land development (EEA).

Land use: Purpose which land is committed to, including the production of goods (such as crops, timber and manufactures) and services (such as defence, recreation, biodiversity and natural resources protection) (Environmental Protection Agency, 2012).

Leakage: The indirect impact that a targeted land use activity (e.g. as a result of land related policies) in a certain place and time has on land use at another place and time (IPCC 2000).

Organic soil: Soil that contains a high amount of organic matter (European Commission, 2008).

Peatland: Wetlands with a layer of high organic matter content, made up with undecayed and partially decomposed material (Wetlands International, 2014).

Soil: upper layer of the earth's crust, resulting from the alteration of rock and enriched with organic matter, that can support plant life

Soil organic carbon (SOC) content: Amount of carbon stored in one kg of soil (% or gC/kg soil) (Gobin, 2011) (European Commission, 2008).

Soil organic carbon (SOC) stock: Total amount of carbon stored contained by soil, often in the 0-30 upper cm (t C/ha) (Gobin, 2011).

Soil organic matter (SOM): Organic fraction of soil, composed by entirely or partially decomposed matter (Gobin, 2011) (European Commission, 2008).

Soil structure: Arrangement of solid parts of soil and pore space located between them (Marshall, et al., 1979).

Soil texture: Physical texture of soil related to the relative proportion of three texture classes: clay (<0.02 mm), silt (<0.075 mm) and sand (<2 mm) (Soil Survey Division Staff, 1993).

Sustainable consumption: The use of goods and services to satisfy basic needs and bring a better quality of life without compromising the ability of others, both current and future generations, to meet their own needs. Such a concept of consumption requires the optimisation of consumption subject to maintaining services and quality of resources and the environment over time (Samil E., 1994).

Sustainable production: Providing goods and services to meet basic needs of the world population without compromising the already burdened environment and ecosystems, i.e. producing goods and services more efficiently, and with the best available techniques, with the aim to use fewer resources and to generate less environmental impacts (VITO et al. 2013).

Tele-connections: Process based interconnections of spatially distant processes, drivers, markets, flows of energy and materials between land systems. In this chapter, tele-connections relate to the land flows embodied in primary biomass products that connect consumer markets with producing countries (Fragkias et al. 2012)

Third countries: Countries outside the EU, where land areas are appropriated by products being imported by the EU.

Underutilised lots: Parcels of land which are already built up, but which offer space for further development. Some examples are second row development, courtyard development as well as complementary buildings in residential, mixed-use and commercial areas (definition based on BBSR, 2011, provided through the call for evidence for this study).

Urban areas: Geographic area with a high density of people over a limited area. Homes and other types of buildings tend to be close together (EEA). Areas within the legal boundaries of cities and towns; suburban areas developed for residential, industrial or recreational purposes (EIONET).

Wetland: Natural or artificial land area saturated with water, either permanently or seasonally, that is characterised by a specific ecosystem. Water can be static, flowing, fresh, brackish or salt, with depth at low tide that does not exceed six metres (Wetlands international, 2014).

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Abstract

This study assesses the feasibility of setting up a suitable framework for measuring progress towards a more sustainable use of land as a resource. The objectives and targets proposed by the Roadmap for a Resource Efficient Europe (related to land take, land recycling and land degradation) are used as a starting point. Possible indicators and targets to promote the multi-functionality of land and preserve its environmental functions, as well as to reduce the impacts of EU demand on global land degradation, are also analysed. Where appropriate indicators are available and the associated baseline is well defined, the relevance and feasibility of setting targets is assessed, covering technical, socio-economic and administrative aspects. This is informed, in particular, by the experience from the few MS having defined land and soil-related targets. The study proposes several possible future targets that could be set at the EU level, subject to a number of improvements with regard to indicators definitions, monitoring processes (methodologies, resources and timeliness), methodological approaches (e.g. with regard to relatively new indicators such as the Weighted Urban Proliferation or the Land Footprint), and the overall knowledge base. Alternative approaches to target setting (e.g. policy guidance) are also identified.

Cette étude examine la faisabilité de développer un cadre opérationnel à l'échelle européenne pour mesurer les progrès vers une utilisation plus durable des terres. Elle utilise comme point de départ les orientations et objectifs quantifiés proposés par la feuille de route européenne pour une utilisation efficace des ressources en lien avec l'artificialisation des terres, leur recyclage et leur dégradation. Elle explore également les indicateurs et objectifs existants qui encouragent un usage multi-fonctionnel des terres et la préservation de leurs fonctions, et qui visent à atténuer la dégradation des sols induite par la consommation de l'UE à l'échelle mondiale. Lorsque des indicateurs appropriés sont disponibles et que leur valeur actuelle est bien caractérisée, l'étude examine la pertinence et la faisabilité technique, socio-économique et administrative de fixer des objectifs quantitatifs. Cette réflexion se nourrit du retour d'expérience d'Etats-Membres ayant déjà fixé des objectifs en lien avec l'utilisation des terres ou la qualité des sols. L'étude recommande plusieurs types d'objectifs potentiellement applicables à l'échelle européenne, tout en soulignant les améliorations nécessaires en termes de clarification des définitions utilisées, de développement d'indicateurs et de processus de mesure/suivi harmonisés (méthodologies, ressources, fréquences), d'approches méthodologiques et plus généralement d'amélioration du socle de connaissances. Des propositions alternatives à la définition d'objectifs sont également identifiées.

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Executive Summary

The issue of land is getting increasing attention in the policy agenda both globally and at the EU level.

The European Commission's Soil Thematic Strategy adopted in 2006 placed soil and land degradation on the policy agenda and helped raise the profile of these issues. However, the report on the implementation of the Soil Thematic Strategy in 2012 confirmed that soil degradation has increased in the past decade both in the EU and worldwide. At the United Nations Conference on Sustainable Development held in 2012 (**Rio+20**), world leaders identified land and soil degradation as a global problem and committed to *"strive to achieve a land degradation neutral world in the context of sustainable development"*.[1] At EU level, the European Commission's **Roadmap to a Resource Efficient Europe**[2] (COM(2011) 571 final) (hereafter, the Roadmap) proposed the following milestone for land and soil: "*By 2020, EU policies take into account their direct and indirect impact on land use in the EU and globally, and the rate of land take is on track with an aim to achieve no net land take by 2050; soil erosion is reduced and the soil organic matter increased, with remedial work on contaminated sites well underway*". This was accompanied by a proposal for a set of targets[3]:

- No net land take by 2050;
- By 2020, the area of land in the EU that is subject to soil erosion of more than 10 tonnes per hectare per year should be reduced by at least 25%; and
- By 2020, soil organic matter levels should not be decreasing overall and should increase for soils with currently less than 3.5% organic matter.

The **7th Environment Action Programme** acknowledged the Rio+20 commitment and supported the development of targets for sustainable land use and soil.

Beyond the policies indirectly tackling land take through the safeguarding of natural resources, land is increasingly recognised as a **non-renewable limited natural resource** that needs to be used efficiently to be able to ensure that it can provide all its functions in the future. In this context, the Commission will issue a Communication on land as a resource in 2015 (hereafter, the **Land Communication**). The Land Communication needs to propose a vision of where the EU should go in terms of land and soil management by 2020 and beyond, and for that purpose, a robust set of indicators is required. Moreover, the implementation of targets based on some of these indicators could be included in the options considered in the Impact Assessment supporting the Land Communication.

[1] "The future we want", paragraph 206 (http://sustainabledevelopment.un.org/futurewewant.html)

[2] http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm

[3] Analysis associated with the Roadmap to a Resource Efficient Europe – Part II, SEC(2011) 1067 final

This study assesses the feasibility of setting up a suitable framework for measuring and tracking the status and progress towards a more sustainable use of land as a resource.

Indicators, targets, monitoring processes and knowledge base improvement actions are discussed. More specifically, the study assessed the **feasibility** of achieving **the objectives and targets** proposed by the **Roadmap** (i.e. no net land take by 2050, remediating soil contamination, reducing soil erosion, and increasing soil organic matter), considering the fact that these objectives and targets had not been subjected to a comprehensive feasibility assessment before their inclusion in the Roadmap. From a broader perspective, the study also identified and assessed possible indicators and targets to promote the **multi-functionality** of land and preserve its environmental functions, and to reduce the impacts of **EU demand on global land degradation**. Consequently, the study covers the following main aspects:

1) **Land take**, in particular the impact of urbanisation on the loss of fertile soils that are essential for agriculture production;
2) **Land recycling**, in particular the redevelopment of brownfields;
3) **Land degradation**, in particular soil erosion and loss of soil organic matter;
4) **Land use functions** and the **multi-functionality** concept;
5) **Global impacts** of EU demand for land-based products.

The outputs of the study are intended to inform the Impact Assessment accompanying the Land Communication.

This report is structured following the five main topics mentioned above.

The general approach adopted is as follows:

1) **Critical review** of existing **data, indicators** and **methodologies** to measure progress in each of the five areas;
2) Review of past and current **trends** for the different indicators;
3) Identification and analysis of **existing targets** and **supporting policy measures** at the **Member State** level (and/or sub-national level, if relevant) and in selected non-EU countries;
4) Identification of **possible EU targets and indicators** (in addition to those already proposed by the Roadmap);
5) Assessment of the **feasibility**, benefits and possible drawbacks of implementing the preliminary list of possible targets and proposal for a shortlist of targets; and
6) Development of **conclusions and recommendations** on the way forward at the EU level and on possible needs for further data, methodologies and monitoring processes, based on the outcomes of the feasibility assessment and considering the **links** between the different proposed targets.

The analysis presented in this report draws upon an extensive literature review, exchanges with key experts in relevant EU organisations (e.g. EEA, JRC) and information collected through the consultation of experts in the MS (via a call for evidence).

Existing and other potentially relevant indicators are assessed using the RACER framework.

For each of the five topics, the overall quality of indicators is assessed using the so-called 'RACER' framework. RACER stands for 'Relevant, Acceptable, Credible, Easy and Robust'. The overall results of this assessment are presented in the table below (Table 1).

Table 1: RACER assessment results for the key indicators analysed

Selection of key indicators analysed	R	A	C	E	R
Development of artificial areas					
Gross land take (% of total area)	Yellow	Green	Green	Green	Yellow
Net land take (% of total area)	Yellow	Yellow	Yellow	Green	Yellow
Utilization density (artificial areas in ha per capita and per job)	Yellow	Green	Green	Yellow	Yellow
Soil sealing (% of artificial area)	Yellow	Green	Yellow	Green	Yellow
Land recycling					
Area of brownfield land (m^2 or other unit of area)	Yellow	Yellow	Yellow	Red	Red
Total area of land within existing urban fabric which is available for inner development (m^2 or other unit of area)	Green	Yellow	Red	Red	Red
Brownfield land redeveloped (m^2 or other unit of area / time unit) or (%)	Yellow	Yellow	Red	Red	Red
Development on brownfield land as a share of total new development (%)	Yellow	Yellow	Red	Red	Red
Land recycling as a share of total land consumption by artificial development (%)	Yellow	Yellow	Green	Yellow	Red
Land recycling as a share of total land consumption by artificial development in Large Urban Zones covered by the Urban Atlas (%)	Yellow	Red	Green	Yellow	Red
Land degradation					
Annual erosion rate by water (t/ha/yr)	Green	Green	Green	Yellow	Green
Annual erosion rate by wind (t/ha/yr)	Green	Yellow	Green	Red	Yellow
Annual erosion rate by tillage (t/ha/yr)	Green	Red	Yellow	Red	Red
Area of land subject to water erosion rate > 10 tonnes/ha/yr (ha)	Yellow	Yellow	Green	Yellow	Green
Soil organic matter content (% or kg SOM/kg soil) or Soil organic carbon content (% or kg SOC/kg soil)	Green	Green	Green	Yellow	Green
Area of soils with organic matter level <3.5%	Green	Yellow	Green	Yellow	Green
Soil organic carbon stock (tonnes/ha))	Green	Green	Green	Yellow	Yellow
Peatland SOC stocks (MtC)	Yellow	Yellow	Green	Yellow	Yellow
Land functions / Multifunctionality[4]					
Area of accessible green space (ha)	Green	Red	Yellow	Green	Green
Potential agricultural and forestry production (m^3/km^2 or t/km^2)	Green	Green	Yellow	Green	Green
Density and connectivity of green infrastructure	Yellow	Green	Green	Green	Yellow
Multifunctionality balance (consistent set of levels for each sustainability dimension / land function; alternatively: level of trade-offs between functions)	Green	Red	Yellow	Green	Yellow
Global impacts					
Land footprint	Green	Yellow	Yellow	Yellow	Yellow
Bio-productivity footprint (embodied Net Primary Production harvest)	Green	Yellow	Yellow	Yellow	Yellow
Normalised land footprint	Green	Yellow	Yellow	Yellow	Yellow

Legend

- Green: Criterion completely fulfilled
- Yellow: Criterion partly fulfilled
- Red: Criterion not fulfilled

[4] For land functions/Multifunctionality: this is a selection of the most promising indicators identified, among the large number of indicators that have been assessed in the present study.

Where appropriate indicators have been identified and the associated baseline is well defined, the relevance and feasibility of setting targets has been assessed in the present study, covering technical, socio-economic and administrative aspects.

With regard to the **land take** issue, several MS have formulated their own targets related to the development of artificial surfaces, at national, regional and/or local levels. These mostly include land take targets, percentages of inner-city developments and soil sealing. Most do not rely on extensive and robust scientific assessment, although ministries or agencies in charge recognise the need for better knowledge about future needs for land development potential. At national level, target setting is mostly used to deliver strong political messages, highlighting the commitment and the strategy of the countries to mitigate issues related to the development of artificial areas. In the future, the EU could provide a strategic vision for MS, for instance through a "no net land take impacts" (i.e. no net environmental impacts) target, as well as guidance and experience sharing. MS could tackle the issue by setting their own targets at national level and apply the principle of subsidiarity down to the most relevant level of governance for setting mandatory targets and include the issue of land take in their planning instruments or develop other relevant policy instruments (e.g. land development taxes). Experience shows that feasibility studies, discussion and coordination of indicative land take targets between different levels of governance can be a good approach to tackling issues related to the development of artificial areas and how to trigger the implementation of relevant policy instruments. This was the approach to land take targets in Germany and Luxembourg, where national targets were negotiated and transformed to regional and/or local targets. This could also be the approach for translating an EU "target" to national level based on feasibility studies as conducted by the JRC. It was observed that the "net land take" concept as defined in the Roadmap could lead to different interpretations. Despite its intent to describe the expansion of artificial areas and to take into account the fact that re-naturalisation can relieve pressures on the environment, the net land take indicator by itself may not deliver information on the actual impacts of the development of artificial areas and on the intensity of land use as an indicator of land use efficiency. Rebound effects may also result from the multiple interpretations of the net land take concept (e.g. through restoration and compensation), which do not limit artificial development on areas with key soil functions, because the associated degradation can be compensated elsewhere. It is therefore suggested to complement the net land take indicator in order to aim to "no net loss of ecosystem services due to land take by 2050", which is in line with the no net loss concept promoted at the EU level for biodiversity and ecosystems.

With regard to **land recycling**, very few targets have been identified in the MS. Examples include: the Austrian target on contaminated site management; the former UK (England) target on brownfield recycling (abolished in 2011 because it was thought to drive land prices up and was not flexible enough in responding to local circumstances); or the general objective adopted by Germany on increasing inner-city development compared to development on new sites (i.e. land take). None of the indicators on land recycling scores well against the RACER criteria, hence no targets associated with these indicators can be implemented at present. The main issue is the lack of a common understanding of the land recycling concept and associated terminology (brownfield, inner-city development potential, etc.) across MS or at EU level. This is reflected in the low quality of data available on the area of land available for recycling, as well as on the share of land currently recycled.

With regard to **land degradation**, few MS have formulated dedicated targets, and when they did so, these targets mostly remain indicative. At the EU level, the targets for soil erosion and organic matter proposed in the Roadmap for a Resource Efficient Europe are based on valid indicators (see the RACER assessment) and relevant levels of ambition. The latter could, however, be strengthened in order to promote efforts in larger areas and better encourage the conservation of soils with high soil carbon content. These indicators of soil quality could be complemented by targets focused on practical actions in order to follow and assess their contribution to the prevention or mitigation of soil degradation.

Various targets exist at Member State level covering key **land functions** such as provision of leisure and recreation, provision of land-based products, provision of biotic and abiotic resources; however, no national targets on land multifunctionality have yet been developed. None of the indicators on land functions scores well against the RACER criteria, hence no targets associated with these indicators can be implemented at present. The detailed review of existing indicators showed that the demand-supply relations within each land use function are not sufficiently reflected by the indicators. The development of novel indicators accounting for these demand/supply relations could be a set of context specific minimum land use function provision levels and maximum acceptable trade-offs, and associated indicators, for each sustainability dimension. This would allow uniform target setting that accounts for the geographical context by including the demand side of land functions.

Setting targets in relation to **global impacts of EU demand for land-based products** is challenging due to the lack of a clear concept that relates land use to local or global thresholds or a safe operating space for stakeholders. In the present study, we elaborated on the concept of safe operating practices and disaggregated this concept into three different dimensions: responsible global supply chains; adequate protection of natural areas and ecosystem functioning; and, sustainable consumption patterns and land appropriation. Overall, it can be concluded that the use of targets in relation to the EU's role in global sustainable land use should cover these three dimensions. Although a single target in a single area will help reduce the EU's global impacts, the three different dimensions suggest the use of multiple targets to contribute to global sustainable land use.

The analysis demonstrates that the five main topics of the study are closely interrelated.

Addressing each of these topics separately would only impede overall efforts towards a more sustainable and efficient use of land as a multifunctional and finite resource. The identification of key indicators for each topic as well as their relationships allows not only maximising existing synergies, but also minimising possible antagonisms. It has been shown for instance that the environmental benefits from land recycling to reduce land take at the fringe of cities may eventually be balanced by increased levels of soil sealing within cities, along with the loss of key ecosystem services. The densification of inner cities may also trigger, as an unwanted rebound effect, the migration of city dwellers to the suburbs because of the degradation of the quality of life within the city. Similarly, the extensification of farming practices to prevent from further soil degradation is usually associated with lower yields in the short term, involving the intensification of practices and the degradation of soils elsewhere, and/or the further consumption of land embodied within commodities imports, therefore further contributing the global impacts of EU consumption.

In particular, the following links are important to note:

- The impacts related to the development of artificial areas can be prevented or mitigated through different strategies such as **intensification** strategies (e.g. densification of urban matrix), **land recycling** strategies (e.g. redevelopment of abandoned industrial sites into new residential or industrial areas) or **compensation** strategies (e.g. re-naturalisation). A 'no net land take' target, if implemented alone, is unlikely to fully address soil sealing issues, land degradation issues as well as the loss of land functions and ecosystem services. Hence, **land take targets must be complemented by the monitoring of other indicators** – and possibly the future development of targets – related to land recycling and land functions, including the provision of various ecosystem services.
- Targets to **reduce erosion** and **loss of organic matter**, which aim to reduce land degradation, are closely linked with the objective to **preserve ecosystem services associated with other key functions of the land**. Reduced land degradation is also likely to

ensure that EU soils remain productive and do not contribute to putting additional demand on land (and their related impacts) in third countries.

Several areas for further EU action are identified in order to set up a suitable framework for measuring and tracking the status and progress towards a more sustainable use of land.

The EU and MS increasingly recognise the importance of land as a multifunctional resource; however, this increasing awareness has not yet led to many examples of concrete actions towards sustainable land management in the EU. Approaches to land planning and management tend to remain sectoral and short-term and/or individual interests often guide long-term decisions. One of the reasons is the insufficient knowledge, tools or technical capacity for land managers and policy-makers to set appropriate targets and take informed decisions for a more sustainable and integrated use of land (taking into account multiple synergies and trade-offs between land use functions).

Recent efforts in monitoring, indicator definition and target setting in the EU and in the MS have gone to the right direction. However, further action is urgently needed in order to halt land degradation and promote an efficient use of land in a coordinated and cost-effective manner for the 28 MS.

In the short-term, key actions that could be taken include:

- **Clarify and harmonise terminologies** (e.g. definition of artificial areas, cropland, grassland, forest, recycling vs. densification);
- **Improve monitoring of existing indicators** (methodology, monitoring capacity) and production of **timely and harmonised datasets** (e.g. increase frequency and reduce time lag between data acquisition and production of processed datasets), in the context of the INSPIRE Directive's implementation; and
- Further promote the **exchange of best practices**, both between regions/MS and between different categories of stakeholders (e.g. researchers, policy-makers, land managers) and the publication of EU guidelines, such as the Soil Sealing Guidelines published by the European Commission.

In the longer-term, further research and development will be needed in order to support integrated land management, including the following actions:

- **Test, apply and peer-review the use of new indicators** based on current databases and monitoring efforts at the EU and national levels (e.g. Weighted Urban Proliferation, LUF-specific indicators accounting for demand/supply interactions);
- Pursue **modelling exercises integrating the different functions of land**, in order to better identify the respective contribution of different drivers and the most promising opportunities in terms of development pathways; and
- Continue research work on the **development of indicators derived from global land flow accounts** (Land footprint, Embodied $NPP_{harvest}$ and Normalized land footprint).

1. Introduction

This introductory chapter describes the overall context of the study, in particular the EU and international policy context around land and soil targets and the forthcoming Land Communication. It also presents the study's objectives, overall approach and key methodological steps.

1.1 Context of the study

Land can be defined in many different ways. For example, the 1994 United Nations Convention to Combat Desertification (UNCCD) defines land as "*the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system' (definition used by the United Nations Convention to Combat Desertification"*. Land can also be defined with regard to its **functions**, i.e. as a multifunctional system that provides vital environmental (or ecosystem) services (water purification and storage, biodiversity hosting, carbon storage, etc.) as well as cultural/societal services (landscape, nature, tourism, etc.), and that supports the majority of human activities and production processes on Earth (agriculture, forestry, industries, transport, housing, tourism, etc.). Furthermore, land is increasingly recognised itself as a non-renewable limited natural **resource**, in particular in the context of improving resource efficiency.

Soil, which is a major component of land, is defined as follows by the EU Thematic Strategy for Soil Protection (European Commission, 2006a): *"The top layer of the earth's crust, formed by mineral particles, organic matter, water, air and living organisms. It is the interface between earth, air and water and hosts most of the biosphere"*.

Although land is a key resource, it is subject to an increasing number of threats and challenges:

- Land take consumes fertile soils that are essential for agriculture production; in Europe, this phenomenon is mostly driven by urbanisation.
- Land degradation is a worrying phenomenon in the EU; soil erosion by water, loss of soil organic matter content and soil contamination are considered the main issues to be tackled.
- Land use planning often lacks strategic thinking.
- EU demand for land is increasing and putting at risk valuable ecosystems in the EU and abroad.

The issue of land is getting increasing attention in the policy agenda both globally and at EU level. For instance, at the UN Conference on Sustainable Development held in June 2012 in Rio de Janeiro (**Rio+20**), the world leaders indicated land and soil degradation as a global problem and committed to *"strive to achieve a land degradation neutral world in the context of sustainable development"*.[5] At EU level, the European Commission's **Roadmap to a Resource Efficient Europe**[6] (hereafter, the Roadmap) sets up the following milestones on land and soil: *"By 2020, EU policies take into account their direct and indirect impact on land use in the EU and globally, and the rate of land take is on track with an aim to achieve no net land take by 2050; soil erosion is reduced and the soil organic matter*

[5] 'The future we want', paragraph 206 (http://sustainabledevelopment.un.org/futurewewant.html)

[6] COM (2011) 571 final; http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm

increased, with remedial work on contaminated sites well underway". This was accompanied by a set of proposed targets[7]:

- No net land take by 2050;
- By 2020, the area of land in the EU that is subject to **soil erosion** of more than 10 tonnes per hectare per year should be reduced by at least 25%; and
- By 2020, soil **organic matter (SOM)** levels should not be decreasing overall and should increase for soils with currently less than 3.5% organic matter.

Moreover, land concerns voiced in Rio+20 processes and in the Roadmap have been integrated in the **7th Environment Action Programme of the EU** (hereafter, the 7EAP)[8]. The 7EAP recognises that "*increasing efforts*" are required "*to reduce soil erosion and increase soil organic matter, to remediate contaminated sites and to enhance the integration of land use aspects into coordinated decision-making involving all relevant levels of government, supported by the adoption of targets on soil and on land as a resource, and land planning objectives*".

In this context, the European Commission (hereafter, the EC) has indicated that it would present a Communication on land as a resource (hereafter, the **Land Communication**) in 2015. An important objective of the Communication will be to raise awareness about the intrinsic value of land as provider of crucial ecosystem services. Land should be considered a limited resource both worldwide and in the EU, particularly in the context of global challenges (climate change, increase in population and in food demand, etc.). Moreover, the Communication will aim to highlight the need for the EU to have a coherent and sustainable approach to land management.

Subject to an impact assessment, the Land Communication may propose targets to deal with some land and soil pressures and to propose a vision of where the EU should stand in terms of land and soil management by 2020 and beyond.

1.2 Objectives of the study

The main objective of this study is to assess the **feasibility** of setting up a suitable framework (**indicators, objectives, targets**) for measuring and tracking the status and progress towards a more sustainable use of land as a resource. More specifically, the study assesses the **feasibility** of achieving **the objectives and targets** proposed by the **Roadmap** (i.e. no net land take by 2050, remediating soil contamination, reducing soil erosion and increasing soil organic matter), considering the fact that these objectives and targets had not been subjected to a comprehensive feasibility assessment before their inclusion in the Roadmap. From a broader perspective, the study also identifies and assesses possible indicators and targets to promote the **multi-functionality** of land and preserve its environmental functions, and to reduce the impacts of **EU demand on global land degradation**.

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[7] Analysis associated with the Roadmap to a Resource Efficient Europe – Part II, SEC(2011) 1067 final

[8] http://ec.europa.eu/environment/newprg/index.htm

The study therefore covers the following main aspects:

- Land take;
- Land recycling;
- Land degradation, in particular through soil erosion and loss of organic matter;
- Land multi-functionality, covering the following functions: provision work; provision of leisure and recreation; provision of land based products; provision of housing and infrastructure; provision of abiotic resources; regulation by natural physical structures and processes; and, provision of biotic resources; and
- Global impacts of EU land demand.

The outputs of the study are intended to inform the Impact Assessment accompanying the Land Communication.

1.3 Approach

1.3.1 Overall approach

The study is structured in five main topics mentioned above. The general methodology adopted is as follows:

- **Critical review of existing data, indicators and methodologies** to measure progress in each of the five areas; for the land take and land recycling topics; this also included a review of possible issues raised by definitions, terminologies and possible classifications used;
- Review of past and current **trends** for the different indicators;
- Identification and analysis of **existing targets** and **supporting policy measures** at the level of **MS** (hereafter, the MS), and/or sub-national level, if relevant, and in selected non-EU countries;
- Identification of **possible EU targets and indicators** (in addition to those already proposed by the Roadmap);
- Assessment of the **feasibility**, benefits and possible drawbacks of implementing the preliminary list of possible targets; and
- Development of **conclusions and recommendations** on the way forward at the EU level and on possible needs for further data, methodologies and monitoring processes, based on the outcomes of the feasibility assessment and considering the links between the different proposed indicators and targets.

Steps 1), 2), 3) and 5) involved: a thorough review of scientific literature, grey literature, modelling results and databases; exchanges with the European Environment Agency (hereafter, the EEA) and the Joint Research Centre (hereafter, the JRC); and consultation of Member State (MS) experts via a MS consultation carried out in February-March 2014. The call for evidence consisted in a list of questions sent to experts in the 28 EU MS and a request for updating a compilation of available information on land take and land recycling. It allowed obtaining further information on the practices and policy context in the MS (indicators monitored, objectives, targets and supporting policy measures) and better understanding the impacts of national policy instruments that have been implemented to date.

As a result:

- Nineteen MS provided written (complete or partial) answers to the questionnaire: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Estonia, Finland, France, Germany, Greece, Italy, Latvia, Lithuania, Malta, Netherlands, Poland, Romania, Sweden, UK;
- In addition, experts from Austria, France, Germany, Luxembourg and Netherlands were interviewed, *de visu* or on the phone.

Annex 1 provides the details of organisations which responded to the consultation. In addition, exchanges with the EEA and the JRC took place several times during the project, in order to share information, ensure consistency between the work performed by the different organisations and avoid any overlaps between ongoing projects. Overall, a significant part of the work has focused on the critical review of indicators and on the collection and analysis of indicators and targets in the MS. The quality of indicators was assessed using the RACER framework, as shown Table 2.

Table 2: RACER framework for the assessment of indicators

Criteria	Key questions	Low	Medium	High
Relevant	Is the indicator highly relevant to the Flagship Initiative and the Roadmap to a Resource Efficient Europe? (i.e. to what extent can the indicator serve as a proxy for measuring specific environmental impacts?) How sensitive is the indicator to policy changes under consideration?	The indicator does not reflect the environmental issues at stake	The indicator reflects to a certain extent the environmental issues at stake	The indicator fully reflects the environmental issues at stake and the results of policy action
Accepted	Has the indicator been applied in EU MS or elsewhere? Is the indicator accepted by EU and/or national policy makers? Is the indicator accepted by statisticians and part of official EU / national statistics? Is the indicator accepted by researchers and academic institutions?	The indicator has never been implemented or is subject to great controversy	The indicator is implemented in some MS and/or is generally accepted by stakeholders as a relevant proxy despite its shortcomings	The indicator is routinely implemented and data available in EU-28 and is not subject to controversy
Credible for non-experts, unambiguous and easy to interpret	Can the indicator be used to convey a clear message with easy and unambiguous interpretation?	The indicator is difficult to understand and the methodology to calculate it is unclear	The indicator is easy to understand but reflects a situation that could be explained by different factors	The indicator can be used to convey clear messages about the processes at stake and policy implications
Easy to monitor	Is necessary data to calculate the indicator available, at the relevant scale(s) and at a reasonable cost? Is the indicator routinely monitored, at the relevant scale(s) and at a reasonable cost?	There is limited availability of underlying data	Data is available but not in a harmonised way across MS	The indicator is routinely monitored in the EU-28 or the necessary data to calculate the indicator is available at the EU-28 level
Robust	Is there only one methodology applied by all users to monitor this indicator or are there several (competing) methodologies making it difficult to reproduce results? Are clear specifications of the underlying methodology available? (e.g. protocols, standards, technical descriptions; including sources and relevant links)	There is no identified methodology applied by all users. The calculation of the indicator lacks transparency.	A limited number of identified methodologies for calculation exist across MS. Changes of approaches over time (e.g. level of disaggregation, spatial scale) remain transparent and limited	The indicator is calculated in a harmonised way across MS and over time

Concrete proposals for EU targets have been made where good quality indicators could be identified and where the baseline associated with these indicators could be defined with a sufficient level of accuracy. Where no targets could be proposed, suggestions were provided with regard to further work requirements on methodologies, indicators and monitoring processes and with regard to possible alternative policy measures.

The feasibility assessment of potential targets covered **technical** aspects (e.g. assessment of suitable geographical scale, expected environmental effectiveness, technical constraints, realistic path to achieve the target, data availability and quality, monitoring requirements), **socio-economic** aspects (cost-effectiveness, social and societal implications) and **administrative** aspects (e.g. coherence with other policy measures and objectives, legal status of the target, possible suitable policy instruments to implement the target, subsidiarity and proportionality issues, stakeholder acceptance, administrative costs and other administrative issues).

In this report, the terms “indicators”, “objectives” and “targets” are used very frequently. It is therefore important to provide some clarifications on the meaning that has been retained for each of these terms in the present report:

- **Objective**: An overall goal that the EU sets itself to achieve[9] (e.g.: reducing soil sealing, promoting land multi-functionality, increasing land efficiency).
- **Target**: A detailed performance requirement, which is derived from environmental objectives and is used to achieve these objectives[10]. It is usually quantified (e.g.: no net land take by 2050).
- **Indicator**: A parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value[11] (e.g.: sealed land area, number of brownfields, soil organic content).

[9] Definition adapted from the EMAS Regulation ((EC) No 1221/2009)
[10] Definition adapted from the ISO 14001 standard
[11] Definition from the OECD reference paper on environmental indicators (OECD, 2003)

1.3.2 Specific methodological aspects

Methodological specificities related to each of the five topics are described below.

Land take and land degradation

The analysis of land take trends is mostly based on the latest information provided by the EEA[12] and Eurostat[13], and on the Prokop et al. (2011) soil sealing study (for past and current trends), as well as on the recent prospective work from the JRC published as a follow-up to the Roadmap for a Resource Efficient Europe (JRC, 2013a).

The review of existing targets and supporting policy instruments to monitor and control land take is mostly based on the Prokop et al. (2011) soil sealing study, on the Panorama of European Land Monitoring developed by Blanes and Green (2012) as part of the FP7 HELM (Harmonised European Land Monitoring) project and on information provided by the MS as part of the MS consultation.

Land recycling

The literature research focused on identification of the following information:

- Number and area of existing brownfield sites in EU MS;
- Definitions used and approaches to land recycling across MS;
- Instruments used to support brownfield redevelopment ; and
- Identification of relevant indicators for target setting.

The literature research revealed a range of relevant sources; however often these were outdated, referring to information gathered in the early 2000s. The MS consultation was intended to play an important role in validating the quality of information gathered and in filling the gaps, especially in the case of MS sparsely described in the literature to date. However, the responses received from MS – on the land recycling topic – have provided little insights with regard to the area of brownfield land available for redevelopment and regarding instruments deployed. The following steps have been undertaken under this task:

- Definitions, relevant instruments, dynamics and challenges associated with brownfield redevelopment as well as existing indicators have been assessed based on the information available in the literature as well as collected through the MS consultation. The indicators have been evaluated using the RACER framework.
- A "bottom-up" approach has been adopted to estimate potential for land recycling in the EU. Data on the area of brownfield sites at MS level identified in the literature has been used as a starting point (where available). An estimate for the EU28 (i.e. gap filling for those MS where no data is available) has been derived based on a number of factors related to brownfield creation, such as total land area, urban land coverage, relevant land use and total population. Additional examples on the share of brownfield land within several EU cities have been provided.
- Based on the above-mentioned steps, possible indicators for land recycling targets have been proposed.

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[12] www.eea.europa.eu/data-and-maps/indicators/land-take-2/assessment-2

[13] http://epp.eurostat.ec.europa.eu/portal/page/portal/lucas/introduction

- Finally, the feasibility of the potential targets has been assessed according to the common framework adopted in all tasks. This has been complemented with other suggestions of instruments that could be deployed at the EU and national level.

Land degradation

This analysis includes the review of publicly available information and data regarding the past, current and future trends on soil erosion and SOM loss, including the recent work of the JRC on the EIONET data collection. A review of existing indicators, targets and supporting policy instruments to monitor and control erosion and SOM decline at national and regional level is based on a literature review and MS consultation. An assessment of the indicators is performed to select the most relevant and feasible indicators. Based on the latter, targets are then proposed and analysed in order to determine their socio-economic and administrative feasibility. The technical feasibility of the targets refers to the technical feasibility of the indicators. It is therefore treated as part of the indicators assessment.

Land use functions

The work on land functions started with an analysis of the different concepts that are available to quantify, map and monitor land based resources and multifunctionality. The Land Use Functions (LUFs) conceptual framework was considered to be the most suitable framework as part of the study. According to ESPON (2013) these LUFs express "*the goods and services that the use of the land provides to human society that are of economical, ecological and socio-cultural value and likely to be affected by policy changes*". The LUF concept was retained here as it provides a holistic integration of all three sustainability pillars, and accounts for both the supply of functions by the land and the use and demand of these functions by society. Six categories of Land Use Function were defined by ETC-SIA (2013), as follows:

- LUF1: Provision of work;
- LUF2: Provision of leisure and recreation;
- LUF3: Provision of land-based products;
- LUF4: Provision of housing and infrastructure;
- LUF5: Provision of abiotic resources; and
- LUF6: Provision of biotic resources.

LUFs 2-3-5-6 were considered to be of particular relevance to the present study. The work on land use functions focused on the critical review of existing indicators and targets and how to operationalise the concept of multifunctionality. As it appears too early to set any EU targets on land functions and multifunctionality, the work has focused on proposing a framework of relevant indicators and further knowledge improvement actions that could facilitate future target setting.

Global impacts

In a first step, a thorough bibliographic research was carried out to gather the available (primarily quantitative) information and data on the EU land demand in third countries needed for understanding the dynamics of land demand from the EU's consumption of food and non-food products.

Literature on the following topics was reviewed:

- Land footprints and related environmental footprints
    - Economic accounting approaches applying input-output analysis
    - Physical accounting approaches or coefficients approaches
    - Hybrid approaches
- Analogous resource demand/footprint methodologies for CO_2, water, and materials
- Environmental pressures and impacts of land demand
    - Ecosystem impacts
    - Deforestation
    - Biodiversity
    - Greenhouse gas (GHG) emissions related to land use and land use change
    - Human Appropriation of Net Primary Productivity (HANPP)
- Indirect land use change
- Land grabbing
- Past and future food and biomass demand and trade
- Biofuels and biomaterials

In a second stage, existing footprint accounting methodologies presented in the literature were evaluated. The evaluation was based on a set of criteria, which is shown in more detail in the respective section of this report.

An overall framework for deriving land footprint targets from an environmental perspective was then developed. On the one hand, the framework distinguishes between quantitative and qualitative aspects. Quantitative aspects refer to absolute amounts, e.g. hectares of land footprint, while qualitative aspects refer to the properties of land, e.g. soil fertility. On the other hand, the framework differentiates between the various dimensions, which have to be considered when framing land footprint targets. In addition to land area, these dimensions address inputs used for agricultural production, the various products harvested from land, various environmental impacts from land use as well as policy-related aspects of land governance.

1.4 Document structure

In addition to this introductory chapter, the report has five main chapters (Chapters 2 to 6) corresponding to the five main topics covered by the study (i.e. land take, land recycling, land degradation, land functions, and global impacts), and a final chapter (Chapter 7) highlighting the interrelationships between the different indicators and targets and providing recommendations in terms of future EU policy actions. Supplementary information is provided in the annexes.

2. Land take

In brief

At the current pace of economic development in the EU, land take, i.e. development of artificial areas at the expense of agricultural, forest and (semi-)natural areas, is increasingly recognised as an unsustainable trend. Associated with various degrees of soil sealing and fragmentation, it disrupts key ecosystem services and drastically decreases the resilience of ecosystems. The Roadmap to a Resource Efficient Europe proposed to halt net land take by 2050, but the "net land take" concept could be subject to different interpretations. It can be defined "arithmetically" as *"changes of non-artificial areas into artificial areas, which are not* ***compensated by the restoration of the same amount of artificial areas*** *into non-artificial areas"* or in a more "ecological" manner depending on the balance between the land functions lost and restored.

The arithmetic net land take is a key easy-to-understand indicator to describe the expansion of artificial areas. However, it may **not deliver information on its actual impacts nor on its efficiency** measured in terms of employment or density of inhabitants. In particular, this concept is debated for its underlying assumption that functions lost through land take can be fully recovered through re-naturalisation, which is rarely the case in practice. The "ecological" net land take is more relevant from an environmental perspective but is difficult to implement in practice, because of monitoring issues and the fact that it requires from decision-makers to prioritise certain land functions (e.g. ecological vs. productive) over others. In order to provide robust policy messages, the net land take indicator must be complemented by a set of other indicators (e.g. gross land take defined as the growth of artificial areas irrespective of re-naturalisation; soil sealing; urban dispersion), complementing the picture of expected environmental impacts.

Progress in monitoring has been achieved for the arithmetic net land take and for most of the complementary indicators at the EU level, although several MS prefer developing their own monitoring systems, which are often more accurate and robust, for planning purposes and despite additional costs.

Based on the recent and preliminary modelling exercise from Lavalle et al. (2013), achieving the "no net land take target by 2050" of the Roadmap would require a reduction of land take of about 17% by 2020 in the EU. This intermediate target at the EU level seems unlikely to be achieved, since most countries recognised that land take could not be halted without the implementation of stringent policy instruments and several attempts in this respect remained unsuccessful. In order to optimise efforts from MS, the EU target must be allocated to countries following their specificities e.g. in terms of land use, demographics, economic development. Because of the substantial discrepancies in the monitoring of artificial areas between EU datasets and certain national datasets, as well as the high political sensitivities related to the land stewardship, it seems **more relevant for MS to propose their own national targets to the Commission** than for the EU to set national targets. Several MS have already done so, at different levels, with more or less success. The EU could provide a strategic vision for MS based on EU modelling, as well as guidance and experience sharing between MS.

2.1. Introduction

Past trends in the EU have shown an alarming rate of development of artificial surfaces at the expense of agricultural, forestry and semi-natural areas. Although latest trends show that growth in built-up areas has overall slowed down, urban development structurally tends to be more dispersed, fragmented and of low density, in particular in Western Europe and Mediterranean countries. Through soil sealing, habitat degradation and fragmentation, the development of artificial areas may disrupt ecosystem services, such as the provision of resources (biomass, raw materials), climate regulation (heat islands in core cities), flood control (increased run-off due to impervious surfaces), groundwater replenishment (barrier to infiltration) and biodiversity support (barriers to migration; pollution of environmental compartments). The density of population and intensity of use often associated with some artificial areas (in particular touristic areas) further contribute to put pressures on natural resources, such as water and energy, sometimes resulting in resource shortages or scarcity. Beyond environmental impacts, land take has socio-economic consequences, e.g. through the loss of productive land and the withdrawal of economic sectors such as agriculture, the impacts on human health and well-being due to urban environment and landscape degradation, the economic impacts of flood damages due to soil sealing, etc.

To be more sustainable, the management of artificial areas must take into account the needs for:

- Reducing environmental impacts of the development of artificial areas;
- Preserving key ecological, productive and/or recreational functions of land;
- Increasing land use efficiency in a context of a finite resource.

To tackle this issue, the Roadmap to a Resource Efficient Europe[14] proposed to halt the net land take by 2050. This chapter aims to assess, as a starting point, the relevance of the net land take concept to drive a more sustainable management of artificial areas and the feasibility for the EU and MS to monitor and achieve the “no net land take by 2050” target. Possible definitions underlying the “no net land take” concept are discussed, along with their environmental relevance and associated monitoring opportunities and shortcomings. Then alternative/complementary indicators are explored, before further investigating the relevance and feasibility of setting quantitative targets.

2.2. Drivers and trends

Land take is defined as the amount of agriculture, forest and semi-natural land taken by urban and other artificial land development. Several reports already extensively describe land use trends and their drivers (Prokop et al., 2011; EEA, 2006; JRC, 2006; EEA, 2013a). Therefore, only some key messages are highlighted below to be able to assess the need for target setting to regulate land take. Since 2000, in the EU, about 920 km^2 of land was taken every year by artificial development (EEA, 2013a), mainly at the expense of agricultural land, as (semi-)natural areas like pastures and forests increasingly benefited from protection measures. Compared to 1990-2000, artificial development has slowed down as annual land take in the EU decreased by 9%. This EU average does not reveal, however, large differences across MS. Cities in Northern and Western Europe have traditionally developed and planned in spacious ways, with suburbs with (semi)detached houses and gardens. On the other hand, Southern European cities had a long tradition of very compact growth, and so had

[14] COM (2011) 571 final

compact cities found in the former socialist countries in central and Eastern Europe. However, urban sprawl has developed recently at unprecedented rates in Southern European cities and in particular in coastal regions in Europe (EEA and JRC, 2006).

Today, land take is essentially driven by the development of economic and industrial activities, of housing and recreation services, and by the development of transport networks[15] and infrastructure. It is influenced by socio-economic trends as well as market and policy signals. The influence of land prices on land demand, of economic instruments and national and local planning regulations show that land take can be relatively decoupled from socio-economic trends, through better efficiency. Throughout Europe, since the mid-50s EU-27 cities have expanded more rapidly (+78%) than the growth of population (+33%), which can be partly explained by the decreasing size of household and increase of residential land take per capita. Targeting efforts on increasing density could help constrain land take (ECOTEC, 2007). However, the development of economic and industrial activities near cities, together with the decline of traditional rural economies, mostly explains current land take since the share of overall conversions for residential purposes have been decreasing for the last decade (EEA, 2010a). In some European regions, like Eastern countries, this is boosted by business opportunities offered by globalisation and EU enlargement. Despite these average trends, the nature of land take drivers highly varies across MS, which has concrete implications regarding the type of leverages that can effectively regulate land take[16]. Figure 1 summarises the main drivers influencing land take patterns.

Land take can be influenced by three variables: (1) the demand for new infrastructures, (2) the opportunities for recycling and building retrofitting within artificial areas, (3) the density of new developments. These variables are driven by housing preferences and market and policy signals. A same decrease in land take can therefore be attributed to a decrease in demand for new developments, but it can also be the result of densification because of stricter planning regulations.

Soil sealing and urban sprawl (dispersion) are two different sub-trends that accompany land take. They both further increase the pressure of artificial land development put on land and soil resources.

Soil sealing is often considered a trade-off of land take containment, which favours densification of the urban matrix. Depending on urban areas dynamics, the relationship between land take and soil sealing can be very different. Urban areas with fast development tend to result in high land take with relatively “low” soil sealing, whereas fast developing cities tend to have a reduced land take with high soil sealing. Overall, in the EU, urban development in the last decade shows that intermediate cities are the most dynamic ones, with high risk of high soil sealing per capita (ESPON, 2013a).

The growth of peri-urban, discontinuous, areas, which increased four times faster than continuous areas (Piorr et al., 2010) is a major factor of land fragmentation, with high ecological impacts. The extent and pace of land‐cover change is often inversely related to distance to urban centres, which explain why landscape fragmentation is generally the highest at the vicinity of cities.

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[15] Road transport is by far the main consumer of land for transport. In comparison, railways require much lower land take per transport unit (i.e. passenger-km and tonne-km).

[16] For instance, while in countries like Belgium (48%), Greece (43%) and Hungary (32%), urban development remains mainly driven by industrial and commercial activities, in Luxembourg and Ireland, the demand for housing, services and recreation was responsible for 70% of the land take.

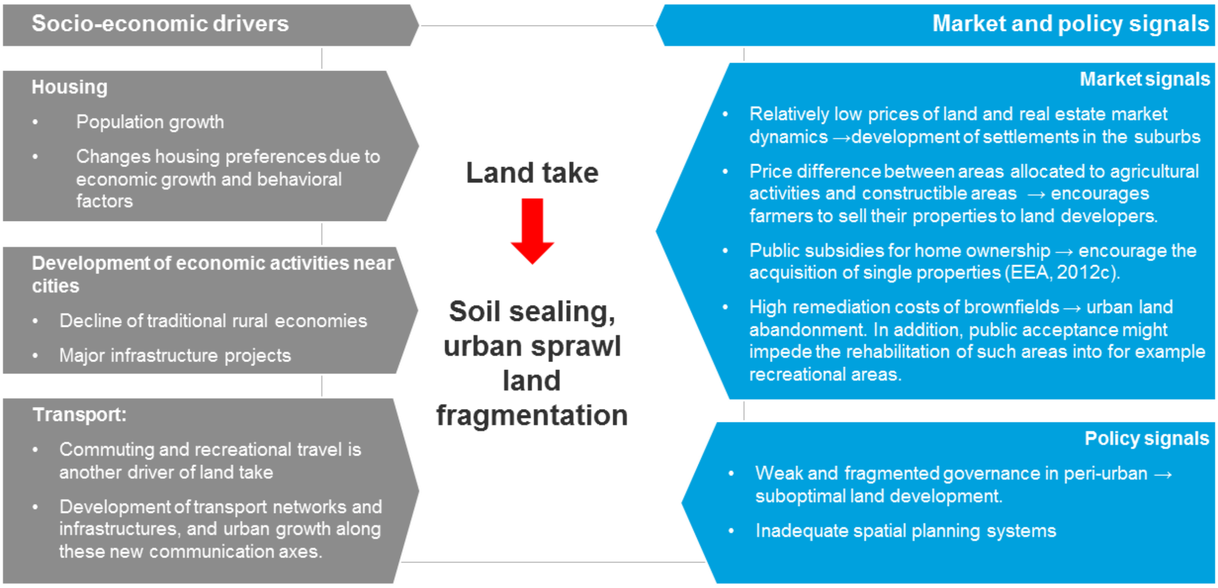

Figure 1: Main drivers influencing land take patterns

2.3. Review of land-take indicators

2.3.1. Introduction

A range of indicators can describe the development of artificial areas. Indicators that are specifically assessed here following the RACER framework are key attributes of this development. They reflect its geographical expansion and pace of development:

- Land take, including “gross” land take and “net” land take (i.e. gross land take minus re-naturalisation);
- Urban dispersion.

Indicators of land take efficiency are addressed here, but will be referred to, as they are closely linked to land-take related issues. They will be discussed in:

- Chapter 3 for land recycling;
- Chapter 5 for utilisation density, through the provision of work (LUF1) and housing and infrastructure (LUF4).

Indicators of impacts exist that can complement these indicators of artificial development by describing its impact on the environment in a simplistic or more complex manner. These indicators will be assessed in chapter 5 as they related to key land functions such as the regulation by natural physical structures and processes (LUF 5b). These include indicators related to:

- Soil sealing (see LUF 5b in Chapter 5), as a proxy for the physical degradation of land;
- Land fragmentation and green infrastructure networks (see LUF 5b in Chapter 5); as proxies for the functional degradation of land.

2.3.2. Assessment of the land take indicators

Discussion on the land take definitions

Land take is defined by the EEA as "the amount of agriculture, forest and (semi-)natural land taken by urban and other artificial land development". Artificial land development is associated to residential, transportation, industrial, commercial and/or recreational land uses. Part of this development results in soil sealing, which consists in the destruction or covering of soils by buildings, constructions and layers of completely or partly impervious material (asphalt, concrete, etc.). Are also included within this definition of artificial areas some bare soils (e.g. areas under construction at an early development stage), gardens, lawns and other urban green areas (e.g. parks, cemeteries) as well as sport facilities and leisure areas such as golf grounds.

For clarity purposes, we suggest distinguishing "gross land take" from "net land take", which is proposed in the Roadmap to set a target limiting the development of artificial areas. Gross net land take describes the amount of land taken from non-artificial areas each year, irrespective of the re-naturalisation of artificial areas. In other words, gross net land take corresponds to the *formation* of artificial land, irrespective of its *consumption*.

The "net land take" concept, for which there is no explicit definition in the Roadmap, can be defined arithmetically as: *"changes of non-artificial areas into artificial areas minus re-naturalisation"*. It deduces from gross land take the re-naturalisation of artificial areas (but not the greening of urban areas) as illustrated in Figure 2. It is the indicator routinely calculated and referred to as "land take" in the EU. This concept is partly in line with the more general "no net loss" concept developed in the EU Biodiversity Strategy to 2020 which seeks to "ensure there is no net loss of ecosystems and their services (e.g. through compensation or offsetting schemes)" (Action 7b under Target 2).

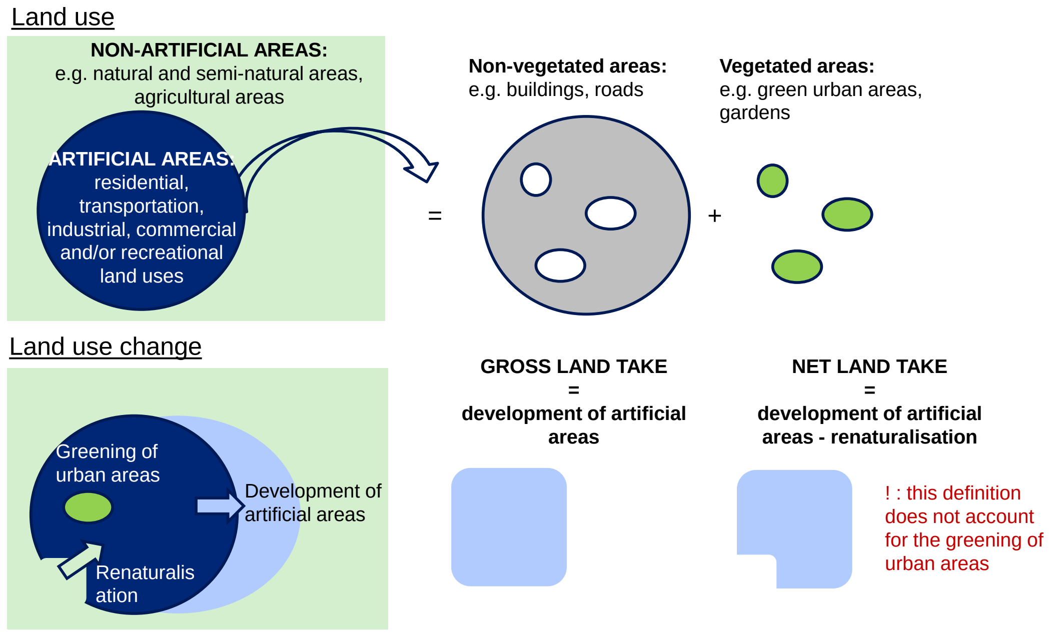

Figure 2: Schematic illustration of artificial areas and land take

Relevance

Net land take informs on the expansion of artificial activities other than agriculture and forestry (gross land take) from which re-naturalisation at the fringe of artificial areas is deduced. Conversely, it can describe the shrinkage of the overall space occupied by (semi)-natural, agricultural and forest areas. It provides interesting information about:

- the **geographical extent** of (semi-)natural, agricultural and forest areas impacted by artificial land development, while taking into account that re-naturalisation may allow releasing pressures associated to artificial areas and restore in theory ecological, productive and/or recreational functions of land;
- the **pace** at which these areas are impacted;
- the main **sectoral drivers** behind land take trends, when disaggregated by type of development (e.g. urban, industrial, transport).

In its most aggregated form, **net land takes hides re-naturalisation efforts** within artificial areas (greening), and therefore the benefits of vegetated vs. built areas (so does gross land take), as these restored areas would still be considered artificial. This can have **both positive and negative implications** on the relevance of the net land take indicator:

- On the one hand, this approach allows not considering restoration within cities boundaries as a compensation of gross land take. The reason is that it could have direct effects on further urban sprawl by displacing the demand for infrastructure at the fringe of cities.
- On the other hand, it hides compensation efforts occurring within cities (a same amount of net - and gross - land take can be attributed to the development of buildings and roads or to the development of green urban areas), whereas this type of restoration contributes to providing key ecosystem services for the urban environment and to improving the overall quality of life in cities. Although it can be said to favour urban sprawl in a context of high real-estate pressure, high levels of soil sealing within cities may in turn decrease the overall attractiveness of city centres, which may encourage, as a rebound effect, further land take through the migration of the population to the suburbs.

Therefore, **it would not be relevant to revise the definition of gross and net land take to exclude green artificial areas**, but **it would be relevant to take into account the greening efforts of artificial areas to complement the net land take concept**.

Net land take is a proxy indicator of the impacts of the development of artificial areas. It provides rough estimates of the overall loss of productive areas and rough indications relative to the expected disruption of the functioning of former ecosystems. As urban parks, golf courses, cemeteries, military sites, garden, etc. are considered “artificial areas”, they are distinguished from grassland and other rural green areas, which, despite “similar” land cover (e.g. grass), may have very different environmental functions due to their different use. For instance, net land take takes into account that golf courses may have detrimental environmental impacts compared to grasslands, or that urban green areas may result in more fragmented habitats than rural green areas.

However, a same amount of net land take can reflect very different realities and **there is no linear relationship between net land take and the magnitude of impacts of artificial development,** as further explained below**.**

The actual impacts of artificial development depend on several factors, including:

- the magnitude of gross land take and re-naturalisation (see Figure 3);
- their location (site and land use types);
- the form of artificial development (dispersion);
- the degree of sealing and % of restoration within artificial areas; and
- the intensity of use.

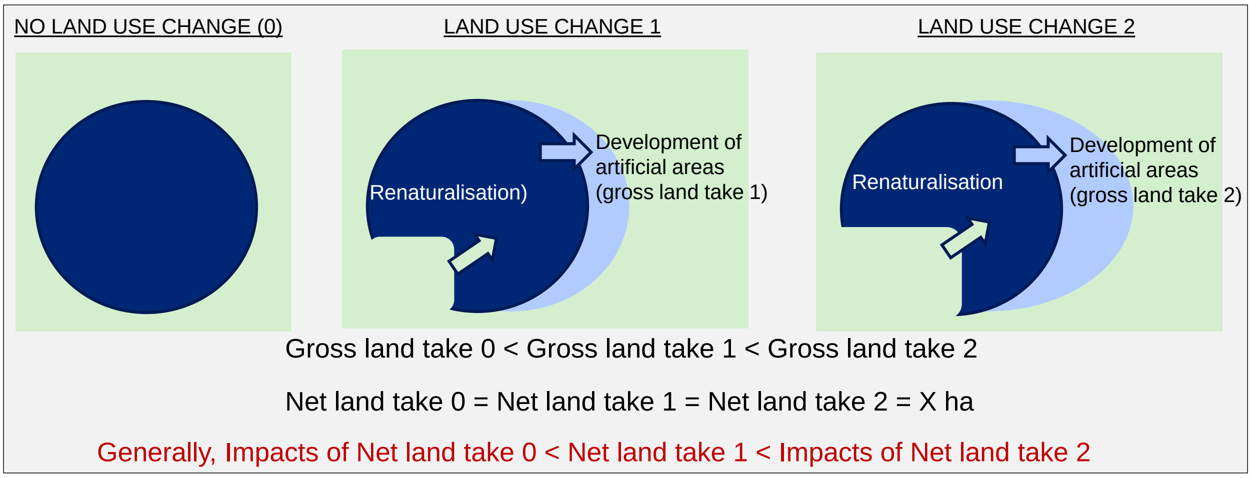

Figure 3: Environmental implications of different gross land take for a same net land take

Figure 4 illustrates the non-linearity of environmental impacts.

The arithmetic **net land take** concept **is therefore only fully relevant, from an environmental and socio-economic perspective, provided the land functions lost through land take are fully recovered through re-naturalisation.**

Yet, experience shows that this is very unlikely in practice:

- at the highest level of aggregation of land use classes (i.e. artificial vs. non-artificial areas)[17], the net land take indicator implies that 1 ha taken by artificial development (whatever the type) is compensated by the restoration, elsewhere, of 1 ha of land into non-artificial land (whatever the type). Yet, that calculation of net land take neglects the actual impacts and benefits of conversions from different land use types within the artificial and non-artificial categories, e.g. that functions lost through the conversion, e.g. of farmland are different from those gained from restoration, e.g. into grassland (see left, Figure 5);
- furthermore, at lower levels of disaggregation, for instance for a same land use type, the calculation of land take does not allow accounting for the fact that functions can only be partially recovered, depending on the restoration efforts as well as inherent technical limitations (see right, Figure 5 and Box 1).

[17] which implies that 1 ha taken by artificial development (whatever the type) is compensated by the restoration, elsewhere, of 1 ha of land into non-artificial land (whatever the type)

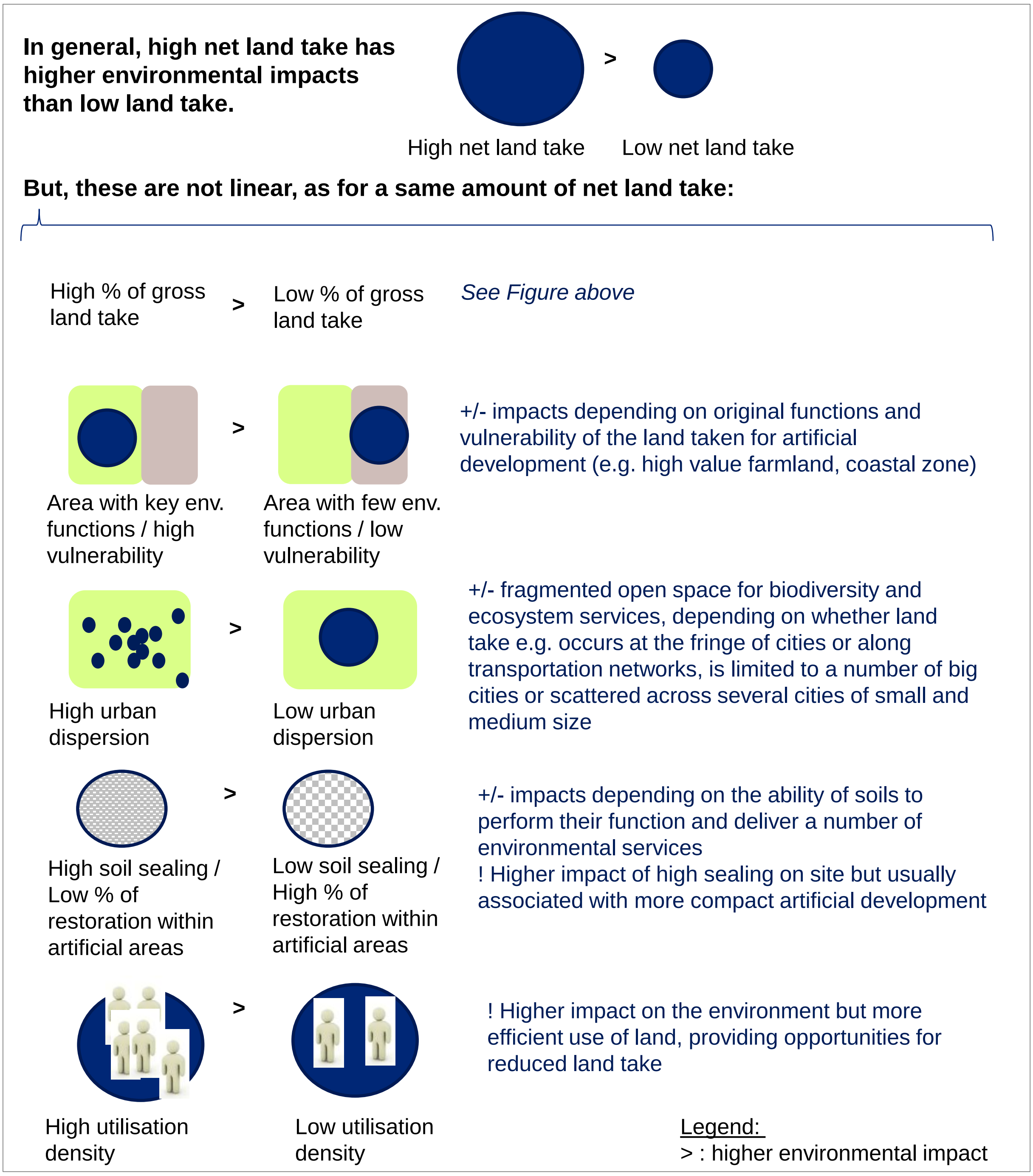

Figure 4: Illustration of the non-linearity of the environmental impacts as estimated by the sole land take indicators

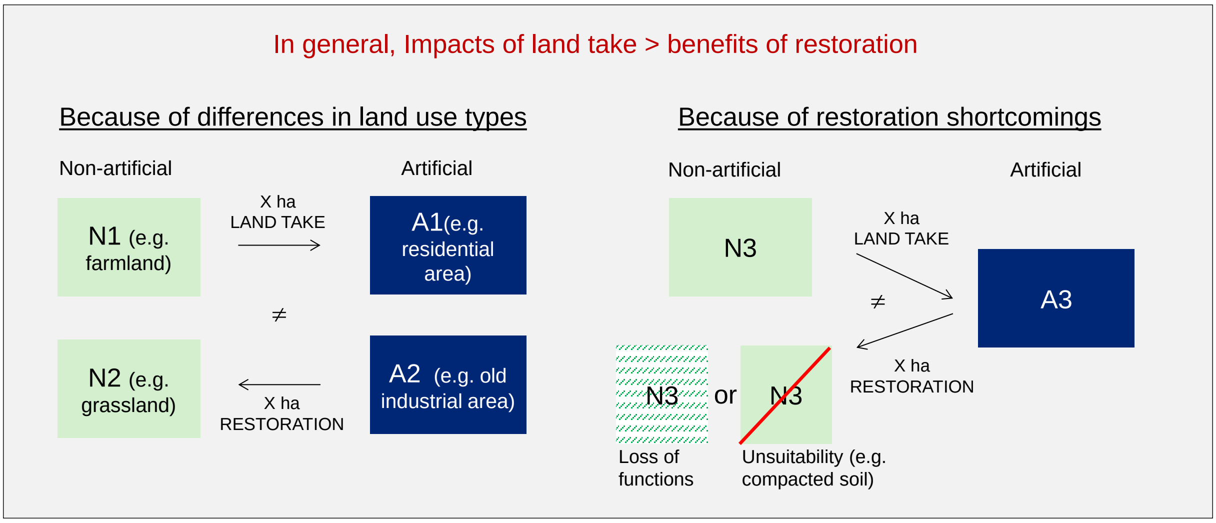

Figure 5: Illustration of the shortcomings of the "net land take" concept

Box 1: Practical experiences illustrating the shortcomings of restoration

Most recoveries considered successful in the literature (e.g. case of the Emscher Park in Germany or the old industrial site of Kodak Sevran in France)[18] remain partial. The restoration of brownfields is usually limited to recreational areas. For instance, the restoration of 10 brownfields (industrial areas, landfill, parking lot etc.) in the city of Toronto was investigated in 2003. Although the restored fields are used as local parks or artificial ecological habitats, their ecological value remains limited compared to semi-natural areas (De Sousa, 2003). In the US, community urban gardens are replacing abandoned areas, but with a very limited productivity and choice of seeds due to soil contamination (EPA, 2011). Nevertheless examples of coal-mine restoration projects using the Forest Reclamation Approach (FRA) have succeeded in recovering forests with equal and sometimes even better productivity than the former ones (Burger et al., 2005). Restoration can aim at recovering key soil or land functions and/or recovering initial use.

Possible scenarios of restoration include:

- the soil surface is restored, i.e. unsealed;
- soil functions are restored, sub-options being: restoration of any soil functions or restoration of specific functions lost by new developments; or
- The soil is returned to its original state before it was developed.

Even under the assumption that soil is returned to its original state or that key functions could be recovered, this does not guarantee that the benefits obtained through restoration would actually fully compensate the impacts of land take. For instance, the impacts of the development of artificial areas at the expense of highly productive land for instance are not equivalent to the benefits obtained from the restoration of a previously abandoned area, which may not be as fertile, may be polluted or may be irremediably degraded through compaction. Moreover, the impacts of soil sealing due to land take for instance are immediate and generally permanent, while the permanence of non-artificial areas is not necessarily guaranteed. The results of restoration efforts can usually only be observed in the medium to long term. Gretchen C. Daily estimated in 1995 that substantial recovery of degraded areas may be achieved in three to five years with intensive management but more typically 20 years. However the recovery of a self-sustaining mature ecosystem may take hundred years or more. Even though techniques and knowledge on restoration have increased, human interventions can only accelerate some phase of the restoration, consequently actual time scale are similar.

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[18] Agence de l'urbanisme pour le développement de l'agglomération lyonnaise, 2008 : www.ville-sevran.fr/terrains-kodak/

To sum up, the net land take indicator does not deliver information on the actual impacts of the development of artificial areas nor on its efficiency. Yet, both of these were highlighted in the introduction to this chapter as key aspects in the overall objectives of a more sustainable management of land. The net land take indicator would be more relevant from a policy perspective if it is complemented at least by:

- disaggregated information on the **rates of artificial formation (% of gross land take)** or consumption (re-naturalisation), as the benefits of re-naturalisation generally do not compensate the negative impacts of artificial formation; and
- information on **recycling of artificial areas**, through restoration (greening) or redevelopment of brownfields within artificial areas (see Chapter 3).

Revising the arithmetic net land take concept to better consider different categories of land take, following the "value" or "functions" of the land converted (e.g. land taken on high value farmland) or the vulnerability of its location (e.g. land taken on coastal areas) could substantially increase the relevance of net land take with regards to the environmental impact of artificial development. This is what is done in some Länder in Germany, through the concept of eco-points (e.g. in Baden Württemberg through the "*ökokonten-verordnung*"[19]), but it is difficult to implement in practice across MS (see sections below).

Other complementary indicators to net land take could help better reflect the actual physical and functional degradation of land, with the loss of services, as well as land efficiency, and deliver robust policy messages. These could include pressure indicators (e.g. urban dispersion as discussed in Section 2.3.3, or intensity of use as discussed in chapter 5) and/or impact indicators (e.g. loss of land functions through proxies like soil sealing and land fragmentation - as discussed in chapter 5).

Acceptability

At EU level, land take indicators are largely recognised as key sustainability indicators. "Land take" is one of the 37 indicators included into the EEA Core Set of Indicators[20], selected on the basis of their policy relevance, data availability and routinely collection, spatial and temporal coverage, understandability and focus on EU priority policy issues (EEA, 2005a). It is referenced as CSI014. After a preliminary analysis, it was proposed by the EREP Working Group II and the Commission as the most suited indicator for target setting at the EU level. Land take is defined as a national sustainability indicator in MS like France, Spain and Germany. In addition, **it is widely used in the EU to monitor land use changes.** When the generic term "land take" is used, it is rarely specified whether it is meant gross or net land take, which may be confusing. In practice, the term "land take" often reflects the "net land take" (as its calculation is based on the difference in artificial areas statistics, which usually already subtract the renaturalised artificial areas from artificial areas). The term "**net land take**" remains, however, a relatively new concept at EU level, emerging in the context of the general "no net loss" approach as advocated by the EU Biodiversity Strategy to 2020.

Rather than the arithmetic approach (1 ha restored land for 1 ha of land take), some countries, like Germany prefer to promote a "functional" approach of net land take through systems of eco-points[21],

[19] www.fachdokumente.lubw.baden-wuerttemberg.de/servlet/is/95976/bewertungsempfehlungen_schutzgut_biotope.pdf?command=downloadContent&filename=bewertungsempfehlungen_schutzgut_biotope.pdf

[20] A set of indicators developed by the European Environment Agency to inform EU policy making. In addition to land, indicators cover other environmental themes such as air pollution, climate change, waste, water etc.

[21] A number of points are attributed to different land use types, based on their estimated ecological functions.

as already implemented in several Länder. There, it is also interesting to note that restoration as compensation of land take is accepted and sometimes even required **within** cities (as in Dresden for instance).

Lessons learnt from practical examples across the EU show that the arithmetic concept of "net land take" may encounter acceptability issues due to the debatable notions of compensation and restoration. In particular, land take often occurs at the expense of agricultural areas, which can generally not be recovered elsewhere, thereby contributing to the overall loss of farming activities and eventually to the intensification of agriculture. On the other hand, the functional approach promoted by Germany implies prioritising certain land use types and functions, with necessary trade-offs[22]. **This highlights the need for a hierarchy when applying the net land take concept, with priority given first to avoiding land take in order to preserve agricultural and semi-natural areas, before considering how to compensate land use changes.** This is in line with the concept of compact cities, which encourages retrofitting and recycling within the city boundaries. Trade-offs include the risk of loss of vegetated areas within cities that contribute more generally to the quality of life within the city, biodiversity, climate regulation, water regulation, etc.

Credibility

Overall, **gross and arithmetic net land take** are easy-to-understand indicators for non-experts reflecting the development of artificial areas. A high level of land take is generally associated with negative environmental impacts through the physical and functional degradation of habitats and the disruption of associated ecosystem services, although we highlighted that these impacts were not linear. This means that a clear case can be made for halting encroachment of artificial land on agricultural, forestry and semi-natural areas. In practice, however, these land take indicators may be subject to some ambiguity which may undermine their credibility.

This relates to:

- the nomenclature used to describe artificial areas, which is not always homogeneous between countries and stakeholders[23];
- the non-linearity of environmental impacts;
- the several possible processes leading to a decrease in gross land take (e.g. decrease in demand for housing and infrastructure or densification of artificial areas to meet this demand).

[22] There, the system of eco-points is mostly based on the ecological value of land; the productive value being little considered in the whole equation. This was shown to create biases between land use types, as agricultural land, with low number of Eco points compared to ecologically valuable areas, is preferably used for artificial developments along with the implementation of greening measures as compensation in agricultural land elsewhere (worth a high number of eco-points). High burden is therefore put on the agricultural sector, at the expense of the productive function of soils.

[23] **"Artificial areas"** can be described through several terms which encompass different land cover and land use types. For instance, depending on the monitoring system nomenclature used, they may (e.g. CORINE Land Cover) or may not (e.g. LUCAS) include vegetated areas. Furthermore, the term "built-up areas" is also often used interchangeably with artificial areas, compared to non-artificial areas. Yet, the terms "built-up" and "non-built up" can also be used to distinguish dense artificial areas from less dense artificial areas (as in the nomenclature of the High Resolution Layer for Imperviousness developed by the EEA), or buildings from roads and transportation network (as in the nomenclature of the LUCAS survey). Likewise, in some MS, the term "sealed" could be interchangeable with land take, as in Austria, when the first soil sealing target was defined. At the time, the semantics were not as defined, and no distinction was made between the two concepts (Pers. comm. with Fiala Ingeborg, from the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management). Similarly, land take is sometimes reduced to "urban sprawl", whether it also accounts for the development of artificial infrastructures and land use types elsewhere than in the vicinity of cities. For the land take indicator to be used, it is therefore very important to clarify the definition of artificial areas. More transparency in the definitions of the terms used is required in order to develop comparable trends and robust analyses.

The possibility to subtract renaturalised areas from gross land take in the net land take concept arithmetic adds to the aforementioned factors of ambiguity:

- another process likely to lead a decrease of net land take, which is the re-naturalisation of artificial areas (Table 3); as well as
- uncertainties related to the extent and efficiency of restoration and the associated level of compensation.

Table 3: Processes leading to decreases in gross and net land take

Processes at stake	Decrease in demand for housing and infrastructure	Densification of artificial areas to meet the demand for housing and infrastructure	Renaturalisation of artificial land (conversion to non-artificial land)
Decrease in gross land take	√	√	
Decrease in net land take	√	√	√
Comments		Redevelopment of brownfields or retrofitting of building instead of building on undeveloped land. May be associated with an increase in soil sealing in the core city, with antagonist environmental impacts	Excludes the greening of artificial areas

Ease to monitor

At the EU level, land use and land use change have been **routinely monitored with remote-sensing services** delivered through the Copernicus programme, and in particular through CORINE Land Cover (CLC)[24,25]. This remote-sensing-based land monitoring system produces datasets since 1990 in a centralised and standardised manner from national reporting based on satellite images, what allows developing a coherent vision of land cover land use within the EU[26]. **The arithmetic net land take can be easily calculated based on this harmonised dataset for the years 1990, 2000 and 2006 (and soon 2012) for most MS, through the difference in the amount of artificial areas.**

Gross net land take can be calculated through changes from class 2, 3 or 4 (Agricultural areas; Forests and semi-natural areas; Wetlands) into class 1 (Artificial areas) (i.e. gross land take). Conversely, **re-naturalisation** can be calculated through changes from class 1 to class 2, 3 or 4 (i.e. re-naturalisation).

This dataset also allows following the greening of artificial areas (e.g. restoration of built-up areas into vegetated areas) to complement the land take indicators through changes from subclasses 1.1 to 1.3 (Urban fabric; Industrial, commercial and transport unit; Mine, dump and construction sites) into 1.4 (Artificial, non-agricultural vegetated areas).

[24] http://land.copernicus.eu/pan-european/corine-land-cover

[25] Although the LUCAS survey also provides statistics on so-called “artificial areas”, the definition is different from the one proposed by the EEA, as vegetated areas are not considered artificial. It rather corresponds to sealed areas.

[26] National datasets are collected by the European Environmental Information and Observation Network (Eionet) National Reference Centres on Land Cover (NRC/LC), and coordinated and integrated by the EEA. Outcomes are usually presented as average annual change in artificial areas (land take in ha or %), % of total area of the country and % of the various land cover land use types taken by artificial development. The latter allows development trends within artificial surfaces to be followed more closely (e.g. Urban fabric (continuous, discontinuous); Industrial, commercial and transport units; Mine, dump and construction sites; and, Artificial, non-agricultural vegetated areas in CLC).

What cannot be currently monitored easily across all MS, is the amount of land taken from valuable or particularly vulnerable areas.

At national level, the coarse resolution of CLC remains a key shortcoming for the actual use of EU harmonised land take values. Parts of artificial land development and conversely re-naturalisation may indeed elude monitoring through CORINE Land Cover which does not detect small urban features in the countryside nor most of the linear transport infrastructures that are too narrow to be observed directly[27]. This technical shortcoming contributes to underestimate the amount of land take and hides the extent of the development of transport networks which are known to put significant pressures on the environment through the fragmentation of habitats. The outcomes of the 2013 EEA workshop on land as an efficient resource showed that land take trends monitored through refined national inventories may actually be twice to six times as large as when monitored through CLC[28]. **These discrepancies highlight the need for higher resolutions and refined thematic assessments of land use changes, which are not deemed accurate enough to be used at national level for planning purposes. Although MS are in charge of producing their own national layer in the context of CORINE Land Cover, the consultation of experts indeed shows that they little rely in practice on the corresponding dataset for their land management and planning activities.**

At the EU level, these shortcomings can be overcome to a certain extent in large urban zones (LUZs) through the **Urban Atlas[29]**, although it does not allow accounting for diffuse land take over the whole country. This detailed information can be very interesting for planning activities in these areas with very dynamic development, and where in-situ data is generally very limited, as they may be out of beyond city planners' responsibilities. The **production of pan-European thematic High Resolution Layers, currently under production,** also complements the CLC datasets by providing more accurate information (20 m spatial resolution) on Imperviousness at a pan-European level, and therefore a more accurate picture of the development of small and isolated infrastructures. However, it cannot be used alone to calculate gross and net land take, as it namely excludes green areas associated with artificial land, and does not allow collecting information on the different classes of artificial areas. However, no MS mentioned in the consultation using of the recent Urban Atlas or Imperviousness High Resolutions Layers to calculate land take. In order to improve spatial detail of CLC products, the JRC recently revised the 2006 CLC map with the land use/cover information present in finer thematic maps available for Europe such as the CLC change map, Soil Sealing HRL, Tele Atlas® Spatial Database, Urban Atlas and Water Bodies Data from the Shuttle Radar Topography Mission (Batista e Silva, 2013). A **newly refined version of the CLC 2006 map (CLC_r)** was obtained with an improved MMU of 1 hectare for all types of artificial surfaces. A revised version of this map for 2012 is currently under production. The main quantitative changes in the newly improved CLC map occurred in the artificial classes, with a net increase in the estimated area (increases ranging from 2.81% to 53.23%, depending on the LULC class) (Batista e Silva, 2013).

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[27] CLC uses a minimum mapping unit of 25 ha for areal phenomena and a minimum width of 100 m for linear phenomena, and does not take into account changes lower than 5 ha

[28] For instance, based on CORINE Land Cover data, 80 km2/yr were taken by artificial surfaces in Germany between 2000 and 2006. However, based on national statistics, the annual land take between 2007 and 2010 was reported to be about 87 ha/day, and 81 ha/day between 2008 and 2011, which corresponds to about 290 km2/yr.

[29] The Urban Atlas is a joint initiative of the European Commission Directorate-General for Regional Policy and the Directorate-General for Enterprise and Industry with the support of the European Space Agency and the European Environment Agency.

Despite some methodological shortcomings[30], **this mapping exercise can be considered more "relevant" and operational so far to monitor land take at the EU level and is likely to be more credible at national level than original CLC datasets**. Improvements foreseen for the monitoring of the land take indicator at EU level also include the implementation of a reliable spatial database of linear transport structures over European countries.

At national level, the growing need for higher resolution has led several EU MS (AT, BE, DE, EE, ES, FI, FR, HU, LU, LV, NL, and UK) to produce their own land cover / land use data in parallel to EU efforts based on remote-sensing[31]. Annex 2.1 provides further details on monitoring systems in MS. Most national monitoring systems rely on a combination of ancillary data (e.g. cadastres, reporting of real estate data, field surveys) and data obtained through remote sensing (orthophotos, satellite images). These initiatives generally require substantial human and financial resources, e.g. for the actual development, testing and administrative logistics[32]. They generally cover overall land use and land cover changes, but some of them specifically focus on the development of artificial areas, as in France[33]. In most countries, classes used in national systems can be translated into the CLC nomenclature, at least at the higher degree of class aggregation (e.g. class 1, 2, 3 and 4 of CLC). In most cases, however, CLC and additional national monitoring systems are developed in parallel, with a duplication of the monitoring process, involving supplementary resources and costs. It is only recently that the need for better consistency between national and European datasets and the intention of avoiding redundant data production has led European countries to reflect on how their national data could be used to derive pan-European datasets, following a bottom-up approach (Arnold et al., 2013). France and Finland are amongst the rare MS which have respectively been developing or already developed a high resolution dataset in the context of the production of their CLC layer[34]. Only a few other countries, such as Austria and Germany, have been working so far on developing Digital Land use land cover Models that could directly feed CLC databases in the future. **National data could be better integrated into pan-European monitoring services, to ensure consistent and accurate datasets and better acceptance and use of EU data by MS. This remains a complex work in progress and is not operational at this stage.** In particular, the implementation of the INSPIRE Directive will be a further opportunity to harmonise data collection and reporting across MS. The EAGLE initiative, under the umbrella of the European Topic Centre on Spatial Information

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[30] The Revised version of the CLC datasets (CLC_r) as developed by the JRC is more accurate as it includes datasets with higher resolution, such as the Imperviousness Layer of the HRL and the Urban Atlas. However, the production process has its limitations, in particular:

- the combination of CLC classes with soil sealing data has potentially introduced some misclassifications in the CLC_r;
- some ancillary datasets do not cover the entire extent of the study area, which limit the consistency of the level of spatial detail of the map (see Batista e Silva, 2013 for more methodological details on the production of the map).

[31] Source: Consultation of MS experts.

[32] As an example, the development and maintenance of the LISA monitoring system over the whole Austria is roughly estimated at about EUR 400k per year, which explains the great difficulty encountered to implement it at a large scale despite its recognised interest (Pers. comm. from Fiala Ingeborg, expert from the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management. Estimate at +/- 50%).

[33] In France, an observatory for the encroachment of agricultural areas by artificial development (ONCEA) has been developed since 2013 to follow the progress towards the national target for reducing by half the consumption of agricultural space. The region Basse-Normandie has also been developing an observatory focused on the development of artificial areas and real estate (Observatoire du Foncier).

[34] In Finland, satellite layer is complemented with aerial photographs, inputs from topographic maps, in-situ data and field surveys. Datasets are available nationally with a resolution of 25 m (www.syke.fi/en-US/Research__Development/Research_and_development_projects/Projects/Producing_land_cover_and_land_use_data_in_CORINE_Land_Cover_2000_project_in_Finland)

In France, a geographic information layer (« OCS-GE ») is currently developed by IGN (national geodesic institute) and is planned to be available in 2017-2018. This will allow following land take in an more accurate and homogeneous manner across the whole national territory, following a nomenclature in line with CLC.

and Analysis (ETC-SIA), is experimenting such an harmonisation through the construction of a comparative matrix of land use and cover nomenclatures. This initiative is inspired by the FAO Land Cover Classification System approach and nomenclature.

Table 4: Summary of EU and national datasets suitability for the calculation of gross and net land take

	Gross land take	Net land take	Land taken from valuable areas / vulnerable areas	Scope	Accuracy	Frequency
CLC	√	√	-	EU	+	Every 6 yrs from 2000
CLC-r	√	√	-	EU	++	Every 6 yrs from 2006
HRL (Imperviousness)	-	-	-	EU	++	
Urban Atlas	√	√	-	LUZs	+++	Every 6 yrs from 2006
Refined national monitoring systems	√	√	√ or -	National or regional	++ to +++	Variable

Robustness

Time-series of gross land take and the arithmetic net land take can be considered consistent across MS provided they are calculated based on standardised EU monitoring systems such as CORINE Land Cover. Yet, the discussion about monitoring showed that MS that developed more sophisticated monitoring systems usually prefer using their own rather than EU land monitoring services, therefore leading to a variety of methodological approaches to define and calculate gross and/or net land take. This may lead to high discrepancies in the calculation of land take. Irrespective of the level of accuracy allowed by monitoring systems developed at national level, and as discussed in the section “Credibility”, there is above all a need to develop common vocabulary across MS and consistent methodology, in order to increase the robustness of land take indicators in the EU.

Synthesis of the RACER assessment

Table 5: Synthesis of the RACER assessment of the land take indicators

Criteria	GROSS LAND TAKE		NET LAND TAKE	
	Score	Rationale	Score	Rationale
Relevant		+ Provides interesting information about: • the overall geographical extent of (semi-natural, agricultural and forest) areas impacted by artificial land development; • the pace at which these areas are impacted; • the main sectoral drivers behind land take trends - no assessment of the actual physical and functional degradation of land, nor efficiency		Same as land take but: + information on the restoration of artificial areas into non artificial areas - assumption that 1 ha of restored land = 1 ha of land take
Accepted		+ largely recognised as a key sustainability indicator at EU and MS level		+ largely recognised as a key sustainability indicator at EU and MS level Concept proposed in the Roadmap for a Resource efficient Europe. Issue with the concept of compensation through restoration
Credible		+ concept very easy to understand - ambiguity related to the definition of artificial areas (that could be overcome with a clarification of definitions) - different policy implications for a same land take trend, depending on the degree of soil sealing, form of development, intensity of use..		Same as for land take - uncertainties related to the extent and efficiency of restoration and difficult to interpret in terms of impacts
Easy		Can be routinely calculated based on data from remote-sensing services		Can be routinely calculated based on data from remote-sensing services
Robust		CLC underestimates the amount of land take and hides the extent of the development of transport networks. National datasets may be very different from CLC. Yet, this is corrected by improvements in EU and national monitoring.		Relatively consistent results across the EU only if based on changes from artificial into non-artificial classes in EU harmonised datasets. Otherwise, high uncertainties related to the concept of compensation through restoration activities, which may lead to inhomogeneous interpretation.

2.3.3. Assessment of the urban dispersion indicator

The purpose of this analysis is to evaluate to what extent the urban dispersion indicator is a good indicator to complement the land take indicator.

Relevance

Urban dispersion is an indicator of urban sprawl. "Urban dispersion" is defined as "the average weighted distance between any two points chosen randomly within the urban areas in the landscape investigated". It was proposed recently as a sub-indicator in the context of the work of Jaeger et al. (2010) on the composite Weighted Urban Proliferation Indicator. The Urban dispersion indicator is particularly relevant in the urban environment, where it may provide clear policy messages about the sustainability of city morphological developments and refine the analysis of the land take indicators (see Figure 4 about the non-linearity of impacts of land take). There is not a lot of data related to urban dispersion in the EU yet. As it is currently tested, MS may be able to have access to a benchmark of urban morphologies across the EU, allowing to position themselves and assess their own artificial growth.

Acceptability

The "urban dispersion" indicator is perceived as relatively new, but it was successfully tested in Switzerland in the context of the implementation of the "Weighted Urban Proliferation" (Jaeger et al., 2010). It is currently tested at the EU level by the EEA and the JRC (pers. Communication), which will provide further elements to discuss its acceptability.

Credibility

It is currently studied by the EEA and the JRC at the EU level, which will provide elements to discuss its acceptability. Note that it was proposed by Jaeger et al. (2010) as a sub-indicator to better describe urban sprawl following the suitability criteria originally described in Jaeger et al. (2009).

Ease to monitor

Urban dispersion can theoretically be calculated based on the CLC dataset (with low accuracy), on the refined CLC datasets, on the Imperviousness HRL, or in LUZs on the Urban Atlas.

Robustness

This indicator meets the suitability criteria defined by Jaeger et al. (2009). Currently, this indicator has been successfully tested in Switzerland. It is now tested in the EU.

Synthesis

Because of the reservations related to the fact that the indicator is currently tested for the EU, all criteria have been noted as orange.

Table 6: Synthesis of the RACER assessment of the urban dispersion indicator

Criteria	Score	Rationale
Relevant		+ Complements the land take indicator with the concept of dispersion, likely to influence the functional degradation of ecosystems due to urban sprawl. - Focused on urban sprawl
Accepted		New indicator currently tested at the EU level, but with successful implementation in Switzerland
Credible		Meets the suitability criteria defined by Jaeger et al. (2009)
Easy		Can be calculated based on harmonised EU datasets on land use and land use change.
Robust		Meets the suitability criteria defined by Jaeger et al. (2009).

2.3.4. Summary and conclusions of the RACER assessment

Table 7 summarises the key findings of the previous analysis. The limited relevance of the “net land take” concept to preserve and/or restore ecosystem services calls for considering an overarching concept that would better take into account the actual impact of land take vs. the benefits of land restoration: the concept of **“net land take impact”.** A definition for the “net land take impact” concept could be enounced as: “changes of non-artificial areas into artificial areas which **impacts** are not compensated by the restoration of artificial areas into non-artificial areas or vegetated artificial areas”. This concept is further discussed in Chapter 5 about multifunctionality. It promotes the decoupling between land take and the loss of ecosystem services.

The following sections discuss how the concept of “net land take impact” can be approached based on a combination of net and gross land take with indicators of pressure and impacts.

Table 7: Summary of key findings, including the assessment of indicators of soil sealing and efficiency performed in Chapter 5

Code	Indicator name	Definition	Available data and sources	Information on existing uses	R	A	C	E	R
LT1	Gross land take (% of total area)	The amount of agriculture, forest and semi-natural land taken by urban and other artificial land development	Can be routinely calculated through local and pan-European Copernicus land services, as well as through national monitoring systems, in parallel to EU services	At the EU level, land take is largely recognised as a key sustainability indicator. It is also widely used as a key monitoring indicator in MS, although the distinction is rarely made between gross and net land take. Net land take was highlighted in the Roadmap to a Resource Efficient Europe. It is used to produce land take statistics but the notions of restoration is still debated in MS.					
LT2	Net land take (% of total area)	Changes of non-artificial areas into artificial areas, which are not compensated by the restoration of the same amount of artificial areas into non-artificial areas							
LT3	Urban dispersion	Average weighted distance between any two points chosen randomly within the urban areas	Currently tested at the EU level by the JRC and EEA. Developed by Jaeger et al. (2010)	Currently tested at the EU level by the JRC and EEA. Successfully implemented in Switzerland	?	?	?	?	?
LT4	Utilization density	Intensity of use of residential areas through the combination of the number of inhabitants and the number of jobs	Developed by Jaeger et al. (2010)	Intensity of use, through land take per capita or land take per GDP for instance is routinely used to analyse land take in the EU. Utilization density as defined by Jarger et al. currently tested in LUZs					
LT5	Soil sealing	Loss of soil resources due to the covering of land for housing, roads or other construction work.	Can be routinely calculated through local and pan-European Copernicus land services, as well as through national monitoring systems, in parallel to EU services	Used across MS and well accepted.					

2.3.5. Indicators suitability for target setting and need for further EU actions

Indicators suitability for target setting

The RACER assessments performed in the previous sections show that, currently, there is no ideal indicator allowing to account properly both for the impacts and the efficiency of land take.

The "No net land take target" as proposed in the Roadmap for a Resource Efficient Europe is at first sight a seducing concept relying on a straightforward arithmetic conception of land cover. The No net land take target by 2050 implies that the budget of changes between artificial and non-artificial areas will be neutral, at least at the EU level. Yet, the relevance of the "net land take" as a stand-alone indicator for target setting is limited by the fact that it does not properly account for the environmental impacts of land take nor its efficiency.

Table 8 illustrates how complementary indicators allow accounting for the key factors influencing the impacts of land take.

Table 8: Ability of the complementary indicators to address the shortcomings of the net land take indicator

Indicators	Magnitude of the development of artificial areas	Location of the development of artificial areas	Form of development (dispersion)	Degree of sealing / presence of vegetated areas	Intensity of use
Soil sealing				√	
Intensity of use					√
Gross land take		√ outside urban areas			
	√				
Recycling indicators		√ within urban areas			
Impact indicators			√		

A relevant conceptual scheme to ensure the sustainable development of artificial areas should combine indicators allowing accounting for:

- the demand for artificial areas;
- the impacts of the development of artificial areas, including the loss or maintenance of ecosystem services;
- the efficiency of land take.

The previous analysis calls for the **combination of a limited number of specific and measurable indicators to be deployed at different governance scale: some for target setting and others for "control" to support decision making**[35].

[35] The composite "weighted urban proliferation" indicator developed by Jaeger et al. (2010) is a seducing initiative illustrating the use of several sub-indicators to better account for the complex phenomenon of urban sprawl. It is currently tested at the EU level, but how the results of this aggregated indicator will be interpreted remains uncertain. Here, it is rather suggested to rely on individual indicators, which combination allows understanding the complex picture, without aggregating their results.

These indicators may allow covering the three key challenges of a more sustainable artificial land management (Table 9), which are:

- Reducing the environmental impacts;
- Preserving key functions;
- Maximising efficiency.

Based on the previous analysis, we suggest:

- a new strategic goal, the “**net land take impact**”, more in line with the no net loss concept developed in the frame of the Biodiversity Strategy, in order to convey the vision of a more sustainable management of artificial areas through a “no net land take impact’ target (see Chapter 5).
- a triptych of operational indicators for target setting including:
    - indicators of land take (amount of net land take and location of gross land take);
    - a soil sealing indicator (see LUF5b in Chapter 5); and
    - a utilisation density indicator (see LUF 2 and LUF 4 in Chapter 5).
- “control” indicators to monitor the impacts of land take and planning strategies for new developments:
    - gross land take indicator;
    - indicators for land recycling outside and within cities (see Chapter 3);
    - indicators of impacts (see LUF5b in Chapter 5).

Table 9: Ability of the proposed combination to cover the challenges of a more sustainable artificial land management

Indicators	Role	Reducing env. impacts	Preserving key functions	Efficiency of use
Net land take	Target setting	√		
Soil sealing	Target setting		√ within urban areas	
Intensity of use	Target setting			√
Gross land take	Target setting		√ outside urban areas	
	Control	√		
Recycling indicators	Control			√
Impact indicators	Control	√		

This approach allows accounting for the impacts and efficiency of artificial development while relying on acceptable indicators. In particular it provides clear operational messages on land take drivers (urban expansion, soil sealing, urban permeation and development of transport infrastructure), pointing out improvement areas in terms of planning and implementation of policy instruments.

The practical experience from MS shows that these indicators are not suitable for target setting at any geographical scale (see Section 2.4).

Need for further EU action

To date, there is a lack of harmonised terminologies across MS to describe issues related to the development of artificial areas as well as a lack of consensus regarding how to assess their environmental and socio-economic impacts and how to define compensation. Although a number of proxy indicators - relatively ready to use - could be identified to take concrete steps towards a more sustainable management of the development of artificial areas, further work in relation with the development of indicators could be done, as suggested in Table 10.

Table 10: Suggestions of potential actions required to develop indicators related to the development of artificial areas

Indicator	Problem definition	EU actions required to develop, implement or improve the indicator
Gross land take (ha or % of total area)	Accuracy of CLC datasets contested by some MS, which rather develop their own national datasets. Difficulty to set relevant targets, as the future needs for infrastructures/housing and the potential for inner city development are not correctly known.	Revising 2012 CLC datasets following the recent work of the JRC for the 2006 datasets, which integrates other datasets such as HRLs, Urban Atlas, etc. Pursuing the work conducted by the EAGLE network and other initiatives in the context of the INSPIRE Directive in harmonising MS monitoring efforts and standards EU procedures, in order to avoid duplication of work and increase comparability of accurate data. Testing different scenarios for allocation of land take across MS, based on past and future trends in population, land take and socio-economic contexts, beyond the harmonised allocation currently proposed by the JRC, in order to support MS in the definition of their own land take targets and in the reflexion about the implementation of subsidiarity principle. Further work on land recycling indicators and indicators of city redevelopment (see section 7.2.2)
Restoration within and outside cities	Difficulty to assess the potential for restoration, and therefore to set a relevant target for the net land take	Exchanging best practices in estimating de-sealing potential in cities, following the Berlin example. Further work on identifying potential for restoration (see section 7.2.2).
Weighted Urban Proliferation Indicator		Testing the feasibility of the Weighted Urban Proliferation and its sub-indicators for different types of cities in the EU, following the example of Switzerland, based for instance on data from the Urban Atlas and/or the high resolution layer.

2.4. Possible targets and assessment

2.4.1. Lessons learnt from practical implementation of targets

As sustainable land management requires a strategic and coherent vision of the development of artificial areas in the long term, a key challenge is to ensure stakeholders awareness of related issues across the EU and their permanence in EU and national political agendas. Target setting at EU and national levels of governance is a powerful instrument to deliver clear messages about political commitment and to trigger further actions in the field of monitoring, regulation and development of economic and information policy instruments.

In the Roadmap for a Resource Efficient Europe, the European Commission proposed an indicative target for land take, as a result of the increasing awareness of land as an environmental resource*: "no net land take in the EU by 2050"*. This indicative target consists in compensating gross land take through re-naturalisation elsewhere. It has not been detailed per Member State. There is no other EU target relevant to the development of artificial areas, regarding for instance soil sealing or utilization density.

Several MS have formulated their own targets related to the development of artificial surfaces, at national, regional and/or local levels. Annex 2.2 provides an overview of existing targets in MS at national, regional and/or local level, along with information about their implementation and related achievements where available. The following key messages with regard to target setting can be highlighted. They are further detailed in Annex 2.2:

- The no net land take target set in the Roadmap appears to be a supporting political tool for national governments that have already been trying to implement targets as well as a driver for other countries to be more proactive in the definition of targets.
- In practice, "no net land take" targets have been very little implemented across MS so far.
- Without necessarily promoting "no net land take", regulating the amount of land take or restricting the location of new developments appear to be the most widespread strategies when setting quantitative targets.
- At national level, targets set remain mostly indicative. They are relevant to ensure the permanence and high ranking of issues related to the uncontrolled development of artificial areas in national agendas, but are rarely based on robust prospective studies.
- The acceptability and implementation of targets seem to mostly depend on the involvement of regional and/or local governance – in charge of concrete planning decisions - in the process of target setting.

2.4.2. Target proposals

Based on the previous analysis and currently available data, Table 11 highlights relevant indicators for target setting and control at different scales.

Table 11: Target proposals

Scale of implementation	Types of indicators for target setting	Possible expressions of targets	Scale for target setting	Types of control indicators
EU	Net land take	"No net land take by 2050"	EU	Gross land take Indicators of impacts: • land fragmentation (SHORT TERM), • development of green infrastructures *(when available)* or • total value of ecosystem services *(when available)*
National	Net and gross land take	Reduction of net land take by X% by YYYY and no gross land take in areas Z identified for their key functions *To be declined at relevant lower levels of governance*	National under EU guidance	Gross land take Indicators of impacts
Regional or local	• Land take • Utilization density • Soil sealing	• Reduction of land take by X% by year Y AND no gross land take in areas Z identified for their key functions • Minimum utilisation density for new developments • Maximum soil sealing as a % of total area OR Maximum soil sealing as a % of new developments	Regional or local, under national or regional guidance	Gross land take Indicators of recycling / re-naturalisation within cities Indicators of impacts

2.4.3. Assessment of target proposals

"No net land take by 2050" at the EU level

The feasibility of this target is assessed in more details for the MS level, in section below.

Setting such a target at the EU level is relevant as it provides a strategic vision on the long term of the ultimate objective to reach, and offers political support for MS efforts in developing targets, while leaving flexibility in their way to reach the objective. It can be monitored easily based on EU harmonised datasets, and in particular based on the refined CLC datasets (CLC_r) which are more accurate at describing the artificial areas.

Based on the recent modelling exercise from Lavalle et al. (2013), achieving such a target in the EU would require a reduction of land take of 17% by 2020 compared to the baseline scenario (which is since then being refined). This intermediate target at the EU level seems unlikely to be achieved, since most countries recognised that land take could not be halted without the implementation of stringent policy instruments and several attempts in this respect remained unsuccessful. In practice, the feasibility of achieving such a target will depend on individual efforts from MS (see section below). It will also depend on having the most dynamic EU regions subject to artificial development finance the restoration of less attractive areas, which means that the no net land take must not necessarily be achieved per MS. The challenge will be to coordinate national contributions to reach towards the EU target. Principle of subsidiarity is further discussed in the following section. However, this should not prevent from setting a target at the EU level, as it is a powerful instrument to trigger further action at the MS level and negotiate national targets.

To further benefit from this momentum, it is suggested that indicative intermediary targets, for instance every ten years, disaggregated by country based on a homogeneous contribution (such as – 17% across MS by 2020), are provided for information purposes to drive MS efforts towards reaching the EU 2050 target.

"Reduction of net land take by X% by xxx" and "no land take in areas Z"

Technical feasibility:

These operational targets provide a clear and practical policy message: overall, land take must be reduced but remains authorised provided compensation efforts are made and areas of high importance (e.g. ecological/productive) are preserved. Efforts of each country should tend towards no net land take. Several reasons call for setting targets at the national and/or regional levels, most of them similar to those that can be given in the context of the no net loss initiative. From an ecological and conservation perspective, many ecological functions and services highly rely on the connectivity of ecosystems, which cannot be ensured if compensation takes place in a remote area. Species and habitats are mostly landscape and context-specific, which explains why conservation priorities are often set at national and/or regional scale (BBOP, 2012). Considering net losses in a national and/or regional context is also very relevant from a cultural and socio-economic perspective. From an operational perspective, it is also justified because of the modes of governance and strong land stewardships.

Opportunities/constraints for target setting and monitoring of progress

Several questions can be raised with regards to the relevance of the targets set: **At which geographical scale(s) should the target be implemented? Based on which datasets? At which level of ambition? Which level of governance should be in charge of setting the targets?**

As discussed above, a no net land take target by 2050 was set at the EU level, corresponding in practice to a reduction in 17% of land take by 2020. MS specificities, in terms of land take history, culture of land stewardship, and socio-economic trends, justify to modulate the contribution of each country and not to apply a target of - 17% homogeneously. In this respect, Lavalle et al. (2013) highlights in a preliminary estimate that achieving a – 17% target by 2020 would require substantially different efforts from MS. They are indeed at very different stages in their socio-economic and infrastructure development and are therefore engaged in different dynamics for land take. For instance, it will require more efforts for a country still in the process of rapid urbanisation to change their paradigm towards reduced land take than for already highly urbanised countries like the Netherlands, which already have had to take into account the issue of limited space in their development strategies. Applying homogeneous rates of reduction across MS would not contribute to an optimal allocation of efforts and may penalise specific countries.

Setting appropriate targets will result from a delicate equilibrium between the fair level of efforts that each MS can afford without imposing unnecessary burden on their development and the necessary level of ambition to be able to reverse unsustainable trends significantly. This is a challenging exercise as it is expected to be difficult to halt land take in the EU without negative effects on the economy or society in the short term.

Several options are possible to allocate EU efforts to each MS. National land take targets could be set based on:

- historic and future land use trends;
- demographic trends;
- GDP trends; or
- a combination of these factors.

An example of implementation of the subsidiarity principle based on demographics and land use trends is provided by Germany in the framework of the running model project on the trade of certificates on land take. A formula ("*Zertifikaterechner*") has been developed regarding how to distribute the 30-hectares-goals on local communities[36].

So far, in most countries aiming to limit land take, targets are usually not defined from a robust analysis of land take trends and future infrastructure needs. Without such a proper analysis, it is very difficult to set the right level of ambition for these targets. As of today, these kind of targets set at national level rather remain a political message, with a powerful effect to trigger action and research, at lower governance levels that are in charge in practice of land planning and development.

Information about infrastructure needs for different economic sectors and housing as well as potential for inner city development and/or re-naturalisation is usually not available, and remains mostly local. This lack of knowledge may be a barrier to the setting of relevant binding targets, but should not impede target setting as such, as such a process will trigger further work on the issue.

On the contrary, information about land take trends is easily accessible, as discussed earlier, although it can be more or less accurate depending on the monitoring systems. It can inform MS in their target setting process. Several options are possible for target setting and monitoring of progress:

a. requiring MS to rely on a specific harmonised EU dataset. In this case, it is suggested that MS rely on the revised CLC time series (CLC_r) as refined by the JRC;

[36] www.flaechenhandel.de

b. letting MS choose between using the EU harmonised datasets or their own monitoring systems, where available.

Because most MS that developed their own monitoring systems beyond CLC recognised using these ones – usually more accurate - for their practical land management and planning, option "b" seems more relevant, for environmental and acceptability reasons. A concrete example can be provided by Germany[37].

Because of the substantial discrepancies in the monitoring of artificial areas between EU datasets and certain national datasets and high political sensitivities related to the land stewardship, it seems more relevant for MS to propose to the Commission their own national targets than for the EU to set national targets. The work of Lavalle et al. (2013), which applied a reduction of 17% of land take across MS provides indicative values that are powerful instruments to guide MS in the preparation of their own proposals. On this basis, MS could refine these indicative targets and develop new target proposals, based on their own monitoring datasets where available and their national contexts and history, including strategies for economic development if they are to be implemented.

From there, MS could apply the principle of subsidiarity down to the most relevant level of governance for setting further mandatory targets and/or develop any other relevant policy instruments (e.g. taxes) (see Section 0). It is interesting to see how the subsidiarity principle can be applied from the impulse of a national initiative down to the regional level, where planning can be much more binding, as in the case of France, Luxembourg or Germany. There, Länder are now voluntarily working on target definitions, based on population and land use trends (see Annex 2.2).

As for a "no gross land take in priority areas", it is already relatively well implemented in the EU through the concept of "protected areas". Some countries implemented special regulations regarding territories of national significance to prevent land use change in these areas[38], although they are not necessarily stringent enough yet to prevent gross land take. However, it could be expanded at regional level notably, where there could be identified areas with key functions that need to be preserved, such as particularly valuable soils for ecological or productive purposes. These requirements would need to be binding and included in planning documents. Some countries already promote this land take hierarchy, such as in Wallonia, Belgium. There, if urbanisation has to take place in agricultural land, criteria such as the preservation of best agricultural soils, permanent grassland close to the farm and of large extend of contiguous agricultural fields should be taken into account[39].

Expected effectiveness or difficulties to achieve the target, based on the lessons learnt from practical implementation

From a socio-economic perspective, and despite the overall decrease in population which was an historic driver of land take, it would not be realistic, in practice, to forbid gross land take at large scale. It is already perceived as very difficult to decrease gross land take, because of the momentum of development activities, the economic interests at stake and the scattered governance of land related

[37] Germany set a target of land take of max. 30 ha/day by 2020. This corresponds to an overall land take of about 110 km^2/yr. Based on Corine Land Cover data, this target does not seem very ambitious, as it is higher than annual land take between 2000-2006, which was reported to amount to about 80 km^2/yr. However, based on national statistics, this target appears fairly ambitious for Germany, as the annual land take between 2007 and 2010 was reported to be about 87 ha/day, and 81 ha/day between 2008 and 2011, which corresponds to about 290 km^2/yr. This significant difference highlights the importance of refined statistics related to land take, to be able to set appropriate targets and appropriately monitor progress.

[38] E.g. Regulations Regarding Agricultural Territories of National Significance in Latvia: http://m.likumi.lv/doc.php?id=257136

[39] Regional Land Development Scheme adopted by the Walloon Government on the 7th of November 2014 (http://spw.wallonie.be/dgo4/sder/dwnld/5806-sderprojetbr1.pdf in French).

issues. The preliminary work from Lavalle et al. (2013) highlighted that reducing land take would require higher efforts for some countries (e.g. AT, BE, BG, CZ, FR, IT, PL, RO, SE, SK, UK) than for others (e.g. DE, ES, GR, NL, PT).

The no net land take concept is more technically feasible as it is aimed at reducing the impact of artificial development, not only through gross land take reduction but also through opportunities for restoration.

It provides MS with the flexibility to choose the strategy they deem the most adapted to their regional and local challenges:

- in the least dynamic regions, the target can be achieved through a decrease in land take due to the decreasing demand for housing and infrastructure;
- in the most dynamic regions, this target is expected to be achieved through re-densifying the urban matrix, through recycling and retrofitting;
- the targets can also be achieved through the compensation of new developments (e.g. in dynamic regions) by the restoration and greening of abandoned areas (in areas with shrinking population and economic activities).

The development of the concept of compact cities[40] and the increasing switch from industrial economies to service economies in the EU are key opportunities to decrease gross land take.

The question remains, however, **to what extent the potential for re-naturalisation can compensate land take.** In other words, to what extent re-naturalisation can contribute to reduce net land take compared to a decrease in gross land take. Between 2000 and 2006, restoration into non-artificial areas represented about 10% of gross land take in the EU (based on CLC 2006). It is expected that opportunities for restoration will not be able to satisfy the demand for gross land take and that efforts to reach the net land take targets will mostly have to come from an absolute reduction in gross land take. It is, however, very difficult to answer this question, as data on the issue is lacking (see Chapter 3).

This points to another question, which is **within which spatial perimeter re-naturalisation can be considered as compensation for land take**. This perimeter could indeed be global, EU, national, regional or even local. This question can be answered from three perspectives: environmental, operational and technical.

In theory, compensation could make sense at any scales, provided land functions are recovered. However, from an ecological perspective, the smaller the perimeter, the more the ecological balance and connectivity, on which rely most ecological services, can be ensured locally (BBOP, 2012). Examples of local compensation to achieve “net land take” exist in Dresden (DE), which requires desealing within the city, and in Wallonia (BE), which requires bringing back one hectare of buildable area to “unbuildable” for each new buildable area in planning at municipality level. It is interesting to see that **the greening of areas within these cities is accounted there as “restoration”, whereas it is excluded from the EEA definition of net land take.** Where there is high demand for housing and infrastructure, without appropriate regulation, this is more likely to favour unwanted urban sprawl, as the space dedicated to green areas within cities cannot be used anymore to accommodate new developments. It is also questionable whether the underlying aim that the overall ecosystem services are maintained and enhanced with this approach to achieving net land take. An urban green area

[40] www.oecdobserver.org/news/fullstory.php/aid/3806/Compact_cities.html#sthash.LHvp9PrO.dpuf

does not provide the same ecosystem functions or quality of functions as agricultural, forest or natural land.

For technical reasons, however, **in a reduced perimeter, the greening of urban areas could still be acceptable when the availability of other suitable sites is limited.** However, **it should only be considered as compensation in areas where it does not risk displacing other land use types and contribute to urban sprawl -** i.e. for instance in the least dynamic areas which are subject to shrinking population or economic activities – and **regularly controlled by the monitoring of the gross land take indicator**. Technically, the larger the perimeter, the more opportunities for restoration of 'equivalent' key functions. The lower the perimeter, the lower the availability of suitable sites.

From an operational perspective, it seems easier to ensure compliance with compensation mechanisms at the local level. The predefined boundaries of municipalities and regions may be an administrative constrain for what can be considered compensation at a local level. Depending on the type of governance, the perimeter can be increased in case of financial compensation, e.g. allowing a regional agency to restore non-artificial areas elsewhere than at the local level.

To sum up, the selection of a geographical perimeter rather depends on political and institutional decisions, in addition to the issue of technical feasibility related to the availability of sites for compensation activities. Once again, **a common principle to increase technical feasibility could be that the most dynamic regions subject to artificial development would finance the restoration of less attractive areas.**

Timescale and path to achieve the target

There is a need for an intermediate horizon for target setting, before 2050, if the targets are to be operational. For comparability purposes across MS, it is suggested for MS to set a national target for net land take and identify priority areas for no gross land take by 2017 with the horizon of 2030.

Socio-economic feasibility:

Expected socio-economic benefits include:

- Benefits in terms of efficiency of infrastructure investment, reduction of the cost of maintenance for transport, energy, water supply, and waste collection and disposal;
- Benefits in terms of mobility through public transportation in case of compact cities;
- Benefits in terms of resilience of the natural capital (e.g. flood protection) and preservation of ecological and productive functions.

The implementation of these targets may be impeded by socio-economic constraints, such as:

- the attractiveness of areas with high demand for gross land take;
- land recycling costs compared to development on green land;
- the lack of financial resources to renaturalise former commercial and industrial areas.

Furthermore, it may also increase the risk of speculation and increase in land prices. It is important to highlight the risk of detrimental rebound effects for the economic development of countries and/or regions that are originally less dynamic and may see their development opportunity shrink consequently through land pre-emption for restoration activities to compensate land take elsewhere. Governance patterns with an overall vision of the ecological and economic assets and shortcomings of a territory seem to be a condition to the implementation of sustainable and equitable compensation mechanisms. In this respect, the larger scale at which it would seem relevant to implement the compensation mechanism is at EU level. It must be reminded that limiting the amount of land take is only a proxy for the ultimate objective which is to mitigate environmental impacts.

Administrative and legal feasibility:

There would not be any key administrative barriers at the national level, as the target could remain indicative. There is however an expected additional administrative burden for the development of binding targets at the regional scale, which requires regular monitoring and assessment.

Such targets would be in line with the no net land take target set at the EU level. Several supporting instruments (land planning, economic, participatory, etc.) could be implemented to support the achievement of this target, as highlighted in Section 0. As underlined in the work related to the No net loss initiative, applying the concept of net land take should not undermine existing legislation and must in no way legitimise projects that would normally be rejected as a result of measures in existing environmental legislation. A **clear hierarchy** is needed consisting in first assessing the relevance of a project requiring land take, and then considering any mitigation measures likely to reduce its impacts before considering compensation elsewhere.

Possible trade-offs are expected with regional strategies of economic development and transport policies, because of the restriction of infrastructure development, which may impede the implementation of the target. The PLUREL project for instance highlighted that unless governance and spatial planning can be rapidly strengthened, in particular in some parts of Eastern and Southern Europe, the Europe 2020 Strategy is likely to produce more urban expansion and uncontrolled urban development. This target may also favour high soil sealing, through increased recycling and retrofitting, hence the interest of combining both targets to monitor possible trade-offs.

Maximum soil sealing as a % of total area OR Maximum soil sealing as a % of new developments

Technical feasibility:

Based on the RACER assessment of the soil sealing indicator performed in Chapter 5, soil sealing targets can be set in a regional and/or local context. So far, examples mostly exist at the local level (see Annex 2.2), although no information related to the ex-post assessment of the implementation of such targets could be found. Indicative soil sealing targets at regional could highlight the necessary level of ambition expected from the local level in the definition of binding targets for instance. It is suggested that national or regional levels (depending on the mode of governance) identify priority areas for development by 2017 in collaboration with local levels, based on which local binding requirements related to soil sealing could be proposed (by the region based on local collaboration). Soil sealing targets should allow regulating expected trade-offs from reduced land take, through redevelopment of brownfields and retrofitting. Depending on the dynamics and attractiveness of the area considered, targets can be defined as percentages of the total area (where there is capacity for greening or “desealing” although opportunities are expected to be greatly limited) or as percentages of new development. Targets can build on information provided harmonised datasets from the Imperviousness HRL (EU coverage) and Urban Atlas (main EU LUZs), which are a robust basis. However, these do not allow considering permeable materials, which would require local ancillary data. A weighting factor could be proposed at local level to take into account the development of (semi-) permeable areas.

Socio-economic feasibility:

This target is more likely to be achieved through a control of the development of new artificial areas than through de-sealing, because of the costs of restoration/de-sealing involved.

Administrative and legal feasibility:

A supplementary administrative burden can be added by the definition and implementation of targets at the local level.

This target may be contradictory with the land take target, hence the need to consider both of them in parallel and tailor policy implications to the actual dynamics of the area considered. It is in line, however, with the EU no net land take impact.

Soil sealing targets at the local levels can theoretically be effective if they are binding and integrated into permit authorisations and building requirements. They can also be linked to taxes for compensation or require mandatory compensation elsewhere.

Minimum utilisation density for new developments

Technical feasibility:

The main technical difficulty consists in reaching an agreement of what should be the “minimum utilisation density”. There is no optimal “minimum utilisation density” at the EU level. There are rather a range of “optimal” options depending on the specificities of use of urban areas (e.g. residential or touristic area; urban vs. rural environment; dynamic or shrinking city) and on the challenges perceived locally as a priority (e.g. environmental, socio-economic). “Optimal” densities may therefore highly vary across regions and municipalities, and for different stakeholder categories. Thus, setting harmonised targets at the EU or national level could be counterproductive as it would not allow targeting areas with key challenges and tailoring the required efforts. A minimum utilisation density target would be especially relevant to implement at the **city level, or group of cities**, in order to assess the efficiency of urban areas. It could be set by national and/or regional level (depending on the mode of governance) in close collaboration with local governance, in order to increase compliance in the field.

It is suggested to set the target in relation to the **number of inhabitants and/or the number of jobs**, as depending on situations (seasonal variations, high rate of vacancy, etc.) one, the other or both indicators could be relevant. The target will be all the more efficient that it is tailored to the city specificities. It appears to be complementary to the land take and soil sealing targets for taking into account the sustainable performance of cities.

It is suggested that **national and /or regional levels** (depending on the mode of governance) **identify by 2017, in cooperation with local levels, priority areas where binding requirements** related to minimum utilisation density for new development **should be proposed by 2020.**

Socio-economic feasibility:

Expected socio-economic benefits include:

- Reduced public costs for the development of infrastructures and maintenance;
- Lower traffic congestion through individual transport;
- Better access to public transport, jobs, and services;
- Higher opportunities for urban rural linkages and local food consumption;
- Benefits in terms of resilience of the natural capital (e.g. flood protection) and preservation of productive functions.

Setting such targets could have the following shortcomings:

- Low acceptability for developers, for instance of the tourism industry;
- Higher costs for investors;
- Risks of a lower quality of life for inhabitants through higher densities, who may decide to move further in the suburban area to benefit from individual housing.

Administrative and legal feasibility:

The acceptability of the target may be the main challenge for its implementation. Cooperation with local levels is key in the target setting process. Once set, progress towards the target could be easily followed based on local statistics.

The target could be namely achieved through:

- changes in the demand for housing and space per capita;
- building and infrastructure requirements with regards to the number of inhabitants and/or expected creation of jobs;
- increases in recycling within urban areas.

This could require the revision of existing policy instruments to better take into account the concept of efficiency, such as in the procedures related to the delivery of building permits or to the agreement of development projects (e.g. environmental impact assessment). Where no relevant alternative to a low density project could be found, a fee for low-density could be set by municipalities, which could then be used for redensification projects within the city. Other instruments could also be implemented in relation to the promotion of land recycling (see Chapter 3) and awareness raising for households.

This type of target is in line with the overall EU strategic approach on resource efficiency, while being tailored to local challenges and specificities.

2.5. Supporting policy instruments: lessons learnt from practical implementation and recommendations

Several policy instruments have been implemented by MS to reduce/restrict the development of artificial areas and to achieve targets set. Most instruments, however, remain insufficient to substantially curb unsustainable trends. The following section highlights key messages related to their implementation, which are further detailed in Annex 2.3, along with extensive information related to policy instruments implemented in MS. Across MS, the most common approach to controlling land take is to develop **spatial planning regulations**, which authorise or restrict certain developments within a territory[41]. Building regulations also represent interesting opportunities for halting land take, although their impact remains mostly local, with uncertainty regarding consistency at the regional level. In any case, binding policy instruments do not always guarantee compliance. In particular, requirements for physical compensation of land take are not implemented much. To overcome these difficulties, some MS have developed their own **economic instruments**, to encourage inner development, through densification and recycling, or to optimise new developments on greenfields. Another leverage relates to **land governance and stewardship**, with the development of public-private partnerships and the creation of specific development agencies to raise awareness of land take issues and/or to acquire land in order to preserve its functions.

[41] The recent report from ETC/SIA provides extensive information on this issue across MS: Ludlow et al. (2013). Land Planning and Soil Evaluation Instruments in EEA Member and Cooperating Countries. Final Report for EEA - December 2013

3. Land recycling

This chapter provides evidence on the progress achieved to date in land recycling in the EU and on policy instruments introduced by MS to facilitate it. It contains an estimation of the potential for land recycling, identifies potential indicators that could be used for future monitoring and discusses the feasibility of establishing land recycling targets at an EU, national or regional level.

In brief

Land recycling is a key strategy to reduce land take. Previously developed land can be recycled either for the purpose of new economic use (commercial, domestic etc.), or in order to create green areas (for example by removing existing structures and de-sealing of soil). This first of all removes a demand for development of agricultural, forest and (semi-)natural land (i.e. land take), but also provides an opportunity to compensate for land take elsewhere. In addition to the redevelopment of brownfield land, there is a potential for further inner urban development in the EU, for example by making use of gaps between existing structures and densification of already developed land

No consistent or comprehensive datasets of brownfield sites or share of land recycled exist at an EU level. A review of the practices in the EU MS demonstrated that monitoring of land recycling in the EU is undertaken using either land cover data or brownfield land data. However based on the evidence identified in this study monitoring of land recycling is not a common practice.

The estimates of the brownfield area available in the EU suggest that land recycling can contribute significantly to the objective of no net land take. However these estimates are based on the very weak evidence which demonstrates that the current quality of data on land available for recycling in the EU, as well as current progress in land recycling, is very low. The initial steps at the EU level should be focused on improving the quality and availability of data on land available for land recycling as well as the share of land redeveloped in the MS.

Six potential land recycling indicators have been evaluated in relation to their potential for setting targets as part of this study. Monitoring against the indicator LR1: “Area of brownfield land” and LR2: “Total area of land within existing urban fabric which is available for inner development” would allow quantification of the extent to which land recycling could contribute to meeting the no net land take objective in the EU. In order to improve the quality of data on land recycling in the EU, the following instruments at the EU level should be investigated more closely:

- Implementation of a common definition of brownfield land in the EU;
- Introduction of the requirement on MS to establish a system to record and maintain up to date information on the area of brownfield land within their territories

In addition the European Commission should consider producing EU guidance on best practices in land recycling, which could suggest a range of common inventory approaches.

As for the remaining indicators for land recycling further investigation of the suitability of using CLC, CLC_r and the Urban Atlas data for the purpose of monitoring of land recycling could be undertaken. While these data sources are not considered sufficiently accurate to monitor land recycling or define potential land recycling targets in the short term, they may provide high-level estimates using datasets systematised and harmonised across the MS.

There has been little experience in the EU to date in implementing land recycling targets. Lessons learnt from the UK show that such targets need to be implemented with caution, in order to prevent undesirable impacts on the economy (e.g. property prices, housing stock supply), environment (e.g. soil sealing, biodiversity) and society (e.g. human well-being). Given existing data limitations, introduction of land recycling targets at the EU level, using any of the indicators assessed is not possible. Nevertheless, MS could consider implementing national or local level targets, subject to availability of local level data and results of assessments of potential impacts of such targets. A number of regulatory, market-based and non-regulatory instruments have proved successful in supporting land recycling in the EU MS to date. There is scope to improve the status of land recycling in the EU by encouraging further use of these instruments in MS, specifically: introducing sequential planning rules in national policies, issuing guidelines to ensure a coherent approach to monitoring, providing grants, setting up urban development funds and revolving loan funds, using tax incentives, setting up land development agencies and promoting public private partnerships.

3.1Introduction

3.1.1 Overview

Land recycling is a key strategy for limiting land take, as illustrated by the figure below. Previously developed land can be recycled either for the purpose of new economic use (commercial, domestic etc.), or in order to create green areas (for example by removing existing structures and de-sealing of soil). This removes a demand for development of new land (i.e. land take) and can also provide an opportunity to compensate for new land developed elsewhere. In the context of Chapter 2, this makes it a critical element of the framework for efficient management of land as a resource in the EU. Nevertheless, to date there have been no specific objectives set at the EU level to stimulate land recycling across MS.

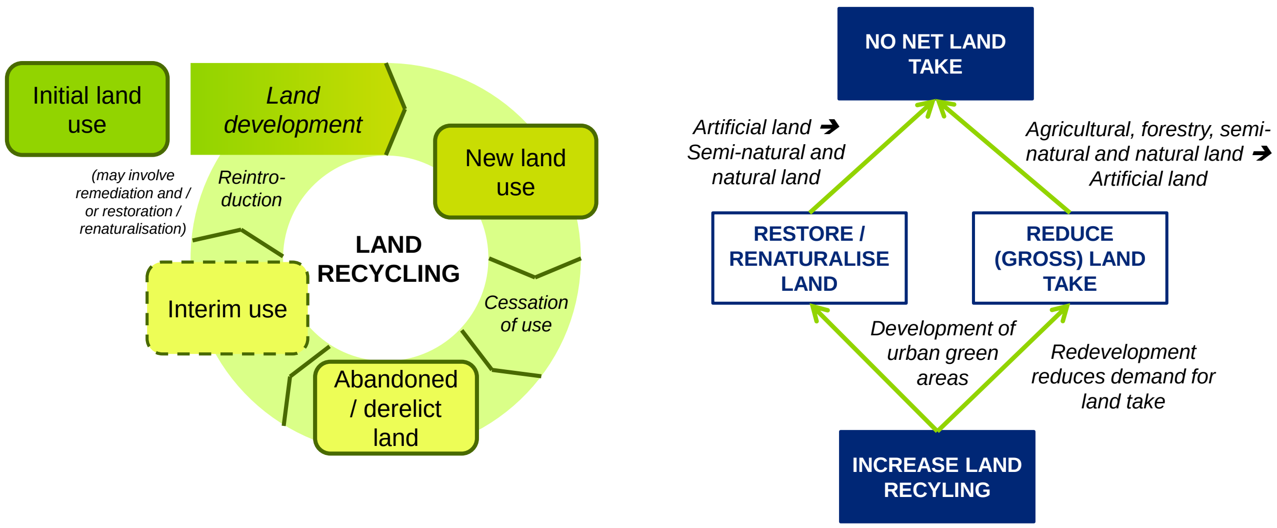

Figure 6: Land recycling and the link between land take and land recycling targets

Potential for land recycling is often discussed in the context of management of brownfield land and this is the primary focus of the assessment presented in this chapter. Brownfields are derelict, abandoned, vacant or underutilised sites, most commonly located in urban areas or in regions with an intensive industrial past. Brownfield emergence is associated with a decline in industrial production, migration of population away from less prosperous regions and availability of greenfield land for new development. For the purpose of this study land recycling comprises redevelopment of previously developed land (brownfield) for economic purpose, as well as ecological upgrading for the purpose of soft-use (e.g. green areas in urban centres) and re-naturalisation of land (bringing it back to nature) by removing existing structures and de-sealing surfaces. While some MS have already introduced policies and use other instruments to prevent brownfield creation and to facilitate its redevelopment, emergence of brownfields together with its associated economic, social and environmental impacts is still a new issue for many MS and regions in the EU (CircUse, 2013).

In addition to the redevelopment of brownfield land, there is potential for further inner urban development in the EU, for example by making use of gaps between existing structures and densification of already developed land (CircUse, 2013). While these approaches are not specifically covered by the definition of land recycling adopted in this study, they are also briefly discussed in this chapter.

3.1.2 Redeveloping brownfield land

Definition of brownfield

Brownfield land is not uniformly defined across the EU MS **and no definition has been adopted officially at the EU level**. Information gathered through the literature research and MS consultation for this study on how different MS define brownfield sites is presented in Annex 3. Given that in some MS a legal definition of brownfield has not been introduced, or an equivalent word for "brownfield" does not exist in the national language, information was also gathered on its national equivalent and common understanding of related terminology. For example brownfield is translated into Polish as "post-industrial site"[42], but common understanding of the term may also be "post-agricultural" land (see Annex 3). Such issues contribute further to the lack of common understanding of the term brownfield across the EU.

Analysis of the information on definitions and common understanding of brownfield reveals that in 15 MS (Austria, Belgium, Croatia, Czech Republic, Germany, Estonia, France, Greece, Hungary, Ireland, Latvia, Luxembourg, Netherlands, Romania, Slovakia) the term is associated with previously developed land / degraded areas. In four MS (Bulgaria, Finland, Slovenia, Spain (the Basque country)), the concept of brownfield land is associated with soil contamination. Information gathered for five MS (Italy, Denmark, Poland, Sweden and Ireland) does not allow for any clear conclusions on how the term is defined, due to a lack of common understanding of the term or inconsistencies across various sources. For the four remaining MS (Portugal, Malta, Lithuania and Cyprus) no information has been identified on what the common understanding of the term is.

The following definition of brownfield land was proposed in a 2006 study undertaken by the CABERNET[43] (Ferber et al., 2006): "*sites that have been affected by the former uses of the site and surrounding land; are derelict and underused; may have real or perceived contamination problems; are mainly in developed urban areas; and require intervention to bring them back to beneficial use*". The review of national level definitions undertaken as part of this study demonstrates low uptake of the CABERNET definition across the MS. A conclusion from Ferber et al. (2006) on the need for a clear and robust definition of brownfield land to be used across the EU remains valid.

Box 2: Why is a robust definition of brownfield land important?[44]

In 1998, the UK Government set a target that by 2008 60% of additional housing in England is to be provided on previously developed land or by re-using existing buildings. The definition used gave some flexibility in what could be classified as previously developed land and, for example, allowed residential gardens to be categorised as "brownfields". This encouraged construction of new housing in back gardens (phenomena often referred to as "garden grabbing"). To address the issue, in 2006 the UK Government specified exclusion of residential gardens from definition of "previously developed land" - old and revised UK definitions are presented in Annex 3.

The following definition of brownfield land is proposed for this study: **Derelict, underused or abandoned land which has been previously developed for industrial, commercial or residential purposes, and**

[42] See the Polish translation of the EC Guidelines on best practice to limit, mitigate or compensate soil sealing, http://ec.europa.eu/environment/soil/pdf/guidelines/PL%20-%20Sealing%20Guidelines.pdf
[43] Concerted Action on Brownfield and Economic Regeneration Network http://www.cabernet.org.uk/
[44] Source: Department for Communities and Local Government (2000) and Department for Communities and Local Government (2011)

which may have real or perceived contamination problems. This definition does not specify the location of brownfield land, therefore the additional concept of "urban brownfield" is proposed. Urban brownfield is limited to land within existing urban areas.

Brownfield land is characterised by varying redevelopment potential. The so called "A-B-C" concept, developed as part of project CABERNET (Oliver et al., 2005), categorises brownfields into category "A" – economically viable sites, redevelopment of which is driven by the free market and rely on private sector investment; category "B" - marginally profitable sites, redevelopment of which required public-private cooperation; and, category "C" – unprofitable sites, redevelopment of which requires public sector support (Oliver et al., 2005). While such categorisation of sites might be useful for local and regional authorities as well as municipalities from a planning and prioritisation perspective, it is not commonly used across MS. Evidence of a similar categorisation of sites has only been found in France and Germany (Jankových, 2005).

Brownfield redevelopment

In this study, **brownfield redevelopment** is defined as: Bringing brownfield land back into use. This involves one or more of the following: bringing the site back to the market without a change in land use, changing existing or past land use by integrating the site into the planning strategy for the local or regional area (this includes also re-naturalisation and de-sealing of brownfield land) and cleaning up existing soil pollution.

The key steps in redevelopment of brownfield land include: identification of the site, determining whether the site is contaminated and if remediation is needed; determining the new site use (domestic or commercial development, mixed development, recreational uses, re-naturalisation); obtaining necessary planning consents; remediating site if necessary; and finally undertaking redevelopment.

Due to the impacts of brownfields on surrounding areas (see section 3.2) they are not the sole problem of the landowner but also of the local community, municipality and local authorities (Ferber et al., 2006b). The main stakeholders involved in the brownfield redevelopment process are the government / local authorities, investors, developers and users of the land (Glumac et al., 2010). Initiatives to redevelop a site can be raised by an individual citizen, local NGOs, community groups or local politicians (Ferber et al., 2006b). The role of local authorities or private/public organisations is particularly important in cases of sites that are not sufficiently attractive to the private sector. National and regional governments can support the redevelopment process, through national initiatives, providing financial support or project guidance and regional spatial planning policy.

3.1.3 Using gaps between buildings and underutilised lots

While the primary focus of this chapter is on the redevelopment of brownfield land, other types of urban land could be considered for development before developing greenfield sites, thus contributing to the overall reduction in land take. Project CircUse (2011) identified the following land types as providing an opportunity for urban development (based on the categorisation proposed in Germany in Difu, 2006): gaps between buildings and scarcely developed lots. Definitions of these terms are not documented widely in the literature reviewed as part of this study. The consultation with MS experts provided the following definitions as used in Germany for the purpose of the study by the Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR, 2011) on the infill development potential of German cities:

- **Gap sites** are non-built-up sites that offer potential for development (individual plots as well as several contiguous plots) which lie within established or newly built settlement areas.
- **Underutilised lots** are parcels of land which are already built up, but which offer space for further development. Some examples are second row development, courtyard development as well as complementary buildings in residential, mixed-use and commercial areas.

It should be noted that suitability of such sites for development depends on the local circumstances and development pressures.

3.1.4 Existing barriers to land recycling

Over the last fifty years, the land use patterns in Europe have changed due to significant changes in the industrial sector (Ferber et al., 2006a). Europe has lost some of its historic industries, enterprises started downsizing and the services sector growing. More recently, brownfield emergence has been driven by the economic recession and demographic changes in cities and regions (referred to as shrinking) (Ferber, U., 2014).

In some regions of Europe, where a small quantity of brownfield exists and there is high **demand for land**, these would be absorbed by the local property markets and redeveloped. The demand for land in these regions mean that any abandoned land is generally re-introduced into the economic cycle without additional intervention. However in regions with a high level of abandoned or underused land and little demand for new development (in some cases due to a shrinking population), the property market may be too saturated, and unable to absorb newly created brownfields. This leads to **multiple brownfields being present in shrinking regions and cities** of Europe. While brownfield redevelopment can create an opportunity to make these places more attractive to businesses and local population, the opportunities to fill in the gaps between the supply and demand are often limited, for example due to high costs of redevelopment and other barriers as discussed below.

Availability of greenfield land for new developments is hindering land recycling, as development on greenfield remains cheaper and less risky compared to brownfield (CircUse, 2013). The sequential planning rule, in which redevelopment of previously developed land is considered first, is not yet a common practice across the planning authorities in the EU MS (Petríková & Vojvodíková, 2012). **Weak legislative frameworks and badly designed strategies and plans, specifically those addressing urban sprawl and controlling greenfield development** increase barriers for brownfield redevelopment by allowing developing on greenfield (Petríková & Vojvodíková, 2012). In this context, a target set in Germany to reduce growth in land use for housing, transport and related soil sealing to 30 ha per day by 2020 is highlighted as an example of a national policy encouraging brownfield recycling. Policy instruments used in the EU to support land recycling are discussed in further detail in section 3.5.1.

One of the possible reasons why planning authorities do not utilise land recycling potential, may be a **lack of information on the locations, sizes and types of brownfield sites** (Siebielec et al., 2012). Insufficient understanding of the potential for brownfield redevelopment makes it difficult for relevant authorities to design policies supporting land recycling efforts at the national, regional or municipal level, and monitor progress against possible targets and objectives. In addition to informing the policy makers, databases/inventories of brownfield sites may serve as a useful tool to promote the sites to potential private sector investors. In the absence of sufficient information, investors may prefer to delay redevelopment of brownfield land until more comprehensive data on the site becomes available (a delayed investment based on better information may be more profitable and carry less risk) (Paccagnan & Turvani, 2007). Monitoring of brownfield land and availability of relevant data in the EU is discussed in further detail in section 3.5.

Poor availability and quality of data on the areas of brownfield land can be linked to **limited funding available at municipal, regional and national levels** to undertake monitoring. For example until 2010 in the United Kingdom there was a dedicated officer at the national level authority responsible for maintenance of the database on the previously developed land in England[45]. Local authorities benefited from management support, as well as funding to help identify brownfield sites within their territories. However the resources available to this activity at the national level were reduced in 2010, resulting in only half the time of a full time member of staff devoted to these activities. The cuts also affected budgets, monitoring practices and possibility to deploy expert consultancy services by the local authorities.

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[45] Source: Information received from the Homes and Communities Agency as part of consultation for this study

At the local level, the main economic challenges associated with land recycling are also related **to land and property prices. Economic viability of an individual site** is a key driver for its regeneration (Urbact, 2013). In the municipalities and regions experiencing economic growth, high demand for land and high land prices this can often be sufficient to drive redevelopment of brownfield land (such sites would be categorised as “A” or “B” in the A-B-C model presented earlier). However in the shrinking regions and cities of the EU[46], where demand for land is low and/or where remediation of soil is required, redeveloping a brownfield site for commercial purposes at an acceptable cost may be challenging (Grimski and Dosch, 2009). In such cases, brownfield land could be turned to “second hand” natural areas (Grimski and Dosch, 2009) however this would generally need to be financed by the public sector (such sites would be categorised as “C” in the A-B-C model).

Availability of public sector finance to aid redevelopment of brownfields minimises the **investment risk** for potential developers. An analysis of several central European cities (Siebielec et al., 2012) demonstrated that despite brownfield redevelopment offering benefits such as existing infrastructure, investors may still prefer to locate new developments on greenfield due to lower overall risks of investment. Higher risks associated with brownfield redevelopment are linked to sites which are potentially contaminated. This is due to the uncertainty surrounding the costs of remediation (Ferber et al., 2006a). **Contamination of soil** on previously developed land may also have implications on the possible future use of the site for certain types of developments (for example, housing or children playgrounds) and finally due to negative public perception, despite remediation. The returns on such investments may be lower compared to development on greenfield land (CityChlor, 2012).

In case of more complex sites (for example larger areas with potential or confirmed contamination), redevelopment may be further hindered by **lack of sufficient technical and management skills** (Petríková & Vojvodíková, 2012). While the land remediation industry in Europe is well developed (Perez, 2012), some MS, specific regions or municipalities may still face problems in managing the private-public cooperation, securing required funding and co-ordinating interactions with other stakeholders involved (Petríková & Vojvodíková, 2012).

3.2Impacts of land recycling

Redevelopment of brownfield land, densification measures and use of underutilised lots can have different social, economic and environmental impacts. For example, utilising gap sites and underutilised lots would lead to greater densification of urban areas, which may have a number of (positive and negative) social and environmental impacts. The table below presents an overview of these processes indicating their potential impacts. They are further detailed in Annex 3 (Impact of land recycling).

Table 12: Overview of land recycling processes and key potential impacts

Land recycling process	Description	Overview of key impacts
Brownfield redevelopment	Bringing brownfield land back into use. This may, but does not have to, involve soil remediation.	+ Site value benefits + Increased neighbouring property values + Reduced exposure to contamination where remediation of soil is undertaken +Improved mental and physical well-being if brownfield is developed into green urban space

[46] Shrinking regions and cities of Europe can be characterised by declining revenues, rising unemployment, outward migration of economically active populations, surplus buildings and land, with infrastructure which is oversized for the population it serves (Urbact, 2013)

Land recycling process	Description	Overview of key impacts
		+ Positive influence on social cohesion and safety - Likely to result in denser development compared to development of new land (based on the UK evidence where nature of housing development changed from houses with gardens to flats thus changing the character of local areas) -/+ Varying impacts on biodiversity depending on local status -/+ Varying impacts on soil sealing depending on the type of development
		Joint impacts: + Reducing need for new infrastructure (although increased densification in urban areas will place greater pressure on existing services, but would potentially be more resource efficient) + Improved employment opportunities + Greater productivity of urban areas + Reduced urban sprawl and development of new land (land take) - Increased densification in case of redevelopment for commercial or housing use - Reduced flooding mitigation function of soil (depending on existing state of site e.g. may already be sealed)
Making use of gaps between buildings and underutilised lots	Densifying existing urban areas by making use of inner urban land currently undeveloped or not used in an efficient manner	+ Less land being turned over compared to development of new land, leading to lower releases of carbon stored in soil - Reduction in open spaces - Adverse impact on quality of life and personal well-being

3.3Trends in land recycling

This section discusses existing barriers to land recycling, current trends and future projections in the context of brownfield land creation as well as existing monitoring initiatives for land recycling. It concludes with an estimation of potential brownfield area available for the redevelopment in the EU and discussion of data quality and limitations.

3.3.1 Current trends

Trends in brownfield emergence

Over the last 50 years, Europe has been affected by globalisation, experienced a range of economic trends and social transition. This led to changes in social, political circumstances and lifestyle, all of which contributed to the changes in spatial development and land use patterns (CircUse, 2013) and creation of brownfield land.

Historical contribution of various industrial sectors to the economy of EU MS

For the purposes of illustrating some of the changes that took place in the economies of EU MS, relative importance of various economic sectors (industry, manufacturing, construction and mining and quarrying) has been analysed based on their historical Gross Value Added (GVA)[47] figures. To understand the trends in contribution of these various sectors to the EU economy, growth of the total GVA between the years 1996-2006 and 2007-2013[48], was compared with the growth in GVA in each sector between these years. It has been assumed that if the growth in sectoral GVA was lower than that of total GVA, the importance of a sector in a given MS decreased in favour of other sectors. If growth in sectoral GVA was higher than growth in total GVA, this suggests that sector was growing faster than other sectors of the economy and thus played a more important role in the economy of that Member State.

Between 1996 and 2006 the majority of EU MS experienced a decrease in the relative importance of industry, manufacturing and mining to their national economies. While direct correlation with emergence of new brownfield sites cannot be drawn based on this data, this declining trend may suggest that between 1996 and 2006 the majority of EU MS have experienced an increase in the emergence of post-industrial brownfields. For eleven MS (Austria, Belgium, Cyprus, Finland, France, Italy, Luxembourg, Malta, Slovenia, Sweden and United Kingdom) this trend could be seen over a longer time period between 1997 and 2013. Manufacturing continued to decrease between 1996 and 2013 in eighteen MS.

The importance of construction decreased between 1996-2006 in six MS (Austria, Czech Republic, Germany, Luxembourg, Malta and Poland). Between 2007 and 2013, a decline in construction was shown in 24 MS (likely reflecting the impact of the economic recession) with relative growth in the sector experienced only in Belgium, Germany and Sweden[49]. Mining continued to decline across Europe in the period from 1996 to 2013 in ten MS (Belgium, Czech Republic, Greece, Luxembourg, Malta, Portugal, Romania, Slovakia, Slovenia and United Kingdom). A few MS (Bulgaria, Cyprus and Denmark) experienced growth in the sector between 1996 and 2006, followed by a decline more recently. This may suggest that these MS may have seen a recent increase in mining brownfields (usually associated with large surface area and rural or semi-rural location).

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[47] Eurostat glossary provides the following definition: Gross Value Added (GVA) at market prices is output at basic prices minus intermediate consumption at purchaser prices; it is a balancing item of the national accounts' production account::

- GVA at producer prices is output at producer prices minus intermediate consumption at purchaser prices. The producer price is the amount receivable by the producer from the purchaser for a unit of a product minus value added tax (VAT), or similar deductible tax, invoiced to the purchaser.
- GVA at basic prices is output at basic prices minus intermediate consumption at purchaser prices. The basic price is the amount receivable by the producer from the purchaser for a unit of a product minus any tax on the product plus any subsidy on the product.

GVA can be broken down by industry. The sum of GVA at basic prices over all industries plus taxes on products minus subsidies on products gives gross domestic product. Gross value added of the total economy usually accounts for more than 90 % of GDP.

[48] 2012 for mining and quarrying

[49] No data was available for Bulgaria

Table 13: Historical trend in relative importance of selected economic sectors to the economy of EU MS

	Industry		Manufacturing		Construction		Mining	
	1996-2006	2007-2013	1996-2006	2007-2013	1996-2006	2007-2013	1996-2006	2007-2012
Austria	↓	↓	↑	↓	↓	↓	↑	↑
Belgium	↓	↓	↓	↓	↑	↑	↓	↓
Bulgaria	↑	↑	no data	no data	no data	no data	↑	↓
Croatia	↓	↑	↓	↓	↑	↓	no data	no data
Cyprus	↓	↓	↓	↓	↑	↓	↑	↓
Czech Republic	↓	↑	↑	↓	↓	↓	↓	↓
Denmark	↑	↓	↓	↓	↑	↓	↑	↓
Estonia	↓	↑	↓	↓	↑	↓	↓	↑
Finland	↓	↓	↓	↓	↑	↓	↑	↑
France	↓	↓	↓	↓	↑	↓	↓	↑
Germany	↑	↓	↑	↓	↓	↑	↓	↑
Greece	↓	↑	↓	↑	↑	↓	↓	↓
Hungary	↑	↓	↑	↑	↑	↓	↓	↑
Ireland	↓	↑	↓	↑	↑	↓	↓	↓
Italy	↓	↓	↓	↓	↑	↓	↓	↑
Latvia	↓	↑	↓	↑	↑	↓	↑	↑
Lithuania	↑	↑	↑	↑	↑	↓	↓	↓
Luxembourg	↓	↓	↓	↓	↓	↓	↓	↓
Malta	↓	↓	↓	↓	↓	↓	↓	↓
Netherlands	↓	↑	↓	↓	↑	↓	↑	↑
Poland	↓	↑	↓	↓	↓	↓	↓	↑
Portugal	↓	↑	↓	↓	↑	↓	↓	↓
Romania	↓	↑	↓	↓	↑	↓	↓	↓
Slovakia	↑	↓	↓	↓	↑	↓	↓	↓
Slovenia	↓	↓	↓	↓	↑	↓	↓	↓
Spain	↓	↑	no data	↓	no data	↓	no data	↓
Sweden	↓	↓	↓	↓	↑	↑	↑	↑
United Kingdom	↓	↓	↓	↓	↑	↓	↓	↓

Socio-economic changes in EU urban areas

It has been estimated that 40% of European cities with populations over 200,000 inhabitants have lost significant parts of their population in recent years (Urbact, 2013). Population and economic decline has been experienced by almost half of all medium-sized cities in Europe (Bernt et al., 2012). Because of the population migrating out of the urban areas, cities see rising unemployment, declining revenues, excess of unused land and buildings and infrastructure too excessive for the population it serves. The so-called "shrinking" of the cities, despite large regional variation in Europe, is a result of demographic changes and concentration of economic activity in only a small selection of cities. Emergence of brownfield sites is closely linked to socio-economic drivers for land take (described in detail in chapter 2), specifically to locating new housing and economic activities at the outskirts of the cities (e.g. locating a new shopping centre at the outskirts of the city contributes to additional land take, while putting shops within city boundaries out of business and creating diffuse brownfields within the urban areas). People employed in the city centres often live at the outskirts (in some cases up to 80% of the population employed in the city centres), creating a need for travelling to work and to access health, social and cultural services (European Commission, 2011a). Despite these trends, analysis of the evolution of cities between 2000 and 2006 concluded that densification processes (reliant on redevelopment and infilling) were slightly increasing in Europe (ESPON, 2012).

Trends in land recycling

Brownfield creation is a dynamic process, with new brownfield being created while others are brought back into use. As an example, an annual increase in industrial/commercial brownfield land in Austria was estimated at 1,100 ha (Siebielec et al., 2012). Furthermore, according to an expert involved in brownfield redevelopment in the Ruhr region of Germany the existence of between 9,000 and 10,000 hectares of brownfield land was estimated in the 1990s. In the last 20 years, the overall area of brownfield land in that region remained more or less unchanged. Progress in land recycling varies depending on the country and locality. For example in the region of Ile-de-France (the region of Paris), urban development is now primarily delivered through recycling of previously developed land.

Box 3: Progress in land recycling in the region of Ile-de-France[50]

Based on the 2012 land cover survey of the region, in 2012 for the first time urban development was primarily delivered through land recycling, with approximately 1,500 ha per annum redeveloped in the period 2008-2012 (approximately 61% of all new land development was on previously developed land). In the previous update of the survey, land recycling has already been a main source of land for new urban development in Paris; however this trend expanded to the rest of the region between 2008 and 2012.

The latest survey estimated that in the same period, 281 hectares per year of artificial land were re-naturalised (this was realised primarily by transformation of old waste sites and quarries). The urban strategy for Ile-de-France (*Schéma Directeur de la Région Ile-de-France*) includes a target to deliver 70,000 new houses by 2025, which represents 79 housing units per hectare by 2025. 75% of this target is to be delivered through densification of existing built environment.

Data on previously developed land in England has been collected from 2002 onwards, with the latest data available for 2010. Figure 7 below presents changes in the area of previously developed land during that time. As shown, the area occupied by vacant and derelict buildings decreased between 2002 and 2008, but increased again between 2009 and 2010, possibly because of the economic downturn affecting property markets.

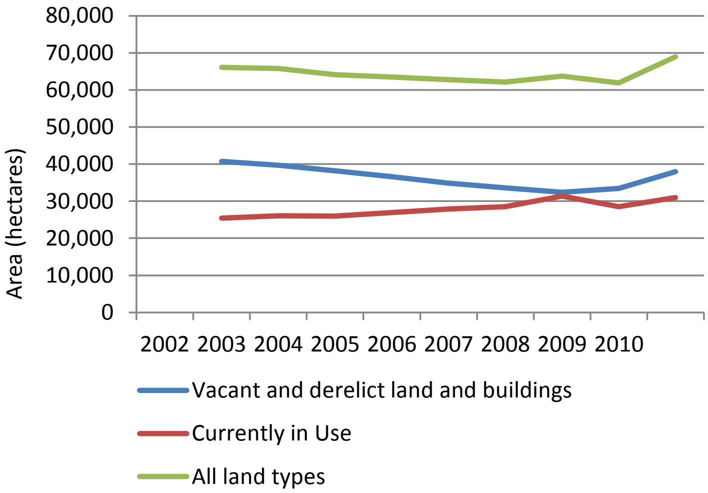

Figure 7: Trends in previously developed land in England 2002-2010[51]

[50] Source: Consultation with a representative of L'Institut d'aménagement et d'urbanisme de la région d'Île-de-France and information published on www.iau-idf.fr/cartes/mode-doccupation-du-sol-mos.html

[51] Source: HCA (2010)

Information on 100 successfully redeveloped brownfield projects across a selection of MS, collected as part of the EU-funded FP7 project Timbre (Frantal et al., 2012), illustrates some of the recent trends in brownfield redevelopment in Europe: 66% of the redeveloped sites covered by the study were previously used for industrial purposes, 17% were used for transport and the remaining for military and mining (5% each), business (3%) and cultural and sport activities (2% each). Around a third of the sites were developed for multifunctional purposes and about a fifth for cultural facilities (galleries, museums, etc.). A trend to redevelop post-industrial sites into cultural amenities has been particularly visible in EU MS (UK, Spain, Austria, Netherlands, France and Slovakia).

3.3.2 Projections of future brownfield emergence and land recycling

No clear projections for future trends in land recycling or emergence of brownfield have been identified in the literature or through the MS consultation. Progress in land recycling is expected to depend on the future availability of brownfield land and demand for it. These are likely to be governed by future changes in population, urbanisation, land take and industrialisation. Evidence presented below shows that impacts will not be distributed uniformly across the EU, resulting in different types of drivers for land recycling across the EU MS and regions.

Future population and migration trends

Land recycling is likely to increase in importance given that the population in Europe is expected to grow by 3.5% and 3.8% by 2030 and 2050, respectively, with high differences among MS (based on the EUROPOP-2010 dataset). Projections of changes in population of the EU MS are illustrated in Annex 3. Rising population in Europe is likely to be associated with increased pressure for new housing and infrastructure, thus putting greater pressure on land resources, especially in MS that are already densely populated, such as the United Kingdom, Netherlands or Cyprus.

Intra- and extra-EU migration, which is expected to be a driving force behind changes in local population up to 2050 (ESPON, 2013b), will put a greater pressure on local land resources. The ESPON project DEMIFER[52] analysed the impact of migration on European cities and regions by comparing a scenario based on the current migration rates with a no migration scenario. The key findings of the study were that future migration will benefit already wealthy regions of Europe, while poor regions are expected to continue losing population. In 2050, the majority of regions of Lithuania, Latvia, Estonia, Bulgaria, Poland, Romania, Czech Republic and Slovakia, as well as some regions of Germany, France and Finland, are expected to lose population due to migration. On the contrary, the majority of regions of Spain, France, Italy, Belgium, the Netherlands, Greece, Croatia and the United Kingdom are expected to see an increase in population due to migration. These results suggest that the problem of shrinking regions and cities may deepen towards 2050, and the problem of brownfield emergence may persist in regions negatively affected by future migration trends. Furthermore, demand for land in regions experiencing surplus migration may increase, thus escalating the importance of reusing previously developed land.

Urbanisation and land take projections

Modelling of urbanisation trends, undertaken by the JRC (2013b) with regard to changes to Cohesion Policies, showed that in the period until 2030 *"the rates of urbanization are generally higher than those of population growth"* in Austria, Czech Republic, Germany and Poland under all scenarios modelled. The results suggest that urban sprawl is likely to continue in these countries, with greater land area required per person and household.

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[52] Demographic and Migratory flows Affecting European Regions and Cities

The increase in urban sprawl is in line with the results of another study by the JRC (2013a and 2013g), as mentioned in 2. If legislation limiting land take in the EU is introduced, land recycling will be one of the tools enabling MS to meet this objective.

Future changes in EU industrial patterns

The past trends demonstrated that emergence of brownfields, as well as the rate of their redevelopment, depends on the overall economic performance of a city, region or country, with a greater chance of brownfields being created during periods of economic downturn. In addition, the problem of brownfields in Europe emerged partly as a result of changing industrial patterns, with the decline of some industries in favour of, for example, the services sector. It is not possible to predict how the EU industry will develop in the next 15-35 years and how this will influence emergence of brownfield land. Nevertheless, based on existing tools for modelling future changes to the EU economy, some potential future trends can be identified.

Information on the future contribution of industry to the EU economy (expressed as GVA) has been investigated from the Reference Scenario 2013[53] developed for the purpose of modelling of the EU Energy Transport and GHG Emissions Trends to 2050 (EU, 2013d). The socio-economic assumptions used to create the scenario were modelled using GEM-E3[54]. GVA projections were available beyond 2010 up to 2050.

To understand the trends in contribution of industry to the EU economy, growth of total GVA between the years (covering industry, construction, tertiary and energy and other sectors), was compared to the growth projected for GVA for industry only. As for the discussion of historic trends above, it has been assumed that if the growth in industry GVA is lower than that of total GVA, the importance of industry in a given MS will decrease in favour of other sectors. If industry GVA is higher than total GVA, this suggests that industry will be growing faster than other sectors and thus will play a more important role in the economy of a Member State.

In the period of 2010-2030, industry is expected to grow faster than the total economy only in five MS (Greece, Hungary, Poland, Romania, Slovakia and Slovenia). Out of these MS, only Poland and Slovenia will continue to experience growth in industry in the period of 2030-2050. Growth in industry GVA in Bulgaria and the Czech Republic will be slower than that of the overall economy up to 2030, but is expected to exceed it between 2030 and 2050. For the EU-28 as a whole, industry overall will grow at a slower pace than the rest of the economy and this difference is expected to further deepen between 2030 and 2050. Figures presenting the projected growth between 2010 and 2030, and 2030-2050 for each Member State are presented below.

[53] This scenario mirrors the DG ECFIN projections for short and medium term, and the EPC/DG ECFIN Ageing Report 2012 for the long run (EU, 2013d). Based on the information provided in JRC (2013g) this is consistent with the reference scenario proposed for the land use modelling platform (LUMP).

[54] General Equilibrium Model for Energy-Economy-Environment interactions

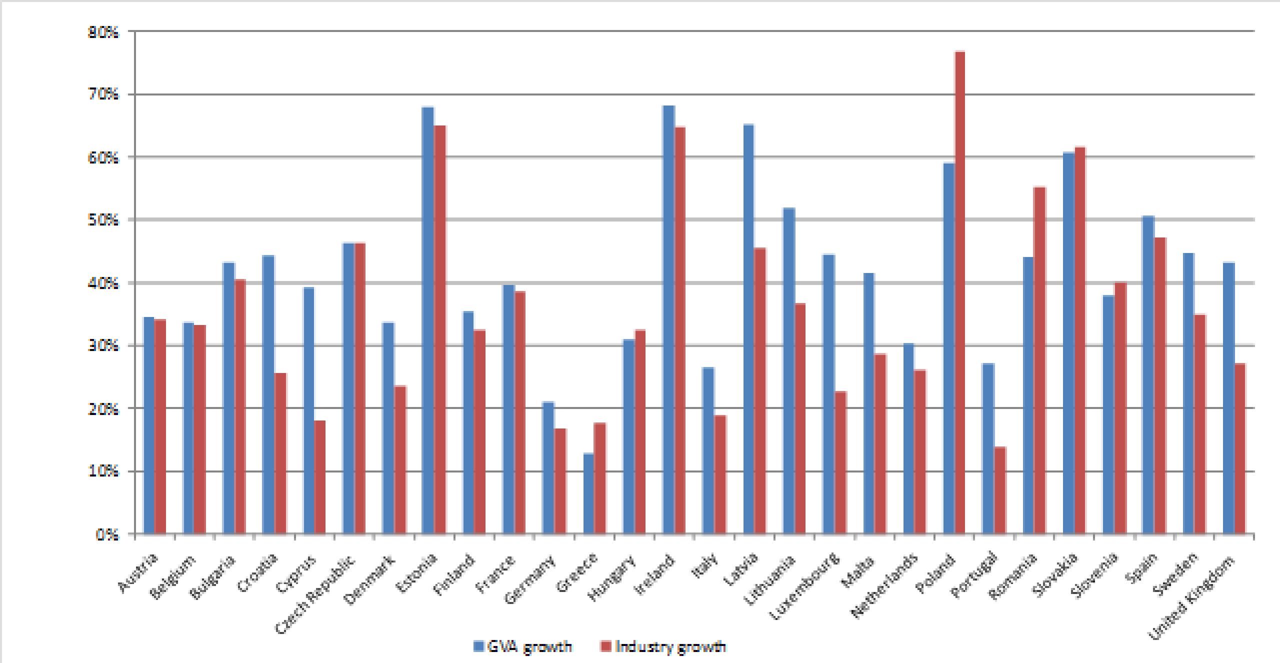

Figure 8: Projected growth in GVA in EU MS between 2010 and 2030

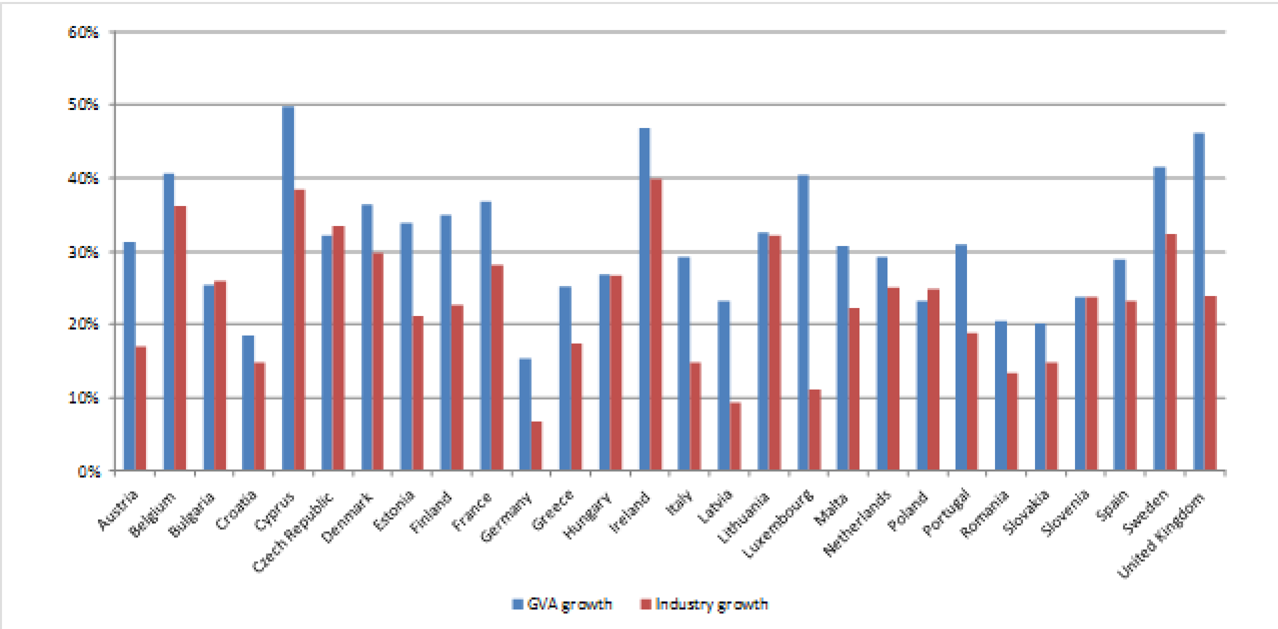

Figure 9: Projected growth in GVA in EU MS between 2030 and 2050

While it is impossible to clearly correlate the GVA projections with emergence of brownfield land in the EU, the above information suggests that industrial patterns in Europe will continue to change, with industry playing a smaller role overall in the economy of the majority of MS. In this context, emergence of post-industrial brownfield land is likely to continue in Europe up to 2050

3.4 Monitoring of land recycling and estimating the potential

3.4.1 Overview of monitoring practices

Monitoring of land recycling in the EU is undertaken either by using:

- **Land cover data:** in this approach, differences in land cover between the years are used to estimate the share of development delivered on previously developed land / brownfield, compared to new land.
- **Brownfield land data:** in some MS (for example in the Czech Republic, Germany, United Kingdom) inventories of brownfield land or land use management databases have been prepared at the municipal, regional or national levels. These serve as a source of information on the area of brownfield land, and in principle provide a facility to monitor the progress in their redevelopment (this is dependent on how regularly the database is updated).

While these two approaches are not mutually exclusive, data they provide may not be directly comparable due to differences in scales (e.g. land cover monitoring may not be sufficiently detailed to be compared against local inventories of brownfield land). In the context of land recycling targets, monitoring should provide the necessary information across MS to determine and compare progress in land recycling (depending on the indicator used for target setting, this could involve information on brownfield area, brownfield area redeveloped etc. – see section 3.5 discussing potential indicators). Considering the no net land take target, monitoring of land recycling would provide the necessary information to determine how much it could contribute to achieving the target.

Using land cover data to monitor how much land is recycled

At the EU level, a methodology to calculate the share of land recycling using land cover information, based on changes between the Corine Land Cover (CLC) 1990 and 2000, has been proposed by the EEA (2006b). The approach was based on the land use stock and change account for European land cover using CLC layers 1, 2 and 3, and identification of the processes which have resulted in the flows between the different stocks of land cover (EEA, 2006b). Based on that assessment, EEA (2006b) estimated the percentage of land recycling as a share of total land consumption by artificial development between 1990 and 2000. This was based on information on total artificial areas created through the flows of land cover identified as: urban development / infilling, recycling of developed urban land and development of green urban areas excluding construction sites, as well as artificial areas created through sprawl of economic sites and infrastructures. The estimated share of land recycling as part of the total artificial area was 2.3-2.5% depending on the flows considered.

It is worth stressing the limitations of using land cover data to estimate progress in land recycling. Based on the land cover monitoring data it is currently not possible to estimate potential area of brownfields sites available for redevelopment. Given its relatively coarse resolution, CLC can provide only a very aggregated (yet pan-European) estimate of land recycling. It should be noted that the underlying data does not take account of changes in land cover lower than 5 ha and the majority of existing brownfield sites in Europe are expected to be below this threshold. At the time of writing this report, the EEA was exploring the application of a similar methodology using the Urban Atlas[55] data which are collected using a finer spatial resolution. As discussed in Chapter 2, land cover monitoring at a Member State level is often undertaken at a higher resolution and thus provide more detailed assessment of land cover changes than is available from CLC

[55] The European Environment Agency (EEA) collects land use and land cover data for Large Urban Zones with more than 50,000 inhabitants as part of the Urban Atlas. The information on urban land use is collected by sensors with spatial resolution of 2.5 m; the minimum mapping unit is 0.25 ha for core urban zones and 1 ha in the urban fringe. The resolution used in the Urban Atlas is 100 times higher than CLC (Prastacos et al., no date). The most recent maps are available for 2006. 2012 maps were under preparation at the time of writing this report.

layers at the European scale. An example of using more detailed, but CLC compatible, land cover data to estimate a share of land recycling has been identified in the region of Ile-de-France.

Box 4: Monitoring of land recycling in the region of Ile-de-France based on the land cover data[56]

The land cover statistics in the region of Ile-de-France have been produced since 1982 and have been updated every four years. The frequency of updates has been aligned with updating information in the population census. The latest land cover survey has been undertaken in 2012. The following steps are undertaken to produce the new land cover survey and identify share of land that is recycled:

- Aerial photographs are used to produce new land cover information. In theory, four days of good weather are sufficient for the contractor to take photographs of the whole region (cover the total area); however, due to the high aviation traffic a lack of available flying slots may extend this period significantly.
- Following refinement of photographs by the contractor, comparison of the latest aerial photographs with the results of previous surveys is undertaken in-house.
- Identification of the urban land which has not been developed or changes in type of development (e.g. through redevelopment of brownfields) are identified based on the aerial pictures only. On-site verification is not undertaken, unless certain areas or sectors are specifically targeted. The total area of brownfield land available for redevelopment is not monitored or identified using the aerial pictures.

The land cover survey is managed by a single member of staff, with support of an in-house GIS team. There is no specific funding provided for conducting the land cover survey or assessment of land recycling. Indicative costs of producing the updated land cover based on the steps outline above is EUR 30 per km^2.

Inventories of brownfield land

Inventories of brownfields are most commonly created at the municipal or regional level, with the overall figures sometimes being collated by national level authorities. For example in England, the Homes and Communities Agency (HCA) annually collects data on the area of previously developed land from the local authorities, and publishes high level analysis and figures on its website (full inventory of sites is not available in the public domain). While inventories of brownfield land do not on their own promote land recycling (VŠB, 2010), they provide the necessary baseline data which informs local, regional and national strategies and policies.

The quantity of information that needs to be collected in an inventory varies depending on its purpose. For example if a municipality wants to promote existing brownfield sites to potential investors, a more extensive set of information on each site may be required. However, building more comprehensive inventories also leads to greater costs of keeping the inventory up to date (VŠB, 2010). In contrast, for policy making, inventories serve as a tool to assess the redevelopment potential and severity of the issue (as well as tracking progress in redevelopment), thus only basic information on sites are required.

The process of drawing up inventories of brownfields at the regional / municipal level is expected to include the following (Frantal et al., 2012):

- **Identification of the potential sites** – as a first step, sites which are suspected to be brownfields could be identified using aerial or high resolution satellite images. For example in Leipzig (Germany), brownfield surveys are based on the real estate GIS information and colour infrared images[57]. Pricing of satellite imagery will depend on several factors, such as areas covered, location and time. Satellite images can be obtained at resolution as low as 1 m but these are more costly compared to

[56] Source: Consultation with a representative of L'Institut d'aménagement et d'urbanisme de la région d'Île-de-France and information published on http://www.iau-idf.fr/cartes/mode-doccupation-du-sol-mos.html
[57] Source: Response from the German Environment Agency to MS consultation

coarser resolution images. Satellite imagery reveals different surface features, but they generally do not allow identifying whether a site is currently in use or abandoned. To some extent, for example in the case of buildings used for commercial purposes and depending on the time of the day the images are taken, it can be possible to determine if a site is in use by for example identifying cars parked outside the structure; however this requires a detailed interpretation of pictures. Cost of interpretation of images depends on whether it can be done in-house by the relevant authorities or whether external contractors are required. The cost will further depend on the area under assessment, how detailed classification of land is applied and whether the process requires setting up a new database / GIS system. Research into identifying brownfields based on satellite imagery and lighting information is currently being conducted[58].

- **Data collection –** this includes collection of basic information on the site, for example current ownership, previous use, total area etc. This may involve an on-site survey to confirm the status of the building and/or consultation with local authorities (e.g. for example planning departments at municipalities). Other information sources may also be useful to verify the status of the site, such as land, tax and/or employment records (e.g. checking if anyone is employed under a given address may provide indication on whether the site is in use). In Leipzig, the site surveys are used as a calibration for remote sensing studies. This allows using remote sensing to investigate larger areas than would be possible by on-site surveys only.
- **Mapping of existing brownfields within territorial administrative units (regions, cities etc.) –** this is more likely to benefit the local planning authorities, rather than being required for the purpose of monitoring the progress in redevelopment of sites at a higher administrative level. For example, the database of previously developed land in the UK does not involve mapping of the sites. Instead, local authorities are required to report total area of sites identified to the central government department (though it has to be recognised that methodologies used and amount of resource applied to gather data varies according to each local authority).

Developing an inventory of brownfield land is generally cheaper in cases where underlying data can be derived from existing GIS layers (VŠB, 2010). If an on-site survey is undertaken as part of the inventory development, the costs will vary depending on the area that needs to be surveyed and the level of detail gathered. With varying labour costs, large discrepancies in costs of surveying are expected across EU MS, as well as across the regions of a single country. The costs quoted in VŠB (2010) vary between EUR50 - EUR500 per site depending on the complexity of the inventory. Underlying assumptions for these costs are not clear from the reference document. Other costs may be associated with setting up the database and keeping the information up to date. An expert in brownfield management consulted as part of the study indicated that more frequent maintenance of the information (e.g. on an annual basis) is considered more cost-effective compared to less frequent updates. In practice, surveys of brownfields are undertaken less frequently; for example in Leipzig a detailed survey of brownfield sites is undertaken every 5 years[59].

[58] This research was mentioned by one of the experts in brownfields management consulted as part of this study. Examples of specific projects have not been identified.
[59] Source: MS consultation

Data on monitoring initiatives and area of brownfield land in the EU MS

No consistent or comprehensive datasets of brownfield sites or share of land recycled exist at an EU level. National estimates on the area of brownfield land in some Member State have been identified through literature research and the MS consultation undertaken for this study. The following observations can be made on the **availability and quality of the national level data**:

- No estimates on either the number or area of brownfield sites have been identified for nineteen MS. Aside from information for Germany (which takes into consideration gap sites as well as brownfields), no estimates have been identified for other MS with regards to other types of land available for recycling.
- In MS for which data has been identified, the information has not been updated regularly and as a result is often out of date. In a few instances, MS (for example France, Belgium Flanders) indicated that they are in the process of collating more recent data but results were not made available in time for this study. There have been no examples where brownfield land has been categorised based on its development potential, for example using the A-B-C model.
- Comparability of data collected from MS is very low due to different definitions of brownfield land used, different criteria to classify land as brownfield and varying data collection methods.
- Data on progress in management of brownfield sites (e.g. rate of their redevelopment) is generally not monitored across MS.
- There are inconsistencies in data collected from regions and municipalities within a single Member State, which limits comparability of data and undermines the robustness of national level estimates. For example in Germany, numerous initiatives exist at the state, regional and municipal level to investigate the potential for inner city development (which includes brownfield land estimates). These differ in terms of the approaches and spatial features considered (e.g. gap sites, brownfields, abandoned buildings, underutilised or inappropriately used lots).

Available national level data on brownfield sites as well as an overview of existing monitoring initiatives across the EU MS is presented in Annex 3.

Current quality of information on the land available for recycling in the EU is very low. There is limited evidence available on the monitoring activities undertaken by the EU MS. Where data has been identified at the national level, a common practice appears to be to collate municipal or local level information.

While evidence collected as part of this study is insufficient to draw clear conclusions on the quality of local data, it appears that best available information on brownfield sites resides with municipal level authorities or agencies. The main challenge appears to be in collating and comparing the information from municipalities or regions in order to provide a comprehensive view of the situation at a national level. Other factors that determine suitability of land for redevelopment, for example its ecological value, is also not captured in the information available.

The following challenges are associated with using data from regional / national brownfield inventories for EU policy making:

- There is no single definition of brownfield land in the EU and often at the national level resulting in inconsistent data;
- There is no single methodology for the development of an inventory; and
- Categorising land as brownfield often relies on subjective judgement of the surveyor (VŠB, 2010).

3.4.2 Estimating the potential for land recycling in the EU

This section presents estimations of the total potential area of land available for recycling in the EU.

Estimation based on the national level data

Information identified at the national level in MS, as presented in Annex 3, has been used in order to estimate the potential area of brownfield land in the EU-28. This approach only provides an indicative estimate and the following issues should be considered when interpreting the estimates:

- Underlying data is available for only nine MS[60]. Given lack of information for the majority of MS, and a weak quality of data for those MS where data was identified, the results presented are highly uncertain.
- Due to the lack of a common definition of brownfield land and methodologies to collect the data across MS, the information is inconsistent and not directly comparable. In addition, the information used for estimating the potential has been gathered across different years.
- The area of brownfield land in MS changes each year, with new sites emerging and others being redeveloped. The estimates presented are based on the situation in MS at the time when the initial data was collected.
- The consultation with Member State experts has not revealed any recent national estimates for the area of brownfield land (though for Germany recent estimates of the inner development potential has been provided); in a number of instances MS highlighted that national level estimates were not available. While it is acknowledged that the data used may not represent the current situation well in MS, and does not reflect the progress achieved in redevelopment of sites since this data was collected, it is considered to be the best information currently available at national level. As data at the national level is not collected methodologically and at regular intervals across MS, it is impossible to comment on the time between the collection and publication of this information.
- The approach to extrapolating data assumes the same share of brownfield land across the MS, based on average values for countries for which data was available. Due to very limited availability of information, the estimates could not take into account the actual potential to redevelop these sites (e.g. consider what share of the sites is likely to be contaminated), types of brownfield sites (e.g. by calculating share of industrial, military brownfields) or their location (e.g. urban versus nonurban).
- Brownfield land may have different impacts across MS depending on the local social, economic and environmental circumstances. For example, 1 ha of brownfield land in a densely populated country will have a different impact and redevelopment potential than 1 ha of brownfield in the more sparsely populated country.

Quantitative data presented in Annex 3 were used as a source of information for existing area of brownfield land across the MS.

Step 1: Initial validation of data

Where information on the number of brownfield sites and total brownfield area were available, an average size of brownfield site was calculated. For MS where only a number of brownfield sites was available (e.g. Slovakia, Poland), the average area was used to determine the possible total area of brownfield sites.

Based on data for seven MS (Austria, Belgium (Wallonia), Czech Republic, France, Netherlands, Germany, Sweden), an average size of a brownfield site was estimated at 0.9 ha (9,000 m^2). The average size of a brownfield site varied between MS from 0.09 ha (900 m^2) for the Netherlands to 4.4 ha (44,000 m^2) for the

[60] Data for Poland was not included in the baseline for extrapolation. The underlying figures for Poland were suggesting an average area of brownfield multiple times higher than for other MS.

Czech Republic, indicating that the actual size of brownfield sites may vary considerably between MS but also reflecting the low quality of data and inconsistencies across the countries[61].

Step 2: Calculating factors for data extrapolation

Official EU statistics sources were considered for selection of possible factors for data extrapolation. The following factors based on information available from Eurostat were shortlisted: total land cover (based on LUCAS2012); total artificial land cover (based on LUCAS2012); area of land used for industry, mining and transport use, services, recreational and residential use (based on LUCAS2009); total population and GDP.

The latter two factors were excluded on the basis that they are not linked to land area, and as such clear correlation with the area of brownfield land cannot be drawn. Area of land used for industry, mining and transport use, services, recreational and residential use was considered to be most suitable on the basis that brownfields are created on land used for these activities. However, the EU-aggregated data for this indicator were not available from Eurostat for EU-27 countries (based on LUCAS2009, no data was available for Bulgaria, Cyprus, Hungary, Malta and Romania; for LUCAS2012 no aggregated results for land use were available), therefore this indicator could not be used.

Extrapolation factors using the total land cover and total artificial land cover information (based on LUCAS2012) were calculated as average values based on available information for MS. No assumptions on the level of soil sealing were made[62].

The following extrapolation factors were obtained:

$$Extrapolation\ factor\ (\%) = \frac{\sum area\ of\ brownfield\ land\ across\ MS (hectares)}{\sum total\ land\ cover\ or\ total\ artificial\ land\ cover\ across\ MS\ (hectares)} \times 100\%$$

Table 14: Extrapolation factors

Method	Extrapolation factor (low)	Extrapolation factor (high)
Based on total land cover	0.10%	0.19%
Based on total artificial land cover	1.79%	3.43%

Step 3: Estimation of total brownfield area in the EU

For MS for which brownfield data was not available, area of total land cover and artificial land cover were multiplied by respective extrapolation factors from Table 14. Combined with existing data on brownfield areas in the EU, it gives an estimate of around 356,000 to 815,000 ha of brownfield land, which represents between 1.5 to 3% of the total EU artificial land cover (according to LUCAS2012).

[61] Large variation between the average site sizes has also been concluded from the assessment of successful redevelopment projects as part of project Timbre (total area covered by the projects was 4,000 hectares). The study concluded that regeneration projects in the UK had the largest average area per project, followed by Poland. The smallest projects were identified in Portugal, Slovakia, Slovenia and Austria.

[62] No single assumption on the level of soil sealing for brownfield land can be made at the EU level. Depending on the type of brownfield land, these can vary from 0% to a 100%. Artificial areas are defined according to LUCAS.

Table 15: Estimates of total brownfield area available for development in the EU (ha)

Method	Range of total brownfield area available for development in the EU (ha)
Based on total land cover	424,322 – 814,802
Based on total artificial land cover	356,012 – 683,630

Due to the lack of information on the total area of land other than brownfield (but available for development e.g. gap sites) across EU MS, estimation of the total potential for inner development in the EU is not possible. The only figures considering total area of brownfield, gap sites and underutilised lots were available for Germany, where the infill potential has been estimated at between 15 and 20 m^2 per inhabitant (BBSR, 2011). 56% of the total infill potential in Germany was associated with gap sites and 44% with brownfields, with high regional differences (BBSR, 2011). If these figures were combined with the total population of the EU[63], it would result in the total area for infill development of between 761,000 and 1,014,000 ha. Due to data limitations, more accurate estimations are not possible at this stage. The estimates suggest that there is a significant potential for land recycling across the EU, however due to low quality of underlying information available these are highly uncertain and cannot be relied upon for the purpose of target setting.

The figure below presents a summary of the potential total area of brownfield (in hectares) estimated for EU MS, indicating the quality of underlying data on the area of brownfield sites.

The criteria used for the assessment of data quality were as follows:

- Weak - Data on area of brownfields was collated / estimated before 2009 (more than five years old), was based on unofficial figures found in the literature or calculated based on quantity of brownfield sites (using average area of brownfield). Figures were not confirmed by the MS experts.
- Good - Data on area of brownfields was collated / estimated in the last five years and was sourced from websites of national level authorities (e.g. national databases) or obtained through the consultation with Member State experts.
- No data - For MS were no data was identified in the literature or through the consultation with Member State experts, the estimates presented are based on the extrapolation exercise.

[63] Assumed population of 507,162,571, based on provisional 2013 figures published by Eurostat.

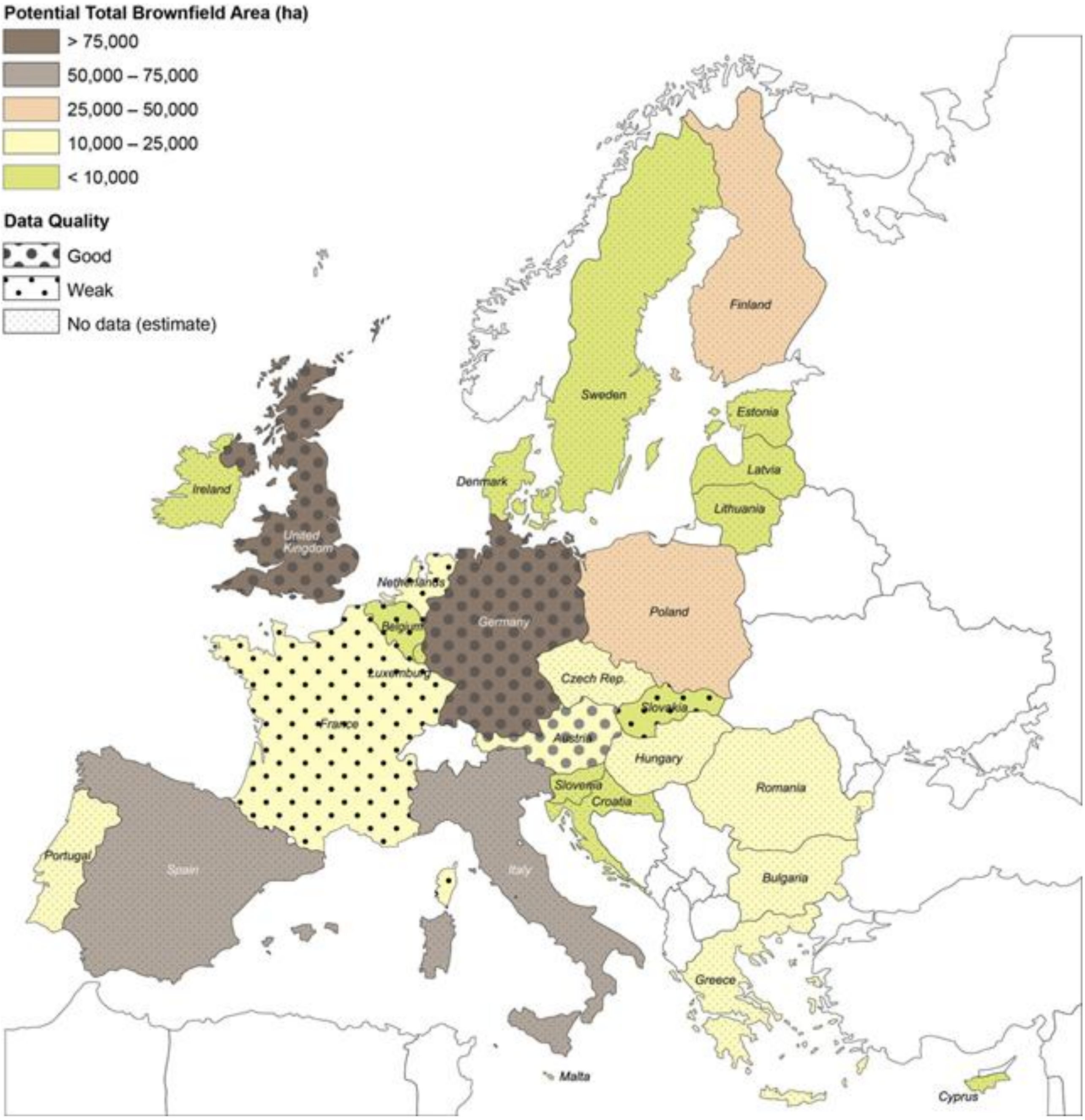

Figure 10: Estimated potential total brownfield area in the EU

Illustration of the potential based on a sample of European cities

In light of the weak data available for MS at the national level, information on brownfield areas in a small sample of European cities were identified to examine potential for urban brownfield redevelopment. It should be noted that the fact that one city has a certain area of brownfields may not adequately reflect whether the problem of brownfield land in that city is significant (VŠB, 2010). Therefore, the city level potential is discussed in terms of share of brownfields (%) as part of the total area of the city. Analysis of information for thirteen UK and four German cities showed that brownfield land constitutes between 0.3% - 6.6% of the total area of cities. The cities in Figure 11 are illustrated in order of population density (with London having the largest number of inhabitants per hectare to the far left, and Aberdeen with lowest population density to the far right). High population densities in cities suggest greater pressure on land resources and as a result, lower share of brownfield land. Nevertheless the analysis of available data does not support this relationship (although it is based on a small sample).

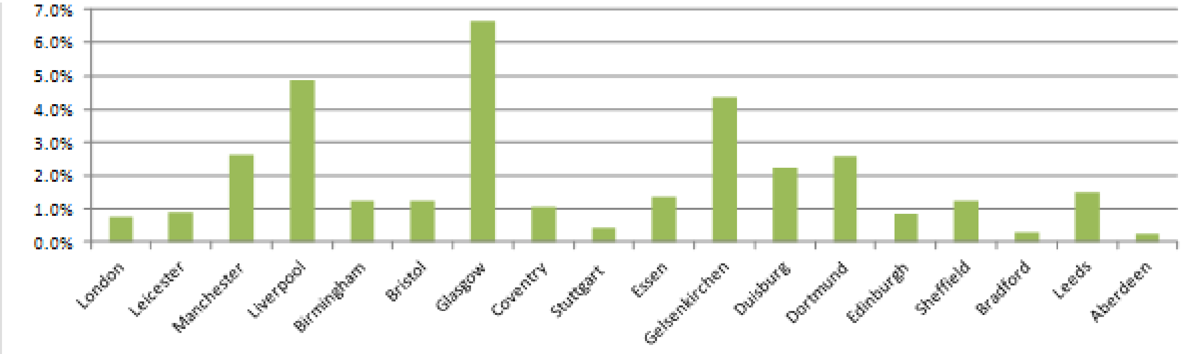

Figure 11: Share of brownfield land in a sample of EU cities (with regard to total city area)[64]

It should be noted that figures above are estimates made for illustrative purposes only. The data on total areas of cities originate from different sources than the information on brownfield land (thus the total area quoted may be different from the area used for brownfield identification); moreover the data may not be available for the same year the brownfield land information was gathered. Deploying Urban Atlas, together with population statistics from the Urban Audit, may provide a more consistent view on the potential for land recycling in the European Cities.

3.5Review of land recycling indicators

3.5.1 Introduction

To date, the focus of research on indicators for land recycling has been on sustainability indicators for brownfield regeneration projects. Such site/project specific indicators have been investigated as part of the projects REVIT[65], RESCUE[66] and more recently project TIMBRE[67]. At the municipality level, economic, social and environmental indicators for early identification of brownfield origination have been proposed as part of project HOMBRE[68]; they have been developed to aid municipalities in predicting the emergence of, or increase in, area of brownfields within a city (Hombre, 2013).

The Core Set of Indicators include CSI015: “Progress in management of contaminated sites”, for which national data is collated at the EU level, with MS reporting data through EIONET National Reference Centres (NRCs) for Soil, to the European Soil Data Centre (ESDAC) of the JRC. The information includes data on the number of contaminated sites identified, sites where preliminary survey was undertaken, sites investigated, where remediation measures were implemented and where measures were completed. Based on the reported figures, the indicator is intended to allow assessing progress in remediation of contaminated land in the EU. The data for the indicator were collected in 2001, 2003, 2005/2006 and in 2011. The latest data collection included two additional questions – on the number of contaminated sites and number of potentially contaminated sites (JRC, 2014a). Up until 2011, the CSI015 indicator included specific questions referring to “brownfield management” but these were removed from the questionnaire due to a very low response rate from MS in the previous years (JRC, 2014a). In 2011, estimates for local soil contamination were available for one third of the surveyed countries (32 EEA Member Countries and cooperating West Balkan countries). When extrapolating existing data to complete the gaps in the database, overall 2.5 million potentially contaminated sites are estimated in Europe, of which about 14% (340,000) is expected to be contaminated and in need of remediation measures (JRC, 2014a).

[64] Source: Authors’ analysis based on available data (see further details on the data sources in Annex 3).
[65] http://www.revit-nweurope.org/
[66] http://www.rescue-europe.com/
[67] http://www.timbre-project.eu/
[68] http://www.zerobrownfields.eu/

Despite the CSI015 data being useful in understanding the extent of land contamination in Europe, some of the contaminated sites reported in the database are likely to be in use (for example for industrial purposes), and therefore given the definition of brownfield adopted for this study it cannot be considered to be representative of brownfield sites. While a fraction of brownfield sites may have soil contamination issues, the majority of land available for redevelopment would not be classified as such. In addition, data available under CSI015 do not include spatial coordinates for the sites, and do not include comprehensive information on the area of land.

This section focuses on the review of potential indicators that could be used for the purpose of monitoring land recycling and policy making in the EU. The table below presents indicators evaluated in this study, which were developed based on the evidence gathered through the literature review and consultation.

Table 16: Overview of land recycling indicators evaluated

Code	Full name of the indicator
LR1	Area of brownfield land [m^2 or other unit of area]
LR2	Total area of land within existing urban fabric which is available for inner development [m^2 or other unit of area]
LR3	Brownfield land redeveloped [m^2 or other unit of area / time unit] or %
LR4	Development on brownfield land as a share of total new development [%]
LR5	Land recycling as a share of total land consumption by artificial development (%)
LR6	Land recycling as a share of total land consumption by artificial development in Large Urban Zones covered by the Urban Atlas (%)

3.5.2 Assessment of land recycling indicators

LR1: Area of brownfield land (m^2 or other unit of area)

This indicator considers a total area of brownfield land within a territory of a Member State in a given time unit. Currently there is no monitoring against this indicator at the EU or national level. Data exists at the regional or municipal levels but there are inconsistencies in definitions of brownfield and in methodologies applied to collect the data. Area of brownfield land is relevant for estimating the potential for land recycling across MS and in the EU, which in turn would allow defining a baseline for potential target setting. Due to a lack of monitoring and baseline data, this indicator currently does not score well against the RACER criteria. In the context of setting potential future targets, this indicator may prompt unequal redevelopment effort across different types of brownfield sites (i.e. larger, non-urban brownfield land could be favoured above smaller, urban sites), unless the definition used for target setting limits the applicability of the target only to urban areas or includes a cap on the maximum area of sites.

Table 17: RACER assessment for indicator LR1: Area of brownfield land (m^2 or other unit of area)

	LR1: Area of brownfield land (m^2 or other unit of area)	
Relevant		This indicator is relevant to the objectives of limiting land take set out in the Roadmap to a Resource Efficient Europe. Use of land area as an indicator for target setting may prompt unequal redevelopment effort across different types of brownfield sites (i.e. larger, non-urban brownfield land could be favoured above smaller, urban sites). The area of brownfield sites may vary from year to year for individual countries and in total for the EU given progress in identification of brownfield sites, progress in their redevelopment and emergence of new brownfield land. Therefore recorded area of brownfield land does not clearly reflect progress achieved in land recycling.
Accepted		The indicator has not been proposed in the past in the EU. There is no voluntarily monitoring of the area of brownfield sites at an EU level and no relevant EU-level statistics available. Area of brownfield land has been measured in some MS (specifically UK, Germany and Austria). Collecting information on brownfield management as part of the CSI015/LSI003 indicator was abandoned in 2011 due to very low level of response to data requests in the previous years. Any indicator based on the concept of "brownfield" may face similar acceptability issues.
Credible		While the indicator is easy to understand due to a lack of common definition of the term brownfield it could be interpreted differently across the MS. At the EU level, monitoring against this indicator requires implementation of the

	LR1: Area of brownfield land (m^2 or other unit of area)	
		common definition of brownfield sites across all MS. Nevertheless, local differences in the methodologies used to collect data as well as classifying land as brownfield would remain.
Easy		Monitoring against this indicator is not possible using data currently collated at the EU level (CLC, LUCAS, Urban Atlas). Where data exist at the national or regional level (information on the area of "previously developed land" is collected in the UK), there are inconsistencies in the methodologies used to collect it. The term is defined differently across MS and so current data may not be comparable or representative, thus measuring progress in achieving policy objectives using this indicator may be challenging. In order to collect information against this indicator, MS will need to collate data from cities or regions and report to the national level authorities. This may require significant effort especially in countries which to date have not introduced any system to monitor the extent of brownfield land.
Robust		Data is not gathered systematically across MS and no common methodology exists. There is a lack of specifications or best practice guidelines on underlying methodologies that could be used to identify and monitor brownfield land.

LR2: Total area of land within existing urban fabric which is available for inner development (m^2 or other unit of area)

This indicator refers to the total area of land available for development within the existing urban fabric of a territory of a Member State.

The following types of land within the urban fabric are included in this indicator:

- **Urban brownfield**: derelict, underused or abandoned land which has been previously developed for industrial, commercial or residential purposes, and which may have real or perceived contamination problems. It is located within existing urban areas.
- **Gap sites**: non built-up sites that offer potential for development (individual plots as well as several contiguous plots) which lie within established or newly built settlement areas (definition based on BBSR, 2011).
- **Underutilised lots**: parcels of land which are already built up, but which offer space for further development. Some examples are second row development, courtyard development as well as complementary buildings in residential, mixed-use and commercial areas (definition based on BBSR, 2011). Underutilised land is characterised by potential for densification (e.g. by building complimentary buildings).

The indicator is based on the estimates of the inner development potential undertaken in Germany (BBSR, 2011). No data currently exists for this indicator at the EU level and no information has been identified for the remaining MS. However the total area of land classed in the Urban Atlas as "land without current use" and "discontinuous very low density urban fabric" in a territory of a Member State may be relevant for the concepts of brownfields, gaps sites and underutilised lots. "Land without current use" is described in the Urban Atlas as *"areas in the vicinity of artificial surfaces still waiting to be used or re-used. The area is obviously in a transitional position, "waiting to be used". Waste land, removed former industry areas ("brownfields"), gaps in between new construction areas or leftover land in the urban context ("green fields"). No actual agricultural or recreational use. No construction is visible, without maintenance, but no undisturbed fully natural or semi-natural vegetation (secondary ruderal vegetation). Also areas where the street network is already finished, but actual erection of buildings is still not visible"*[69]. A discontinuous low density urban fabric is defined in the Urban Atlas as "*residential buildings, roads and other artificially surfaced areas. The vegetated areas are predominant, but the land is not dedicated to forestry or agriculture*". However making a

[69] As provided in http://www.eea.europa.eu/data-and-maps/data/urban-atlas#tab-methodology

closer connection between the Urban Atlas data and the indicator may require refinement of the definition of underutilised land or introduction of quantitative thresholds[70].

It should be highlighted further that as the Urban Atlas focuses on large agglomerations only, it may not be considered suitable to estimate total land recycling potential in the EU. To put this in the context of existing data on inner development potential, in Germany more than a quarter of the total potential lies in municipalities with less than 5,000 residents (BBSR,2010). However while the data will not provide a full picture, it will give useful insights on the potential for land recycling within the larger urban areas which will be key to achieve reductions in land take and limit urban sprawl in the EU. Especially in the short term, while better quality data is developed at national level, this indicator could be used as a proxy to estimate the land available for redevelopment in the EU urban areas. The data for the indicator could be calculated using 2006 and 2012 (when ready) Urban Atlas data; however producing information against this indicator is currently outside the scope of the EEA's tasks on the Urban Atlas.

Establishing this indicator would allow estimating the potential for land that could be recycled within the EU urban areas (as it focuses on the urban component), as well as establish how much other land could be utilised within the urban areas of the EU before greenfield is considered. Primarily due to a lack of monitoring and baseline data, this indicator currently does not fulfil the RACER criteria. In the context of setting potential future targets, caution must be taken when defining the level of ambition given potential negative social and environmental impacts of densification of urban areas.

Table 18: RACER assessment for indicator LR2: Total area of land within existing urban fabric which is available for inner development (m^2 or other unit of area)

	LR2: Total area of land within existing urban fabric which is available for inner development (m^2 or other unit of area)	
Relevant	(green)	Due to the wider scope of the indicator (inclusion of additional types of land to brownfield) this indicator is considered most relevant to the objectives of limiting land take set out in the Roadmap to a Resource Efficient Europe out of the portfolio of land recycling indicators identified in this study. Specifically it allows estimating what potential for new development is located within the existing urban areas, and preventing development of new land.
Accepted	(amber)	Use of similar indicator, expressed in m^2 per inhabitant, has only been identified in Germany. In the UK, the database of previously developed land could provide a close estimate but it is not directly linked to urban fabric land cover. Acceptability of the indicator among MS may depend on the provision of guidance on the definitions, how such indicator should be calculated, and how data should be gathered. Collection of data against this indicator may be associated with high costs in MS which to date did not require municipalities or regions to prepare similar types of assessments. On the other hand some data may already have been gathered in municipalities as part of preparation of housing and urban development strategies.
Credible	(red)	There is lack of common definition of the term urban brownfield, gaps between buildings and underutilised lots. As a result it could be interpreted differently across MS. At the EU level, monitoring against this indicator requires implementation of the common definitions. Nevertheless given evidence on the use of this indicator has only been used in Germany, the indicator may be difficult to understand or misinterpreted.
Easy	(red)	Monitoring against this indicator is not possible using data currently collated at the EU level (CLC, LUCAS, Urban Atlas). The Urban Atlas classes 'discontinuous urban fabric' and 'land without current use' could be used as a proxy for estimating total area of land within existing urban fabric which is available for inner development; however this data would not allow to distinguish between three sub-types of land included in this indicator.
Robust	(red)	Currently there is lack of available information at the EU level against this indicator. There is no specific methodology developed to monitor this indicator; though Urban Atlas data could be tested as a proxy. Data is not gathered systematically across MS and no single methodology exists.

[70] EEA, Personal communication, 22/08/2014

LR3: Brownfield land redeveloped [m^2 or other unit of area / time unit or %]

There are two possible options to define a land recycling indicator based on the information on brownfield land redeveloped in a given time unit. Both versions of the indicator include brownfield land redeveloped for an economic use, as well as land which was returned to nature, de-sealed or transformed into green areas:

- **Area of brownfield land redeveloped (m^2 or other unit of area / time unit) -** This indicator considers a total area of brownfield land redeveloped in a given territory and unit of time.
- **Brownfield land redeveloped (%) -** This indicator measures progress in brownfield redevelopment in relative terms (%). It considers a total area of brownfield land redeveloped, expressed as a percentage of the total area of brownfield land defined in a baseline for a given territory.

Feasibility of the latter indicator, expressed in %, is dependent on the availability of baseline information on the area of brownfield land. As such it does not meet the RACER criteria. In the context of potential target setting, indicator based on brownfield land redeveloped would however have an advantage over the use of "brownfield area" indicator, as it would clearly express what progress has been achieved in redevelopment of brownfield land.

Table 19: RACER assessment for indicator LR3: Brownfield land redeveloped [m^2 or other unit of area / time unit or %]

	LR3: Brownfield land redeveloped	
Relevant		This indicator is relevant to the objectives of limiting land take set out in the Roadmap to a Resource Efficient Europe. Unlike "Area of brownfield land", the focus of this indicator is only on the area of land that has been redeveloped. It is therefore considered more relevant for monitoring progress in land recycling compared to the "Area of brownfield land" indicator. Use of land area as an indicator for target setting may prompt unequal redevelopment effort across different types of brownfield sites (i.e. larger, non-urban brownfield land could be favoured above smaller, urban sites).
Accepted		The "Area of brownfield land redeveloped" indicator has been proposed in the past as part of the CSI015 (LSI03) indicator on management of contaminated sites (expressed in hectares/ time unit). However data collection has been abandoned in 2011 due to very low response rates. Evidence collected on the current monitoring across MS suggests that use of this indicator may face similar acceptability issues. No evidence on the use of this indicator has been found in any of the EU MS. In Germany, such an indicator was only considered as part of research.
Credible		While the indicator is easy to understand due to a lack of common definition of the term brownfield it could be interpreted differently across the MS. At the EU level, monitoring against this indicator requires implementation of the common definition of brownfield sites across all MS. Nevertheless, local differences in the methodologies used to collect data as well as classifying land as brownfield would remain.
Easy		Monitoring against this indicator is not possible using data currently collated at the EU level (CLC, LUCAS, and Urban Atlas). In order to collect information against this indicator, MS will need to collate data from cities or regions and report to the national level authorities. This may require significant effort especially in countries which to date have not introduced any system to monitor the extent of brownfield land. Once data is collected, the indicator does not require further calculations and is easy to understand.
Robust		Currently data is not gathered systematically across MS and no single methodology exists.

LR4: Development on brownfield land as a share of total new development (%)

This indicator refers to the share (%) of development undertaken on brownfield land as a share of all new development undertaken within a territory of a Member State in a given time unit. "New development" is development of land for economic purpose, such as for industry, housing and commercial services. It excludes creating green areas on brownfield land.

This indicator considers brownfield land that has been redeveloped, as a share of total land developed in a given period of time. Monitoring against this indicator would not require collating information on the total area of brownfield land; however a clear classification system of land into brownfield and greenfield would be required. This indicator does not meet the RACER criteria. In the context of target setting, due to differences in brownfield land available for redevelopment across MS, as well as in demand for land; use of this indicator may not be considered equitable. Furthermore, this indicator would not take into account brownfield land which has been returned to nature and as such would put MS, regions or cities experiencing shrinking at a disadvantage

Table 20: RACER assessment for indicator LR4: Development on brownfield land as a share of total new development (%)

		LR4: Development on brownfield land as a share of total new development (%)
Relevant		This indicator is relevant to the objectives of limiting land take set out in the Roadmap to a Resource Efficient Europe.
Accepted		Measures regulating development on brownfield sites versus greenfield sites have already been introduced in some MS but are primarily qualitative or set as goals or broad objectives for planning authorities (examples include UK, Netherlands and Germany). The business community may already be familiar with such indicator as a result of planning regimes in MS; however, there is insufficient evidence to determine how easily accepted it would be.
Credible		There are no EU level statistics collated against this indicator. Nevertheless, relevant data may exist in some MS as it may be gathered as part of planning process. Definition of the term "new development" and "brownfield" land would be required first to ensure that the indicator is clear and unambiguous. These definitions would need to be adopted in all MS to ensure data gathered is comparable.
Easy		Monitoring against this indicator is not possible using data currently collated at the EU level (CLC, LUCAS, and Urban Atlas). Collection of information may require less effort from MS compared to "Area of brownfield land" and "Total area of land within existing urban fabric which is available for inner development", as data on what land the development was built on may already be gathered as part of the planning processes / cadastre. The indicator requires simple calculation.
Robust		Depending on a Member State, data may be available at the national or regional level. For some MS, no data may be currently available. The indicator is relative to the development undertaken in that year, therefore year to year fluctuations in the area of brownfield sites as progress in identification of sites continues will not affect the ability to measure progress against the objectives. At the same time, due to differences in brownfield land available for redevelopment in MS, and in demand for land at the national and regional levels, monitoring against this indicator may not provide robust and comparable information on progress in land recycling across the EU. Primarily, it would not consider brownfield land which has been returned to nature / de-sealed. There are currently no guidelines or methodologies to ensure credible results of monitoring against this indicator.

LR5: Land recycling as a share of total land consumption by artificial development (%)

This indicator refers to the total area of land recycled within a territory of a Member State, expressed as a share of total land consumption by artificial development in a unit of time. This indicator is suggested considering the methodology developed by EEA (2006b) to estimate the % of land recycled in the EU using CLC data. Given its relatively coarse resolution, CLC can provide only a very aggregated (yet pan-European) estimate of land recycling.

Table 21: RACER assessment for indicator LR5: Land recycling as a share of total land consumption by artificial development (%)

		LR5: Land recycling as a share of total land consumption by artificial development (%)
Relevant		This indicator monitors a share of land recycling as part of the total land consumption by artificial development. As such, it is considered relevant to the objectives of increasing share of land recycling across MS with a view to limit consumption of new land.
Accepted		This indicator is based on the methodology proposed by EEA (2006b) using the CLC data. The indicator is not routinely implemented however calculation of data against this indicator can follow the proposed methodology of land use accounts and land use flows.
Credible		Given systematic methodology of data collection for the CLC, data obtained for this indicator would be comparable across MS. The indicator if calculated centrally would be easy to understand.
Easy		The underlying data to monitor this indicator is routinely monitored in the EU-28, at regular time intervals. If monitoring against this indicator is undertaken centrally at the EU level based on the latest CLC data, MS would

		LR5: Land recycling as a share of total land consumption by artificial development (%)
		not be required to deploy additional resources locally to report against this indicator.
Robust		The methodology to calculate the indicator has been developed by EEA (2006b) but it is not currently calculated across MS over time. Given its relatively coarse resolution, CLC can provide only a very aggregated (yet pan-European) estimate of land recycling.

LR6: Land recycling as a share of total land consumption by artificial development in Large Urban Zones covered by the Urban Atlas [%]

This indicator refers to the area of land recycled expressed as a share of total land consumption by artificial development in the Large Urban Zones (LUZs) covered by the Urban Atlas. This indicators could be calculated if similar methodology to the one proposed by EEA (2006b) is applied to the Urban Atlas data (with some adjustments for different nomenclature). Monitoring against this indicator could provide valuable insights at the EU level, on how much development in the Large Urban Zones is undertaken on brownfield. In the context of target setting, however, it is not considered sufficiently robust due to its limitation to large agglomerations only.

Table 22: RACER assessment for indicator LR6: Land recycling as a share of total land consumption by artificial development in Large Urban Zones covered by the Urban Atlas [%]

		LR6: Land recycling as a share of total land consumption by artificial development in Large Urban Zones covered by the Urban Atlas
Relevant		This indicator monitors the share of land recycling as part of the total land consumption by artificial development in Large Urban Zones in Europe. As such, it is considered relevant to the objectives of increasing the share of land recycling across MS with a view to limit consumption of new land (i.e. land take).
Accepted		The indicator has not yet been implemented in the EU or individual Member State.. The methodology to calculate this indicator has not been developed. The methodology of land use accounts and flows as applied by EEA (2006b) to the CLC data could be considered with some modification to calculate this indicator.
Credible		Given systematic methodology of data collection for the Urban Atlas, data obtained for this indicator would be comparable among the Large Urban Zones in Europe.
Easy		The underlying data to monitor this indicator is routinely monitored in the EU-28, at regular time intervals. If monitoring against this indicator is undertaken at the EU level based on the latest Urban Atlas data, MS would not be required to deploy additional resources locally to report against this indicator.
Robust		Assuming that a similar methodology to the one proposed by EEA (2006b), with some adjustments for nomenclature, is applied to the Urban Atlas information, the results may better reflect the share of land recycling compared to using the CLC data. Due to finer resolution, this would allow to account for smaller changes within the urban fabric compared to the CLC. However, the Urban Atlas information is limited to Large Urban Zones only and therefore data obtained against this indicator would not take into account the progress in land recycling undertaken in smaller agglomerations.

Synthesis

Summary of all indicators together with data requirements and application in policy making to date is provided in table below.

Table 23: Synthesis of RACER assessment for land recycling indicators

Code	Indicator name	Definition	Available data and sources	Information on existing uses	R	A	C	E	R
LR1	Area of brownfield land [m^2 or other unit of area]	Total area of brownfield land within a territory of a Member State. See definition in section 3.1.	No available source of data to monitor against this indicator at the EU level. Relevant data may be available at the national, regional or municipal levels; no consistent methodology is applied.	No evidence of use for policy purposes.					
LR2	Total area of land within existing urban fabric which is available for inner development [m^2 or other unit of area]	Total area of land available for development within the existing urban fabric of a territory of a Member State. This includes urban brownfield, gaps sites and underutilised land - see definition in section 3.1. Inner development is defined as development within the existing urban fabric.	No available source of data to monitor against this indicator at the EU level. The Urban Atlas land classes “land without current use” and “low density urban fabric” may be relevant concepts. Relevant data at the national level has only been identified for Germany. No single methodology currently exists.	In Germany the data has been collected in the context of the land use target; no other use for policy making purposed was identified.					
LR3	Brownfield land redeveloped [m^2 or other unit of area / time unit] or [%]	Total area of brownfield land which was redeveloped within a territory of a Member State over a time unit.	No available source of data to monitor against this indicator at the EU level. Relevant data may be available at the national, regional or municipal level; no consistent methodology is applied.	No evidence of use for policy purposes.					
LR4	Development on brownfield land as a share of total new development [%]	Share (%) of development undertaken on brownfield land as a share of all new development undertaken within a territory of a Member State in a given time unit. Includes development of land for industry, housing, commercial / services, and excludes creating green areas on brownfield land.	No available source of data to monitor against this indicator at the EU level. No information collated at the EU level on the total new development undertaken.	Germany (qualitative goal) UK (quantitative target; subsequently removed).					
LR5	Land recycling as a share of total land consumption by artificial development [%]	A total area of land recycled within a territory of a Member State, expressed as a share of total land consumption by artificial development in a unit of time.	Corine Land Cover using methodology proposed in EEA (2006b).	No evidence of use for policy purposes.					
LR6	Land recycling as a share of total land consumption by artificial development in Large Urban Zones covered by the Urban Atlas [%]	The area of land recycled expressed as a share of total land consumption by artificial development in the Large Urban Zones (LUZs) covered by the Urban Atlas.	Urban Atlas using methodology proposed in the EEA (2006b).	No evidence of use for policy purposes.					

3.5.3 Indicators suitability for target setting and need for further EU actions

Indicators suitability for target setting

None of the land recycling indicators identified in this study score well against the RACER criteria. To date no common understanding of the land recycling concept and associated terminology (brownfield, inner development potential etc.) has been established across the MS or at an EU level. This is reflected in the low quality of data available on the area of land available for recycling, as well as on the share of land currently recycled. This is the primary factor affecting the results of the RACER analysis, as this methodology of evaluating indicators "is biased towards established indicators that can be used immediately" (European Commission, 2013b). Due to these limitations, all indicators for land recycling score low in the assessment of suitability for defining EU targets based on the scoring criteria defined for this study (see section1.3).

At the local and regional level, indicators LR1, LR2, LR3 and LR4 could be considered by the relevant authorities for setting land recycling targets. Their suitability will be closely linked to the local circumstances, specifically:

- availability of data against the indicator at the regional or local level
- results of the assessment of environmental, social and economic impacts of proposed targets

Need for further EU actions

The following actions have been identified that could potentially improve the quality and robustness of underlying data, thus contributing to the development of RACER indicators for land recycling. The development of the indicators listed requires differing levels of action by the EU. While a number of indicators can be developed simultaneously, it is suggested that priority is given to the indicators identified as most suitable for monitoring of:

- the amount of brownfield land available for redevelopment (indicator LR1);
- the area of brownfield and other type of land within the urban areas that could be developed before greenfield (indicator LR2); and
- the progress achieved in land recycling by MS (indicator LR3).

Development of these indicators will further allow quantification of the potential contribution of land recycling to meeting the no net land take objectives. Indicators LR5 and LR6 are considered relevant and worth developing for the purpose of short term monitoring; however as presented in the table above these are not seen as suitable for target setting. Indicator LR4 is only considered suitable for target setting at the local level and as such is not considered a priority for EU action.

Table 24: Suggestions of potential actions required to develop EU land recycling indicators

Indicator	Problem definition	EU actions required to develop, implement or improve the indicator
LR1: Area of brownfield land (m^2 or other unit of area)	Lack of robust and comparable data on the area of brownfield land is the key barrier hindering use of this indicator.	Implementation of a common definition of brownfield land at the EU level, to be adopted across MS. Requirement on MS to establish appropriate systems to monitor brownfield area in their territory. EC to provide guidance to MS on best-practices in identifying and monitoring brownfield land.
LR2: Total area of land within	Lack of robust and comparable data on the	Implementation of common definitions of types

Indicator	Problem definition	EU actions required to develop, implement or improve the indicator
existing urban fabric which is available for inner development (m^2 or other unit of area)	area of brownfield land, gaps sites and underutilised lots is the key barrier hindering use of this indicator.	of land included in this indicator (brownfield, gap sites, underutilized lots) as well as what is considered as urban fabric / urban area. Requirement on MS to establish appropriate systems to monitor inner development potential within the urban areas of their territory. EC to provide guidance to MS on best-practices in assessing inner development potential. Investigation of suitability of using the Urban Atlas land classes to monitor this indicator.
LR3: Area of brownfield land redeveloped (m^2 or other unit of area / time unit) / Brownfield land redeveloped (%) [71]	Lack of robust and comparable data on the area of brownfield land and the amount that is being redeveloped is the key barrier hindering use of this indicator.	Implementation of a common definition of brownfield land at the EU level, to be adopted across MS Requirement on MS to establish appropriate system to monitor brownfield area in their territory. EC to provide guidance to MS on best-practices in identifying and monitoring brownfield land.
LR4: Development on brownfield land as a share of total new development (%)	Lack of robust and comparable data on the share of development on brownfield land is the key barrier hindering use of this indicator. There is currently no EU level data available on new development undertaken across MS.	Implementation of a common definition of “brownfield land” and “new development” across MS. Requirement on MS to implement specific provision in their legislation to ensure that permissions granted for new development include information on the type of land it is built on (whether classified as brownfield or greenfield). Requirement on MS to establish a system to collate the information at the national level.
LR5: Land recycling as a share of total land consumption by artificial development (%)	CLC provides only high level estimate of the share of land recycling.	Assess the limitations of the methodology used in EEA (2006b) for the purpose of monitoring land recycling. Explore with EEA and the JRC whether application of the similar methodology to one proposed in EEA (2006b) to the “revised” CORINE data produced by the JRC (CRC_r) could result in more accurate estimates. Re-assess the applicability of this indicator to monitor land recycling.
LR6: Land recycling as a share of total land consumption by artificial development in Large Urban Zones covered by the Urban Atlas (%)	The methodology to calculate this indicator has not been developed. This indicator is proposed on the basis of feedback provided by EEA that similar methodology to the one proposed in EEA (2006b) could be tested with the Urban Atlas.	Develop methodology similar to the one in EEA (2006b) for use with the Urban Atlas data.

[71] RACER evaluation is common for these two indicators.

3.6 Possible targets and assessment

3.6.1 Lessons learnt from practical implementation of targets

Understanding lessons learnt from previous implementation of land recycling targets is critical when considering introduction of land recycling targets. However use of targets in the MS to facilitate land recycling has to date been very limited. Table 25 below provides a brief description of land recycling targets identified in this study.

Table 25: Examples of land recycling targets in the EU MS

Target	Indicator	Source	Comments
Targets related to new development on brownfield land			
By 2008, 60% of additional housing should be provided on previously-developed land or by re-using existing buildings	New housing built on previously developed land.	UK (England)	National level target, with each region proposing its own level of target, based on respective contribution that can be delivered. The target has subsequently been removed.
General policy objectives related to new development on brownfield land			
Aim for more inner-city development compared to development on new sites (3:2 or 3:1)	New development on brownfield / previously used/ inner-city land	Germany	Set as an objective to promote development on all types of inner-city land available for recycling (not only brownfield).

Targets implemented in the UK (England) provide an interesting case study given their direct relevance to land recycling and their subsequent removal from the UK law[72]. A target for a minimum of 50% of new housing development to be built on brownfield land was introduced in England in 1995, and increased to 60% in 1998. Prioritisation of development on brownfields above greenfield has been introduced in the national planning policy alongside the target. The brownfield target was not binding on local authorities. The target was achieved within 2 years, with 73% and 76% of houses being built on brownfield land in 2005 and 2010, respectively. However the amount of development delivered on brownfield land varied across local authorities. The level to which brownfields could have been developed by local councils was dependent on availability of brownfield land in the local authority and its overall technical and economic viability for the purpose of housing development.

In the early years following the target introduction, the policy was found to encourage so called garden grabbing – that is building denser housing or blocks of flats in gardens attached to residential properties. In order to prevent this, the definition of brownfield was changed to specifically exclude private gardens (see Annex 3 for details of the revised definition). However, brownfield redevelopment was not always the most sustainable or appropriate option to deliver housing locally and the national target was subsequently abolished in 2011 with implementation of the new National Planning Policy Framework (NPPF).

The evidence collected for the impact assessment of the NPPF and abolition of the brownfield target demonstrated that brownfield targets influenced the nature of development, supporting development in locations not suitable for housing (e.g. on land of high ecological value or located within high flood-risk

[72] This section of the report is based on the information published by the UK Department for Communities and Local Government (2012)

zone). Furthermore, targets led to the imbalance in housing provisions by indirectly encouraging a replacement of single family houses with blocks of flats. This led to an overall increase in the average density of new dwellings built in England from 25 dwellings per hectare in 1989, to 43 dwellings per hectare in 2011. An average density of new dwellings built in 1989 on previously developed land was 29 dwellings per hectare compared to 21 dwellings per hectare built on land that was not previously developed. In 2011 the densities for the two different types of land were 53 dwellings per hectare and 33 dwellings per hectare, respectively. This indicates more intensive and denser developments taking place on previously developed land compared to greenfield.

The existence of brownfield targets was considered to inflate the costs of brownfield land. These costs were subsequently being passed onto the house buyers thus affecting the national property market. In addition the Impact Assessment for the NPPF stressed the negative impacts of brownfield targets on biodiversity, highlighting that some brownfields over the years had developed unique ecosystems and provided valuable habitats. Brownfield targets were driving redevelopment of such sites despite greenfield sites being of lower ecological value in some cases thus providing a more sustainable location for the development. Thus by removing the brownfield target, it was felt that greater flexibility would be given to local authorities to develop land in the most suitable locations. This was expected to support better use of land as a resource according to its environmental value.

The following arguments were put forward for the abolition of the target:

- Ability for local authorities to make more sensitive decisions about where to locate new development.
- Opportunity to consider the environmental value of brownfield land, and compare it to the value of greenfield, before redevelopment decisions are made.
- Authorities will have greater discretion in deciding on the best options for locating housing within their territories, based on the assessment of local costs and benefits.

The key impacts of removing the targets were identified as:

- On land supply – change in the mix of the type of land used for residential development.
- On housing supply – lower density of dwellings compared to building on brownfield land, building on greenfield could require provision of new infrastructure, no costs of remediation would be incurred if non-brownfield land is developed.
- On environment – removal of the targets would support retainment of brownfield land of high ecological value. It would provide opportunities to increase biodiversity on low value agricultural land as part of development.

Despite the national level target being removed, local authorities in England retained the flexibility to introduce local targets if this instrument is found to be appropriate to support sustainable development in their area.

3.6.2 Possible options for introducing land recycling targets

None of the potential land recycling indicators assessed in the previous section meets the RACER criteria. Therefore an EU level target for land recycling using any of these indicators cannot be proposed at this stage. Nevertheless, setting land recycling targets in the EU could contribute positively to achieving the objectives of more efficient land management. Based on the evidence gathered, redevelopment of brownfield sites and realising the infill development potential has not been on the political agenda in many MS. Based on the evaluation of potential indicators, subject to the availability of local and national level data and taking into consideration lessons learnt from previous implementation of targets, several indicators could be used for potential target setting at national or local level as summarised in table below.

National or local level targets for land recycling may be more feasible compared to those at an EU level as they would allow MS to tailor the design of the policy to their specific needs and circumstances (specifically ensuring that targets fit well with the local fluctuations in land and property demand). Furthermore, targets could be made complementary to the existing national planning and urban regeneration objectives. However, lessons learnt from the UK suggest that given the complexity of the issues driving land recycling, such as varying availability and demand for land, and some specific issues such as higher ecological value of brownfield compared to greenfield, any targets must be implemented with caution, ensuring sufficient flexibility for the authorities when making decisions on new development.

Table 26: Possible options for national or local level land recycling targets

Scale of implementation	Types of indicators for target setting	Possible expressions of targets	Scale for target setting
National / local	Area of brownfield land (LR1) Total area of land within existing urban fabric which is available for inner development (LR2)	By year X, to decrease the area of brownfield land (or land within urban areas available for inner development) within the territory to Z m^2.	National / local
National / local	Area of brownfield land redeveloped (LR3)	By year X, to redevelop Y% of brownfield area compared to the baseline year Z.	National / local
National / local	Development on brownfield land as a share of total new development (%) (LR4)	By year X, to ensure Y% of new development is undertaken on brownfield land.	National / local

3.6.3 Feasibility assessment of possible land recycling targets

Introduction

Feasibility of the hypothetical targets for land recycling at a national and local level as described above is discussed in the following sections. The Commission's Communication that accompanied the Thematic Strategy for Soil Protection (EC 2006) describes the overall objectives that the Strategy (part of which included the proposed Soil Framework Directive) aims to achieve as protection and sustainable use of soil, based on two main guiding principles:

- Preventing further soil degradation and preserving its functions; and
- Restoring degraded soils to a level of functionality consistent at least with current and intended use, thus also considering the cost implications of the restoration of soil.

National or regional targets for land recycling can help contribute to these objectives by limiting further increases in soil sealing (i.e. through reduced development on greenfield) and reducing soil contamination where such sites are remediated prior to redevelopment. Furthermore land recycling clearly has an important role to play in achieving an objective of "no net land take by 2050" laid down in the European Commission's Roadmap and discussed in detail in Chapter 2.

Based on the UK example - the only Member State identified in this study with experience in implementing land recycling targets – such targets can be successful in encouraging redevelopment of brownfields. Of key importance is establishing correct definitions of the terms used to set the targets while making them flexible enough to respond to local needs. MS may want to introduce interim targets and schedule regular evaluations to ensure appropriate implementation and early identification of any unanticipated consequences.

Feasibility of land recycling targets

Technical feasibility

Monitoring

Setting national or local level targets related to the area of brownfield land (or total inner development potential) would require taking into account the existing brownfield area, as well as current redevelopment / creation rate. Based on the information gathered in this study, without further action to improve the monitoring of brownfield land, the baseline information in MS would generally not be sufficient to define appropriate timescales and level of ambition.

In order to improve the baseline information on area of brownfield land and rate at which it is redeveloped, MS would need to draw up national level inventories of brownfield sites, as well as gap sites and underutilised lots as required (depending on whether indicator LR1 or LR2 is selected). Generally better quality information may be available from the municipalities or regional authorities, and targets set at that level may be more appropriate in the short term.

Targets set based on the share of "new development on brownfield land" would not require drawing up inventories of brownfield land, but would require implementation of a clear definition and set of criteria for when land should be classed as brownfield. One option to implement such targets is for the planning processes in MS to include a requirement to determine whether the area proposed for the development is brownfield land. To monitor progress against such target, information on the planning permissions granted could be collected from the regional or municipal level administrations. In the first instance, MS may decide to set a minimum requirement for regional authorities to locate a certain share of new development on brownfield land, with an option for local administrations to set more ambitious targets. This approach gives flexibility to those regions or cities where land recycling might be of higher immediate priority and where there is vast amount of brownfield land available for redevelopment.

Effectiveness of the target

Lessons from the implementation of targets in England suggest that even if national level targets are non-binding on local authorities, they may not be flexible enough to respond to local drivers and challenges. Local targets (e.g. at municipal level) could provide more flexibility with regard to the type of development to be encouraged at brownfield sites (e.g. housing, cultural centres, etc.).

The impact assessment for the abolition of the target in England showed that councils with no or little greenfield available developed 95% of new housing on brownfield between 2006 and 2009, thus far exceeding the national target of 60%. This suggests that if non-binding national level targets for land recycling are set, the redevelopment might be achieved primarily in the localities with little greenfield. In these areas brownfield comprised the majority of land available for new development, and thus are likely to be redeveloped without any additional policy levers. Based on the UK assessments, despite national brownfield target being in place, redevelopment of brownfield land fell in 16% of local authorities between 1998-2001 and 2006-2009 (the assumption made in the impact assessment was that these authorities reached their maximum rate of redevelopment). This shows that non-binding national level targets may not be effective in uniformly encouraging brownfield redevelopment across a Member State. On the other hand implementation of the targets binding local authorities to a single redevelopment rate would not be feasible in practice due to territorial and socio-economic differences between local authorities. Therefore consideration should be given to a situation where there is no purpose for development of brownfield land and/or developers do not want to develop sites at a given locality (e.g. there is little demand for commercial development). To account for such instances targets should include mechanisms that would support soft-use of brownfield land (e.g. transformation into green urban area), or its full re-naturalisation, where no development for commercial or residential purpose was possible.

Socio-economic feasibility

Costs of implementation

To assess the potential costs of implementing land recycling targets it is important to understand what actions may result from them. Defining targets and appropriate level of ambition will need to be supported by sufficiently high quality data; this is considered the primary bottleneck for introduction of land recycling targets in the EU.

A requirement on MS or regions to establish an inventory of brownfields according to a common definition will lead to administrative impacts on local, regional and/or national bodies. Methodologies for and possible costs of drawing up the inventories of brownfields at the regional / municipal level have been discussed in section 3.4. Whilst some MS have already established national level inventories of brownfields, as the example below shows for the Czech Republic these are often outdated and include variable assumptions, e.g. in relation to the definition of brownfield. Evidence reported by Germany also suggests that no uniform approach to data collection is adopted across the Federal States.

Box 5: Experience in drawing up inventory of brownfield sites in the Czech Republic[73]

In the Czech Republic, the database of brownfield sites was created by the development agency CzechInvest. The primary purpose of creating the inventory of brownfield sites was to promote land recycling to potential investors and provide information on the location and basic characteristics of the sites available for redevelopment. Data was collected regionally; however the methodology used to collect the information was not consistent across the regions. Furthermore owners of some brownfield sites did not give their consent to publish information on their land on site, and hence information available to potential investors covers only around 400 sites. This is a small fraction compared to recent estimations of the total brownfield area in the Czech Republic of between 8,500 and 11,700 sites.

If a target were to be set for land recycling (e.g. for the area of brownfield land redeveloped), then ultimately it would place a requirement on the regions or municipalities to ensure that a certain level of development takes place on brownfield land. Where this is likely to happen without intervention from the competent authorities (e.g. the site is developed entirely by private sector and development is fully market driven) then no additional costs to the authorities would be anticipated as the development would have gone ahead with or without policy intervention. However authorities which will be required to additionally support redevelopment of the less economically attractive sites (e.g. sites classed as B or C according to the A-B-C model) in order to meet the targets would face additional costs.
Costs of brownfield redevelopment (and subsequent economic returns) will vary depending on the characteristics of the site. Potential costs of remediation of contaminated soil are discussed in the section below. When considering potential costs of implementing land recycling targets, it is worth

[73] Source: Frantal et al.,2012 ; VSB, 2010

considering existing support mechanisms at the EU level which may help to finance brownfield regeneration. The European Regional Development Fund (ERDF) appears to be one of the most successful mechanisms used to support brownfield redevelopment at the EU level to date – further details are provided in Annex 3. Overall, ERDFs have been able to help local authorities and regions when their own budgets were insufficient to finance brownfield redevelopment, while monitoring the quality of delivery and success of the projects.

Social and environmental impacts

Beyond purely economic impacts, land recycling has a number of environmental and social benefits and costs. As illustrated by lessons learnt from the UK – see section 3.6.1 above, these need to be considered in the local context, before land recycling targets are introduced. This is especially relevant when considering implementation of targets based on the "total inner city development" indicator, which would result in densification of urban areas. There is evidence of some negative impacts associated with densification on the well-being of urban populations as well as flood mitigation services of soil and these should be considered when designing targets. As demonstrated in the section on the impacts of land recycling, the ecological value of brownfield land should also be taken into account before redevelopment of land is undertaken. This is one of the impacts that had not been accounted for prior to the implementation of the UK brownfield targets.

Administrative and legal feasibility

Coherence with other policies

Consideration of land recycling targets should be discussed in the context of existing EU, national and local legislative frameworks. A lack of EU level legislation targeting land recycling means that varying levels of progress have been achieved across MS. Land recycling is influenced by the same EU instruments as listed in Chapter 2 regarding land take (e.g. Environmental Impact Assessment, Strategic Environmental Impact Assessment). In addition, the EU Environmental Liability Directive aims at ensuring that the financial consequences of certain types of harm caused to the environment (including soil pollution) will be borne by the economic operator who caused this harm (EC, 2014). In the case of soil contamination, the Directive requires that the land concerned is remediated to the level at which there is no longer any serious risk of negative impact on human health (EC, 2014). However, the Directive does not tackle historical pollution, thus the cost of remediation of abandoned brownfield sites would not be recovered from previous operators under this regime. To date, land recycling in the EU has been mainly supported indirectly through objectives, strategies and priorities that influence allocation of European funds (as discussed above).

At the national and local level one of the key barriers to introduction of land recycling targets from an administrative perspective relate to the significant variation in the way in which land use and planning in general is co-ordinated and managed in MS. Significant powers in that area are often delegated to the regional level authorities or municipalities, which may have developed bespoke tools and approaches while complying with national level policies. This is specifically important in case of monitoring initiatives where data gathering at regional or municipal level could be undertaken using various methodologies thus leading to overall inconsistencies within a single Member State, as demonstrated for example in Germany and the UK where data collection at federal and local authority level does not follow a single methodology or guidance. Quality of local governance and leadership from local authorities on the issue are often driving forces for local urban regeneration (CircUse, 2013).

When considering implementation of land recycling targets at the national level, their coherence with other instruments already implemented in the Member State need to be assessed case by case. These are discussed in detail in the following section.

3.7 Supporting policy instruments

The description of, and lessons learnt from, the implementation of instruments supporting land recycling in the MS is provided in Annex 3, with detailed information on the use of these instruments in specific MS. Within the scope of this study it has not been possible to determine how effective individual instruments have been in supporting land recycling. These are often implemented as packages of measures and as such it is impossible to assess them in isolation. Where possible, case studies have been provided to illustrate the impact of the assessed instruments.

3.8 Conclusions and recommendations

This section summarises the overall conclusions from the chapter and presents recommendations for the next steps to be developed under the Impact Assessment accompanying the Land Communication.

3.8.1 Potential for land recycling

The estimates of the brownfield area available in the EU suggest that land recycling can contribute significantly to the objective of no net land take. However these estimates are based on the very weak evidence gathered as part of this study which demonstrates that current quality of data on land available for recycling in the EU, as well as current progress in land recycling, is very low.

The initial steps at the EU level should therefore be focused on **improving the quality and availability of data on land available for land recycling as well as the share of land redeveloped in the MS**.

3.8.2 Actions required to develop land recycling indicators

Across a number of indicators identified in the study, monitoring against the indicator LR1: "Area of brownfield land" and LR2: "Total area of land within existing urban fabric which is available for inner development" would allow quantification of the extent to which land recycling could contribute to meeting the no net land take objective in the EU. Brownfield management, despite issues related to the lack of common definition, is a better developed and more mature concept in the EU compared to the inner development potential (evidence for which has only been identified in one Member State). For that reason, the immediate step suggested at the EU level would be to improve the underlying data related to brownfield management. For that purpose the following instruments could be utilised and explored in the Impact Assessment study for the Land Communication:

- Implementation of a common terminology on land recycling in the EU (definitions of brownfield land, land recycling, densification, inner development); and
- Introduction of the requirement on MS to establish a system to record and maintain up to date information on the area of brownfield land within their territories (indicator LR1). If complemented with information on the area of land redeveloped in a given unit of time, this would additionally enable monitoring against indicator LR3: Area of brownfield land redeveloped.

Establishing a system to record and maintain up to date information on the area of brownfield land in EU MS is in line with the recommendations made to MS by the European Court of Auditors

(ECA,2012), to "*require regional or local authorities to maintain registers of brownfield and contaminated sites; these should be standardised at least at Member State level in order to allow for their consolidation into a national register to facilitate the implementation of a brownfield regeneration and remediation policy*".

As for the remaining indicators for land recycling assessed in this study (LR2, LR5, LR6) further investigation of the suitability of using CLC, CLC_r and the Urban Atlas data for the purpose of monitoring of land recycling could be undertaken. While these data sources are not considered sufficiently accurate to monitor land recycling or define potential land recycling targets, in the short term they may provide high level estimates using datasets systematised and harmonised across the MS.

3.8.3 Monitoring of land recycling in the EU

A minimum requirement for the monitoring system could be to include a total area of brownfield land in a Member State. MS should consider designating a single authority responsible for collation of data at the national level and reporting it to the EU. Depending on the local circumstances MS may decide to develop more complex inventories of brownfield sites which could include information relevant to potential investors as well as planning authorities, e.g. more detailed description of the site, information on existing structure, ownership, etc. The inventories may also contain information on the potential contamination of the sites. For example, ECA (2012) recommended that MS compile lists of brownfield sites where contamination is suspected and classify them according to health and environmental risks to allow preparation of remediation strategies.

Recommending a single methodology for the development of inventories is unlikely to be acceptable for some MS given varying progress in monitoring of the issue between countries as well as the range of regional and municipal initiatives. Furthermore, the most suitable and cost-effective approach to identifying brownfields depends on the local circumstances (e.g. availability of land data, existing systems to record information, technical know-how, etc.). A more appropriate approach to improve availability of data and systematise the information could be a **production of EU guidance on best practices in land recycling**, which could suggest a range of common inventory approaches.

3.8.4 Feasibility of introducing land recycling targets

To date, there has been little experience in the EU in implementing land recycling targets. Lessons learnt from the UK show that such targets need to be implemented with caution, in order to prevent undesirable impacts on the economy (e.g. property prices, housing stock supply), environment (e.g. soil sealing, biodiversity) and society (e.g. human well-being). Given existing data limitations, introduction of land recycling targets at the EU level, using any of the indicators considered is not possible. Nevertheless, MS could consider implementing national or local level targets, subject to availability of local level data and results of assessments of potential impacts of such targets. National and local level targets for land recycling are more likely to be able to ensure sufficient flexibility to respond to the dynamics of land recycling as well as socio-economic differences between regions or municipalities (e.g. associated with demand for land, shrinkage and economic performance). Experience from the UK indicates that targets aimed at increasing the rate of land recycling may lead to a number of unintended consequences, including increase in property prices, changes to the nature of development, increase in densification or urban areas, impacts on biodiversity and increasing rate of development in areas at high risk of flooding. These and other potential impacts have to be closely accounted at the policy design stage, taking into consideration national and local circumstances.

3.8.5 Potential other policy instruments to support land recycling in the EU

In addition to targets, there exist a range of other policy instruments which proved to successfully support land recycling in the MS.

Regulatory instruments

A strong planning policy is a pre-requisite to successful brownfield redevelopment. A number of MS have set the key principles aimed at supporting land recycling within their planning legislation. This includes the **sequential planning rule** requiring considering locating new development on brownfield land first, before new land is developed (Germany and UK). Redevelopment of brownfield land is also encouraged by restricting development zones to existing urban areas (green belt policy in the UK). There is scope to **influence progress in brownfield redevelopment in the EU by encouraging MS to lay down the sequential planning rule in their national policies**. This is in line with the findings from the ECA (2013), which stated that MS should "*promote the regeneration of brownfield sites, avoiding the use of greenfield unless strictly necessary and otherwise requiring the application of compensation measure*".

Urban and land use / development plans play an important role in the successful regeneration of brownfield sites. Brownfield regeneration projects should be undertaken in the context of such plans to ensure they reap both economic and environmental benefits. **A requirement to demonstrate how a brownfield redevelopment project fits within a wider development plan for an area could be made a pre-requisite to accessing national or European funding support.** This is in line with suggestions by ECA (2012) to MS to "*require brownfield regeneration projects to be part of an integrated development plan for the city or area concerned*". The European financial instrument JESSICA already requires the establishment of an integrated urban development plan (ECA, 2012).

An integration of land recycling / brownfield redevelopment objectives in the framework of existing legislation and strategies on contaminated land and urban regeneration can help remove some of the existing barriers to land recycling. Especially in MS with large quantity of contaminated, post-industrial brownfields, clear legislation governing both processes and actors involved in soil remediation could facilitate redevelopment of brownfields. Following recommendations of the ECA (2012), MS **could choose to introduce instruments (e.g. inventories of sites, remediation plans) which would prioritise remediation of brownfield sites with suspected contamination.** Furthermore, including brownfield redevelopment as part of national documents laying down the principles of sustainable development (e.g. national sustainability strategies) could help raise awareness of the importance of land recycling and bring it on the political agenda across MS. In cases where redevelopment of publicly owned brownfield land is restricted to the public sector only, MS should consider **releasing this land for redevelopment by the private sector**. Such an approach may prove beneficial where redevelopment is not being delivered by the public sector but where demand for land is high and thus could be realised by private investors.

Guidelines serve as an important tool in clarifying the key principles (e.g. laws, procedures and actors involved in the process) governing land recycling in a Member State, region or a municipality. Issued at the EU or national level, **guidelines can ensure a coherent approach to monitoring, planning and executing land recycling projects**. In some MS relevant guidelines and tools may have already been published at a regional or municipal level. In such cases, MS should evaluate the costs and benefits of preparing national level guidelines to avoid duplicating the efforts already undertaken at lower levels of administration. It is desirable that guidelines also cover redevelopment of brownfields for soft re-use as well as bringing them back to nature. Such advice may be particularly relevant for the regions and municipalities with shrinking population and economy, and thus a low demand for land.

Market-based instruments

Grants, urban development funds and revolving loan funds have proved successful in supporting brownfield redevelopment across EU MS. Grants may be specifically useful in supporting redevelopment of brownfield for soft-end use redevelopment. Provisions of low-interest loans through urban development funds and revolving funds can help breach the gap between the risks in redevelopment of brownfield land compared to greenfield. They also proved useful in some MS to help local authorities and other organisations access money available from the EU Structural and Cohesion funds. **Varying levels of tax,** depending on the type of land being developed, could be used to facilitate brownfield redevelopment and direct urban development inward. Evidence collected as part of this study suggests that in order for such taxes to be successful, they need to be sufficiently high. Furthermore, spatial development taxes alone may not be sufficient to guarantee redevelopment of brownfield land thus MS should ensure these are implemented as part of a well-functioning planning system.

Non-regulatory instrument

At a Member State level, **land development agencies** have a versatile role to play in the land recycling process, from identifying brownfield land, to assisting stakeholders in accessing relevant sources of funding. **Public private partnerships** also provide an attractive structure for the cooperation between public and private entities as they allow sharing the risks and benefits associated with the redevelopment work.

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4. Land degradation, in particular by erosion and loss of organic matter

In brief

Large areas of the EU are affected by land degradation, which impairs vital land use and soil functions. The two greatest factors contributing to soil degradation are erosion and the decline of organic matter.

The European Commission's Soil Thematic Strategy, adopted in 2006, made it clear that the EU needs to improve the quality of its soils and protect its functions. A proposal for a Soil Framework Directive, which would require MS to identify areas at risk of erosion, organic matter decline and other land degradation issues and then implement appropriate programmes and measures to address these issues, was never adopted. Nonetheless, soil degradation issues remain important as mentioned in the 2011 Roadmap for a Resource Efficient Europe and the 2012 global commitment of achieving a land degradation neutral world at the United Nations Conference on Sustainable Development (Rio+20).

Soil erosion and loss of soil organic matter trends are likely to continue – with strong regional differences to the extent and impact. It is estimated that 130 million hectares are affected by water erosion in the EU-27. The Mediterranean region is particularly at risk to water erosion, but also arable land in northern Europe is also susceptible. Some 45% of soils in Europe have low or very low organic matter content, and another 45% have a medium content. A majority of soils in southern Europe have low levels of organic matter as well as other regions across the EU. Given the state and future outlook of economic, social and environmental impacts, there is justification for setting long term targets for both erosion and the loss of soil organic matter to foster a more strategic approach to sustainable and resource efficient land use.

Appropriate indicators are needed to set policy targets. An assessment of the existing indicators for soil erosion (by water, wind and tillage) and soil organic matter (including soil organic carbon and carbon stocks in peatlands) showed that the water erosion rate and soil organic matter content would be best suited to be used to set targets. As it is difficult to measure on-site, soil erosion is tracked at the EU level through modelling performed by JRC using data on the influencing factors. Soil organic carbon (SOC) content can be easily measured in the field. Soil organic matter (SOM) is estimated based on the measured SOC content. Currently, the SOM content indicator is the indicator for which the highest quantity of data is available at the EU scale – though not all areas of the EU territory are covered. In general, data needed to monitor soil erosion and organic matter development is available and reliable, although additional data and updates are required. There is however a need to ensure that the modelled erosion rates correspond with reality - further research may be relevant to determine how remote sensing can be used to confirm the estimated water erosion.

When developing potential targets for soil erosion this can be based on either setting a minimum level for not increasing and / or reducing annual erosion rate by water (e.g. 10 t/ha/yr) or based on the amount of area subject to soil erosion over a certain amount. The target could be specified according to minimum erosion rates, land use type (e.g. agricultural land) or land cover type (e.g. cropland, pasture, forest, etc.). Similarly, SOM / SOC targets could either be based on a certain level of content (e.g. 3.5% organic matter) or type of land (e.g. cropland, pasture, peatlands, etc.).

Several studies have provided a range of estimates of the economic costs and benefits (e.g. avoided yield losses, water quality, etc.) of protecting and restoring soils. The main administrative challenges relate to monitoring of the progress towards the targets. At the EU level, the Common Agricultural Policy should contribute efficiently to monitoring soil erosion by water and soil organic matter and encourage MS to attain the proposed targets. Several MS have implemented policy measures that would support the soil targets across the EU such as requiring land users to establish to protect and improve soil quality; providing subsidies and compensation; developing a national soil reporting framework; and, developing guidelines for sustainable soil management.

This chapter first describes the past, current and future trends regarding soil erosion and soil organic matter (SOM) loss. It then provides an overview of the targets and supporting policy instruments implemented in the MS to address erosion and SOM loss and, more broadly, land degradation. Existing indicators for monitoring soil erosion and SOM are then reviewed based on the RACER framework. Finally, proposals are made with regard to possible targets that could be developed at the EU level, and a feasibility assessment of these possible targets is carried out.

4.1. Introduction

Land degradation is a complex multidimensional concept. It results from the interaction of biophysical and socio-economic processes and influences the land's productive capacity. The above and below ground ecosystem functions that condition productive capacity can be reduced by intensive use leading to their overexploitation. The increased socio-economic driven pressures on the use and management of land resources provoke bio-physical deterioration, called land degradation. A healthy good structured soil is key to balanced land-based nutrient cycles and biomass production. It regulates vast amounts of water and carbon and allows biodiversity to flourish.

Land degradation encompasses many different issues such as soil sealing, soil erosion, loss of soil organic content, soil compaction, desertification, soil contamination by hazardous substances (e.g. due to industrial activities), etc.

In accordance with the Terms of Reference for the present study, this chapter focuses on the two aspects of soil for which targets have been proposed in the Commission's Roadmap for a Resource Efficient Europe, i.e. soil erosion and loss of soil organic matter. Soil sealing issues are addressed in Chapter 2 on Land Take, while soil contamination is closely related to Land Recycling discussed in Chapter 3.

Soil erosion consists of the removal of soil material by water or wind. It is a natural process, occurring over geological time scales (Joint Research Centre, 2012a). Accelerated erosion, where the natural rate has been significantly increased by human activity, is a critical issue as it causes soil degradation. Runoff is the most important direct driver of severe soil erosion by water. With a very slow rate of soil formation, any soil loss of more than 1 tonne per hectare per year (t/ha/yr) can be considered as irreversible within a time span of 50-100 years (Kirkby M. J., 2004). However, soil formation can vary from 0.3 to 1.4 t/ha/yr (Verheijen F. , Jones, Rickson, & Smith, 2008). Hence, tolerable rates of erosion can be variable following rates of soil formation under different geoclimatic conditions. Erosion can be due to several factors. The most common factors are water, through abundant rainfall, and wind. Erosion can also be due to tillage or harvesting. . Tillage induces a displacement of the cultivation layer as soil is moved by machinery and becomes more sensitive to water erosion. The harvesting of specific crops such as sugar beets not only displaces the cultivation layer but also removes a large amount of soil that is transported from the field to the factory (Tugrul, Içoz, & Perendeci, 2012). Finally, forest fires result in bare soils whose particles are easily removed by wind.

In the Commission's proposal for a Soil Framework Directive (COM (2006) 232 final), **soil organic matter (SOM)** was explicitly defined as "*the organic fraction of the soil, excluding undecayed plant and animal residues, their partial decomposition products, and the soil biomass*". SOM includes elements such as carbon, hydrogen, nitrogen and oxygen that are components of organic compounds. SOM is composed of several fractions with different levels of decomposition. Humus is the fraction composed of degraded organic compounds that is stable and resistant to microbial action. It constitutes the main SOM fraction (60-80%) and the least likely to be influenced by environmental conditions and changes in management practices. The other fractions are partially decomposed matter and less stable. In particular, they include a labile fraction composed of new residues that can be readily used by microorganisms. They are highly sensitive to environmental conditions and changes in management practices, and turnover occurs within 2-3 years. While humus is the fraction responsible for most cation exchange, the labile fraction provides most nutrients for plants (Mitchell & Everest, 1995) (Pluske, Murphy, & Sheppard, 2014).

4.2. Land degradation drivers and trends

4.2.1. Soil erosion

Past and current trends of soil erosion by water

Soil erosion by water is one of the most widespread forms of soil degradation in Europe, and in particular in the Mediterranean region. The JRC estimated that it concerned 105 million ha or 16% of Europe's total land area in the 1990s. A new model constructed by the JRC estimated the surface area affected by water erosion in EU-27 at 130 million ha (Jones, et al., 2012).

In 2003, the JRC mapped s erosion by water in Europe, based on calculations with the Universal Soil Loss Equation (USLE) model, as part of the PESERA project (Kirkby M. J., 2004). In 2012, the JRC revised this data using data from 2006 and the Revised USLE (RUSLE) within EU-24 (soil erosion by water cannot be estimated for Cyprus, Greece and Malta due to the lack of CLC data (EEA, 2012a). In 2010, the JRC - in collaboration with members of the European Environment Information and Observation Network (EIONET) - also collected data on the erosion by water in eight MS[74] for the European Soil Data Centre (ESDAC). The data collected by the EIONET also uses the USLE or RUSLE model. The main differences between the PESERA project and the EIONET project are the input data needed to estimate erosion. While the geographical and/or time scope and the resolution is homogeneous within the EU in the PESERA model, the input data used by the MS is country-specific and their scope and resolution may vary across MS.

According to the data using the RUSLE model, the average rate of erosion by water in the EU-27 is 2.8 t/ha/yr (see Figure 13). Countries located in the southern part of the EU show higher average rates of erosion. The erosion rates can even reach 100 t/ha/yr in the case of extreme events. The results of

[74] Austria, Belgium, Bulgaria, Germany, Italy (10 regions), the Netherlands, Poland and Slovakia. Three other countries provided data with coverages less than 50%: Estonia, Ireland, Norway. Data source: EIONET Erosion data. European Soil Portal of the JRC - Soil Data and Information Systems: http://eusoils.jrc.ec.europa.eu/library/data/eionet/Erosion.htm

erosion in southern EU are mostly encountered on-site - leading to soil thinning. The northern loess zone shows moderate erosion rates, whose effects are mostly off-site - erosion sediment being moved into water bodies. In the eastern part of Europe, those two zones overlap, which increases the erosion risk (EEA, 2000b).

According to data derived from the RUSLE model, an area of about 21 million ha in the EU-24 was estimated to suffer from moderate to severe water erosion (more than 10 t/ha/yr) in 2006, which represents 16% of the total EU territory[75].

[75] Percentage of the EU territory affected by soil water erosion (%) according to soil erosion rate (tonnes per ha per year), 2006, EU-27. Agri-environmental indicator - soil erosion: http://epp.Eurostat.ec.europa.eu/statistics_explained/index.php/Agri-environmental_indicator_-_soil_erosion

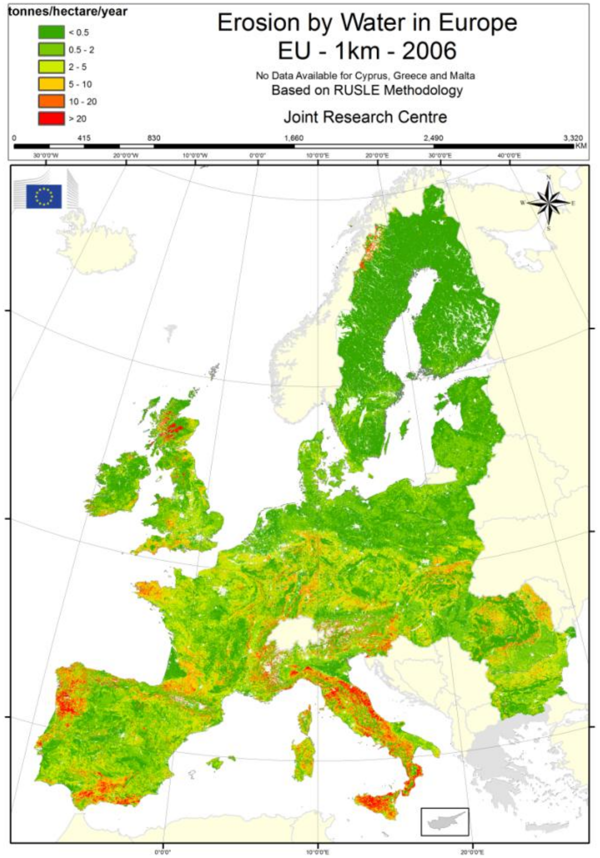


Figure 12: Erosion by water in Europe in 2006

Source: Jones et al., 2012

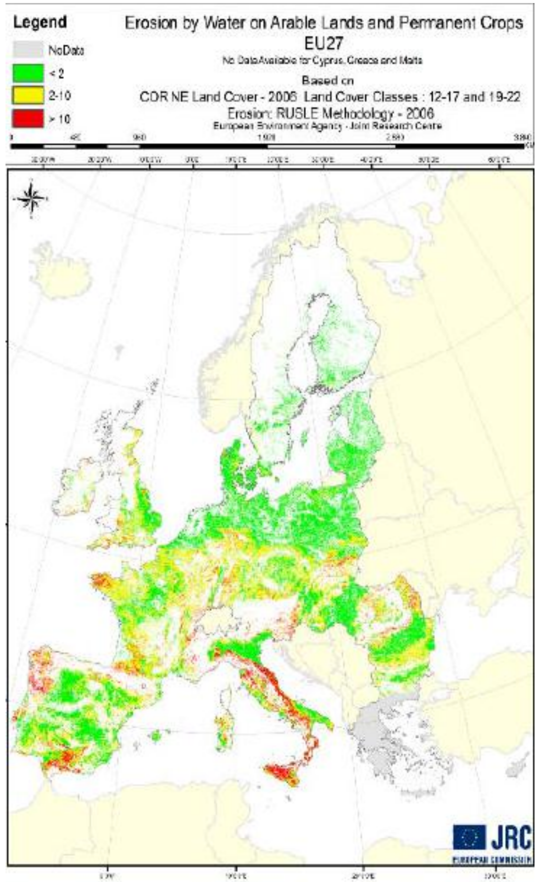
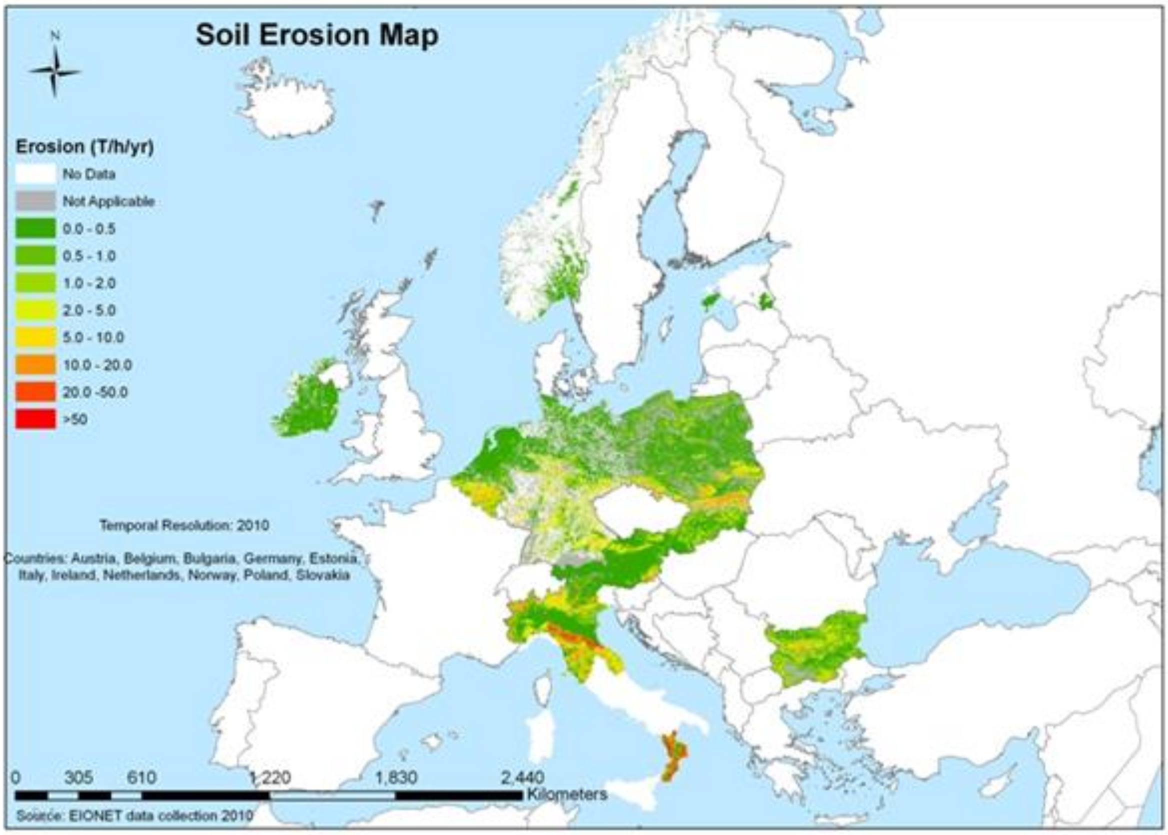


Figure 13: Erosion by water on arable land and permanent crops in the EU-27 (excl. Cyprus, Greece and Malta) in 2006

Source: Jones et al., 2012

According to the EIONET data, the average erosion varies from 0.25 t/ha/yr in the Netherlands to 6.6 t/ha/yr for Italy with a high standard deviation (see Figure 14).

The absence of correlation between the surface area affected by an erosion rate higher than 10 t/ha/yr and the average soil erosion rate shows that more precise data are needed to estimate the erosion threat of a Member State. For instance, 10% of Austria's territory is affected by an erosion rate higher than 10 t/ha/yr, while the average erosion rate would suggest that erosion is not an issue in Austria since the average rate (0.66 t/ha/yr) is lower than the rate of soil formation; this indicates that erosion is a very local issue. On the contrary, in Belgium, a small share of the territory is affected by erosion of more than 10 t/ha/yr (1%) while the average erosion rate is 3.65 t/ha/yr (European Commission, 2013; Panagos, Meusburger, Van Liedekerke, Alewell, Hiederer, & Montanarella, 2014).



Source: European Commission, 2013

Figure 14: Soil erosion by water for the year 2010

According to the data based on the RUSLE model, the agricultural area suffering from erosion of more than 11 t/ha/yr was estimated at 12.4 million ha, which only represented 6% of the total agricultural area of the EU-27 in 2006-2007. This share was higher in the EU-15 (7.6%) than in the EU-12 (2.4%). Italy was the country that contributed the most in terms of surface area with 4.8 million ha affected. Spain and France represented 2.1 million ha and 1.7 million ha, respectively. Slovenia had the highest share of land affected by erosion of more than 11 t/ha/yr (37%) but this represented only 0.3 million ha (European Commission, 2013).

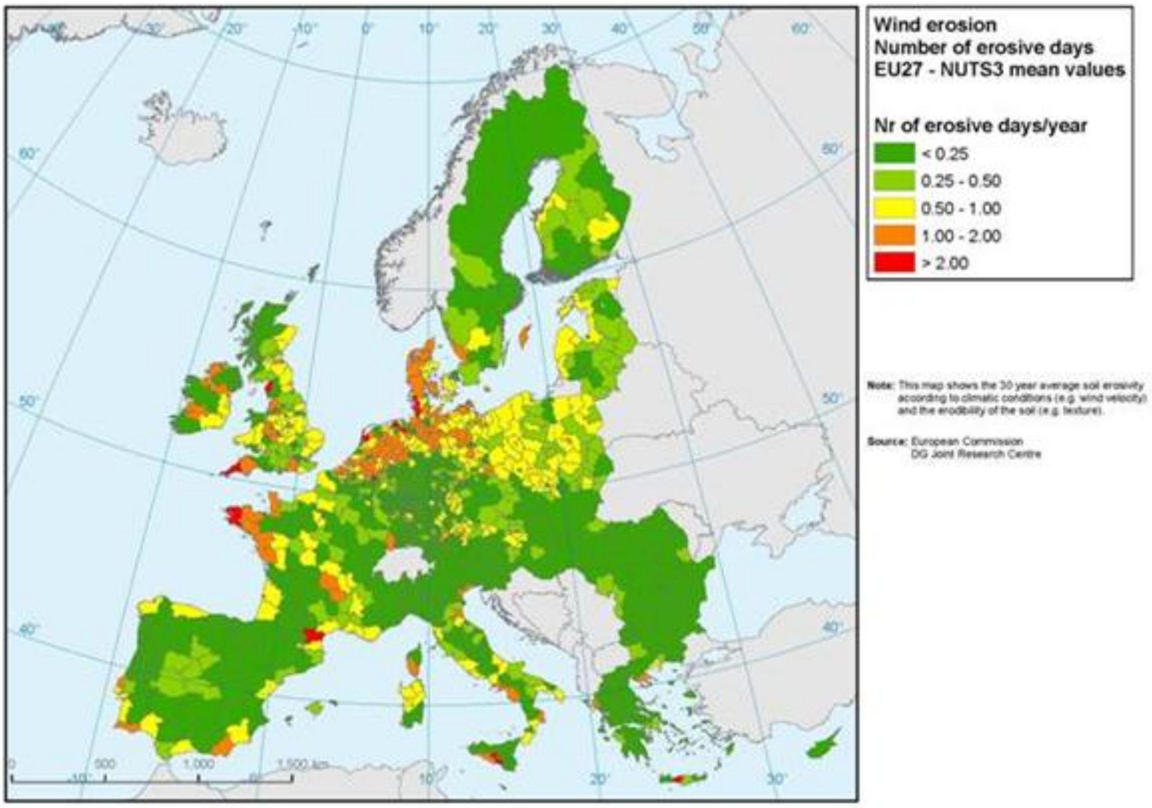
Cultivated land (arable and permanent cropland) is estimated to be affected by moderate to severe water erosion (7%) more than permanent grasslands and pasture (2%) (Jones, 2012). This demonstrates the importance of maintaining permanent vegetation cover as a mechanism to combat soil erosion.

Past and current trends of soil erosion by wind

The JRC estimates that 42 million ha were affected by wind erosion in 2003, i.e. 4% of the European's total territory. In England, the mean wind erosion range was of 0.1-2.0 t/ha/yr in 2003 and could be up to 10 t/ha/yr in the case of severe events (Jones, et al., 2012). In Mediterranean ecosystems, Breshaers et al. (2003) estimate that wind erosion exceeded water erosion in shrubland (55 t/ha/yr) and forests (0.62 t/ha/yr) but not in grasslands (5.5 t/ha/yr) (Breshears, Whicker, Johansen, & Pinder, 2003).

The precise erosion rate by wind is difficult to evaluate. The extent of wind erosion is determined by the climate's erosivity (capacity of climatic events such as rainfall or wind to induce erosion in a particular area) and the soil's erodibility (susceptibility of soil to erode due to its characteristics) that allow obtaining a mapping of the area potentially affected by wind (see the figure below). To date, no homogeneous data is available for the EU-28.

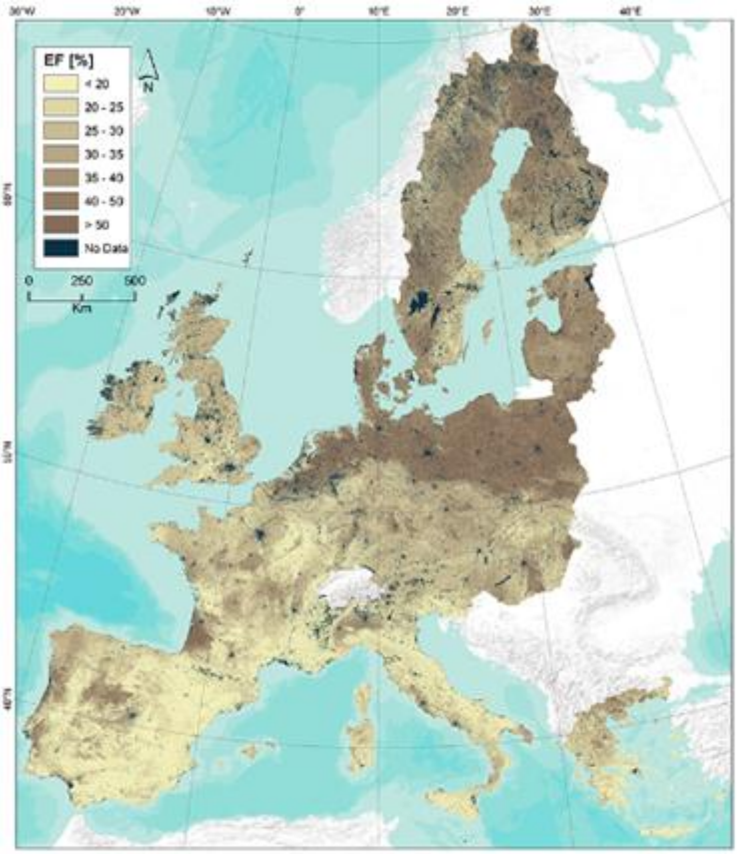
Climate erosivity and soil erodibility have been mapped by the JRC. The number of erosive days is shown in Figure 15. The number of erosive days is particularly high in northern Germany, eastern Netherlands, eastern England, Denmark, Brittany and the coastal regions of the Iberian Peninsula.



Source: JRC, 2013d

Figure 15: Geographic spread of areas prone to wind erosion (1961-1990), based on the number of erosive days per year

The soil erodibility was studied in recent work conducted by Borelli et al. (2014) that evaluated wind erosion susceptibility by mapping another parameter influencing wind erosion, i.e. the wind-erodible fraction of soil (EF), for the EU-25 (see Figure 16). Bulgaria, Romania and Croatia were excluded from the study due to the lack of LUCAS-Topsoil data (Borrelli, Ballabio, Panagos, & Montanarelle, 2014). This calculation shows that wind is likely to cause erosion in northern countries. Soil erosion is also particularly intensive in areas prone to forest fires, estimated at 500,000 ha/yr by the European Forest Fire Information System (EFFIS) (JRC, 2013a).



Source: Borrelli, Ballabio, Panagos, & Montanarelle, 2014

Figure 16: Wind erosion susceptibility of European soils in 2014

By comparing the previous two maps, the regions that are the most likely to be eroded by wind are Belgium, the Netherlands, Denmark, the north of Germany, the north of Poland, Estonia, Latvia, Lithuania and the southwest of France.

Past and current trends of soil erosion by other factors

Though not as widespread as erosion by water or erosion by wind, other types of erosion can locally induce significant soil losses.

Tillage erosion refers to soil translocation or downhill displacement and dust emissions due to tillage. The rate of erosion by tillage through soil translocation often exceeds 10 t/ha/yr, even attaining up to 68 t/ha/yr in Spain in downslope. The dust due to tillage can result in up to 50 t/ha/yr of soil losses (Blanco et Lal, 2008; Govers et al., 1999; Govers et al., 2003).

Soil erosion by harvest can range between 0.2 and 30 t/ha/yr, depending on the type of soil and the type of crops (Blanco & Lal, 2008). Crop harvesting is responsible for soil loss from 2 t/ha/yr for potatoes to 9 t/ha/yr for sugar beets on average (Jones, et al., 2012). Contrary to erosion by tillage that is an increasing concern, erosion by harvest is rarely studied.

Drivers and future trends for soil erosion by wind and water

Drivers

Erosion rate is very sensitive to land use, soil properties (soil organic matter, soil texture and structure, and permeability) and climate (e.g. long dry periods followed by heavy bursts of erosive rain). The environmental factors that drive soil erosion are (European Commission, 2006a) (JRC, 2014b and c):

- **Climate** is one of the factors that influence soil erosion the most, in particular intense **precipitation** and **wind velocity**. Rainfall can affect the soil structure and moisture, depending on the amount, the distribution, the intensity, the energy load and the seasonality of the precipitation. Thus, runoff is the most important direct driver of severe soil erosion by water. The velocity of wind, in particular along the coast, consequently causes detachment of material by saltation through air.
- **Soil properties**, including soil organic matter, texture, structure and permeability influence **soil erodibility** (the capacity of a soil to be eroded, also called the K-factor). Water erosion is also influenced by the aeration, the compaction and the drainage soil capacity. The aggregate capacity, linked to the SOM content, increases the resistance to raindrops. Wind erosion is also influenced by soil compaction and humidity: the drier the soil, the higher the probability for soil elements to be transported by wind.
- **Vegetation cover** highly influences erosion. Water erosion rates decreases exponentially with increasing vegetation cover. Root systems help maintain the elements of soil, depending on the depth and the density of the root systems (Gyssels, Poesen, Bochet, & Li, 2005).
- **Steep slopes** also increase soil erosion, by gravity.

Certain anthropogenic activities also lead to soil erosion by influencing the natural parameters that impact erosion (European Commission, 2006a) such as land abandonment, forest fires or agricultural practices (Jones, et al., 2012). :

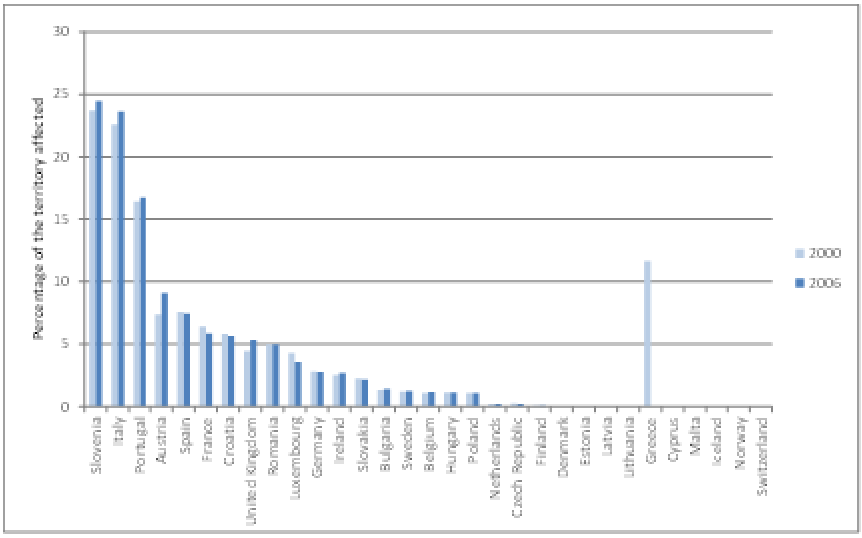
- Soil disturbance and inappropriate use of heavy machinery. Tillage is both a cause and a driver of soil erosion by water or wind. Ploughing, in particular in up-and-down slopes, aerates the soil and reduces soil compaction. By decreasing the cohesion between the soil particulates, tillage increases soil erodibility and thus the risk of soil losses due to rainfall or wind. Heavy machinery may create high compaction. It may increase run-off and transfer of particulates by water.
- Practices that leave the soil bare or remove the vegetative soil cover and/or hedgerows, such as the absence of cover crops, late sowing of winter cereals, overgrazing, deforestation and forest fires, and the increase of field size (open fields). Soil erosion is also particularly intensive in forest fire areas, estimated at 500,000 ha/yr by the European Forest Fire Information System (EFFIS), but there is no information available on soil erosion rates due to forest fires (JRC, 2013a).

Soil properties, climate and land cover are the major components that influence the erosion rate and its extent. Erosion is larger in agricultural areas (crops) than in natural land-cover types such as forests, independent of the soil and climatic conditions (UNEP/RIVM, 2004). In the south of the EU, severe water erosion results from intensive seasonal rainfall, often in association with overgrazing and a move away from traditional crops. In the northern loess belt, erosion is due to intensive rainfall falling in saturated, easily erodible soils. Local wind erosion also induces the loss of light soils (EEA, 2000b).

Future trends

Only an estimate of the changes in the surface area affected by erosion is available. Future trends of the erosion rate are not available. In 1997, the European Commission estimated that water erosion risk would increase by the year 2050 in about 80% of EU agricultural areas, in particular where soil erosion is currently severe, based on data from the EEA (EEA, 2000b). According to Eurostat and based on the data from the JRC estimated by the RUSLE model (see Figure 17), the erosion rate increased by 0.08 points overall between 2000 and 2006, with a significant variability between the MS and within each Member State.

Figure 17: Soil erosion by water – Area eroded by more than 10 tonnes per hectare per year



Source: Eurostat[76]

The Background Report to the OECD Environmental Outlook confirms a global increase in soil erosion. In particular, global agriculture areas with high soil erosion risk are expected to increase by 19% between 2000 and 2030 in OECD countries (from 5 to 7 million km^2). This increase may be due to the expansion of agriculture and its intensification, in particular in new EU MS. However, this figure is not representative for the EU, since the OECD members are different from EU MS (despite the numerous common members). Moreover, the estimates do not take into account agronomic soil conservation practices and mechanical conservation practices. More precisely, according to the Dutch National Institute for Public Health and the Environment (RIVM), the area with high water-erosion risk is expected to increase in Western Europe by 2030 while a slight decrease is expected in Central Europe (UNEP/RIVM, 2004). In Western Europe, changes are due to the expansion of cultivated areas for food and biofuels. In Central Europe, the decrease of erosion risk is due to the decrease of grazing areas.

Given the close link between meteorological events and land cover, the rates and the extent of erosion are expected to reflect changing patterns of land use and climate change. Regarding climate change, the Intergovernmental Panel on Climate Change (IPCC) Special report on Emissions Scenarios (SRES) provides four future scenarios. In the conservative scenario (A2), only marginal changes of

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76 http://epp.Eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=t2020_rn300&language=en

temperature and precipitation patterns are expected until 2030. Hence, climate change is not expected to significantly influence water erosion by 2030. Insufficient information is available for wind erosion. The potential seasonal shift of precipitation from summer and autumn to winter and spring months may also not have significant impacts on soil erosion. Scholz et al. (2007) show that, in Austria, higher precipitation rates in spring and winter resulted in a seasonal increase of soil water erosion rates during these seasons. This observation is outweighed by a decrease of water erosion during the other seasons, due to a shift of intensive rainfall towards erosion insensitive months[77] (decrease from 10.6 to 21.1% according the tillage technique) (Scholz, Quinton, & Strauss, 2007).

Therefore, additional information is necessary to determine the development of the areas affected by erosion risk at Member State level, and the evolution of the associated erosion rates.

4.2.2. Soil organic matter (SOM)

The SOM represents the organic fraction of soil, including components from organic compounds such as carbon, hydrogen, nitrogen or phosphorus. Soil organic carbon (SOC) content refers to the amount of carbon stored in one kg of soil. It is expressed in percentage of soil or in g C/kg soil. The total amount of organic carbon contained in soil constitutes the SOC stock and it is expressed in t C/ha of land. SOC is the main component of SOM by weight. Soil organic matter is difficult to measure, since tests present high variability and questionable accuracy (Mitchell & Everest, 1995). Therefore, the organic carbon content is usually measured instead. According to the soil type and depth and the type of organic matter, the quantity of organic carbon contained in organic matter varies. However, it is assumed that the conversion factor commonly used to convert organic carbon to organic matter is 1.72, which means that organic matter contains 58% organic carbon (Pluske, Murphy, & Sheppard, 2014).

Past and current trends of soil organic carbon content

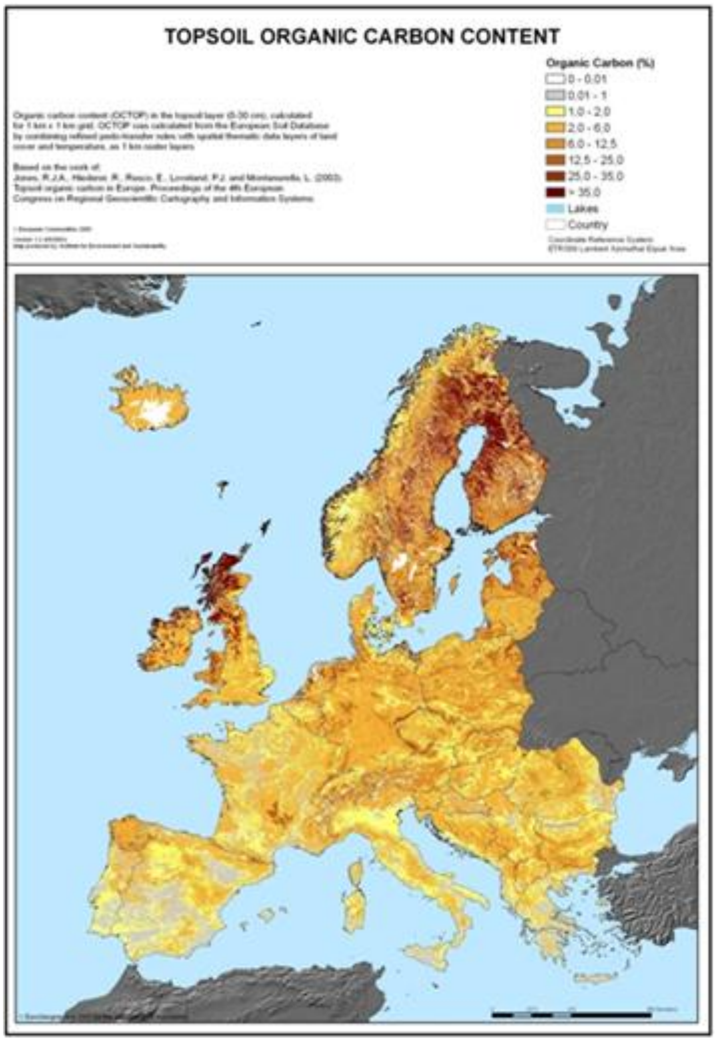
Currently, some 45% of soils in Europe have low or very low organic matter content (0-2% organic carbon or 0-3.5% organic matter, and 45% have a medium content (meaning 2-6% organic carbon or 3.5-9% organic matter) (Jones, et al., 2012). The SOC content is estimated to vary from 0 to more than 35% across the EU.

The JRC collected data on the SOC content and SOC stock of seven countries[78] in 2010, for the European Soil Data Centre (ESDAC) (EIONET data). The average SOC content varies from 1.3% for Slovakia to 3.5% for the Netherlands. The maximum SOC content can be much higher than the average content. This suggests that the distribution of carbon content is very heterogeneous within the EU, with areas where soils are almost entirely constituted by SOM. For instance, the maximum SOC content of Slovakia is 50%. In other MS, it varies from 4.6% for Belgium (average SOC content: 1.9%) to 58% for Denmark (average SOC content: 2%) (JRC, 2012; Panagos, Hiederer, Van Liedekerke, & Rampa, 2013). The highest estimated contents are localised in West Ireland, North United Kingdom, Sweden, Finland and Estonia (Jones, Hiederer, Rusco, Loveland, & Montanarella, 2005) (see Figure 18).

[77] Sensitive months corresponds to months with low vegetation cover

[78] Austria, Belgium, Denmark, Italy, the Netherlands, Poland and Slovakia. Three other countries provided data with coverages less than 50%: Bulgaria, Estonia, Norway

By contrast, estimations reveal that the issue of low and medium carbon content soils particularly concern Southern European countries, where 74% of the soil has less than 2% organic matter in the top soil, as well as parts of France, the United Kingdom, Germany and Sweden (European Commission, 2006a).

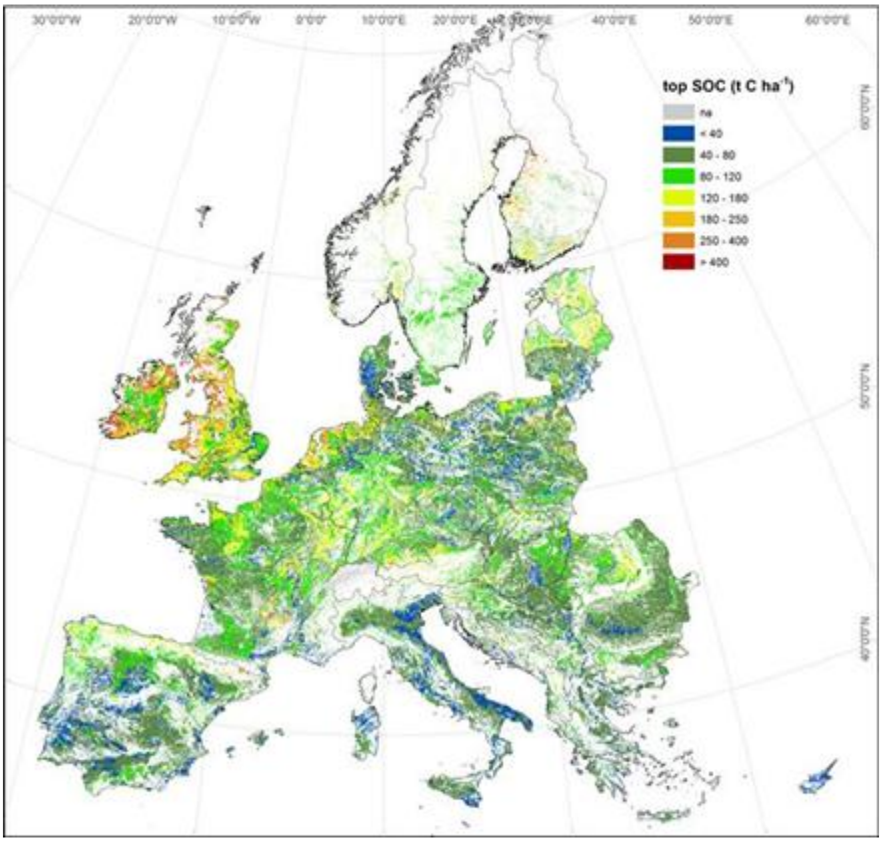


Source: (Jones, Hiederer, Rusco, Loveland, & Montanarella, 2005)

Figure 18: Total soil organic carbon content in topsoils in 2003

Regarding the carbon stock, the EU-27 soils contain between 73 and 79 Gt of organic carbon, which is equivalent to almost 50 times the EU's annual greenhouse gas emissions[79] (Gobin, 2011). Half of the carbon stored is found in peatlands and forest soils of Sweden, Finland and the United Kingdom (Jones, et al., 2012). This also corresponds to the area with the highest SOC content. The current estimate of total top soil SOC stock is 17.63 Gt in EU agricultural soils in 2010 (JRC, 2013b), with an average top soil SOC of 82.5 t/C/ha. Arable land is predicted to store 7.65 Gt of carbon and pasture contains 5.5 Gt of C (Lugato, Panagos, Bampa, Jones, & Montanarella, 2014). Peatlands represent 17 tC. Other carbon stocks are located in forests and, to a lesser extent, in other types of land.

[79] Excluding land use and land use change and forestry (LULUCF)



Source: Joint Research Centre, 2013b

Figure 19: Soil organic carbon stock under agricultural land use (2010)

Within MS, the carbon stock in agricultural soils varies according to regions, from 20 tC/ha to more than 400 t C/ha. In organic soils, this amount varies from 35 tC/ha to more than 1,250 t C/ha (JRC, 2012; JRC, 2013b; Gobin, 2011) (Figure 19). In MS, the average organic carbon stock varies from 28 tC/ha for Bulgaria to 100 tC/ha for the Netherlands[80] according to the data collected by the JRC in 2010. According to the new model developed by the JRC, countries with the highest total estimated SOC stock are France (2,588 MtC), the UK (2,367 MtC) and Germany (1,866 MtC). The results of this model are close to the data provided by the EIONET for four countries, with less than 20% difference between the stock calculated and the stock provided by the EIONET. However, higher differences are observed for the other countries, confirming the uncertainty regarding the SOC stock across Europe (Lugato, Panagos, Bampa, Jones, & Montanarella, 2014).

Peat soils contain the highest concentration of organic matter of all soils (Jones, et al., 2012). The current area of peatlands in the EU is estimated at more than 318,000 km^2, representing 8% of the EU-27 surface area and storing 20-25% of soil carbon stock (17 tC) (European Commission, 2011b; Gobin, 2011). The carbon content of peatlands varies from more than 10% of SOC to 50% of SOC. The forest is also an important carbon sink. It stores between 190 MtC/yr for the lower estimation[81] to 380 MtC/yr for the highest estimation (Gundersen, 2006; Gobin, 2011; EEA, 2012). The conversion of

[80] The data provided concerns either agricultural land only or all land areas, depending on the MS
[81] in Central Europe

land (UAA) to forest allows a SOC stock gain of 47 t/ha/yr. Carbon is also stored in wood product to a lesser extent (less than 10% of the carbon stored) (Vallet, Meredieu, Seynave, Bélouard, & Dhôte, 2009).

The current rate of global C loss due to land use change is about 1.6 ± 0.8 GtC/y (Gobin, 2011; Smith, 2008). The conversion of peatlands and their use is particularly worrying. The estimated peatlands carbon stock loss in the EU-27 range is estimated at 1.6 tC/ha/yr (between 0.13 and 0.36% of the stock per year), with large regional differences (European Commission, 2011b; Gobin, 2011).

In 2009, European croplands emitted an average of 0.45 tCO_2/ha, much of which resulted from land conversion (European Commission, 2012c). The National Soil Inventory (NSI) of England and Wales showed that an average of 0.6% of organic carbon content was lost per year between 1978 and 2003 (Bellamy, 2005). The same trends were observed in France, Belgium and Austria (Dersch & Boehm, 1997) (Saby, 2008) (Goidts, 2009).

For instance, Austria stores 820 Mt of carbon within its soil, mostly from forest soils (60%). The Federal Research Centre for Forest estimated that forest soil C stock decreases by 0.2 tC/ha/yr. Furthermore, 400 kt of CO_2 is released each year due to land use change (Environment Agency Austria, 2013).

Drivers and future trends for soil organic matter content

Drivers

Soil organic matter content is highly variable depending on the soil type, geoclimatic conditions, land use changes, agricultural practices, soil erosion and wild fires (Jones, 2012). Environmental conditions and agriculture practices are the main drivers of SOM decline. Environmental conditions influencing SOM are as follows:

- **Climate** is the main factor that influences SOM content (Jenny, 1994; Mitchell & Everest, 1995). **High temperatures** increase the decomposition of organic matter (mineralisation) and consequently decrease the level of organic matter in soil (Kibblewhite M. , 2005) (Jones, et al., 2012). Hence, the SOM content is lower in southern regions than in northern regions (SoCo project team, 2009). Moreover, **precipitation** increases the accumulation of undecayed organic matter, as it may lead to wet and anaerobic conditions. Anaerobic conditions occur in the case of poor soil aeration and/or poor soil drainage. In these conditions, micro-organisms do not degrade organic matter. This consequently leads to the creation of organic soils such as peatland.
- **Vegetation** contributes to the supply of organic matter. Depending on the type of cover and the type and the amount of residues, the latter is degraded more or less rapidly depending on the C:N ratio. The C:N ratio is the ratio between the amount of carbon (C) and the amount of nitrogen (N) contained in the organic matter. Thus, residues such as straw have a high carbon content compared to their nitrogen content (C:N = 80-100), while vegetables have a lower ratio (C:N = 10-20). Considering the interconnection between the carbon and the nitrogen cycles, decomposition of material occurs with a C:N ratio equal to the ratio of soil and microorganisms (8-10) (Peyraud, et al., 2012). Consequently, microorganisms require N inputs to degrade matter with high C:N ratio (i.e. to decrease the C:N ratio of the residues that must be decomposed). Hence, nitrogen content can be a limiting factor that slows the decomposition rate.
- **Soil type**, and in particular soil texture, contributes to explaining the initial carbon content of soil. Fine texture soils, typically containing clay, have higher soil organic matter content than coarse-textured soil.

Human activities that lead to a loss of soil organic matter influence the natural conditions mentioned above. For instance, intensive and continuous arable production may lead to a decline of soil organic matter. Land use changes can result in rapid carbon losses (i.e. instant), whereas gains accumulate more slowly (i.e. decadal). These include (Kibblewhite M. , 2005) (Jones, et al., 2012):

- Conversion of grassland, forests and natural vegetation to arable land;
- Deep ploughing of arable land, as it increases soil aeration, in particular in the case of clay soils.
- Drainage and fertiliser use;
- Tillage of peat soils;
- Crop rotation with reduced proportion of grassland;
- Soil erosion; and
- Wild fires.

Future trends

Given the close link between SOM, meteorological events and the agricultural practices, the SOM content is expected to reflect changing patterns of land use, agricultural practices and climate change.

As mentioned in relation to the estimated trends for soil erosion, the IPCC conservative scenario (A2) estimates that only marginal changes of temperature and precipitation patterns are expected until 2030. Thus, the trend of SOM loss calculated for some EU countries in this scenario will not be significantly influenced by temperature and precipitation.

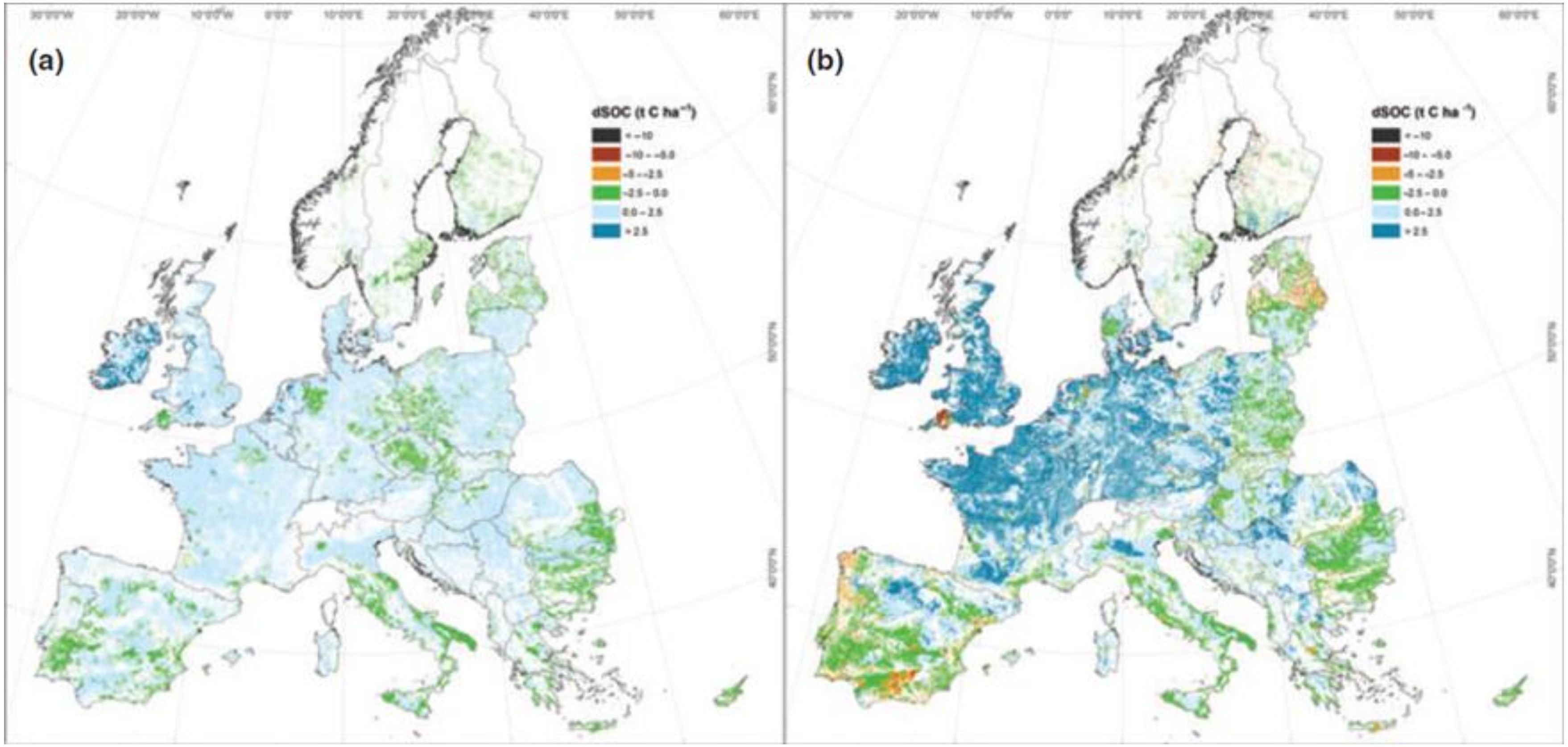
Regarding land use, agricultural area that was present in 2012 is expected to decrease by 2020. In particular, grazing land is expected to decrease significantly. As grassland sequestrates a significant amount of organic carbon, the latter will be potentially lost.

According Gobin et al. (2012), the possible variation of the SOC stock by 2030, according to future agricultural practices are the following:

- Land use conversions to and from agricultural land: SOC stock gain of 1 tC/ha/yr in the EU-27 in 2030;
- Residue management: SOC stock gain of 0.5 to 1.58 tC/ha/yr in 2030 according to the type of residues, in particular 1.15 tC/ha/yr for cereals that represent the largest area (+ 0.4 tC/ha compared to 2000);
- Organic residues management (manure and compost): SOC stock gain of 0.23 tC/ha/yr in 2030 (stable compared to 2000);
- Forest residues management: SOC stock gain of 0.22 to 0.42 tC/ha/yr in 2030 depending on the type of trees (stable compared to 2000);
- Peatland management: SOC stock loss of 1.52 tC/ha/yr in 2030 (- 0.08 tC/ha compared to 2000).

According to the “Business as usual” scenario, the SOC content is expected to increase by 2030. However, the uncertainty regarding this future scenario is high. Since the future scenario will have a significant influence on SOC stock, the estimation of an accurate evolution of SOC stock by 2030 is difficult. The study from Gobin et al. (2012) proposes scenarios ranging from optimistic scenarios to a worst-case scenario. According to the “Business as usual” scenario, the SOC stock in 2030 may significantly vary. For instance, the SOC stock related to land use change may vary from a loss of -9.7 tC/ha/yr to a gain of 5.0 tC/ha/yr for the year 2030. Moreover, the combination of scenarios may differ in each Member State. In the specific case of peatland, no further conversion would result in a loss of 1.4 tC/ha. The restoration of 50% of the peatland would decrease the SOC losses to 0.58 tC. The restoration of 100% of the peatland would lead to the sequestration of 0.23 tC.

These results are confirmed by the recent model developed by the JRC to estimate the SOC stock. The overall SOC stock for the EU is projected to increase from 17.63 GtC (in 2010) to 18 GtC until 2080. However, strong regional differences are predicted, involving net losses of about 30% in the south and in the east of the simulated area, compensated by a SOC stock gain in central and northern regions. Despite the higher vulnerability of southern and eastern European countries to SOC loss, the magnitude is limited (almost <5 tC/ha by 2100), suggesting that SOC stock should be resilient enough against climate change (Lugato, Panagos, Bampa, Jones, & Montanarella, 2014).



Source: Lugato, Panagos, Bampa, Jones, & Montanarella, 2014

Figure 20: Predicted SOC stock change (tC/ha) with respect to the actual value in 2020 (a) and 2010 (b)

There is no data on the future trends of SOC content. However, considering the trends expected for SOC stock, it could be estimated, with a high level of uncertainty, that the SOC rate is expected to follow similar trends.

4.3. Review of indicators

This section provides a description of the indicators related to soil erosion and soil organic matter, an analysis of their quality based on the RACER framework, and an assessment of their suitability for target setting.

The following indicators have been analysed:

- Annual erosion rate by water (t/ha/yr);
- Annual erosion rate by wind (t/ha/yr);
- Annual erosion rate by tillage (t/ha/yr);
- Area of land subject to water erosion rate > 10 t/ha/yr (ha);
- Soil organic matter (SOM) content (% or kg SOM/kg soil) or Soil organic carbon (SOC) content (% or kg SOC/kg soil);
- Area of soils with organic matter level <3.5%;
- Soil organic carbon (SOC) stock (t/ha); and
- Peatland SOC stock (MtC).

In addition to the above indicators, it should be noted that land productivity indicators are discussed in Chapter 5 (Land Functions). Erosion and soil organic matter are two factors that may influence land productivity significantly; however, their respective levels of influence – among various other factors – are difficult to establish when analysing land productivity data.

4.3.1. Indicators description

Table 27: Overview of the indicators analysed

Code	Indicator name	Definition	Available data and sources	Information on existing uses
LD1	**Annual erosion rate by water (t/ha/yr)**	Soil erosion consists of the removal of soil material by water or wind. It is a natural process, occurring over geological time. Erosion is driven by local natural conditions such as water (rainfall) and wind and human activity, in particular tillage. With a very slow rate of soil formation, any soil loss of more than 1 tonne per hectare per year (t/ha/yr) can be considered as irreversible within a time span of 50-100 years. The average rate of erosion by water in the EU-27 is 2.8 t/ha/yr. The rate of wind erosion range was of 0.1-2.0 t/ha/yr in 2003 and could be up to 10 t/ha/yr. The erosion rate by tillage often exceed 10 t/ha/yr.	Data on soil erosion are directly available through PESERA and USLE databases at pan-European scale that provide data of the estimated erosion rate at a resolution of 1 km x 1 km. The data are also available from Eurostat. Other European models exist, such as the MESALES model. The data collection performed by the JRC from the EIONET members gathers data from eight MS. Some national models also exist, most of all using the USLE equation.	Common Monitoring and Evaluation Framework (CMEF) for the CAP 2014-2020 Environmental assessment of soil for monitoring (ENVASSO project) , aimed at developing a soil monitoring system in support of the Soil Directive proposal (Kibblewhite, et al., 2008) Proposed at the Rio+20 conference to achieve the global "Zero Net Land Degradation" target
LD2	**Annual erosion rate by wind (t/ha/yr)**		At EU level, no consensual model and data is available on the erosion rate by wind for all MS. However, the several parameters influencing the erosion by wind are already mapped (number of erosive days and wind erosion susceptibility of soils). Models have been developed for soil erosion by wind, some of them being used at national level.	Environmental assessment of soil for monitoring (ENVASSO project) (Kibblewhite, et al., 2008) Proposed at the Rio+20 conference to achieve the global "Zero Net Land Degradation" target
LD3	**Annual erosion rate by tillage (t/ha/yr)**		At EU level, tillage erosion was estimated in several MS (e.g. Spain, Portugal, Belgium) but no consensual model exists.	Environmental assessment of soil for monitoring (ENVASSO project) (Kibblewhite, et al., 2008)
LD4	**Area of land subject to water erosion rate > 10 t/ha/yr (ha)**	Moderate to severe erosion concern soil with an erosion rate higher than 10t/ha/yr. The surface area affected by water erosion in EU-27 at 130 million ha. Almost 20% of this area is subject to soil loss in excess of 10 t/ha/yr.	See Annual erosion rate by water	Derived from the Roadmap for a Resource Efficient Europe Proposed by the study 'Modelling milestones for achieving resource efficiency' performed for the European Commission (BIO Intelligence Service, 2013) Common Monitoring and Evaluation Framework (CMEF) for the CAP 2014-2020
LD5	**Soil organic matter content (% or kg SOM/kg soil)**	Soil organic matter (SOM) is defined as *"the organic fraction of the soil, excluding undecayed plant and animal residues, their partial decomposition products, and the soil biomass"*. Mainly composed	Regular sampling is performed in the LUCAS project. Data are available at a resolution of 2 km x 2 km for 25 MS. Bulgaria, Romania and Croatia are not included in the LUCAS survey due to the lack of CLC data. Datasets for	Environmental assessment of soil for monitoring (ENVASSO project) (Kibblewhite, et al., 2008) Proposed by the Roadmap to a Resource Efficient Europe

Code	Indicator name	Definition	Available data and sources	Information on existing uses
	Soil organic carbon content (% or kg SOC/kg soil)	by humus, SOM includes elements such as carbon, hydrogen, nitrogen, oxygen that are components of organic compounds. Soil organic carbon (SOC) content refers to the amount of carbon stored in one kg of soil. It is expressed in percentages of soil or in g C/kg soil. SOC is the main component of SOM by weight. It is assumes that the conversion factor commonly used to convert organic carbon to organic matter is 1.72.	Bulgaria and Romania are being produced.	
LD6	**Area of soils with organic matter level <3.5%**	As of today, some 45% of soils in Europe have a low or very low organic matter content (0-2% organic carbon or 0-3.5% organic matter. The SOC content is estimated to vary from 0 to more than 35% in the EU.	See Soil organic matter content	Proposed by the Roadmap for a Resource Efficient Europe Proposed by the study 'Modelling milestones for achieving resource efficiency' performed for the European Commission (BIO Intelligence Service, 2013)
LD7	**Soil organic carbon stock (t/ha)**	The total amount of organic carbon contained in soil constitutes the SOC stock and it is expressed in tC/ha of land. The carbon stock in agricultural soils varies according the regions, from 20 tC/ha to more than 400 tC/ha. The current estimation of total top soil SOC stock is estimated to be 17.63 Gt in EU agricultural soils in 2010, with an average top soil SOC of 82.5 t/C/ha.	The data are available in LUCAS project and EINET data collection. SOC stock is also estimated by the new model proposed by the JRC to estimate SOC stock (CENTURY).	Environmental assessment of soil for monitoring (ENVASSO project) (Kibblewhite, et al., 2008)
LD8	**Peatland SOC stock (tC/ha peatland)**	Peatland corresponds to the area with the highest SOC content. It represents 17 tC in the EU-27.	Peatlands are located with a good level of accuracy in the EU-28. The carbon stock of peatland can be statistically estimated or estimated thanks to the new model proposed by the JRC to estimate SOC stock.	Environmental assessment of soil for monitoring (ENVASSO project) (Kibblewhite, et al., 2008)

4.3.2. RACER assessment

The above indicators have been evaluated using the RACER framework. The results of the evaluation are summarised in the subsections below.

LD1 – Annual erosion rate by water (t/ha/yr)

Annual erosion rate by water (t/ha/yr)		
Relevant		The indicator directly targets soil erosion which is the most extensive form of erosion in Europe. Since the GAEC of the CAP require that farmers implement measures to reduce erosion, this indicator is relevant to monitor the effects of these measures on water erosion. Moreover, the new CAP 2014-2020 has proposed the use of an indicator on erosion by water to monitor the farmers' progress.
Accepted		A consensual equation for the estimation of the erosion risk by water (RUSLE) is recognized and widely used by the MS. Based on this equation, the model from JRC (PESERA model) can estimate the erosion by water, by converting rainfall into run-off and run-off into potential erosion considering the local climate, soil and land use conditions. The methodology is well-known and recognised. Data used in the JRC model are from recognised European databases (CLC for land use, European Soil database, Digital elevation model and JRC Mars project for climate) and Earth Observation data for land cover. Data regarding the estimation of erosion by water is available at EU scale in Eurostat or in the European Commission's soil portal. While data are often used for research purposes, data are sometimes used by national and sometimes regional institutions for the monitoring of erosion in their territories.
Credible		The erosion model is recognised at European level and widely used at Member State and regional levels. The model provides data with a resolution of 1 km x 1 km which allow estimating the erosion at a local level. However, the resolution is not specific enough to allow identifying the cause of erosion. However, the erosion risk is only estimated and does not reflect, for instance, the potential effects of measures that aim at addressing soil erosion.
Easy		Areas affected by erosion and the erosion rate can be estimated through repeated observations and measures in the field, or through calculations using a model analysis based on factors such as soil properties, climate, landscape, etc. The use of high-resolution maps obtained from remote sensing allows extending the model analysis to EU level for example, providing observational data and a visual approach for displaying results. Measuring soil erosion is difficult to carry out, especially on a large scale, and it demands many resources. Only few measurements of on-site erosion rates have been made. They use different methodologies and scales. Repeated field measures provide a qualitative (based on observations) and quantitative (measures of soil depth for instance, or sediment load) assessment of soil erosion. It implies adapting the existing protocol for the observation of erosion (JRC, 2003), training for surveyors and recording data. These field observations have to be repeated at least twice in order to observe potential erosion, and have to be repeated more frequently to observe the evolution of soil erosion, with a periodicity ranging from five to ten years (European Commission, 2002a). Obtaining information at territory scale requires to repeat this protocol at different places and calls upon a large workforce. Therefore, field measures are often limited to reduced areas. They are used in the context of research work or local actions against erosion or to confirm the results provided by the models that estimate erosion. In order to quantify water erosion at the European level, a series of projects have been launched, using digital technology and harmonised data, such as the PESERA model (Pan-European Soil Erosion Risk Assessment) (Kirkby, et al., 2003), the MESALES model (Regional Modelling of Soil Risk) or recently the JRC data collection from EIONET members. The use of remote sensing is the subject of the Geographical Information Systems (GIS) projects that aim at mapping soil losses due to water erosion. The models developed are mostly based on runoff thresholds, which depend on soil properties, topography and vegetation cover.

Annual erosion rate by water (t/ha/yr)		
		Data on soil erosion are directly available through PESERA and USLE databases at pan-European scale. The data are also available from Eurostat, which proposes a water erosion indicator among the agri-environmental indicators (AEI) based on the PESERA project at NUTS 3 level. However, the data are not regularly updated (the most up-to-date ones are from 2004). Data at the smaller scale are also necessary to allow a more precise monitoring of erosion and associated measures. The data collection performed by the JRC from the EIONET members gathers data from eight MS that have evaluated the erosion by water using the USLE or the RUSLE equation. In case data is lacking to monitor erosion in a more accurate or more frequent manner, soil erosion could be estimated using the parameters listed in the table below. The suggested data sources are databases largely used by experts. If needed, data could be updated annually.

Table 28: Parameters needed to calculate and map soil losses, and possible data sources

	Parameters required	Possible sources
Land use	Land cover, in particular surface and location of agricultural land (arable area, pasture, etc.)	Corine Land Cover Remote sensing data
Soil characteristics: crusting and erodibility	Soil classification Soil texture Parent material class Soil structure	European Soil database
Topography	Elevation Slope	Digital elevation model
Climate	Temperature Rainfall (frequency, intensity)	JRC Mars database

Source: (European Commission, 2002b) (Le Bissonais, Montier, Daroussin, & King, 1998)

Robust		Field observations allow setting models for water erosion risk or soil losses calculation. This is the case for instance for the (Revised) Universal Soil Loss Equation (RUSLE) method that is used for many research studies on soil erosion (Michigan State University, 2002). However, further measures are required to increase the quality of the model calibration, specify the results of the model and decrease the uncertainties (Ecologic Institute and SERI, 2010). While soil characteristics do not change quickly, isolated climatic events may have significant impacts on soil erosion. Although annually updated data is not necessary (furthermore it would not always be feasible or would be very costly), regularly updated and recent data are expected to ensure the quality and the relevance of the data on soil erosion. Moreover, data on soil erosion highly depends on data on land use from the CLC database. At present, data are only available for 2000 and 2006.

LD2 –Annual erosion rate by wind (t/ha/yr)

Annual erosion rate by wind (t/ha/yr)		
Relevant		The indicator directly targets soil erosion by wind, which causes significant soil losses at the local level, although these are less extensive than losses caused by water erosion. Similarly to the previous indicator, this indicator is relevant to monitor the effect of the measures implemented in the context of the CAP to reduce erosion.
Accepted		Although less extensive than erosion by water, erosion by wind is an issue, widely recognised by stakeholders, that concerns in particular coastal areas. A geographical breakdown of the indicator may induce administrative challenges to define costal area and inland area at regional level.
Credible		As for erosion by water, provided that a model is developed, the erosion risk is only estimated and does not reflect for instance the effects of the measures that could be

Annual erosion rate by wind (t/ha/yr)		
		implemented to address soil erosion.
Easy		As for water erosion, measuring the erosion in the field is difficult and very time consuming. Currently, no consensual model and data are available to estimate the erosion rate by wind in all EU MS. However, several parameters affecting the rate of erosion by wind were independently studied. The JRC has mapped the number of erosive days per year and the wind erosion susceptibility of soils. The erosive days estimation was calculated by taking into account the climate conditions and the erodibility of soils over 30 years.. A model combining both data would allow estimating wind erosion in the EU. Some models estimating the erosion rate by wind are applied at the national scale, such as the WATEM model using the RWEQ equation (Revised Universal Wind Erosion Equation). Therefore, monitoring this indicator is not possible at the EU level with a common methodology. Monitoring is only possible in some MS, although the model only provides estimation of the erosion by wind but not "real" measurements.
Robust		The study of the erosion parameters has been developed by the JRC and based on the analysis of parameters. In addition to the parameters already mapped, it provides information on the wind-erodible fraction (EF) for 19,967 geo-referenced LUCAS soils, showing a large and specific spatial distribution of the information. In addition, while this model only provides data on the wind erosion susceptibility, regional observations gave encouraging results about the reliability of the results.

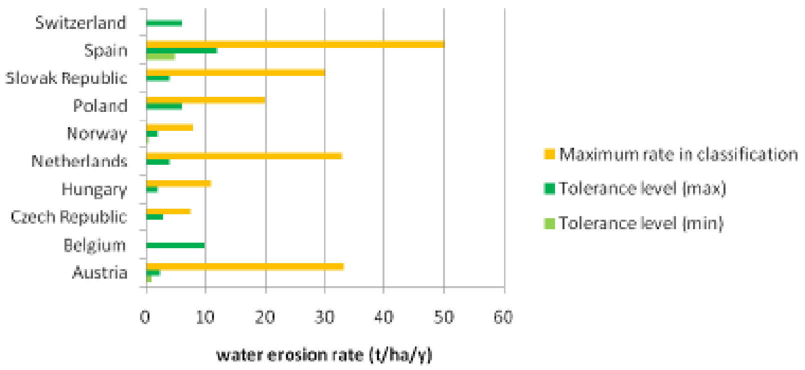
LD3 –Annual erosion rate by tillage (t/ha/yr)

Annual erosion rate by tillage (t/ha/yr)		
Relevant		The indicator directly targets soil erosion by tillage. Although this type of erosion is of an increasing concern, it only represents a small share of the total EU area subject to erosion.
Accepted		Erosion by tillage is recognised but not commonly studied.
Credible		As for erosion by wind and water, provided that a model is developed, the erosion risk is only estimated and is unlikely to reflect the effect of measures that could be implemented to address soil erosion.
Easy		Tillage erosion was estimated in a few MS (e.g. Spain, Portugal, Belgium) (Blanco & Lal, 2008) but no consensual model exists. The adaptation of a model is necessary to provide homogenised data at the European level and to allow the monitoring of this indicator.
Robust		Erosion by tillage cannot be estimated yet.

LD4 – Annual area subject to an erosion rate by water of more than 10 t/ha/yr (ha)

Annual area subject to an erosion rate by water of more than 10 t/ha/yr (ha)		
This indicator derives from the indicator LD1 and shares many properties. Therefore only properties that are specific to this indicator are detailed below.		
Relevant		The indicator directly targets soils subject to a severe erosion rate. According to the latest model developed by the JRC, about 26 million ha are affected by water erosion > 10 t/ha/yr, representing 20% of the area subject to water erosion in the EU-27. However, the area affected by a water erosion rate > 11 t/ha/yr represents12.4 million ha, i.e. 6% of the total agricultural area of the EU-27 in 2006. Hence, the threshold related to 10 t/ha/yr is more relevant since it covers a larger surface area than a threshold of 11 t/ha/yr. Several MS also use the "tolerable erosion rate" indicator, which corresponds to an indicator of "annual area subject to an erosion rate above the tolerable rate". The thresholds above which erosion is not tolerable anymore vary between 1 to 6 t/ha/yr (see

Annual area subject to an erosion rate by water of more than 10 t/ha/yr (ha)		
This indicator derives from the indicator LD1 and shares many properties. Therefore only properties that are specific to this indicator are detailed below.		
		below). A threshold that is too low may not be stringent enough and may require significant efforts from all MS. It may also require the implementation of numerous measures along with administrative burden. The threshold of 6 t/ha/yr would increase the area concerned by the indicator. A decrease of the threshold at 5 t/ha/yr (data were not publicly available for the threshold 6 t/ha/yr) would increase the concerned area two-fold, representing 15% of the total EU-27 area (SoCo project team, 2009;) (Eurostat[82]).
Accepted		The threshold of 10 t/ha/yr, used in the Roadmap for a Resource Efficient Europe, is commonly used in numerous reports to designate "moderate to severe erosion" (Eurostat, JRC). The OECD classification and the FAO prefer the threshold of 11 t/ha/yr. Maximum tolerable erosion rates are below 10 t/ha/yr and even well below the maximum rate encountered, but there appears to be no clear consensus. **Tolerance levels for soil erosion by water in some European countries are shown below:**



Source: (van Beek & Toth, 2012)

		While the soil formation rate varies from 0.3 to 1.4 t/ha/yr, the tolerable erosion rate is generally accepted to be 1 t/ha/yr, above which the erosion process may be irreversible within a time span of 50-100 year. However, there is no consensus regarding the threshold above which erosion is no longer tolerable. It can vary between 1 to 2 t/ha/yr (Ecologic Institute and SERI, 2010). In several MS (Austria, Czech Republic, Hungary water erosion is no longer tolerable at rates that are lower than those proposed by generally accepted standards like the expert-based rate of 2 t/ha/yr (van Beek & Toth, 2012). According to the OECD, the erosion risk is tolerable when the erosion rate is lower than 6 t/ha/yr (OECD, 2013)
Credible		The use of a threshold provides a clear objective for the MS. However, this threshold needs to be revised according to the progress of MS.
Easy		The assessment is similar to the indicator on the water erosion rate.
Robust		The assessment is similar to the indicator on the water erosion rate.

LD5 – Soil organic matter content (% or kg SOM/kg soil) and soil organic carbon content (% or kg SOC/kg soil)

Soil organic matter content (% or kg SOM/kg soil) and soil organic carbon content (% or kg SOC/kg soil)

[82] Soil erosion by water – area eroded by more than 10 tonnes per hectare per year. Eurostat: http://epp.Eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=t2020_rn300&language=en

Soil organic matter content (% or kg SOM/kg soil) and soil organic carbon content (% or kg SOC/kg soil)		
Relevant		The indicator directly targets SOM content and possibly SOM decline when measured over time. As SOC is mathematically related to SOM and more easily measured, it is recommended that the indicator is based on SOC. Since the GAEC of the CAP require that farmers implement measures to protect SOM (content and stock), this indicator is relevant to monitor the effects of these measures on SOM content. This indicator could also be relevant for climate-related policies since the SOC losses may result in CO_2 emissions.
Accepted		This indicator is well-known and consensual, whether for farmers, scientists or policy makers.
Credible		This indicator is understandable to policy makers, who can interpret it to inform policies that can have a direct influence on soil conditions (e.g. conservation tillage, maintenance of grasslands, afforestation, etc.).
Easy		SOC content can be easily measured in the field. The SOM content is estimated based on the measured SOC content. The use of remote sensing data may help estimating SOM. Measurement involves performing soil sampling and measuring carbon content in a laboratory. In the LUCAS survey, soil sampling was performed on topsoil (0-20 cm) in 25 MS. Around 20,000 points were selected out of the main LUCAS grid (2 km x 2 km) for the collection of soil samples. Each point was geo-referenced and classified according to land cover, using remote sensing (orthophotos or satellite images) and land cover datasets (such as CLC). For each point, five samples were extracted, weighting 0.5 kg of soil each. Then, the samples were packed, recorded, dried if necessary, and dispatched to a central laboratory for physical and chemical analyses (Toth, Jones, & Montanarella, 2013). Field sampling provides very precise data. The depth of sampling is a major issue because soil organic matter content varies strongly with depth, and as the depth of interest might be the upper few centimetres (e.g. risk of erosion linked to aggregate stability) or the whole arable layer (e.g. nutrient availability) or the depth of the whole soil profile (e.g. available water capacity). This implies the elaboration of a common protocol for collection, record and analysis, the management of the sampling logistics and the training of surveyors. This action is costly since it requires significant resources. Measuring SOM requires: • The acquisition of data on land cover; • The acquisition of a GIS software to allow easier assessment of SOM content in the territory through visual observations; • The elaboration of a management plan for the sampling logistics; • An analysis protocol; • The record of all the soil samples and results; • The analysis of all samples in a laboratory; • The training of surveyors. Currently, the SOM content indicator is the indicator for which the highest quantity of data is available at the EU scale (among the other indicators analysed). However, due to sampling difficulty, and the significant amount of resources required, data are not available for the entire EU territory (not covered: high altitude, forest with difficulty of access, etc.). Regular sampling in terms of geography and time scale is needed. The data from the LUCAS project are updated every 6 years (originally, the frequency was expected to be every 3 years); the latest data update was performed in 2006. The data should be updated more often to precisely monitor SOM development, and in particular the effectiveness of measures implemented.
Robust		The current work of the LUCAS project proposed by the JRC allows a common methodology and data on SOC/SOM content to be provided for most of the EU-27 territory at a regular frequency.

Soil organic matter content (% or kg SOM/kg soil) and soil organic carbon content (% or kg SOC/kg soil)		
		Data are collected by Eurostat and processed by the JRC.

LD6 – Area with soil organic matter (and soil organic carbon) content of less than 3.5% (less than 2.0%) (ha)

Area with soil organic matter (and soil organic carbon) content of less than 3.5% (less than 2.0%) (ha) This indicator derives from the indicator LD5 and shares many properties. Therefore only properties that are specific to this indicator are detailed in this assessment.		
Relevant		At present, some 45% of soils in Europe have a low or very low organic matter content (0-2% organic carbon or 0-3.5% organic matter), and 45% have a medium content (meaning 2-6% organic carbon or 3.5-9% organic matter) (Jones, et al., 2012). Higher thresholds can also be interesting to implement in order to protect organic rich land. The threshold should be high enough to include land naturally rich in SOC, such as peatland and wetland, without including areas that are saturated in unstable nutrients, leading to water pollution. Eckelmann et al (2006) propose a threshold of 8% of SOC (13.8% of SOM). Hence, the corresponding indicator would be "area with SOC content of more than 8%".
Accepted		The 3.5% threshold is the most commonly used to identify soils with a low carbon organic content, and was adopted by the EU (Eckelmann, et al., 2006). However, there is currently no consensus on this threshold, as there is no conclusive evidence of significant effects on other soil properties and crop yields. There are some suggestions that below a threshold of 1% of soil organic carbon, and without addition of exogenous soil organic matter and fertilizers, a disruption in the balance in N-supply to plants might occur, leading to a decrease of both soil organic matter and biomass production (Kibblewhite, et al., 2008). In the absence of clear evidence, the threshold of 2% can be used as a precautionary value.
Credible		The credibility of this indicator is similar to the credibility of the SOC content indicator.
Easy		The ease of monitoring of this indicator is similar to the credibility of the SOC content indicator.
Robust		The robustness of this indicator is similar to the robustness of the SOC content indicator.

LD7 – Soil organic carbon stock (tC/ ha)

Soil organic carbon stock (tC/ ha)		
Relevant		The SOC stock is the total organic carbon stock in the soil. The top soil SOC stock that refers to the SOC stock for the depth range of 0-30 cm in one hectare is the appropriate indicator since it creates a comparable baseline between the different areas. It provides an overall vision of the carbon cycle, connected to the GHG emissions. Since the GAEC of the CAP require that farmers implement measures to protect SOM (content and stock), this indicator is relevant to monitor the effects of these measures on SOM stock. This indicator could also be relevant for climate-related policies since the SOC losses may result in CO_2 emissions.
Accepted		This indicator is well-known and consensual. It has mostly been studied by scientists but only recently used by policy makers, in particular in the context of climate change. Moreover, the new estimation model aims at providing a comprehensive and harmonised topsoil dataset of the EU based on harmonised sampling and methodology.
Credible		This indicator is easily understandable by stakeholders. It provides a clearer view of the overall state of soil regarding organic matter than the SOC content that only concerns one kilogram of soil.
Easy		The SOC stock is estimated from the measured SOC content for one hectare, considering the soil depth and density. The data are available in the LUCAS project and EINET data collection which takes into account the main agricultural practices (irrigation, mineral and organic fertilisation, tillage, etc.). SOC stock is also estimated by the new model proposed by the JRC (CENTURY) (Lugato, Panagos, Bampa, Jones, & Montanarella, 2014).

Soil organic carbon stock (tC/ ha)		
Robust		The results of the CENTURY modelling were tested against inventories from the EIONET and the results of the LUCAS survey (Lugato, Panagos, Bampa, Jones, & Montanarella, 2014).

LD8 – Peatland SOC stock (tC/ ha peatland)

Peatland SOC stock (tC/ ha peatland)		
Relevant		Although this indicator only focuses on specific areas, peat soils are the soils that are the richest in organic matter (Jones, et al., 2012). Therefore, a decline of organic matter in these areas can have significant effects on the overall SOC stock. The indicator may show a good efficiency in preserving a large SOM share. This indicator is relevant for several policies. It is relevant for the CAP since the GAEC require that farmers implement measures to protect SOM. It is also relevant for climate-related policies since the SOC losses may result in CO_2 emissions. Lastly it may also be relevant for policies related to protected areas since it helps identify carbon rich areas.
Accepted		Peatland is recognised as the richest sink of organic carbon.
Credible		Peatland is increasingly damaged due to the increasing land demand. Thus, peatland is drained in order to create new arable lands. The resulting aerobic environment enhances the degradation of organic matter, inducing consequent loss of SOC and SOM. The effects of agricultural practices on peatland are well-known and the indicator can directly reflect the results of the implementation of measures against SOM loss.
Easy		Peatland is well located in the EU-28. The carbon stock under peatland can be statistically estimated or estimated thanks to the new model proposed by the JRC. This indicator echoes the idea of the maintenance of a SOC content higher than 8%.
Robust		The robustness of this indicator is similar to the robustness of SOC stock.

For erosion, indicators with the highest RACER scores are:

- Annual erosion rate by water (%); and
- Area subject to an erosion rate by water of more than 10 t/ha/yr

The indicator **'Annual erosion rate by water'** directly targets the most extensive form of soil erosion in Europe. It mostly concerns agricultural areas. Erosion rate can be estimated through repeated observations and measures in the field, or through calculation using a model analysis based on factors such as soil properties, climate, landscape, etc. Measuring soil erosion is hard to carry out, especially at large scale, and requires many resources. Therefore, on-site field measures are often limited to reduced areas. They are used in the context of research work or local actions against erosion or to confirm the results provided by the models that estimate erosion. In order to quantify water erosion at the European level, a series of projects have been launched, using digital technology and harmonised data. Among them, the PESERA model developed by the JRC provides data at a resolution of 1 km x 1 km at NUTS 3 level at pan-European level. This model is recognised and data are used at European level, although data are not regularly updated (the most up-to-date ones are from 2004). Recently, the JRC has also gathered data from eight MS (members of the EIONET), providing detail information on national erosion rate.

The indicator related to the **area subject to an annual erosion rate by water above a specific threshold** shares some similarities with the previous indicator. This commonly used indicator refers to a threshold of 10 t/ha/yr, which is the threshold used in the Roadmap for a Resource Efficient Europe. It concerned 20% of the area subject to water erosion in the EU-27 and 7% of the total territory in

2006, according to the JRC. The area affected by a water erosion rate higher than 11 t/ha/yr represents 6% of the total agricultural area of the EU-27. The 10 t/ha/yr threshold is more relevant than the 11 t/ha/yr threshold since it concerns a larger area, however it only represents a small share of the EU agricultural area. Therefore, it would be relevant to propose a lower threshold. On the other hand a threshold at 5 t/ha/yr would increase two-fold the area concerned, representing 15% of the total EU-27 area (SoCo project team, 2009; Eurostat[83]).

Erosion by wind causes significant soil loss at local level, although it is less extensive than water erosion. Erosion by wind especially concerns coastal areas, which can affect land use for tourism. **Erosion by tillage** is an increasing concern but it only represents a small share of the area subject to erosion. For both types of erosion, models exist but are not widely spread, even though they are sometimes used at national level (for instance the WATEM model). Furthermore, the model developed for erosion by water by the JRC (PESERA project) can be adapted to erosion by wind and tillage. Since these types of erosion cannot be monitored yet, these indicators cannot be used for the moment. For SOM decline, indicators with the highest RACER scores are:

- SOM (or SOC) content;
- Area with SOM content of less than 3.5% (SOC content less than 2.0%);
- SOC stock; and
- Peatland SOC stock.

The well-known indicator related to the **SOC (and SOM) content** directly targets SOM decline over time. As SOC content can be easily measured on-field and the SOM content is mathematically estimated based on the measured SOC content, the indicator proposed can only focus on SOC. Currently, it is the soil organic matter-related indicator for which the largest quantity of data is available at the European scale. The current work as part of Project LUCAS, proposed by the JRC, enables a common methodology and data on SOC/SOM content for the EU-23 territory to be provided on a regular time scale. Soil sampling was performed on topsoil (0-20 cm) in 23 MS, providing data at a resolution of 2 km x 2 km. The data was last updated in 2006. The data should be updated more often to precisely monitor the SOM development, and in particular the effectiveness of measures implemented. In addition, due to sampling difficulty, and the significant amount of resources required, data are not available for the entire European territory (high altitude, forest with difficulty of access, etc. are not covered). The JRC also collected data from seven EIONET members.

The indicator on the **area with SOM content of less than 3.5%** (SOC content less than 2.0%) is a relevant indicator as is concerns 45% of European soils. This threshold is commonly used. Although some sources suggest that the SOC could decrease to 1% without creating significant effects on crop yield, the threshold used in the Roadmap for a Resource Efficient Europe can be used as a precautionary value in absence of clear evidence. Higher threshold could also be interesting to implement in order to protect rich organic land and its role, e.g. in carbon sequestration and climate mitigation. The threshold should be high enough to include land naturally rich in SOC, such as peatland and wetland, without including areas that are saturated in unstable nutrients leading to pollution. Eckelmann et al. (2006) propose a threshold of 8% of SOC (13.8% of SOM). Hence, the corresponding indicator would be “area with SOC content of more than 8%”.

[83] Soil erosion by water – area eroded by more than 10 tonnes per hectare per year. Eurostat: http://epp.Eurostat.ec.europa.eu/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=t2020_rn300&language=en

The **SOC stock** is the total organic carbon stock in the soil. The top soil SOC stock that refers to depth ranges of 0-30 cm in one hectare is the appropriate indicator since it allows a comparable baseline between the different areas. It provides a global vision of the carbon cycle, connected to GHG emissions, and is a relevant indicator of global SOM decline. This indicator is well known and consensual. It has especially been studied by scientists and recently used by policy makers, in particular in the context of climate change, rather than by farmers. It is also more easily understandable than the SOC content that only concerns 1 kg of soil.

The **peat stock** indicator is similar to the SOC stock except that it refers to specific organic carbon rich areas such as peatland or wetland. Peat soils have the highest organic matter content. Therefore, a decline of organic matter in these areas can have significant effect on the overall SOC stock. The indicator may show a good efficiency in preserving a large SOM share. In addition, the effects of agricultural practices on peatland are well known and the indicator can directly reflect the results of the implementation of measures against SOM loss. This indicator echoes the indicator encouraging the maintenance of SOC content of more than 8%.

Overall, significant efforts have been made to create a homogenised soil database in Europe and to enhance information and data sharing through the creation of a European Soil Portal managed by the JRC (JRC, 2014b). In addition to data elaborated during European projects, the website also gathers 16 national databases (JRC, 2014c). Hence, data needed to monitor erosion and soil organic matter development is available and reliable, although additional updates will be required.

4.3.3. Indicators suitability for target setting and need for further EU actions

Indicators suitability for target setting

Considering the RACER analysis, some indicators are more suitable than others for setting future targets at the EU level. An analysis of their suitability is presented in Table 29.

Table 29: Suitability of indicators for target setting - Overview

Indicators	Possible levels of disaggregation	Suitability of different geographical scales*			Comments
		EU level	MS level	local level	
Soil erosion					
Annual erosion rate by water (t/ha/yr)	Land use type Land cover type	High	High	Medium	According to the share and the importance of the area affected by erosion (and the level of erosion) in terms of economy, social and cultural interests, environment, etc. authorities may decide to focus on a specific type of land use or propose different objectives according to the land use. Target setting at Member State level (or even at a lower level) is more suitable for such a disaggregation but a general target at EU level can also be proposed
Annual erosion rate by wind (t/ha/yr)	Geographical area Land use type	Medium	High(depending on the Member State)	Medium	The number of erosive days is heterogeneous among the MS and also within the MS: coastal regions are much more affected than other regions. Setting a target at Member State level would allow focusing efforts on regions with a high erosion rate by wind such as coastal areas. This should be discussed to avoid inequitable burden between the MS which have coastal borders and inland MS. The disaggregation per geographical area should be discussed in view of the land use. For instance, while this is worth setting a target in touristic areas, the burden associated with the target setting may be too high compared with the gains for other types of coastal areas that do not present a recreational function.
Annual erosion rate by tillage (t/ha/yr),	Farming production system (conventional, integrated, extensive, organic) Production types (animal, crops, etc.) Type of crops	Low	Low	Medium	This indicator only concerns arable land.
Area of land subject to water erosion rate > 10 t/ha/yr (ha)	Land cover type	Medium	High	Medium	See LD1
Soil organic matter decline					
Soil organic matter content (% or kg SOM/kg soil) **Soil organic**	Land cover type	Medium	High	Medium	SOM decline only concerns agricultural land and forests. SOM decline varies according to the land cover. Hence, it could be suitable to set a target at Member State level which would allow taking into account the share of the different land cover types and the related state of SOM content.

Indicators	Possible levels of disaggregation	Suitability of different geographical scales*			Comments
		EU level	MS level	local level	
carbon content (% or kg SOC/kg soil)					
Surface area of soils with organic matter level <3.5% (ha)	Land cover type	Medium	High	Medium	See LD5
SOC stock (t/ha)	Geographical area	High	High	High	The SOC stock decrease is expected to be particularly high in the south and the east of the EU. However, this disaggregation should be discussed to ensure equity between the MS regarding the setting of this indicator and the related burdens.
Peatland SOC stock (tC/ha peatland)		High	High	High	The share of peatlands in the EU territory varies according to the MS.

*
High: a majority of RACER criteria assessed as “high”
Medium: a majority of RACER criteria assessed as “medium”
Low: at least one of the RACER criteria assessed as “low”

Need for further EU action

Potential actions required to develop further the indicators related to land degradation are highlighted in the table below.

Table 30: Potential actions required to develop indicators related to land degradation

Indicator	Problem definition	EU actions required to develop, implement or improve the indicator
Soil erosion		
Annual erosion rate by water (t/ha/yr)	The data from the European model is not regularly updated. The models used by some MS to estimate the erosion rate in the EIONET project differ and the results are not comparable.	Data on soil erosion highly depends from the CLC database. This database should be more frequently updated. Audits in the MS that model the water erosion rate could be performed to make sure the model and data used to estimate the erosion rate comply with key requirements (to be defined at the EU level).. In addition, further research may be relevant to define how remote sensing can be used to confirm the estimated erosion rate (for water erosion).
Annual erosion rate by wind (t/ha/yr)	No consensual model to estimate the erosion rate by wind is available at EU level.	Since the JRC has already mapped several parameters influencing the erosion rate, the development of a model combining these data sets should be easy. As for erosion by water, further research may be relevant to define how remote sensing can be used to confirm the estimated erosion rate.
Annual erosion rate by tillage (t/ha/yr),	No model is available at EU level to estimate the erosion by wind. Some models have been developed at Member State level.	Further research is required to develop a model at the EU level. The extent of the erosion by tillage in the EU should also be further studied to specify the relevance of the development of such a model at the EU level. If tillage erosion mostly affects some regions in specific countries, national models may be sufficient.
Area of land subject to erosion rate by water > 10 t/ha/yr (ha)	See the indicator on water erosion rate.	
Soil organic matter decline		
Soil organic matter content (% or kg SOM/kg soil) **Soil organic carbon content (% or kg SOC/kg soil)**	Data from the European model are not regularly updated. Data are missing for three MS. Data are missing for some areas of the EU territory (high altitude, forest with difficulty of access)	The measurement of the SOC content requires a high amount of resources in terms of workforce, time and money. The accuracy of the data from LUCAS survey could be improved by national data between two measurements campaigns. The data for the missing MS should be collected. The data gaps due to sampling difficulties could be addressed by using the possible national or regional data or by using an estimation of the SOM/SOC content.
Surface area of soils with organic matter level <3.5% (ha)	See the indicator related to the SOM and SOC content.	
SOC stock (t/ha)	Unknown	
Peatland SOC stock (tC/ha peatland)	Unknown	

4.4. Possible targets and assessment

4.4.1. Practical implementation of targets

Targets to control land degradation have been implemented at international, EU and MS levels. Further details are provided in Annex 4.1.

4.4.2. Target proposals

Based on the indicators analysed in the previous section, possible targets proposed for addressing erosion and SOM loss are presented in Table 31.

Table 31: Target proposals

Scale of implementation	Indicators for target setting	Possible expressions of targets	Scale for target setting
Soil erosion			
EU	Annual erosion rate by water (t/ha/yr)	• By 2020, the annual erosion rate by water should not increase overall and decrease in EU areas subject to erosion of more than 10 t/ha/yr. Possible breakdown: • Per land use type: By 2020, the annual erosion rate by water should not increase overall and decrease in agricultural areas subject to erosion of more than 10 t/ha/yr. • Per land cover type: By 2020, the annual erosion rate by water should decrease by A% compared to the baseline year Z for crop land, by B% for pasture, by C% for permanent crops and by D% for forest.	EU/MS
EU/MS	Area subject to a water erosion rate > 10 t/ha/yr (ha)	By 2020, the area of land in the EU that is subject to a water erosion > 10 t/ha/yr should be reduced by at least 25% (derived from the Roadmap target)[84] Possible other thresholds: By 2020, the area of land in the EU that is subject to a water erosion rate > 6 t/ha/yr should be reduced by at least X% compared to 2006. Possible breakdown: • Per land use type: By 2020, the annual erosion rate by water should decrease in agricultural areas subject to erosion of more than 10 t/ha/yr. • Per land cover type: By 2020, the area subject to a water erosion rate > 10 t/ha/yr should decrease by XX% for cultivated land, at least.	EU/MS
Soil organic matter			
EU/MS	Soil organic matter and soil organic carbon content (t/ha)	By 2020, the SOM level/SOC content should not be decreasing overall and should increase for soils with currently less than 3.5% organic matter (or 2% of organic carbon) (Roadmap target).	MS

[84] The proposed target is a slightly modified version of the erosion-related target of the Roadmap. It is proposed to narrow the scope of the target, so as to only covers erosion caused by water. The reasons for proposing this modified target are that other types of erosion cannot be measured with a sufficient level of reliability, as demonstrated by the RACER assessment of the erosion-related indicators, and water erosion is by far the main form of erosion in the EU (concerns approximately 130 million ha vs 42 million ha for wind erosion).

Scale of implementation	Indicators for target setting	Possible expressions of targets	Scale for target setting
		Possible breakdown: Per land cover type: By 2020, the area of arable land with SOM content lower than X1% should decrease by Y1% compared to the baseline year Z, the area of pasture with SOM content lower than X2% should decrease by Y2%, the area of permanent crops with SOM content lower than X3% should decrease by Y3% and the area of forest with SOM content lower than X4% should decrease by Y4%.	
EU/MS	Area with soil organic matter content of less than 3.5% (soil organic carbon less than 2%)	• By 2020, the total EU agricultural area with SOM level lower than 3.5% (or SOC content lower than 2%) should decrease. • By 2020, the EU area with a SOC content higher than 8% should remain stable overall. Possible breakdown: Per land cover type: By 2020, the area of arable land with SOM content lower than X1% should decrease by Y1% compared to the baseline year Z, the area of pasture with SOM content lower than X2% should decrease by Y2%, the area of permanent crops with SOM content lower than X3% should decrease by Y3% and the area of forest with SOM content lower than X4% should decrease by Y4%.	MS
MS	SOC stock	By 2020, the top soil SOC stock should not decrease. Possible breakdown: Per geographical area: By 2020, the top soil SOC stock should not decrease by more than 20% in the south and the east of the EU (i.e. half of the expected decrease for these regions (to be specified).	EU/MS
MS or regions	Peatland SOC stock	By 2020, the peatland SOC stock should not decrease by more than X%/yr.	EU/MS

4.4.3. Assessment of target proposals

In this section, the feasibility of implementing the proposed targets is analysed from a technical perspective, a socio-economic perspective, as well as from an administrative and legal perspective.

With regard to the technical feasibility assessment, the monitoring feasibility aspects – including data availability issues, technical constraints linked to data access and collection – have already been discussed in detail in the assessment of indicators (Section 4.3.2) and actions to address the gaps identified have been proposed in Section 4.3.3. Therefore, the feasibility assessment presented here, for targets related to both soil erosion and soil organic matter, focuses on other feasibility aspects, including the possible level of ambition for the targets, how to define a realistic path to achieve them, and the representativeness of the targets.

With regard to the socio-economic, administrative and legal aspects, the different targets proposed on soil erosion and soil organic matter are assessed together, because the general types of impacts identified are common to all types of proposed targets.

Targets on soil erosion

Technical feasibility

An analysis of how ambitious the proposed targets are and what would be a realistic path to achieve them is presented in Table 32.

Table 32: Targets on soil erosion – Level of ambition and realistic path to achieve the targets

Proposed EU targets	Elements to be taken into account
Indicator LD1: Annual erosion rate by water (t/ha/yr)	
By 2020, the annual erosion rate by water should not increase overall and decrease in EU areas subject to erosion of more than 10 t/ha/yr	The JRC estimates the surface area affected by water erosion in the EU-27 at 130 million ha. Almost 20% of these are subject to soil loss in excess of 10 t/ha/yr (European Commission, 2012c). Based on data from the EEA, in 1997 the European Commission estimated that the water erosion risk would increase by the year 2050 in about 80% of EU agricultural areas, in particular where soil erosion is currently severe. Between 2000 and 2006, the erosion rate increased by 0.08 points overall, with a significant variability between the MS and within each Member State. Considering the expected trends, the time required for reinforcing or implementing policy instruments to address the issue and the time lapse between the implementation of measures and their expected effects, attaining the target by 2020 seems ambitious but realistic.
<u>Breakdown per land use type:</u> By 2020, the annual erosion rate by water should not increase overall and decrease in agricultural areas subject to erosion of more than 10 t/ha/yr	The level of ambition of the proposed target is based on the fact that agriculture areas represented more than half of the area affected by water erosion in 2006-2007.
<u>Breakdown per land cover type:</u> By 2020, the annual erosion rate by water should decrease by A% compared to the baseline year Z for crop land, by B% for pasture, by C% for permanent crops and by D% for forest	The erosion rate differs according to the type of land cover. Hence, this breakdown would directly reflect the effects of the agriculture practices.
Indicator LD4: Area subject to erosion rate by water of more than 10 t/ha/yr (ha)	
By 2020, the area of land in the EU that is subject to soil erosion of more than 10 t/ha/yr should be reduced by at least 25% (derived from the Roadmap target)[85]	In the EU-24, 7% of the territory was affected by moderate to severe water erosion in 2006 (21 million ha) while 12.4 million ha UAA were affected by erosion of more than 11 t/ha/yr (6% of the UAA). Decreasing by 25% the area affected by an erosion rate higher than 10 t/ha/yr means decreasing the erosion rate in 5.3 million ha of land and in at least 3 million ha of UAA (considering that, for UAA, only data on areas affected by an erosion rate higher than 11 t/ha/yr is available). Agriculture areas with a high soil erosion risk are expected to increase by 19% between 2000 and 2030 in OECD countries (European Commission, 2012b). According to RIVM, the area with a high water erosion risk is expected to increase in Western Europe by 2030 while a

[85] The proposed target is a slightly modified version of the erosion-related target of the Roadmap for a Resource Efficient Europe. It is proposed to narrow the scope of the target, so as to only cover erosion caused by water. The reasons for proposing this modified target are that other types of erosion cannot be measured with a sufficient level of reliability, as demonstrated by the RACER assessment of the erosion-related indicators, and water erosion is by far the main form of erosion in the EU (concerns approximately 130 million ha vs 42 million ha for wind erosion).

Proposed EU targets	Elements to be taken into account
	slight decrease is expected in Central Europe. Considering the expected trends, the target may be attainable for Central Europe. However, the target may be too ambitious for Western Europe considering the time required to reinforce or implement policy instruments to address the issue and the time lapse between the implementation of measures and their expected effects. A lower reduction target or a longer time horizon such as 2030 would be more realistic.
Possible other threshold: By 2020, area of land in the EU that is subject to soil erosion of more than 6 t/ha/yr should be reduced by at least X% compared to 2006	Decreasing the threshold to 6 t/ha/yr would allow a larger EU area to be covered. Moreover, the target may be more easily achieved since it may concern areas with a wider variety of erosion drivers and probably additional levers to address erosion.
Breakdown per land use type: By 2020, the annual erosion rate by water should decrease in agricultural areas subject to erosion of more than 10 t/ha/yr	The level of ambition of the proposed target is based on the fact that agriculture areas represented more than half of the area affected by water erosion in 2006-2007.
Breakdown per land cover type: By 2020, the area subject to erosion of more than 10 t/ha/yr should decrease by XX% for cultivated land and by XX% for grassland, at least	7% of cultivated land (arable and permanent cropland) is estimated to be affected by moderate to severe water erosion, vs only 2% of permanent grasslands and pasture (Jones, 2012). Grassland is less sensitive to erosion than cultivated land due to the vegetation cover and the soil management. Hence, a different target could be proposed for cropland and grassland. As mentioned above, this breakdown would also directly reflect the effects of the agriculture practices.

Socio-economic feasibility

Expected costs of implementation

The costs for implementing prevention and mitigation measures cover the following aspects, in particular:

- Update of the regulation;
- Staff and training;
- Monitoring and data collection; and
- Expenses for policy instruments: economic instruments (subsidies, financial compensation, etc.) but also dissemination of good practices.

The estimated cost for implementing agricultural practices to control erosion with a rate higher than 10 t/ha/yr is 293 EUR/ha. For soils with an erosion rate between 2 and 10 t/ha/yr, the cost is estimated at 139 EUR/ha. These measures also enhance the SOM content. The control of erosion on construction sites is estimated at an average cost of 22 EUR/ha, up to 54 EUR/ha. The implementation of measures to reduce erosion would cost a total of EUR 2.6bn for the EU area with an erosion rate of more than 10 t/ha/yr and EUR 3.4bn for the EU area with an erosion rate between 2 and 10 t/ha/yr (European Commission, 2006a). According to Kuhlman, the implementation of appropriate measures against erosion would cost EUR 9.3bn per year (Kuhlman, Stijn, & Gaaff, Estimating the costs and benefits of soil conservation in Europe, 2008) (Verheijen F. , et al., 2012).

Currently, the expenditure of EU-25 on agri-environmental schemes (AEM) allocated to measures addressing erosion and SOM losses amounts to EUR 1.8bn for MS that show an erosion rate higher than 2 t/ha/yr.

Social and societal costs and benefits

The implementation of the targets should allow the impacts related to human health, goods and activities to be addressed. In particular, soil loss may decrease crop yields and consequently jeopardize farmers activity and revenue. Soil erosion also has a significant negative effect on the quality of potable drinking water supplies. Suspended sediments resulting from soil losses affect the taste of water. Moreover, potential contaminants such as heavy metals may be carried by sediments or may be leached into water due to insufficient capacity of the soil to retain these elements. Thus, additional treatment of water is necessary. Soil erosion may affect quality of life when the change of landscapes having aesthetic value (scenic views) or when the quality and quantity of landscapes are reduced in areas that are attractive for recreational activities. Moreover, flood caused by soil erosion may damage individual houses and constructions. It affects individual well-being induced by the loss of goods such as food, personal effects or buildings.

The implementation of the proposed targets may result in additional burdens for farmers. As most of the measures that address erosion should be implemented by farmers. It induces consequent efforts in terms of acceptability, technical practices and knowledge and investments to comply with the law. Erosion is already targeted through the cross-compliance systems of the CAP and the EU provides subsidies for the implementation of measures in the context of the agri-environmental measures (AEM). However, additional changes and measures, and consequently efforts from farmers, may be necessary to attain the targets. Furthermore, the status of soil as a “public good” or a “common resource” should be questioned: since soil provides food and services that are necessary for the whole population, soil protection should be a shared concern and farmers should not be the only stakeholder to bear the largest part the burden for the protection of this resource.

Environmental costs and benefits

From an environmental perspective, implementing targets to reduce soil erosion is expected, on-site, to (Jones, et al., 2012) (WWF, 2006):

- Protect the soil stock, which cannot be considered a renewable resource given the slow soil-forming process (formation under typical permanent grasslands in temperate climates: only 1-2 cm per 100 years);
- Maintain soil organic matter, by limiting the removal of the top soil that is the most productive component of soils;
- Avoid restrictions on land use and land value depreciation.

Off-farm impacts of soil erosion largely affect the wider society and take a number of forms such as flooding, declining water quality and emissions of greenhouse gases such as carbon dioxide, methane and nitrous oxide. Implementation of targets to reduce soil erosion are expected to (Jones, et al., 2012) (WWF, 2006):

- Increase the quality of water bodies by reducing turbidity and chemical/nutrient load. Chemicals and nutrients (in particular phosphates) are often bound to the clay fraction of soil. High amounts of phosphate induces algae blooms that lead to oxygen depletion (i.e. eutrophication), mostly in freshwater; and
- Have positive effects on biodiversity and, in particular, on habitats. By avoiding eutrophication, reducing erosion allows maintaining oxygen levels, and thus avoids hypoxia (oxygen depletion) in water bodies, extensive fish and plant death and ultimately loss of biodiversity. Erosion prevention may notably prevent soil losses from wetlands and floodplains, which could reduce their buffering and filtering capacity as well as flood-control capacity. It is also likely to preserve marine and freshwater environment from the impact of sedimentation on fish, shellfish and coral. Soil erosion can, for example, impede salmonids' eggs to survive and develop correctly due to insufficient oxygen.

Tackling soil erosion allows avoiding both **on-site and off-site use value damages**[86]. On-site costs of erosion result from:

- Yield losses as a consequence of soil fertility loss, degradation of soil stability (with risk of compaction) and soil loss. It leads to a decrease of food production, which may lead to an increase in land demand and expenses due to additional fertiliser use. Reduced nutrient availability and moisture holding capacity also result in less secure incomes for farmers;
- Land value depreciation due to the loss of yield but also to damages to recreational land functions.

[86] Use value damages (UVD) consist of two components: (i) the market value damages (MD), which refer to the financial losses due to the reduced revenues derived from agricultural harvest as well as the increased healthcare expenditures in some extreme cases; (ii) the non-market value damages (NMD), which refer to the intangible economic losses associated with reduced recreational activities due to the destroyed freshwater & coastal environment and agricultural landscape..

The off-site costs result from:

- Land value depreciation and damage of recreational land functions, which induces impacts on socio-economic activities like tourism (e.g. the excessive algae development in Brittany, France);
- Increases in food prices;
- Damage costs to infrastructure such as roads and footpaths (the latter can be blocked by soil deposition, inducing slowdown in the best case or accidents due to the creation of slippery surfaces) and disturbance of water navigation if the level of sediments is too high;
- Maintenance costs of reservoirs, valves and drains blocked by sediments. These issues can be tackled by implementing traps in the reservoirs that allow sediment dredging, or by using mechanical removal - both solutions being costly;
- Treatment for drinking water to address water turbidity; and
- Public health risks due to ingestion of waterborne contaminants.

The EC estimated in 2006 the total costs of soil degradation in the EU-25 at EUR 38bn per year. This includes EUR 720m to EUR 14bn due to land erosion (on-site and off-site costs) for thirteen MS. On-site costs vary from EUR 40m to 860m and could reach EUR 3.25bn if long term effects were taken into account. Montanarella et al. (2007) estimate that the total costs of erosion amounts to EUR 33 billion (Montanarella, 2007) (Telles, Guimaraes, & Dechen, 2011). In the United Kingdom, the Environment Agency estimated the cost of soil erosion at around EUR 54m per year, including EUR 11m in lost production in 2007. The other costs concern water treatment, damage to property and dredging stream channels. In Wales, a conservative estimate of the consequence of the loss of soil, based on potential loss of wheat yields, reveals that agricultural production in the region of EUR 3.5bn could be under threat. If the economic impacts of soil carbon losses were also added, the figure would be even higher (WWF, 2006).

However, there is a large variability regarding the estimation of costs related to erosion. The Roadmap to a Resource Efficient Europe estimated the economic effects due to erosion-induced on-site income losses at 10-90 EUR/ha/y (2006 value) (European Commission, 2011b). Kulhman et al. (2010) estimate the on-site costs to range from 122 to 302 EUR/ha for the EU-25 (erosion rate: 0.5-10 t/ha/yr).

The on-site benefits of reducing erosion are estimated at 3.25bn EUR/yr for the EU-25 over 20 years, plus 5.8bn EUR/yr of off-site benefits (European Commission, 2006a).

Administrative and legal feasibility

Opportunities and barriers

The barriers from an administrative point of view relate to target monitoring. For erosion, while it could be relevant to let MS choose their own target, the MS should agree on a common model to estimate the erosion risk at NUTS 2 level. The use of different models at the national level induces additional administrative constraints to harmonise the model used and to ensure that the estimation method is similar in each model. The harmonisation of the methodology will be the subject of the Common Monitoring and Evaluation Framework (CMEF) that provides a single framework for monitoring and evaluation of all rural development intervention, including erosion and SOM loss, since the agreement on the new CAP.

Moreover, the calculation of the erosion rate requires numerous data that must be regularly collected by different organisations. It results in numerous exchanges of information between organisations within a MS and between each MS and the institution in charge of data collection at European level.

Furthermore, soil degradation including soil erosion and SOM depletion, may have transboundary effects and therefore require coordination of policies at the EU level (e.g. floods caused by erosion and indirectly by soil depleted in SOM that is not able to retain water properly). Indeed, sediments washed away by soil erosion in one country can also block dams or damage infrastructure such as harbours in other countries. Nutrients leached from soil can pollute the groundwater in a neighbouring country. In that case, EU policy is thus seen as a way to protect land users in a given country from the harmful consequences of practices in another country for which they are not responsible. Where transboundary effects occur, cooperative initiatives between regional and local authorities are essential. However, a number of MS consider that land degradation has no transboundary consequences and that soil legislation should be a matter of national competence only (Jones, et al., 2012).

Coherence with other policies and policy requirements

The proposed targets are fully coherent with the CAP: the CAP directly addresses soil erosion in the GAEC, and indirectly through the implementation of AEM. Moreover, for the CAP 2014-2020, a disaggregated indicator related to erosion by water has been proposed for land degradation. The implementation of this indicator is currently being discussed (European Evaluation Network for Rural Development, 2014) (European Commission, 2011b) (European Commission, 2013d).

Soil erosion is specifically mentioned in the GAECs that farmers must comply with to receive full subsidies. Mandatory targets would provide clear outcome obligations. However, all proposed targets should not be mandatory. Making one target for each type of land degradation compulsory would be sufficient. Adoption of other targets could be proposed on a voluntary basis to help MS attain the objectives while avoiding additional administrative and resource requirements and potential implementation burden for farmers, with limited added value compared the mandatory target chosen.

Targets on soil organic matter

Technical feasibility

An analysis of how ambitious the proposed targets are and what would be a realistic path to achieve them is presented in Table 33.

Table 33: Targets on soil organic matter – Level of ambition and realistic path to achieve the targets

Proposed EU targets	Elements to be taken into account
Indicator LD5: Soil organic matter content (% of kg SOM/kg soil) and soil organic carbon content (% of kg SOC/kg soil)	
By 2020, the SOM/SOC levels should not be decreasing overall and should increase for soils with currently less than 3.5% organic matter (or 2% of organic carbon) (Roadmap target)	Around 45% of soils in Europe had a low or very low organic matter content in 2003 (i.e. less than 2% of organic carbon or 3.5% of organic matter) and 45% had a medium content (3.5% to 9% of organic matter). The distribution of carbon content is very heterogeneous within the EU. The available data on trends regarding SOC only concern SOC stock, hence the future percentage of SOC rate is difficult to estimate. However, if it follows similar trends as the SOC stock (see below), the target may not be attained in 2020. Hence, it would be more realistic for the target to only cover soils with a low SOC content (i.e. less than 2%), or to postpone the deadline of the current target.
Breakdown per land cover type: By 2020, the area of arable land with SOM content lower than X1% should decrease by Y1% compared to the baseline year Z, the area of pasture with SOM content lower than X2% should decrease by Y2%, the area of permanent crops with SOM content lower than X3% should decrease by Y3% and the area of forest with SOM content lower than X4% should decrease by Y4%	The different land cover types show different SOC contents. For instance, grassland has a higher SOC level than forest. Therefore, the level of ambition of the target should be adapted to the type of land. This will also help identify areas where measures should be implemented in priority and monitor their effects.
Indicator LD6: Area with soil organic matter content of less than 3.5% (soil organic carbon less than 2%) (ha)	
By 2020, the total EU agricultural area with SOM lower than 3.5% (or SOC content lower than 2%) should decrease **By 2020, the EU area with a SOC content higher than 8% should remain stable overall**	As mentioned above, few elements are available regarding the future trends of SOC content. While it may not be feasible to increase the SOC content of all areas with a SOC content lower than 2%, it seems feasible to decrease the entire area showing this low content. A particular focus on the areas concerned should allow increasing, at least locally, the SOC content. Regarding the areas with a SOC content higher than 8%, see the comments on peatland stock.
Breakdown per land cover type: By 2020, the area of arable land with SOM content lower than X1% should decrease by Y1% compared to the baseline year Z, the area of pasture with SOM content lower than X2% should decrease by Y2%, the area of permanent crops with SOM content lower than X3% should decrease by Y3% and the area of forest with SOM content lower than X4% should decrease by Y4%	As mentioned above, the different land covers show different SOC contents. Hence, this breakdown would allow prioritising the areas where measures should be implemented and monitoring their results.

Proposed EU targets	Elements to be taken into account
Indicator LD7: SOC stock (tC/ha)	
By 2020, the top soil SOC stock should not decrease	The overall SOC stock for the EU is projected to increase from 17.63 Gt C to 18 GtC until 2080. However, the uncertainty is high regarding the trends of SOC stock by 2020. According to Lugato et al. (2014), the SOC stock may decrease by 2020. Gobin et al. (2011) expect the SOC level to increase by 2030, underlying the uncertainty related to the future scenario regarding agriculture practices. Considering the expected trends, the time required for reinforcing or implementing policy instruments to address the issue and the time lapse between the implementation of measures and the expected effects, attaining the target by 2020 seems ambitious. A longer time frame such as 2030 could be proposed for regions that have high SOC losses.
Breakdown per geographical area: By 2020, the top soil SOC stock should not decrease by more than 20% in the south and the east of the EU (i.e. half of the expected decrease for these regions)	By 2080, strong regional differences are predicted, involving net losses in about 30% in the south and the east of the simulated area, compensated by a SOC stock gain in central and northern regions. This means that the proposed target aims at decreasing, by one third, the expected decrease for these regions - that should be more precisely defined.
Indicator LD8: Peatland SOC stock (tC/ha peatland)	
By 2020, the peatland SOC stock should not decrease by more than X%/yr	The annual SOC stock loss of peatland is expected to attain 1.52 tC/ha in 2030, with a slight decrease compared to 2000. No further conversion of peatland would result in a loss of 1.4 tC/ha. The restoration of 50% of the peatland would decrease the SOC losses to 0.58 tC. The restoration of 100% of the peatland would lead to the sequestration of 0.23 tC. Considering the different scenarios, the more realistic target is to consider a slower decrease of the SOC.

Socio-economic feasibility

Expected costs of implementation

Similar to soil erosion, the costs for implementing prevention and mitigation measures cover the following aspects, in particular:

- Update of the regulation;
- Staff and training;
- Monitoring and data collection; and
- Expenses for policy instruments: economic instruments (subsidies, financial compensation, etc.) but also dissemination of good practices.

The implementation of agricultural practices that prevent SOM loss is estimated to cost 116 EUR/ha. The application of exogenous organic matter for improving soil quality is estimated at 384 EUR/ha, including the production, the transport and the application of organic matter (European Commission, 2006a).

Currently, the expenditure of EU-25 on agri-environmental schemes (AEM) allocated to measures addressing erosion and SOM losses amounts to EUR 1.8bn for MS that show an erosion rate higher than 2 t/ha/yr.

Social and societal costs and benefits

The implementation of the targets is expected to provide benefits for human health and for farming activities. In particular, soil organic matter decline due to soil erosion has a significant effect on the quality of potable drinking water supplies. The loss of soil organic matter (and indirectly soil loss) directly affects farmers. Due to yield losses, the land cannot provide sufficient and sustainable revenues to farmers. This may contribute to creating precarious situations and accelerating rural depopulation.

The implementation of the proposed targets may result in additional burdens for farmers, as most of the measures that address erosion and SOM losses should be implemented by farmers. Significant efforts in terms of acceptability, technical practices and knowledge and investments would be required to reach the targets. SOM loss is already targeted through the cross-compliance systems of the CAP and the EU provides subsidies for the implementation of measures in the context of the agri-environmental measures (AEM). However, similar to soil erosion, additional changes and measures, and consequently efforts from farmers, may be necessary to attain the targets. Furthermore, the status of soil as a “public good” or a “common resource” should be questioned: since soil provides food and services that are necessary for the whole population, soil protection should be a shared concern and farmers should not be the only stakeholder to bear the largest part of the burden for the protection of this resource.

Environmental costs and benefits

Tackling soil organic matter depletion allows avoiding both **on-site and off-site use value damages**. On-site costs of erosion and loss of organic matter result from:

- Yield losses as a consequence of soil fertility loss, degradation of soil stability (with risk of compaction) and soil loss. It leads to a decrease of food production, which may lead to an increase in land demand and expenses due to additional fertiliser use. Reduced nutrient availability and moisture holding capacity also result in less secure incomes for farmers; and
- Land value depreciation due to the loss of yield but also to damages to recreational land functions.

Implementing targets to avoid losses of SOM is expected to (European Commission, 2011b):

- Maintain soil fertility and avoid land use change due to land value depreciation. Indeed, soil organic matter provides easily decomposable and well decomposed organic materials that constitute an important source of energy and nutrients for plants and micro-organisms. Moreover, SOM participates to stabilize soil structure, which improves the physical environment for roots to penetrate through the soil, retains nutrients essential for plants and enhances water retention capacity.
- Have a positive effect on biodiversity, since SOM provides energy and nutrients for soil organisms.
- Avoid GHG emissions by participating in carbon storage. Indeed, soil organic carbon is the second biggest carbon pool on the planet after the oceans. EU soils contain 73 to 79 billion tonnes of organic carbon, while the EU MS' activities are responsible from annual emissions of approximately 4.6 billion tons of CO_2 equivalent. Accumulation of non-degraded vegetation residues, i.e. with high carbon content, is particularly favoured in anaerobic and wet conditions. This is the case of peatland and wetland. To a lesser extent, forests and permanent grassland also constitute important carbon sinks. The conversion of peatland is estimated to induce carbon losses of 0.13 to 0.36% per year, with large regional differences.
- Increase water storage by maintaining soil structure. Improving soil water retention capacity avoids run-off and erosion, enhances nutrient absorption by plants and decreases the risk of leaching. Good soil structure also indirectly improves water quality.

The EC estimated in 2006 the total costs of soil degradation in the EU-25 at EUR38 billion per year. On-site costs vary from EUR40 to 860 million and could be up to EUR3.25 billion if long term effects were taken into account. Between EUR 3.4 to 5.6bn are due to the decline of SOM, including EUR 2bn of on-site costs mainly due to lower soil productivity (European Union, The Committee of the Regions, 2012; Bowyer, et al., 2009). The specific on-site costs result from the compaction of soil that increases the risk of run-offs and may decrease the quantity of nutrients assimilated by plants. This may induce yield losses and costs due to additional nutrients required. SOM decline may also lead to specific off-side costs since SOM decline may affect biodiversity. Hence, addressing SOM may avoid the costs for the replacement of the ecosystem services provided by biodiversity. Particular attention is necessary to avoid adverse effects while tackling soil organic matter losses, i.e. to induce an excess of nutrients that may result in nutrient leaching and water pollution. Excess of nutrients may have negative impacts on environment and human health that will induce remediation costs.

The on-site benefits for the protection of SOM are estimated at EUR 2.1bn per year for EU-25 over 20 years, plus EUR 2.8bn per year for off-site benefits (European Commission, 2006a).

Administrative and legal feasibility

Opportunities and barriers

The barriers from an administrative point of view relate to target monitoring. In the case of SOM, the measurement of SOM throughout Europe by a single independent organisation (i.e. the LUCAS project) would ensure that the collection methodology is similar for all MS and that data can be compared. The administrative constraints may be reduced by an initial agreement with all MS for the conduction of sampling.

Furthermore, soil degradation including SOM depletion may have transboundary effects and therefore require coordination of policies at the EU level. Nutrients leached from soil can pollute the groundwater in a neighbouring country. In that case, EU policy is thus seen as a way to protect land users in a given country from the harmful consequences of practices in another country for which they are not responsible. Where transboundary effects occur, cooperative initiatives between regional and local authorities are essential. However, a number of MS consider that land degradation has no transboundary consequences and that soil legislation should be a matter of national competence only (Jones, et al., 2012).

Coherence with other policies

The proposed targets are fully coherent with the CAP: the CAP directly addresses soil organic matter losses in the GAEC, and indirectly through the implementation of AEM. Moreover, for the CAP 2014-2020, an indicator related to erosion by water has been proposed for soil organic matter in arable land. The implementation of this indicator is currently being discussed (European Evaluation Network for Rural Development, 2014) (European Commission, 2011b) (European Commission, 2013d).

The objectives of other policy frameworks, such as the Habitat Directive or the Nitrates Directive, are coherent with the proposed targets. For instance, the Nitrates Directive aims at limiting nutrient loads in water by avoiding nutrient losses by leaching and run-off and reducing nutrient surplus. Amongst others, the measures associated with the reduction of nutrient excess consist in capping organic fertilisers inputs (170 kg N/ha), with some exceptions for several MS (up to 230 kg N/ha). These requirements are still coherent with the maintenance of SOM, since the amount of nitrogen set by the Directive was established so as to avoid excess of labile elements but not to decrease the nutrient budget, even for crops that are nitrogen-consuming or located in nutrient-poor areas.

Similar to soil erosion, soil organic matter is specifically mentioned in the GAECs that farmers must comply with to receive full subsidies. Mandatory targets would provide clear outcome obligations. However, all proposed targets should not be mandatory. Making one target for each type of land degradation compulsory would be sufficient. Adoption of other targets could be proposed on a voluntary basis to help the MS attain the objectives while avoiding additional administrative and resource requirements and potential implementation burden for farmers with limited added value compared the mandatory target chosen.

4.5. Supporting policy instruments

4.5.1. Lessons learnt from practical implementation

Lessons learnt from the implementation of policy instruments at the EU and MS levels to address land degradation are detailed in Annex 4.2.

4.5.2. Recommendations

In order to achieve the proposed targets, a number of policy instruments could be developed and implemented at the EU and Member State levels.

At the EU level, the new CAP led to the creation of a new monitoring indicator on soil erosion by water, that should contribute efficiently to addressing the erosion issue and encourage MS to attain the proposed targets.

At the MS level, supporting policy instruments could include:

- Legislative instruments: for instance by the creation of a Soil Enhancement Act or Action Plan that requires land users to establish a plan to protect and improve soil quality (such as e.g. in Austria or the UK) or the creation of a Soil Act aiming to protect soil, in particular agricultural soils (such as e.g. in Bulgaria, Croatia, Czech Republic, Germany, Poland, Slovakia, Slovenia and Spain (for erosion only)) and to monitor and maintain soil fertility (such as e.g. in Latvia);
- Economic instruments: for example by providing subsidies (in addition to CAP subsidies) to municipalities where measures that address erosion and/or SOM decline are implemented (such as e.g. in Belgium and Denmark) or where compensation measures are implemented (such as e.g. in Germany, Latvia, Poland and Slovakia);
- Procedural instruments: for example by developing a national soil reporting framework (such as e.g. in Austria);
- Persuasive instruments: for instance by creating a soil protection festival to increase public knowledge (such as e.g. in Austria) or by creating guidance (such as e.g. in Finland, Germany, the Netherlands and Poland) and developing research projects (such as e.g. in Denmark or the Netherlands).

In addition to the targets focusing on the soil status, it could be worth proposing targets with other indicators focusing on the measures that have to be taken to tackle soil degradation issues. For instance, the “area of restored degraded land with high SOM content” could be used as an indicator for SOM. To achieve the Rio+20 agreement, the dedicated working group also proposed sub-targets using indicators related to the effectiveness of measures, i.e. the “rate of peatland conversion” and the “deforestation rate” (Ehlers, Lobos, Montanarella, Muller, & Weigelt, 2013). Indicators related to the implementation of measures that address soil erosion and SOM decline may be important to get an overview of the evolution of these indicators and of the implemented actions. These measures should be relatively easy to monitor since they are required by the CAP and data are already annually recorded per type of measures and per area. It would be preferable to propose adoption of these targets on a voluntary basis in order to limit the implementation burden for farmers. Further work would be needed to evaluate the contribution of voluntary targets related to the measures that address erosion and SOM decline at EU scale.

5. Land use functions

In brief

Land provides a wide variety of fundamental resources that cover the sustainability dimensions "people-planet-profit", including space for housing, infrastructure and recreation, water and soil resources, ecosystems and biodiversity. The provision of these individual resources (also referred to as 'Land use functions' or 'LUFs') is finite. Together with the finite total space available for LUF provision, this results in competition in the provision and use of different LUFs by society.

The currently available indicators for the provision and use of LUFs focus on individual LUFs. While for LUFs equivalent to ecosystem services a wide range of indicators is available, for the "people" and "profit" LUFs few, highly diverging indicators of a limited relevance were identified. All LUF indicators have the disadvantages of (1) not considering the demand or use of LUFs by society, (2) not considering trade-offs within LUFs and between different LUFs, and (3) a lack of independent data for validation.

Many EU and national policies address or influence LUFs, although rarely in a direct or deliberate manner. Most importantly, the EU Biodiversity Strategy aims at no net loss of biodiversity and ecosystem services by 2020 and sets targets for some LUFs. Additionally, targets that affect multiple LUFs are included in the Common Agricultural Policy and the EU Forest Strategy. Policies related to LUFs could be improved by better specifying the existing targets and by setting consistent targets for the full range of LUFs, taking into account trade-offs between LUFs. Definition of targets to safeguard or enhance LUFs calls for: (1) the development or further specification of indicators that account for LUF supply, demand, and links between supply and demand, at the appropriate scale; (2) the quantification of minimum levels required by society for different LUFs, using land use and integrated assessment modelling; and (3) an ex-ante assessment of land targets using land use and integrated assessment modelling, including the macro-economic consequences, in order to highlight cost, benefits and spatial trade-offs.

This chapter analyses indicators for land-based resources and the concept of multifunctionality. Section 5.1 elaborates the different concepts that are available to quantify, map and monitor land based resources and multifunctionality. Section 5.2 lists the available indicators for components of one of these concepts, and describes past and current trends. The indicators presented in Section 5.2 are evaluated in Section 5.3. Section 5.4 addresses existing national, EU and international policies, targets and initiatives that directly or indirectly influence land use functions. Based on the findings of the indicator evaluation (Section 5.3) and the description of existing policies and targets (Section 5.4), a framework for setting EU targets and policies is proposed in Section 5.5.

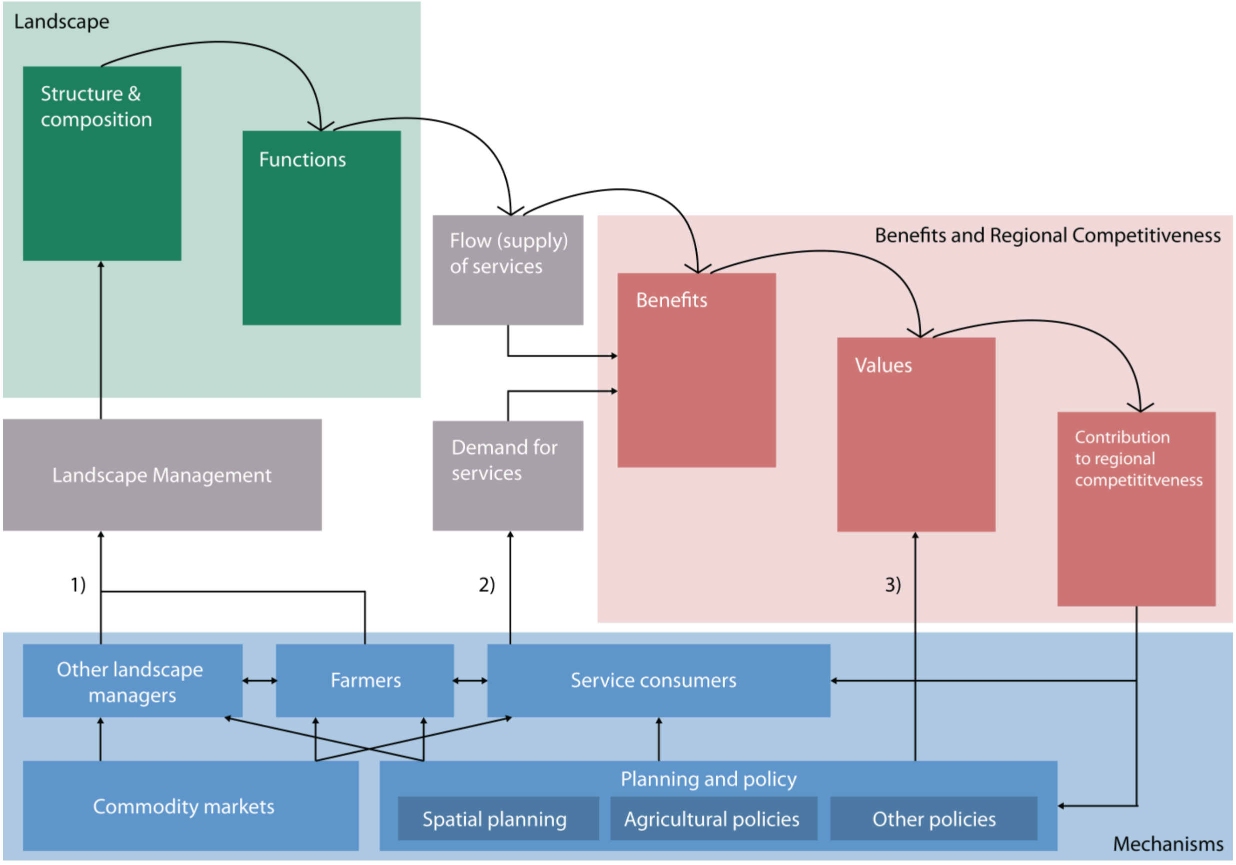
5.1. Introduction

5.1.1. Concepts for quantifying land based resources

Land provides a wide variety of resources that are fundamental to people. These resources include e.g. space for housing and infrastructure, areas for recreation, and resources like water and soils that support food production. Finally, land forms the basis of ecosystems, thereby supporting multiple other ecosystem services and biodiversity.

Several conceptual frameworks are available to define and quantify the links between landscapes and the benefits of land resources to humans. The most elaborated concept is the **ECOSYSTEM SERVICES** concept. It refers to the capacity of natural or semi-natural components and processes to provide goods and services, which directly or indirectly benefit society and human well-being (Batista e Silva 2011). The ecosystem service concept focuses on services provided by (semi-)natural processes, although services provided by humanised landscapes are often also accounted for.

The ecosystem service approach distinguishes between the ecological structures and processes, and the benefits they provide to people. This is most commonly elaborated in the ecosystem service cascade (De Groot et al., 2010). Ecological structures and processes are believed to perform specific ecosystem functions. When there is a flow of these functions to society, often triggered by a demand, the functions provide a benefit to society or society can attach a value to them. Therefore, society has a stake for managing the landscape. An example of the cascade for agricultural landscapes (Van Zanten et al. 2014) is presented in Figure 21. Modifications of the original conceptualisation by the global Economics of Ecosystems and Biodiversity (TEEB) initiative have been made by several authors (e.g. Van Oudenhove et al., 2012; Martin-Lopez et al., 2014) to better distinguish the role of land management and policy, as well as the role of the demand and supply of goods and services, as determinants of the values associated with these services. Also, the capacity–pressure–demand–flow framework defined by Villamagna et al. (2013) explicitly accounts for the role of management for ecosystem service provision.



Source: Van Zanten et al. (2014)

Figure 21: Links between ecosystem functions, services and benefits in managed agricultural landscapes as described in an ecosystem service cascade.

The ecosystem service concept was not considered broad enough to incorporate the requirements of a full sustainability assessment, as it is focused on the environmental pillar of sustainability (Batista e Silva 2011). This shortcoming is addressed in the **LAND FUNCTION** approach. Land Functions are defined as "the goods and services provided by the land use systems and ecosystems within the landscape". Land functions include provision of goods and services related to the intended land use, as well as goods and services such as the provision of aesthetic beauty, cultural heritage and preservation of biodiversity, which are often unintended by the land manager (Verburg et al., 2009).

For an application at European scale, ESPON (2013) elaborated the concept of **LAND USE FUNCTIONS (LUFs)**. The LUF framework provides a tool to assess the impact of policies on sustainable use of land. It provides a more holistic integration of all three sustainability pillars and reflects the progress towards multifunctionality.

Six different LUFs were defined based on the following criteria:

- These LUFs are representative for the main land uses in Europe. Agriculture and forestry areas are the main production areas, nature conservation and rural tourism are land-conserving activities and settlements, transport and energy infrastructure are urbanized types of land use;
- The key relevant economic, environmental and societal issues associated with land use have an equal representation in the framework; and
- All six LUFs are likely to be affected by European policies and the framework summarises three sustainability dimensions of a region.

ESPON (2013) defines these functions as land use functions rather than land functions, as they express "*the goods and services that the use of the land provides to human society*". Thus, a LUF only "exists", i.e. provides benefits to society, once there is an actual use of the function by the users. This is equivalent to the ecosystem service cascade where an ecosystem function only provides benefits if there is a flow of the ecosystem service. In this sense, the LUFs as defined by ESPON differ from the land function concept defined by Verburg et al. (2009) as they do not include functions of which the flow of goods and service is, in the current conditions, not used by society.

In spite of the similarities between the LUF concept and the ecosystem services concept, most ecosystem service classification systems – including the most recent CICES[87] classification as elaborated in the EU Mapping and Assessment of Ecosystem Services (MAES) action (European Commission 2014) – remain unclear about services provided by agricultural land. In addition, several types of resources that are land-based - but not directly originating from or related to ecosystems - are not included at all in the ecosystem service concept (EC 2014a). This is true for LUF1, LUF4 and LUF5, while it can also be argued that LUF3 is not an ecosystem service (Batista da Silva, 2011). LUF3, however, commonly appears in ecosystem service classification systems, including the Millennium Ecosystem Assessment, TEEB and CICES. As the LUF concept provides a holistic integration of all three sustainability pillars, and accounts for both the supply of functions by the land and the use and demand of these functions by society, it is the most obvious concept for elaborating multifunctionality targets. Table 34 summarises the LUFs.

Table 34: Overview of Land Use Functions as defined by ETC-SIA (2013)

Sustainability dimension	Land Use Function (LUF)		Issues included
Mainly societal	LUF1	Provision of work	Employment provision for all, in activities based on natural resources
	LUF2	Provision of leisure and recreation	Recreational and cultural services, including cultural landscapes and green spaces in urban areas
Mainly economic	LUF3	Provision of land-based products	Land-dependent production of food, timber, and biofuels
	LUF4	Provision of housing and infrastructure	Building of artificial surfaces: settlements (residential areas, offices, industries, etc.), transport infrastructure (roads, railways, airports and harbours)
Mainly environmental	LUF5	Provision of abiotic resources	Regulation of the supply and quality of air, water and minerals
	LUF5a	Provision of abiotic resources	Productive activities using abiotic materials, energy production with abiotic energy sources and non-renewable

[87] Common International Classification of Ecosystem Services

Sustainability dimension	Land Use Function (LUF)		Issues included
			sources (coal, oil, gas)
	LUF5b	Regulation by natural physical structures and processes	Maintenance of physical, chemical and abiotic conditions, mediation of substances and flows
	LUF6	Provision of biotic resources	Factors affecting the capacity of the land to support biodiversity (genetic diversity of organisms and habitats)

5.1.2. Multifunctionality

The concept of multifunctional land use recognises that it is often desirable to maximise the benefits obtained from a given parcel of land, and that a more equitable balance of the competing economic, environmental and social demands on land is more sustainable in the long term than an unbalanced system (ESPON 2013). Multifunctionality can be defined at different scales. In a narrow sense multifunctionality exists at the level of an individual location of the landscape, e.g. an agricultural field or forest patch that provides multiple functions to society, e.g. food production and carbon sequestration. Multifunctionality can also be found at the level of a farm or a landscape as a whole in which different components of the landscape provide different functions. While there are advantages of combining different functions at the same location as these may provide synergistic values, it is likely that none of the functions is at an optimal level. In a case study in the Netherlands, Willemen et al. (2010) demonstrated that with an increasing number of functions provided by the landscape the provision level of the individual functions decreased. Optimising the provisioning of the different functions at places in the landscape that are most suited for these functions may be another way to achieve multifunctionality, although trade-offs between the different locations due to negative interactions between the functions (e.g. pollution of neighbouring ecosystems as result of intensive agriculture) are possible.

Multifunctional landscapes refer to areas that simultaneously and in integrated ways supply a number of these functions, combining different qualities. This implies the co-existence of ecological, economic, cultural, historical and aesthetic functions. This does not imply that these functions are provided by multiple land uses in the same landscape, but rather that a single land use can involve a number of functions. For certain functions a combination of multiple land uses is needed and the functions may be influenced by the spatial configurations of the different land uses within the landscape.

A high level of multifunctionality is implied in the “ecological intensification” principle. Ecological intensification is defined as “environmentally friendly replacement of anthropogenic inputs and/or enhancement of crop productivity, by including regulating and supporting ecosystem services management into agricultural practices” (Bommarco et al., 2012). Another initiative building on multifunctionality is the e-flow introduced by the Global Environmental Flow Network[88]. eFlow describes the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems. The concept recognises that water flow support a range of ecosystem services and aims at holistic water management at catchment scale.

[88] www.eflownet.org

5.2. Indicators, drivers and trends of land use functions

This section describes how LUFs are currently being measured, their spatial distribution in Europe, and recent changes therein. Most importantly, ESPON (2013) provides a consistent EU-scale evaluation and description of LUFs and proposes two general indicators to measure LUFs:

- Land use performance: the degree to which the land use to deliver a specific function complies with a related policy target.
- Efficiency: the extent to which time or effort is well used for the intended task or purpose. For LUFs, this could be specified as the extent to which land is well used for the intended function considered. It is quantitatively determined as the ratio of input to output.

While ESPON (2013) proposes methods for quantifying the efficiency for all LUFs, the performance is not further evaluated.

Additionally, many other indicators have been developed. For several LUFs these originate from ecosystem service quantification efforts done by the Maes initiative (European Commission 2014), the No Net Loss initiative (Tucker et al 2014) and FP7 and BiodivERsA projects including VOLANTE[89], CLAIM[90] and CONNECT[91]. Note that some indicators are relevant for several LUFs, such as indicators of connectivity and fragmentation.

5.2.1. LUF1: Provision of work

LUF1 is defined as the provision of employment for all in activities based on natural resources (ESPON, 2013a). This can be interpreted as covering workers in the agricultural, forestry and mining sectors, as primary employment opportunities. No further specification is provided with respect to spatial scale and thematic aggregation that should be applied upon quantification of LUF1. As described below, the very limited applications of LUF1 indicators differ significantly in their definitions and quantification methods.

Indicators

ESPON (2013) calculates the efficiency of LUF1 as the number of jobs per NACE sector per km^2 land used by the sector, at a NUTS2 scale. This is specified for jobs in the NACE sector “agriculture” and jobs in all other NACE sectors. Efficiencies are calculated using NACE data on jobs per sector and the area of agricultural land and built-up areas, respectively. Van Berkel and Verburg (2011) define the capacity for off-farm employment as employment opportunities in rural areas outside the agriculture sector per NUTS2 region. The capacity is described using a semi-quantitative index that includes the accessibility to/from urban centres, the supply of rural employment in natural resources, industry and manufacturing sectors, and entrepreneurial spirit. Third, employment statistics in different sectors by Eurostat can be used to quantify LUF1. While Eurostat collects data following the NACE categories at multiple scales (NUTS0-3), no specific indicators have been developed based on these data.

The efficiency of use of urban areas, based on employment and/or population density, is further discussed in LUF4 through the indicator “utilisation” density.

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[89] www.volante-project.eu
[90] www.claimproject.eu
[91] www.connect-biodiversa.eu

Drivers, past and current trends

The ESPON efficiency indicator described above shows high values in the zone ranging from the Netherlands to northern Italy. Over the years 2000-2006, decreases were observed along the fringes of the EU and positive scattered changes were seen, e.g. in western Spain and central Europe. A high capacity for off-farm employment in rural areas was found in Western Europe, Italy, and in scattered parts of Spain and Scandinavia (Van Berkel and Verburg 2011). This map strongly favours areas where urban proximity and good infrastructure ensure accessibility of rural areas. Eurostat employment numbers showed a decrease in employment in agriculture, forestry, hunting and fishery of 22% over the years 2000-2007. Strongest decreases were seen in Romania, Bulgaria and Lithuania while some increases were seen in Belgium and Slovenia[92].

5.2.2. LUF2: Provision of leisure and recreation

Many landscapes, including cultural landscapes and natural and semi-natural ecosystems, provide a source of recreation. People enjoy these landscapes for hiking, hunting, fishing, cycling, camping, bird watching, or just being there. The capacity of landscapes to provide recreation depends on multiple factors: their beauty, uniqueness, cultural heritage, possibility for outdoor activities, etc. (ETC-SIA, 2013). Also the accessibility of landscapes is of importance: landscapes must be accessible to provide a flow of leisure and recreation services to people (Maes et al., 2011). Studies that inventory people's appreciation for landscapes often indicate that especially varied landscapes with some relief are preferred for recreation (van Berkel and Verburg, 2011).

LUF2 includes the provision of recreational and cultural services, including cultural landscapes and green spaces in urban areas. LUF2 is equivalent to the CICES category 'cultural ecosystem services' which includes spiritual and religious values, aesthetic values, cultural diversity, recreation and ecotourism, and knowledge systems and educational values (Maes et al., 2013).

Indicators

ESPON (2013) calculates the efficiency of LUF2 as the number of nights spent in tourist accommodations per km^2 of urban areas. This is based on the nights spent in tourist accommodations[93] and the area of urban land which is derived from Corine Land Cover (EEA, 2000a) at NUTS2-3 level. Bathing water quality is an important factor influencing the possibilities for recreation. EEA compiles data on bathing water quality following the Bathing Water Directive in its Core Set of Indicators (EEA, 2005b) (CSI022). Levels of bacteria from sewage and livestock are measured at over 22,000 sites across EU28 and Switzerland. This level is classified into four classes, ranging from excellent to very low.

While these two indicators only address a single component of the provision of recreation, more holistic indicators for recreation have been developed in the context of the MAES initiative, among others. Maes et al. (2011) map an indicator for the recreational potential available to EU citizens. The recreational potential is positively correlated to, and quantified based on a semi-quantitative dimensionless indicator for the degree of naturalness, the presence or absence of protected areas and

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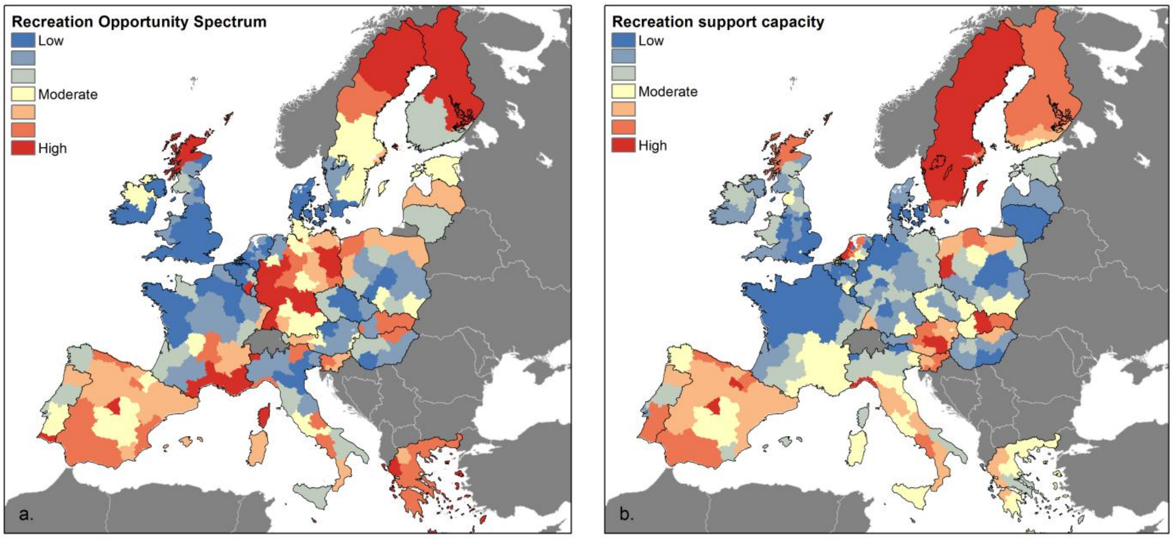
[92] Source: Eurostat. Employment and unemployment (LFS). Accessed 19/05/2014 at http://epp.Eurostat.ec.europa.eu/portal/page/portal/employment_unemployment_lfs/data/database

[93] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (accessed 3.27.13)

coastlines in a given radius, and the quality of bathing water as described above (Figure 5). This indicator is applied in the VOLANTE FP7 project to simulate future changes in recreational capacity (Mouchet et al., 2013). Van Berkel and Verburg (2011) developed an indicator for the capacity of ecosystems to provide recreational services. The variation of land use and the presence of urban areas in a 5 km vicinity are used to quantify the degree of naturalness, based on CLC. Furthermore, the landscape relief, proximity of lakes, rivers and marine coasts, the presence of natural monuments, protected areas and High Nature Value (HNV) farmlands are included as assets for nature-based tourism and recreation. These characteristics were evenly weighted into a single semi-quantitative indicator for the capacity to support recreation. This approach is consistent with many studies on people's preferences for tourism / recreation areas. This indicator is applied by Tucker et al. (2013) for analysing policy options for a No Net Loss initiative.

Next, indicators exist that map the capacity of the landscape or the land cover to provide the service using an expert-based rating of land cover types or environmental characteristics (Burkhard et al., 2012; Kienast et al., 2009). The approach by Burkhard et al. (2012) produces a classification of the land cover into five classes ranging from "no capacity to supply the service" to "very high capacity to supply the service", while the approach by Kienast et al. (2009) first evaluates if a certain land cover type, landscape type or management type provides the service (1) or not (0) and combines this into a single semi-quantitative indicator.

Finally, the cultural functions of the landscape are measured, in locations, by landscape preferences assigned by the users of these services. A wide range of studies have tried to measure these preferences in single case studies by ranking different land uses or landscape characteristics. As landscape preferences are often context dependent and also depend on different groups of users, it is difficult to identify a single indicator for these preferences as has been shown in a recent meta-study of van Zanten et al.(2014) that synthesises landscape preference studies across Europe.



Left: From Maes et al. (2011); right: from Tucker et al. (2013).

Figure 22: Examples of quantifying recreation land use functions: Capacity of EU landscapes to support recreation

Drivers, past and current trends

Recreational values are most importantly found in natural and cultural landscapes that are accessible to people. Consequently, land use change and land management change are the main drivers for the supply of LUF2. The demand is driven by population size and characteristics. Generally, the demand for recreation increases with increasing wealth and with increasing availability of leisure time. The highest recreation potential is found along scattered parts of the Mediterranean coast, Germany, Scotland, and scattered parts of Southern Europe (Maes et al., 2011). Tucker et al. (2013) expect some similar spatial patterns, e.g. high capacities in Scotland (Figure 22). Some decreases are expected in the near future due to urban expansion in the Netherlands and Belgium, and due to agricultural expansion in Poland. In Southern and Northern Europe some increases are expected due to heterogenisation of the landscape or due to expansion of nature areas (Tucker et al., 2013). Bathing water quality in coastal areas has remained rather stable over the past decades, while inland bathing water quality showed a steep increase halfway the nineties and remained stable afterwards. In 2011, over 80% of the coastal bathing waters and almost 90% of the inland bathing waters complied with the mandatory minimum values set in the Bathing Water Quality Directive[94]. The meta-analysis of van Zanten et al. (2014) across European landscape preference studies indicates a strong Europe-wide preference for more diverse landscapes consisting of multiple land cover types as compared to landscapes dominated by either forest or agriculture. Also there is generally a high preference for the presence of landscape elements.

5.2.3. LUF3: Provision of land based products

LUF3 is defined as the land-dependent production of food, timber and biofuels, which are essential to people. LUF3 comprises production of agricultural and forestry products (ESPON, 2013a) and gathering of berries, fruit, mushrooms, wood, timber, flowers and wild plants (ETC-SIA, 2013). LUF3 is equivalent to the CICES ecosystem services 'biomass for nutrition and biomass for fibres' (Maes et al., 2013).

Indicators

Area based indicators

The efficiency of LUF3 is calculated as the area harvested divided by the total agricultural area (ESPON, 2013a). Although not further specified by ESPON (2013a), this could be calculated based on the area harvested for all agricultural crops merged together, or for specific groups of crops (annual crops, permanent crops, etc.)[95], and the agricultural land area (EEA, 2000a) at NUTS2-3 level. Similarly, Maes et al. (2011) and Tucker et al. (2013) map cropland production as the area percentage of cropland per NUTS2 region.

Productivity based indicators

In order to facilitate integration of the EU Soil Strategy into other policies, a common framework has been developed to assess soil functions in relation to soil use and degradation threats. In this framework, a set of indicators was developed that quantify the biomass production function. Based on the European Soil Database, CLC, GLOBCOVER land cover, climate data and topographical data, the biomass productivity of agricultural land was quantified for grassland and cropland separately. All components were rated into separate indices and combined into a 1km-resolution index that quantifies biomass production into 10 dimensionless classes. The resulting map was validated against remote sensing based Normalized Difference Vegetation Index (NDVI) estimates (Toth et al., 2009).

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[94] http://www.eea.europa.eu/data-and-maps/indicators/bathing-water-quality/bathing-water-quality-assessment-published-4

[95] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (accessed 3.27.13)

Cherlet et al. (2013) quantify the change in land productivity, based on remotely sensed data on changes of Net Primary Productivity (NPP). Currently, a map exists for the change in land productivity over the period 1982-2010. The map has a 5 km resolution.

Production based indicators

Maes et al. (2011) map an indicator for timber production at NUTS2 level based on annual increment (m^3/ha per year) of the timber standing stock from EFI forest inventory data. Tucker et al. (2013) use the forest biomass stock (tonne biomass/km^2) as indicator. The indicator by Tucker et al. (2013) is based on country-level biomass stock inventories from the European Forest Institute (EFI), which are downscaled to 1 km resolution based on a 1 km forest mask (Perez-Soba et al., 2010). Forest growing stock (m^3/ha), increment and fellings (m^3/ha per year) are used to calculate the forest utilization rate at country level in EEA SEBI017 (EEA, 2013b). This indicator expresses the felling as a percentage of the increment, providing direct information on the availability and sustainability of timber. Within the VOLANTE project, an indicator for wood supply was mapped as roundwood harvest (m^3/km^2 per year) at a 1km resolution. Also, the energy content of agricultural production (MJ/ha) was mapped at a 1km resolution (Mouchet et al., 2013). Crop yield statistics and forest harvest volumes at various NUTS levels are collected on an annual basis by Eurostat[96]. These Eurostat data are crop specific, therefore food crops and biofuels can be distinguished. Finally, Maes et al. (2011) map livestock production as the density of grazing animals on grassland.

Resource efficiency indicators

A third way to describe LUF3 is to estimate the ratio between inputs used for production and outputs gained. No readily available indicators exist to reflect this ratio. Both inputs and outputs of agriculture are, however, regularly monitored by Eurostat at NUTS2-3 level, allowing the calculation of such indicators. Time series for the gross nutrient balance are available through Eurostat.

Drivers, past and current trends

LUF3 depends on the actual land cover and on the productivity of the land, i.e. the natural productivity and the management intensity. Figure 23 summarises the drivers for changes in agricultural land. In Europe, expansion of forest and nature is strongly driven by area changes of agricultural land. Forest management is an additional driver for changes in forest productivity.

[96] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (accessed 3.27.13)

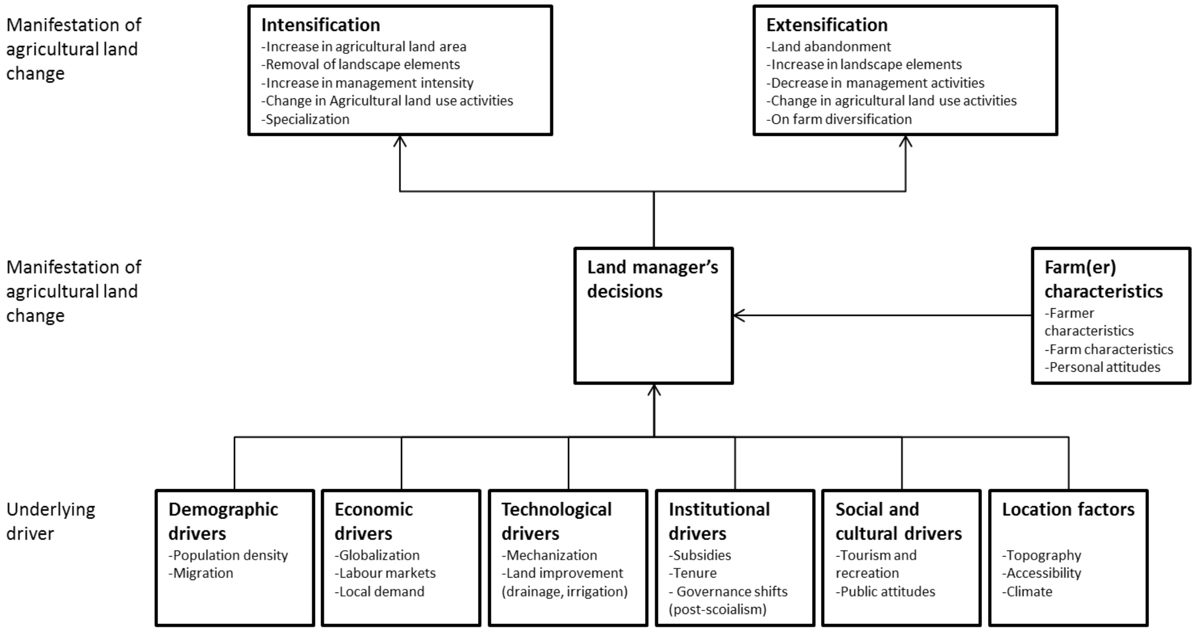

Figure 23: Drivers for agricultural land use change[97]

Major timber stocks and timber increments are found in the southern half of Scandinavia and the mountainous and hilly areas in central Europe (Maes et al., 2011). The felling ratio is relatively stable at around 60%, but is expected to increase to 70-80% by 2010 (EEA, 2013b) due to an increasing wood demand. The main croplands are found in flat or rolling areas in England, Denmark, Poland, northern France and Romania (Maes et al., 2011). Livestock densities are highest along the Atlantic and North Sea coasts, and in Italy. The highest grassland biomass productivities are found in the western half of France, Belgium and the clay/peat landscapes of the Netherlands, and in Ireland. Recent changes in land-based production due to area changes are mainly decreases of agricultural land due to land abandonment (ESPON, 2013a) and land take by urban development (ETC-SIA, 2013). An increasing demand for food due to increasing population and increasing wealth also induced intensification of arable production.

Highest crop biomass productivities are found in the western half of France and in England (Toth et al., 2009). Increases in temperature and extremes in climate conditions negatively affect the productivity of maize, especially in the Mediterranean area, while increasing temperatures enhance the productivity of maize and root crops in northern Europe (ETC-SIA, 2013). In Western Europe, over the years 1950-2000, the average slope of croplands increased and the soil depth decreased (Bakker et al., 2011). This indicates that croplands are abandoned in areas with favourable conditions while new cropland expansion increasingly takes place at less favourable conditions with a larger risk for degradation. This trend is not observed in Eastern Europe, where cropland expansion in areas with favourable conditions like deeper soils and less steep slopes has been observed.

With regard to the gross nutrient balance, strong decreases were observed between 2000 and 2009 in the nitrogen balance per hectare for arable land, permanent crops and permanent grassland in the

[97] Source: From Van Vliet et al. 2015.

EU15 countries, and slight increases in the EU12 countries. The current level is of around 50 kg/ha across the EU28. For phosphorus, decreases are seen throughout the EU.

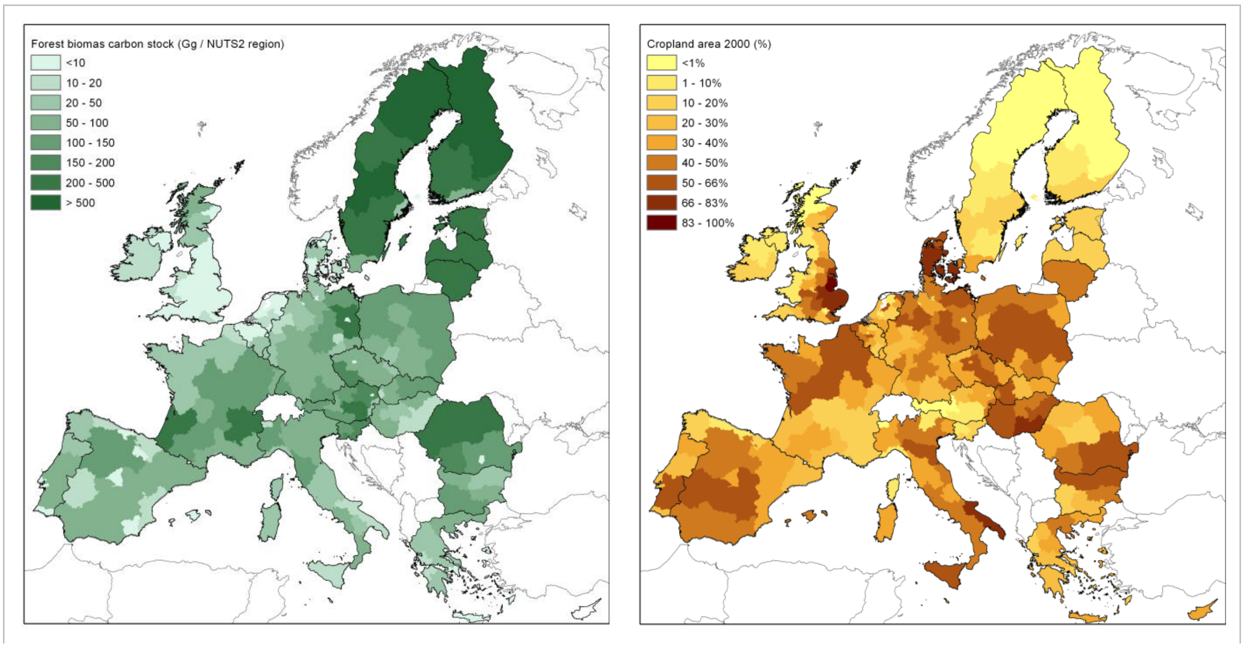

Figure 24: Forest biomass stock (left) and share of cropland area (right)[98]

5.2.4. LUF4: Provision of housing and infrastructure

LUF4 is defined as the presence of artificial surfaces, like settlements and transport infrastructure.

Indicators

The indicators described in Chapter 2 (Land take) describe the provision of LUF4. Examples of indicators include:

- The efficiency of LUF4 as the population number per km^2 built-up area or roads, as defined by ESPON (2013); and
- The share of low-density and high-density urban areas, and the available built-up area per person to describe urban sprawl in Europe, as proposed by EEA and JRC (2006).

Other indicators could include energy production, waste production, etc.

Drivers, past and current trends

The density of urban areas is strongly influenced by income and by national and local planning regulations, which affect a wide range of issues such as land price, competition between municipalities, preferences on housing and green space, and possibilities for travelling (EEA and JRC, 2006). Combined with demographic developments, it influences the quantity of land take as described in Chapter 2. Throughout Europe, urban areas have expanded more rapidly than the growth of population and there is no slowing down of these trends being observed (EEA and JRC, 2006).

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[98] Source: Tucker et al., 2013

5.2.5. LUF5a: Provision of abiotic resources

LUF5a includes the regulation of the supply and quality of air, water and minerals. LUF5a is also defined as covering the economic uses of abiotic materials, energy production with abiotic energy sources and non-renewable resources. Examples of LUF5a include the provision of building materials, salt, sunlight, coal, oil and gas (ETC-SIA, 2013). Available indicators that cover LUF5a focus on regulating water quantities. Additionally, indicators for mining in general could be defined.

Indicators

Indicators for water provision and abstraction

Maes et al. (2011) map the capacity of ecosystems to provide freshwater as the surface area of freshwater ecosystems, based on CLC. This is either expressed as the presence/absence of water at a 100 m resolution, or as the area share of freshwater per NUTS2 region. A similar approach is used by Tucker et al. (2013), who calculate the area of freshwater systems per capita per basin-country unit[99]. JRC provides a map of groundwater hydrology, springs, and groundwater abstraction for the EU15, based on data from the 1980s[100]. The Water Information System for Europe provides information on the spatial distribution of lakes and rivers, and the water quantities available in Europe's lakes, rivers, groundwater bodies and transitional, coastal and marine waters[101]. This information underlies the indicators described below. Water abstraction quantities are available from Eurostat per NUTS2 region, approximately on an annual basis[102]. This includes differentiation between fresh surface water, fresh groundwater, non-fresh water sources, desalinated water and reused water.

Droughts are defined as a natural, temporary, negative and severe deficit during a significant time period, and over a large region, with regard to average precipitation values (EEA, 2012b). Droughts are continuously monitored using a combined drought indicator by the JRC Drought Observatory[103]. This indicator combines a Standardized Precipitation Index (SPI), soil moisture and the Fraction of Absorbed Photosynthetically Active Radiation (which reflects the vegetation water stress) into a single indicator that warns for significant rainfall or soil moisture deficits or vegetation stress.

Water scarcity describes the balance between water supply and human demand for water. Water scarcity is a recurrent imbalance that arises from an overuse of water resources, caused by consumption being significantly higher than the natural renewable availability (EEA, 2012b). The EEA indicator 'CSI018' (Water Exploitation Index, WEI) quantifies water abstraction as a percentage of the freshwater resources available, at a national scale and over an annual timescale (EEA, 2005b; 2012d). The indicator was developed to monitor if rates of extraction are sustainable over the long term, which is an objective of the EU's 6th Environment Action Programme (2006-2010). The WEI assumes that abstraction of <20% of the long-term available renewable resources is sustainable, while values above 40% indicate unsustainable water use, i.e. water scarcity. Values between 20 and 40% indicate that the country is under water stress.

[99] A basin-country unit is defined as the spatial portion of a river basin that is within a single country (De Stefano et al. (2012) and is mapped by intersecting a map delineating river basins and a map delineating countries.

[100] http://eusoils.jrc.ec.europa.eu/library/esdac/Esdac_DetailData2.cfm?id=10

[101] http://www.eea.europa.eu/themes/water/dc#tab-datasets

[102] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (accessed 3.27.13)

[103] http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000

The WEI was further specified into the WEI+. A national scale WEI does not reflect variations between (sub)catchments and seasonal variations. WEI+ accounts for water required by the catchment to maintain its ecological status, and for water returns after e.g. use for industrial cooling. Additionally, WEI+ analyses (EEA, 2012b) are based on data at river basin level, to accounted for within country variations. Due to data constraints, WEI+ is currently still calculated on an annual timescale.

Indicators for the provision of building materials, salt, coal, oil and gas

Although no specific indicators exist for this component of LUF5a, mineral extraction sites are included as a category in CLC (EEA, 2000a), hence their surface area or surface area share can be monitored. Secondly, Eurostat monitors indicators for the mining and quarrying industry, including the number of enterprises, number of employees and production value[104]. These numbers are country-specific and collected on an annual basis. Toth, Gardi et al. (2013) assessed the provision of raw materials from the soil in Europe. This includes organic soil for horticultural and other applications, and soil materials for construction. Other raw materials that are excavated in mining activities were not considered as they do not originate from the soil, but from underlying geological layers. Toth, Gardi et al. (2013) mapped the availability of organic soil material based on the presence of histosols while the availability of soil materials for construction was mapped based on the presence of stones, gravel or sand in the topsoil. Both were mapped as index scores that express the area percentage of soil potentially supplying raw materials.

Drivers, past and current trends

Availability of water and other abiotic resources is driven by geology, soil conditions, hydrological conditions, topography and land use conditions. Demand for these resources is driven by population size, wealth, climate conditions, and measures to reduce resource use per capita. Currently, five EU countries are severely water-stressed: Cyprus, Belgium, Spain, Italy and Malta. These countries house 19.5% of Europe’s population (EEA, 2005b). Over the past 10-17 years, the water use efficiency decreased in 24 countries, representing a decrease of about 12% in total water abstraction. The Netherlands, Greece, Finland and Slovenia increased their WEI. The area covered by mineral extraction sites increased by around 2% between 2000 and 2006. This increase goes mainly at the cost of arable land, forest and pasture. Organic material in soils is mainly available in the Northern half of the EU, mainly in Sweden and Finland. Sand, gravel and stones can be found throughout the EU, with high potential in Sweden, Finland and the Northwest European sand area in the Netherlands and Germany.

5.2.6. LUF5b: Regulation by natural physical structures and processes

LUF5b includes ecosystem services related to the regulation and maintenance by natural physical structures and processes, focusing on the maintenance of physical, chemical and abiotic conditions, mediation of substances and flows (ETC-SIA, 2013). Examples include atmospheric dispersion and dilution, screening by natural physical structures, and control of erosion. The provision of LUF5b is strongly related to land use and land cover patterns. LUF5b is equivalent to many regulating and maintenance ecosystem services defined by the CICES, including mediation of mass, liquid and gaseous flows and climate regulation (Maes et al., 2013).

[104] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_na_ind_r2&lang=en (accessed 5.21.14)

Indicators

LUF5b contains a range of regulating ecosystem services that are often related to land cover and land use patterns. Consequently, two groups of indicators are available for LUF5b: (1) land cover or land cover pattern based indicators, and (2) indicators for single regulating services. This section focuses on land cover (pattern) based indicators and on indicators for three main regulating ecosystem services for which multiple indicators are available (Schulp et al., 2014a): climate regulation, flood regulation, and erosion prevention. These three ecosystem services operate at three distinct spatial scales. They are representative of the types of indicators associated with other ecosystem services for which less data are available. For the regulation of other processes, including e.g. regulation of droughts or local-scale climate regulation, little work on indicator development has been carried out so far.

Indicators based on land cover extent or patterns

(ESPON, 2013a) calculates the efficiency of LUF5b as the area percentage of unsealed soil[105] per NUTS2-3 region. A related indicator is land take (EEA CSI014) (see Chapter 2). Land take by expansion of residential areas and construction sites is the main cause of urban land coverage increase in Europe (EEA, 2005b), which is very commonly accompanied by soil sealing, although this relationship is not linear (as discussed in Chapter 2). This mainly affects agricultural land and, to a lesser extent, forests and (semi-)natural.

The SEBI004 indicator (ecosystem coverage) describes the area, as well as proportional and absolute changes in the extent and turnover of main ecosystem types, based on CLC maps (EEA, 2013a). Based on LUCAS inventories, several land cover pattern indicators were mapped by JRC[106]. These include field size area, field direction, length to width ratio, field length, the percentage agricultural wind erosion susceptible fields/ non-susceptible field numbers per NUTS3 region.

A fourth relevant land cover pattern indicator is a forest pattern and fragmentation map developed by JRC[107]. This is a high-resolution set of indicators that maps forest extent, location and size of forest patches, length of forest edges, and connectivity. However, several other indicators have been suggested in the literature to describe land fragmentation (EEA-FOEN, 2008), such as:

- the SEBI 13 Indicator on fragmentation of natural and semi-natural areas, developed by the EEA[108];
- the average patch size (APS);
- the density of transportation lines (DTL) in relation to total area of the landscape;
- the number of the remaining large undissected low-traffic areas larger than 100 km^2; and
- the effective mesh size “m_{eff}” (which describes the probability that two randomly chosen points in the landscape would be in the same patch) and mesh density “s_{eff}”(effective number of meshes per 1000 km^2, which describes the probability that two randomly chosen points in the landscape would be within areas divided by barriers). The effective mesh size and effective

[105] http://www.eea.europa.eu/data-and-maps/data/eea-fast-track-service-precursor-on-land-monitoring-degree-of-soil-sealing
[106] http://eusoils.jrc.ec.europa.eu/library/esdac/Esdac_DetailData2.cfm?id=77
[107] http://forest.jrc.ec.europa.eu/activities/forest-pattern-fragmentation/
[108] www.eea.europa.eu/data-and-maps/indicators/fragmentation-of-natural-and-semi/fragmentation-of-natural-and-semi#toc-3

mesh density are described by Jaeger et al. (2007). The more fragmented the landscape, the lower the mesh size and the higher the mesh density. The larger the patches fragmented, the bigger the effect on the effective mesh size and reciprocally.

Finally, Van der Zanden et al. (2013) mapped the density of green linear elements throughout Europe based on LUCAS inventories as the probability to encounter a linear green element on a 250 m transect.

A lot of work is being undertaken on developing indicators of ecosystem services, for instance with the development of an integrated indicator of "net Landscape Ecological Potential"[109] (composite of land cover data, 'greenness', protection status and fragmentation) and more recently through the MAES (Mapping and Assessment of Ecosystem Services Initiative). The mapping of ecosystem services is a promising body of work that could help monitor net land take impacts in the future. It is an emerging research activity in the EU, which relies on a combination of land use and land cover data and "in-situ" data providing information on soil ecosystem services. A significant conceptual and mapping work has been carried out recently by Maes et al. (2011, 2013, 2014) on ecosystem services, building on the CICES classification[110] (Haines-Young et Potschin, 2013). They namely worked on defining indicators for ecosystem assessments and produced maps at the EU level for both individual ecosystem services, which allow maximising each of them, and for the total ecosystem service value, which allow maximising multifunctionality. However, there is no consensus yet within the European stakeholders' community as to which sets of indicators to use.

Soil sealing, fragmentation and green infrastructure could efficiently complement the net land take indicator, (discussed in Chapter 2) to reflect the loss of ecosystem services due to land take through the physical and functional loss of ecosystems (see Section 5.3). This combination of indicators could contribute to promoting a "no net land take impact" approach.

Indicators for climate regulation

Land cover and land use play two roles in climate regulation. First, vegetation and soil sequester or emit CO_2 and with that regulate atmospheric CO_2 concentrations. Secondly, vegetation plays a role in regulating the local or regional climate, mainly through exchange of water and water vapour with the atmosphere. Changes in land cover result in alterations to surface moisture, heat, and momentum fluxes, and CO_2 exchange. These changes influence all aspects of local and regional weather and climate (Mahmood et al., 2014). For example, urbanisation generally results in replacement of natural vegetation with built environment. This shifts the total energy flux between land and atmosphere towards being dominated by fluxes of sensible heat that results in urban heat island effects. These changes in energy fluxes subsequently affect precipitation patterns, leading to heavier rainfalls in more urbanized areas (Mahmood et al., 2014). Similar effects on temperatures are observed in large-scale rainfed agriculture areas. This thorough process to understand the regulation of the local climate has not yet resulted in the development of operational indicators. However, the area and structure of natural vegetation are often related to the level of regulation of local climate conditions. For example, urban heat island effects are stronger in completely sealed areas than in suburbs with some natural vegetation (Mahmood et al., 2014). Indicators based on the extent and patterns of natural vegetation could therefore possibly represent the level of local-scale climate regulation. As indicated by MacAlpine et al. (2010), quantification of the links between land use change and surface fluxes of

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[109] http://unstats.un.org/unsd/envaccounting/seeaLES/egm/issue5-EEA.pdf

[110] http://cices.eu/wp-content/uploads/2012/07/CICES-V43_Revised-Final_Report_29012013.pdf

water vapour and heat is mostly lacking; it is a key step required to deal with the problem of climate change and variability, and to inform policy making in this area.

For the regulation of CO_2 concentrations by land cover and land use, multiple indicators are available. A common indicator for climate regulation that captures the sequestration in both vegetation and soil is the Net Ecosystem Productivity (NEP). It is calculated as the net primary productivity minus respiration, commonly expressed as mass of carbon per unit area. This is used by Maes et al. (2011) who provide an estimate based on a model's direct interpretation of remote sensing images. Schulp et al. (2008) calculate the NEP with a bookkeeping model based on a simplified CLC map. The latter approach is used by Tucker et al. (2013) and in VOLANTE (Mouchet et al., 2013). Secondly, indicators exist that map the capacity of the landscape to regulate the climate using an expert-based rating of land cover types or environmental characteristics (Burkhard et al., 2012; Kienast et al., 2009). These indicators are calculated similarly to the capacity indicators described under LUF2. Third, the carbon stock (tonne/ha) provides an indicator for the capacity of the landscape to regulate the global climate. Maes et al. (2011) developed an indicator for the carbon stock in biomass and carbon stocks in soil are monitored within LUCAS (Gallego and Delincé, 2010).

Indicators for flood regulation

Stürck et al. (2014) mapped the demand and supply for flood regulation and demonstrated that a high supply and a high demand for flood regulation hardly occur in the same catchment. The indicator for flood regulation supply developed by Stürck et al. (2014) describes the relative water retention in a normalized index that includes the impacts of land cover, catchment type, catchment zone, land management, and soil water holding capacity. This approach is also used by Tucker et al. (2013) and in VOLANTE (Mouchet et al., 2013). JRC maps an indicator on flood regulation based on water quantity regulation, i.e. annually aggregated soil infiltration, derived from a pollutant pathway model with 1 km^2 resolution (Maes et al., 2011). JRC continuously monitors on-going floods and provides an overview of flood risks, past floods and potential flood damages throughout Europe[111], but no tangible indicators have been developed. Finally, indicators exist that map the capacity of the landscape to regulate floods using an expert-based rating of land cover types or environmental characteristics (Burkhard et al., 2012; Kienast et al., 2009).

The "Natural Water Retention Measures" (NWRM) initiative[112] aims to develop a structured knowledge base on NWRM that can easily be accessed by all within the Water Information System for Europe (WISE). In a concept note[113], the initiative highlights the importance of land cover for functions such as slowing down water flows, increasing infiltration rates, controlling storm flows, storing water, reducing pollution loads and so on. This applies both at very small scales (e.g., introducing green roofs in cities or buffer strips in agricultural land) as well as at large scales (e.g., wetland restoration or afforestation of mountainous areas). The progress in the implementation of such measures could be measured by land cover based indicators. However, the initiative so far has not proposed tangible indicators.

[111] http://floods.jrc.ec.europa.eu/ongoing-floods.html
[112] nwrm.eu
[113] http://nwrm.eu/sites/default/files/documents-docs/nwrmconceptnote_to_regional_stakeholders.pdf

Indicators for erosion prevention

Additional to indicators that map or quantify the severity of erosion as described in Chapter 4 (Land degradation), there are indicators for the level of prevention against erosion. Maes et al. (2011) and Tucker et al. (2013) map erosion prevention using an area based indicator, to express the protective function of forests and semi-natural areas (based on CLC) in areas with a high erosion risk. Finally, indicators exist that map the capacity of the landscape to provide erosion prevention using an expert-based rating of land cover types or environmental characteristics (Burkhard et al., 2012; Kienast et al., 2009). All mentioned indicators assign a semi-quantitative indication of the erosion reducing effect to different land cover types. Generally, it is assumed that pasture, semi-natural vegetation and forests provide a high level of erosion protection. Tucker et al. (2013) additionally make a distinction between different climatic regions within the EU, to account for the difference in vegetation structure – and thus with erosion prevention – between e.g. Mediterranean scrublands and temperate scrublands.

Drivers, past and current trends

Main drivers for the provision of LUF5b are land take by urban expansion, scale enlargement and intensification of arable production, and expansion and abandonment of agricultural land. Figure 25 shows spatial patterns of climate regulation, flood regulation, erosion prevention, and a bundle of regulating services that represents all components of LUF5b. Hotspots for climate regulation are mostly found in forested areas, mainly in Southern and Central Europe. High flood regulation capacity is expected in areas with large patches of natural vegetation or extensive agriculture, like Ireland, North-western Spain, the Pyrenees, Eastern Sweden, and the Carpathians. The main restriction on the supply of flood regulation is the available water holding capacity. This leads to low flood regulation supply in e.g. Scotland. Over the years 1960-2000, decreases of the flood regulation were seen. Especially in agricultural areas, intensification has decreased the flood regulation supply. Only in Italy, increases are seen in the mountain regions (Sturck et al., 2014). Hotspots for erosion prevention are seen in natural areas in Central and Northern Europe (Tucker et al., 2013).

Compared to 1990-2000, land take shifted from pastures and mosaics to arable land and permanent crops. Also, many conversions of heterogeneous land cover, pasture and semi natural vegetation into arable land took place, as well as conversion of agricultural land into forest (EEA, 2013b). Net changes between 2000 and 2006 indicate an increase of built-up area, transitional woodlands and forests, at the cost of agricultural land. Most likely, this has decreased the provision of LUF5b in areas of urban expansion and increased the provision of LUF5b where agricultural abandonment takes place. Thus, a polarization of the provision of regulating ecosystem services is expected, where more hotspots are emerging as well as more locations with a low provision. At a small scale, such a polarization is indeed observed in case studies in Germany (Lautenbach et al., 2011) and the UK (Jiang and Bullock, 2013). At the EU scale, there is no quantitative evidence on this.

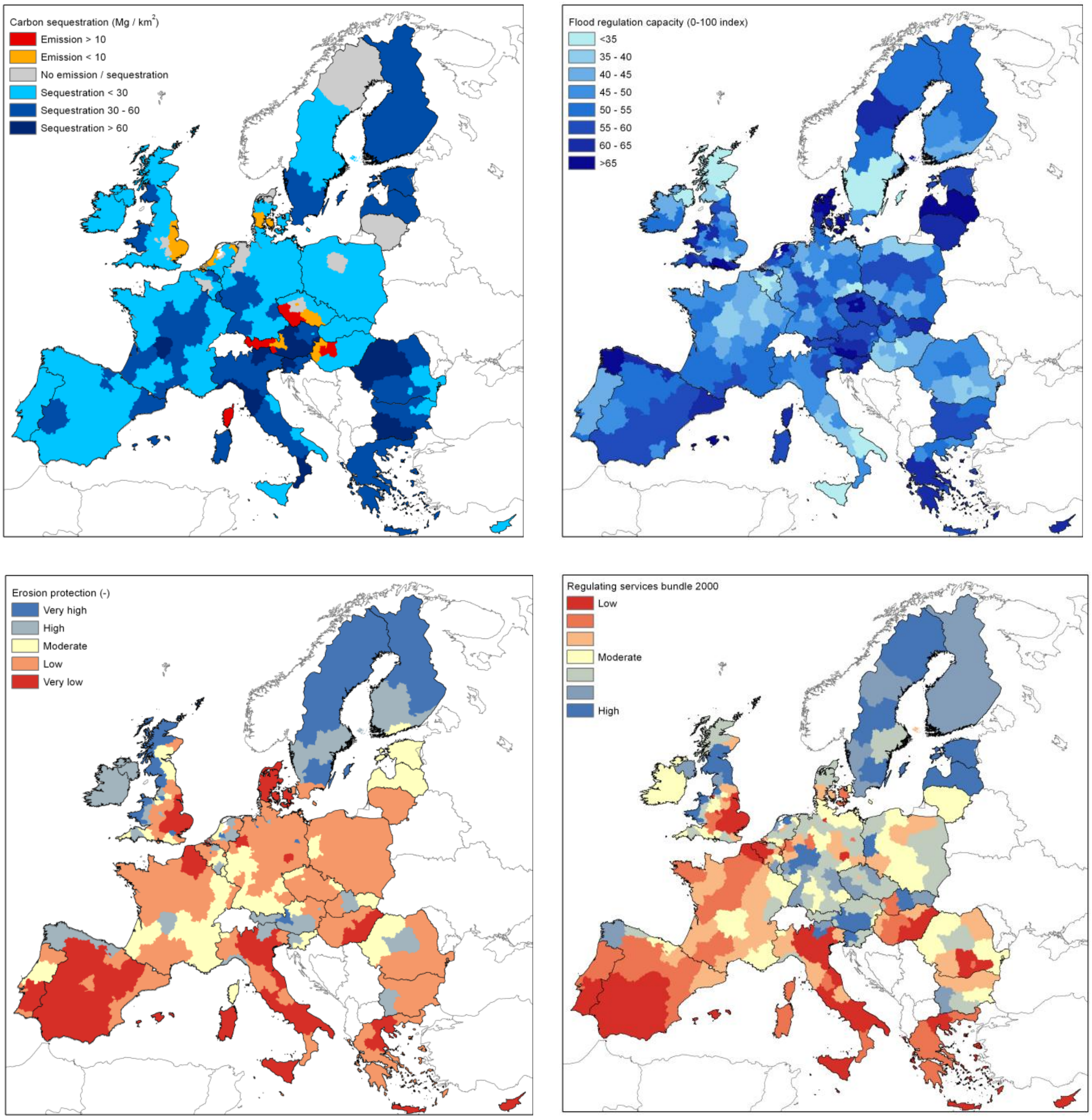

Figure 25: Climate regulation, flood regulation, erosion prevention, and bundles of regulating services[114]

5.2.7. LUF6: Provision of biotic resources

LUF6 includes factors affecting the capacity of the land to support biodiversity (genetic diversity of organisms and habitats). Examples are pollination by bees and other insects, and seed dispersal by insects, birds and other animals. LUF6 is therefore closely related to the presence of species (i.e. species richness and abundance), or the presence of natural habitats for these species. LUF6 is equivalent to the CICES category defined as 'Regulating and maintenance services: pest and disease control, pollination, lifecycle maintenance, habitat and gene pool protection' (Maes et al., 2013).

[114] Source: From Tucker et al., 2014

Indicators

Four categories of indicators exist for LUF6: (1) indicators based on the extent or pattern of natural habitats, (2) indicators based on the extent of protected areas, (3) species based indicators, and (4) indicators for specific ecosystem services.

Indicators based on the extent or pattern of natural habitats

SEBI020 (EEA, 2013b) quantifies the area share of agricultural land under organic farming at country level, and the area of agricultural land with a high nature value (HNV farmlands). HNV farmland provides habitat for a wide range of species. HNV farmlands can comprise: farmlands with a high proportion of semi natural vegetation; farmland with a mosaic of low intensity agricultural and natural structural elements; or farmland supporting rare species or a high proportion of European or world populations. This indicator contains an explicit spatial estimate of the likelihood of occurrence of these areas.

SEBI013 shows the average size of patches of (semi-)natural areas and changes therein, based on CLC (EEA, 2013b). The indicator can be calculated by NUTS2/3 region, biogeographical region or country. This gives an indication of the integrity of the ecosystem, which might affect the capacity of a given ecosystem to deliver ecosystem services, including biotic resources. A comparable indicator of fragmentation is used by Tucker et al. (2013).The extent or pattern indicators for LUF5b described in Section 5.2.6 also apply to LUF6.

Indicators based on the extent of protected areas

The efficiency of LUF6 is calculated as the area share per region of Natura 2000 areas and Nationally Designed Areas (ESPON, 2013a). A Nationally Designated Area indicates an area designated by a national designation instrument based on national legislation. This can comprise sites designated under the EU Birds and Habitats directives or Natura2000 sites as well, if these are included in country-level legislations. This can be calculated at different spatial scales. Equivalent with the previous indicator, EEA compiles data on the number of protected sites and their area on a country basis. Indicators are specified for nationally designated areas (SEBI007), percentage of the target for designating areas that has been achieved at a national level (SEBI008), the total protected area which encompasses SEBI007 and SEBI008 (CSI008), and an indicator for the conservation status and trends of habitats of European Interest (SEBI005) (EEA, 2013b).

Species based indicators

The genetic diversity of organisms can be expressed as the number of species present, i.e. the species richness. These are quantified in EEA indicators CLIM022 and CLIM024[115], often at country level. Separate indicators are defined for the species richness of plant and animals, and for different animal groups. First, the SEBI003/CSI006 indicator shows changes in the conservation status of species of European interest. These are the species listed in Annexes II, IV and V of the Habitats Directive, where they appear because they were perceived to be under some sort of threat at EU scale. The species set covers various taxonomic groups, trophic levels and habitats (EEA, 2013a). The Red List Index (SEBI002) shows trends in the overall threat status of European species. Indicator SEBI001 describes overall trends of common birds (farmland birds and forest birds) and butterflies, relative to 1980 (EEA, 2013b). Tucker et al. (2013) developed indicators for bird species richness and Overmars et al. (2014) developed an indicator for farmland biodiversity. These indicators describe the

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[115] http://www.eea.europa.eu/themes/climate/indicators#c10=&c5=all&c7=all&c13=50&b_start=0

number of species as a function of potentially present species and several pressures, including land use, land use intensity, and fragmentation. This is based on a simplified version of the CLC map.

Indicators for biodiversity and biotic regulating services

The Mean Species Abundance (MSA) is constructed to show the potential impact of land-use change on biodiversity. The approach used is derived from the GLOBIO3 concept. The MSA ranges from 0 to 1. By definition, the MSA is 1 (or 100%) in pristine nature areas. Environmental pressures result in lower MSA values. Environmental pressures considered in the MSA are land-use, land use intensity (both in agriculture and forestry), nitrogen deposition, fragmentation, infrastructure developments and policy assumptions on e.g. high nature value (HNV) farmland protection and organic agriculture. The MSA was developed for global scale biodiversity assessments (Alkemade et al., 2009), but has also been applied at EU level (Perez-Soba et al., 2010; Tucker et al., 2013; Verboom et al., 2007). Biotically regulated ecosystem services for which indicators are available are pollination and pest control. For pollination, multiple indicators exist at the European scale. A first category of indicators maps the capacity of the landscape to provide pollination using an expert-based rating of land cover types or environmental characteristics (Burkhard et al., 2012; Kienast et al., 2009). Secondly, there are indicators that quantify the supply of pollination as a direct function of the area of suitable pollinator habitat, based on CLC maps (Schulp et al., 2014b; Serna-Chavez et al., 2014; Tucker et al., 2013). A third group of indicators quantifies the probability that a location gets visited by pollinators based on the distance to patches of semi natural vegetation (Zulian et al., 2013) or the distance to patches of semi natural vegetation or green linear elements (Schulp et al., 2014b). Pest control is quantified based on the richness of species that moderate pests in VOLANTE (Mouchet et al., 2013).

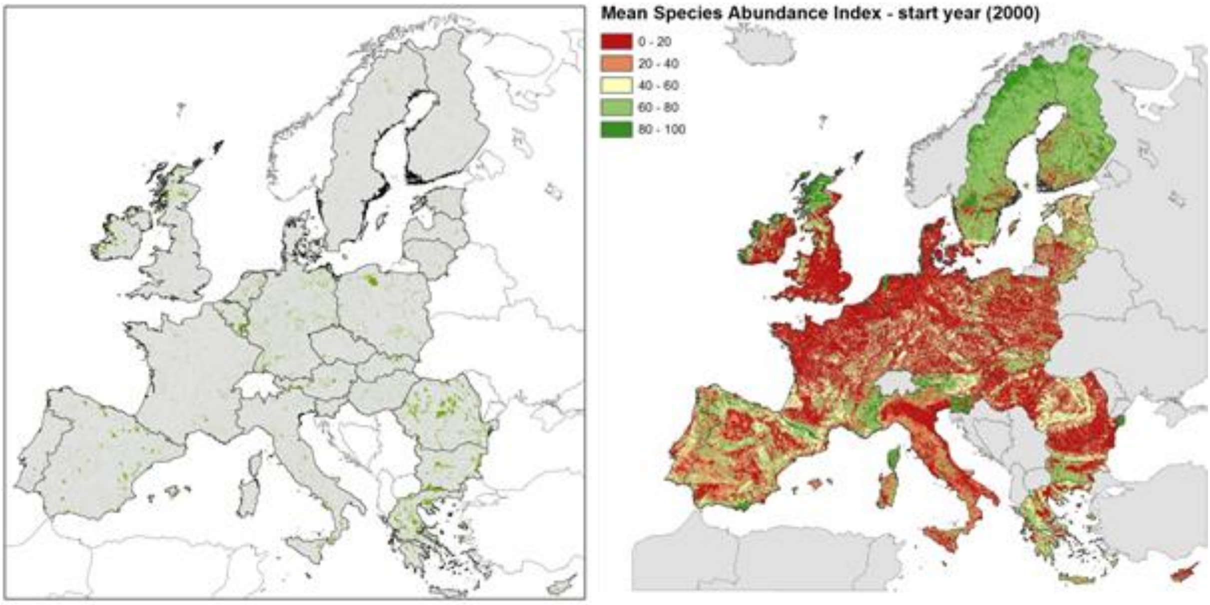
Drivers, past and current trends

Drivers

The main drivers for LUF6 are land take by urban expansion, scale enlargement and intensification of arable production, and expansion and abandonment of agricultural land. These drivers result in the fragmentation of natural habitats, pollution, over-exploitation, spread of invasive alien species, and climate change. Agricultural habitats are affected by widespread changes including intensification and agricultural expansion (Tucker et al., 2013). Habitat fragmentation hampers the migration of many animal species, potentially leading to an overall decline in biodiversity. Fragmentation is, at a European scale, mostly driven by anthropogenic causes. In South-western Europe, due to the spread of artificial and agricultural areas into previous core nature areas resulted in the emergence of more fragmented, mixed landscape patterns. Climate changes result in an overall uphill and northward shift of many animal and plant species (EEA, 2013b). Furthermore, there are drivers that have different effects on different locations or different groups of species. Farmland birds are declining both due to the increasing intensity of agricultural land use, and due to marginalization and land abandonment (EEA, 2013b). This can be however be favourable for other bird species (Tucker et al., 2013).

Past and current trends

The 39 countries that are member to or cooperating with the EEA have on average 16% of their terrestrial area designated as a national protected area, representing approximately one million km^2 and almost 90,000 sites. Over the recent years, this area has shown a small increase, while over the past few decades it has almost doubled (EEA, 2013b). The Natura2000 network showed a steady increase over the recent years. The state of progress in designating sufficient protected areas for the Habitat Directive at MS level ranges between 17% (Poland) and 100% (Denmark, Netherlands) (Figure 26).



Source: Tucker et al., 2013

Figure 26: Natura2000 areas and nationally protected areas (left) and Mean Species Abundance (right)

The likelihood of HNV farmland presence is low in most of North-western Europe except Scotland and Wales, and higher elsewhere in Europe. No time series are available on HNV extent. The area of organic farming has expanded rapidly since 1990, to 6.5 Mha in 2004 (EEA, 2013b). High MSA values are seen in mountainous areas throughout Europe while low MSA's dominate in intensive arable lands in Northwest Europe and the Po area in Italy (Figure 26).

A large part of Western and Central Europe has been converted to urban land between 1990 and 2000. Especially in the lowlands and along the coasts, urban sprawl resulted in large settlements. Forest cover has been growing at a rate of 8,000-9,000 km^2 per year since 1990. Unless the widespread expansion of forests, this hardly favours biodiversity as many newly established forests are intensively managed with little attention to biodiversity. Especially in Spain, Portugal, Ireland, Baltic countries, Poland, Denmark and Southern Germany, fragmentation caused significant losses of connectivity of nature areas between 1990 and 2000 (EEA, 2013b). Large areas of semi-natural grasslands have been lost over the past years, and many grasslands are degraded or converting into scrubland and forest due to lack of management. Substantial areas of wetlands have been lost due to agricultural expansion and developments in the (recent) past. Many remaining wetlands are degraded, drying out, or are being afforested (Tucker et al., 2013).

Species richness continues to decline across Europe, although the decline of farmland birds has levelled off due to stabilizing inputs of nutrients and pesticides, due to introduction of set-aside land in EU15, due to lower nutrient inputs in EU10 following policy reforms and economic crisis (EEA, 2013b). Around half of the species of European interest have an unfavourable conservation status, meaning that these species are either in danger of becoming extinct (22% of the species) or a change in policy or management is needed to secure the species (30% of the species). Unfavourable conservation states are particularly found in the Baltic Sea region, continental Europe and the Atlantic region. For European bird species, the overall extinction risk is increasing.

Many animal species in Europe have been moving northward and uphill over the past decades. Many terrestrial animals have shifted to higher elevations at a median rate of 1.1m per year, and to higher latitudes at a rate of 1.7km per year. This movement is projected to continue during this century. Species with specific demand or a small distribution range are at risk, especially if they face barriers due to fragmentation or changes in the availability of host or prey organisms (EEA, 2013b). Europe's common bird populations have reduced by around 10% since 1980. However, falls have levelled off since the late 1990s. Grassland butterflies have declined by 60% since 1990 and this reduction shows no signs of levelling off. For the butterflies, the intensification is the most important threat in western Europe while elsewhere abandonment and unsustainable grazing is the main reason for the declines (EEA, 2013b).

5.2.8. Multifunctionality

Multifunctionality can be defined as the joint supply of multiple functions, services or benefits by landscapes or ecosystems (Gallego and Delincé, 2010; Mastrangelo et al., 2013). Multifunctionality implies the co-existence of ecological, economic, cultural, historical and aesthetic functions.

Multifunctional land use is seen as a useful principle to guide sustainable land management and policy development since it seeks to combine a variety of social, economic and environmental functions to serve a wide range of users, while putting emphasis on spatial integration and resource efficiency (ETC-SIA, 2013). It forms the basis of the "sustainable intensification" principle, defined in the work of the RISE foundation[116] as the combination of practices "improving the productivity and environmental management of agricultural land". This foundation is promoting and researching this principle, but has not yet developed tangible indicators for sustainable intensification or multifunctionality. There is no official definition of this concept yet in the EU.

Multifunctionality is generally defined at the landscape level and implies that there is a variety of land cover types, each of them providing a variety of LUFs. Consequently, multifunctionality generally occurs in landscapes where both drivers for the provision of regulating services are present, as well as drivers for provisioning services.

The level of multifunctionality can be quantified as the number of services that are supplied at each location. This indicator is used by Gulickx et al. (2013), Willemen et al. (2010) and Crossman et al. (2009) at landscape scale and by Mouchet et al. (2013) at European scale. Raudsepp-Hearne et al. (2010) first define a threshold for each ecosystem service (ES) to indicate if it is provided at a certain location or not, and secondly apply a Simpson Diversity Index to quantify multifunctionality. The Simpson Diversity Index is calculated as the summed probabilities that an ecosystem service is provided at a certain location. Although calculated at local scale, such an indicator can also be calculated at the EU scale.

[116] http://risefoundation.eu

5.3. Evaluation of indicators

This section provides an evaluation of the quality of the indicators described in Section 5.2, based on the RACER framework, and identifies actions needed to address the shortcomings of current indicators in the perspective of future target setting.

5.3.1. RACER evaluation of indicators

LUF1: Provision of work

The currently available indicators for LUF1 focus on specific components of LUF1 only. This is attributed to the incomplete elaboration of LUF1 in the land use functions framework: the definition of the LUF is unclear, unspecific and ambiguous.

The efficiency as calculated by ESPON (2013) distinguishes jobs in agriculture and outside agriculture. Other jobs based on natural resources, like hunting or forestry, are not considered. Consequently, the indicator does not properly reflect how policy changes will influence all components of the LUF, limiting its *Relevance*. The indicator is not applied elsewhere than in (ESPON, 2013a) and is therefore rated as not *Accepted.* The indicator itself is easy to understand but the calculation lacks clarity. Additionally, the indicator does not reflect the demand for provision of work in land-related sectors and does not explain to what extent this demand is fulfilled. This makes it impossible to convey clear and unambiguous messages on the status of LUF1 using this indicator. Therefore, the *Credibility* is rated as low*.* The indicator is *Easy* to monitor: the underlying data are routinely collected at Eurostat at NUTS2 scale and– as it is directly based on these consistent EU scale statistics – its *Robustness* is rated as high.

The off-farm employment indicator defined by Van Berkel and Verburg (2011) addresses rural jobs outside agriculture, but does not include employment in agriculture itself. The indicator thus does not properly reflect how policy changes will influence all components of LUF1, which limits the *Relevance* of the indicator. Although peer reviewed and used in the scientific community, the indicator is not applied in EU MS or operationalized as part of official statistics. This demonstrates a low *Acceptance.* Just as the efficiency (ESPON, 2013a) the indicator does not reflect the demand for provision of work in land related sectors and does not reflect to what extent this demand is fulfilled. This makes it impossible to convey clear and unambiguous messages on the status of LUF1 using this indicator. Therefore, the *Credibility* is rated as low*.* It is *Easy* to monitor and *Robust,* as it is based on already regularly monitored data from Eurostat.

The employment numbers per NACE sectors from Eurostat (Agriculture, hunting, forestry, fishing) are regularly monitored and provide a basis for indicator definition at country level. Because directly derived from official statistics, these data in itself are considered *Accepted, Easy* to monitor and *Robust.* If data on second order employment (see below) were included, a *Relevant* indicator could be developed as well that covers the full LUF and is sensitive to policy changes. However, the contribution of second order employment to the LUF is not clear, meaning that an indicator covering all land-based NACE employment sectors still does not cover all externalities and may fail to convey a clear message. The *Credibility* of such an indicator is therefore low. Its *Acceptance* is rated as low because this newly developed indicator still needs to be taken up by scientists, governments and statistical offices*.*

An issue for all indicators is that other LUFs may also, as a second order effect, provide work. For example, the provisioning of cultural services may attract tourism with work for the tourism sector; areas that attract second houses and pensioners may indirectly lead to a demand for health services and - through these pathways - land use functions may contribute to the provision of work. European peri-urban areas and rural areas have now become attractive to many people because of the LUF provided, but they work in the urban regions. These second order effects on regional employment could be large, but are difficult to quantify. As a consequence, the use of all indicators for LUF1 described here for target setting may lead to unexpected externalities.

LUF2: Provision of leisure and recreation

There are few existing indicators for LUF2, because it comprises multiple cultural ecosystem services which are difficult to quantify, both because they are intangible and because of lacking data. The indicators developed by (ESPON, 2013a) and (EEA, 2005b) (CSI 022) are based on regularly monitored data, but only cover single aspects of LUF2. The efficiency indicator is *Easy* to monitor as directly based on CLC time series, which are monitored routinely with a 5-10 years' time interval, and on Eurostat data. However, this approach disregards the capacity to support recreation in landscapes outside cities, while numerous studies indicate the importance of cultural and natural landscapes for supporting recreation. Also, the number of overnight stays is more likely to represent the efficiency for tourism rather than for recreation. The efficiency thus does not properly reflect the LUF and is not *Relevant*. The efficiency indicator is not applied elsewhere than in ESPON (2013) and therefore not considered *Accepted.* The efficiency is a clear, unambiguous and therefore *Credible* indicator. As only used by ESPON (2013), there is one calculation method, which fulfils the *Robustness* criterion.

The bathing water quality indicator is *Easy* to monitor as part of regular monitoring schemes under the Water Framework Directive, but it only covers one aspect of LUF2 and thus lacks *Relevance*. Bathing water quality is a well-*Accepted* indicator that is already used for policy support, is part of regular statistics and used in the scientific community (e.g., Paracchini et al., 2014). Bathing quality is considered a *Robust* indicator as based on EU consistent datasets and a clearly documented and harmonised calculation method.

The holistic indicators proposed by Maes et al. (2011), Van Berkel et al. (2011), Kienast et al. (2009) and Burkhard et al (2010) are based on a set of inputs that are either static (relief, topography) or *Easy* to monitor (CLC, spatial distribution of protected nature areas). Although they build on criteria based on a wide range of empirical studies on the attractiveness of landscapes, the choice of these criteria is subjective. Other studies that proposed indicators for this function provide different results and multiple methods exist for calculating holistic recreating indicators, demonstrating a limited *Robustness* of the indicators. Such subjectivity could only be resolved if a thorough validation was be possible. Due to the lack of suitable independent data on e.g. actual visitor numbers or visitor appreciation, the indicators lack a full validation, limiting their use in a policy context (Schulp et al., 2014a). These four indicators are reasonably *Relevant* as they provide a proxy for multiple components of the LUF and are sensitive to environmental impacts and policy changes, but do not cover some components of the LUF. The methodologies are commonly used in FP7 projects (e.g., VOLANTE; Mouchet et al. 2013) and other scientific studies as well as applied in studies for the European Commission (e.g., Tucker et al. (2013)), and therefore considered *Accepted.* The subjectivity of parameterization can, although based on empirical evidence on landscape preferences, limit the *Credibility.*

A shortcoming of the holistic indicators is that they focus on recreation only and disregard the other issues included in LUF2. These other issues include, in particular, cultural ecosystem services, which are generally not mapped because they are intangible and difficult to quantify, and because data is lacking (Feld et al., 2009; van Berkel and Verburg, 2014). Absence of information on the spatial distribution of cultural landscapes hampers their inclusion into an indicator for this land use function. This is currently addressed by the HERCULES FP7 project[117].

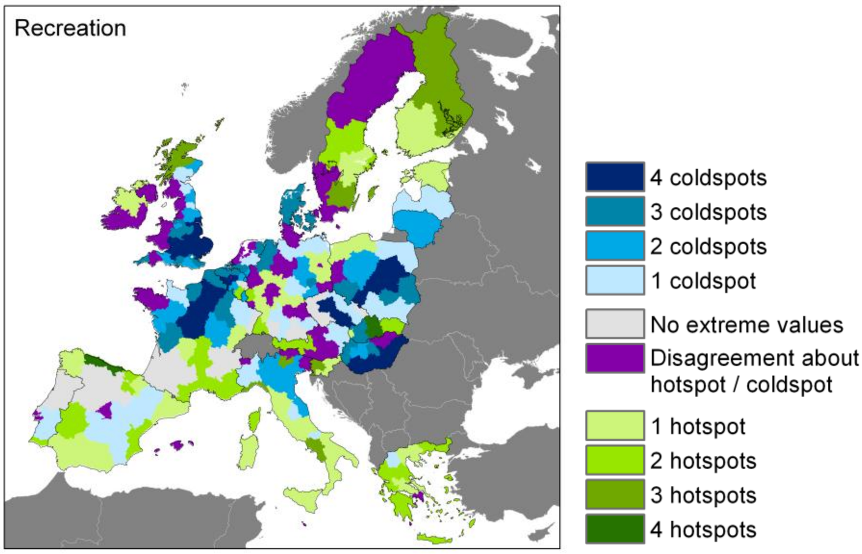


Figure 27: Comparison of indicators values to assess the recreational potential

The above figure results from the comparison of four maps assessing the recreational potential (Van Berkel et al. 2011, Maes et al. 2011, Burkhard et al. 2010, and Kienast et al. 2009). The figure indicates the number of maps that have values in the upper or lower quartile of their distribution, showing the level agreement between the maps (based on Schulp et al. (2014a)). LUF2 only provides benefits if the supply (i.e. capacity of the landscape to support it) and demand (i.e. people's need for recreation) match each other. This match needs to occur at a local scale, as the flow of LUF2 is a local-scale process. Space and features for recreation are needed close to where people live. For example, for collecting berries or going hunting, people do not travel regularly longer than a few hours (Schulp et al., 2014c). The indicators by Maes et al. and Van Berkel et al. do comprise a proxy for accessibility to account for this. The provision of LUF2 implies a trade-off between demand and supply. With an increasing population, both the demand for recreation and for housing increase. Often urban sprawl associated with these demands decreases the capacity of the landscape to support recreation. This trade-off cannot be accounted for with the available indicators.

LUF3: Provision of land-based products

Although LUF3 comprises the production of food, biofuel, and timber, indicators focus on single LUF3 components. Due to the trade-offs among and within the LUF3 components, a holistic indicator for LUF3 will inherently show unexpected and unwanted responses to policies and therefore convey ambiguous and difficult to interpret messages. A holistic indicator for LUF3 is, therefore, not *Credible* and component indicators, although not *Relevant* for the complete LUF, provide a better basis for target setting. Area-based LUF3 indicators are *Easy* to monitor and *Robust*, as based on routinely collected data from CLC and Eurostat, covering the full EU at a high resolution in a consistent way. The advantage of using the harvested area instead of all agricultural areas is that it provides a closer estimate of the actual production. These indicators however do not represent the amount of food actually produced, making them less *Relevant* (they do not directly describe the environmental issue

[117] www.hercules-landscapes.eu

at stake and only partly describe the related environmental impacts). Secondly, the readily available area-based indicators focus on cropland production only and disregard livestock food production, timber production and wild food. However, grassland areas are also regularly monitored by Eurostat[118], which allows calculating an *Easy* to monitor area based indicator for grassland based food production as well. Area based indicators are commonly used (e.g. Tucker et al. (2013) and the MAES initiative)) and thus considered *Accepted*. Although area-based indicators do not directly reflect the production of land-based products, they are clear and easy to interpret, and therefore considered as *Credible.*

Production of food from agriculture (crops and livestock) and biofuel is monitored regularly through Eurostat at a NUTS0-3 level[119]. Timber production is monitored regularly (see (Mouchet et al., 2013)). Production indicators provide a *Relevant* direct picture of single components of the LUF. A full set of such production indicators would make a *Relevant* indicator for LUF3 as a whole. Production-based indicators are accepted in science, included in regular monitoring efforts by national statistical offices and Eurostat, and production levels are already used for target setting. This demonstrates that production indicators are *Accepted*. A production level is easy and unambiguous to understand, making it highly *Credible.* Production indicators are monitored routinely by Eurostat and EFI at EU level and sub-national resolution, and therefore considered as *Easy* to monitor. Little misunderstanding on these inventory data is possible, showing that production indicators are *Robust.*

The development by Toth et al. (2009) of potential production indicators of arable land, grassland as well as forest was a one-time effort. The indicators are nevertheless based on data that are either static or *Easy* to monitor. The latter applies for weather data and land cover data which are routinely monitored. Providing information on the potential production enables the identification of areas where production could be increased in response to changes in the demand for land-based products. This makes them more responsive to policy changes, and more *Relevant* than the production-based indicators. Potential production indicators are commonly applied in science and in FP7 projects. There are no regular monitoring schemes for potential production indicators; the *Acceptance* is thus medium. Potential production indicators are clear and well documented (*Credible)* and they enable setting sustainable intensification related targets.

The "productivity dynamics" indicator by Cherlet et al. (2013) is based on interpretation of remotely sensed images from several satellite information systems, among others NOAA AVHRR, SPOT and NOAA-MODIS. Thus, there is a monitoring framework in place for these data with a high temporal resolution and a global coverage, making monitoring *Easy.* Calculating NPP form satellite imagery is a routine task with a well-established methodology and well-documented, *Robust,* calculation methods. The classification of NPP changes into risk classes, as proposed by Cherlet et al. (2013), is not fully transparent and can strongly influence the final results. Showing changes in the NPP, it closely reflects the environmental issue at stake, however making no differentiation between the proportion of the NPP associated with products that can be harvested and products that cannot be harvested. While showing an integrated picture of the complete LUF, this implies overestimation of the LUF provision by forests. Altogether, the *Relevance* is therefore medium for forests and high for agricultural systems. Using NPP and changes therein as indicator is widely *Accepted* in the scientific community; it is frequently used as a monitoring tool for multiple environmental issues but is not operational in policies

[118] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (accessed 3.27.13)
[119] http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (accessed 3.27.13)

or implemented in national or EU statistical data collection. A main problem with the current indicator seems to be its low *Credibility*. The indicator currently quantifies changes in productivity at a 5 km-resolution, over the period 1982-2010. In such a 25 km^2 grid cell, a plurality of land cover and land use changes occur. Each land use or land cover change process has an impact on the NPP. Decreases of NPP can be due to e.g., urban land take, erosion, conversion from intensive to organic agriculture, meteorological changes, land use changes or changes in cropping patterns. Increases in NPP can be caused - among others - by land use changes, land abandonment, agricultural intensification, or changes in the cropping patterns. Due to the 25 km^2 resolution, it is very likely that multiple processes that influence (both positively and negatively) the productivity occur in the same grid cell. It is impossible to disentangle the contribution of each of these causes to the overall change in productivity. Therefore, it is not possible to translate the observed changes in NPP into clear messages on potentially damaging environmental processes, and to design policy measures based on this indicator.

Indicators based on inputs or on input-output ratios, such as nutrient balances, enable linking LUF3 to environmental quality. These indicators, however, do not provide insight into the (potential) provision of land-based products itself, limiting their *Relevance*. The input-output ratio indicators described in this study proved *Easy* to monitor as they are part of routine Eurostat monitoring efforts. There are many different agricultural inputs and outputs with each input-output ratio telling a different story. This limits the credibility of the indicator as well as the *Robustness*. Although they are *Accepted* as a way to make the link with environmental issues, they are not commonly used in science and policy and thus less *Accepted* as indicators for LUF3 specifically.

A shortcoming of LUF3 is that it merges production of food from agriculture and wild sources, timber and biofuels into a single category. There are spatial and use-related trade-offs among these components. Obviously, abandonment of arable land at the cost of forest decreases arable production but increases timber production. Intensification of agricultural land by scale enlargement, increased nutrient input or increased livestock stocking rates, increases agricultural production but is likely to decrease the availability of berries and other wild food (Schulp et al., 2014c). Expansion of arable biofuel crops can go at the cost of natural land cover and forest and thus decrease timber production (Hellmann and Verburg, 2011). Use-related trade-offs refer to competition between products that can be used for food as well as for livestock feed, biofuel or fibre. These trade-offs cause market competition for products between different sectors and could harm the availability of food.

LUF4: Provision of housing and infrastructure

Indicators for the extent of housing and infrastructure are addressed in Chapter 2 (Land take). The density indicator as applied by EEA and JRC (2006) is a *Relevant* indicator for the efficiency of urban areas in terms of space needed per capita and clearly reflects the impact on environmental issues related to urbanisation.

The relevance of estimating land efficiency only on the basis of population remains debated as same trends in artificial area per capita may result from very different urban dynamics, thereby with different policy implications. For instance, increasing trends in artificial area per capita may reflect:

- an expansion of artificial area faster than population, due to the demand for more residential space per capita, the inclusion of second homes that are only used a few weeks per year, or the development of industrial, commercial and transport activities, which are not directly related to the population size.
- a phenomenon of shrinking population in some areas due to migration to more dynamic cities, as often observed e.g. in Eastern EU countries or old industrial cities as in the North of France and some regions from Germany (e.g. Ruhr); or

- a phenomenon of sub-urbanisation coupled with the shrinkage of city centres, with increased share of vacancy or abandoned areas.

The area used per capita or the density of urban areas depend on a wide range of factors and have multiple trade-offs with other planning considerations. Over the past few years, there has been a trend towards reduced household sizes, leading to more space needed per capita. Verburg et al. (2013) compare future urban sprawl simulations with and without assumed policies to reduce urban sprawl and expect a 5-10% reduction of land take in the case of policies limiting household density. However, an important trade-off is expected between the efficiency of urban areas and the provision of other LUFs. A higher household density leaves less space for green urban areas, strongly limiting the provision of regulating ecosystem services and - potentially - the connectivity for specific species. Setting targets on urban efficiency thus can have highly detrimental effects, demonstrating a limited *Relevance* of the indicator if not tailored to regional or local situations.

The concept of “utilization density” has recently been promoted through the integrated Weighted Urban Proliferation Indicator (Jaeger et al., 2010), along with the extent of built-up area and its dispersion, in order to describe urban sprawl. It measures the intensity of use of residential areas through the combination of the number of inhabitants and the number of jobs (utilization density=residential area/(inhabitants + jobs)).

Restricting the indicator to residential areas and/or considering associated jobs provides a more accurate idea of the situation but still has shortcomings. Ideally, the indicator of land efficiency should be associated with contextual indicators of population dynamics, share of abandoned areas within cities and share of vacancy.

Despite the different policy implications of a same “utilization density” trend, this indicator could provide a signal for policy action. It makes particular sense at the urban community level, which is the operational scale for planning and development activities, although it may provide information on the overall efficiency at national level.

This indicator is easy to understand thus *Credible*, although the fine interpretation of its policy implications may require a set of complementary contextual indicators. The indicator is widely used in science and practice and statistical offices, and can thus be considered as well *Accepted* although shortcomings related to contextual specificities were highlighted during the IUME[120] meeting where the utilization density was presented, in the context of the implementation of the Weighted Urban Proliferation Indicator[121]. Associating these indicators could clarify policy implications of high or low utilization density but could decrease the comparability of datasets at the EU level. This indicator is based on regularly updated and *Easy* to monitor data. Shortcomings of this indicator are related to the difficulty of collecting contextual statistics, such as the share of permanent and seasonal population, as well as the rate of vacancy and abandoned areas within cities. There are a few slightly different calculation methods for urban density, based on different data sources, showing a medium *Robustness.*

[120] Integrated Urban Monitoring in Europe

[121] www.blog.urbact.eu/2014/04/urban-sprawl-definition-and-action/

LUF5a: Provision of abiotic resources

The definition of LUF5a is ambiguous, which hampers target setting. It is defined as including the regulation of the supply and quality of air, water and minerals, as well as only covering the economic uses of abiotic materials, energy production with abiotic energy sources and non-renewable resources. Given examples do not match this definition but include the provision of building materials, salt, sunlight, coal, oil and gas (ETC-SIA, 2013). Based on the latter definition and the examples, the provision of wind energy might also be included in the LUF. This ambiguity limits the *Credibility* of the LUF as a whole as well as all its indicators and limits the *Relevance* of any of the described indicators.

Readily available indicators related to LUF5a focus on water supply. Data on the water provision indicator proposed by Maes et al. (2011) are not accurate given the low resolution and the 25 ha minimum mapping unit of CLC data (Maes et al., 2011). Also, it does not account for water resources other than surface water and does not consider the demand and the actual amount of water provided to the end users. The indicator used by Tucker et al. (2013) also only includes water provision from surface water. Streams are included based on the Global Lakes and Wetlands Database (GLWD) (Lehner et al., 2006). This provides a better overview of surface water extent, but the GLWD is not regularly updated. The different calculation methods and underlying data of the indicators demonstrate a lack of *Robustness.* Nevertheless, they are *Easy* to monitor and *Accepted*, as demonstrated by their popular use.

Water abstraction rates from Eurostat are *Easy* to use to monitor changes in water provision, and *Robust* due to the monitoring and the straightforward indicator definition. The indicator provides information on the water quantities actually provided to the end users, contributing to its *Relevance* and demonstrating *Credibility* because of the unambiguous definition of the indicator. Water abstraction rates are well *Accepted* indicators for this LUF5a component. A drawback is that it is not made explicit from where the water is provided, i.e. the provision is not linked to the location of supply, which limits the *Credibility* of this indicator

The Eurostat data are used to calculate the CSI018 EEA WEI indicator. This indicator provides information on both the availability and the use of water. The updated WEI+ also considers water needed to sustain ecosystems within the catchment and accounts for water returns after e.g. use for industrial cooling; therefore, it gives a quite complete overview of the water balance. WEI and WEI+ are based on regularly updated data and are therefore *Easy* to monitor. Compared to water abstraction rates, the *Relevance* and *Credibility* of the WEI(+) and the indicator developed by Tucker et al. (2013) are higher due to the inclusion of the demand. Water provision is most relevant at watershed scale as the watershed defines the boundaries for the flow from provisioning areas to beneficiaries. WEI is calculated at MS level, which is not always relevant as a considerable number of EU's watersheds cross country borders. Setting targets based on this indicator might lead to unwanted effects, which limits the *Relevance* of the indicator. Commonly, an annual timescale is used for water provision indicators. A drawback of an annual timescale is that is does not reflect intra-annual fluctuations of rainfall and human demand for water. Commonly, human demand for water peaks in summer while precipitation surpluses occur in winter. Unless a sufficient WEI value, thus, water scarcity can still occur. Due to data restrictions, both WEI and WEI+ are currently calculated on an annual timescale (EEA, 2012b) which limits their *Relevance.*

The indicator used by Tucker et al. (2013) quantifies the demand-supply ratio at watershed scale, which is the relevant scale to monitor water supply. The most suitable indicator for water supply would be a WEI+ specified at watershed scale. This is not readily available but data exist for such a calculation. WEI is a widely used and *Accepted* indicator, while WEI+ is not yet fully *Accepted.* A few case study scale applications exist. Use in the scientific community is not common and WEI+ is not integrated in existing frameworks for collecting statistical data.

The Combined Drought indicator by the JRC Drought Observatory describes an environmental condition that may generate risks rather than a land use function. It is monitored frequently, but is mainly suitable for analyses in retrospect, and for analysing the effects of droughts rather than for target setting.

With regard to raw materials provided by soils, Toth, Gardi et al. (2013) indicate where these products are available. The available quantities are not given, nor does the indicator indicate if the materials are extractable. Furthermore, the indicator does not account for the quality of the raw materials and is limited to materials available in the topsoil. As many raw materials are available in deeper sediment layers, this indicator does not provide a complete picture of the available raw materials. The indicator thus lacks *Relevance*, *Credibility* and *Robustness*. The indicator in itself *Easy* to monitor, however the actual LUF provision associated with it is not *Easy* to monitor. The indicator is not applied elsewhere than in Toth, Gardi et al. (2013) and thus not *Accepted* yet.

For other abiotic resources quoted in the definition of LUF5a, no existing indicators were identified. However, the area of mineral extraction sites is monitored within CLC. This allows easy definition of an indicator that can be used for monitoring. The land take by mineral extraction sites would be the most simple and straightforward indicator. However, absolute areas may obscure the indirect impacts on water and other LUFs that are not directly correlated with the land areas occupied by these activities.

LUF5b: Regulation by natural physical structures and processes

The land cover based LUF5b indicators are based on regularly updated land cover surveys (Gallego and Delincé, 2010; EEA, 2000a) and are, therefore, relatively *Easy* to monitor. Another advantage of land cover based indicators is that they provide a single, easy to understand, *Credible,* indicator that is *Relevant* for multiple synergetic regulating ecosystem services included in LUF5b as it directly responds to land use and land cover changes, and thus to policies that influence land cover.

Soil sealing indicator

Similarly to land take (see Chapter 2), the sealing (ESPON, 2013a) indicator is highly simplistic. Although unsealed soil can store, supply or regulate water or minerals or can contribute to regulating air quality, many other factors including soil conditions, land use/cover, management, groundwater regime, etc. define the capacity of the land to provide LUF5b. However, it can be considered as an efficient proxy for the loss of ecosystem services in urban areas, which complements the net and gross land take by highlighting trade-offs of urban densification. It can therefore be considered *Credible* and *Relevant* in this respect. It can also be considered as well *Accepted*, although it does not fully accounts for variations in LUF5b supply. It is therefore less *Credible* and less *Relevant* than the land cover based indicators by JRC[122] (Vogt et al., 2007) or Burkhard et al. (2012).

Until 2006, with the publication of the first soil sealing map by the EEA (now Imperviousness layer), soil sealing was not directly observed through remote sensing, but rather calculated from land take at national level, based on a set of more or less refined assumptions. For instance, Prokop et al. (2011) reported that in Germany, soil sealing is merely estimated at 46% of land take. In Austria, assumptions are more complex, as “Sealed land” is defined as the sum of the built-up areas (the areas used for “buildings” and “paved” are factored in at a rate of 100% and areas whose use “is unspecified” are

[122] http://forest.jrc.ec.europa.eu/activities/forest-pattern-fragmentation/

factored in at a rate of 30%) and of “Other Areas” (the areas used for “roadways” are factored in at 60% and the areas whose use is “unspecified” are factored in at 10%). This limited its *robustness.*

Soil sealing is now routinely monitored through the pan-European and the local components of the Copernicus programme. The Imperviousness High Resolution Layer[123] provides a spatial distribution of all artificially sealed areas in the EU, including the level of sealing of the soil per region and per capita (from 0 to 100%, distributed across four main classes from low to high imperviousness). It has already been mapped for 2006 and 2009[124], in the frame of GMES precursor activities and is currently under production for the year 2012. The Urban Atlas also indicates with high accuracy the degree of soil sealing in LUZs through a categorisation into the following classes: Continuous Urban Fabric (S.L. > 80%); Discontinuous Dense Urban Fabric (S.L. 50% - 80%); Discontinuous Medium Density Urban Fabric (S.L. 30% - 50%); Discontinuous Low Density Urban Fabric (S.L. 10% - 30%); Discontinuous Very Low Density Urban Fabric (S.L. < 10%). In addition, the “Artificial non-agricultural vegetated areas” class allows identifying non-built up areas within artificial areas. It provides more information than CLC, which nomenclature only allows distinguishing continuous from discontinuous urban areas. The monitoring of sealed areas is based on NDVI (Normalized Difference Vegetation Index) contrast, which means it is essentially based on the recognition of non-vegetated areas. This means that bare soils are therefore considered sealed, which they usually are in an urban environment because of compaction. If this may make a difference in terms of restoration opportunities, it can be considered relatively negligible. Such an approach to the monitoring of soil sealing also means that engineered surfaces allowing infiltration, such as permeable pavements, will not be detected through remote-sensing, and will simply be considered as sealed. This is to be considered when analysing soil sealing trends, as some soil functions can be preserved in the urban environment through permeable materials.

The validity of the CLC, HRL and Urban Atlas datasets, which rely on remote observation, are partly validated with the results from the in-situ LUCAS Survey[125].

Indicators of fragmentation

The land cover based indicators by JRC (Vogt et al., 2007) or Burkhard et al. (2012) are considered more *credible* and *relevant* than the land take indicator to describe LUF5b.

EEA-FOEN (2008) also highlighted the comparative relevance of the method of the effective mesh size and the mesh density to describe land fragmentation.

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[123] produced from 20 m resolution satellite imagery, for a final product with 100 by 100 m grid cells

[124] www.eea.europa.eu/articles/urban-soil-sealing-in-europe

[125] The LUCAS database, which contains statistics down to the NUTS 2 level, allows monitoring “artificial areas”, defined here as “non vegetated” built-up (buildings) or non built-up (roads, transport infrastructure) areas, unlike the definition of artificial land provided by the EEA (which includes for instance green urban areas and gardens). The exact extent to how these nomenclatures match or do not match at a fine level of disaggregation remains to be explored and is an exercise currently conducted by the EEA. It is, however, important to be aware of these differences in semantics between monitoring tools when analysing associated land take trends, as figures can end up being significantly different.The definition of sealed areas in the LUCAS survey can extend to some of the bare land that is significantly compacted such as construction sites and parking lots, which is consistent with soil sealing as monitored through Earth observation (relying on the NDVI index). This survey on the state and the dynamics of changes in land use and cover has been carried out by Eurostat since 2006, and results are published every 3 years. The latest LUCAS survey (2012) covers 27 EU countries and observations on more than 270 000 points.

In particular, it underlined that:

- such a method takes account of all patches remaining in the 'network' of transportation infrastructure and urban zones;
- it is suitable for comparing the fragmentation of regions with differing total areas and with differing proportions occupied by housing, industry, and transportation structures.

The method of effective mesh density and effective mesh size can be used at any level (e.g. NUTS-X regions, districts, or at the local scale) for instance to plan future development, assess planning alternatives for transport infrastructure and built-up areas, and impacts of current transport modes. Furthermore, some fragmentation geometries include only man-made barriers (roads, railways and built-up areas), which allows pinpointing land fragmentation specifically associated with land take. However, the effective mesh size and density are still subject to methodological improvements, e.g. in order to better take into account the issue of connectivity between patch boundaries (e.g. permeability of barriers such as roads).

The effective mesh size has been monitored by the EEA for the EU-28, as well as for 580 NUTS-X regions (corresponding to a mix between the NUTS-2 and the NUTS-3 levels in order to create reference regions that are more homogenous in size than the other two) and for 1 km^2 grid units within the 28 countries. The NUTS-X analysis has been considered the most relevant to date, because of the availability of information allowing for meaningful statistical analysis (EEA-FOEN, 2008).

The analysis for the year 2009 used the 2006 CLC data for the built-up areas at a scale of 1:100 000 (minimum mapped unit size of 25 ha) and the 2009 TeleAtlas dataset for the linear features. It revealed that a higher resolution of CLC datasets would be required to be able to capture low-density sprawl in units < 10 ha as well as sufficient fragmentation accuracy for the purpose of traffic planning at the regional scale. This shortcoming should now be overcome with the availability of the Imperviousness HRL and the Urban Atlas. Previous analysis could not be done because of changes in classes between TeleAtlas 2002 and TeleAtlas 2009 (EEA-FOEN, 2008). The EEA planned an update of this indicator every 3 to 5 years.

Although the approach for a refined effective mesh size is now available (Jaeger et al., 2007), it is not yet possible to include the differing barrier strengths of roads between 0 % and 100 %, the probability of successful road crossings (as a function of traffic volume) and the positive effect of wildlife crossing structures on landscape connectivity, as data is not yet available.

Based on the EEA-FOEN 2008 report on landscape fragmentation, the effective mesh size was already widely implemented as an indicator for environmental monitoring by various countries in 2008, e.g. m_{eff} is officially implemented in Switzerland, in Germany (as one out of 24 core indicators in the National Sustainability Report and in the National Strategy on Biological Diversity, and in Baden-Württemberg) and in Italy (South Tyrol). The consultation conducted in this study did not highlight new information related to this indicator, which is not directly related to land take.

Should the Effective mesh size be too burdensome to be regularly monitored, relying on the indicator of urban dispersion (see Chapter 2) could be an alternative although it is limited to urban areas, as it was demonstrated that the higher risks of landscape fragmentation occurred in the direct vicinity of cities.

Green Infrastructure (GI) related indicators

Green infrastructure related indicators (GI) incorporate the concepts of connectivity, multi-functionality and smart conservation (Mubareka et al., 2013), which make them *Relevant* to describe the preservation or degradation of land functions. Related indicators may apply to a range of different scales from individual buildings to neighbourhoods and cities to entire regions. It would allow capturing the impact of land take on the functionality of ecosystems. Yet, Naumann et al. (2011) showed that the interpretations of GI vary in the functions and services provided, which limits its *robustness*. They are still under development and not operational yet. It is not clear how they could be used to provide clear messages to policy makers about operational decisions, which limits their *acceptability* and *credibility*.

Mubareka et al. (2013) recently investigated how to develop a land-use-based modelling chain to assess the impacts of Natural Water Retention Measures on Europe's green infrastructure. The same approach could be developed to assess the impacts of land take, and therefore complement the net land take indicator. In particular, they identified three key indicators of the morphology of green infrastructure, which could be equally applied to the impacts of the development of artificial areas:

- Size of GI cores, branches and other morphological categories;
- Land composition within the GI network components;
- Average and maximum size of network components.

They could help answer the following questions:

- How is the quantity of GI affected by land take, and what proportion of that GI is most valuable?
- What is the location of the most critical nodes and connectors of GI, and what land-use conversions occur under these?
- Are the average components getting larger or smaller?

This work holds great potential but the indicator is too recent to be routinely monitored at the EU level and practically used within MS. It is still subject to several shortcomings related to monitoring capabilities. From a land take perspective, these may include for instance the complexity of monitoring land-use intensity, or hedgerows and very narrow vegetated corridors. Yet, further work should be conducted to be able to fully appreciate the impacts of land take on GI and related functions and services.

Ecosystem services indicators

The matrix approach for quantifying and mapping ecosystem services as proposed by Burkhard et al. (2012) is very widely applied in the scientific community, but not taken up in practice. The indicators are not considered fully *Robust.* The indicators classify a land cover map into general provision levels of a set of ecosystem services. Without a better understanding of the relations between land cover and ecosystem services, this classification remains subjective. As there is not always a direct correlation between the indicator and the provision of LUF5b, target setting based on these indicators could lack effectiveness*.*

Climate regulation, flood regulation and erosion prevention

The indicators for climate regulation, flood regulation and erosion prevention describe spatial patterns of the supply of LUF components, based on land cover and additional driving factors such as rainfall intensity, soil management and soil conditions. Such indicators are well *Accepted* in the scientific community and commonly used in FP7 projects, planning, and DG consultations, but not commonly accepted by statisticians. The indicators are easy to understand (*Credible)*. Although they focus on single ecosystem services, they are commonly used to calculate ecosystem service bundle maps, which are *Relevant* for LUF5b as a whole. Due to the inclusion of all relevant driving factors, they are expected to properly react on environmental changes as well as changes in policies. All indicators are based on a combination of static data and data that are regularly updated (CLC, LUCAS, weather data), and thus are *Easy* to monitor.

A main weakness of the indicators for climate regulation, flood regulation and erosion prevention is that they cannot be properly validated due to the lack of independent data. Different indicators for these ecosystem services often show clearly different patterns, as a result of differences in indicator definition, level of process understanding, mapping aim, data sources and methodology (Schulp et al., 2014a). This is illustrated in Figure 28; in all areas shown in purple, different indicator maps show highly contrasting patterns. Especially for erosion protection, the indicator patterns diverge strongly. This dependence of exact parameterization demonstrates a lower *Robustness.* With the data currently available, it is not possible to tell which indicator best represents actual spatial patterns and quantities of the LUF components.

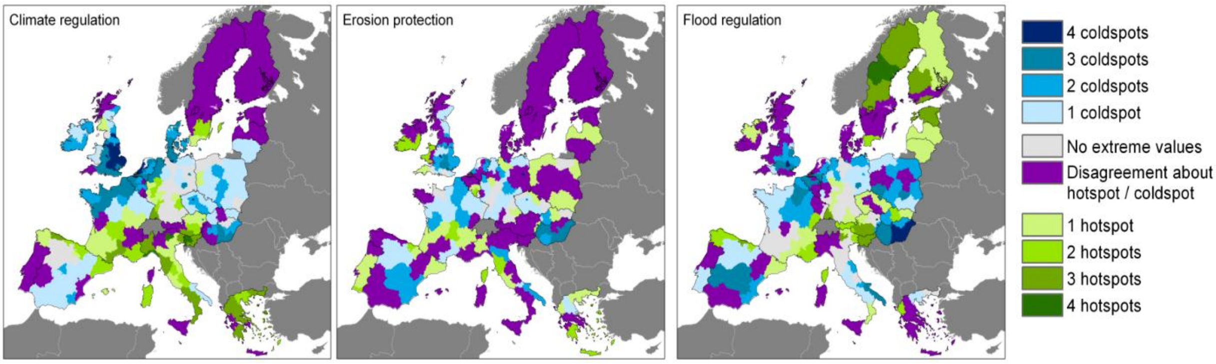


Figure 28: Comparison of indicators values for climate regulation, erosion protection and flood regulation.

The above figure results from the comparison of four maps, for each ecosystem service (Van Berkel et al., 2011, Maes et al. 2011, Burkhard et al., 2010, and Kienast et al., 2009). The figure indicates the number of maps that have values in the upper or lower quartile of their distribution, showing the level of agreement between the maps. Based on Schulp et al. (2014a)

The components of LUF5b act at very different scales, ranging from global (e.g. climate change) to watershed (flood regulation) or local scale (erosion prevention), and show a different response to land use changes and policies. Climate regulation is supplied locally by natural vegetation, but the demand for regulation of climate change acts at a global scale (Serna-Chavez et al., 2014). Ensuring climate regulation is mostly to be achieved by avoiding gross land use changes between natural vegetation and arable land, while the exact location of the land use changes is less relevant. Both supply and demand of flood regulation act at a watershed scale. Maintaining and enhancing flood regulation depends on targeting land use changes at specific locations within watersheds, e.g. avoiding loss of natural vegetation in upstream areas and avoiding conversion to urban land in downstream areas (Sturck et al., 2014; Tucker et al., 2013). Erosion prevention ecosystem services are effective locally, i.e. the demand for the service is found in the direct vicinity of the supply. These scale differences are representative for all other regulating services that are included in LUF5b (Serna-Chavez et al., 2014). Due to these process and scale differences between the different components of LUF5b, the risk of aggregating them into a single indicator is that policies associated with such an indicator would result in unexpected side effects on the different components. This intrinsically limits the *Robustness* of LUF5b.

A joint indicator for LUF5b can best be based directly on detailed land cover data, given the data availability and the representation of the complete LUF. Implementation of this indicator should be done at multiple scales.

LUF6: Provision of biotic resources

Area-based indicators for LUF6 are *Easy* to monitor as directly based on routinely collected data and are easy to understand (*Credible).* They are well *Accepted* as basic proxies for LUF6 and its components in the scientific community, widely used as such in practice and monitored as such by statisticians. However, shortcomings of area-based indicators are that there is a wide variety of competing area-based indicators (lack of *Robustness*) and that it is not always clear if they are actually related to the level of biodiversity (limited *Relevance*). Also, when targets are set based on areas without regarding the quality of the ecosystems, this may lead to unwanted effects. Often, HNV or organic farmland is correlated with a higher provision of biotic resources (e.g. Andersson et al., 2012; Verboom et al., 2007) but this relation is not always found (Brittain et al., 2010; Schulp et al., 2014d; Winqvist et al., 2011). It can therefore be doubted if this indicator properly reflects the actual level of biotic resource provision. The area of organic farming has several specific additional drawbacks as an indicator. First, the intensity of agriculture differs strongly across Europe. The share of organic farmland at country level therefore does not necessarily reflect the intensity of the farmland and the provision of biotic resources by farmlands. Second, organic farming tends to be less intensive and may therefore require more land to produce the same amount of food as intensive agriculture. Although leading to higher provision of biotic resources to the farmland itself, organic farming may decrease the space for natural habitats elsewhere. With regard to protected areas, it is difficult to know exactly to what extent they contribute to halting the loss of biodiversity. For this, information on site management and species richness would be more relevant. Nevertheless, urban and infrastructure expansion put a strong pressure on biodiversity. This suggests that expansion of protected areas would help halting the biodiversity loss, making the area of protected areas a more *Relevant* indicator (EEA, 2013b).

Fragmentation indicators (SEBI013, JRC forest pattern and connectivity indicators) are often well correlated with the presence of species that provide biotic resources, making them *Relevant*. Fragmentation indicators are unambiguous, thus *Credible.* Provision of several biotic resources including pollination is favoured by the presence of a lot of small patches rather than less, but larger patches. This can be accounted for with the JRC forest pattern and connectivity indicators. Because directly based on regularly monitored land cover data such as CLC and LUCAS, they are *Easy* to monitor. Multiple ways of calculating fragmentation exist. This limits the *Robustness*, although calculation methods are well-documented and different fragmentation indicators are reasonably consistent (also see previous discussion on LUF5b). Such indicators are *Accepted* as LUF6 indicators (e.g. used by DG ENV in Tucker et al. (2013) and Perez-Soba (2010)).

Species-based indicators directly quantify the genetic diversity of organisms. They are closely linked to existing policies and reporting obligations (EEA, 2013a). This is a *Relevant* measure of the state of biodiversity as it directly addresses a key component of biodiversity loss at EU level. It is an easy to understand, *Credible* type of indicator. Most species presence data have, however, a low resolution, hence their monitoring is *not Easy*. Due to the limited data availability, multiple calculation methods have been developed, which hampers the *Robustness* of this indicator (EEA, 2013b). Birds and butterflies are *Relevant* as indicator species for the total quality of the environment, and provide several biotic services. The method for calculation is scientifically sound, well *Accepted* in the scientific community as well as in practice, and properly harmonised across Europe; it is based on available and routinely collected data. However, although more and more countries are joining, the indicators do not yet cover the whole EU. The indicators developed by Tucker et al. (2013) and Overmars et al. (2014)

combine a species based approach with the impact of land cover, fragmentation and other environmental pressures. The indicators are based on static broad-scale species distribution data. Consequently, no effects of climate change are included and the indicators are only suitable for timescales up to a few decades, unless new species monitoring data become available.

The MSA is one of the few generic biodiversity indicators that can be calculated when data are scarce, i.e. *Easy* to monitor. It includes a wide variety of drivers for biodiversity change and thus is responsive to many environmental changes and policy changes, making it a *Relevant* indicator. A shortcoming is that the MSA is based on expert judgement on species responses to environmental pressures and may therefore be subjective and less *Robust*. Secondly, the MSA lumps multiple taxa into a single indicator. Different taxa contain different numbers of species and it is not clear how the species that represent each taxon have been selected and if the selected set and assumed responses to environmental change is representative for the taxon as a whole. As a result, two areas can get the same MSA value, but because of very different environmental conditions. This makes the MSA a less *Credible* and *Accepted* indicator.

Multifunctionality

Multifunctionality is defined based on the number of LUFs or ecosystem services provided at a certain location, or with other measures that quantify the variability of LUFs. Such quantifications are mostly done in landscape scale case studies. Although counting the number of LUFs is a straightforward and easy to understand *(Credible)* method for quantification, there are a few limitations that need to be discussed.

First, a multifunctionality indicator is based on a set of indicators for individual LUFs. Consequently, all the issues described in the above assessment of individual indicators culminate when calculating multifunctionality.

A second consideration is that for counting the number of LUFs that are provided, a threshold should be set that, for each LUF, defines if the LUF is provided or not. Mouchet et al. (2013), for example, assume that an ecosystem service is provided at a specific location if the value at that location is within the upper 25% of the distribution of the map values, while Raudsepp-Hearne et al. (2010) define specific thresholds for each service. For some LUFs, sensible thresholds can be defined, however a lack of insight into the demand for LUFs often leads to the definition of arbitrary thresholds, and - consequently - to multifunctionality indicators which lack *Robustness*.

A third issue is that combining LUFs into a multifunctionality indicator involves weighting the individual LUFs, which requires a detailed understanding of the importance of individual LUFs to society.

A final consideration is the scale at which multifunctionality should be defined and at which the flow of functions from provisioning areas to beneficiaries should be described. Mastrangelo et al. (2013) provide a conceptualization of multifunctionality for a range of spatial arrangements. Under a “land sharing” spatial pattern, there is a close mix of land cover for food / fibre production and natural land cover. A land sharing pattern combines food / fibre production with provision of relatively high levels of services with a local-scale flow, like pollination, erosion protection and recreation. On the other hand, under a “land sparing” land cover arrangement, land for food / fibre production is spatially disconnected from natural land cover. A land sparing land cover pattern decreases the provision of local scale functions like pollination, but enhances multifunctionality at a regional scale. This favours services operating at a larger scale, including tourism, provision of natural habitats, and climate regulation.

To conclude, the scale of multifunctionality is important and currently insufficiently addressed. The currently available and simple indicators of multifunctionality lack *Relevance*, *Credibility* and *Robustness*, as they are ambiguous and do not capture the assets of multifunctionality. Several components not *Easy* to monitor. Nevertheless, the indicators identified in this study are reasonably well *Accepted* in the scientific community but not operationalized in practice or in statistical data collection. The flow of services and the specific scale of the flow of each service need to be accounted for in order to build a credible indicator. A set of combined LUF indicators might be a more *Credible* and *Relevant* basis for target setting.

5.3.2. Overview of the indicators assessment

An overview of the indicators assessment's results is provided in the table below, based on the analysis presented in the above sections. The results are summarised in Table 35 using a colour code associated with the RACER framework.

Table 35: Results of the RACER evaluation of existing indicators

LUF	Indicator	R	A	C	E	R
LUF1: Provision of work	Efficiency: Number of jobs per sector per km^2 (ESPON, 2013a)					
	Off-farm employment in rural areas (Van Berkel and Verburg, 2011)					
	Employment per NACE sector (Eurostat)					
LUF2: Provision of leisure and recreation	Efficiency: Number of nights spent in tourist accommodations per km^2 of urban areas (ESPON, 2013a)					
	Bathing water quality index (CSI022) (EEA, 2005b)					
	Indicators for recreation capacity ((Maes et al (2011), Van Berkel et al. (2011), Kienast et al. (2009) and Burkhard et al. (2010))					
LUF3: Provision of land based products	Area-based indicators: share of agricultural area that is harvested (ESPON, 2013a); % of cropland per NUTS2 region (Maes et al., 2011)					
	Productivity-based indicators for grassland and cropland (Toth et al., 2009)					
	Productivity dynamics (Cherlet et al. (2013)					
	Production indicators: timber production at NUTS2 level (Maes et al., 2011); forest biomass stock (Tucker et al., 2013); national forest utilization rate (SEBI017) (EEA, 2013b); roundwood harvest (VOLANTE project); crop yields (Mouchet et al., 2013); livestock production (Maes et al., 2011)					
	Input-output ratios of agriculture (based on Eurostat data)					
LUF4: Provision of housing and infrastructure	Population number per km^2 built-up area (ESPON, 2013a) Share of low-density and high-density urban areas (EEA and JRC, 2006) Available built-up area per person (EEA and JRC, 2006)					
LUF5a: Provision of abiotic resources	Water provision indicator defined as surface area of freshwater ecosystems (Maes et al., 2011)					
	Water provision indicator defined as area of freshwater systems per capita per watershed (Tucker et al., 2013)					
	Water abstraction rates (Eurostat)					
	Water Exploitation Index (WEI): % of freshwater resources available at a national scale (CSI018) (EEA, 2005b)					

LUF	Indicator	R	A	C	E	R
	WEI+: WEI accounting for water required by the catchment to maintain its ecological status and for water returns (EEA, 2005b)					
	Area % of soils potentially supplying raw materials (Toth, Jones et al., 2013)					
LUF5b: Regulation by natural physical structures and processes	Land cover based indicators (JRC)					
	Sealing (ESPON, 2013a)					
	Land take (EEA, 2013b) for the provision of LUF5b					
	Fragmentation / connectivity indicators (Vogt et al., 2007; EEA-FOEN, 2008)					
	Green infrastructure indicators (Mubareka et al., 2013; Naumann et al., 2011)					
	Indicators for the capacity of single Ecosystem Services: Maes et al. (2011), Schulp et al. (2008), Stürck et al. (2014), Tucker et al. (2013), Mouchet et al. (2013), Kienast et al. (2009) and Burkhard et al. (2012)					
LUF6: Provision of biotic resources	Area based indicators: High Nature Value (HNV farmland and organic farmland area (SEBI020 (EEA, 2013b); extent of forest and (semi)natural land cover (SEBI013) (EEA, 2013b)					
	Area based indicators: Extent of protected areas ((ESPON, 2013a) and EEA indicators)					
	Fragmentation / connectivity indicators (SEBI013, JRC Forest patterns, Tucker et al. (2013))[126]					
	Species based indicators (EEA)					
	Mean Species Abundance (MSA) (Perez-Soba et al., 2010)					
Multifunctionality	Number of services provided (Mouchet et al., 2013)					

Legend

Criterion completely fulfilled

Criterion partly fulfilled

Criterion not fulfilled

5.3.3. Conclusions

The LUF concept is the most obvious concept for setting holistic targets on sustainability, as it aims to capture both the provision of functions by land, as well as the use of the functions by society through land use. The inclusion of LUFs from all sustainability dimensions enables accounting for trade-offs between these dimensions. For each LUF, indicators are available. For LUFs that are equivalent to ecosystem services (LUF6, 5b, 3, 2), a wide range of indicators is available while for the other LUFs few indicators are available or only indicators exist that cover specific components of the LUF.

[126] Land fragmentation and connectivity indicators can be relevant to several LUFs. Depending on the function focused on, their RACER assessment may differ.

The LUF concept and its indicators need further elaboration before operationalization is feasible. First, several LUFs are not clearly defined. LUF1 and LUF5a and to a lesser extent LUF2, LUF3 and LUF5b are interpreted in highly different ways in the literature. Secondly, some LUFs are very broadly defined and consequently one LUF can comprise a wide range of (socio/agro/)ecological processes, which operate on different scales or have different drivers. This applies most importantly for LUF3 and LUF5b. This hampers the definition and quantification of indicators for these LUFs, as these different processes cannot be reasonably captured within one indicator. Also, trade-offs between different components of the LUF can emerge, potentially resulting in unwanted effects when targets are set for these LUFs.

The LUF concept explicitly addresses both the functioning of the land itself as well as the benefits provided to society through the use of land and its functions; however, many available indicators insufficiently address these demand-supply relations and are thus of limited *Relevance.* Commonly, only the supply of LUFs is addressed in indicators. Quantification of the demand and flow of LUFs is insufficiently addressed in current indicators. Also, indicators are not always specific to the scale at which the LUF flow operates.

A final issue is the limited attention for validation of LUF indicators. If the LUF is properly defined and indicators are directly based on monitored statistical data, this is not problematic. For most LUFs, direct measurement (especially of the demand) is however not possible and proxy indicators are used ranging from simple land cover based proxies to more complex model based proxies. Due to a lack of independent data, it is uncertain to which extent these proxies actually reflect the presence and level of LUF supply and demand. This applies for simple as well as for more complex, process-based indicators.

Further EU actions required to address the current limitations are discussed in Section 5.6.

5.4. Assessment of existing initiatives, targets and policies

An overview of existing initiatives, targets and policies at EU and MS level is provided in Annex 5.

As shown in Table 36, EU policies deliberately setting objectives and/or targets on LUFs only exist for LUF5b and LUF6. For the other LUFs, although EU policy objectives/targets exist that influence or enhance the LUF, this is a side effect or a coincidence rather than a specific purpose of the policy in question; this may generate unintended trade-offs and externalities.

Table 36: Overview of existing EU-scale objectives and targets that affect LUFs and multifunctionality

	LUF1: Provision of work	LUF2: Leisure and recreation	LUF3: Land-based products	LUF4: Housing and infrastructure	LUF5a: Abiotic resources	LUF5b: Regulation functions	LUF6: Biotic resources	Multifunctionality
Biodiversity Strategy		□	□			■	■	
Habitats Directive, Birds Directive, Natura2000						•	•	
Landscape Convention		○						
CAP		○	□					○
Forest Strategy		○	○					○
Water Framework Directive					□			
Bathing Water Directive		□						
Floods Directive						□		
Climate policies						□		
Renewable Energy Directive			□					
Roadmap for Low Carbon Europe 2050						□		

Legend:

■ Objective or target that aims at enhancing the LUF as a whole

□ Objective or target that aims at enhancing the LUF by addressing one of its components

• Objective or target addressing another LUF or another sector and indirectly enhancing the whole LUF

○ Objective or target addressing another LUF or another sector and indirectly enhancing some of the LUF components.

5.5. Proposed indicators for target setting and assessment of potential targets

The RACER assessment of available indicators (section 5.3) showed that, for most LUFs, there are serious gaps between the LUF definition and the indicators contents. The analysis of existing EU policies demonstrated that EU policies deliberately setting objectives and/or targets on LUFs only exist for LUF5b and LUF6. For the other LUFs, although EU policy objectives/targets exist that influence or enhance the LUF, this is a side effect or a coincidence rather than a specific purpose of the policy in question; this may generate unintended trade-offs and externalities. Hence, there is room for improvement on target setting.

This section makes proposals on the way forward with regard to indicator definition and target setting at the EU level. Technical, socio-economic, administrative and legal feasibility aspects of defining such indicators and targets are also discussed, where relevant.

5.5.1. Targets for individual LUFs

LUF1: Provision of work

Given the various connections between LUF1 and different economic sectors, target setting within the context of land use functions is not straightforward. Our recommendation is to test policy incentives aiming to strengthen the provisioning of work with regard to their impact on other land (use function) related targets, in order to reduce potential policy conflicts and negative trade-offs between different LUFs.

LUF2: Provision of leisure and recreation

Although a target for sustainable provision of ecosystem services, including LUF2, is included in the Biodiversity Strategy, it is not specified whether Target 2 of the Biodiversity Strategy applies to the overall bundle of ecosystem services or to each individual ecosystem service. Given the importance of green space for recreation and the importance of having recreation opportunities in the living neighbourhood in an increasingly urbanized society, it would be relevant to better specify targets for this LUF. The available indicators, including those developed within the MAES initiative (Paracchini et al., 2014), do not meet the RACER criteria. Most importantly, the link between demand and supply is insufficiently addressed.

The importance of a balance between LUF2 demand and supply within a local context, and the possible trade-offs involved, asks for local-scale planning to ensure minimum levels of available provisioning of leisure and recreation functions. Target setting could be done by providing a generic target for spatial planning purposes to secure the availability of minimum levels of accessible green space (non-urban land cover) within a designated maximum distance from the residential location.

The area of non-urban space per citizen within a reasonable distance from residential areas would make a straightforward, *Credible* indicator to support this target. As it addresses the trade-offs between supply and demand and captures the basic impacts of land cover on recreation provision, it is a highly *Relevant* indicator as well.

Although such an area-based target is technically feasible and would provide a clear guideline for planning purposes, there are a number of complications. The first consideration relates to the quality of LUF2. Not all green areas provide the same capacity and quality of recreation/leisure functions and maximum densities per area unit of provisioning of this service are variable depending on the type of ecosystem and facilities available. Simple classification of land cover types according their capacity to support outdoor leisure / recreation could further differentiate the quality of the services provided. Accessibility is a second issue: agricultural areas can provide recreational functions if sufficient infrastructure for accessing the area is available and the agricultural landscape has attractive features, e.g. cultural heritage values. In case the agricultural landscape would be inaccessible, the capacity for providing LUF2 would be lower.

Setting appropriate indicator values for implementation of such a target would require additional analysis. A "reasonable distance" in which to find recreation space can be specified based on a review of previous studies, e.g., Paracchini et al. (2014). Secondly, a systematic review of local-scale studies on the appreciation of different landscapes (e.g. following Van Zanten et al. (2013)) and studies on the use of recreation space by citizens (e.g. De Vries et al. (2013) or Weyland and Laterra (2013)) can help to quantify the required area. A "minimum of accessible green space (non-urban land cover) within a designated maximum distance from the residential location" indicator can be solely based on land cover data which is routinely monitored in a harmonised way at EU scale (e.g., CLC) (*Easy)* and is straightforward and clear (*Credible).* To develop a *Robust* indicator, the literature review described above would help parameterize the indicator in a consistent way. The *Acceptance* of newly developed indicators is, by definition, low and the indicator would need to be taken up in science, policy and practice to prove its acceptability.

LUF3: Provision of land based products

Trade-offs between the production of food, biofuel and timber call for separate targets for the components of LUF3. Such targets are included in the CAP, Biodiversity Strategy and the Renewable Energy Directive.

The demand for food, biofuel and timber acts at a global scale while they are supplied locally. EU scale and international policies play an important role in linking the global land demand to local land properties, and in optimizing the use of land properties. For example, trade policies influence land take outside the EU by influencing the demand for products from outside the EU. Additionally, local protection of land functions other than production functions may generate displacement of impacts, by decreasing the availability of land within the EU.

Simple target setting in terms of food and (bio)economy self-sufficiency or setting minimum levels of self-sufficiency may lead to non-optimal solutions, as production is not as efficient in all countries and differential trade-offs may occur upon further intensifying or expanding production within certain regions. In some cases, import from outside the EU may be more sustainable in terms of trade-offs to other LUFs while high production volumes (e.g. for export) may limit other LUFs. Target setting for the provisioning of land-based products should not be done without serious consideration of these aspects. If targets on food self-security were set, they should include the local production conditions and trade-offs with regard to other LUFs in a model comparing alternative options to sustain or enhance food products. Target setting could identify areas/regions that are best suited for enhancement of this LUF as well as regions that are poorly suited for this LUF, rather than providing a stringent overall target.

Targets for biofuel production and use are included in the Renewable Energy Directive and the draft ILUC Directive, hence there is little need for additional targets. The negative consequences and trade-offs on other LUF of this target need careful assessment as the current target may have strong impact on other LUF through the potential to stimulate displacement of production, substitution of food production by energy crop production and intensification of production in currently extensively managed areas that have high levels of provisioning of other LUFs. Incentives aimed at achieving food and (bio)economy targets may provide incentives towards intensification of agricultural use in vulnerable areas, create market distortions and other externalities that have been frequently commented on with respect to earlier implementations of the CAP.

On the other hand, if no targets are specified, competition between LUFs (e.g. residential or recreational uses) may lead to the conversion of the best agricultural areas to land uses favouring other LUF. While locally this is not necessarily a problem, it may lead to displacement of agricultural production to more marginal areas or to areas outside the EU with higher environmental impacts.

A land target that aims at keeping the best agricultural soils of the EU available for agricultural production would provide a meaningful contribution to maintaining this LUF and avoiding irreversible damage to the land use capacity to provide this service in the future. Such a target could inform a strategy to protect farmland reserves. An indicator based on potential production is best suited for this, because it can provide insight into the potential consequences on land use change. Such an indicator is available based on a combination of static and routinely monitored data (Toth et al. (2009)) enabling target quantification and monitoring.

A target on the preservation of highly productive farmland bears the risk of locking up cities and driving urban sprawl elsewhere with subsequent infrastructure sprawl. An advantage of setting such a target at EU level (specifying farmland reserves at an EU scale) would be to ensure that the most suitable agricultural areas in Europe are protected instead of, possibly, more marginal lands in each Member State. However, there are several drawbacks, mostly at the local scale. For example, MS could be obliged to protect a certain percentage of their highly productive farmland from conversion to nature and urban area. The level of such a target needs to be consistent with e.g. the Habitat Directive targets and with the CAP greening targets. A target on the preservation of the most fertile lands for agriculture links to initiatives promoting sustainable intensification practices. It could help reduce external inputs to agriculture and reduce the associated adverse environmental impacts.

A specific and time-bound target on the “preservation of the most fertile lands” cannot be quantified at the moment. An analysis of the spatial consequences of different thresholds, using land use change modelling tools, can help quantify the feasibility both in terms of area requirements and in terms of the impacts on food supply. For timber production, the available indicators also allow setting a target on sustainable harvesting, i.e. harvest should not exceed a specific increment. To integrate a timber production target into an overall set of sustainability targets, trade-offs with other functions should be considered. This can be done with a target that sets requirements on forest intensification by e.g. indicating that this is only allowed in the case of regional-scale no net loss of other functions (recreation, regulation). Targets would be based on the indicators for LUFs 2, 5b and 6.

LUF4: Provision of housing and infrastructure

The efficiency of residential use can be measured by the number of living units per built-up area and per urban area. Using these two indicators allows both assessing the overall urban land use efficiency and the efficiency of built-up area. For both indicators, minimum targets could be set, but here we refer to 2 (Land take) as these indicators are linked to the land take issue and discussed in that context. The trade-offs emerging from the target setting exercise are further elaborated in Section 5.5.2.

LUF5a: Provision of abiotic resources

LUF5a is insufficiently defined and elaborated to be used as a basis for target setting. The only component that is properly defined, i.e. water provision, is already well covered by targets and objectives associated with the implementation of the Water Framework Directive.

LUF5b: Regulation by natural physical structures and processes

Although direct targets exist for LUF5b in the Biodiversity Strategy and several CAP measures and targets indirectly influence components of LUF5b, these targets leave room for further specification. Most importantly, the scale of flow from supply to demand of LUF5b is not considered and it is not specified whether Target 2 of the Biodiversity Strategy applies to the overall bundle of ecosystem services or to each individual ecosystem service. A target aiming at no net loss of the regulating capacity could be proposed. Multiple indicators are available for monitoring. Given that, under the LUF concept, different processes are merged into one LUF, and given the lack of insight into the accuracy of existing indicators (see Schulp et al. 2014a for an evaluation of indicators by the MAES initiative and several other indicators), a straightforward indicator based on land cover is considered as the most suitable indicator based on the RACER criteria. It would provide the most straightforward possibilities to account for trade-offs with other LUFs. A broad target at EU scale could be set, but would need specific evaluation at smaller scales. Flood regulation can be integrated in land use planning by avoiding conversion of land cover with a high water retention capacity upstream and avoiding sealing downstream. Climate regulation can be integrated by avoiding gross changes of natural land cover and avoiding intensive land management of peatland. Local-scale services are enhanced by promoting mosaic land uses. A land cover based target could integrate natural water retention measures. It could also help capture the role of non-urban and non-arable land cover in local-scale climate regulation and in the regulation of surface fluxes of water vapour and heat; harmonised land cover data covering the whole EU is available for such target quantification and monitoring.

As targets related to the connectivity issue are already available in the CAP, Biodiversity Strategy and Green Infrastructure Strategy, it would be more relevant to further specific those targets than to define a new target on this. Specifying existing targets related to connectivity would involve many local scale measures. To fulfil subsidiarity requirements, detailed target setting should probably be left to MS. This could be implemented by requiring MS to ensure that no net loss of regulating capacity is considered in spatial planning actions.

Further actions needed would be to quantify the role of different vegetation types in local climate regulation (McAlpine et al. 2010), and to quantify the land cover pattern requirements for natural water retention measures. This may be achieved, to a large extent, based on a literature review or expert panel evaluation, e.g. (Stoll et al., 2014).

On the specific issue of land take, Chapter 2 discusses how soil sealing targets could be set by MS (or lower relevant levels of governance) to efficiently complement the net land take concept, and how impact indicators such as indicators of fragmentation/connectivity and provision of ecosystem services could be used as control indicators to accompany these targets.

LUF6: Provision of biotic resources

The supply and demand for biotic resources are relevant at both European and local scales. Connected habitats across national borders enable species to migrate and ensure stable populations. This calls for European scale targets for the provision of biotic resources. Such targets are set in the Biodiversity Strategy, Habitats Directive and Birds Directive. The demand for biotic regulating services, however, is local: the service needs to be provided in the direct vicinity of where the service is needed, e.g. pollinators or pest controllers need habitats close to croplands. Optimal match between the provision and the demand of LUF6 thus calls for a varied agricultural landscape. This is one of the objectives of the CAP greening measures, most importantly the Ecological Focus Areas. Finally, the Green Infrastructure strategy promotes the establishment of green infrastructure through mainly administrative measures.

The impact of connectivity and green infrastructure is not explicitly addressed in current targets and policies. A quantitative target on the connectivity of green infrastructure could enhance both migration of species and the provision of biotic ecosystem services. A minimum level of green infrastructure connectivity could be used as a target, as the related indicator is close to meeting the RACER criteria and allows taking into account trade-offs with other LUFs. Such a target would be relevant at the EU level, while its implementation would require many specific measures to be defined and implemented by MS.

5.5.2. Multifunctionality targets

Many existing policies directly or indirectly provide targets for individual LUFs. More specific target setting on some individual LUFs could have added value. Any decision on a LUF involves trade-offs (when the provision of one function is enhanced at the cost of other functions) or synergies (when multiple functions are enhanced simultaneously) with other LUFs. Trade-offs and synergies are well described for ecosystem services. Often, synergies occur between multiple regulating ecosystem services, and trade-offs occur between provisioning services and other categories of services (Bennett et al., 2009; EEA, 2013b; Gulickx et al., 2013; Schulp et al., 2012; Tucker et al., 2013). Enhancing single LUFs inherently leads to enhancement of synergetic functions and decreases in the functioning of conflicting functions. In case different LUFs would be addressed by different targets or policies, policy conflicts can emerge. If not each LUF is associated with a specific target, it may be difficult to mitigate negative environmental impacts due to rebound effects (Maestre et al., 2012). For example, if land targets are set on all LUFs except production functions, production is likely to be displaced to areas outside Europe with negative impacts on other LUFs at those places. Setting targets for individual land functions might not contribute to reaching an overall goal of increasing efficient use of land, avoiding land take and reducing land degradation.

To illustrate the trade-offs between different LUFs, Figure 29 below shows normalised levels of LUF provision in five typical EU landscapes: Urban (Paris region); Peri-urban (Belgium), Agriculture (east England), forested (Sweden), and mosaic (central Europe). The normalised land function levels are shown for local scale (10 km radius around the point shown on the map) and regional scale (100 km radius around the point shown on the map, indicated by the circle).

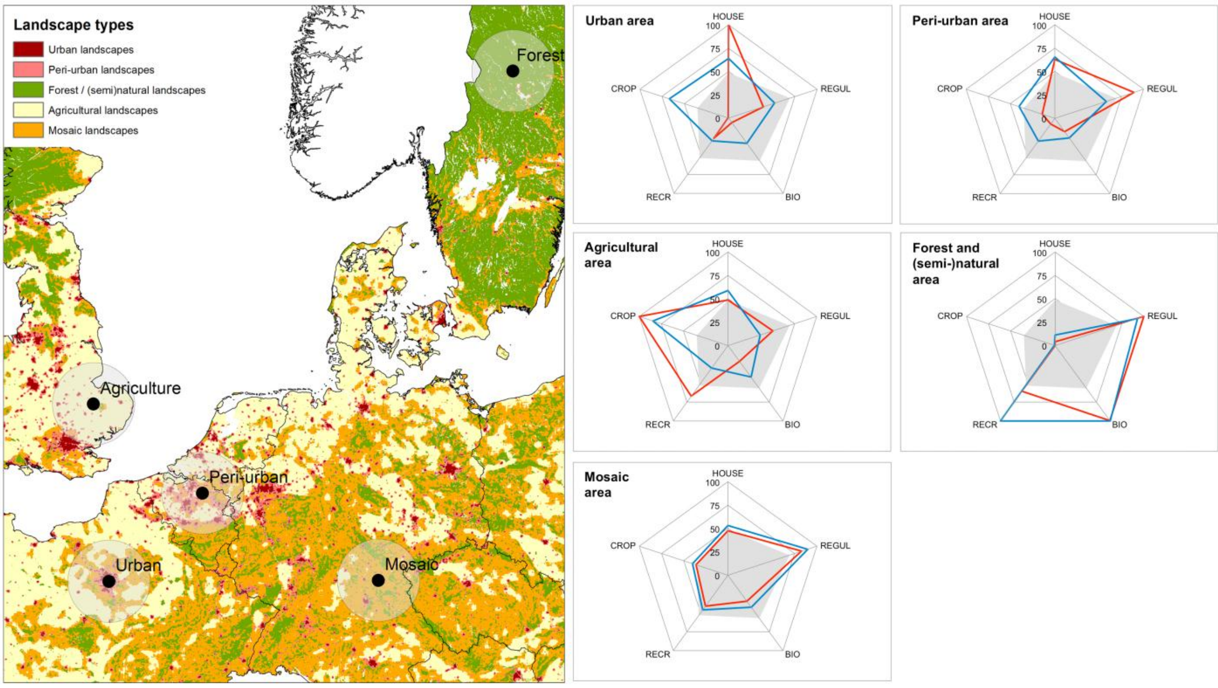


Figure 29: Normalized provision of land use functions in five example landscapes[127]

Legend: The five landscapes are indicated in the left map. Red lines show the land use function provision in a 10 km radius, blue lines show the land use function provision in a 100 km radius. The grey area is the average level at EU scale. Abbreviations: HOUSE = housing, REGUL = regulating services, BIO = biodiversity, RECR = capacity of the landscape to support recreation, CROP = crop production.

Figure 29 can be analysed as follows:

- The urban area has a very high provision of housing and a very low provision of other LUFs at local scale. This optimisation towards housing limits the land take needed to provide housing, which will leave more space for e.g. high-biodiversity areas. Due to the large population, urban

[127] Source: Based on data from Tucker et al. (2013) and Verburg et al. (2010).

areas have a large demand for food, recreation and other LUFs. The absence of recreation and food production at the local scale does not affect the supply of these LUFs, as this landscape is embedded in the surrounding region (100 km radius and EU scale) where more recreational functions and crop production functions are available. Crop production flows to beneficiaries through trade while people are able to travel some distance for recreation. In the 100 km radius around the city, a high level of the crop production LUF is seen. This demonstrates that setting a cropland protection target could trigger a displacement of urban sprawl.

- The peri-urban example landscape has, at a local scale, a clearly lower score on the housing function than the urban example landscape. Although the regulating capacity score is higher, for the other functions the gain relative to the urban landscape is limited, especially as the demand for other LUFs can be fulfilled at larger scales.
- Open, large-scale agricultural areas are typical landscapes for the fertile, flat parts of European river basins (Renes, 2010; Zimmermann, 2006). The example landscape has a high level of crop production and a rather low biodiversity and regulating function level. This low level of regulating functions can result in more land and soil degradation. However, an enhanced climate regulation function can be achieved by concentrating agricultural land in favour of forest areas (avoiding deforestation). Also, intensive agricultural systems can help increase EU internal food production, thereby limiting the impact of European food, biofuel etc. demand in third countries. Finally, it leaves more space for undisturbed forest or nature areas which might be hotspots for biodiversity and other large-scale regulating functions.
- While forest/nature landscapes have a high biodiversity, recreation potential and regulating capacity, they have very limited other. The LUFs provided by the forest landscape will, however, be delivered to the beneficiaries by trade (wood), biophysical processes (regulating capacity) or travel (recreation). As the forested landscape is embedded within other types of landscapes, the low level of certain functions produced by this landscape is not problematic.
- Mosaic landscapes are typical landscapes in the more hilly parts of Europe, where a variety of biophysical conditions underlays a variety of land cover (Renes, 2010; Zimmermann, 2006). These landscapes can be considered as the most multifunctional: they provide reasonable levels of all LUFs. Agriculture in these landscapes is often strongly mixed with patches of (semi-)natural land cover. Such landscapes often show less risk of land degradation and a higher biodiversity than agricultural landscapes. However, crop production is lower than in predominantly agricultural landscapes, while biodiversity is lower than in forest / nature areas and housing is lower than in urban areas. Expansion of mosaic land at the cost of more mono-functional landscapes would thus lead to more space required for agricultural production and housing. This could result in increased import from and impact in third countries, and threaten biodiversity in nature areas. These landscapes thus need a flow of LUFs from other landscapes as well.

To summarise, the five examples demonstrate that different landscapes provide different bundles of LUFs, but, at the same time, they might be not be fully multifunctional. Most of these landscape types are traditional European landscapes that have formed as a response to local conditions. All such landscapes and the functions they provide have since long been connected with each other. Land functions flow between areas through trade, people travelling to go recreating, and biophysical processes.

Ensuring sustainable provision of all LUFs would mean that each LUF is available to users within the region where it is produced. This means that the spatial units that encompass demand and supply of LUFs are a determining factor for defining the minimum levels of ecosystem services to account for the flow of services from locations producing the services to the locations of the beneficiaries. Overall, EU-scale targets based on multifunctionality must therefore be defined in such a way that they can be translated to the local context, accounting for the possible flow of the services to the beneficiaries.

To operationalize this concept into policy targets, two possibilities are identified:

- (1) Define a set of minimum levels for each LUF or 'sustainability dimension' (i.e. people, planet, profit), or
- (2) Define maximum acceptable trade-offs.

Defining a set of minimum levels of supply for each LUF or each sustainability dimension could be done by, e.g., quantifying a threshold for sustainable provision of each LUF. There are different possibilities in defining such minimum levels. It is important to set these according to demand. For example, the minimum level of flood regulation required downstream depends very much on downstream risks for flooding and the assets at risk. A threshold for sustainable flood regulation would be based on the acceptable flood frequency and magnitude in downstream areas where flooding can harm people, business, industry, agriculture, etc. Most likely, this can to a large extent be achieved through review of literature and existing accepted risk levels, for each LUF individually, as described in Section 5.5.1 and Table 38. Setting a consistent set of targets to ensure minimum levels of supply would ensure integrated land use planning aimed at minimising trade-offs that may originate from a focus on a single sector or LUF.

A further elaboration of LUF-specific minimum levels would be to define maximum acceptable trade-offs. As shown in the examples, each landscape type has specific assets although conversion between the land use types also leads to loss of LUFs. This could be overcome through a policy that obliges to evaluate land use changes for trade-offs at local level. For instance, expansion of built-up area could be constrained by the requirement of minimising the loss of regulating capacity and fertile agricultural soils, while residual losses should be compensated. A second example can be given with regard to the trade-offs between forest productivity and other functions of forests. With an intensification of forest management, the capacity to support recreation (LUF2), regulating ecosystem services (LUF5b) and biodiversity (LUF6) are at risk of decreasing; forest management intensification could thus be constrained to areas where the supply of such other functions is already low, or requirements for compensating loss of the other functions could be set e.g. in the form of a target aiming at No Net Loss of these functions. These trade-offs would need to be evaluated at the process scale of the land use function: flood regulating capacity should be evaluated in watershed management plans for the loss of fertile agricultural soil, EU-scale displacement might be acceptable, while recreation should be available close to people's houses. This would require additional investigation to ensure feasibility of targets at this level of complexity. These targets would require cross-boundary interaction in the case of directional regulating services. For LUFs whose goods and services flow through (international) trade, displacement effects should be taken into account.

Setting targets for multifunctionality can result in displacement effects, similar to targets for individual LUFs. While in Europe it might be possible to replace anthropogenic inputs by increasing ecosystem services (Bommarco et al., 2012), there is little room for increasing production through ecological intensification. Stimulating multi-functional agriculture with high levels of supply of other LUFs would require expansion of agricultural land area to accommodate the increasing global demand for food, either within Europe or through displacement of production in other parts of the world. This encompasses an increasing risk for degradation when cropland expands into areas with unfavourable conditions for cropland production, like shallower soils and steeper slopes (Bakker et al., 2011; Bommarco et al., 2012).

Defining targets for multifunctionalities as described above or setting minimum sustainable levels for individual functions or sustainability dimensions is also difficult for various reasons. First, as described earlier, it is difficult to find a set of consistent, easy to monitor and accurate indicators for the individual LUFs. All weaknesses of the separate indicators described in the previous sections also apply for multifunctionality indicators. Actions towards improving indicators for individual LUFs are described in Table 38. Secondly, problems arise when defining minimum sustainable levels for the individual functions (as was proposed by Batista e Silva (2011)). Rockstrom et al. (2009) define a “safe operating space” for land use change and biodiversity - among others, but acknowledge that the proposed thresholds are highly uncertain. Third, the geographical scale of the targets should ideally match the process scale of the LUF provision; however, the scales at which the different LUFs operate differ strongly, and so will the scale of the targets. The context and demand dependence of minimum LUF provision levels is also scale-dependent as ecosystem services and goods can, to some extent, be transported, but this strongly depends on the category of such goods and services. A final concern is that targets tend to focus on supply-side indicators. Land only provides goods and services to people once they reach people in demand for the services. As demand for land functions is spatially heterogeneous and its location rarely matches the location where the functions are supplied, the LUFs need to be delivered from provisioning to benefiting areas through either biophysical or anthropogenic processes (ecosystem service flow, (Serna-Chavez et al., 2014)). Generic targets based on the supply-side disregard the importance of the flow and demand for the actual provision of goods and services by land. This may lead to unexpected and unwanted side effects of supply side targets.

5.5.3. Conclusions

Based on our RACER assessment of indicators for LUFs and the evaluation of potential targets in sections 5.5.1 and 5.5.2, the most promising indicators for target setting are presented in the table below. The most promising indicators for individual LUFs are the indicators that are closest to meeting all RACER criteria among all the reviewed indicators. The identified multifunctionality indicator is evaluated as the only relevant multifunctionality indicator among those reviewed by the study.

Table 37: Most promising indicators for setting targets related to LUFs and multifunctionality

Indicator name	Definition	Available source data	Existing uses (if any)	R	A	C	E	R
Area of accessible green space (LUF2)	Area of accessible non-urban land cover within a threshold distance from residential areas.	Corine Land Cover data (routinely monitored)	This is a new indicator proposed here because existing indicators for LUF2 are not considered suitable.					
Potential agricultural and forestry production (LUF3)	Based on the European Soil Database, CLC, GLOBCOVER land cover, climate data and topographical data, the biomass productivity of agricultural land was quantified for grassland and cropland separately.	Static data on soil and relief (routinely monitored) Climate and land use data (Toth et al. 2009)	Included in common framework developed in order to facilitate integration of the EU Soil Strategy into other policies.					
Density and connectivity of green infrastructure (LUF5b, 6)	The density of (semi) natural and forest cover, including small green infrastructure elements, provides a proxy for the capacity of the landscape to provide regulating ecosystem	Corine Land Cover data; JRC (Vogt et al. (2007)) (routinely monitored)	Density indicators are commonly used as proxies for regulating services in scientific studies but have not yet been operationalized in policy for LUF5b. For LUF6, there are					

Indicator name	Definition	Available source data	Existing uses (if any)	R	A	C	E	R
	services.		targets specified in the Biodiversity Strategy.	Yellow	Green	Green	Green	Yellow
Multifunctionality balance	Consistent set of levels for each sustainability dimension / land function. Alternatively: level of trade-offs between functions.	Corine Land Cover; JRC (Vogt et al. (2007); Toth et al. (2009)	This is a new indicator proposed here, because existing indicators are not considered suitable.	Green	Red	Yellow	Green	Yellow

Legend

- Green: Criterion completely fulfilled
- Yellow: Criterion partly fulfilled
- Red: Criterion not fulfilled

All proposed indicators need further elaboration to be used for target setting. Target setting based on these indicators will require further work on quantifying the indicators, identifying relevant thresholds, and modelling the impacts in order to assess the feasibility of different thresholds. This is outlined in Section 5.6.

5.6. Suggestions for further EU actions

The LUF concept explicitly addresses both the functioning of the land itself as well as the benefits provided by society through the use of land and its functions. Including land use functions in policy development could involve setting targets and monitoring progress with respect to various specifications of multifunctional land use, including natural water retention measures and sustainable intensification. There are, however, many ambiguities in the LUF concept and available indicators are of limited *Relevance,* especially because they insufficiently reflect the demand-supply relations of LUFs (LUFs are only valued when there is a demand for the specific functions). The current conceptual limitations and gaps in indicator development restrict the development of policies to safeguard or enhance LUFs.

To allow uniform target setting that accounts for the geographical context, includes the demand side of LUFs, and overcome potential trade-offs among and within LUFs, the following research steps are needed:

1. Further elaboration of the LUF concept to clarify the characteristics and scope of each LUF. This can be done, to a large extent, through a literature review and stakeholder consultation:
    a. A full evaluation of the topics to be addressed in each LUF and their relations with land should be performed. For the LUFs that are related to the equivalent to ecosystem services, this can be based on the extensive literature and conceptual development on the ecosystem services framework, its components and its classification systems, including CICES. For the people and to a lesser extent the profit-related indicators, review should focus on the relation with land and the spatial scale at which the LUF operates.
    b. Trade-offs among components of LUFs (e.g., food crop production vs biofuel crop production vs wild food provision) need to be assessed and, if appropriate, components of LUFs need to be defined as new or sub-LUFs.
    c. The demand for LUFs requires a better quantification in order to be able to quantify targets in a non-arbitrary manner and assess the needs for context-specific target setting. Currently, existing indicators mostly quantify only the supply and do not consider human needs for the functions, nor the demand-supply relationships. For the LUFs for which

targets could be foreseen, concrete actions for establishing demand quantification are proposed in Table 38 below.

   d. Improved insight and quantification is needed to understand by which processes, under which drivers and at which scales LUFs flow from the supply areas to the beneficiaries. This understanding is critical for determining the scale and location-specificity of future targets and supporting policies. Such quantification efforts have been performed recently or are ongoing (e.g., Serna-Chavez et al. (2014) and Schroter et al. (2014)) and are commonly based on conceptual evaluations, literature review, data review and spatial modelling.

2. Development of LUF-specific indicators that account for demand/supply relations at the scale of LUF demand/supply interactions (catchment vs NUTS vs national vs planning regions). For LUFs where existing policies are not sufficient to ensure the maintenance or improvement of the LUF, a number of actions are proposed in Table 15 below.

3. Monitoring and validation:

   a. Indicators for LUFs are commonly based on a selection of (static) biophysical data and (dynamic) data on land use, land cover, and climate conditions. Continuation of this monitoring in a harmonised way at EU level should be ensured.

   b. Monitoring the status and trends of LUFs would benefit from regularly updated land cover data. The current updates of the wall-to-wall CLC database occur every 6-10 years, with a substantial time lag between the data acquisition and operational availability of the processed data. This limits the possibilities for monitoring and for providing “early warnings”.

   c. Independent data are needed to validate the model-based indicators, in order to make the indicators more credible. The actual provision of LUF2, 5b and 6 is difficult to measure directly. While the result of LUF3 (i.e. the quantity of crops or timber produced) falls under the scope of regular monitoring efforts by EUROSTAT, this is not the case for LUF2, 5b and 6, resulting in a lack of validation data representing the LUF.

4. Feasibility assessment: Once indicators are quantified (including the demand at the appropriate scale), potential targets should be evaluated in a quantitative manner through ex-ante assessment (involving land use models and models assessing the impacts on human well-being and the economy). While for individual LUFs values can be defined based on data or literature review, assessing potential trade-offs and assessing appropriate levels of a combined multifunctionality target require an integrated approach. By evaluating the impact of a variety of scenarios on land use and LUF provision in a land use change or integrated assessment modelling framework, synergies and conflicts between the LUFs can be identified. This can inform target setting.

Table 38: Suggestions of potential actions required to develop indicators and targets related to LUFs

Indicator	Problem definition	EU actions required to develop, implement or improve the indicators and set targets
Area of accessible green space (LUF2)	This is a promising indicator, but not yet tested or applied. No full coordinated monitoring framework in place.	A quantification of the minimum demand for green space and the willingness to travel to recreation areas is needed. This could be achieved based on literature studies and stakeholder consultation. The feasibility in terms of land use allocation can be assessed using land use modelling approaches. Following a feasibility assessment, MS could be encouraged or obliged to set targets using this indicator. As the indicator depends on consistent time series of land cover data, continuation of such monitoring needs to be ensured.
Potential agricultural and forestry production (LUF3)	No thresholds defined. No insight into the spatial consequences of target setting. No full coordinated monitoring framework in place.	Thresholds can be identified based on literature review and data surveys. The spatial consequences of setting targets based on the indicator need to be assessed. This can be done by simulating the impacts of a range of thresholds for the protection of the most fertile lands. Based on this, recommendations on the feasibility of such a target can be elaborated. The indicator depends on consistent time series of land cover and climate data. Continuation of such monitoring needs to be ensured.
Density and connectivity of green infrastructure (LUF5b, 6)	Quantification of relation between the indicator and the provision of LUF5b and 6 is incomplete, especially with respect to local scale climate regulation and natural water retention measures. No insight into the feasibility of related targets. No full coordinated monitoring framework in place.	Better quantification of the indicator, including minimum levels required to maintain the LUFs, can be achieved based on a literature survey. Modelling of the distribution of key species under a range of land cover pattern scenarios can be used to identify critical thresholds. The feasibility of related targets needs to be evaluated. Continuation of land cover time series needs to be ensured.
Multifunctionality balance	No quantification of the minimum levels of individual services. Lack of insight into the feasibility of related targets.	Based on the indicators described above, this indicator needs quantification of minimum levels of individual LUFs. Land use and integrated assessment modelling can be used to evaluate trade-offs and feasibility of targets.

The use of models such as LUMP/Dyna-CLUE-CAPRI and the MAES ecosystem service models will allow assessing the consequences of different levels of ambition for future targets in the context of existing policies, and identify trade-offs between LUFs. It is obvious that target setting will not only benefit a certain LUFs but also lead to negative impacts on other LUFs and displacement of functionality across regions. A first stage of exploratory simulation and assessments of the cost-benefits and spatial trade-offs between LUFs/multifunctionality and regions will allow accounting for unexpected trade-offs in the detailed target specification. Ex-ante assessment of land target setting using a similar suite of models, including the macro-economic consequences, will be required before implementation of targets can be made.

6. Global impacts of EU demand for land-based products

In brief

Complementing the other chapters in this report, which focus on land-related issues within the borders of the EU, Chapter 6 addresses the issue of EU's land demand from a consumption perspective, i.e. including land use in non-EU countries (so-called third countries) for imports to and final consumption of goods and services in the EU.

After discussing the global environmental and social impacts related to land use, we analyse the scale and the potential impacts related to EU consumption. Two key features turn out to be important in this context: the large scale (area) of the EU's global land use and the increasing share of products (and related embodied land) supplied by third countries. When looking at the origin of the land areas related to EU consumption, it is shown that South America is a key production hotspot for several products such as maize, soy and fruits, and that there are several countries supplying only one or two products, e.g. wood supplied by Russia. Key drivers for these developments are also analysed, showing that urbanisation, trade liberalisation and (bioenergy) policies have been most responsible for changes in EU demand and supply patterns, as well as for the related global impacts. We provide an in-depth review of key indicators, which are currently being applied to monitor foreign land demand, i.e. the land footprint indicator and the bio-productivity footprint indicator. We give clear recommendations for the further development of biomass and land flow accounting approaches as the basis for the calculation of consumption-based land use indicators. We argue that the expressiveness of the land footprint indicator is limited for international comparisons and propose the use of a bio-productivity indicator for this purpose. We indicate the shortcomings of available bio-productivity indicators (embodied $NPP_{harvest}$ and normalized land footprint) which refer mainly to their communicability and credibility, and offer options for further development.

To be able to relate the EU's global land use with potential social and environmental impacts, we also discuss the current state of the art in developing indicators on embodied environmental and social impacts. We propose two alternative ways of calculating impact-oriented land footprint indicators. The land footprint impact matrix is a simple way to identify priority areas with low efforts and based on available information. Detailed impact-oriented land footprints apply a more sophisticated approach by calculating the environmental impacts related to products consumed in Europe. The difficulty in calculating such indicators is to establish a (causal) link between an environmental impact and a land area/use or a certain amount of crop production. We show that some indicators are currently in development or have been developed recently (e.g. footprint indicators regarding deforestation, biodiversity loss, global warming, water scarcity and water pollution). Most social impacts as well as the important issues of soil degradation, however, cannot be addressed adequately due to a lack of data.

The chapter closes with an evaluation of potential targets related to the EU's global land demand and a discussion of potential policy options to reach these targets. The feasibility assessment shows that targets on impact-oriented indicators would support responsible production and trade, and safeguard natural areas and related ecosystem functioning, while resource fairness is best covered by a bio-productivity target. However, implementation of impact-oriented indicators proves to be particularly challenging in the institutional context (WTO). Furthermore, according to the SMART criteria none of the proposed targets is currently fully suitable to be implemented in a binding policy context.

The overall assessment shows that the implementation of a land footprint target on an indicative basis is feasible. Indicative targets can be implemented as a first step to increase awareness and to build the knowledge base on current use and efficiency of land resources and the distance to a potential target. Indicative targets are most suitable for a bio-productivity footprint in relation to resource fairness and for a deforestation footprint in relation to the protection of natural areas and related ecosystem functions.

6.1 Introduction

Current practices of global land use are causing a number of severe environmental problems, which endanger the future functioning of global ecosystems and their ability to provide fundamental ecosystem services to humanity, including food production, fertile soils, a stable climate and clean water. The main drivers for these developments are the expansion of land used for agricultural production, the intensification of land use as well as the increasing expansion of commodity crop production for exports in many developing countries. The resulting environmental problems include deforestation and related emissions of greenhouse gases, loss of biodiversity and soil degradation (UNEP 2014; for a detailed description of the various global environmental and social impacts related to land use see Annex 6.1).

High levels of affluence and related high levels of consumption in the EU have led to growing land demand. Liberalisation of trade and globalisation of markets allowed this demand to be increasingly supplied by countries outside of the EU. The EU today is a major player in global agricultural trade and for many products, the world's biggest importing region, including for feed products, coffee and other cash-crops such as bananas (FAO 2014). As we will illustrate in this chapter, with almost 40%, the EU has one of the highest shares of foreign land in its overall cropland footprint of all world regions.

Furthermore, pressures on land are continuously growing in many world regions. On the one hand, this is a result of population and economic growth, particularly in Sub-Saharan Africa and Asia, which increase pressures on and competition for land, for example through changes in diets from plant-based towards animal-based products (Kastner et al. 2012). On the other hand, regions such as Europe have contributed to this intensifying global competition over fertile land, for example through the implementation of biofuel policies, which require blending biofuels into vehicle fuels (Hertel et al. 2012). Current and future EU policy measures, which affect land resources, must therefore always be analysed in their global context.

Several options exist to reduce the direct environmental and social impacts of agricultural production outside the EU, e.g. by addressing these issues at global supply-chain level, frequently developed and implemented as public-private partnerships. Examples for such improvements in responsible supply chains include training of farmers to implement soil management programmes with the aim to increase efficiency in agricultural production; fair trade or similar programmes to enhance local social standards; or environmental programmes that focus on a reduction of water use, the expansion of organic production or the conservation of natural areas.

However, even in the theoretical situation in which production of all supply-chains satisfying EU demand is based on environmentally and socially sustainable practices, the pressures on global land use and related impacts might persist without alleviation. In the first place, these pressures are related to the ongoing expansion of total EU land demand, causing further pressure on natural ecosystems worldwide, both through direct and indirect land use changes. Secondly, the EU has a relatively large per capita land demand compared to the world average, meaning that growing land demand of other (developing) regions pushes agriculture further into natural areas. For example, the mitigation of deforestation in the palm oil supply chain of European foodstuff and consumer goods may – in absence of global deforestation policies – result in a mere relocation of deforestation to other supply chains, leaving global levels of deforestation unchanged. In a situation of increasing global demand on limited land resources, addressing the high overall amounts of EU land demand in third countries and exploring options for absolute reductions of that demand is therefore at least as important as transforming existing supply-chains towards higher environmental and social standards. Third, lacking enforcement of environmental and social standards in several countries worldwide allows expansion of unsustainable supply chains to supply both their own domestic and export markets. The latter situation is the reality, meaning that products from unsustainable supply chains enter the EU market, also as a result of leakage effects.

Against this background, this chapter defines the following **four main objectives**, which will be addressed in the respective subchapters:

- **Identify hot spots for environmental and social impacts of EU land demand in third countries and their driving forces.** In section 6.2 we analyse in which regions of the world the EU has the highest land demand and how this demand has developed over time. We analyse the main drivers for the development of the EU's global land footprint such as international trade liberalisation and EU policies affecting the region's global land use. Finally, we discuss the relation between the EU drivers for global land demand and the main environmental and social impacts in the EU's distant production hotspots.
- **Review the current state of the art in measuring land footprints.** In section 6.3 we provide a concise review of the state of development of land flow accounting methodologies, which form the basis for deriving various land-related footprint indicators. We provide an in-depth discussion and evaluation (including RACER analyses) of the main indicators currently applied to measure foreign land demand, i.e. the land and bio-productivity footprint indicators.
- **Discuss options to consider environmental and social impacts in land footprint indicators**. Various environmental and social issues cannot be adequately reflected with the land footprint or bio-productivity footprint indicators. Therefore, chapter 6.4 discusses options to further extend the land footprint concept towards considering various impacts. We review the availability of impact-oriented data and explain how these impacts can be traced along international supply chains. We summarise the currently available literature on impact-oriented footprint indicators and provide recommendations for their further development.
- Discuss potential targets and related policy options to reduce Europe's land demand in third countries and related negative impacts. In the final chapter 6.5, we present a concept for the formulation of targets related to the EU's global land use. We relate potential targets to policy fields that support changes in land demand towards the defined targets. We carry out a technical feasibility assessment for the EU's land, bio-productivity and deforestation footprints as well as an assessment of their potential environmental and socio-economic impacts, both within the EU as well as in the rest of the world. We conclude this chapter with a discussion on target levels.

Box 6: Definitions of key terms used in Chapter 6 (alphabetical order)

Bio-productivity footprint indicator: The bio-productivity footprint indicator is a variation of the land footprint indicator. Results from the land footprint indicator measured in actual hectares can either be normalised against a benchmark of global average productivity, or the bio-productivity indicator can be calculated as a mass indicator, illustrating the carbon content of the harvested biomass corresponding to the land footprint.

Direct land use: Land directly appropriated for the production of specific agricultural or forestry products.

"Embodied", "embedded" or "virtual" land imports: Land areas that were appropriated in countries outside the EU to produce a good that is imported to the EU.

Environmental impact: Changes to the environment, adverse or beneficial, that result from external pressures are called environmental impacts. In this study, EU consumption of goods and services is considered an external pressure and the relationship between EU consumption and environmental impacts is one of cause and effect.

Impact-oriented indicators: Indicators illustrating the various environmental impacts related to land use outside the EU, most importantly deforestation, biodiversity loss, soil degradation and global warming.

Indirect land use change (iLUC): Land use and corresponding land use changes, which are indirectly driven by secondary factors. For example, when expansion of cropland production in Southern Brazil dislocates the former cattle production to Northern Brazil, it thereby indirectly contributes to deforestation of the Amazon.

Land displacement: Land displacement is a tendency of nations with rising affluence to 'outsource' a growing share of their cropland requirements to third countries and mainly involves leakage and indirect land use effects.

Land footprint indicator: The land footprint is an indicator to assess the total domestic and foreign land required to satisfy the final consumption of goods and services of a country or world region. The land footprint is an area-based indicator measured in area units (e.g. hectares).

Leakage: The indirect impact that a targeted land use activity (e.g. as a result of land related policies) in a certain place and time has on land use at another place and time.

Sustainable consumption: The use of goods and services to satisfy basic needs and bring a better quality of life without compromising the ability of others, both current and future generations, to meet their own needs.

Sustainable production: Providing goods and services to meet basic needs of the world population without compromising the already burdened environment and ecosystems, i.e. producing goods and services more efficiently, using fewer resources and generating less waste and pollution.

Tele-connections: Process based interconnections of spatially distant processes, drivers, markets, flows of energy and materials between land systems. In this chapter, tele-connections relate to the land flows embodied in primary biomass products that connect consumer markets with producing countries.

Third countries: Countries outside the EU, where land areas are appropriated by products being imported by the EU.

6.2 Global environmental problems related to land use and the role of the EU in the global land system

The EU's land area is one of the most intensively used on the globe, with the highest share of land used for settlement, production systems (including agriculture and commercial forests) and infrastructure (EEA 2010). Both land used for agriculture (44% of total land (Eurostat, 2013)) and the level of urbanization (5% artificial areas in 2012 (Eurostat, 2013)) are high compared with global averages. Furthermore, a growing amount of land outside the EU is required to satisfy final consumer demand in the EU. BIO IS et al. (2014) calculated that 39% of the total cropland required to satisfy EU final demand for goods and services were embodied in imports to the EU in 2007. Kastner et al. (2012) calculated that 51% of EU cropland requirements in 2009 were located in third countries.

This section summarises:

- the major global environmental and social impacts related to land use and land use change,
- EU's global land footprint related to the consumption of biomass products,
- the main countries supplying the EU, and

the drivers behind the EU's growing demand for biomass and related land resources from third countries.

6.2.1 Environmental and social impacts potentially related to EU consumption

The UNEP International Resource Panel (UNEP 2014) identifies land use change as the most important driver of alteration of land cover and a deprivation of natural capital. Land use change mainly involves the expansion of agricultural land and urban areas at the expense of grasslands, savannahs and forests (Holmgren 2006). In addition, intensification of land use is a profound mechanism that can be related to degradation of soil functions, including soil fertility (land management). Hence, the relation between land use and environmental impacts is both driven by demand (land use change) and by production (changes in land management).

Impacts of globalisation and trade on global land use involve both degradation and depletion of natural resources and environmental pollution. UNEP (2014) summarises the main global environmental issues related to land use and land use change (LULUC) as follows:

- soil degradation,
- nutrient pollution,
- biodiversity loss, and
- GHG emissions and climate change.

Deforestation is both a key environmental degradation process, as well as a major impact resulting from land use.

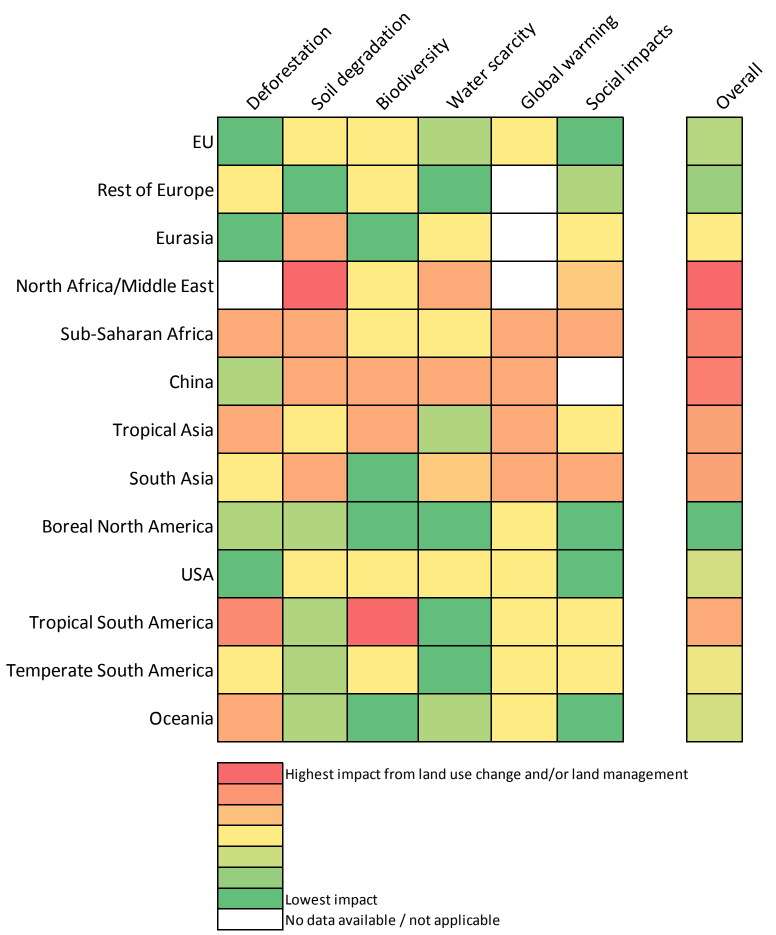
Social impacts, both from a food availability (access to food) as well as from a land tenure (access to land) perspective.

Social impacts of LULUC involve a broad group of issues, ranging from labour conditions in supply chains to adverse effects on food security and food prices, as well as land tenure conflicts related to large scale land investments (Anseeuw et al. 2012). These rural poor are dependent on the natural resource base which is increasingly under pressure of both quantitative threats (less land availability) and qualitative threats (pollution of natural resources). The land which has been in highest demand for large scale acquisition is the land which is close to water resources and can be irrigated at a relatively low cost in infrastructures, and the land which is closest to markets and from which the produce can be exported easily. The main target countries are in Sub-Saharan Africa (e.g. Cameroon, Ethiopia, the Democratic Republic of Congo, Sudan, Tanzania and Zambia), but also in Central Europe, Asia and Latin America. Developing countries in general are targeted, because of the perception that there is plenty of land available; their climates are favourable to the production of crops; the local labour is inexpensive; and, the land is still relatively cheap (De Schutter O., 2009). The rural poor are particularly vulnerable to the consequences of large scale land acquisitions as poor land registration and rights systems drive smallholder farmers off their land to less fertile (erosion prone) soils or to urban areas in search for work (De Schutter 2011).

As (local) social impacts are interrelated with land-related environmental impacts and associated with the expansion of global supply chains, social impacts are also considered a major global impact in the context of this study.

Based on the analysis of the environmental and social impacts from agricultural production related to consumption of goods and services worldwide (see Annex 6.1 for more details), we have summarized the impacts per region, relative to each other. The resulting impact map (Table 79) only serves as illustrative purposes and is based on a rough and indicative analysis of global impact maps per theme (included in Annex 6.1). In order to provide a robust assessment of the various environmental impacts by world region, more spatial data work and evaluation by experts in the related fields of environmental impacts is required. Furthermore, actual local environmental impacts within a region may be much stronger than the regional average. Social impacts are based on reported occurrences of land conflicts (Africa, South America), conflicts related to high food prices (mainly North Africa and the Middle East) and a general poor protection of social and labour conditions (Africa, Asia).

Table 39: Summary of (indicative) environmental impacts per region



Source: Own compilation based on existing global impact maps per environmental theme (see Annex 6.1 for full descriptions and sources).

The map shows a concentration of environmental impacts in the southern hemisphere regions, in particular in Africa, the Middle East, China and the tropical regions of South America and Asia. This is partly related to climatic conditions (warmer and drier periods) and the fact that the southern hemisphere contains the majority of land resources. Other reasons relate to the development stage: southern hemisphere countries tend to develop natural areas (land use change) whereas developed regions have stabilized their land use and management.

In Sub-Saharan Africa, impacts are likely to occur at all levels, mainly related to a lack of protection of natural resources (governance) whereas in Asia, the impacts largely result from the - already - intensive land management systems in combination with the transformation from natural to production forests. In tropical South America, impacts can be related to an intensification of land management, in combination with agricultural area expansion in ecologic hotspots such as the Cerrado (the tropical savannahs of Brazil).

Boreal regions in North America and Europe seems to have been affected least, whereas the impacts in the EU show to be mostly related to its large share of intensively used cropland areas.

Such an indicative global mapping of environmental impacts related to land use can be the basis for evaluating environmental impact indicators, as explained in Chapter 6.4 below.

6.2.2 Global land use related to EU consumption

The EU's land use is related to several functions, but by far the most important function (in terms of area) is biomass supply (EEA, 2010). For most countries or regions, the majority share of the consumed biomass is produced within the territorial borders of the domestic market or region (FAO, 2014). However, globalisation and liberalisation of trade policies support a growing share of food, feed and non-food traded around the globe. As a result, many regions show a large or growing share of their domestic consumption being supplied by third countries.

In order to support this assumption with evidence, EU consumption can be calculated and expressed in the original, primary commodities that have been used to supply the end-products (meat, dairy, processed products, etc.) to the EU. These primary (embodied) biomass requirements are then translated into land use on the basis of average yields in the country of origin, to assess the global land demand related to EU final consumption of biomass products. Figure 30 shows the global cropland demand for the EU (the current 28 MS) between 1990 and 2009, based on the described calculation approach (Kastner et al., 2012). It shows that total embodied cropland use has remained more or less stable over the years, but that the share of domestic land use has decreased and is being replaced by cropland in third countries (imports). In 2009, 51% of the EU's total land requirements were calculated to be located in third countries. BIO IS et al. (2014) calculated the EU's foreign land requirements at 47% of the total, on the basis of monetary values of world trade flows. Foreign cropland requirements were calculated to amount to 39% (see Annex 6.2). The domestic (EU) land areas are higher on the basis of nominal trade values compared to physical land use calculations which can be related to:

- the difference between land allocation on the basis of monetary trade values and calculated land use;
- the domestic area for non-food products, in particular bio-energy (underestimated by FAO);
- the yields (average per country or average in world market).

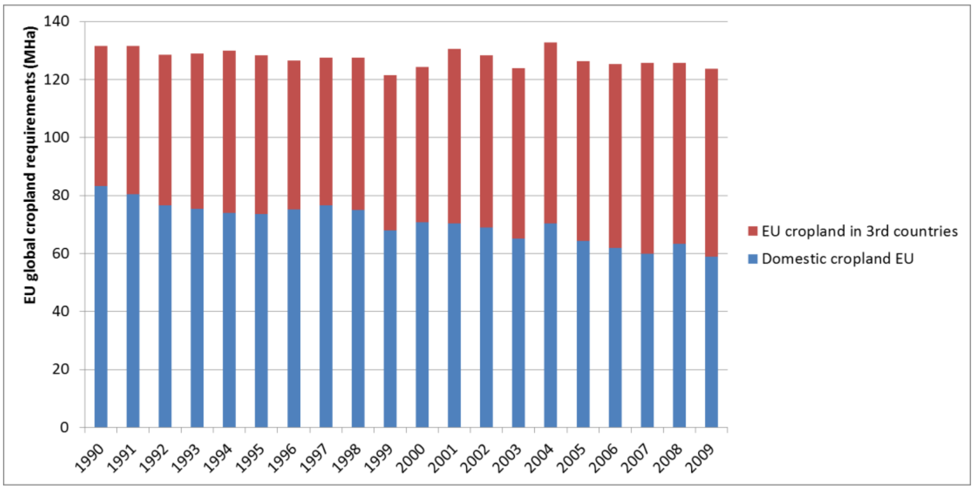


Figure 30: EU global cropland footprint between 1990-2009 (million hectares) [128]

Figure 30 supports the general trend towards more open markets with increased trade. Furthermore, the domestic cropland area in the EU is slowly decreasing (FAO, 2014; European Commission, 2014b), which indicates that the EU is a net land importer of global land resources. Considering the associated environmental impacts with growing consumption worldwide (UNEP, 2014), growing land demand in third countries requires close attention. In this respect, it should be noted that grassland and forest areas show the same pattern of growing land use in third countries (BIO IS, 2014). In Annex 6.2, it is shown that the EU's cropland use in third countries amounts to 39% of its global land use. This share is the highest among all world regions.

6.2.3 EU land use per capita in comparison to world average

Next to the global land use of the EU as a whole, per capita land use is also important. Based on embodied cropland use, it can be calculated that both the EU and the USA have the largest embodied land use per capita: 0.25 ha/cap vs. 0.19 ha/cap for the global average in 2009. Figure 31 shows that land demand related to consumption per capita is decreasing in most areas, including the world average (as a result of technology and efficiency improvements). Japan and China have a lower than average land use per capita, i.e. related to the intensive nature of agriculture (and aquaculture). The figure shows, however, that China's per capita embodied land consumption is largely related to its rapidly increasing meat consumption (Kastner et al., 2012).

It needs to be mentioned that these land use calculations are based on actual (embodied) hectares and thus differ from the Ecological Footprint approach (Wackernagel and Rees, 1996), where actual biomass consumption has been converted to a normalised land use on the basis of a global average yield. The latter is considered a fairer basis for the comparison of per capita land use (see also the discussion on bio-productivity indicators in section 6.3).

With respect to the relatively high global land use per capita for the EU, it is important to mention that land is increasingly associated with equity challenges, associated to the (ethical) problem that countries with a relatively low land footprint should be allowed to grow their footprint. Although environmental thresholds are not specified, it seems fair to assume that countries or regions with a

[128] Source: Kastner et al., 2012

relatively large footprint should make further efforts to reduce their footprint towards the global average.

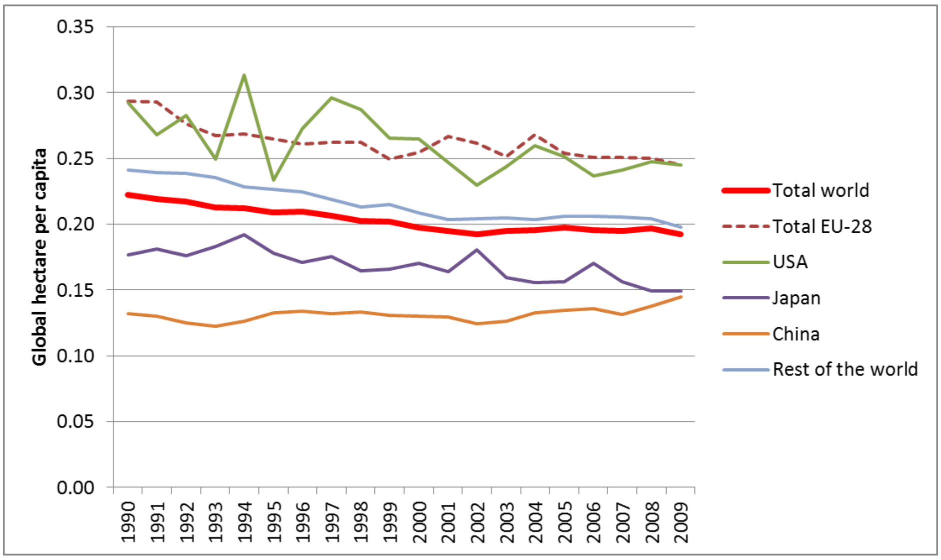


Figure 31: Global land use per capita (actual embodied hectares per capita), 1990-2009[129]

6.2.4 The origin of land areas related to EU consumption

In order to be able to associate EU consumption with potential environmental or social impacts in third countries, EU consumption needs to be traced back to the land areas used for the production of raw materials in the country of origin. Table 40 shows the global land use related to EU consumption, split out in different cropland categories, grassland and forest areas (BIO IS, 2014). The authors used a footprint methodology approach that allocates land to consuming countries on the basis of monetary trade flows. This approach is intensively used in academia and statistics to illustrate the global tele-connections between production and consumption (for example, Bruckner et al. 2012a; Lugschitz et al. 2011; Weinzettel et al. 2013; Yu et al. 2013; Bringezu et al. 2012; Kastner et al. 2011a; Statistisches Bundesamt 2013). When looking at the land area per crop category (rice, wheat, oilseeds etc.), more information can be gathered regarding tele-connected production areas, e.g. in relation to potential environmental hotspots (i.e. a large area of a specific crop, e.g. maize or oilseeds) related to EU consumption.

[129] Source: Kastner et al. 2012, FAO 2014 (population data)

Table 40: The EU's global land use in 2007 (in Mha)[130]

	Rice	Wheat	Other grains	Vegetables, fruits, nuts	Oilseeds	Sugar	Fibre crops	Other crops	Fodder	Total cropland	Grassland	Forest area	Total land
EU	0	21	27	12	12	1	0	2	24	100	53	84	237
Boreal non-EU Europe	0	1	0	0	0	0	0	0	0	2	0	23	25
Temperate Eur-Asia	0	1	1	1	2	0	1	0	0	6	1	4	11
Boreal America	0	1	0	0	1	0	0	0	0	3	0	3	6
USA	0	2	1	0	2	0	0	1	0	6	1	4	11
Tropical America	0	0	3	2	5	0	0	1	0	12	5	6	23
Temperate South America	0	0	1	0	5	0	0	0	0	7	5	2	13
North Africa & Middle East	0	1	0	1	1	0	0	0	0	3	4	1	8
Sub-saharan Africa	0	0	1	2	1	0	1	3	0	8	9	14	30
Temperate Asia	0	0	0	0	0	0	0	0	0	0	1	1	2
China	1	1	2	1	1	0	1	0	0	7	33	6	46
South Asia	1	1	0	0	1	0	2	0	0	5	0	2	7
Tropical Asia	1	0	0	1	1	0	0	1	0	4	0	16	20
Oceania	0	0	0	0	0	0	0	0	1	2	5	1	8
EU's global land footprint	4	29	37	21	32	2	5	9	26	166	117	166	448
of which imported (embodied land) (Mha)	4	9	11	9	20	1	4	6	2	65	64	82	212
of which imported (embodied land) (%)	90%	29%	28%	43%	62%	35%	91%	75%	8%	39%	55%	49%	47%

The table should be read from column (crop category) to row (the producer country or region of the specific crops related to end-consumption in Mha). For example, 2 Mha of wheat is imported into the EU from the USA. Based on Table 40, the following production hotspots can be identified:

- Tropical America (incl. Brazil) is an EU production hotspot for a large number of products of which oilseeds (soybeans) are by far the most important product group. Other products are cereal grains (mainly maize), rice, vegetables, fruits and nuts. Furthermore, Tropical America – mainly Brazil in this case – is a major supplier of tropical wood products and grassland embodied in beef exports to the EU;
- Temperate South America (Argentina, Paraguay, Uruguay and Chile) is a production hotspot for oilseeds and embodied grassland in beef cattle;
- Sub-Saharan Africa is a major hotspot for forest land serving EU consumption. Forest land in this respect is calculated as the area required when the amount of woody biomass for EU final

[130] Source: BIO IS, 2014

consumption is harvested with a sustainable yield (meaning that actual forest areas may be lower). However, it should be mentioned that a monetary trade flow approach tends to overestimate biomass exports from countries where large shares of the net primary production is used (unregistered) for subsistence use (among other database inconsistencies). Nevertheless, Eurostat also shows that the EU is importing a significant volume of wood resources from Sub-Saharan Africa.

- Sub-Saharan Africa is also a significant supplier of 'other crops' – which is mainly coffee and horticulture – and to a lesser extent - of vegetables for the EU;
- Boreal non-EU (Russia) is the most important supplier of woody biomass to the EU;
- Tropical Asia is also an important region for woody biomass supply to the EU. In addition, although indicated as 1 million ha only, tropical Asia is considered a production hotspot with steep growth rates in exports of palm oil and palm kernel oil to the EU;
- China is an important supplier of embodied land in several crop categories, mainly woody biomass, but also rice and other grains – which are probably embodied in processed foods. Grassland shows an extraordinary large embodied land flow to the EU, especially since exports from dairy and beef products to the EU are not allowed. Although large areas of grassland are embodied in processed products from livestock, e.g. leather, pharmaceutical products and porcelain, this high amount also results from the fact that land allocation followed monetary trade flows and that large grassland areas (also due to low yields) have been allocated to a relatively small volume of value-added products;
- The USA is an important region for land embodied in several products, mainly forestry products, oilseeds and wheat;
- South Asia is an important production hotspot for fibre crops.

Other studies also show that the consumption-based perspective of land use provides an alternative to production-based accounting by shifting (some of the) responsibility for environmental pressures to consumers. Yu et al. (2013) looked at the impact of globalisation and liberalisation of markets on global displacement ('outsourcing') of production for domestic consumption. Although absolute areas differ, it was shown that the EU countries together have the largest foreign land displacement with 27% of global total land displacement, mainly to Brazil and Sub-Saharan Africa. In terms of grazing land, most land is appropriated in South America because of the relatively high levels of beef consumption. In terms of forest land, the EU imports embodied forest land from Russia, Sub-Saharan Africa, S.E. Asia and China, which is in line with the global footprint calculation in Annex 6.2.

6.2.5 Drivers of EU land demand in third countries

In this last section, following the scale of tele-connected production areas related to EU consumption, the drivers behind EU land use are analysed. This analysis covers historical trends and developments, as well as research literature covering future developments until ca. 2030. These drivers serve as an indicator of the development of the EU's global land use and tele-connected production hotspots for different crop categories.

Conventional drivers: reaching a turning point?

Biomass demand and related land use is growing worldwide, mainly as a result of population and economic growth. On the other side, efficiency developments in agricultural production, as a result of technology changes, reduces the land footprint as less land is needed over time to produce the same amount of output. These three key drivers – population, affluence and technology – are the key drivers for the total land footprint of a country (Chertow 2001; Kastner et al. 2012).

In the EU, population growth is projected to show marginal growth rates in the coming decades (0.2% per year between 2010 and 2030) (UN, 2012). In some MS, e.g. in Germany and central European countries, population numbers are decreasing. Diet changes in relation to economic growth are also limited; some MS show increasing consumption levels of luxury food products such as meat, coffee, chocolate and vegetable oils, but other MS show stagnating or even declining consumption levels (Alexandratos and Bruinsma, 2012). Healthy diets are slowly gaining interest in a growing number of MS (e.g. the UK, the Netherlands) and the first signs of a decreasing meat consumption are noticeable in some MS with high meat consumption levels (e.g. Germany, the Netherlands) (Kanerva 2013). A change in diet, in particular a reduction in meat consumption, or a further shift from beef and pork towards more efficient poultry meat, can free up agricultural land and reduce both land use changes in third countries and related environmental impacts (Giljum et al. 2013). Overall, however, there are no signs of an autonomous decline in demand for biomass products in the EU; total biomass demand, including food, feed and non-food, is projected to show a marginal growth of ca. 0.5% per year (Alexandratos and Bruinsma, 2012), which is more or less in line with a conservative estimate for annual yield growth rates towards 2030/2050. However, EU demand for bioenergy related crops shows a relatively strong demand, causing the total EU cereals and oil crop demand to grow faster than production (European Commission, 2012a). The latter is not fully covered by the FAO projections for EU biomass use (Alexandratos and Bruinsma, 2012).

Globalisation and trade: EU focus on added value

Trade developments in EU agricultural products indicate a balanced biomass development with increasing imports and exports. It supports the findings of the previous sections that biomass markets are globalising and that the EU has increased its land footprint in third countries over time. As economies continue to liberalise, agricultural goods compete with equivalent goods produced further away. Both the profit per unit of land and the opportunity costs of agricultural land use vary immensely between regions, where biomass rich regions with low population densities, in particular North and South America, seem to profit from comparative advantages in international biomass markets and allowing regions with limited (free) land availability, such as the EU, to use land resources for higher value functions, largely related to land development and urbanisation, and to increase imports of biomass and embodied land.

Import developments of different commodities and products into the EU show the strongest increase in cereals, fruits and oilseeds/oilcakes. Only starchy root imports show a significant decline over time. When looking at the trade balance for agricultural products (Figure 33), it can be noted that the EU is a net exporter for cereals and alcoholic beverages and that it is a net importer for all other agricultural products, in particular for fruits, oil cakes, oil crops and stimulants (coffee, tea, cocoa).

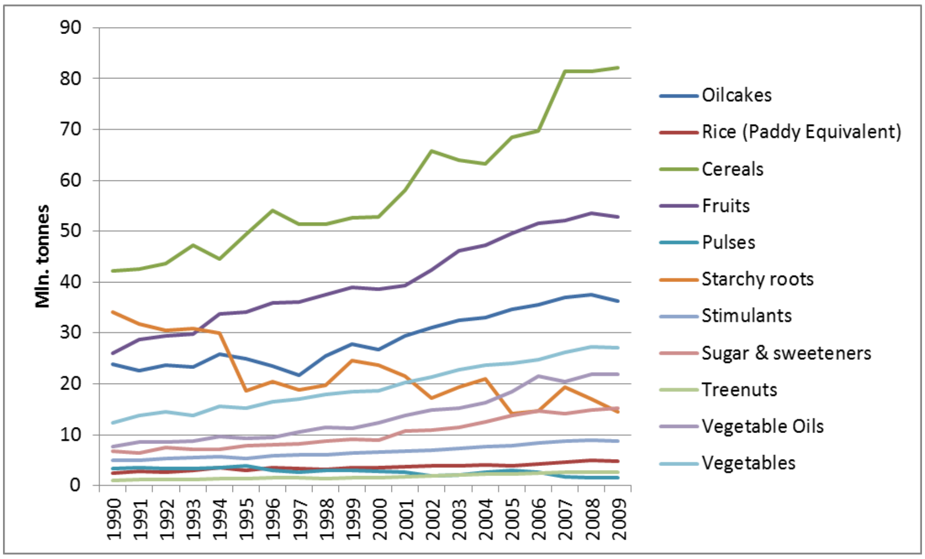


Figure 32: Developments in EU imports for agricultural crops[131]

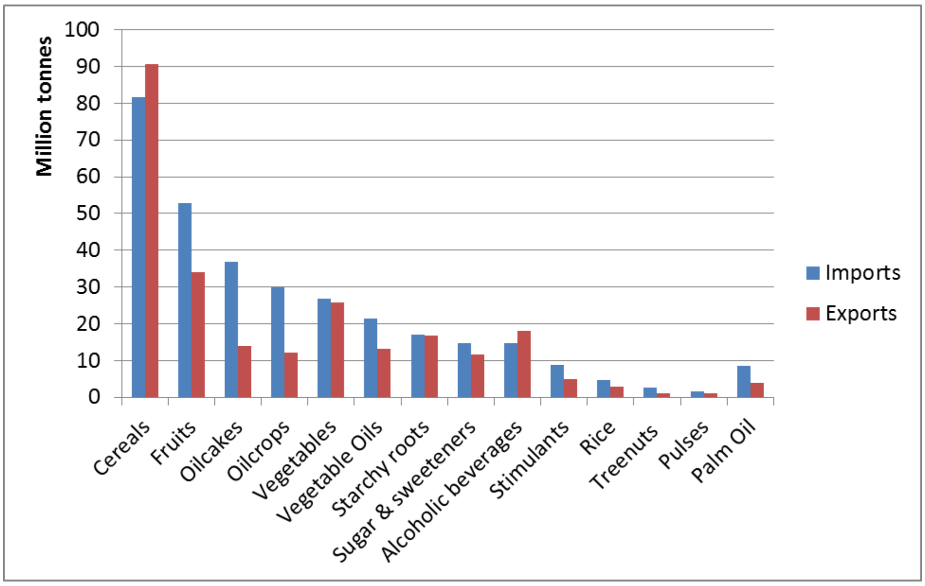


Figure 33: Trade balance of selected agricultural products, 2007-09[132]

A recent study also supports the hypothesis that trade liberalisation is becoming an increasingly important driver for the growth of the EU land footprint in third countries (Huber et al. 2014). As a result, food, agribusiness and other biomass related companies within the EU increase their focus on adding value (processing): trade statistics show that the EU is an increasing importer of agricultural commodities and an increasing exporter of added value products such as dairy or other further processed products (Eurostat). The share of foreign imports in the EU's exports has increased by more than 50% since 1995, to reach 13% in 2012. As such, EU imports have become essential to

[131] Source: FAOSTAT
[132] Source: FAOSTAT

economic growth as both domestic and export-oriented companies or industries in the EU are becoming a driver for, or benefit from, embodied land from third countries.

Policies and sustainable land use: adverse effects?

Increasing land and water scarcity is becoming an emerging driver in food & agricultural production chains. European economies depend on natural resources, including land, water and biomass, and, as a result, policy measures increasingly aim at a sustainable use of these resources. On the other hand, biomass has becoming increasingly important in relation to low carbon and bio-related strategies and policy development, which increases the pressure on land resources. In order to reduce its dependency on international energy markets, biomass is subject to policies supporting renewable energy and a broader bio-based economy, putting more pressure on land and related resources. Examples are the 2020 Climate and Energy Package and in particular the Renewable Energy Directive that potentially affect global land use by supporting the demand for bioenergy and biomass to reach the targets for increased renewable energy production in 2020. Such targets increase the demand for feedstock for both biofuels (e.g. rapeseed, palm oil, soy for biodiesel and wheat, maize and sugar for bioethanol) and for bio-heating and bio-electricity (mainly woody biomass). Although the use of these feedstocks is subject to sustainability criteria, e.g. with respect to the required greenhouse gas savings, indirect land use changes and more intensive management of forests, this may well lead to increased GHG emissions. This is related to the unintended release of carbon emissions as a consequence of the domestic expansion (or embodied imports) of cropland for biofuel production (Hertel 2010). The increase of biofuel demand in EU countries will most likely include imports of biodiesel feedstock, such as palm oil, soybeans and other oil crops, which may further impose pressure on the global food markets and increase cropland intensification and expansion for example in Latin America (Yu et al. 2013). As both food crops and woody biomass are related to negative environmental impacts in a global context, DG Energy projects a significant shift towards fast rotating plantation wood (perennial crops) as a 2nd generation feedstock for bioenergy. However, policy measures and/or incentives are not yet formulated to support a shift towards a more resource efficient and environmentally friendly use of natural resources for EU bioenergy purposes.

Policies affecting land use and land use change are, e.g., the policies under the Common Agricultural Policy (CAP), in particular the greening measures and MS' rural development programmes supporting a transition towards organic agriculture. In a meta-study at a global scale, it has been shown that organic agriculture generally results in a 5 to 34% lower than conventional productivity per hectare as a result of more extensive land management (Seufert et al. 2012).The trend towards growing consumption of organic products in the EU may thus increase the total land use and iLUC in third countries. In eastern MS, however, more sustainable land management, involving more nutrients and/or carbon added or returned to the soil, could potentially help to close the yield gap within the EU and to reduce imports and/or indirect land use change. Furthermore, the CAP includes policy measures on market instruments and trade, which influences the supply and import of food crops and commodities from third countries into the EU. As such, it is not clear whether the CAP can be associated with increasing pressure on land resources, but the trend is likely to support a slight increase in land use, especially in third countries.

The EU Forest Strategy and Action Plan contains various elements that have an impact on third countries. The EU Timber Regulation prohibits placing illegally harvested timber and products derived from such timber on the EU market. EU operators (those who place timber products on the EU market for the first time) must exercise due diligence (a risk management exercise so as to minimise the risk of placing illegally harvested timber, or timber products containing illegally harvested timber, on the EU market). In addition, EU traders have an obligation to keep records of their suppliers and customers to facilitate traceability. An important scheme in this respect is FLEGT; a voluntary scheme to ensure that only legally harvested timber is imported into the EU. Wood carrying a FLEGT licence, or a CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) permit, is considered to comply with the Regulation. Given that the EU Timber Regulation came into effect in March 2013, it only has an effect on future land demand.

Last, but not least, the EU Biodiversity Strategy 2020 aims to halt biodiversity losses both within and outside the EU. Within the EU, biodiversity loss is largely related to degradation or loss of permanent grassland and the high fragmentation of landscapes, whereas outside the EU, biodiversity loss is highly correlated with deforestation (VITO et al., 2013). In this respect, it is important that the EU Biodiversity Strategy aims e.g. to reduce embodied deforestation of products produced and to increase products with a low deforestation impact within the EU. Furthermore, the Strategy aims to step up its efforts to stop further biodiversity loss worldwide. However, stricter criteria related to imports into the EU may not be in line with WTO trade agreements.

For the coming decades, the European Commission has developed and launched several initiatives to increase resource efficiency: in particular the Flagship Initiative for a Resource Efficient Europe points the way towards sustainable growth. One of the building blocks of this initiative is the European Commission's Roadmap for a resource efficient Europe (European Commission 2011a). The Roadmap proposes ways to increase resource productivity and decouple economic growth from resource use and its environmental impact. It builds upon elements of the Sustainable Consumption and Production Action Plan, the Thematic Strategy on Waste Prevention and Recycling (European Commission 2011b) and the Thematic Strategy on the Sustainable Use of Natural Resources (European Commission 2005). However, all of these initiatives are still intentions rather than implemented policies.

To conclude, the policy summary above illustrates that different policies aiming to reduce environmental impacts of land use in third countries may have adverse or leakage effects, which need commitment of stakeholders from production to consumption in order to be effective for the environment. In section 6.5, we will elaborate on this issue in the context of target setting.

Table 41: Summary of key drivers in the EU and the impact on EU land use

Driver	Force of the driver	Impact on total land use
Population growth	Low	Stable-slight increase
Diet change	Limited; Stable or slightly less meat Increased luxury products (e.g. coffee, chocolate)	 Slight reduction Slight increase
Urbanisation	Medium-high impact on domestic (local) land value Expansion of urban (built-up) areas	Reduction in domestic land use (agriculture), increase in foreign land use,
Technology & investments (policies)	Medium impact on all crops Low impact on cereal grains and woody biomass	Reduction related to yield growth Slight increase related to bio-economy
Trade liberalisation	Medium-high impact on all crops, both imports and exports	Increase
Climate and renewable energy policies	Medium impact on imports of starch crops, oil crops and wood	Increase
Agricultural policies (Greening and market support)	Low	Unclear, but likely to support a slight increase (see above)

Driver	Force of the driver	Impact on total land use
EU Forestry Action Plan	Medium	Low, although afforestation in the EU may affect arable land use and indirect land use change.
EU Biodiversity Strategy	Low	Slight increase
Resource scarcity (initiatives)	Medium impact on cereals and fruits/vegetables (reduced waste)	Reduction as a result of efficiency improvement, waste targets

6.2.6 Conclusions

This review showed that the EU has increased its arable land use in third countries to satisfy domestic demand for biomass products. Including the required grassland and forest areas (each accounting for ca. one third of the EU's total land use), it is likely that the EU also increased its domestic land use and, hence, its total global land footprint. These developments are mainly driven by a growing demand for biomass products (meat, bio-energy, organic products), by changes in domestic land use (from agriculture to built-up land) and, as a result, of the reduced competitiveness in primary agricultural production in a liberalising world market. Considering the (potential) environmental impacts related to global land use and land use change, not only the development but also the absolute size (area) of the EU land footprint is of importance. Environmental and social impacts related to global land use involve soil degradation, nutrient pollution, biodiversity loss, GHG emissions and climate change, and social impacts, both from a food availability (access to food) as well as from a land tenure (access to land) perspective. Deforestation is considered to be a key degradation process that is associated with several of the mentioned impacts. These impacts are increasing as a result of the large land footprints of developed regions in combination with a projected growth of consumption and related land use of other (mainly developing) regions worldwide. A direct link between EU land use and related impacts is, however, difficult to establish as environmental impacts are highly context specific, may involve adverse effects (e.g. higher soil organic content but more land use) and commodity flows can generally not be traced back to the actual land plot.

6.3 Review of land footprint methodologies & indicators

The challenge to reduce the negative environmental and social impacts related to the EU's global biomass consumption and land use is complex as:

(1) both the capacity and the priority of land functions differ with each local context,

(2) the relation between drivers and impacts is blurred by distance and supply networks between producing and consumer markets, and

(3) the lack of consistent datasets prevents adequate monitoring of impacts that can be related to end-consumption.

In this section we review methodologies and the state of the art in data sources related to environmental and social impacts in the context of a growing global demand for biomass and land resources. We propose indicators to measure and monitor potential impacts associated with EU consumption.

Various approaches and models exist for quantifying environmental footprints of biomass consumption by estimating the related "virtual" resources (e.g. land, water) or environmental pressures and impacts (e.g. deforestation, GHG emissions, biodiversity loss, HANPP) embodied in international trade flows. While the first area-based indicators depicting the consumption perspective, i.e. indicators using hectares as their accounting unit, were already developed about two decades ago, impact-oriented indicators are just recently discussed in academia and policy contexts. In this chapter, we present a review of the literature on resource flow accounting approaches, tracing the hectares of land or tonnes of biomass embodied in trade. The following chapter then provides an outline of the recent developments and state of the art in the area of impact-oriented land use indicators from a consumption perspective.

The land demand estimates found in the rapidly expanding body of literature vary widely. Table 42 shows available results for the land footprint and virtual land import and export flows for the EU-27.

Table 42: Results from recent land footprint studies for the EU-27, in hectares per capita (LF = land footprint, IM = virtual land imports, EX = virtual land exports)

Source	Base year	Land types	EU-27		
			LF	IM	EX
Lugschitz et al. 2011	2004	Agricultural and forest areas	1.31	0.93	0.24
ibid.		Cropland		0.76	0.08
BIOIS et al. 2014	2007	Agricultural and forest areas	0.92	0.44	0.21
ibid.	2007	Cropland	0.34	0.13	0.02
Yu et al. 2013	2007	Agricultural and forest areas	1.17	1.45	0.82
ibid.		Cropland		0.31	0.18
Bringezu et al. 2012	2007	Cropland	0.31		
Prieler et al. 2013	2007	Cropland	0.31	0.14	0.08
van der Sleen 2009	2005	Cropland		0.04	0.01
von Witzke & Noleppa 2010	2007	Cropland		0.10	0.03

When comparing land footprint studies, it is important to be aware of the land uses considered. Agricultural areas include cropland and grassland. Some studies calculate cropland footprints only, while others include grassland and forest. When comparing the overall cropland footprints for the EU-27, the differences between the available studies are relatively small (see table above). Yet, more detailed results, e.g. on the cropland embodied in imports and exports, show variations by an order of magnitude. Robustness, and in some cases even directionality of the results are not yet guaranteed for land footprint calculations (Kastner et al. in press). However, it is not always obvious which of the methods are best suited for the estimation of national land footprints. Specific pros and cons need to be evaluated, before recommendations for further development and use in the EU policy context can be provided.

Against this background, this chapter provides a structured overview of existing approaches for estimating land footprints. It provides a detailed description of the underlying models and methodologies, highlighting the technical and structural characteristics, comparing strengths and weaknesses of the individual methods and drawing conclusions on their applicability to measure the EU's land demand in third countries for the European Commission's upcoming Land Communication.

6.3.1 General concept of land flow accounting

Figure 34 illustrates the general concept of the land flow accounting methodology. In a nut-shell, land flow accounting follows two overarching steps:

- observed land use is attributed to the primary producing sectors, and
- the land embedded in goods and services is tracked along global supply chains through to its final use.

Data used for this purpose provide information on the sources of supply (domestic production and imports) and describe utilization in terms of exports and different domestic use categories including intermediate consumption (e.g. feeding livestock) and further processing. Supply chains are either tracked up to final demand or end at a point of apparent final consumption (i.e. no further processing is recorded in the data system). Different accounting approaches exist for tracking the land content embodied in products.

Figure 34: General concept of land footprint methodologies

An important difference between approaches is whether supply chain flows (and embedded land uses) are tracked in terms of monetary values or physical quantities. This is on one hand because many industries involve joint production processes (e.g. crushing of soybean results jointly in soybean oil and soybean cake) requiring rules to attribute the land embedded in the raw material to the jointly produced commodities. On the other hand due to the fact that land embedded in a country's domestic supply (i.e. from production and imports) has to be attributed to different utilization categories, which can be done in different ways, e.g. allocating in terms of economic values describing the different consumption categories or by applying relationships based on technical coefficients and actual physical volumes. We henceforth term approaches applying monetary values as 'economic accounting', and approaches using physical volumes as 'physical accounting'. Hybrid accounting uses a combination of both aiming to overcome some specific limitations or weaknesses of the individual methods.

In this study we hence classify land flow accounting methodologies as follows:

- Economic accounting, applying environmentally-extended input-output analysis and tracking supply chains in monetary values;
- Physical accounting, using an accounting framework based on data for production, trade and utilization of agricultural and forestry commodities and tracking supply chains in physical units;
- Hybrid accounting, combining elements from both economic and physical accounting.

Economic accounting is based on statistical data compiled in national economic input-output tables (IO tables) and trade. IO tables are available only for selected years. Time-series of agricultural production data, bilateral trade statistics and overall commodity balances (Supply Utilization Accounts (SUA)) compiled by the UN Food and Agriculture Organization (FAO) provide fairly detailed and comprehensive national data for physical accounting methods of the most land-intensive sectors, i.e. crop production, livestock production and forestry. These global databases commonly used for respectively economic and physical accounting approaches differ in their levels of commodity detail as well as the detail and depth at which they cover the supply chains and consumption of agricultural and forestry products. Economic input-output tables cover the entire economy of a country but use fairly aggregate sectors to portray agriculture and forestry. FAO provides very detailed data at commodity level (both physical volumes and value estimates) but are not able to track the entire supply chains of all commodities, especially of highly processed non-food uses of agricultural raw materials. Detailed descriptions of the three main approaches in land flow accounting can be found in Annex 6.

6.3.2 Review of resource flow accounting approaches

The review of existing accounting methods covered about 50 publications in the thematic area of virtual land flows and tele-connecting production and consumption. Moreover, some of the most influential papers and reports presenting recent developments in material flow accounting (material footprint / raw material equivalents) were considered. The review identified more than 20 organizations/teams working and publishing in the field of land flow accounting and covered more than 40 publications, which we structured according to authors, research institutions and the applied models/methodologies. The detailed literature list can be found in Annex 6.4. Descriptions of all reviewed methodologies and publications can be found in Annex 6.5. Please note that publications in the areas of virtual water flows, material flows, Ecological Footprint and eHANPP (embodied Human Appropriation of Net Primary Productivity), although methodologically related, have not been included in the review of physical accounting techniques. Note that the Ecological Footprint (EF) was excluded, as it is an aggregated indicator, where CO_2 sequestration areas make up a huge fraction of the overall indicator. As this is a virtual calculation concept, which abstracts from real land use, the EF differs from all studies reviewed in this report, referring only to actual land use. Input-output analysis (economic accounting) and hybrid methods were used only lately for the calculation of land footprints, with most publications less than five years old. We therefore also reviewed a number of studies applying these methods on consumption-based indicators for biodiversity loss, deforestation, bio-capacity, materials and emissions. The review clearly revealed some general differences between economic and physical accounting approaches and their specific advantages and shortcomings. The differences are summarized in Table 43 below.

Table 43: Summary of main characteristics of available methodologies for land flow accounting

Criterion	Economic accounting	Physical accounting	Hybrid accounting
Level of commodity detail	× aggregate sectors with limited commodity detail	✓ high level of detail for primary and processed crop and livestock products	✓ high level of detail possible
Land attribution	× attribution of land to aggregate monetary production data can be problematic	✓ specific allocation of land to biomass production according to actual yields	✓ allocation of land to biomass production; extension of supply chains with monetary flows at higher stages of processing
Supply chain coverage	✓ full coverage of all supply chains; however, sometimes representing only marketed production	× partly incomplete supply chains, especially for flows at high stages of processing	✓ potentially covering all supply chains

Criterion	Economic accounting	Physical accounting	Hybrid accounting
Allocation logic	× land is allocated according to monetary flows, leading to potential errors due to different value-to-weight ratios for the same products[133]	✓ land is allocated according to physical flows, thus avoiding distortions by inhomogeneous prices[134]	✓ economic and/or physical allocation
Reliability of source data	× reliability of IO data varies across available sources, geographical regions and different sectors	× reliability of international agricultural statistics for production, land use and trade varies across geographical regions and for different data sources	× see economic and physical accounting methods
Regional specificity	✓ country level	✓ country level	✓ country level
Consistency with aggregate global land use statistics	✓ consistency of input data is fully maintained	✓ consistency of input data is fully maintained	✓ consistency of input data is fully maintained

Economic accounting, represented by (multi-regional) input-output analysis, stands out with its comprehensive coverage of the full (global) economy, thus all indirect effects are covered, independently of the complexity of supply chains. IO models therefore avoid truncation errors, as per definition all products, including highly-processed biomass-based products are being considered by the calculations. In addition, all IO models fully consider re-exports, based on the assumption that exports are a weighted mix of imports and domestic production. Major disadvantages include the limited commodity detail determined by the sector definitions of each IO model as well as problems related to the allocation of land flows following monetary structures. Furthermore, only a few countries' IO tables include estimates of the agricultural and forestry production which is not traded on markets (e.g. wood fuel harvested or vegetables grown for subsistence use).

A major advantage of **physical accounting** is the high level of commodity detail, which allows a more detailed and consistent allocation of land to harvested biomass. The aggregation to only a few highly inhomogeneous product groups in economic accounting and inconsistencies between economic and agricultural statistics can lead to significant distortions of results. Physical accounting approaches are also superior regarding the geographical coverage and detail, the level of detail on products and land use types, timeliness of the calculations and (potential) availability of time series. Furthermore, only very few existing models are able to distinguish between different categories of end use, such as food, feed, fuel, textiles or cosmetics. If any, only physical accounting approaches seem to attain this detail of results. Finally, physical accounting offers the possibility to apply a physical allocation logic, while economic accounting is restricted to economic allocation.

To illustrate this difference, let us take the example of a country producing a crop, say rice, of varying quality but uniform yield. Furthermore, let the country selectively export the better (i.e. higher priced) quality and use the lesser quality rice for domestic consumption. In this case, economic accounting methods will attribute a larger share of the rice cultivation area to the importing country than was

[133] Economic allocation tracks land use in economic supply chains and thus follows the monetary flows (e.g. in Dollar or Euro) of commodities/sectors.

[134] Physical allocation tracks land use in physical supply chains and thus follows the physical commodity flows (in tons).

actually used for production. In this example, land attribution according to physical flows will produce more realistic and robust results.

However, data availability clearly limits the applicability of physical accounting. Take the example of a cotton producing country where cotton lint is processed by domestic textile industries and textiles are then exported overseas. The physical accounting based on available statistics would reliably estimate the land content of the produced textiles but would attribute the respective cotton area to the country of origin rather than to consumption in the countries where the textiles are received simply because processed textiles are not recorded in the FAOSTAT system. In this case an economic accounting method of the textile sector should be applied to extend the representation of the supply chain for cotton products. As Table 43 suggests, **hybrid approaches**, building on the available data and methods, have the potential to exploit the specific advantages of the physical and economic accounting methods and can thereby overcome some of the underlying limitations and weaknesses.

Finally, physical accounting often uses land intensity coefficients based on various sources including life cycle assessments. Since these studies are technically detailed but rely on assumptions and data from certain representative industries the regional specificity and consistency with national and global land use statistics will usually be impaired.

Domestic technology assumption

The evaluation of methodologies as summarised above assumes that all approaches apply a global multi-region accounting framework using country-specific supply chain information and agricultural statistics. It is also worth noting that the different approaches can also be applied under a “domestic technology assumption”, i.e. assuming that imported goods are produced with the same economic structures, processing efficiencies and crop yields (same land use intensities) as domestic production. In the case of using the domestic technology assumption, data availability and reliability can be expected to be better than for global databases, as national statistical data (e.g. German agricultural production statistics) can be used. However, this simplifying assumption is hard to defend as it can lead to significant errors in cases where land intensities per tonne or per Euro of product vary widely across countries and regions. For example, wheat yields for the year 2007 vary between more than eight tonnes per hectare in Ireland and New Zealand and less than one tonne per hectare in some African and Latin American countries (FAOSTAT 2014a). Even within the EU-27, wheat yields between less than two tonnes and more than eight tonnes per hectare can be observed for Romania and Ireland, respectively, with an average of almost five tonnes per hectare. Therefore, results generated with a simplified national model will not reflect the reality of the global production-trade system and will therefore be inconsistent with land use statistics when aggregated to the global level.

6.3.3 Recommendations for the further development of land flow accounting approaches

This section provides a summary of recommendations concluded from the review of methodologies. The recommendations are listed according to the two overarching calculation steps in land flow accounting: first, how land areas are attributed to primary production and second, how embodied land is tracked along global supply chains. Detailed analyses and recommendations for the further development of land flow accounting approaches can be found in Annex 6.6.

Recommendations for the land use module

Account for different land use types

It is strongly recommended to calculate land footprints separately for cropland, grassland and forest land in order to account for differences in accuracy and availability of land use data by broad primary sectors (crops, livestock, wood production) and to facilitate better impact-oriented interpretation of the results.

Account for country-specific land use patterns

- Since yields (land intensities) among crops and across countries vary widely, it is essential for land accounting to retain in the tracking procedures both the commodity and geographical details of land-based production and commodity flows and avoid (to the extent possible) aggregation at an early stage in the supply chain.
- Realistic and consistent accounting of land actually embedded in the consumption and trade of agricultural and forestry products requires using country-specific technology and land use information (i.e. country-specific crop yields, livestock herds, feeding practices, etc.)
- The Food and Agriculture Organization (FAO) of the United Nations compiles national statistical data (e.g. supply utilisation accounts and food balance sheets). Data are checked and, where relevant, estimates included. It is the only available consistent global dataset on land use and agricultural and forestry production, and thus the only available source for large-scale global studies related to biomass production and land use. We recommend using these publicly available country-level, time series databases for the agricultural and forestry sector in land footprint accounting.

Account for multi-cropping and fallow periods when attributing physical cropland to primary crop production

- Apply agronomic logic and data to differentiate in the calculation of multi-cropping and land intensities among annual and perennial crops.
- Calculate average multi-cropping intensities, separately for annual and perennial crops, across all crops cultivated in a country and apply respective intensities to harvested areas of individual crops to estimate physical land associated with production.
- Meaningful land accounting requires to differentiate among feed sources and land inputs of different livestock types and to treat ruminants (e.g. cattle, sheep) separately from other livestock (mainly pigs and poultry) production.

Ensure robustness of grassland and forest land data

- For countries where no robust data is available, grassland and forest land actually used for livestock and wood production should be estimated rather than assuming all reported grassland and forest land as being part of the production cycle.
- For instance, regional data or model-based simulations of grassland productivity, net annual forest increments, etc., together with estimated livestock feed balances and reported timber harvests can be used to fill information gaps needed for enhancing estimates of forest and grassland utilization of livestock and wood production.

Ensure consistency between the applied statistical sources

- Errors resulting from inconsistencies between National Accounts and land use statistics can only be avoided by applying physical or hybrid accounting methods.
- A physical accounting approach based on detailed commodity production and trade data should therefore be used for the first stages of the supply chains. When industrial uses cannot be tracked further by the physical accounting methods due to data limitations economic accounting of flows from these sectors based on monetary IO tables should be applied to extend (non-food) supply chains to final consumption.

Recommendations for the supply chain module

Maintain global consistency of land attribution along supply chains. This entails:

- Follow a 'top-down' approach, starting with land attribution to the production of primary products and following the supply chain to final utilization.
- Avoid the 'domestic technology' assumption; account for country specific supply and utilisation patterns and conversion rates, particularly for processed food and non-food products such as animal products, biofuels and biomaterials.
- Fully consider re-exports of primary and processed commodities; tracking the origin of raw materials for processed commodities is required for calculating meaningful (and fully consistent) product land intensities.
- Set up a fully consistent representation of bilateral trade flows, considering inconsistencies in trade statistics.

Apply a detailed physical attribution scheme for tracking land flows along the supply chains:

- Land embodied in a country's supply of a certain crop or commodity should be allocated according to physical quantities as far as possible, as price variations for different utilisations otherwise impair the results. This implies that a physical accounting approach should be applied for these supply chains.
- Retain high commodity detail, i.e. single crops and commodity flows are tracked via their physical flows (tonnes) and associated land areas are attributed in proportion to physical volumes.
- Use global agricultural statistics, particularly supply utilisation accounts (SUAs), for the modelling of global physical supply chains.
- Ensure consistent treatment of joint production processes along the supply chain. We argue that the consistent use of economic allocation for attributing land to joint products is an appropriate compromise, as it can be applied to all joint products consistently, while other allocation logics could only be implemented very specifically on a case-by-case basis. Economic allocation can either be achieved by applying monetary supply use structures (as in economic accounting) or by translating physical quantities into values using price information (in physical accounting).

Track land embodied in non-food biomass flows:

- Use a hybrid accounting approach tracking physical flows to final consumption as far as possible and extend supply chains for processing industries using monetary IO tables, where

SUAs are cut-off at industrial uses (recorded as 'Other Utilization' in FAOSTAT) and thus recorded physical volume flows are not available.

- Additionally, agricultural statistics, and particularly supply utilisation accounts, should be extended to cover also the main industrial uses, e.g. for energy purposes or in the chemical industry. Currently, efforts in the areas of data gathering and knowledge acquiring are being made by the Bioeconomy Observatory[135].

Use robust IO statistics and further advance IO tables in terms of detail and coverage of the physical economy:

- Disaggregation of IO tables has only limited benefit as the uncertainties related with assumptions and auxiliary data used for the disaggregation compromise the robustness of results generated with such IO datasets.
- Nevertheless, a more detailed reporting of economic accounts by European Statistical Offices, particularly adding detail in the areas of agriculture and food processing (including bioenergy), would provide a robust basis for land flow accounting.
- Moreover, the development of detailed physical IO tables (PIOT) for biomass, such as for example done in a pilot study by Statistics Austria in 2011,[136] would be of great value for land flow accounting. However, solid and comprehensive datasets with global coverage cannot be expected within the next years.

6.3.4 Footprint indicators derived from land flow accounts

In this section, we analyse the main consumption-based indicators that can be derived from land (and biomass) flow accounts, as described above. We in particular discuss data requirements and the state of development of the various indicators, and provide an outlook on further developments.

Land footprint

The land footprint quantifies EU's contribution to global land use and is a proxy for land use related environmental impacts occurring within but also outside the EU territory. It measures all land areas required to produce the goods demanded by EU consumers. The indicator can provide a high level of detail in terms of land type, geographical origin and land use type, e.g. showing the amount of Brazilian cropland embodied in a Member State's milk consumption. The land footprint indicator is an aggregated, high-level indicator with strong synergies to most land-related impact-based indicators. This is the case as a change in the amount or the type of land used affects several environmental issues. For example, an increasing land footprint generally comes along with increasing intensive land use and land use change and thereby deforestation, habitat and biodiversity loss, water use and soil erosion. The land footprint is quantified by applying a material flow accounting framework extended by land use data. This methodology has been developed during the past ten years and is well advanced. Currently, various approaches and models exist, developed mainly within academia but also at national statistical institutions. However, standardisation is needed and land footprint estimates for the EU found in the rapidly expanding body of literature vary widely.

[135] See http://europa.eu/rapid/press-release_IP-13-113_en.htm

[136] See www.statistik.at/web_en/static/report_eurostat_grants_2009_-_physical_supply_and_use_tables_2005_070486.pdf

Required data sources for land footprint calculations are:

- Material Flow Accounts:
  - Bilateral trade data for food, feed and other biomass-derived products (FAOSTAT, UN Comtrade, Eurostat COMEXT)
  - Supply utilization accounts for agricultural commodities (FAOSTAT)
  - Supply chain information for food products (FAO, USDA)
  - Supply chain information for non-food products (input-output statistics from, e.g., OECD, Eurostat, WIOD, GTAP, EXIOBASE)
- Land use:
  - Crop yields for different crops, years and countries (FAOSTAT)

Data availability to calculate the land footprint indicator is generally good. Agricultural statistics are available for all countries worldwide, providing production, trade and yield data up to the year t-1 on a very detailed (product) level; however, some weaknesses can be identified, such as missing information on cropping intensities and fallow. In the future, agricultural statistics should be expanded in order to provide information on non-food biomass uses, i.e. bioenergy and biomaterials. The importance of non-food uses is increasing rapidly, while agricultural statistics still do not explicitly report these uses.

Supply utilization accounts are only available up to the year t-3, but can be extrapolated.

Especially in developing regions where statistical reporting on land use is not well advanced, data quality is often not sufficient, in particular with regard to managed or harvested grassland and forest areas. Furthermore, supply chain information is available for different years with some gaps and uncertainties stemming from variations in the available input-output statistics.

Despite these uncertainties in basic data, top-down physical accounting models already today provide a robust basis for calculating the land footprint indicators and discussing indicative targets of land footprint reductions. The land footprint indicator is currently being used in the work on planetary boundaries (Rockström et al. 2009) and resource use (Giljum et al. 2011) and in several related policy processes, e.g. in Sweden (Nykvist et al. 2013), Finland[137], Germany[138] and Switzerland[139]. Also the EU's 7th Environmental Action Plan[140] calls for examination of land (and other) footprints.

Bio-productivity footprints

The amount of biomass supplied by a hectare of land differs significantly between land use types and countries. The bio-productivity footprint provides a measure of these provisioning services of ecosystems, illustrating the bio-productivity required to satisfy the consumption of goods by a country. The bio-productivity footprint thereby brings the land footprint to a common reference level and allows for better international comparison compared to the comparisons of hectares as used in the standard

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[137] See http://www.ym.fi/en-US/Latest_news/News/Proposal_for_societys_commitment_to_sust(17497)
[138] See http://www.intress.info/
[139] See http://www.post2015.ch/post2015/en/home.html
[140] See http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32013D1386:EN:NOT

land footprint. For example, extensively used arid areas take a big share in the land footprint of many countries, resulting in extremely high land footprints for countries such as Mongolia or Australia, while the bio-productivity footprint per capita of these countries is comparable to or even below that of EU citizens.

Strong synergies can be assumed to exist with many environmental impact-oriented indicators including soil organic carbon and nutrient loss, water scarcity and water pollution, considering that high rates of productivity are mostly linked to intensive use of soils and agricultural inputs, such as fertilizers or pesticides. As high levels of bio-productivity harvest reduce the energy availability for other local species, it is also linked to the issue of biodiversity loss. Furthermore, the indicator has a social dimension by providing comparable information on the consumption of provisioning ecosystem services for different countries and regions and is thus better suited to illustrate a “global fair share” compared to the land footprint indicator.

The bio-productivity footprint, either measured with the embodied $NPP_{harvest}$ indicator or with the normalised land footprint, can be very useful to monitor the appropriation of the bio-productive capacity of ecosystems, a truly limited and valuable resource.

$NPP_{harvest}$

A highly standardized approach currently available to calculate a bio-productivity footprint indicator is $NPP_{harvest}$, one of the HANPP indicators (Human Appropriation of Net Primary Productivity), measuring the harvested biomass translated in its carbon content. This is a territorial (production-based) indicator, but in combination with global biomass flow accounts, it can be calculated as a consumption-based (footprint-type) indicator, i.e. calculating the embodied $NPP_{harvest}$ in consumption (measured in carbon content).

For calculating this indicator the **required data sources** are:

- Material flow accounts (harvest and trade statistics, supply utilization accounts) – for details see data requirements of the land footprint indicator
- Information on the carbon content of different crops (IPCC, FAO)

The embodied HANPP, and along with it also embodied $NPP_{harvest}$, has been developed and calculated by Erb et al. (2009) and Haberl et al. (2012).

As with the land footprint above, **data availability** of basic data is generally good. Detailed and comprehensive data for land use and related energy content of plants are available by international sources such as FAO and IPCC on a global scale, at a very disaggregated level of single products and up to recent years with annual updates. The calculation of the embodied $NPP_{harvest}$ indicator therefore can be done relatively easy by multiplying the respective biomass flows with their carbon intensities. Tracing these flows along international supply-chains also requires setting up a robust accounting framework for embodied biomass, as discussed above.

Normalised land footprint

An alternative approach to calculate the appropriated bio-productivity is to normalise the land footprint according to global average yields. This concept is used for the calculation of the “Ecological Footprint” indicator, where different land use types are weighted using ‘yield factors’ and ‘equivalence factors’ in order to aggregate all land use into a common unit of “global hectares”, i.e. hectares with average global productivity. The yield factor quantifies to what extent a country’s productivity of, e.g. a certain agricultural crop differs from the global average yield of that crop, while the equivalence factor weights the various land use types against each other, e.g. taking into account that agricultural areas in general are more productive compared to pasture land. This approach is contested scientifically for its large number of underlying assumptions. However, it has the advantage to offer clear and simple results expressed in hectares, which makes the physical limit, i.e. the total available productive land on the planet, more tangible than for indicators measured in tonnes.

Required data sources:

- Material or land flow accounts (harvest and trade statistics, supply utilization accounts)
- Normalization factors (country-specific measures for the bio-productivity of different agricultural and forestry areas; global average bio-productivity)

Data availability:

Information on the production of single agricultural products is readily available from FAOSTAT on a timely basis. FAOSTAT also provides information on global average yields for all products, which can be used for deriving the "yield factors". For grassland and forests, global bio-geographical models such as GAEZ (Global Agro-Ecological Zoning, IIASA/FAO 2012) can provide the required information.

The normalised land footprint has been developed as a part of the Ecological Footprint indicator (Wackernagel and Rees 1996; Ewing et al. 2008). The calculation of the indicator does not require a particular technical skill and can be done once a robust accounting framework for tracing international trade flows and embodied land is set up, as discussed above. However, weighting benchmarks and the related yield and equivalence factors may still need some further discussion and consent between the relevant stakeholders. Such equivalence factors, in the case of the Ecological Footprint, are often criticized to be arbitrary or unscientific. However, solid data on global bio-productivity is available (e.g. from GAEZ) and can be used to derive evidence-based and scientifically sound normalisation factors.

6.3.5 RACER assessment of indicators

In the following, we provide RACER assessments of the three main indicators derived from global land flow accounts: the land footprint indicator as well as the two variations of the bio-productivity indicator (embodied $NPP_{harvest}$ and normalised land footprint).

Table 44: RACER Evaluation: Land footprint

R: Relevant	The indicator addresses the amount of land required to satisfy EU consumption of products. It is therefore directly related to the objectives of the Resource Efficiency Roadmap and its acknowledgment of the fact that also aspects beyond the EU's border should be taken into account. On the aggregated level, the land footprint has a particular strength for awareness raising purposes of how much (global) land the EU is appropriating for its consumption. Application on the level of single products on the basis of life cycle analysis is straight forward, however distortions introduced by yield variations between different countries need to be duly considered.
A: Accepted	The land footprint is not (yet) an established indicator within the European indicator systems. However, it is an established concept within the scientific community with a large number of academic groups currently working on its application and improvement. The concept has also appeared in various policy reports on the level of EU MS. Acceptance by statistical institutions is also high, as land use data undergo no modifications (as is the case with the bio-productivity indicators). Land footprint accounts for cropland and grassland have been established by the German Federal Bureau of Statistics.
C: Credible	The underlying concept provides very simple and useful information on the amount of land used to satisfy final demand of a country or the EU and has a particular strength for awareness raising for the issue of Europe's global land demand. However, it has the strong shortcoming of not being able to provide any information on the amount of biomass withdrawn from the used land and the bio-productivity being occupied by EU consumption and is therefore a poor measure for international distributional equity and an inappropriate basis for international comparison (for this, bio-productivity related indicators need to be applied - see below).

	Furthermore, the land footprint is only of limited validity as a measure of environmental impacts, as the impacts per hectare differ widely between different crops and regions.
E: Easy	Detailed and comprehensive data for land footprint calculations are available, on a global scale, at a highly disaggregated level, up to recent years and with annual reporting. However, integrating these big amounts of data into a consistent global accounting framework is not trivial and requires programming techniques.
R: Robust	The indicator currently faces a lack of robust and comparable land flow accounts, as various methodologies exist in parallel. Also a lack of robust data on the grassland and forest areas used for agricultural and forestry purposes can be observed, as well as a lack of physical supply chain data for non-food biomass commodities. Requirements on the EC and MS to establish consistent land or biomass flow accounts include: i) agreeable standards for the definition of cropland, grassland and forest land use, and ii) standards for the treatment of supply chains, particularly in the case of non-food biomass commodities.

Table 45: RACER Evaluation: Embodied $NPP_{harvest}$

R: Relevant	The indicator relates very well to the overall demand on biomass from other countries caused by EU final consumption and the objective to reduce the pressure caused by it. Compared to the land footprint, this indicator has the specific strength of providing values in an internationally comparable unit and thus serves as a basis for discussions of resource distribution. The concept could also be applied on the level of single products, as long as the origin of all ingredients of a biomass product is known.
A: Accepted	The indicator is not (yet) routinely calculated and reported on the EU level. However, the indicator has appeared in scientific research for a long time and has been mentioned in the context of environmental reporting on a European level (EEA, 2010c). The indicator expressed in tonnes of Carbon (or alternatively in energy units) is rather difficult to communicate, which might pose an obstacle when applying the indicator in a policy context.
C: Credible	Applies a coherent approach to address the pressure on land and the actual demand on bio-productivity in a proper measurement. However, clear evidence on the correlation between $NPP_{harvest}$ and observed environmental impacts is still missing.
E: Easy	Detailed and comprehensive data for land use and energy content of plants are available, on a global scale up to recent years and with annual reporting. However, as with the land footprint above, worldwide data with varying quality in particular for non-OECD countries is required to calculate the embodied $NPP_{harvest}$ indicator.
R: Robust	The indicator follows one consistent calculation concept developed by a single academic group located at the Institute of Social Ecology in Vienna, Austria. Despite this methodological specificity, the indicator has not yet been routinely calculated as an EU indicator. Furthermore, the indicator underlies a lack of robust and comparable biomass flow accounts, as well as a lack of physical supply chain data for non-food biomass commodities.

Table 46: RACER Evaluation: Normalized land footprint

R: Relevant	The normalized land footprint relates very well to the overall demand on biomass from other countries caused by EU final consumption and the objective to reduce the related global environmental pressures. As part of the "Ecological Footprint" indicator, this indicator has proven very powerful for communicating and awareness raising purposes, particularly regarding the global distribution of the consumption of the earth's bio-productivity. The indicator can be calculated on a country or product level.
A: Accepted	The indicator has not yet been applied in a policy context, but has been a research topic for many years and is steadily advanced in terms of data compilation and calculation routines. Furthermore, the

	ecological footprint indicator, which includes a normalised land footprint, has been used in a policy context.[141]
C: Credible	Applies a coherent approach to address the pressure on land and the actual demand on bio-productivity in a simple dimension. However, the use of one common weighted unit of measurement (normalised hectares) has been steadily criticised as being too much dependent on arbitrary assumptions. During the last years, solid data on global bio-productivity has become available (e.g. from GAEZ) and can be used to derive evidence-based and scientifically sound normalisation factors.
E: Easy	Detailed and comprehensive data for land use and actual and potential land productivity (yields) are available from statistics (FAOSTAT) and geobiophysical models (e.g. GAEZ model) and cover the global scale and recent years. As the indicator is not a part of the official statistical system, the underlying factors are not harmonised across calculations.
R: Robust	The indicator underlies a lack of robust and comparable land flow accounts, also a lack of robust data on the grassland and forestland used for agricultural and forestry purposes, as well as a lack of physical supply chain data for non-food biomass commodities. Moreover, there is currently no agreed procedure for translating actual hectares into normalized hectares.

Table 47 summarises the results from the RACER assessments for the three indicators derived from land flow accounts.

Table 47: Summary of the RACER assessment for indicators derived from land flow accounts

Indicator	R	A	C	E	R
Land footprint					
Embodied $NPP_{harvest}$					
Normalized land footprint					

It can be seen that none of the indicators are yet ready to be implemented, although all three are considered relevant indicators to measure the global dimension of land use related to EU consumption. The land footprint indicator is widely accepted in academia, but lacks the relation with bio-productivity and impacts on ecosystems. Furthermore, land footprint calculations are sensitive to the varying quality of basic datasets and are therefore recommended to be calculated separately for the different land use types (cropland, grassland, forest area) to increase robustness of results. Incomplete coverage of non-food uses is also important in relation to robustness and acceptability.

Bio-productivity indicators are subject to the same methodological challenges as the land footprint. The normalised land footprint is a measure that is relatively easy to interpret and communicate, however it has been criticised for its reliance on assumptions to make the various land uses comparable in one unit (the normalised hectare). The embodied $NPP_{harvest}$ though (measured in kg Carbon) is a more exact measure and requires less assumptions, but is more difficult to communicate by linking land use, biomass harvest and related carbon contents, and thus might be difficult to apply in a policy context.

[141] See http://www.footprintnetwork.org/en/index.php/GFN/page/national_reviews/

6.3.6 Need for further EU action

The previous analysis has illustrated that all three indicators derived from global land flow accounts have not yet been implemented, as they all face specific challenges. The priority issues for further development are summarised in the following table.

Table 48: Need for further EU action

Indicator	Problem definition	EU actions required to develop, implement or improve the indicator
Land footprint	Lack of quality in basic statistics, in particular in non-OECD countries. Lack of robust data on the grassland and forest areas used for agricultural and forestry purposes. Lack of robust and comparable land flow accounts. Lack of physical supply chain data for non-food biomass commodities.	Support the establishment of robust statistics related to biomass use in developing countries. Support the process to agree on standards for the definition of cropland, grassland and forest land use. Support the process of harmonising various approaches (physical/economic/hybrid) for establishing global land flow accounts. Develop standards for the treatment of supply chains, particularly in the case of non-food biomass commodities.
Embodied $NPP_{harvest}$	See land footprint[142] Indicator so far developed and calculated only by a few academic groups.	See land footprint Broaden the testing, application and peer-review of the $NPP_{harvest}$ methodology, including statistical institutions.
Normalised land footprint	See land footprint Currently no agreed procedure for translating actual hectares into normalized hectares.	See land footprint Support the process of developing and agreeing on a normalization procedure using global statistics and recently developed spatially explicit global data sets on the actual and potential bio-productivity.

6.4 Impact-oriented land footprint indicators

Land flow accounting approaches and derived indicators such as the land footprint or bio-productivity footprint indicators, as described in chapter 6.3 above, can provide valuable insights into the question of how much land and appropriated bio-capacity a nation requires globally in order to satisfy consumption and related demand for products and services. Yet, there exist a number of environmental and social impacts related to EU's land demand in third countries, which cannot be illustrated by these indicators alone. Therefore, developing impact-oriented land footprint indicators is an important additional step in order to provide a more holistic assessment and developing a broader empirical basis for designing specific impact-oriented targets in the future. The following table provides an overview of the major environmental and social issues related to the EU's use of foreign land.

[142] All footprint indicators described in this section are based on land or biomass flow accounts for the European Union. Thus, related limitations and development needs apply equally to all footprint indicators..

Table 49: Environmental and social issues related to Europe's land use in third countries

Issue	Specification of impact
Environmental issues	Deforestation
	Soil degradation
	Biodiversity loss
	Global warming
	Water scarcity
	Water quality (including eutrophication)
Social issues	Food availability
	Working conditions
	Land conflicts

Developing indicators related to the environmental and social impacts of EU's land use in third countries is a complex task. In a first step, additional data sets on the various impacts (e.g. on deforestation or greenhouse gas emissions) need to be compiled. For each of the issues, the state of development of impact-oriented data sets will be described in chapter 6.4.1 below. In a second step, these impact-oriented data need to be linked to land flow accounting models, in order to trace the respective impact along international supply-chains all the way to the final consumer in Europe. Approaches to link impact-oriented data to land flow accounting models differ between the various impact categories; the various options are described in chapter 6.4.2. The concluding chapter 6.4.3 then integrates the knowledge on the availability of impact-oriented data with the possibilities to link them to international supply-chains and presents a list of impact-oriented land footprint indicators and their state of availability. We also provide recommendations regarding the next steps required to enhance the availability and quality of these indicators.

As will be elaborated throughout this chapter 6.4, impact-oriented land footprint indicators are generally in an early stage of development. For some issues (e.g. deforestation embodied in EU consumption), pilot studies have recently been presented. For other impact-oriented issues (e.g. biodiversity-related issues), not even the basic data sets exist on the global level yet, impeding the calculation of footprint-type indicators. This chapter will therefore elaborate on the current availability of required data as well as options for further development of this type of indicators. We will not present detailed RACER assessments, as these analyses can only be carried out in a meaningful way once the impact-oriented indicators have been further developed.

6.4.1 Data availability for impact-oriented indicators

Impact-oriented land footprint indicators can only be calculated, when data on various environmental and social impacts are available on the global level. These data need to be available on a territorial basis, i.e. for the producing countries where land is being used directly or indirectly to satisfy European consumption. Examples for these territorial data are hectares of deforested land in Brazil due to expansion of livestock farming, species lost in Indonesia due to expansion of palm oil plantations or water scarcities in Mediterranean countries as a result of increased specialisation in agricultural export production.

In Annex 6.7, we have described the current status of data development underlying the various impact-oriented indicators in detail and list the most important currently available data sources as well as major on-going efforts to improve the data basis. We have also elaborated on the geographical specification of the impact-oriented data, i.e. whether data are only available on the national level or on a more spatially explicit level (e.g. grid cell data). The level of geographical specification determines to what extent the impact-oriented data can be allocated to land used for the production of specific commodities and thus linked to specific supply chains, which is a requirement for calculating impact-oriented land footprint indicators. In the table underneath, we list the main sources of available datasets with regard to the current quality and usability for calculating indicators related to EU consumption of biomass.

Table 50: Summary of data sources for the key environmental and social impact themes

Impact theme	Possible data sources	Data quality
Deforestation	FAO's Forest Resource Assessment (FRA) FRA 2010 Remote Sensing Survey (RSS) (FAO and JRC 2012)	Quality can be evaluated as robust enough to perform footprint-type assessments. Major problems are the existing discrepancies between estimates on forest area (change) based on national forest inventories and country questionnaires. Data is also relatively old, i.e. FRA data up to 2010, RSS data only up to 2005.
Soil degradation	ISRIC Global Soil partnership (ISRIC and JRC)	Data availability and quality not yet adequate on a global level; soil profiles do not cover the entire world and algorithms have been developed to derive secondary datasets.
Biodiversity loss	UN CBD GEO BON SEBI (EEA/ DG Environment) IUCN Red List UNEP/WCMC	No comprehensive quantitative indicator exists for biodiversity. There is no global, harmonized system to measure its change on a regular basis.
Global warming	UNFCC IPCC FAOSTAT (calculations based on land management)	Annex 1 countries need to report GHGs related to land use (change) under UNFCCC convention. Data for non-Annex 1 countries can be calculated based on IPCC emission factors, however, uncertainty in calculations is high, in particular related to emissions from wood and forestry.
Water scarcity	WEI (EEA) WSI (Pfister et al., 2009; Harding et al., 2011; Alcamo et al., 2003)	The WEI is well-developed on a national level for EU countries, but not available for other world regions. The WSI is very comprehensive (global coverage) and developed on a spatially highly disaggregated level (several thousands of water sheds).
Water quality	Waterbase (EEA) United Nations Global Environment Monitoring System (GEMS)	Waterbase contains comprehensive data for water pollution in Europe, but not for other world regions. Various groups working on the modelling of N and P balances on the global level. For example, FP7 CREEA project estimated soil nutrient balances on a grid cell basis (5 by 5 arc minutes) and disaggregated by crops. Furthermore, the UNEP GEMS/Water Programme provides a composite index of water quality by country. Data are collected from UN member states on a voluntary basis. GEMS/Water pays attention to ensure the quality of data. Yet, for some participating countries, data may have a limited geographic representation and/or temporal coverage.
Food availability	Average dietary supply (FAOSTAT) GHI (IFPRI)	Dataset quality sufficient, but challenge to relate undernourishment in a certain region to (over)consumption in another (cause-effect).
Working conditions	Child and forced labour (ILAB)	Comprehensive data with clear indication on products and countries. But not clear if assumption can be generalized to the whole export trade of one indicated product from a country.
Land conflicts	Land Matrix Global Observatory	Good and comprehensive data set. Does probably not reflect

Impact theme	Possible data sources	Data quality
	(ILC)	all existing transnational land acquisitions.

6.4.2 Linking impact-oriented data to land use and supply-chains

An environmental or social problem occurring in producing countries can only be put into relation to EU consumption, if it is linked with land use data and data on trade flows and international supply-chains. In order to analyse to what extent EU consumption is contributing to these impacts, we suggest a two-step approach. Approach 1 puts the EU land footprint by country/region (in hectares) in relation to national data on environmental or social problems in producing countries. Using a simple colour system, this approach allows to quickly identify possible hotspots of high negative impacts related to EU's land footprint in producing countries. However, this approach does not allow quantifying the specific contribution of the EU to the respective problems. In order to do so, Approach 2 explains the elaborated impact-oriented land footprint approach, in which environmental or social impact data are disaggregated below the national level (e.g. in the form of spatially-explicit grid cell data) and thus allows linking the production of specific products to supply-chains, which can then be traced to various consuming countries following the land flow accounting approach explained in chapter 6.3 above.

Approach 1: land footprint impact matrix

Various environmental and social data are available on the national level across a large number of countries outside the EU. In order to obtain a quick overview, in which countries/regions of the world the EU's land footprint might cause the highest negative impact, a simple matrix can be established, which presents the EU land footprint (in hectares) by region and contrasts these numbers with the degree of the various environmental impacts occurring in the different world regions (see Figure 35).

The following figure illustrates such a simple matrix for the EU land footprint and the case of selected environmental impacts. The table builds on information already presented earlier in section 6.2 above. Note that this map is only tentative serving an illustrative purpose of how the future possible application of Approach 1 could look like. In order to provide a robust assessment of the various impacts related with land use occurring in different world regions, more spatial data work and evaluation is required.

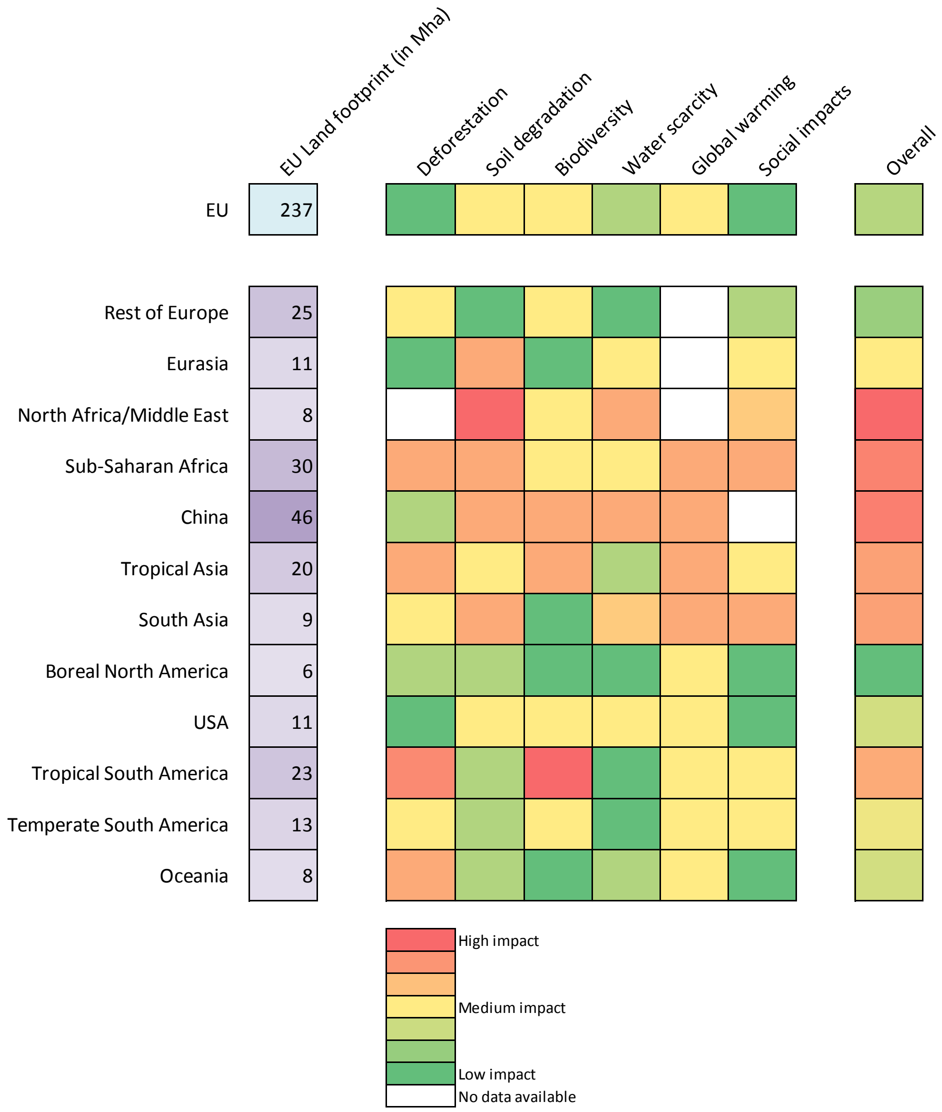


Figure 35: Indicative impact matrix contrasted by the EU land footprint

A tentative evaluation of the environmental and social impacts related to the EU's land footprint could be as follows. The figure illustrates that the largest fraction of the EU's land footprint is located in the EU itself; however, the related environmental impacts seem to be low to medium. With a land footprint of 46 Mha (or a share of 22% in EU's foreign land footprint), China is clearly a hot-spot, as – apart from deforestation – all other environmental impacts seem to be significant. Also Sub-Saharan Africa shows both a high share in the foreign footprint and possibly significant environmental and social impacts in several categories. Other regions with high impacts across several categories are Tropical Asia and Tropical South America.

With very low efforts and based on available information, such a matrix can therefore quickly point to potential hot spots of negative impacts across world regions and thus identify priority areas, where current production practices should be investigated in the first place, in order to pursue the objective to reduce EU's impacts in third countries.

The assumption underlying such a rapid assessment is that EU's contribution to the problem in the producer country is proportional to EU's share of the land footprint in that country, because (1) supply-chains delivering to the EU do not perform better compared to supply-chains directed towards domestic consumption or towards other world regions, or (2) because effects cannot be fully traced to the cause, forcing land users in a specific country or region to bear a joint responsibility for environmental and social pressures related to land use. In those cases, we consider the land footprint a valuable proxy of the impact of EU consumption on environmental – and consequential social – pressures related to land use, land use change and land management in other countries.

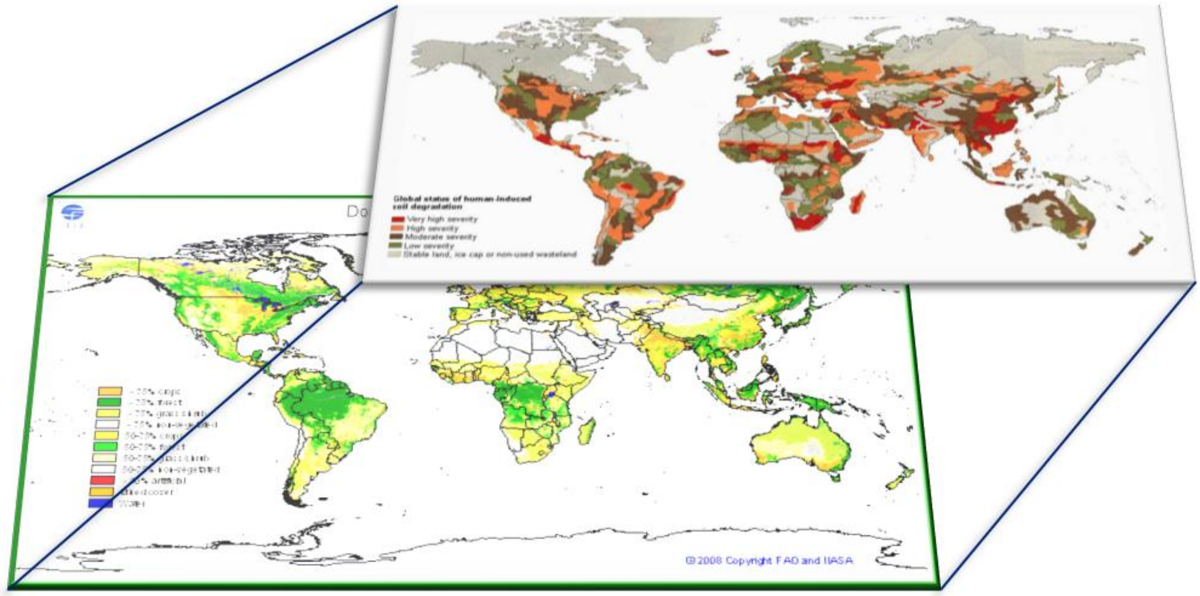
However, it can be important to analyse supply-chains serving European consumers more specifically. This is particularly the case, when the impacts of these supply-chains significantly differ from other supply chains, e.g. due to the introduction of higher environmental or social standards. In such cases, a more detailed calculation approach needs to be developed. This Approach 2 of calculating detailed impact-oriented footprint indicators shall now be investigated in more detail.

Approach 2: detailed impact-oriented land footprints

The assessment of the environmental and social impacts of the supply-chains of specific products requires developing and applying a more sophisticated approach, i.e. the calculation of impact-oriented land footprint indicators for products consumed in Europe. Calculating these indicators requires that the data on impacts in producing countries can be linked to the land use of primary production, or to the products produced on the land, and thus also to specific supply-chains.

In case the impact directly occurs on the production area itself (e.g. loss of soil organic carbon, leakage of pesticides into water bodies, pressures on biodiversity), the main challenge is to obtain data on a sufficiently high geographical resolution. If high-resolution impact maps are available on the global level, these can be overlaid with detailed grid-cell based bio-geographical information (see Figure 36), illustrating where in a country the production of specific crops or forestry products takes place. By overlaying the impact and the production maps, the link between impact and a product can be established, thus allowing to link impact data to land flow accounting models, which then trace an impact along the international supply-chains to the final consumer in Europe.

Figure 36: Linking environmental impacts to crop production based on spatially explicit data



Source: Illustration based on Fischer et al. (2008) and FAO (1995).

Regarding other environmental impact categories, the causality is much more complex and the allocation of impacts to crops or products needs to be based on a set of assumptions. In case of deforestation, the study by VITO et al. (2013) used FAO data to allocate deforestation to crops, livestock production, logging, natural hazards and the remainder to ‘unexplained’ causes, assuming that expansion of agricultural and livestock production is the main driver for deforestation.

Furthermore, there are different options to attribute deforestation occurring in a country to agricultural and forestry products. On the one hand, deforestation in a specific year can be attributed to the crop grown on that land the year after. On the other hand, deforestation can be distributed over all agricultural and forestry production, assuming that the overall land use system of a country is equally responsible for the occurring deforestation. A detailed discussion of these different forms of allocation can be found in VITO et al. (2013).

Also regarding social issues, various impacts require differentiated approaches for assessment. Some aspects, such as the implementation of social standards or the abolishment of child labour are being specified for products and supply-chains, thus allowing the calculation of an impact-oriented land footprint indicator.

Other social issues, such as the issue of food availability and the link to undernourishment in developing countries is a complex field with a number of influencing factors, which can certainly not be directly linked to the export of specific commodities to one region such as the EU. Identifying options for Europe to improve food availability and combat hunger require additional indicators beyond an impact-oriented land footprint. The land footprint tabbed against food availability in all countries, however, may help identifying potentially unsustainable supply chains (see Approach 1 above).

6.4.3 Overview of impact-oriented land footprint indicators

After reviewing the availability of impact-oriented data in the environmental and social domains as well as discussing options and limitations to link these types of data to land use and specific supply-chains, we can now draw the conclusions regarding the state of the art of impact-oriented land footprint indicators. Table 51 lists the various impact-oriented indicators reflecting the environmental and social impact issues as discussed above. It is important to note that all impact-oriented indicators take a consumption-perspective, i.e. illustrate the environmental or social impacts embodied in EU consumption. We include definitions of the indicators in the table, but many of these indicators have not yet been defined from a footprint-perspective and might thus need to be specified in the future, when underlying data has become available or has been improved. We also provide references to existing literature.

Applying a simple traffic-light concept, we also illustrate to what extent the available data can be used for a quick monitoring of hot-spots with an indicative land footprint impact matrix (Approach 1) versus for the calculation of a more detailed impact-oriented land footprint indicator (Approach 2). Concerning Approach 1, a green colour indicates that sufficient and robust data is available for inclusion in a land footprint impact matrix. Yellow colour implies that data is available, but lacking in data quality. Red colour means that no data is available so far. In the column on Approach 2, green colour indicates that the impact-oriented land footprint indicator has already been developed and successfully tested. Yellow colour indicates that the data would be available, but has not yet been tested for the specific case of impact-oriented land footprints. Red colour implies that the issue cannot be addressed with an impact-oriented land footprint indicator and that other approaches are required for the assessment of the respective issue.

Table 51: Overview of impact-oriented land footprint indicators

Environmental/ social issue	Potential indicator	Definition of the indicator	Approach 1: Indicative land footprint – impact matrix	Approach 2: Impact-oriented land footprint indicator	Available publications regarding Approach 2
Deforestation	Deforestation	The indicator “Deforestation” quantifies the amount of deforested area associated with the final consumption of goods and services in the EU. It can be disaggregated by products and their country/region of origin.	Deforestation data available from FAO and JRC	Deforestation embodied in EU’s consumption already available from a pilot study for DG ENV	(Karstensen et al. 2013; VITO et al. 2013)
Soil degradation	Soil organic carbon loss	The indicator “Loss of Soil Organic Carbon” indicates reductions in soil carbon, leading to a reduction in soil fertility, land degradation and desertification.	Pilot data on global carbon content available from FAO/ISRIC	Issue not yet tested with a footprint-type approach	No publications found
Biodiversity loss	Species threat	This indicator refers to animal species threat records from the International Union for Conservation of Nature Red List.	Data available on the global level	Footprint-type indicator already calculated in a pilot study for 187 countries	(Lenzen et al. 2012)
	Mean species abundance (MSA)	This indicator measures biodiversity as the remaining mean species abundance (MSA) of original species, relative to their abundance in pristine or primary vegetation, which are assumed to be not disturbed by human activities for a prolonged period.	Data available on the global level	Issue currently tested with a footprint-type approach for all EU countries (FP7 DESIRE project)	(Alkemade et al. 2009)
	Biodiversity damage potential (BDP)	The indicator quantifies biodiversity losses related to a broad selection of different plants and animals. The impact on biodiversity of a specific type of land use in different biomes of the world is extrapolated using species richness data of these biomes.	Data available for a broad selection of different plants and animals world-wide	Footprint-type indicator already calculated for Switzerland (BAFU) and applied in policy processes. Could be extended to cover EU level, as data are available	(de Baan et al. 2013a; de Baan et al. 2013b; Koellner et al. 2013; Frischknecht et al. 2013)
	Essential Biodiversity Variables (EBVs)	The Essential Biodiversity Variables (EBVs) cover the minimum biodiversity aspects that should be used in order to study and monitor biodiversity change, based on their suitability across taxa and ecosystems, their temporal sensitivity and their feasibility.	EBVs database still under development	Issue currently tested with a footprint-type approach for EU countries (FP7 DESIRE project)	(Pereira et al. 2013; Marques et al. 2013)
Global warming	GHG emissions from AFOLU	This indicator illustrates the AFOLU related carbon emissions (i.e. emissions/removals from Agriculture, Forestry and Other Land Use) embodied in the EU’s consumption (AFOLU carbon footprint).	Data available on the global level	AFOLU-Carbon Footprint already calculated in a pilot study for DG CLIMA for the EU-27	(BIO Intelligence Service et al. 2014)
Water scarcity	Water stress	The indicator of “Water stress” embodied in EU consumption illustrates, which products being consumed in the EU have been	Data on water stress available for all water-	Various studies on water embodied in EU	(Pfister et al. 2009; Lenzen et al. 2013b;

Environmental/ social issue	Potential indicator	Definition of the indicator	Approach 1: Indicative land footprint – impact matrix	Approach 2: Impact-oriented land footprint indicator	Available publications regarding Approach 2
		produced in various water-sheds under moderate or significant water stress. The indicator can be calculated for specific products and is spatially explicit for water-sheds around the world.	sheds world-wide	consumption published	Kounina et al. 2013; Ridoutt and Pfister 2013) (Lutter et al. 2014)
Water quality	Nutrient pollution to water	The indicator of embodied "Nutrient pollution to water" quantifies the contribution of EU consumption to the eutrophication of foreign water bodies with nitrogen and phosphorous. As data is available on a very high geographical detail, the indicator can be made spatially explicit and also be specified for the product level.	Data on nutrient outflows available on a detailed grid-cell basis	Several studies on embodied nutrient pollution available including for the EU	(Leach et al. 2012) (Lutter et al. 2014)
Food availability	Global hunger	The Global Hunger Index (GHI) illustrates the various dimensions of hunger, such as undernourishment, child underweight or child mortality by country.	Data is available for 120 countries	Issue not yet tested with a footprint-type approach	No publications found
Working conditions	Child labour / Forced labour	This indicator reflects to what extent EU imports have been produced under working conditions which include child labour or forced labour	Data available on product level for all producing countries world-wide	Issue not yet tested with a footprint-type approach. But data exists and approach is feasible	No publications found
Land conflicts	Land grabbing	This indicator reflects to what extent EU imports of agricultural products are based on land labelled as "grabbed land".	Data available from Land Matrix database	Issue not yet tested with a footprint-type approach	No publications found

The table illustrates that Approach 1, i.e. the tentative land footprint – impact matrix can be applied based on existing data for almost all environmental and social impact issues. Exceptions are the areas of soil degradation, where the global data bases are still under development, and some approaches to measure biodiversity loss. The table also emphasises that for a number of impact-oriented issues, footprint-type pilot studies have been published in the past few years, covering a variation of issues such as deforestation, biodiversity loss, water scarcity or water pollution.

Data on social impacts have not yet been linked to land flow accounting models, but at least for some of the social issues addressed above, such calculations could conceptually be performed. It can be expected that ongoing research and data efforts in Europe and other world regions concerning all areas of environmental and social impacts will significantly increase the availability and robustness of impact-oriented land footprint indicators related to land use in the near future.

Major areas for further work and development concern in particular the improvement of impact-oriented data on the worldwide level, which is still under development for several environmental and social areas, as well as the developing and testing of approaches to link impact data and land use data, for example by overlapping spatially-explicit global maps.

6.5 EU land targets in the context of global sustainable land use

This section aims at providing a target setting concept which allows the EU to contribute to a more sustainable global land use system by reducing its environmental and social impacts worldwide.

In contrast to the EU scale of the targets' assessments in the previous chapters on land take, land recycling, land degradation and land functions, this chapter takes a global perspective and therefore has a more exploratory character. Where land targets within the EU elaborate on the process of setting targets on advanced RACER indicators, this section will start with (1) the development of an adequate global land use system, followed by (2) proposal for (indicative) targets that support the EU in reducing its impacts and (3) identification of the most effective indicators that support measuring and monitoring EU impacts in relation to targets. The latter takes a broader perspective than footprint based indicators.

It is emphasised that this section is written for discussion and exploration purposes. It does not aim to recommend target levels nor a specific time frame for implementation of indicators or targets.

6.5.1 From production to consumption based targets

A key message from the previous chapters in this study is that the EU widely recognises the environmental impacts related to its intensive land use, both for agricultural and other land functions. Advanced agricultural and environmental policies, governance systems and protected natural areas aim to support a sustainable management of EU land resources related to the production of goods and services within the EU (production perspective).

From a consumption perspective, the management of land resources is more complex and requires a global perspective. As a significant share of the EU land requirements is located outside EU territories, efforts to reduce potential impacts related to EU consumption involves private, state and civil stakeholders in the country of origin that operate in a different context. Analysis of the EU's land use over time shows that both the absolute area and the relative share of foreign cropland appropriated by EU consumption is increasing, while the share of domestic cropland in final consumption is slowly but continuously decreasing. As demand for land in third countries is growing, the supply of affordable food and non-food products in the EU is increasingly associated with environmental and social impacts elsewhere. Measuring and monitoring these impacts with robust indicators is an important step towards managing global land resources and related impacts (section 6.3 and 6.4). Setting targets in the context of EU and international policy options is a further step towards responsible land use and will be discussed in this section. We will elaborate on the concept of global sustainable land use and propose EU targets and options to allow the EU to contribute to a more sustainable global land use.

6.5.2 Concepts for target setting in relation to land resources

Planetary boundaries

Rockström et al. (2009) defined the concept of planetary boundaries as scientifically informed values of the control variable established by societies at a 'safe' distance from dangerous thresholds. The planetary boundaries concept has a global dimension, as a threshold within which human development must navigate. The authors identified nine planetary boundaries of which seven were found to be quantifiable. Rockström et al. (2009) estimated that humanity has already transgressed three planetary boundaries, which are climate change, rate of biodiversity loss and changes in the global nitrogen cycle. With respect to land use, a planetary boundary for cropland has been defined at 15% of the earth's land availability (currently at 10.7%, leaving 555 Mha available cropland (FAOSTAT, 2014)). This threshold lacks the impact of increased use of grassland and forest area in response to socio-economic changes. Furthermore, no clear arguments are given for the definition and calculation of the threshold, which are explained to be the result of normative approaches.

The complexity issue in the planetary boundary concept is, that all boundaries interact and pressures occur at both local and regional scale; these boundaries affect national and regional governments, supply chains, businesses as well as communities. Scientific efforts try to link, where possible, the global boundaries defined to regional boundary targets. For example, for freshwater withdrawals, research is focusing on translating and linking the global boundary to appropriate regional boundaries at the river basin scale, defined at levels to avoid collapse of water dependent ecosystem services in the respective catchment areas. Potentially, it ought to be possible to make assessments about the maximum freshwater withdrawals possible at national levels, and then establish targets for water use at individual company levels (Wijkman A. and J. Rockström 2012). Although this path theoretically allows to link biomass consumption with distant production impacts, criteria to define a safe threshold for land use limits remain unclear and establishing regional or local thresholds with respect to its impacts may involve a huge workload and cost. Furthermore, Rockström's boundary approach is a production approach which is limited in generating land use options from a consumption perspective that remains within the boundary.

Safe operating space and practices

Bringezu et al. (2014) elaborated on Rockström's planetary boundary concept by taking the safe operating space (SOS) as its central issue, but argue that provision of reference or target data for a globally safe operating space should be separated from the question of how to allocate targets to countries and regions. The latter question must also distinguish between the use of biomass for production versus consumption, where a strong case for a global consumption perspective is made (including use in industry). With respect to target setting in relation to land use, land use change (the land footprint over time) is considered the key mechanism for measuring impacts in relation to the SOS – a mechanism which can be adequately monitored by a land footprint indicator over time. However, land use accounting alone cannot control the negative environmental and social impacts of production on a certain hectare. The latter is referred to as safe operating practices. A mixture of both (land use change in relation to consumption and local management of land in relation to production) is recommended.

Global sustainable land use

Based on the concept of a safe operating space and safe operating practices (Bringezu et al. 2014), we have developed a target framework for the EU's land use in the context of a global sustainable land use. This framework is based on the fact that the EU currently has a more than (global) average per capita land appropriation and on the assumption that global land use will continue to grow with economic development (dietary change and urbanisation). The left triangle in Figure 37 shows the globally available natural areas (in green) in contrast to the cultivated land resources (in red) which are expanding at the expense of natural areas and threaten ecosystem functioning (black arrows). In the right triangle, land resources are managed towards a more fair appropriation of global land resources, resulting in a reduction of land use by countries or regions with a larger than average per capita land footprint and a growing land use by countries with small per capita land footprints (black arrows point both ways). This will protect natural areas by reduced pressures of land use expansion and, when supply chains are managed towards environmentally and socially environmental standards in responsible supply chains, prevents further impacts of land use change and intensification.

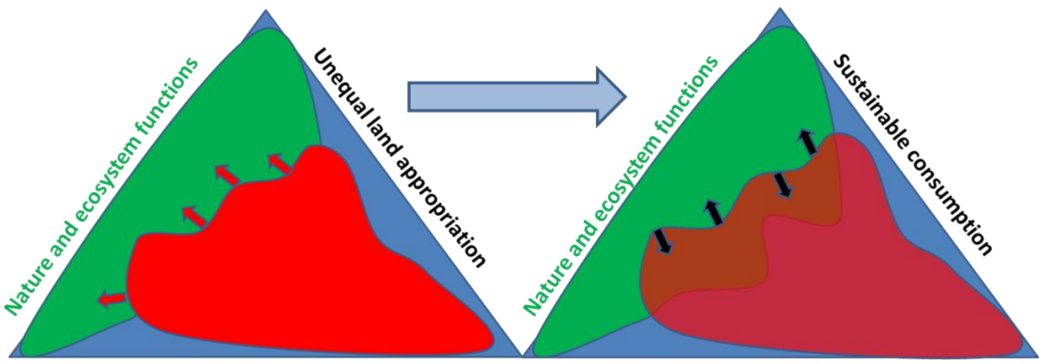


Figure 37: From global land demand to global sustainable land use

In summary, global sustainable land use has three dimensions (see righter triangle of Figure 35):

1. **Responsible production**, i.e. supply chains that produce and trade according to environmentally and socially responsible standards;
2. **Sustainable consumption patterns and land appropriation**, i.e. equitable consumption patterns that allow all human beings to fulfil their basic needs and optimise the distribution of additional welfare benefits from the consumption of food and non-food biomass, both among current generations and with respect to future generations;
3. **Sufficient and protected natural areas and ecosystem functioning**, i.e. natural and/or semi-natural areas that are protected from expanding industrial or intensive land cultivation, with the aim to safeguard local and global biodiversity and key ecosystem functions such as temperature cooling, carbon sequestration, water purification etc.

As long as the three dimensions of global sustainable land use are not safeguarded by international governance structures, global land resources may not be managed sustainably due to displacement (leakage and indirect land use effects) of agricultural production to less protected areas. The EU's land use pattern of decreasing domestic land use and increasing foreign land use to supply its consumers can be regarded as an indicator of this leakage effect. It is therefore necessary that measuring and monitoring systems of land use are based on sound databases and methodologies that can relate the consumption of a country or region to its environmental (and social) impacts worldwide. This allows a consuming country or supply chain to take responsibility and reduce its environmental and social impacts by changing consumption patterns towards less land consuming products and/or by shifting production to areas with lower impacts. Setting targets related to land use should thus be based on indicators that link consumption with its (distant) impacts and should support a reduction of these impacts.

6.5.3 Target proposals aiming at responsible production

Responsible production in a global context

Targets supporting supply chains that incorporate a sustainable or responsible management of land resources take a production perspective. Key stakeholders in this type of governance structures are companies, industry branches or public-private partnerships that commit to international or global production standards (e.g. Global GAP, Fair Trade, Global Round Table for Responsible Soy). These standards tend to focus on social standards and efficiency improvement, i.e. appropriate crop fertilisation levels, application of irrigation technologies, land management techniques such as reduced or no tillage of soil, etc., but can also include biodiversity targets such as a wildlife and conservation plan on the farm. Generally, a large number of environmental standards in these programmes are recommendations and based on voluntary implementation.

Along the same line, social standards are being incorporated in international or global supply chains. Most frequently seen are: fair payment conditions, training of local farmers, education of employees (and family members) and/or business support to a cooperative of local farmers. It can be argued that social pressures can be effectively mitigated at supply chain level. However, social pressures also result from deteriorating environmental conditions, e.g. water scarcity, ground water pollution, land conflicts and deforestation and, most importantly, from reduced access to food when smallholders are being driven off their land by large scale industrial operations. In those cases, the negative impact of responsible supply chains may still persist and certification of production conditions may not be adequate to alleviate social pressures in a country or market.

Box 7: The Global G.A.P. farm assurance program

GLOBALG.A.P. is a **global farm assurance program**, translating consumer requirements into Good Agricultural Practice in, currently, more than 100 countries. GLOBALG.A.P. started in 1997 as EUREPGAP, an initiative by retailers belonging to the Euro-Retailer Produce Working Group in response to growing consumers' concerns regarding product safety, environmental impact and the health, safety and welfare of workers and animals. The solution had been to develop own standards and procedures and an independent certification system for Good Agricultural Practice (G.A.P.). Global G.A.P. standards help producers worldwide to comply with Europe-wide accepted criteria for food safety, sustainable production methods, worker and animal welfare, and responsible use of water, compound feed and plant propagation materials. *Source: www.globalgap.org*

The following table is cut out of the checklist for Global G.A.P. Livestock programme.

Table 52: Checklist for Global G.A.P. Livestock programme

Nº	Control Point	Compliance Criteria	Level
AF 6.1	**Impact of Farming on the Environment and Biodiversity (cross-reference with AB.10 Aquaculture Module)**		
AF 6.1.1	Does each producer have a management of wildlife and conservation plan for the enterprise that acknowledges the impact of farming activities on the environment?	There must be a written action plan that aims to enhance habitats and maintain biodiversity on the farm. This can be either an individual plan or a regional activity, if the farm is participating in or covered by such. The action will include knowledge of integrated pest management practices, nutrient use of crops, conservation sites, water supplies, the impact on other users, etc.	Minor Must
AF 6.1.2	Has the producer considered how to enhance the environment for the benefit of the local community and flora and fauna and is this policy compatible with sustainable commercial agricultural production and does it strive to minimize environmental impact of the agricultural activity?	There should be tangible actions and initiatives that can be demonstrated 1) by the producer either on the production site or 2) by participation in a group that is active in environmental support schemes looking at habitat quality and habitat elements. There is a commitment within the conservation plan to undertake a base line audit of the current levels, location, condition etc. of the fauna and flora on farm so as to enable actions to be planned. Within the conservation plan there is a clear list of priorities and actions to enhance habitats for fauna and flora where viable and increase bio-diversity on the farm.	Recom.

With respect to land use, responsible supply chains generally aim at a reduction of land area per unit of output (increased resource efficiency). Total land use is generally not restricted in order to be able to pursuit a growth strategy. With respect to land use change, responsible supply chains generally include a condition that restricts expansion on native forested areas and areas of high conservation values. However, expansion on other forested land is allowed under certain conditions (BEFSCI, 2010). These production conditions, included in responsible supply chains, show that global land resources cannot be managed sustainably on the basis of responsible supply chains alone.

Furthermore, despite growing market shares and land use relevance, standards and certification schemes for agriculture still cover mainly niche markets (Schlegel et al., 2008). Certified areas of responsible palm oil fruit production accounted for 16% of the global palm oil fruit area in 2014 (RSPO web site). Furthermore 17% of the global coffee bean production area and 9% of the world's productive forests are certified (Steering Committee, 2012). For soy, a crop which is generally associated with high environmental impacts related to land use change, the certified area amounts to a mere 0.5% of the global production area. The growing demand for bioenergy worldwide, as well as the increasing concern about the sustainability of biofuel production, has also led to the development of certification schemes for bioenergy: the Roundtable on Sustainable Biofuels (RSB) and the Global Bioenergy Partnership (GBEP). And considering its large (grazing) land use worldwide, its impact on soil degradation and the large share in global GHG emissions, sustainability criteria for responsible beef supply chains are currently being developed by the Global Roundtable for Sustainable Beef (GRSB).

Research also highlights that there is little empirical evidence regarding whether large scale change has occurred, how durable the impacts (including yields) are, and whether they can be attributed to certification (Steering Committee, 2012). At the same time, these challenges of impact measurement are not unique to standards and certification alone and also apply to policy instruments and any other interventions. In fact the Steering Committee review concludes that rather than the direct impacts, indirect impacts such as learning, demonstration and spill-over effects (e.g. raising awareness and creating demand), enhancing institutional capacity and providing policy recommendations are the main positive impacts of standards and certification systems (Ecologic, 2013).

With respect to governance and standardisation of certification programmes, most studies point to the lack of sustainability standards, adequate monitoring and reporting systems and the governance structures of certification schemes. Although there seems to be a growing notion that standards need to be implemented on a wider geographical scale, there is criticism and controversy from stakeholders regarding transparency and participation in the development of such standards (Schlegel et al., 2008). An analysis of a number of initiatives for responsible supply chains show that common principles and criteria can be found for all kinds of biomass use (Schlegel et al., 2008); agriculture or forestry, or whether biomass is produced for food, feed or energy purposes. These common principles and criteria, argue the authors, give ground for a global initiative to cover the key environmental and social impacts which would reduce complexity and duplication of efforts for stakeholders.

Box 8: Building global responsible supply chains – The Solidaridad Network

Solidaridad, founded in the Netherlands in 1969, is a global network organisation with the aim to support a transition towards responsible supply chains in mining and agriculture. Solidaridad works with local partners, such as the Rainforest Alliance, in producing countries and has its own marketing organisation in the northern part of the EU. Solidaridad builds south-north supply chains with local partners for the training and support of farmers, and with traders, processors and retailers from the EU. Solidaridad is a partner in several global roundtable groups and builds responsible supply chains for targeted commodities such as soy, sugar, beef and cotton. The main issues covered by the programmes are poverty, environmental degradation and social issues. Solidaridad's global cocoa programme, for example, aims at increasing the number of farmers to 400,000 by 2015; improving yields; increasing market share; providing more credit for farmers; and creating new partnerships with universities, banks and input providers. Programmes for responsible supply chains are co-financed by private partners, input suppliers and the Dutch government. Together with the Dutch government, targets are defined for the increase in the number of smallholders and the number of hectares to be included in the partner programmes. *Source: www.solidaridadnetwork.org*

Target proposals aiming at responsible production

Certain impacts associated with the production of agricultural products can be reduced or relieved by a policy target to reduce environmental and/or social impacts at country, industry, supply chain or company level. E.g. when the EU would like to reduce its impacts on biodiversity loss, it could implement a target to reduce biodiversity losses embodied in imported products. In theory, global supply chains supplying the EU are thus incentivised to monitor, act and report on a reduction of biodiversity impacts. In practice, these requirements may be stringent, have broad impacts and may be highly complex in terms of governance..

Table 53 gives an indicative, though not complete, overview of potential targets that could be implemented with the aim to support value chains towards responsible practices. The list includes indicators that affect production in the countries of origin, or they are implemented at the EU (import) level and related to the consumption of embodied land in products and goods for the EU market (footprint indicator). A long list of targets would be needed to safeguard responsible business practices in the field of soil, air and water use. Furthermore, adequate and efficient targets are likely to differ from market to market as, even within markets, degradation pressures, indicators and targets may be specific to the local context.

In general, targets to support responsible production relate to 3 groups of impacts:

1. Environmental or social impacts that can be managed by a single farm: generally soil related impacts (SOC, SOM, N emissions or excretion, P excretion (eutrophication) or shortages of these minerals);

2. Environmental or social impacts that can be managed at farm level but that positive effects are enhanced by a supply chain approach: generally (LCA) impacts related to air pollution, such as GHG emissions, land use (e.g. organic or GMO-free) and to social standards (such as minimum wages, free of land conflicts etc.)

3. Environmental or social impacts that can't be managed at farm or supply chain level as they generally involve one or more aspects of 'common pool resources', such as deforestation, biodiversity loss, water stress. These impacts require a governance approach that involves policy agreements on the use of these resources – either from a production perspective or from a consumption (import) perspective (or both).

It should be noted that (1) and (2) may also be supported by policy measures and governance structures at the EU level, but that (3) cannot be implemented at the farm (production) level alone.

Table 53: Target proposals and control indicators in the context of responsible supply chains

Goals	Possible expressions of targets	Types of control indicators
Imported products should not come from (recently) deforested areas	Imported products should not come from (recently) deforested areas, or, Imported products should not come from countries with (recently) deforested areas	Certified products (production level – country of origin) Or Footprint (FP) indicator (at EU import level)
Imported products should not contribute to further soil degradation	In principle, targets for products from third countries should be in line with EU (potential) targets, e.g.: Soil organic matter (SOM) should not be decreasing overall in countries of origin of EU imports The top soil SOC stock should not decrease in countries of origin of EU imports.	Soil organic matter content (% or kg SOM/kg soil) Soil organic carbon stock (tonnes/ha) (both at production level-country of origin) Or FP indicator 'embodied soil degradation' (at EU import or supply chain level)
Imported products should not contribute to water stress/ depletion	Imported products should not be produced from water-sheds under moderate or significant water stress.	Implementation of water management systems in critical areas (production level – country of origin) Or FP indicator 'Water stress embodied in EU consumption' (water use/water availability) (at EU import level)
Imported products should prevent water pollution	Limit nutrient (N & P) pollution to water	Implementation of farm mineral accounting system (at production level – country of origin) Or FP indicator 'Embodied N & P pollution in imported products' (at EU import or supply chain level)

Goals	Possible expressions of targets	Types of control indicators
Imported products should limit air pollution (at least to EU norms)	Limit emissions of polluting gases, e.g. NH_3, NO_X	Implementation of farm technologies (at production level – country of origin)
Imported products should prevent global warming/ climate change	Limit direct emissions of GHGs, in particular CO_2, N_2O, CH_4	FP indicator based on LCA emissions (e.g. kg. CO_2 per kg end-product) (at supply chain level)
Protection of vulnerable ecosystems / biodiversity	Imported products should not come from protected areas or other vulnerable ecosystems	Certified imports (at production level – country of origin) Or FP indicator 'Embodied biodiversity loss' (at EU import level)
Acceptable social standards (wages, working hours, no child labour, …)	Imported products should be transparent regarding social standards in the supply chain	Certification of social standards (at supply chain level)
Imported products should be (land) conflict free	Imported products should come from countries with a functioning land right system	Certification of social standards (at supply chain level) Or FP indicator 'Embodied land conflicts allocated to imported products' (at EU import or supply chain level)

Feasibility assessment of target proposals

We will briefly assess the feasibility of the proposed targets on their technical, socio-economical and administrative suitability. In general, it can be assumed that production standards in third countries differ from EU standards, though products are not necessarily more polluting or damaging to the environment. Impacts of agricultural production differ widely with the local context which implies that a global target at EU level will have a much larger (socio-economic) impact on one country compared to the other. For example, a target that prohibits imports of products that embody deforestation may have a much larger impact on countries with large forest areas (e.g. as a result of the allocation of a share of the national deforestation to all products) than it has in countries with limited forest areas. As a result, such targets may cause trade distorting effects and therefore may not be supported by (key) stakeholders. Responsible production targets are therefore best be implemented in line with strengths and weaknesses in the local context, either obligatory at the national level, or voluntary at the supply chain level. In this section, an assessment is based upon potential target implementation at the production or supply chain level, and at the EU import level.

The assessment of target proposals aiming at a reduction of negative impacts related to the production of agricultural products and goods for EU consumption – or at an increase in the share of products that is responsibly produced - is largely dominated by the WTO treaty: Implementation of binding targets in voluntary environmental labelling schemes or at government level may raise issues and complaints in the context of the WTO (TBT Agreement's Code of Good Practice for the Preparation, Adoption and Application of Standards). These standards involve a non-discrimination clause, avoid unnecessary barriers to trade and aim at harmonization and transparency of trading conditions (WTO, 2012). It can thus be concluded that the administrative feasibility of targets related to responsible production in third countries is relatively weak.

As a result, binding targets, or targets focused at certain product groups or certain ecological hotspots, e.g. a reduction of biodiversity loss related to palm oil imports from Indonesia, or a reduction of soil erosion related to cattle grazing in Brazil, will probably not be allowed if implemented by governments in (developed) importing countries. On the other hand, recent developments have been focusing at a number of specific environmental requirements in the WTO context including organic product requirements, biofuel certification, private voluntary standards and carbon footprint measures. It can thus be concluded that targets supporting the trade of products that positively distinguish by environmental friendly production standards (though not clear which attributes or standards) are more likely to be allowed than exclusion of trade on the basis of negative production standards. Furthermore, the EU can implement supporting or awareness measures to import or consume such products.

Furthermore, targets set at the level of public-private partnerships to support local farmers and SMEs in developing countries, is also considered a trade supporting measure that does not hinder trade but helps increasing environmental standards in developing countries. Impact-oriented targets at these (supply chain) levels are more likely to be accepted in a WTO context, provided the evidence base is strengthened with data supporting the link between imports (consumption) and environmental impacts in production areas. Developed countries can play a significant role in the establishment and development of adequate databases to allow stakeholders in exporting countries to join voluntary binding or global indicative targets to reduce environmental and social impacts. An estimation of the costs and other requirements to develop such databases, e.g. in the field of soil erosion, soil nutrient management, water stress or biodiversity losses, could be an important step towards a broader implementation of environmental targets (WTO, 2012). Responsible production targets, such as an adequate crop rotation plan or fair wages, are likely to be supported by (international) policy options. A number of policy options are listed and assessed in Annex 6.8.

Deforestation targets at the production level are hard to implement as deforestation generally is a result of overusing land resources at a global scale and is thus difficult to relate to the actual cause or stressor. As existing footprinting methodologies for ‘common pool resources’ such as forests, water and biodiversity are generally based on allocation principles, all products will embody some deforestation. A zero deforestation target will thus result in a ban from countries with small deforestation activities and – if that is the target – a footprint target may thus be replaced by a ban on imports from countries with (recent) deforestation. As explained in the introduction, however, this will lead to (unfair) trade distorting patterns and is therefore not feasible from an administrative perspective. Responsible production targets focusing on reduction in deforestation, biodiversity loss and water stress reduction should thus be implemented at the (voluntary) supply chain level, though leakage effects may occur. Alternatively, the level of deforestation or biodiversity losses may be classified into low, medium and high (as has been done for the water stress level of a country or region) and it can be determined at which levels a country or region stops importing (or exporting).

Socio-economic effects of footprint or production targets at the EU import level are high for third countries as these countries generally have a less pronounced policy and governance system to regulate responsible production. Related economic costs are also high, both at the EU and exporting country level, as adequate data collection, tracking and tracing, and monitoring systems need to be set up and maintained to be able to calculate the relevant indicators.

Table 54: Feasibility assessment of potential targets that aim at an increase in responsible production practices

Potential targets	Technical feasibility	Socio-economic feasibility	Administrative feasibility
By 20XX, imported products should not come from countries with (recently) deforested areas	Low, not possible at production level	Low: many developing countries suffer from deforestation High implementation and	Not feasible as deforestation largely takes place in developing countries and would thus affect them most

Potential targets	Technical feasibility	Socio-economic feasibility	Administrative feasibility
		monitoring costs	(not in line with WTO)
E.g.: By 20XX, soil organic matter (SOM) should not be decreasing overall in countries of origin of EU imports	Id.	Id.	Unclear in view of WTO context; SOM levels are very difficult to increase, especially in view of the pressure to increase yields
By 20XX, products should not be imported from countries (of origin) with water stress levels higher than XX.	Medium: may be feasible at supply chain level	Medium: database exists Costs: unknown	Unknown: may be eligible for a positive exception
Limit nutrient (N & P) pollution to water by 20XX	Medium: feasible at farm/production level	Medium: poor mineral/ fertilizer availability in a large number of countries, problem also related to low SOM levels	Not feasible, highly dependent on local context
Limit emissions of polluting gases, e.g. NH_3, NO_X, by 20XX	Feasible at farm level	Low: largely dependent on technical applications, mineral use and, thus, financial resources	Id.
Limit direct emissions of GHGs, in particular CO_2, N_2O, CH_4 by 20XX	Feasible on the basis of LCA in supply chains	Low: high costs and LCA is case specific and dependent on cooperation in the value chain	Not feasible for the EU to set tailor made targets at supply chain level
By 20XX, imported products should not come from protected areas or other vulnerable ecosystems	Feasible on the basis of local certification	Medium: High costs as all exporters need to certify that products are not from vulnerable ecosystems (+ tracking & tracing)	Unknown: may be eligible for a positive exception
By 20XX, imported products should be transparent regarding social standards in the supply chain	Medium: acceptable social standards are case and context specific but can be certified at supply chain level	Medium: costs are relatively high, but a growing number of supply chains exist on this basis	High
By 20XX, imported products should come from countries with a functioning land right system	Low/medium: land right conflicts are hard to assess and databases may be incomplete. Feasible at supply chain level	Low: countries with a poor functioning land right system try to benefit from land development projects	Low: no legal ground to use a case based conflict at national scale High at supply chain level

From Table 54 it can be seen that none of the proposed targets are positively assessed. Overall, it can be concluded that target implementation at EU (import) level is not feasible for most responsible production criteria. Only the criteria that relate to vulnerable ecosystems and biodiversity may be eligible, but these can probably only be implemented at the (voluntary) supply chain level due to high economic costs when all companies would need to comply with these (certification) standards.

It can also be concluded that, like in the EU, responsible production is best be supported at the production (farm) level. However, due to a lack of governance structures, financial services and farm knowledge, a broad implementation of responsible production targets at the farm level is not to be expected in the near term in most developing countries. That leaves the EU with the ‘supply chain’ option to support a reduction of its negative impacts in third countries. This – rough – target analysis shows that voluntary (binding or non-binding) targets can be implemented on pollution impacts that can be measured by an LCA in supply chains (e.g. GHG emissions).

6.5.4 Target proposals aiming at safeguarding natural areas and ecosystem functioning

Safeguarding natural areas and ecosystems in a global context

Global land resources are limited with 1.4 billion hectare cropland, 3.4 billion hectare grassland and 4 billion hectare forest area in 2011 (FAOSTAT). Whereas cropland mainly serves human needs in terms of food and non-food biomass supply, forest areas are pivotal in supplying ecosystem functions such as temperature buffering, carbon sequestration, water purification (more than 75% of the planet's accessible freshwater comes from forested catchments (MEA, 2005)), as well as a supplier of food, non-food and energy. Grassland can be considered a 'dual-purpose' land category, with both important food supply purposes (livestock grazing) and ecosystem services including biodiversity habitats, carbon sequestration and erosion prevention.

An important feature of land use is that an increase in one land use category will reduce land availability of another: global cropland expansion largely takes place at the cost of forested areas, either directly from forest to arable land conversion, or indirectly by displacing livestock farmers (grassland-arable land conversion) and causing livestock farmers to turn forested areas into grassland elsewhere. This transition is largely driven by global growth in affluence and diet change. As a result, producers and supply chains will increase their land use in response to the growing demand, causing environmental (and social) impacts related to land use to persist. VITO et al. (2013) showed that the EU imported more than a quarter of the global embodied deforestation with ruminant livestock products – both with feed and meat– whereas other world regions are likely to increase their livestock product footprint substantially in the coming decades. This mechanism shows that the development of responsible supply chains will not be effective to safeguard natural areas and their ecosystems. Countries or regions need effective indicators to monitor and, if feasible, targets to reduce the pressure on total land resources, both quantitatively and in terms of environmental impacts.

Target proposals aiming at safeguarding natural areas and ecosystem functioning

In absence of global and local threshold levels and a global land management system to safeguard natural areas and their functions, countries or regions could develop a monitoring system to control their total land demand and related environmental and social impacts. Controlling the negative impacts of EU consumption on natural areas and ecosystem functioning in third countries requires adequate protection of forested and other vulnerable ecosystem functions, such as biodiversity and carbon sequestration capacities, in the countries of origin of the imported products. Footprint indicators which allocate these negative impacts to the consumers of the end-products allows the EU to gradually reduce imports that embody negative environmental or social impacts.

Table 55 lists a number of potential targets in the relevant fields. In absence of adequate data bases on impacts or evidence to relate EU consumption to these impacts, the general land footprint indicator could be used as a proxy for exerted pressure on land resources worldwide and, thus, to natural areas in third countries. In the table, all targets are proposed to be based on a footprint indicator (see section 6.4). However, when a 'zero impact' target applies, these indicators can be replaced by the primary databases as footprint indicators tend to allocate augmented shares of the total environmental impact to the products and goods.

Table 55: Target proposals and control indicators in the context of protecting natural areas and ecosystem functioning

Goals	Possible expressions of targets	Types of control indicators
Protection of forested areas	By 20XX, imported products should not come from countries with (recently) deforested areas	Footprint indicator of embodied deforestation (m2 per kg or per EUR end-product)
Protection of vulnerable ecosystems and/ or biodiversity	By 20XX, imported products into the EU should not come from countries with an increase in endangered species	Footprint indicator of embodied lost or endangered species per ha
Prevention of global warming/ GHG emissions	By 20XX, imported products into the EU should not come from countries with an increase in land related CO2 emissions	Footprint indicator of the EU's AFOLU related carbon emissions
Safeguarding all natural areas	By 20XX, the EU should stabilise or decrease its global land use	Footprint indicator of the EU's embodied land use (total MHa)

Feasibility assessment of target proposals

The indicator underlying a potential **deforestation target** is well advanced. However, embodied deforestation at products level requires (internationally) agreed allocation principles which may be constrained by differences in the local context and stakeholder interests. Data accuracy is rather poor as deforestation data are updated every 5 years. Timescale and target level can be determined at EU level, but (also) depends on stakeholder cooperation in international supply chains.

The administrative assessment shows that, from the perspective of the rest of the world (outside the EU), a deforestation target may be controversial as developed country host the majority share of global forests and trade-offs may exist with local development goals (development of agricultural production in biomass rich countries). Costs of implementation of a deforestation reduction target are acceptable when the target is based on allocation principles in a footprint indicator (or when a 'zero deforestation' target applies). However, it will also depend on the cooperation of international private and public stakeholders and agreements, which may be low in both exporting countries and importing countries that depend on imports of low cost commodities and wood (EU, Asia).

In principle, the above assessment applies also to other impact oriented reduction targets (CO_2 emissions, biodiversity). Impact-oriented targets primarily protect forest areas and related ecosystem functioning, and have strong synergies with each other as they all prevent land use change from forest land to other land uses. From 6.4 (assessment of impact-oriented indicators) it can be concluded that a deforestation footprint indicator is most advanced at this stage and that an (indicative) target implementation would be feasible for awareness and knowledge development purposes.

The (arable) **land footprint indicator** (section 6.3) is also feasible to be implemented on an indicative basis and will – to a certain extent – render the same effect (protection of natural areas) as impact oriented indicators, though the actual impact (e.g. deforestation) is not directly measured and, thus, safeguarded.

Table 56: Feasibility assessment of potential targets that aim at protecting natural areas and ecosystem functioning

Potential targets	Technical feasibility	Socio-economic feasibility	Administrative feasibility
By 20XX, imported products should not embody deforestation)	Indicative target implementation is feasible; Indicator is advanced but data availability is still limited (5 yr. interval)	A 'zero deforestation' target would impact (agricultural) development in developing countries.	Due to the potential socio-economic impacts in developing countries, WTO issues arise and developing countries tend to develop own conservation policies for natural areas/resources.
By 20XX, the EU should stabilise or decrease its global land use	Monitoring the (arable) land footprint over time is feasible. For a total land footprint calculation, the quality of the grassland data needs to be improved.	Any reduction target for the total land or cropland footprint is likely to meet resistance from both importing and exporting countries (threat to GDP development and/or food availability) and will need internationally agreed policy incentives	A cropland footprint target is likely to be implemented as an indicative target and may best be implemented at both member state and EU level (as with renewable energy targets).

The protection of natural areas and ecosystem functioning is a priority area with respect to the implementation of land targets worldwide. It is therefore recommended that indicative targets are implemented for awareness and knowledge sharing purposes, which also allow to develop supporting policies to move in the direction of an indicative target. From the target assessment, it can be concluded that an indicative deforestation target would be most appropriate – due to strong synergy effects with other environmental impacts – but that the land footprint indicator is also feasible in absence of (adequate datasets underlying) impact oriented indicators.

Furthermore, in line with the urgency to safeguard biodiversity and ecosystem services, a large number of policy measures are recommended to support the effectiveness of targets related to the preservation of forests and natural areas (VITO et al., 2013c). For the purpose of this section (land related targets), we mention and assess a selection of options in Annex 6.8.

6.5.5 Targets and policy options supporting sustainable consumption and land appropriation

Sustainable consumption and land appropriation in a global context

In order to contribute to the aim of more sustainable consumption patterns of land related goods on a global scale, appropriation of biomass and/or land resources needs to be managed from an equity perspective that allows regions with a lower than average land or biomass appropriation to increase their land use (if necessary) without intolerable environmental and social impacts related to the use of land resources. As a consequence, this requires countries or regions with a higher than average land or biomass appropriation to reduce their land or biomass appropriation.

From a EU perspective**, a reduction of the appropriated biomass, measured as a weighted bio-productivity footprint,** is of particular importance in relation to the land use embodied in the high levels of animal protein consumption. In 2007, the EU average per capita protein intake was about 70% higher than the WHO recommendations. High meat consumption levels are associated with negative effects on environmental and human health. As livestock products embody a lot of land per unit of output (due to the low average feed efficiency) and animal protein consumption is projected to increase with 1.8% annually (+35% by 2030) (Alexandratos and Bruinsma, 2012), a reduction in EU animal protein consumption could potentially free up large cropland areas globally, and reduce indirect land use effects, in particular in South America and Sub-Saharan Africa (VITO et al., 2013a). Another area of particular interest relates to the increasing use of wood resources related to EU bioenergy demand (de Schutter and Giljum, 2014), where it is calculated that global primary wood resources for EU bioenergy required an area equalling 29% of the total EU forest area in 2010, increasing to a 39% share in 2030.

Target setting and policy options in the context of sustainable consumption patterns and land appropriation

Weighted bio-productivity indicators allow a country or region to monitor its biomass consumption or land use with other countries or regions on a fair basis. As described in section 6.3, biomass consumption levels are proposed to be measured with the embodied $NPP_{harvest}$ indicator or with the normalised land footprint indicator (the weighted global ha per capita, based on a global average yield). Global average embodied $NPP_{harvest}$ or normalised land footprint levels can be considered a EU target in relation to the current consumption pattern. Bio-productivity targets for the EU are likely to increase the need for a reduction in per capita consumption of biomass or embodied land, e.g. by a shift from carbon or land intensive products (e.g. meat) towards more resource efficient food products (more direct consumption of plant based products). As curbing consumption patterns hardly occur autonomously, policy efforts are important to support such a transition. Annex 6.8 lists some of the options to support resource fairness in relation to EU consumption.

Table 57: Target proposals and control indicators in the context of sustainable consumption patterns and land appropriation

Goals	Possible expressions of targets	Types of control indicators
Equitable distribution of available biomass	By 20XX, the EU should not appropriate more than an equitable share of globally available biomass	Carbon appropriation per capita
Equitable distribution of available land resources	By 20XX, the EU should not appropriate more than an equitable share of globally available land resources	Normalised land footprint (global ha per capita)

Feasibility assessment of target proposals

Table 58summarises the feasibility assessment with respect to target implementation to support more sustainable consumption patterns. The general weakness of target implementation in this policy field is that no clear definition exists regarding fair, sustainable or equitable consumption patterns. In practice, such targets will thus monitor the increase in consumption in developing countries, showing the need to complement equity targets with targets that support a reduction in, or increase efficiency of, resource use.

Table 58: Feasibility assessment of potential targets that aim at sustainable consumption patterns and land appropriation

Potential targets	Technical feasibility	Socio-economic feasibility	Administrative feasibility
Equitable distribution of available biomass	Feasible	Feasible as indicative target, but high resistance can be expected with respect to measures supporting a reduction of appropriated biomass or land resources in developed regions.	Feasible as an indicative target, but a lack of a definition of 'equitable distribution of biomass' will complicate implementation of effective measures to support such target

Potential targets	Technical feasibility	Socio-economic feasibility	Administrative feasibility
Equitable distribution of available land resources	Feasible, but discussion exists regarding underlying calculation principles	Id.	Id.

Targets supporting more sustainable consumption patterns and land appropriation, i.e. more equitable distribution of available biomass and/or land resources, are feasible to be implemented as indicative targets. However, unsustainable consumption patterns are hard to curb and will need strong supporting measures to reduce the biomass or land appropriation of developed countries such as the EU. In practice, control indicators are projected to increase as a result of an increase in consumption of biomass and land resources in less developed regions.

6.5.6 Summary and conclusions

Setting targets in relation to global sustainable land use is challenging due to a lack of a clear concept that links global thresholds to the local operating space and/or land use to its environmental impacts. This poses a challenge on how a region with a large land footprint in third countries can reduce the related negative social and environmental impacts in these distant production areas. As recommended by Bringezu et al. (2013), we elaborated on the concept of safe operating practices and disaggregated this concept into three different dimensions:

- Responsible global supply chains;
- Adequate protection of natural areas and ecosystem functioning; and
- Sustainable consumption patterns and land appropriation.

The use of (indicative) targets in relation to the EU's role in global sustainable land use should cover the abovementioned three dimensions; preventing environmental or social impacts on a hectare of land is not enough as a growing number of these hectares and an unfair appropriation of these land resources increase the pressure on natural resources and ecosystem functioning. Although a single target in a single area will help reduce the EU's global impacts, the concept suggests the use of multiple targets to contribute to global sustainable land use.

The feasibility assessment on targets related to EU land use showed that each dimension of the concept of a global sustainable land use has its particular challenges to overcome:

With respect to **land targets that support responsible supply chains** for products imported into the EU, it can be concluded that target implementation at EU (import) level is not feasible for most production criteria yet as (1) the technical assessment shows that the allocation of impacts to end-products is a poor basis for responsible supply chains, and (2) negative socio-economic impacts in developing regions are likely to raise issues in the WTO context and are, thus, not feasible in a legal/administrative context. Targets to prevent impacts on vulnerable ecosystems and biodiversity may be eligible, but these can probably only be implemented at the (voluntary) supply chain level due to high economic costs when all companies would need to comply with these (certification) standards.

It can also be concluded that, like in the EU, responsible production is best be supported at the production (farm) level. However, due to a lack of governance structures, financial services and farm knowledge in a large number of developing countries, a broad implementation of responsible production targets at the farm level is not to be expected in the near term. Joint efforts between developing and developed countries or regions that result in the implementation of responsible production targets, including indicators and targets to improve social conditions and reduce land conflict, is recommended. This will ultimately also improve the technical possibilities to relate EU consumption with actual (not allocated) production impacts. With respect to the issue of land conflicts, the assessment shows that setting targets at EU level is hampered by the complexity of the issue and, consequently, by the lack of adequate data to monitor such issues. That leaves the EU with the 'supply chain' option to support a reduction of negative impacts in third countries, where negative impacts may not only relate to EU stakeholders, but also to local stakeholders in the country of production. This – rough – target analysis shows that voluntary (binding or non-binding) targets can be implemented, which is in line with current developments in public-private supply chain partnerships worldwide.

Land targets that support the protection of natural areas and ecosystem functioning is a priority area with respect to the implementation of land targets worldwide. It is therefore recommended that indicative targets are implemented for awareness and knowledge building purposes, which allows developing and assessing supporting policies to move the EU's land use in the direction of such an indicative target. From the target assessment, it can be concluded that an indicative deforestation target would be most appropriate – due to strong synergy effects with other environmental impacts – but that the land footprint indicator is also feasible in absence of (adequate datasets underlying) impact oriented indicators.

Targets supporting sustainable consumption patterns and land appropriation, i.e. more equitable distribution of available biomass and/or land resources worldwide, are feasible to be implemented as indicative targets. However, unsustainable consumption patterns are hard to curb and will need strong supporting measures to reduce the biomass or land appropriation of developed countries such as the EU. In practice, control indicators are projected to increase as a result of an increase in consumption of biomass and land resources in less developed regions, which supports the need to complement sustainable consumption targets with – at least – a target to protect natural land areas and ecosystems.

Overall, our assessment identifies the following promising options:

1. Implementation of binding and/or non-binding targets at global supply chain level that support database and infrastructure developments to measure and monitor responsible production indicators in the countries of origin;

2. Implementation of a deforestation (or other impact-oriented) target to prevent global natural areas - in particular forests, but also other vulnerable ecosystems- and their ecosystem functioning; and

3. Implementation of an indicative bio-productivity target that monitors the EU's biomass and/or land appropriation in comparison to the rest of the world to support the development towards sustainable consumption patterns.

7. Key conclusions

This chapter explains how the different indicators and targets may interact with each other, highlights the potential synergies and trade-offs and provides recommendations for further EU actions.

7.1 Links between the different indicators and targets

7.1.1 Links between land take and land recycling indicators

Land recycling allowing inner city development or the re-naturalisation of abandoned artificial areas is a key part of sustainable land management. It is intricately linked to the issue of land take, as in the absence of brownfield redevelopment, artificial areas are created at the fringe of cities thus increasing the annual consumption of new land. Simultaneously, new attractive developments at the outskirts of urban areas may attract local populations leading to the gradual dereliction of the core city areas, and eventually creation of new brownfield sites. In order to better control land take and mitigate the overall impacts of the development of artificial areas, greater effort is required to redevelop brownfield land and utilise inner-development potential of the urban areas in the EU.

Indicators

Data collected as part of this study does not allow quantification of how much land recycling could contribute to the reduction of land take, or the mitigation of the impacts of the development of artificial areas (e.g. through compensation mechanisms). While there might be some level of dependency between data collected on land take and on land recycling, no clear correlation between the indicators linked to these two concepts has been determined to date.

Subject to the improved availability of quality information on brownfield areas and/or total areas within the urban fabric available for (re)development(in addition to urban brownfields including also gaps sites and underutilized lots some of which may have been destined for development but have not been developed before), it would be possible to determine the total area available for development in the EU, and analyse it in the context of the EU land take trends. This would also aid analysis of potential future EU land take trends.

To realise the benefits of land recycling in the context of reducing land take, the current knowledge base on the areas of brownfield (and other urban land available for (re)development) needs to be improved. While at the moment no relevant EU-level target can be set for land recycling, related indicators can be monitored more closely (e.g. as control indicators), to better understand how land recycling contributes to achieving land take and soil sealing targets. This will be subject to determining appropriate monitoring mechanisms across MS.

Monitoring

At the EU level, the CLC or LUCAS, which could be used to monitor land take, do not allow At the EU level, CLC can be used to routinely monitor land take. In comparison, the use of LUCAS is more limited, because of the difference in sampling approaches from a campaign to another (e.g. 2009 and 2012). Neither CLC nor LUCAS allow determining the potential area of land that could be recycled or developed within existing urban areas, or estimating a share of already recycled land. A methodology to estimate the share of land recycled as part of artificial area created has been proposed (EEA, 2006) but the coarse resolution of the underlying CLC data does not allow accounting for smaller land use changes. The CLC nomenclature does not allow determining what area of land could be classed as brownfield.

The Urban Atlas may provide more accurate estimates due to its higher resolution; however it would be limited to large agglomerations only. Information could be obtained on the area of land that is currently not used (according to the existing definition in the Urban Atlas it incorporates brownfield land), and if the land accounts and flows methodology (proposed for CLC by EEA, 2006) is used, on the share of land that has been recycled based on the comparison of data between years. The feasibility of such approaches needs to be investigated in collaboration with EEA.

The use of the revised CLC dataset, which includes information from CLC, HRL and Urban Atlas, at the pan-European level, could in the short term provide better EU-level estimates of the share of land being recycled, provided it is produced routinely (a methodology to calculate it has not yet been developed; the feasibility of applying the land account and flows methodology could also be considered). It would also allow providing a consistent approach between the reporting against land take and land recycling indicators. For the urban zones specifically, the Urban Atlas would be the preferred data source given its finer resolution.

In the long term, given the local character of brownfield redevelopment, monitoring of land recycling would be best served by analysis of the data from national level inventories developed by MS. It would help them better understand how much new land will be required to meet their future infrastructure and housing needs; and how much could be delivered through recycling of previously developed land and/or inner development. At the MS level there are already examples of combined approaches to monitoring land use and land recycling. The share of land recycling has been estimated in the region of Ile de France based on land use maps (CLC compatible but with higher level of detail based on aerial photographs). This has also allowed comparing trends in land take and land recycling in a consistent way over the years. The work carried out under the INSPIRE Directive and the initiative from the EAGLE network could allow harmonising national and EU approaches in the medium term.

Role of land recycling in providing compensation for land take

The "no net land take" concept considers an option to compensate for greenfield development by desealing / renaturalising land elsewhere. Turning existing brownfields into green areas could be one option to allow for such compensation to take place. This solution could be particularly relevant in cases of brownfield land that is located outside urban areas and which would be undesirable for the purpose of economic development (e.g. due to limited infrastructure available, lack of other local amenities etc.). EC Guidelines on best practice to limit, mitigate or compensate soil sealing[143] state that

"De-sealing as a compensation measure is sometimes linked to a wider approach aiming at urban regeneration, for example by removing derelict buildings and providing for suitable areas of green space. In this case, developments in inner urban areas are exempted from compensation measures with the objective of encouraging inner urban development and stopping urban sprawl." However, in some instances renaturalising brownfields may be a suitable option in shrinking cities and regions where demand for land, even within inner urban areas, is low. Furthermore there is a value in

[143] SWD(2012) 101 final

development of green infrastructure in urban areas, reflected, for example, in improved mental and physical well-being of the population.

Realising the compensation concept in practice is complex, especially since land prices rarely reflect the environment quality of land and its capacity to deliver ecosystem services. The design of such a mechanism should also consider the administrative level at which it should be functioning. If the compensation mechanism is limited to a single municipality, this may indeed encourage fragmentation and urban sprawl as stated in the abovementioned EC Guidelines; however, at a higher administrative level (e.g. regional), a compensation mechanism may encourage soft-end use of brownfield in areas where no redevelopment would take place otherwise. In a context of high real-estate pressure and private investments, growing cities deciding to develop greenfields may not have brownfield land available for re-naturalisation (in order to compensate for new development). Cities or regions may also prefer developing greenfields despite the availability of brownfields, as economic and technical constraints of brownfield redevelopment may represent higher risks for the developers. Brownfield suitable for soft-end use or re-naturalisation may however be available in another municipality or region. This suggests that the compensation measures could better operate at the supra-municipal level and be coordinated by either regional or national level authorities.

Interaction between proposed policy instruments and other EU actions

The close link between increasing the share of land recycling for redevelopment and reducing land take means that the majority of policy instruments implemented to facilitate one of these objectives will co-benefit the other. For example, the target in Germany to reduce growth of land use for housing, transport and related soil sealing to 30 ha per day by 2020 is highlighted as an example of a national policy encouraging brownfield redevelopment. The primary impact of having this objective in place in Germany has been the start of a discussion on how land can be managed efficiently, and what land could be re-used first, before developing new sites.

Given lack of sufficiently robust data on the current area of brownfield land in the EU, it is not possible to quantify potential co-benefits at this stage. Furthermore, as discussed above the influence of re-naturalisation within cities boundaries on land take trends is not straightforward, as it may favour developments at the fringe of cities.

Because of this close link between land take and recycling, synergies in terms of future actions and research needs can be exploited. In particular knowledge exchange between MS, regions or municipalities could be facilitated on:

- The use of land recycling as a strategy to reduce land take, including examples of well-functioning policy frameworks and approaches to compensation measures;
- Best practices for estimating de-sealing, inner-development potential in cities and monitoring of land recycling;
- Best practices in delegating national land-take and land-recycling related responsibilities to the regional and local level authorities within MS (example of methodology to define regional targets and attribute local land take certificates in Germany).

7.1.2 Links between land take, land recycling and land use function-based indicators and targets

Reducing land take is expected to result in more space being preserved for the provision for other LUFs elsewhere, e.g. for nature protection, agricultural production and biodiversity hotspots. This can contribute to improving overall levels of LUF provision but might also lead to a spatial separation between areas that provide LUFs and the beneficiaries. Specifically, targets aiming at reducing land take can result in increasing population density in urban areas, i.e. an increasing efficiency of urban areas in terms of LUF4 provision (i.e. provision of housing and infrastructure). Such targets might provide an incentive for land recycling. This would however encompass the risk of development of mono-functional urban areas where there is little provision of other LUFs. Most importantly, in urban areas with a high LUF4 efficiency, less space is left for green urban areas, which have a high capacity for regulating temperature and air quality and provide space for recreation. As the demand for these regulating ecosystem services also increases with urban densification, this has to be considered and properly balanced when setting any future targets.

With a “no net land take” target, a mechanism would be needed to evaluate and compensate the impacts of gross residual land take. Rather than simply compensating land take on an area basis, LUF offsetting mechanisms could be considered. Compensation measures could be targeted at restoring or enhancing connectivity, or providing accessible green space to provide recreation possibilities to people.

7.1.3 Links between land degradation and land use function-based indicators and targets

With a high intensity of agriculture, less space is needed for agricultural production. This leaves more space elsewhere for nature protection and biodiversity hotspots. However, intensive agriculture often goes with low provision of other land functions and tends to increase the loss of soil organic matter, erosion, and pollution.

The emerging concept of “sustainable intensification”, explored by the RISE foundation, aims at more multifunctional agriculture; it does not yet have an official definition in the EU. Sustainable intensification does not point to a single development path for all agricultural systems or farms, as it depends on current agricultural productivity and environmental performance of a farm or system. Agriculture in the EU is already amongst the most productive ones, as it is considered to achieve 80% of potential yields (Jaggard et al., 2010). Yield gaps, however, may widely vary across the EU. In the most productive MS (generally from the EU-15), it is therefore expected that moving towards sustainable intensification would require more space for agriculture to fulfil the demand for agricultural products. This can be fulfilled in two ways:

- Expansion of agriculture within Europe can result in a loss of natural land and biodiversity, but could also help avoid unwanted land abandonment in, e.g., valued cultural landscapes. Under sustainable intensive agriculture, biodiversity in agricultural land would likely be higher than in the case of traditional intensive agriculture. Where it replaced natural habitats, sustainable intensive agriculture is likely to modify the biodiversity as typical species from a natural habitat can be replaced by typical species from agricultural habitats. However, depending on the level of sustainability of practices, agricultural biodiversity may not necessarily be less valuable. Many managed habitats are indeed valued for their biodiversity (e.g. farmland with hedgerows).
- Increased import of agricultural products potentially causes displacement of land take and subsequently loss of soil organic matter, erosion, and loss of ecosystem services outside the territory and control of the EU.

7.1.4 Links between global impacts-related indicators and land take / land degradation indicators in the EU

Land take largely involves the take of agricultural land for soil sealing related to housing, industry, roads or recreational purposes (1.9 m^2/yr per EU citizen, amounting to ca. 95,000 ha per year). As expansion of urban areas (esp. capital cities) often involves land sealing of the most fertile soils in a country, lost agricultural areas are likely to be compensated by lower yields, larger areas elsewhere in the EU or, directly or indirectly, outside the EU (Gardi et al., 2011). The current trend in the EU's global land footprint shows a slow but steady decrease in domestic cropland area and an increase in the foreign cropland area related to EU consumption. It has, however, not been possible to relate domestic land take to an expansion in foreign land use, as built-up land developments are not yet included in the global land accounts. The use of a domestic (EU) land take indicator could be related to more specific types of land use categories being sealed (e.g. vegetable production), which would support the monitoring of land flow accounts for this specific crop category.

Soil erosion and degradation contribute to a larger global land footprint for the EU. However, yield improvements both within and outside the EU prevent analysis and determination of evidence based land use change. Positive impacts of reduced soil erosion and land degradation in the EU depend on the effective targets that will be put in place. In general, a reduction of soil erosion will be achieved with carbon increasing land management practices which may gradually increase crop yields on those soils. Alternatively, marginal lands may also be used to promote afforestation or fast rotating lignocellulose crops (for bioenergy) which may result in a reduction of embodied forest area. As such, soil degradation and erosion targets in the EU are likely to reduce EU global land demand and to contribute to a reduction in environmental impacts in the longer term.

Table 59 provides an overview of how the various land and soil issues assessed in this study are linked with land use functions.

Table 59: Overview of land and soil issues in relation to land use functions

	LUF1: Provision of work	LUF2: Provision of leisure & recreation	LUF3: Provision of land based products	LUF4: Provision of housing & infrastructure	LUF5a: Provision of abiotic resources	LUF5b: Regulation by natural physical structures & processes	LUF6: supporting the provision of biotic resources
Land take Agricultural, forest and other semi-natural and natural land ➔ Artificial land	– Reduces employment in the agricultural, forestry and mining sectors	- Reduces recreational and cultural services in forests and other semi-natural and natural land (+) Potential to increase green urban spaces and sport and leisure facilities	- Reduces production of food, feed, fibre, wood, bioenergy and other agricultural and forestry products	+ Increases surfaces for housing and infrastructure	- Reduces the supply of minerals (e.g. salt, construction minerals) and fossil fuels	- Reduces the ecosystem services related to the regulation and maintenance by natural physical structures and processes	- Reduces the capacity of the land to support biodiversity
Land recycling Artificial land ➔ New artificial land ➔ Green urban areas ➔ Natural areas	(+) Potential to increase employment in managing natural areas	(+) Potential to increase cultural areas, green urban spaces and sport and leisure facilities	(-) Potential to increase production of food (e.g. community gardens) and other small scale agricultural and forestry products	+ Increases surfaces for housing and infrastructure *(new artificial land)*	(+) Potential to increase the supply of minerals (e.g. salt, construction minerals) and fossil fuels	(+) Potential to increase the ecosystem services related to the regulation and maintenance by natural physical structures and processes (*green urban areas, natural areas*)	(-) Can reduce the capacity of the land to support biodiversity
Land degradation In particular: soil erosion and soil organic matter	(-) Long term risk of reducing employment in the agricultural and forestry sectors	(-) Long term risk of reducing the quality of recreational and cultural services in forests and other semi-natural and natural land	- Reduces production of food, feed, fibre, wood, bioenergy and other agricultural and forestry products	- Reduces the suitability of soils for construction.	- Reduces the supply of minerals (e.g. salt, construction minerals) and fossil fuels	- Reduces the ecosystem services related to the regulation and maintenance by natural physical structures and processes	- Reduces the capacity of the land to support biodiversity

	LUF1: Provision of work	LUF2: Provision of leisure & recreation	LUF3: Provision of land based products	LUF4: Provision of housing & infrastructure	LUF5a: Provision of abiotic resources	LUF5b: Regulation by natural physical structures & processes	LUF6: supporting the provision of biotic resources
Global impacts of EU land demand	**-**/+ Various influences on employment in the agricultural, forestry and mining sectors abroad	(**-**) Risk of reducing recreational and cultural services in forests and other semi-natural and natural land abroad	+ Increases production of food, feed, fibre, wood, bioenergy and other agricultural and forestry products abroad	(+) May increase development of infrastructure abroad	**-** Reduces the supply of minerals (e.g. salt, construction minerals) and fossil fuels abroad	**-** Reduces the ecosystem services related to the regulation and maintenance by natural physical structures and processes	**-** Reduces the capacity of the land to support biodiversity abroad

Legend:
+ Clear benefit for the LUF
(+)Potential benefit for the LUF
- Negative impact on the LUF
(-) Potential negative impact on the LUF

7.2 Key recommendations for further EU actions

Key steps to enable future target setting at EU level, as well as possible alternative policy options, have been proposed in Chapters 2 to 6. A summary of the key recommendations is provided below.

7.2.1 Land take

There is a lack of harmonised terminologies across MS to describe issues related to the development of artificial areas, as well as a lack of consensus on how to assess their environmental and socio-economic impacts and how to define compensation. Although a number of proxy indicators - relatively ready to use - could be identified to take concrete steps towards a more sustainable management of the development of artificial areas, further work could be undertaken to improve the indicators and allow future target setting:

- Refining 2012 CLC datasets following the recent work of the JRC for the 2006 datasets, which integrates other datasets such as HRLs, Urban Atlas, etc.
- Pursuing the work conducted by the EAGLE network and other initiatives in the context of the INSPIRE Directive in harmonising MS monitoring efforts and standards EU procedures, in order to avoid duplication of work and increase comparability of accurate data.
- Testing different scenarios for allocation of land take across MS, based on past and future trends in population, land take and socio-economic contexts, beyond the harmonised allocation currently proposed by the JRC, in order to support MS in the definition of their own land take targets and in the reflexion about the implementation of the subsidiarity principle.
- Exchanging best practices in estimating de-sealing potential in cities, following the Berlin example.
- Testing the feasibility of the Weighted Urban Proliferation and its sub-indicators for different types of cities in the EU, following the example of Switzerland, based for instance on data from the Urban Atlas and/or the high resolution layer.

7.2.2 Land recycling

The initial steps at the EU level should be focused on improving the quality and availability of data on land available for recycling as well as the share of land redeveloped in the MS. Other key steps should include:

- Implementation of a common terminology on land recycling in the EU (definitions of brownfield land, land recycling, densification, inner development) in the EU; and
- Introduction of a requirement on MS to establish a system to record and maintain up to date information on the area of brownfield land within their territories (indicator LR1). If complemented with information on the area of land redeveloped in a given unit of time, this would additionally enable monitoring against indicator LR3 (Area of brownfield land redeveloped). Production of EU guidance on best practices in land recycling could support the development of a range of common inventory approaches.

As for the remaining indicators for land recycling assessed in this study (Total area of land within existing urban fabric which is available for inner development (LR2); Land recycling as a share of total land consumption by artificial development (LR5); Land recycling as a share of total land consumption by artificial development in Large Urban Zones covered by the Urban Atlas (LR6)), further investigation of the suitability of using CLC, CLC_r and the Urban Atlas data for the purpose of monitoring of land recycling could be undertaken. While these data sources are not considered sufficiently accurate to monitor land recycling or define potential land recycling targets, in the short term they may provide high level estimates using datasets systematised and harmonised across the MS. At the national or regional level, these should be supplemented with higher-resolution and more accurate monitoring.

7.2.3 Land degradation

The following actions at EU level would support the implementation of possible future targets on erosion and soil organic matter:

- Water erosion – Data on soil erosion highly depends on the CLC database. This database should be more frequently updated. Audits in the MS that model the water erosion rate could be performed to make sure the model and data used to estimate the erosion rate comply with key requirements (to be defined at the EU level). In addition, further research may be relevant to define how remote sensing can be used to confirm the estimated erosion rate (for water erosion).
- Soil organic matter – The measurement of the SOC content requires a high amount of resources in terms of workforce, time and money. The accuracy of the data from the LUCAS Topsoil survey could be improved by national data between two measurements campaigns. The data for the missing MS should be collected. The data gaps due to sampling difficulties could be addressed by using the possible national or regional data or by using an estimation of the SOM/SOC content.

7.2.4 Land functions/multifunctionality

To allow uniform target setting that accounts for the geographical context, includes the demand side of LUFs, and overcomes potential trade-offs among and within LUFs, the following research steps are needed:

- Further elaboration of the LUF concept to clarify the characteristics and scope of each LUF. This could be done, to a large extent, through a literature review and stakeholder consultation.
- Development of LUF-specific indicators that account for demand/supply relations at the scale of LUF demand/supply interactions (catchment vs NUTS vs national vs planning regions). For the four indicators considered as being relevant for target setting (Area of accessible green space; Potential agricultural and forestry production; Density and connectivity of green infrastructure; Multifunctionality), a number of actions to improve the indicator quality were discussed in Chapter 5.
- Monitoring and validation:
    - Indicators for LUFs are commonly based on a selection of (static) biophysical data and (dynamic) data on land use, land cover and climate conditions. Continuation of this monitoring in a harmonised way at EU level should be ensured.
    - Monitoring the status and trends of LUFs would benefit from regularly updated land cover data. The updates of the wall-to-wall CLC database currently occur every 6 years, with a substantial time lag between the data acquisition (e.g. CLC 2000, 2006 and CLC 2012 correspond to data from +/- 1 year) and operational availability of the processed data

(e.g. CLC 2012 will only be available in the end of 2014 or early 2015). This limits the possibilities for monitoring and for providing “early warnings”.

  - Independent data are needed to validate the model-based indicators, in order to make the indicators more credible.

- Feasibility assessment: While for individual LUFs values can be defined based on data or literature review, assessing potential trade-offs and assessing appropriate levels of a combined multifunctionality target require an integrated approach. By evaluating the impact of a variety of scenarios on land use and LUF provision in a land use change or integrated assessment modelling framework, synergies and conflicts between the LUFs can be identified. This can inform target setting.

7.2.5 Global impacts

The analysis showed that global impacts of EU land use refer to three challenges for a more sustainable land use: (1) land use change, which affects natural areas and ecosystem functioning, (2) sustainable consumption, which affects others’ access to land and food, and (3) land management, which affects the environmental degradation of agricultural land already in use. Indicators should be developed and implemented in all three areas. Furthermore, it was shown that the indicators derived from global land flow accounts (Land footprint, Embodied $NPP_{harvest}$ and Normalized land footprint) have not yet been implemented, as they all face specific challenges. The priority issues for further development of these indicators are as follows:

- Support the establishment of robust statistics related to biomass use in developing countries.
- Support the process to agree on standards for the definition of cropland, grassland and forest land use.
- Support the process of harmonising various approaches (physical/economic/hybrid) for establishing global land flow accounts.
- Develop standards for the treatment of supply chains, particularly in the case of non-food biomass commodities.
- Broaden the testing, application and peer-review of the $NPP_{harvest}$ methodology, including statistical institutions.
- Support the process of developing and agreeing on a normalization procedure using global statistics and recently developed spatially explicit global data sets on the actual and potential bio-productivity.
- Support the international initiatives to build and complete global environmental databases on environmental and social impacts that are potentially related to EU consumption.

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Annex 1: Overview of responses to the consultation

The consultation was launched on 24/02/2014, with a deadline originally set on 21/03/2014. Several organisations required to postpone the deadline in order to coordinate answers, as expertise relevant to land is scattered amongst different sectors. The consultation process was ended on the 18/08/2014. Table 60 provides the status of responses as collected by then. In brief:

- 19 MS provided written (complete or partial) answers to the questionnaire: Austria, Belgium, Bulgaria, Croatia, Czech Republic, Estonia, Finland, France, Germany, Greece, Italy, Latvia, Lithuania, Malta, Netherlands, Poland, Romania, Sweden, UK;
- In addition, representatives from Austria, France, Germany, Luxembourg and Netherlands were interviewed, *de visu* or on the phone.

Extensive and relevant information was provided for the land take and land recycling themes. Less information was provided for the land degradation theme. In addition to the information gathered from the respondents' answers, a desk research was conducted so as to further investigate and/or complement data retrieved from the consultation.

Table 60: Status of responses to the consultation

MS	Organisation	Response	Issues covered	Comment
Austria	- Environment Agency - Federal Ministry of Agriculture, Forestry, Environment and Water Management	X	t r (partial) d?	*Contact interviewed* *Email exchange*
Belgium	- Foundation for the Urban Environment - OVAM - Public Service of Wallonia, Division for Agriculture, Natural Resources and the Environment	X	t r (partial) economics of soils d	*Email exchange*
Bulgaria	- Environment Agency	X	t (partial), r (partial), d (partial)	*Email exchange*
Croatia	- Environment Agency	X	t, r, d	*Email exchange*
Cyprus	- Ministry of Agriculture, Natural Resources and Environment	O	/	*Desk-based research*
Czech Republic	- Czech Environmental Information Agency - Institute for Sustainable Development of Settlements	X	t, r, d	*Contact interviewed*
Denmark	- Ministry of Environment	O	/	*Desk-based research*

MS	Organisation	Response	Issues covered	Comment
Estonia	- Environment Agency - Ministry of the Environment - Agricultural Research Centre (ARC)	X	t, r, d	*Email exchange*
Finland	- Ministry of the Environment - Finnish Environment Institute	X	t, r, d	*Email exchange*
France	- Ministry for Sustainable Development, Directorate General for Sustainable Development - Etablissements Publics Fonciers	X	t, r, d	*Contact interviewed* *Email exchange*
Germany	- Federal Environment Agency - Ministry of Environment, Land Saxony - Federal Office for Building and regional Planning - Project TIMBRE - Projektgruppe Stadt+Entwicklung	X	t, r, d	*Contact interviewed* *Email exchange*
Greece	- Ministry for the Environment, Energy and Climate Change - Institute of Soil Mapping and Classification - National Agricultural Research Foundation	X	t, r, d	*Email exchange*
Hungary	- Geographical Research Institute - Ministry of Rural Development	O		*Desk-based research*
Ireland	- Environmental Protection Agency - Department of the Environment, Heritage and Local Government	O		*Desk-based research*
Italy	- ISPRA (Institute for Environmental Protection and Research)	X	t	*Email exchange*
Latvia	- Ministry of the Environmental Protection and regional Development	X	t, r, d	*Email exchange*
Lithuania	- Environmental Protection Agency	X	t, d	*Email exchange*
Luxemburg	- Ministry of Sustainable Development - GeoVille Environmental Services	X	t, r, d	*Contact interviewed* *Email exchange*
Malta	- Malta Environment and Planning Authority	X	t, r, d	*Email exchange*
Netherlands	- Ministry of Housing, Spatial Planning and the Environment - Ministry of Infrastructure and the Environment - Technical Soil Protection Committee - Radboud University Nijmegen, Nijmegen School of Management, Mapping and Planning Geography, Planning and Environment department	X	t, r, d	*Email exchange*
Poland	- Institute for Ecology of Industrial Areas	X	t, r	*Email exchange*
Portugal	- Ministry of Agriculture, Sea, Environment and Spatial Planning - Environment Ministry	O	/	*Desk-based research*

MS	Organisation	Response	Issues covered	Comment
Romania	- NHN Ecoinvest, S.R.L.	X	t, r (partial)	*Email exchange*
Slovakia	- Slovenian Environment Agency	O	/	*Desk-based research*
Slovenia	- Agricultural Institute of Slovenia - Ministry of the Environment and Spatial Planning - Environmental Agency	O	/	*Desk-based research*
Spain	- Ministry of Agriculture	O	/	*Desk-based research*
Sweden	- Swedish Environmental Protection Agency	X	r, d	*Email exchange*
UK	- DEFRA	X	t, r, d (in England and Wales)	

Legend:
X: Response; O: No response; t: land take; r: land recycling; d: land degradation

Table 61 provides an overview of the available information regarding the setting of targets with regards land take, land recycling and land degradation. Further information on the results of the consultation are available in the other annexes.

Table 61: Overview of existing targets across MS for land take, land recycling and land degradation

MS	Land take			Land recycling			Land degradation		
	T	Indicator	Scale	T	Indicator	Scale	T	Indicator	Scale
AT	Q	Soil sealing	N, L (Vienna)				Q	Share of organically farmed areas	N
							q	Natural nutrient depletion	N
							q	Soil loss caused by erosion and soil compaction	N
BE	Q	Land take	R Wallonia)						
	q	Land take	R (Flanders, Brussels)						
BG	q	Land take per capita	N				Q	Share of organically farmed areas	N
HR	q	Urban sprawl	N						
CY	No response from experts – no targets identified based on desk-based research								
CZ	q	Urban sprawl, land take and fragmentation							
DK							Q	Increase of natural areas	
EE	Q	Built-up areas	N				Q	Volume of soils exposed to erosion	N
FI	q	Urban sprawl	N				Q	Share of organically farmed areas	N
FR	Q	Land take	R,L				Q	Protected areas	N
	Q	Protected areas	N						
	Q	Reduction of agricultural areas	N						
DE	Q	Land take	N (federal), R (Länder), L (municipalities)	q	More inner development compared to development on new sites		q	Soil erosion	N
							q	Loads and levels for acidification, heavy metal and nutrient discharges and ozone	
EL				q	Restoration of the main contaminated waste disposal sites until 2020				
HU	No response from experts – no targets identified based on desk-based research								
IE	No response from experts – no targets identified based on desk-based research								
IT	Q	Soil sealing	L (municipalities)						
LV	Q	Share of agricultural areas	N						

MS	Land take			Land recycling			Land degradation		
	T	Indicator	Scale	T	Indicator	Scale	T	Indicator	Scale
	Q	Urban sprawl	N						
LT	No response from experts – no targets identified based on desk-based research								
LU	Q	Land take	N						
MT	No response from experts – no targets identified based on desk-based research								
NL	No response from experts – no targets identified based on desk-based research								
PL	q	Landscape integrity	N						
PT	No response from experts – no targets identified based on desk-based research								
RO									
SK	No response from experts – no targets identified based on desk-based research								
SI	No response from experts – no targets identified based on desk-based research								
ES	Q	**Land take per capita in cities**	R (Andalusia)						
SE					*Development on previously built sites* *(target abolished in 2011 due to implementation issues*	*N*			
UK				Q, q	Development on previously developed land	*N* R, L	q	Loss of soil carbon	

Legend: T: target; Q: Quantitative targets; q: qualitative targets ; N: national; R: regional; L: local

Annex 2.1: Overview of land use/land cover monitoring systems in place in Member States, with a focus on land take

Table 62: Overview of monitoring systems in place in MS

MS	Comments
Austria	Land use and land cover have been historically monitored based on aerial photographs and in-situ data from cadastres (*Benützungsarten Kataster*). The settlement areas, land take and soil sealing per year have been estimated every 2 years since 2007 based on this national dataset. The frequency of update of the cadastre, however, remains irregular and based on available information, it is not clear how compatible this initiative is with EU harmonised dataset nomenclature nor how accurate. Today, Austria mostly relies on this cadastral monitoring system to follow land take indicators. This monitoring system is supported by the development of regional initiatives (e.g. in Salzburg and Tyrol provinces) and its accuracy will be enhanced through inputs from the implementation of the Digital landscape model. There is no reference to the use of GMES Land Monitoring Services. The project of an Austrian wide Land Information System (LISA: www.landinformationsystem.at/) is still pending because of debates regarding the terms of its implementation. It will be based on airborne images and satellite images, with a very high resolution of 25m^2 (higher than CLC and GMES Land Monitoring Services). It is conceived to be compatible with the EAGLE nomenclature. It is currently planned to be implemented in selected regions.
Belgium	In Belgium, there is no harmonised monitoring system at the national scale beyond CLC. Belgian regions do not rely on CLC for their land planning and management, because of its insufficient accuracy to deliver robust policy recommendations (although data could not be compared in the present study). Flanders is developing its own large scale reference database (GRB), based on inputs from its municipalities (http://agiv.be/gis/organisatie/?artid=982). It has also produced a Vegetation Map in 2009 which allows mapping urban green areas. Wallonia had to abandon its regional mapping project but does monitor land use change and land take based on thematic field data, like information from the cadastres (http://etat.environnement.wallonie.be/index.php?page=key-environmental-indicators-for-wallonia-2012). It also estimated land fragmentation through the effective mesh size in a 2010 project led by SPW – CREAT.
Bulgaria	Bulgaria has developed its own initiative for a national and cover database (*Земно покритие - Референтен слой*), following the Land Cover Classification System of the FAO and compatible with CLC (http://bsdi.asde-bg.org/lccs_en.php / http://eea.government.bg/en). This database is both more accurate (MMU: 1ha) and more frequently updated than CLC (every 3 years). It is complemented by a 2009 database (2008 data) targeting 27 regional cities with a MMU of 0.01ha, which is even more accurate than the Urban Atlas developed at

MS	Comments
	the EU level (http://bsdi.asde-bg.org/lccs_en.php). This database may, however, not be updated regularly. The picture of the development of artificial areas in Bulgaria can be completed by a specific monitoring exercise of land cover along the main transportation networks, conducted in 2009 (2006 data, no planned update: http://bsdi.asde-bg.org/lccs_en.php).
Croatia	There is no information available on national monitoring systems beyond CLC.
Cyprus	There is no information available on national monitoring systems beyond CLC.
Czech Republic	There does not seem to be any national monitoring system in Czech Republic going beyond datasets produced with CLC. Czech Republic seems to mostly rely on CLC to monitor land use, which is an indicator [18] amongst the national Core set of environmental indicators (http://issar.cenia.cz/issar/page.php?id=1963). Further information on the nature of artificial areas can be provided at the municipality level, through the monitoring of basic settlement units.
Denmark	No information on a monitoring system beyond CLC could be collected.
Estonia	In Estonia, land take is monitored through the monitoring of changes in natural and agricultural areas in the frame of the Estonian National Environmental Monitoring Program (http://seire.keskkonnainfo.ee). This project aims at developing more accurate and more adequate datasets for policy making than those delivered through CLC. The definition of land take follows the one of the EEA.
Finland	Finland is one of the rare MS which developed a high resolution dataset in the context of the production of CLC datasets, by complementing satellite layer with aerial photographs, inputs from topographic maps, in-situ data and field surveys. Datasets are available nationally with a resolution of 25 m and at the EU level with a resolution of 25 ha (conventional CLC datasets) (www.syke.fi/en-US/Research__Development/Research_and_development_projects/Projects/Producing_land_cover_and_land_use_data_in_CORINE_Land_Cover_2000_project_in_Finland). An attempt was made to combine existing land use databases with a MMU of 0.25ha through the SLICES project (Separated land use element of Finland), which was eventually abandoned. Similarly, the attempts to monitor detailed thematic indicators such as “total amount of green areas within city boundaries” and “unpaved land areas” in Helsinki and Lathi were abandoned. The analysis of land take based on this high resolution CLC dataset can be complemented with inputs from the Monitoring system of spatial structure and urban form (YKR).
France	In France, several initiatives are being developed at national and regional levels, which will allow providing a more accurate picture of land take than currently available through CLC and the results of the yearly statistical survey of artificial areas compatible with LUCAS nomenclature and conducted by AGRESTE (the statistical services of the Ministry of Agriculture). First, at national level, a Geographic information layer (« OCS-GE ») is currently developed by IGN (national geodesic institute) at the national level. It is planned to be available in 2017-2018. This will allow following land take in an homogeneous and more accurate manner across the whole national territory, following a nomenclature in line with CLC. Meanwhile, the national CLC layer is used, along with the results of the yearly statistical survey of artificial areas compatible with LUCAS nomenclature and conducted by AGRESTE (the statistical services of the Ministry of Agriculture). Then, an observatory for the encroachment of agricultural areas by artificial development (ONCEA) has been developed since 2013 to follow the progress towards the national target for reducing by half the consumption of agricultural space (*article L 112-1 du code rural et de la pêche maritime*). It is expected to be extended to (semi-) natural and forest areas. Monitoring of land take based on real estate database required by Finance Ministry for the calculation of land taxes is also in progress. It will allow locating with high accuracy evolution of land take. These data are produced annually and are available to local communities and state services involved in the development of spatial and urban plans. Furthermore, several regional initiatives are being developed and progressively implemented. These include: • In Alsace : CIGAL (www.cigalsace.org/portail/fr/projet/472/sig-et-urbanisme). Urban designers and SIG experts are working together with 10 municipalities, in order to

MS	Comments
	produce relevant information to urban planners. • In Nord-Pas de Calais : PPIGE (www.ppige-npdc.fr/portail/ppige) • In Languedoc Roussillon: SIG-LR • In Île de France : IAURIF • In Normandie : *Observatoire foncier of Basse Normandie* and MOS (land cover land use) of Haute Normandie, focused on the development of artificial areas and real estate.
Germany	Land use is monitored regularly in Germany based on the cadastral survey (the so-called “*Flächenerhebung nach Art der tatsächlichen Nutzung*”- Surface survey according to the actual use) used for monitoring the 30-hactare-goal. It has a higher resolution (m^2) than CLC. It is considered the best available monitoring basis in Germany, although there are statistical inaccuracies in the history. Data of the “Flächenerhebung” are published annually at federal states-level as well as NUTS3 Level by the Federal Statistical Office (www.bundesregierung.de/Content/EN/StatischeSeiten/Schwerpunkte/Nachhaltigkeit/Anlagen/2012-06-07-fortschrittsbericht-2012-englisch-barrierefrei.pdf?__blob=publicationFile&v=2). The data is updated in case of change of land owners or in case of construction activities and sometimes also verified in the framework of land use monitoring by regional or local governments in order to actualise maps and plans. Monitoring is often done by aerial photography from air planes.
Greece	Based on available information from the consultation, there does not seem to be any national monitoring system beyond CLC.
Hungary	Hungary developed its Hungarian National Land Cover database (CLC50: www.fomi.hu/portal_en/index.php/product/national-land-cover-database-clc50) based on CLC methodology enhanced to include 79 level – 4/5 classes. CLC Layer for the EU are produced based on this enhanced monitoring with a MMU of 4 ha. Hungary also relies on a Digital monitoring system, based on Google Earth, allowing for the assessment of needs and calculations for each settlement providing a better control of land take and urban sprawl.
Ireland	Apart from the CORINE Land Cover data sets, no data from Irish authorities with regard to soil sealing or land take are available. A national land cover/land use map was made in 1995 (Teagasc) but not updated since then. The limited information available on land use, land cover and soil condition prevents robust analysis. Datasets relating to different aspects of land use and land cover in Ireland have been produced and maintained by various agencies, institutions and individuals. A significant research effort is required to bring these data together to form a consistent picture of changing land use and land cover in Ireland within a robust methodology that addresses data quality control. The EPA is currently involved in discussions with the other national agencies to try and develop an Irish national land cover mapping programme (www.epa.ie/soilandbiodiversity/soils/land/#.U5_0daFOJ1s). This will aim to replace Corine as the main national land cover dataset with a land cover data series that is more detailed in terms of spatial resolution and in its classification structure. It is envisaged that it will be based on the OSi's new Prime2 national geo-infrastructure and will have a spatial resolution of 1ha or less.
Italy	At the moment, in addition to CLC layer, land take monitoring is assured by ISPRA in collaboration with Regional Environmental Protection Agencies (ARPA) network. It is based both on a monitoring network (a sample of about 150.000 points) and on a Soil sealing map (a Copernicus-compatible map with a better spatial resolution is currently being developed). The regions Emilia-Romagna, Lombardy and Sardegna rely on sub-national CLC-compatible monitoring, respectively based on CORINE 4th thematic level (83 classes) with MMU 1560 m^2 and 5th thematic levels (105 classes) (focused on agricultural and forestry areas with MMU 1600 m^2 for Lombardy). These regional databases are based on aerial photographs, topographic maps, in-situ data and/or field survey as well as satellite for Sardegna. The Sardegna database is updated every 5 years (latest date from 2008). There is no information related to update frequency. *See links below.* The issue of a more accurate and harmonised national Land take Monitoring is being raised with the implementation of a new law currently discussed at the Italian Parliament (http://www.camera.it/leg17/126?tab=2&leg=17&idDocumento=2039&sede=&tipo=) which will limit land take. The latest report regarding land take in Italy, published in 2014, is available at: www.isprambiente.gov.it/it/pubblicazioni/rapporti/il-consumo-di-suolo-in-italia *http://www.regione.emilia-romagna.it/temi/territorio/cartografia-regionale/vedi-anche/uso-del-suolo*

MS	Comments
	http://archiviocartografico.regione.emilia-romagna.it/bookshopfe/mappeonline.html *http://www.territorio.regione.lombardia.it/cs/Satellite?c=Redazionale_P&childpagename=DG_Territorio%2FDetail&cid=1213302903435&pagename=DG_TERRWrapper* *http://www.sardegnaterritorio.it/j/v/1293?s=141401&v=2&c=8162&t=1*
Latvia	Changes in the land use types and changes in the purpose of the land use are registered in the National Real Estate Cadastre Information System, maintained by the State Land Service. The State Land Service prepares an annual overview on land and includes the changes of the indicators mentioned before. These changes are described and analysed in national and local levels. The land use type is determined by cadastral surveyors according to the existing land use, whereas the purpose of the land use is set by a local municipality's decision for the purpose of taxation and reflects existing or in some cases planned land use. The change of land use type or the purpose of land use is monitored by information updating in the National Real Estate Cadastre Information System, although this information is not graphical and may not reflect accurately the real land use type because of the time delay since cadastral surveying. In the frame of the new Law for Providing a Sustainable Land Management in the Republic of Latvia, the development of an efficient land information system for provision of complete and actual land related data is expected, but no further information on its status could be collected.
Lithuania	Land take can be followed through the Landscape monitoring, itself component of the State Environmental Monitoring Programme (SEMP), approved by Governmental Resolution. One of the main goals of LM - to assess changes of the land cover classes on national, regional and local level, to evaluate their distribution and estimate the degree of landscape polarization. It is foreseen to update SEMP every 6-7 years, and current SEMP is established for the period of 2011–2017. At national and regional levels, this monitoring is based on CLC. At a more local level, it involves the use of cartographic material – analogue and digital maps, satellite images, aerophotographs, and orthophotographic images, as well as required data collection in-situ in case of the local level evaluations.
Luxemburg	Beyond CLC, Luxembourg relies on its own national land cover map based on satellite data, aerial photographs and field survey, updated approximatively every 10 years (1989, 1999, 2007) based on CLC production. Its nomenclature is compatible with CLC level 5. MMU = 500m^2, with a pixel size of 0.5 to 1m.
Malta	Malta relies on a national landcover/landuse map for local planning and strategic planning beside CLC but no more information on the associated monitoring system could be collected.
Netherlands	The Netherlands have developed the *Landelijk Grondgebruiksbestand Nederland* (LGN) Land use/cover database (www.lgn.nl). The LGN dataset is based on satellite imagery and additional data from aerial photographs, topographic maps, statistical information, etc. It is updated every 4 years approximately. It is not clear to which level its nomenclature may be compatible with CORINE. Another interesting initiative is the development of the *Bestand Bodemgebruik* (BBG) land use database (www.cbs.nl/nl-NL/menu/methoden/classificaties/overzicht/bestand-bodemgebruik/default.htm), which is a hierarchical classification based on the different land use functions, updated every 2 to 4 years.
Poland	Corine Land Cover as well as Urban Atlas (for selected cities according to EEA) are used for monitoring "land take", although the main tool for monitoring "land take" in Poland is the database of topographic objects (*baza danych obiektów topograficznych - BDOT10k*). The Database of topographic objects, at a scale 1:10 000, is based on satellite data, topographic maps, field survey and statistical data. Digitalised maps and databases are available to the beneficiary through Documentation Centre of Geodesy and Cartography (CODGIK). Head Office of Geodesy and Cartography is responsible for activities related to this issue. At the regional level the same data are provided by the Regional (Voivodeship) Centre of Geodesy and Cartography.
Portugal	Besided CLC at national and regional scales, Portugal has developed a more accurate Land Use and Land Cover map of Continental Portugal for 2007 (CO2007). There is no

MS	Comments
	information on its latest update that could allow monitoring land take. It is based on high spatial resolution data, with aerial images. The technical specifications of COS2007 built on the INSPIRE Directive. Thus, COS2007 builds on CLC nomenclature, with the first three levels of both maps being the same. Initiatives are also developed at the regional level, as in the Madeira region with the COSRAM initiative (which aims to attain a better spatial resolution, with a refined nomenclature - compatible with the COS - tailored to regional specificities) (www. Geocidmadeira.com/).
Romania	There is no specific monitoring system beside the national CLC.
Slovakia	According to the information collected, there is no specific monitoring system beside the national CLC.
Slovenia	According to the information collected, there is no specific monitoring system beside the national CLC.
Spain	Besides CLC, Spain has an interesting monitoring initiative (SIOSE), managed by the Spanish National and Regional Public Administration, consisting in integrating and harmonizing the land cover/land use information of the National and Regional Public Administration (www.siose.es). It is updated every 2 years and rely on satellite data, aerial photographs, topographic maps, field surveys, cadastre, regional land cover databases, etc. Initiatives of high resolution cartography are also developed at the regional level, as in Cataluna (www.creaf.uab.cat/MCSC/esp/index.htm), also based on a combination of satellite data, photographs, filed surveys, cadastre data, etc. (MMU=500m^2).
Sweden	According to the information collected, there is no specific monitoring system beside the national CLC. However, although it is produced following the EEA methodology, it is complemented by ancillary information as well as data from various national registers, maps and orthophotos.
UK	The UK developed a national Land Cover Map, an associated product of Countryside survey, which maps changes in land cover including changes in developed area at a significantly higher resolution than Corine. Further detail can be found at http://www.ceh.ac.uk/landcovermapping.html#Introduction. Land Cover Map has many applications and is the primary driving data utilised for Land Use Land Use Change and Forestry (LULUCF) Green House Gas Inventory reporting. The LULUCF calculates the emissions and removal associated with land use and reports against a range of climate change reduction commitments including Kyoto Protocol, United Nations Framework Convention on Climate Change and the European Commission Reporting Mechanism. Land Cover Map has also been used to parametise the Glastir Monitoring and Evaluation Programme modelling framework. Within this framework we simulate intervention impact upon a wide range of ecosystem functions and pressures including fragmentation.

Annex 2.2: Overview of Member States' targets relevant to the development of artificial areas

Overview and lessons learnt

The no net land take target set in the Roadmap appears to be a supporting political tool for national governments that have already been trying to implement targets as well as a driver for other countries to be more proactive in the definition of targets.

In practice, "no net land take" targets have been very little implemented across MS so far, which prefer implementing economic compensation mechanisms. This is observed in several MS, as in most Eastern central European countries (e.g. Czech Republic, Poland, Slovakia), which established a compensation fee when new developments occur on valuable agricultural soils. However, to our knowledge, examples of implementation of such targets exist in Belgium and Germany, with more or less success (Box 9).

Box 9: Examples of implementation of net land take 'targets'

Until recently, the example of the **Walloon region** (Belgium) was the closest from applying the arithmetic concept of "no net land take". There, in 2005 it was required that any new zone to be urbanised must be compensated arithmetically in land use plans, i.e. that for each hectare of land made buildable, one hectare of "buildable" land should be brought back to "non-buildable". Since then, this requirement has been progressively soften, through Decree Resa and Resa bis. The first one introduced the possibility to apply an alternative compensation, consisting in debatable restoration actions, rather than "arithmetic" one. The second one introduced flexibility in the requirement for compensation, leaving it to the appreciation of the land developer, depending on the estimated impact of land take.

Germany also promoted "no net land take" targets at regional (e.g. in Baden Württemberg) or local level (e.g. in Dresden) through requirements for compensating every newly artificialised land by desealing/renaturation elsewhere. However, it does not advocate for the arithmetic approach (1 ha restored land for 1 ha of land take). It rather promotes a "functional" approach through systems of eco-points. In Dresden (Sachsen), the restoration for compensation must take place within the city. Similarly, in Baden-Württemberg, for a same ecological value, proximity between the site of land take and the restored site ("*Ausgleichmassnahme*" – restoring type of compensation) is generally advocated vs. a remote place of intervention (*Ersatzausgleich* / replacing type of compensation)[144].

[144] § 19 Abs. 2 BNatSchG, § 21 Abs. 2 NatSchG

However, with the entry in force of the new *Bundesnaturschutzgesetz* in March 2010, stakeholders are likely to become able to choose between both approaches.

Without necessarily promoting “no net land take”, **regulating the amount of land take** or **restricting the location of new developments** appear to be the most widespread strategies when setting quantitative targets. Corresponding targets mostly rely on expert judgement and details about the target setting process are rarely available[145]. The achievements made in the different countries show that these targets are perceived as ambitious in the field, although generally relevant from an environmental perspective.

At national level, targets remain mostly indicative. However, they **deliver strong political messages, highlighting the commitment and the strategy of the country** to mitigate issues related to the development of artificial areas. National targets set in national planning strategies are particularly relevant to ensure the **permanence and high ranking of issues related to the uncontrolled development of artificial areas in national agendas**, irrespective of administrative and political changes in governance at regional and local levels. These targets have shown to be a powerful incentive that triggered further research, the development of monitoring and assessment tools and successful awareness raising amongst stakeholders (e.g. AU[146], DE[147], FR[148], IT[149]).

The acceptability and implementation of targets seem to mostly depend on the involvement of regional and/or local governance – in charge of concrete planning decisions - in the process of target setting. Specificities of land use and socio-economic trends as well as governance models call for disaggregating these strategic targets at lower levels of governance in order to ensure both their relevance and acceptance. Where the national scale has a direct influence on local communities, targets could be set nationally. Where the regional scale has higher influence on spatial planning, it could be more effective to set quantitative targets at regional levels coordinated by national guidance. The challenge is to ensure that the overall contributions allow the national and EU target to be achieved, hence the necessity to develop adequate and harmonised reporting as well as compatible monitoring systems.

Except in Germany and Luxembourg (see

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145 The target setting processes observed in Luxembourg seem to be an exception.

146 In Austria, setting a land take target allowed clarifying semantics and developing a national monitoring system to better detect land take. The research programme REFINA “Research for the Reduction of Land Consumption and for Sustainable Land Management” was launched in 2006 and is part of the German National Strategy for Sustainable Development. More than 100 projects in about 50 research collaborations and individual projects are involved in the REFINA research programme.Funded projects have developed innovative concepts for reducing the rate of land take and for encouraging sustainable land management.Special emphasis is put on inner urban development and reuse of brownfield sites.

147 In Germany, research projects have been conducted to better understand how to achieve the national targets and identify new political instruments that could help move towards a more sustainable path.

148 In France, a specific observatory is being created to monitor the consumption of agricultural areas. Local urban communities have to reflect on how to reduce their space consumption.

149 Italy is also about to set national land take and/or soil sealing targets, as currently discussed in the Italian Parliament, but no information could be obtained yet on the process for target setting nor on the scale at which targets will be set. Source: www.camera.it/leg17/126?tab=2&leg=17&idDocumento=2039&sede=&tipo=

Box 10), where significant research has been done on the principle of subsidiarity, the reasoning behind how national land targets can be redistributed in practice across the different levels of governance (regional, local) is not established.

Box 10: Examples of implementation of the subsidiarity principle

In Germany:

In 2009 the Commission for Soil Protection also recommended regional goals for each of the federal states (Länder) which taken together add up to the 30-hectares goal[150]. Research work from the German Environment Agency identified key relevant subsidiarity criteria to transpose the national target into Länder targets and local targets. At the Länder level, these include population trends and historic trends of land take. At the local level, only the population is considered, as historic land take trends were not considered relevant. The experience of Germany showed that national guidance defined through quantitative targets could be successfully undertaken by lower levels of governance. Several Länder are now voluntarily working on developing their own target based on the national proposal, such as North-Rhine-Westphalia with a proposal of a maximum land take of 5 ha / day by 2020[151].

In Luxembourg:

In Luxembourg, the Ministry of Environment launched a study (confidential) to allocate a 1 ha land take/day national target to different municipality types. The results are not published but the allocation lies on the distinction between urban and rural environments as well as on levels of utilization density (number of jobs and inhabitants per artificial areas). National planning decisions, such as future development of business parks, are also taken into account in the allocation of development opportunities and restrictions, for equity purposes between municipalities. The values obtained are powerful guidance instruments for the Luxembourg government to negotiate with municipalities their future plans for artificial development (to be revised following the revised law of 19 July 2004 related to municipal and urban planning. In general, this approach is well accepted by municipalities, although more reluctance is encountered in the rural environment, as they are given less opportunities for expansion than in the urban environment[152].

This issue of land stewardship seems to be politically sensitive in a large majority of MS. This makes the principle of subsidiarity a great challenge. Lessons learnt from practical cases show that local communities are very reluctant to adhere to binding requirements from higher levels of governance, even from the regional level. Binding requirements therefore do not guarantee the implementation of the target. In some countries, like in the Netherlands, this seemed to have favoured in the last few years the transition towards weak national and provincial land planning and instead benefited decision-making at the very local level. In others, like in Spain, the implementation of targets is impeded by political debates between different levels of governance (see

[150] www.umweltbundesamt.de/publikationen/flaechenverbrauch-einschraenken-jetzt-handeln.
[151] www.bezreg-koeln.nrw.de/brk_internet/gremien/regionalrat/sitzungen_regionalrat/lep_nrw_koeln.pdf
[152] Pers. Comm. with Peter Phillips, from the Luxembourg Ministry of Environment

Box 11).

Box 11: Examples of difficulties related to land stewardship

<u>In the Netherlands:</u>

The National Spatial Plan was not renewed and the country could assist to the progressive withdrawal of provincial land contingencies[153].

<u>In Spain:</u>

In the region of Andalucía in Spain, the setting of binding requirements for the location of new developments, in order to limit urban sprawl, has been rejected by both private land developers and some municipalities. The municipalities brought the matter to court in order to reclaim the right to manage their own territory themselves. It is interesting to highlight that the court decided in favour of the province of Andalucía, because of the principle of land as a common good, where sustainable management goes beyond private interests. Andalucía had, however, to consent to some adjustments in the targets, through the Decree 11/2008, which provided some flexibility by removing the targets on industrial areas and by adjusting the percentage of population following different city typologies[154]. In 2012, however, it reiterated its commitment to have the targets implemented at local level through the introduction of emergency measures (Decree Law 5/2012). These encourage municipalities to revise their general plans. For instance, the national government can pre-empt the planning powers of municipalities or the strict prohibition of developments, should municipalities not adapt their plans to the Territorial Plan for Andalucía (POTA). The targets are still heavily debated by developers and municipalities that would like to introduce new exemptions for commercial and touristic activities, as well as to base the population target on the population during the peak season rather than based on the census of permanent population (the current practice).

France is another case where governance at the regional level can set binding targets for a group of local urban communities, but the fact that all communities are involved in the drafting of the planning document following a participatory process may increase the acceptability and their engagement for the target set[155].

The acceptability issue seems to be less of a debate when it is directly suggested at local level, although pressures from economic stakeholders can lead to exemptions weakening some requirements. Key examples of local binding requirements relevant to the development of artificial areas relate to soil sealing, which is addressed in Chapter 5.

[153] Pers. comm. from Lidia Carton, from the Mapping and Planning Geography, Planning and Environment department of Nijmegen School of Management.

[154] Regarding the population target, it foresees exemptions to the 30% limit for municipalities featuring a population growth lower than the regional average of 10,2% over the last ten years, according to the following typology:

a) 60% for municipalities with less than 2,000 inhabitants,
b) 50% for municipalities between 2,000 and 5,000, and
c) 40% for municipalities between 5,000 and 10,000 inhabitants.

In addition it also provides exemptions for municipalities of less than ten thousand inhabitants that have exceeded the 10.2% growth in the last ten years, under specific circumstances.

[155] Unfortunately, more specific information could not be gathered on the actual implementation and acceptability of these regional targets based on the consultation.

Details per Member State

Table 63: Overview of Member States' targets relevant to the development of artificial areas, at national, regional and/or local levels

Indicator	Location	Scale	Target	Status	Comment	Target source
Amount of land take	Austria	N	Until 2010 the increase of annually sealed soil shall be reduced to one tenth of its initial value (i.e. about 1 ha / day)	Indicative + project of law	Definition of target based on expert judgment, without a clear idea at the time of the difference in semantics between soil sealing and land take. Austria did not reach the policy target for 2010. Policy instruments were not associated to the process of target setting. It was more perceived as a recommendation for the regional levels to take action. Target setting, however, triggered interest for the issue as well as further work on semantics and awareness raising. The previous soil sealing target is expected to evolve into regional land take targets, to be defined jointly by Ministry of the Environment and Agriculture, the Austrian association of municipalities, the Trade Association and other key stakeholders, as claimed in the "Soil Charta 2014" which was signed on March 27 2014. There is no reasoning yet on the issues of subsidiarity. (Pers. comm. with Gundula Prokop from the Austrian Environment Agency and Fiala Ingeborg, from the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management)	2002 Austrian Strategy for Sustainable Development
	Estonia	N	Limit for built-up areas to 1.5% of total mainland areas in 2013 compared to the 1993 level (at 1.1%).	Indicative	No information on a possible update	National Environmental Action Plan for 2007-2013
	Germany	N	Reduction of land take to 30 hectares per day by 2020.	Indicative	Between 1997 and 2000, Germany consumed about 130 ha a day through the development of artificial areas. In 2007 the reduction of land take and implemented measures were evaluated. A decreasing trend in annual land take was observed as it reached about 113 hectare per day between 2004 and 2007 but was still clearly insufficient and showed that powerful measures were still necessary to reach the "30 hectare" policy target. For the succeeding period a slight decrease of the average daily land take was observed to reach 104 hectare per day in 2010 down to 74 ha/day in 2012. In 2014, the latest (unpublished) figures amounts to 69 ha/day. If figures are extrapolated to 2020, the goal will not be reached, especially with expected growth in construction after the 2008 crisis. Germany has put efforts to develop proposals to distribute the national target at regional and local level. This approach is based on population trends (past and future) and historic land use trends. To allocate new developments efficiently, Germany is now considering the implementation of innovative policy instruments that are tradable land certificates and the production of follow-cost estimators to achieve the targets in a consistent manner across the country.	German Federal Government (2002): Perspektiven für Deutschland.

Indicator	Location	Scale	Target	Status	Comment	Target source
					Beyond the target, the ultimate goal remains the decoupling of economic development from the loss of land resource. With the revision of the Sustainable Strategy expected in 2016, a full evaluation of the 30 ha target will be performed. (Pers. Comm. With Gertrude Penn-Bressel from the German Environment Agency and Günther Bachmann from the German Council for Sustainable Development) Details of the application of the subsidiarity principle are provided in Table 64	
		R	Land take limits		North-Rhein Westfalen: In the medium term, reduction from 15.5 ha per day to 5 ha per day by 2020. In the long term, target to reach "*Netto-Null*". This target was formulated in 2007 and derives from the target set at federal level. It is not binding. Sachsen: Reduction to less than 2 ha a day by 2020 Hessen: Increase of the area converted to housing and transport reduced to 2,5 ha/day as of 2020; intermediate goals: 3,1 ha/day as of 2012 and 2,8 ha/day ab 2016. This target was formulated in 2012. Baden-Württemberg: In the long term, target to reach "*Netto-Null*". This target was formulated in 2006. Saarland: Limit land take to less than 0,5 ha/d	
	Italy	N	Land take limits	To be determined Project of law	Project of law (Pers. Comm. With Michele Mufano, from ISPRA)	Atto Camera: 2039. Disegno di legge: "Contenimento del consumo del suolo e riuso del suolo edificato" (2039)
	Latvia	N	Land take limits	Indicative	The Land Policy Guidelines 2008-2014 aim to keep the agricultural land in 2014 in the same amount of the total territory as in 2008 – 37% of the total territory. It is anticipated that the forest areas will even expand from 45.5% in 2008 to 48% in 2014. It is also anticipated that the urban sprawl will reduce from 90 % of the territory in 2007 to 10% in 2014. The total amount of built areas is believed to increase insignificantly from 4.1% in 2008 to 5% in 2014. These are considered realistic targets keeping in mind that the main period of economic boom was in 2008, so this was also the period of the most intense land take. These targets were also set considering previous trends in land take and land use changes during the previous years.	Land Policy Guidelines 2008-2014
	Luxembourg	N	Stabilisation of future land take to a maximum of 1 hectare per day until 2020	Indicative	National target set in the National Sustainability Plan for Luxembourg in 2010, which correspond to land take as defined by the EEA. It is based on preliminary studies related to historic trends, future infrastructure needs and estimates of available land for development. Since then, better knowledge has been acquired in particular through the development of the national monitoring system (*Occupation Biophysique du Sol*). This national target is not considered very ambitious by the Ministry of the	2010 National Plan for Sustainable Development

Indicator	Location	Scale	Target	Status	Comment	Target source
					Environment and could be refined in the next few years. However, it is still difficult to reach for rural municipalities. It is more acceptable for urban communities which benefit from more opportunities for dense development. Municipalities are asked to revise their development plans following the national land take target. According to the Environmental Strategic Assessment to be conducted following the revised law of 19 July 2004 related to municipal and urban planning, communalities must conduct an ex-ante analysis of the environmental impacts of their development and submit it to the national government for discussion and recommendations. In order to provide concrete guidance for space consumption threshold for each type of municipality, the Ministry of the Environment ordered a study (confidential) to allocate the national target to each typology of municipality, based on urban vs. rural municipalities and the density of utilisation (number of jobs and population per ha of artificial development). Two scenarios of land take were investigated in order to calculate average values for each type of municipalities: a baseline scenario and a sustainability scenario including the achievement of the target. These local indicative values are successfully used by the government to negotiate the future developments of municipalities. (Pers. Comm. with Peter Phillips, from the Luxembourg Ministry of Environment)	
	France (SCOT)	R	Mandatory target setting for land take in territorial planning documents	Binding	Since the *Grenelle* laws of 2009 and 2010, SCOT (non-obligatory territorial planning documents) should set targets for efficient use of agricultural land, natural land and forests. The economic, administrative and technical feasibility of these targets was assessed and progress is regularly monitored. These targets are binding (L.122-1-2), and their level of ambition must be justified in the SCOT based on past land take trends and future projections. Following the current territorial reform, it is expected that SCOT will be developed at regional level and therefore that land take targets will be defined for each administrative region. (Pers. Comm. With Doris Niklaus from the Environment Ministry / Presentation from Dominique Petigas-Huet on 19/06 at the Land as a resource Conference in Brussels)	SCOT
Urban sprawl (% of new development outside city boundaries)	UK	N	60% of new developments must be performed on already developed land		This target clearly aims to encourage recycling and retrofitting of existing buildings.	
	Luxembourg	N	New developments for housing in rural municipalities must be limited to 20% of the population (existing households), while respecting specific	Binding	Not implemented yet, target still under development, expected to be published in 2014 in the context of the *Plan Structurel Logement*. Target proposed based on an assessment of overall future needs for households. Along with this target, rural communities must define priority areas for urbanisation, where they must respect specific thresholds for density (to be determined). (Pers. comm. with Myriam Bentz, from the Luxemburg Internal affairs Ministry)	Futur Plan Structurel pour le Logement

Indicator	Location	Scale	Target	Status	Comment	Target source
			density			
	Belgium (Flanders)	R	60% of new developments must be realised in urban areas and only 40% in rural regions until 2007	Indicative	Regional binding target under revision, which was not achieved in 2007 nor in 2012. The Spatial Plan is currently being revised into a Flemish Spatial Policy Plan for the period 2020-2050 and will provide stricter and binding regional targets for spatial development. According to the annual Environment Report (2007), land take in rural areas has been decreasing. However, the policy target of 60% development in urban areas until 2007 was not reached.	Spatial Structure Plan for Flanders (RSV)
	Spain (Andalucía)	R	Quantitative urbanisation limit for master plans of medium and large municipalities: 40% of the previously existing urban land or 30% of the previously existing population within eight years	Binding	According to a Spanish real estate agency [156], this target has faced continuous resistance from several municipalities of the Costa del Sol and the Junta de Andalucía, which have been reluctant to adapt their local general plans according to this limit: in early 2014, out of the 62 Andalusian coastal municipalities, only 10 had revised their urban plans in order to adapt them to the POTA, and at the regional level, out of the 595 municipalities that make up Andalusia, only 68 (11%) did so. Since 2006, regulatory measures have been taken in order to introduce some flexibility (Decree 11/2008) and encourage the municipalities to revise their general plans accordingly (Decree-Law 5/2012 which prohibits the development plans exceeding the limits of growth of the POTA in the municipalities that have not negotiated the mentioned revision of the urban plan; Instruction 1/2013 which totally forbids exceeding the percentages of growth allowed), yet without achieving so far intended results.	Decree 206/2006, as part of the General Plan for Andalucía (Art.45) (POTA)
	Germany (Dresden)	L	Long-term planning target whereby built-up land for settlements and traffic is to be confined to 40 % of the total urban land			
Consumption of agricultural areas	France	N	Reduction by 50% of the consumption of agricultural land between 2010 and 2020	Indicative	This non-binding target is mentionned in the « *loi de modernisation agricole et de la pêche* » (LMAP). It is considered a key political message, but is not based on any robust scientific study. There is no reasoning yet on the issues of subsidiarity. (Pers. Comm. With Doris Niklaus from the Environment Ministry)	
	Latvia	N	Agricultural land in 2014 is in the same amount of the total	Indicative		Land Policy Guidelines 2008-

[156] www.panorama.es/blog/1847-regional-development-planning-on-the-costa-del-sol.html

Indicator	Location	Scale	Target	Status	Comment	Target source
			territory as in 2008 – 37% of the total territory.			2014
Degree of soil sealing	Austria (Vienna)	L	In new construction sites larger than 500m², it is required that 10% must stay unsealed. This amounts goes up to 2/3 for new constructions in residential areas.	Binding	This is not a target as such but part of building regulations, which set a minimum threshold for unsealed surfaces. The implementation of these requirements is limited through exemptions, for instance for areas for which the unsealed surface to be respected would be less than 10 m², or if holding the area free would be against a functional use of the site. (Pers. comm. With Fiala Ingeborg from the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management)	
	France	N	Sealing for parking purposes (commercial activities) has to be ¾ of total floor area of commercial facilities of more than 1 000 m²	Binding	Until the *Loi ALUR*, the restriction amounted to 1.5 times the total floor area of commercial facilities. The 75% target is contested and may not be widely implemented because of its additional costs for economic stakeholders, for which parking area is a key element to ensure their commercial activities. The implementation of such targets would then require the development of underground or top roof car parking (with a supplementary costs of about 6 to 10 times based on a estimation from the *Conseil du Commerce de France*[157]), unless permeable pavement is used, which then exempts the implementation of the restriction. Where hybrid or electric vehicles are used, this requirement does not apply either. In some specific cases, the 75% threshold can be increased to 100% (and is then defined in *Plan Local d'Urbanisme*)	Loi Alur (March 2014)
	Germany (Munich)	L	Target to de-seal 15% of sealed surfaces by 2020.		According to an expert of the Munich Department of Horticulture and to the person responsible for de-sealing measures, all public areas have already been de-sealed as far as possible (Artmann, 2013).	
	Italy	L	Sealing limits for new developments (building activities)	Binding	Targets defined in municipal master plans in Milano, Brescia, Padova, Parma, Modena, Bologna, Firenze, Roma; and all municipalities of the Alto Adige region.	art. A-25 , Legge regionale 24 marzo 2000, n. 20 "Disciplina generale sulla tutela e l'uso del

[157] Position paper about Loi Alur, from 05/11/2013

Indicator	Location	Scale	Target	Status	Comment	Target source
						territorio
Degree of fragmentation	Germany	N	Compared to the 2002 situation, reduction in mesh size should be less than 1.,9% for m_{eff} > 10 km^2; less than 2.4% for 10<m_{eff} < 20 km^2; less than 2.8% for 20<m_{eff}<35 km^2; and 3.8% for m_{eff}>35 km^2	Indicative Not implemented	This target was proposed in 2003 by the Umweltbundesamt and was thought to apply to German regions. In the end, it was not implemented. The main reason for this was the difficulty for stakeholders to understand how to achieve the target. (Pers. Comm. With Gertrude Penn-Bressel from the German Environment Agency)	Umweltbundesamt, 2003. Reduzierung der Flächeninanspruchnahme durch Siedlung und Verkehr

Table 64: Application of the subsidiarity principle for target setting in Germany[158]

Bundesland	IST		Zwischenziele (Vorschlag)		Ziel der Nationalen Nachhaltigkeitsstrategie
Zeitraum	**2001 - 2004**	**2004 - 2007**	**2007 - 2010**	**2012 - 2015**	**2017 - 2020**
Berlin	0,29	0,28	0,50	0,68	**0,85**
Hamburg	0,79	0,77	0,68	0,59	**0,51**
Bremen	0,17	0,20	0,17	0,18	**0,18**
Nordrhein-Westfalen	15,2	15,4	11,6	8,7	**5,7**
Saarland	0,72	0,75	0,57	0,44	**0,31**
Baden-Württemberg	10,4	9,3	7,8	5,7	**3,6**
Hessen	3,9	3,9	3,1	2,5	**1,8**
Sachsen	5,2	5,4	3,8	2,6	**1,5**
Rheinland-Pfalz	5,8	6,6	4,2	2,8	**1,5**
Schleswig-Holstein	8,4	6,7	5,8	3,6	**1,4**
Bayern	18,0	16,9	12,9	8,8	**4,7**
Niedersachsen	14,4	13,5	10,2	6,7	**3,2**
Thüringen	2,2	1,6	1,6	1,2	**0,7**
Sachsen-Anhalt	12,8	16,1	5,6	3,5	**1,4**
Brandenburg	8,2	8,3	5,6	3,5	**1,3**
Mecklenburg-Vorpommern	8,7	7,2	5,9	3,5	**1,2**
Deutschland	**115,1**	**112,8**	**80,0**	**55,0**	**30,0**
Berlin und Brandenburg	8,5	8,6	6,1	4,1	**2,2**
Niedersachsen, Schleswig-Holstein und Hansestädte	23,8	21,1	16,8	11,1	**5,4**

158 Kommission Bodenschutz des Umweltbundesamt (2009): Flächenverbrauch einschränken – jetzt handeln (translation: Reducing Land Take -act now), Download: http://www.umweltbundesamt.de/boden-und-altlasten/kbu/index.htm

Annex 2.3: Overview of key policies highlighted by Member States as contributing to the control of land take (instruments going beyond EU policies)

Overview of key policies implemented in countries that set targets and lessons learnt

Across MS, the most common approach to controlling land take is to develop spatial planning regulations, which authorise or restrict certain developments within a territory[159]. Whatever the range of complementary instruments implemented, a strong spatial planning strategy at the national level seems to be a key to ensuring that land take issues are part of the political agenda. Policies can then be developed at regional and local levels to ensure the implementation of these key principles in spatial planning. The situation in the Netherlands is interesting in this respect, as the project of the Fifth National Policy Document on spatial planning (of the Ministry of Housing, Spatial Planning and Environment) was eventually dropped after a change in national government. This document provided the possibility to control urban sprawl in municipalities through the delineation of red contour lines and development planning regulated by the provinces. Since then, governance was fully delegated to the municipalities with a weak role at national and provincial levels, leading to non-harmonised increases in the development artificial areas.

Several **planning initiatives** aim at containing urbanisation in the countries that set targets. However, despite the binding nature of these instruments, their concrete implementation remains difficult. A few examples are highlighted in Box 12.

Box 12: Examples of concrete implementation of planning initiatives

Policies in the UK were particularly successful in the past to constrain urban sprawl. There, the best and most versatile land is mapped to identify land with the potential for high yields and ensure that this land is used for agriculture. Greenbelts, jointly with land recycling policies, have shown to be able to effectively protect green areas in the surroundings of cities in the past. However, they are now increasingly threatened by pressures for new development and questioned by many city councils under the pressure of the housing crisis.

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[159] The recent report from ETC/SIA provides extensive information on this issue across MS: Ludlow et al. (2013). Land Planning and Soil Evaluation Instruments in EEA Member and Cooperating Countries. Final Report for EEA - December 2013

In France, the *Loi Littoral*[160] was considered an essential instrument to preserve coastal areas from uncontrolled urbanisation due to touristic pressure, as it forbids any new construction or development within 100 m from the sea or static water bodies of more than 1000 ha (19 lakes concerned in France, amongst 13 in mountainous areas)[161]. Subject to great pressure from the multiple users of coastal areas, the Loi has been progressively emptied from its original substance through a number of exemptions, even though land take is still increasing at an alarming pace. Despite its acknowledged interest, a report from the French Parliament highlighted in January 2014 the difficulties related to the concrete implementation of the law[162]. In particular, it points to heterogeneous understanding of legislative requirements, which do are not always relevant to local specificities, inconsistencies with other regulations such as the requirement for compliance of buildings with the latest standards. Several recommendations aim to overcome these shortcomings. They include the decentralisation of the implementation of the law, as well as the integration of the notion of density to promote the densification of existing urban fabric. Another proposal would be to integrate a land take indicator to the calculation of local budget dedicated to municipalities (DGF, *Dotation Globale de Fonctionnement*). Spain has implemented a similar law since 1988, which strictly regulated building activities within the first 100 metres from the sea. Similarly to the progression of exemptions in the French Law, the reform from May 2013 (Law 2/2013 from 29 May) limits interdiction of building activities within 20 meters from the sea under certain conditions[163].

Still in France, the *SCOT*, which include binding targets for land take and objectives for urban density, are planning instruments for a group of towns aiming at ensuring the sustainable development of balanced land use types and restrict space consumption. They are approved at the national level, which allows ensuring the consistency with the national strategy. However, as they are not mandatory but only strongly recommended in areas with key development challenges, such as urban and coastal areas, only 20% of the territory has developed and implemented a *SCOT* so far. Furthermore, the administrative complexity caused by the necessity to ensure compliance with multiple sectoral plans impedes their implementation.

In its new *Plan Structurel Logement*, Luxembourg will be requiring rural communities to define priority areas for urbanisation in order to regulate land take and stay in track with the development target. Within these priority areas, cities will have to respect a certain threshold for density, yet to be defined. In addition, in its new *Plan Structurel Transport*, Luxembourg will be setting restrictions for the development of parking lots in commercial and industrials areas, in order to limit the use of private vehicles and reduce the dependency on “private” transport networks, which contribute to urban sprawls. These initiatives have not been implemented yet, so it is difficult to assess their acceptability and efficiency. Furthermore, Luxembourg will extend its reform of municipality and urban planning[164] to 2018 in order to give more time to municipalities to carry out an Environmental Strategic Assessment of their future needs for development (which includes as land take as an indicator) and adjust it following the national land take target.

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[160] *Loi n° 86-2 du 3 janvier 1986 relative à l'aménagement, la protection et la mise en valeur du littoral*

[161] www.vie-publique.fr/documents-vp/loilittoral.pdf

[162] www.maire-info.com/upload/files/Rapport_senat_loi_littoral.pdf

[163] Ley 2/2013, de 29 de mayo, de protección y uso sostenible del litoral y de modificación de la Ley 22/1988, de 28 de julio, de Costas: www.magrama.gob.es/es/costas/temas/modificacion-de-la-ley-de-costas/ley-de-proteccion-y-uso-sostenible-del-litoral-y-de-modificacion-de-la-ley-de-costas/default.aspx

[164] *Loi modifée du 19 juillet 2014 concernant l’aménagement communal et l’aménagement urbain*.

Building regulations also represent interesting opportunities for halting land take, although their impact remains mostly local, with uncertainty regarding consistency at the regional level. Subsidies or penalties for housing have direct guiding effects for the land use, but their overall costs and the permanence of their outcomes, for instance when funding stops, is still controversial.

Other binding instruments may aim to mitigate land take impacts, such as in Germany, where the requirement from "unsealing" included in the Federal Soil Protection Act enables the Federal Government to request from a landowner that he maintains or returns soil to productive use as far as possible and reasonable where the soil has permanently not been used and whose sealing contrasts with planning specifications. In practice, this is not implemented much. A key reason is the difficulty to identify these sites and to provide key information on land value and potential for restoration (see Chapter 3). In this respect, promising initiatives have been recently conducted in the city of Berlin (see Box 13). The case of Dresden is also considered particularly successful for the implementation of the compensation mechanism, in particular thanks to the strong local political commitment. The Saxon Nature Conservation Act (*SächsNatSchG*)[165] states that the compensation of unavoidable damages due to land take is mandatory. Compensation can be made through a range of measures, from extensive planting of trees and shrubs in the city to green roofs. Several other examples in Germany highlight the conversion of brownfields into green urban areas, as in the case of Emscher Park in the Ruhrgebiet[166].

Box 13: Berlin desealing initiative

An initial step was the compilation of Environmental Atlas Map 01.13 Planning Notes for Soil Protection, as an important planning instrument for soil protection assessment. The weighing of the various functions and sensitivities of the Berlin soils permitted a differentiated evaluation of urban development planning. For example, in the case of soils which, from a scientific viewpoint, were classed as particularly valuable, the search for alternative sites for relevant construction planning projects was recommended. Another initiative consisted in assessing the "desealing" potential of the city, after acknowledging that the productivity of the soil is to be restored to the extent possible, and habitats valuable from a conservationist point of view developed for plants and animals. It was initiated from the observation that proposals for removing impervious coverage usually have a chance to be realised if the areas available for "de-sealing" are already known, have been checked for suitability, and are listed in a register. The goal is to support a spatial linkage between the places of impact and the places of upgrade by means of a uniform system for the citywide recording and evaluation of land areas. In the context of the project phases during 2010 - 2012, research was carried out in all 12 boroughs, all four Berlin forestry agencies and among private owners. In 2012,

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[165] www.dresden.de/media/pdf/stadtplanung/__vb6019_anlage_zur_begruendung.pdf

[166] Initiated in 1989, the project has led to run-down industrial landmarks of the region being transformed to serve new recreational uses while still preserving the area's rich history.

The redevelopment consisted in designing a "green connector" between the settlements of the Ruhr valley, following the path of the Emscher River and using the abandoned industrial areas along it as a unique form of greenspace. The park is composed of regenerated brownfields, reclaimed forests, and existing recreational areas that together provide a cohesive set of green infrastructure for the entire region. The specific projects that created the park system ranged from the development of large fallow land areas to small scale construction schemes to installations of biotopes to the simple planting of trees. Part of this project included the regeneration of the Emscher river system, which acted as a waste water canal since the end of late 19th century. Old mining sites are now used to host underground sewers that have been installed to carry waste away from the river. Additionally, the river has been re-profiled to allow for better flooding management and, to slow the speed of the currents, part of the river's course has been changed from a straight narrow concrete channel back to a wide curved pool. Trees and native plants have been introduced along the bank, which have improved the water quality as well as the ecosystems in the area. Altogether, the process of river regeneration has required an investment of 4.4 billion Euros and will take until 2014. However, it has provided a highly visible symbol of positive change that should have lasting benefits for the Ruhr valley.
www.dac.dk/en/dac-cities/sustainable-cities/all-cases/green-city/emscher-park-from-dereliction-to-scenic-landscapes/

the data obtained in 2010 and 2011 was updated. This data was compiled in a centrally administered database, into which further information and suggestions for areas can in future continually be introduced by the various actors in the public administration. Moreover, private landowners are to be able to not only obtain information on potential "de-sealing" areas, but also, if they wish, to propose their own areas which cannot be used for construction purposes and which, after examination for suitability, can be incorporated into the portfolio. This initiative is, however, both resource intensive and time consuming (Senate Department for Urban Development and Environment, 2013). On top of this, concrete restoration depends on the costs involved and the final land use type.

In any case, binding policy instruments do not always guarantee compliance. The substantial pressure exercised by the real-estate market for residential and touristic purposes, namely in coastal areas and at the fringe of cities, has shown to have led to the weak enforcement and/or even withdrawal of binding regulations.

To overcome these difficulties, some MS have developed their own **economic instruments**, to encourage inner development, through densification and recycling, or to optimise new developments on greenfields (see

Box **14**). The specific question of recycling and brownfield restoration is not treated here, as it is substantially developed in Chapter 3.

Box 14: Examples of implementation of economic instruments

In **France** for instance, a package of property taxes and pre-emption rights aim to limit low-density development and speculation on agricultural land. Since the end of 2010 (and the *Loi de Finance Rectificative*), local communities together with EPCI (public organisations in charge of communities cooperation) have the possibility to set, on a voluntary basis, a payment for low density developments to be paid by developers. Below a certain threshold, developers will pay a tax equal to half of the value of the area used in addition to the area that would have been constructed if the threshold had been respected. This instrument is specifically aimed to halt urban sprawl. A prospective study carried by Aurier et al. (2010), showed that the implementation of such a tax could limit urban sprawl from the Parisian metropolis by 4% by 2040 (the actual threshold for low-density used could not be found). The efficiency of such an instrument could be considered relatively low compared to the efforts implemented, but this remains to be assessed in practical cases. In September 2013, 2.5 years after the launch of this voluntary policy instrument, only 34 municipalities had decided to implement this tax. Unfortunately for land take regulation, most of the relevant taxes (e.g. tax on abandoned commercial areas; tax on constructible unbuilt plots) remain optional and are not widely implemented by municipalities, as they could slow down investments. A mandatory tax on vacancy (set in a Decree relatively to the rental value of the flat: 12.5% the first year and 25% from the second year) could be efficient but is weakened once again by series of exemptions (if renting would require expensive renovation, if the population from the relevant urbanisation zone is below 50 000 people, etc.).

In **Germany**, a pilot initiative for tradable certificates for land take is being tested in the context of the implementation of the 30 ha/day national target, where "conventional" instruments have proven inefficient (in line with the Coalition Treaty of Federal Government in the year 2009). It includes 40 municipalities (including major cities) from all over Germany for a four-year experiment. This appears to be a promising instrument to optimise the allocation of efforts. In this respect, because municipalities are responsible for planning, the national and federal governments try to influence their decisions through information and support, such as land management databases or "Follow-cost estimators", which aim to reflect the real costs of settlement development. The “tradable certificate” instrument is not yet operational although it has been tested in municipalities. Its implementation may raise concerns at national level, as such an instrument would require a consistent approach across Germany, which is a key challenge in itself[167].

Another leverage relates to **land governance and stewardship**, with the development of public-private partnerships and the creation of specific development agencies to raise awareness of land take issues. These have been successful at engaging private investors and public authorities/landowners in using built-up land more efficiently, including promoting land recycling as highlighted in Chapter 3, section 0. For instance, in Austria, the development of joint business parks shared by several municipalities has been increasingly observed and is considered a successful concept[168]. Another case, is the possibility for some specific organisations to acquire land in order to preserve its functions. It can then be rented under specific environmental conditions. This is the case in France with the Coastal Protection Agency (*Conservatoire du littoral et des rivages lacustres*) for highly sensitive natural areas, water agencies for wetlands, natural areas protection agencies, and SAFER (for agricultural areas).

[167] Pers. comm. from Günther Bachmann, from the German Council for Sustainable Development.
[168] www.inkoba.at/

Land-take related policies implemented in MS

Table 4: Overview of policies highlighted by MS as contributing to the control of land take (instruments going beyond EU policies)

MS	Type of policy instrument		Examples
AT	Legislative	Protection of natural and agricultural areas	• Spatial planning laws, with zoning: identification and delineation of priority “agricultural areas” and/or “protected green areas”, which are then protected from conversion into building land and new developments
		Construction permits restriction	• Delivery of building permits with an expiration date in order to control the timeframe of conversion of green land into building plots
	Economic	Subsidies	• Implementation of new funding schemes for housing to improve intensification of settlements and limit new development elsewhere • Real estate funding at regional/provincial level with the aim of realising public developments respecting inner urban development and minimal land take
	Co-operative	Private-Public Partnerships	• Soil efficient business developments in Austria, involving the cooperation of municipalities for the development of new commercial areas: inter-municipal business settlements (“INKOBA”) • Public private partnerships to assist business settlements (sharing of costs and revenues) and limit the creation of new brownfields due to business failure
		Guidance and Strategy documents	• Austrian Spatial Development Concept (ÖREK): strategic steering instrument established in 1971 for spatial planning and development at the national-, Länder-, and cities and municipalities level; current ÖREK (2011) aims at reducing surplus building land, automobile traffic growth and related burdens and at achieving greater efficiency in climate and resource use[169]. • Charter on Land (*“Bodencharta*”) signed in March 2014 by 10 organizations committed to the sustainable use of land. The objective of the Charter is to avoid the development of high-quality agricultural soils in the future as much as possible and to increase the use of already developed areas. The Soil Charter includes four major requirements in terms of strengthening awareness, improving the legal framework, taking into account soil protection when undertaking large projects, vitalizing city centres and using empty spaces.

[169]Source : http://www.oerok.gv.at/fileadmin/Bilder/2.Reiter-Raum_u._Region/1.OEREK/OEREK_2011/Dokumente_OEREK_2011/OEREK_2011_EN_Downloadversion.pdf

MS	Type of policy instrument		Examples
		Projects	• Project "Mobility Pass for Real Estate": by showing the user (buyer/tenant) his/her mobility patterns, which are depended on his/her housing situation and mobility habits, this online tool can impact the mobility behaviour and further the spatial patterns in times of sprawling cities, the lack of resources and climate change[170]. • Project "Energy certificates for settlements", which favours compact settlements[171].
BE	Legislative	Urban development restrictions	• A project of joint spatial concept for the Walloon region and the Brussels region may introduce stricter zoning for land development, so that new development zones are only developed along large public transport routes. The target is to limit urbanization to 1,200 ha per year within 2020, and to 900 ha per year within 2040 (compared to 2,000 ha per year these 30 last years in Wallonia). • In Flanders, the Spatial Plan was revised in 2010 into a Flemish Spatial Policy Plan for the period 2020-2050. This plan set the target of realising 60% of new developments in urban areas and only 40% in rural regions until 2007. This goal, which was not achieved in 2010, is not taken up in the new Policy framework document, the Green Paper "Flanders in 2050: Human scale in a metropolis?".
	Legislative	Compensation mechanisms	• In the Walloon region, the principle of compensation for newly artificialised areas at communal scale appeared in March 1998. Since then, the mechanism has been clarified and revised several times, especially via RESA bis and RESA ter reforms. This compensation has to be done within the area covered by the communal spatial development plan (at local scale) and can be done either by a so-called "*compensation planologique*" (which is an arithmetical compensation: 1 urbanized ha has to be compensated by 1 de-urbanized ha or by declassifying 1 ha destined for urbanization), or by a "*compensation alternative*", which requires the urbanised area to be compensated by alternative adequate means. Current trends seem to be towards favouring alternative means of compensation over arithmetic compensation.
	Co-operative	Guidance and Strategy documents	• Spatial Structure Plan for Flanders, enforced for the period 1997-2007 ("60% of new developments have to be realised in urban areas and only 40% in rural regions"), revised a first time in 2004, and then in 2010 into the Flemish Spatial Policy Plan for the period 2020-2050 – which does not entail quantitative targets anymore • The SDER proposal (Regional Land Development Scheme) adopted by the Walloon Government on the 7th of November 2013 sets targets for limiting urbanization: target of limiting urbanization to 1.200 ha per year within 2020, and to 900 ha per year within 2040 (compared to 2.000 ha per year these 30 last years
BG	Cooperative	Protection of natural and agricultural areas	• Spatial planning laws introduce a restrictive regime in relation to construction within protected areas, protect coastline from urbanisation (Protected Areas Act) and restrict uncontrolled building • In particular as regards the Black Sea coastline: Specialized Black Sea Coast Development Scheme; the general development plans of the municipalities along the Black Sea coast and the Detailed Development Plans.

[170] Source: http://www.isocarp.net/Data/case_studies/1977.pdf

[171] Source: http://www.oerok.gv.at/fileadmin/Bilder/2.Reiter-Raum_u._Region/1.OEREK/OEREK_2011/good_practice/Energieausweis_fuer_Siedlungen.pdf

MS	Type of policy instrument		Examples
	Legislative	Guidance and Strategy documents	• National Concept for Spatial Development for the period 2013 – 2025 (signed in 2012) addresses urban sprawl: “Different tools will be used and support from other Operational Programmes will be sought for expanding the impact of the integrated urban regeneration and development beyond the regulation boundaries of the cities” • According to recent research, urban sprawl is still inadequately addressed, i.e. around Sofia (Slaev, 2013)
CY			• The 1992 Act on Nature Conservation and Landscape Protection protects green areas within city borders from urbanization • In general, there does not seem to be policies/tools/projects significantly addressing land take
CZ	Legislative	Unsealing regulations	• The 2006 Act on Landscape Planning and Construction Regulations gives priority to the development of abandoned areas (old industrial estates) instead of developing green land
		Compensation mechanisms	• In the Czech Republic, the Act on the protection of agricultural land requires to pay a compensation fee for converting agricultural land to building (Act No. 334/1992 on Protection of Agricultural Land Resources as amended by Decree No. 13/1994 defining certain details of the protection of agricultural land resources). Until recently, his initiative was not considered to be very efficient given the low value of the fee (used to be less than 1 EUR/m^2). However, the amount of the fee was significantly increased in January 2014 and set according to the quality of the land – the aim being to encourage developers to build on low quality soils. The figure below illustrates some examples of the changes of levies for taking the agricultural soil before and after the Novelization of Act No. 334/1992 Sb[172].

		Before (Czech crown/ha)	After (Czech crown /ha)	Multiplication factor
1	Silnice II/452 Bruntál –Mezina – stavební úpravy *Road development*	23 000,- 15 000,- 40 000,-	274 200,- 246 600,- 43 200,-	11,9 16,4 1,1

[172] Source: http://www.unserboden.at/files/sanka_sealing.pdf

MS	Type of policy instrument		Examples

2	Průmyslová zóna Litovel - Nasobůrky *Industrial zone*	1 980 000,-	13 908 00,-	7,0
3	Rozšíření závodu ORRERO a.s. *Expansion of a plant*	1 625 000,- 2 475 000,-	8 590 000,- 17 385 000,-	5,3 7,0
4	Multimodální cargo Ostrava - Mošnov *Multimodal transport services complex*	270 000,-	2 622 000,-	9,7
5	Technologický park Olomouc - Slavonín *Technology park*	117 000,-	1 492 200,-	12,7
6	Průmyslová zóna Přerov *Industrial zone*	990 000,-	6 954 000,-	7,0
7	Silnice II/435 Dub – Tovačov – stavební úpravy *Road development*	2 340 000,-	29 844 000,-	12,7
8	ČS PHM Velké Meziříčí *Residential development*	49 000,-	49 800,-	1,02

MS	Type of policy instrument		Examples
	Economic	Guidance and Strategy documents	• Highly decentralized land planning system • "Principles of Urban Policy" published by the Ministry for Regional Development lay down the principles of urban spatial planning policy in recognition of the Leipzig Charta, thus addressing the need for an overall urban policy . In this document, the issues of urban sprawl and brownfields are discussed.
	Co-operative	Knowledge and Research Programmes	• The "*Suburbanizace*" research project aims at assessing the extent and intensity of suburbanization and increasing awareness amongst the public and developers
DE	Persuasive	Unsealing regulations	• §5 of the Federal Soil Protection Act (*BundesBodenschutz Gesetz (BBod-SchG)*) provides a regulation on unsealing. This provision enables the Federal Government to request from a landowner that he maintains or returns soil to productive use as far as possible and reasonable where the soil has permanently not been used and whose sealing contrasts with planning specifications. The Federal Council has passed a resolution with regard to the Federal Soil and Contaminated Sites Ordinance (*Bodenschutz- und Altlastenverordnung (BBodSchV)*) which requires Federal Government to submit a legal framework for unsealing pursuant to §5(1) BBodSchG to the Federal Council at the earliest possible opportunity. Until a legal framework pursuant to §5(1) enters into force, authorities empowered under state law can, in individual cases, issue orders against the person

MS		Type of policy instrument	Examples
			identified in §5(1) provided other conditions set down in §5(1) are met.[173]
	Legislative	Compensation mechanisms	• In order to confine sealed surfaces in the Dresden region and to contribute to flood prevention, the city of Dresden requires that new developments on undeveloped land are compensated by de-sealing or “greening” measures somewhere else but within the city boundaries. Developers have the opportunity to carry out compensation measures by themselves or to pay a compensation fee to the Environment Authority of the City, who is in charge of several de-sealing projects • The City of Munich promotes sealing compensation measures such as de-sealing or greening roofs through financial subsidies or awareness-raising measures for residents and investors. (source : Driving Forces of Urban Soil Sealing and Constraints of Its Management - the Cases of Leipzig and Munich (Germany) Martina ARTMANN, 2013)
	Economic	Impact Assessment	• In 2007 the Council for Sustainable Development reviewed Germany’s policy to reduce land take. Key recommendations are the implementation of powerful economic instruments and to establish a nationwide concept for integrated land management (commitment of all involved sectors). • Implementation of powerful economic measures needed: In 2009 the Commission for Soil Protection concludes that so far implemented measures to reduce Germany’s land take were not sufficient to reach the “30 ha target” and recommends the implementation of tradable development certificates. A nationwide pilot is currently being planned which shall include 40 municipalities (including major cities) from all over Germany and operate for four years.
	Procedural	Guidance and Strategy document	• In Germany, planning occurs within a decentralised decision-making structure and a strong legal framework (Pütz et al., 2011). The primary actors involved in the process are the federal government (Bund), the 16 state governments (Länder), the 114 planning regions and approximately 14,000 municipalities (Gemeinde). In recent years, the EU has also played an increasing, but non-binding, role. • Recommendations on how to achieve the 30 ha target, published in 2004 by the German Council refer to a combination of instruments, including fiscal-economic, regulatory and planning tools. Major objective of the process is to stop the increasing fragmentation and expansion of cities and villages and to support their “inner” development in the municipalities (so called infill-development: use of vacant lots, densification of under-used sites, use of brownfield sites etc.), inter-municipal cooperation and reuse of previously built-up areas. There is a priority of inner above outer development. Moreover the general objective is to prevent urban sprawl by concentrating settlement activity in central places, development axes and in settlement priorities. Because municipalities are responsible for planning, the national and federal governments try to influence mainly through information and support, such as Land Management databases or "Follow-cost estimators" for settlement development. In addition, there are so-called "alliances for land conservation," in several federal states, which include representatives from different institutions,

[173] Source: http://globalsoilweek.org/wp-content/uploads/2013/10/GSW_factsheet_Sealing_en.pdf

MS	Type of policy instrument		Examples
			such as federal state, local government, churches, universities or environmental and interest groups etc...
	Co-operative	Knowledge and Research Programme	• The research programme REFINA “Research for the Reduction of Land Consumption and for Sustainable Land Management” was launched in 2006 and is part of the German National Strategy for Sustainable Development. More than 100 projects in about 50 research collaborations and individual projects are involved in the REFINA research programme. Funded projects have developed innovative concepts for reducing the rate of land take and for encouraging sustainable land management. Special emphasis is put on inner urban development and reuse of brownfield sites. • The Model project “*Flaechenhandel*” started in the year 2012. It will try out the trade with certificates on land take by ca. 100 local governments. The outline of this model project has been worked out in the framework of a forerunning research project “FORUM”, which ran from 2010 to 2012. Starting point of this activity was an item in the Coalition Treaty of Federal Government in the year 2009, which said that the trade with certificates for land take should be tried out in the framework of a model project “in which local governments should voluntarily participate in a nationwide trade of certificates”. In the year 2013, the new Federal Government confirmed that this model project will be continued. One result of this model project will be recommendations on the further development of legal instruments for local and regional planning and on the further improvement of tools in order to assess costs and benefits and other impacts of urban development. If the model project proves clear advantages of the trade with certificates, there will be also proposals on the general installation of the trade on regional or even national level.
DK	Legislative	Construction permit restrictions	• In Denmark, the Danish Spatial Planning Act puts clear restrictions on the construction of large shops and shopping centres on green fields out-side the largest cities and promotes small retailers in small and medium sized towns, hence counteracting dispersed settlement structures in rural regions with a shrinking population The Planning Act provides 3 instruments targeting retailers in city centres: - the delimitation of town centres and the centre of a city district in order to prevent urban sprawl - imposing a max of total floor space for each given area, - imposing a maximum size on shops • Mandatory rural zone permits: Denmark has been divided into urban zones, summer cottage areas and rural zones since 1970. The rural zones include the countryside and many villages. The main purpose of the provisions on rural zones is to prevent uncontrolled development and installations in the countryside and to protect valuable landscapes. A rural zone permit from the municipal council is generally required to parcel out land, construct buildings or change the use of existing buildings and undeveloped land. This does not mean prohibition. A permit may be granted when the municipality specifically assesses the local conditions and concludes that the development applied for is in accordance with the provisions on rural zones. Conditions may also be attached to a permit, such as requiring hedges or removing unused buildings (Danish Ministry of Environment, 2007).
	Co-operative	Guidance and Strategy documents	• The 2009 Danish Strategy for physical planning, states: "The government prioritises more compact cities and initiatives to avoid non-intended spreading of city areas into the open land". • Planning in Denmark is characterised by a top down structure and a strictly enforced land zoning system. In 2007 Denmark reorganised its public sector following local administrative reform in 2005. Alongside this reform, there was a radical shift in Danish spatial planning which saw the former counties’ responsibilities transferred to national and municipal authorities. The new municipalities acquired responsibilities for town and country land-use planning while the Ministry of the Environment created seven environmental centres across the country to ensure the realisation of national

MS	Type of policy instrument		Examples
			planning interests, removing planning decisions from the regions (Galland, 2012). • The Copenhagen Finger Plan urban growth plan aims at controlling urban growth. It is often referred to in the grey literature. However, its objectives remain qualitative and not very operational.
	Economic	Taxes	• Denmark implements Land Value Taxation (LVT) at the county and municipality levels of government, raising about 7% of local government revenue. The county rate is fixed at 1% while the municipalities set a further rate of between 0.6% and 2.4% with the two largest cities allowed to levy up to 3.9%. Interestingly, Danes are also subject to the land tax on land and property owned abroad, which means that there will be large areas of England and certainly Scotland which currently pay no local taxes (agricultural land is exempt from non-domestic rates) but which is assessed and levied by Danish municipalities[174].
EE	Co-operative	Guidance and Strategy documents	• National planning "Estonia 2030" has for objective to maintain compactness, tighten the internal structure, recycle marginalized areas of the cities and other major settlements in the process of planning • The Comprehensive Plan of Tallinn City aims at increasing the usage intensity of existing housing land and use of empty or insufficiently developed areas
	Economic	Taxes	• LVT was introduced in Estonia in 1993 and now, like Denmark, contributes around 7% of local government revenue. Central government levies a fixed rate of 0.5% and local government has flexibility to levy at between 0.3% and 0.7%[175].
EL	Procedural	Monitoring	• The Special Inspectorate for Building and Energy uses satellite photos of different periods to identify urban sprawl and land take, and penalise illegal acts. • Approximately one fifth (or more than 1,000,000) of the constructions are informal build in small parcels without a building permit, not including those built with a permit but with slight informalities, like building-up in semi-open spaces, change of uses, extra rooms in excess of the building permit (Dimopoulou & Zentelis, 2007). • Since 2011, the law 4014/2011 has been adopted by the parliament. By this law, an engineer must check the situation of the construction (formal or informal) for any property transaction (Potsiou et al., 2012)

[174] Source: http://www.andywightman.com/docs/LVT_england_final.pdf

[175] Source: http://www.andywightman.com/docs/LVT_england_final.pdf

MS	Type of policy instrument		Examples
ES (Andalusia)	Legislative	Urban planning	• Quantitative urbanisation limit for master plans of medium and large municipalities: 40% of the previously existing urban land or 30% of the previously existing population within eight years.
FI	Co-operative	Guidance and Strategy documents	• Joint master plans and letters of intent between the state and municipalities in an urban region on land use, housing and traffic issues (MAL) have recently been introduced for a more integrated approach.
FR	Legislative	Protection of natural and agricultural areas	• France adopted a coastal legislation (Loi Littoral), which is however very poorly enforced
		Urban planning and building codes	• Territorial Coherence Schemes (SCOT) are planning documents for several towns or group of towns. They aim to ensure regional balance, urban renewal, efficient land management, social diversity and the preservation of the environment. The law requires that the SCOT (as Local Urbanism Plan [PLU] and communal maps) must reduce space consumption (urban sprawl), preserve areas used for agricultural or forestry activities, and enhance biodiversity conservation and ecosystems (including through preservation and restoration in good condition ecological continuity). Each competent authority is responsible for its SCOT, each city or EPCI (public agency for municipality cooperation) for its PLU and each municipality responsible for the communal mapping are free to define their planning document. This leads to significant changes both in substance and form. SCOT, and to a lesser extent the PLU and communal maps, are the expression of a political vision for the future of the territory. The SCOT must present an analysis of the consumption of natural, agricultural and forest land during the past ten years. It justifies the targets of limitation of land take. It sets up quantified objectives for land consumption and urban sprawl.
	Economic	Taxes	• Possibility since 1st March 2012 to set a payment for low density to be paid by developers, decided on a voluntary basis by local communities and EPCI (public organisations in charge of communities cooperation). Below a certain threshold, developers will pay a tax equal to half of the value of the area used in addition to the area that would have been constructed if the threshold had been respected. It is specifically aimed to halt urban sprawl. • Taxes on the sale of constructible non-built land: national and possibly communal flat-rate tax on plots that became constructible following changes in urban plans, in addition to taxes on capital gain. These instruments aim to regulate speculation about non built, constructible, areas. • Taxes on vacant housing and unused commercial areas from 1 year after the vacancy. The tax rate progressively increases with the duration of vacancy. Exemption from property tax in unbuilt sites in Natura 2000 areas and in agricultural areas under certain conditions.

MS	Type of policy instrument		Examples
	Co-operative	Guidance and Strategy documents	• Strategy for Sustainable Development 2006; 2010-2013
		Land acquisition and regulation of land use types	• Land take regulation through land acquisition by several organisations, including Coastal Protection Agency (Conservatoire du littoral et des rivages lacustres) for highly sensitive natural areas, Water Agencies for wetlands, Natural areas Protection Agencies, NGOs, etc.
	Persuasive	Knowledge and research programs	• Creation of an observatory of agricultural land (ONCEA) in 2013
HR	Legislative	Urban development restrictions & Protection of natural areas	• Spatial planning laws protect coastline from urbanization and restrict uncontrolled urbanization
	Co-operative	Guidance and Strategy documents	• National strategy for Sustainable Development tends to restrict uncontrolled building and protect green areas
HU			• 4 special spatial planning zones where the designation of urban areas is strictly restricted for protection purposes (in terms of soil quality or natural assets) • In general, there does not seem to be policies/tools/projects significantly addressing land take

MS	Type of policy instrument		Examples
IE	Legislative	Protection of landscape	• Landscape strategy : National Landscape Strategy Steering Group Ireland's National Landscape Strategy Steering Group was established by the Department of Arts, Heritage and the Gaeltacht (DAHG) during 2011 in order to develop a National Landscape Strategy with the aim of sustainable management of change that affects landscape
	Cooperative	Urban planning	• Green City Guidelines (2008). The Green City Guidelines are designed to provide practical guidance for planners and developers on how to integrate biodiversity into new developments, specifically medium to high-density housing developments in urban areas. They seek to identify the key stages in planning and development where biodiversity can be integrated and to highlight current best practice methods for protecting and enhancing biodiversity throughout the lifetime of the development. While the Residential Density Guidelines, published in 1999, called for higher densities in urban areas (high density = 50+ units per hectare), the Green City Guidelines examine approaches to enhancing biodiversity within high-density areas or areas undergoing urban "densification". As such, rather than addressing land-take per se, they deal with soil sealing mitigation, by promoting the use of new technologies such as green roofs, green walls, permeable surfaces and sustainable urban drainage systems. In particular, their aim is to counteract the intensification of land use by maximising the ecological value of all walls, roofs and green areas within the development and minimising sealed surfaces that contribute to runoff. As a tool for counteracting the environmental impacts of high-density development and compensating for deficits in open space, the Guidelines refer to an indicator developed in Berlin (Germany), the Biotope Area Factor (BAF), which provides a method for calculating the relative area of land surface with habitat potential that is being lost through urban land use.
	Economic	Taxes	• The Irish Government is currently implementing a new property tax to be levied on the basis of the banded capital values of property. While the Irish government has chosen not to adopt a land value tax, a considerable amount of research was carried out into the feasibility of a site value tax (equivalent to Land Value Taxation - LVT)[176].
IT	Economic	Urban planning and building codes	• In Italy, regional laws on environmental quality in urban areas explicitly demand the restriction/containment of soil sealing (cases of Emilia Romagna, Toscana and Umbria, where soil sealing limits where set at the municipality level). The regional territorial plan covers regulations on particular land use, land development at a larger scale, and the planning of infrastructure such as road network and railways
LV	Legislative	Urban planning and building codes	• In Latvia, The Concept of the Land Management Law for Providing a Sustainable Land Management in the Republic of Latvia was carried out and accepted in 2010. The concept proposes following sections to be included in the Land Management Law (LML): land use, land protection, land administration and monitoring. Expected outcomes include: prevention of uncontrolled urban sprawl and illegal building, and development of an efficient land information system for provision of complete and actual land related data. • Regulations Regarding Agricultural Territories of National Significance (http://m.likumi.lv/doc.php?id=257136): special restrictions regarding agricultural land transformation into another land use type when it is declared as of national significance. However, transformation of this land is

[176] Source : http://www.andywightman.com/docs/LVT_england_final.pdf

MS	Type of policy instrument		Examples
			allowed for building of a new dwelling house per land plot or building of roads.
		Construction permits restrictions	• Construction permits restrictions set in legal acts enable to control the timeframe of realization of building intention expiration date.
	Co-operative	Guidance and Strategy document	• Land Policy Guidelines for 2008 – 2014. Their major objective is to ensure sustainable land use and land protection, including protection of entrails of the earth, forests, waters, and to prevent land degradation. They aim to keep the agricultural land in 2014 in the same amount of the total territory as in 2008 – 37% of the total territory.
LT		In general, there does not seem to be policies/tools/projects significantly addressing land take	
LU	Legislative	Protection of natural and agricultural areas	• Act on the Protection of the Environment and the Natural Resources, under the responsibility of the Minister of the Environment: Classified Green land is not available for urban development.
	Co-operative	Guidance and Strategy document	• The 2009 National Plan for Sustainable Development recommends the introduction of a 'sealing tax' • The 2004 Integrated Transport and Spatial Development Concept for Luxembourg recommended: (1) the definition of specific minimum urban densities and the implementation of a binding index for local land use plans, (2) the establishment of a land management system to identify development potentials and a data base for "fill-in" areas, (3) the introduction of binding development obligations for land with a building permit or otherwise the withdrawal of building permits without refunding, (4) to institutionalise public land management agencies at the municipality level
MT	Co-operative	Projects	• The SENSOR project, finalised 2009, allowed refining the understanding of the land use drivers in Malta. Its main product, SIAT (Sustainability Impact Assessment Tool) - is a quantitative multi-modelling tool providing prospective scenario assessment across disciplines, sectors and sustainability dimensions. It includes the valuation of simulated environmental, social and economic effects in terms of sustainability impacts.
NL	Legislative	Protection of natural and agricultural areas	• Green and blue landscapes are protected from infrastructure development. In particular, red contour lines were introduced through the Fifth national policy document on spatial planning which aims to limit urban sprawl in the vicinity of cities (issued by the Ministry of Housing, Spatial Planning and Environment). • Ever since the first Dutch spatial planning policy in 1955, policies aimed to keep Dutch cities separated by buffer/green area. The most relevant example is Randstadt, the conurbation consisting of Amsterdam, Rotterdam, The Hague and Utrecht. Spatial plans have preserved a so-called Green Heart between the cities by assigning restricted and non-restricted areas, and permitted to guide urbanization in desired areas and limit land

MS	Type of policy instrument		Examples
			take in a very dense area. For those green spaces surrounding urban areas, policies plan to authorise spatial development as long as the landscape and recreational aspect does not suffer as a result. The national government will adopt a stimulatory role and assess the planning regime for the former buffer zones.
	Co-operative	Guidance and Strategy documents	• The Nota Ruimte programme is an integrated approach giving clear priority to polycentric developments, the strengthening of sustainable mobility, climate change aspects and protection of landscapes. There has been deregulation and decentralisation over the last 10 years, which explains why provinces and municipalities within the provinces have currently different approaches concerning urban growth depending upon their local context. • The Nota Ruimte has set multiple goals in relation to land use/land take: ○ Urban areas: The national government is relying on municipalities to use the guideline of 75 square metres of green space per dwelling when planning new locations. In addition, parks and green structures in cities, towns and villages should preferably be retained. However, the restructuring targets may require part of a park or a sports field to be built on. The responsible (local and regional) governments will have to weigh up the different aspects of the matter themselves. ○ Concentration of activities: They planned to concentrate urban and economic activities. For instance, new construction will be largely realized in areas with high concentration[177].
PL	Legislative	Protection of natural and agricultural areas	• The 1995 Law on Protection of Agricultural strictly protects top agricultural land in rural regions[178]. Only 14% of the total agricultural land in Poland is of high quality. Key objective of the law is to give fallow lands priority for urbanisation purposes. The law distinguishes between six soil classes.
	Econ omic	Compensation mechanisms	• The conversion of high quality soils (classes IIII) is charged and the amount of the fee depends on the soil class and on area size of the given land.
	Co-operative	Guidance and Strategy documents	• The Ministry for Regional Development is working on the review of current processes to promote good practices with the aim of finding organisational, planning and implementation activities to respond to problems like spatial chaos, wasteful and dynamic suburbanization, fragmented building development, technical and social degradation of cities and cultural landscapes, ecological systems destruction, and private investors interests not taking into account the common good. • National Spatial Development Concept 2030 (hereinafter also KPZK 2030), approved in 2011
PT	Co -	Guidance and Strategy	• Central programming document for spatial planning is National Sustainable Development Strategy 2005-2015 (NSDS), approved in August 2006: makes specific reference to reversing the trend towards extensive and low quality urban growth and encouraging urban re-qualification and recovery

[177] Source: Publicaties.minienm.nl/download-bijlage/22217/1d338.pdf

[178] Spiyrce: Ustawa o Ochronie gruntow rolnych i leśnych z 3 02. 1995 / translation: Act on agricultural and forestry land protection, 3.02.1995.

MS	Type of policy instrument		Examples
		documents	of degraded areas, promoting higher standards of quality of life. • The National Programme for Spatial Planning (NPSP), approved by the Parliament in September 2007 establishes the major options that are relevant to the organisation of the country, in line with NSDS and with the values encompassed by the concept of regeneration. At a regional level, this Programme is realised by means of Regional Spatial Planning Schemes, and at municipal level, by the Municipal Master Plans. Specific objectives are to re-qualify urban areas, to preserve available natural resources and to better co-ordinate growth.
		Private-Public Partnerships	• Polis XXI, approved in March 2007, is the cities policy programme for the sustainable development and national cohesion of the Portuguese cities. It is constituted by a set of integrated urban policy instruments aimed at promoting urban regeneration, competitiveness and innovation through networking as well as at improving quality of life and environment in the cities. It highlights urban regeneration as an essential dimension of cities cohesion, determinant for the quality of life. Polis XXI will be implemented during the 2007-2013 period, mainly through private-public partnership contracts[179]. This programme illustrates the fact that land take can also be addressed indirectly, by promoting a better urban policy.
RO			• In Romania, there is at present no official spatial development document at a national level, which would contain a delineation of development axes; however, it is being prepared.
SE	Legislative	Spatial planning	• In Sweden, planning is mainly decentralised and a municipal concern. The weak regional level as regards the physical planning in Sweden is sometimes considered a problem. It can lead to a situation where municipalities, instead of complementing each other, compete in a negative way by not co-ordinating their activities although the surrounding territory for most inhabitants in a municipality is a continuous space where administrative borders are invisible. The Environmental Code regulates what is of national interest, such as threatened natural environment, important natural resources, areas for outdoor sports etc. The sites designated as being of national interest are protected and any development affecting them strictly regulated. • There seems to be no policy regarding control of land take.
SI	Procedural	Impact assessment	• There is a long term tradition of spatial planning in which environmental assessment procedures and public participation are involved. Key phases in national spatial planning procedure include: - Preparation of different feasible variations of “spatial arrangements of national importance" (highways, power plants, power lines, electric grids, railways, roads, etc.); - Analyses and comparison of variations from different points of view – spatial development, environmental sustainability, functional and economic point of view, etc.; - Public hearing at the very beginning of the procedure (when all options are still open) and after analysis and comparison of variations; - Proposed solution has to meet development needs and be acceptable from the environmental and, economical point of view as well as in the local community.

[179] http://www.dgotdu.pt/pc/documentos/POLISXXI-apresentacao.pdf

MS	Type of policy instrument		Examples
SK	Legislative	Protection of natural and agricultural areas	• The 2004 Act on Protection and Utilisation of Agricultural Soil was enforced which aims to protect the best agricultural land and to steer new developments to soils with lower quality. In total there are 9 soil classes and the best four classes are protected.
	Economic	Compensation mechanisms	• The Decree of determined amount of payment and specification of payment for agricultural land consumption[180] introduces a tax, which value depends on the quality of soils taken. The instrument applies to all people who want to take agricultural land for non-agricultural purposes i.e. buildings, industrial, traffic, mining etc. Payment is obligatory for agricultural soil consumption (permanent or temporary) according to soil quality classes. The more fertile the soil to be used, the higher the payment (6 to 15 EUR/m^2, for a certain quality class, free otherwise). 21 % of the Slovakian are subject to a compensation fee.
UK	Legislative	Protection of natural and agricultural areas	• National Planning Policy Framework taken as a whole sets out how planning can achieve sustainable development. For example there are policies on urban containment through Green Belts (since 1955). Green Belts are open spaces, mainly areas for agriculture and forestry, surrounding UK's major cities. They prevent urban sprawling as they have high construction restriction (only building for agricultural purposes and only rare cases of developmental project. They represent 13% of the total land area in England, 16% in Northern Ireland, 2% in Scotland. • Best and most versatile land is mapped to identify land with the potential for high yields. This aims to ensure this land is used for agriculture. This mapping is intended to provide a rationalised assessment of the economic and environmental benefits of land use in planning decisions.

[180] Act No. 220/2004 Coll. on Protection and Use of Farmland

Annex 3: Land recycling

Understanding of the term "brownfield" across the EU MS

The following table presents the definitions of brownfield land used across the EU MS based on the literature review and consultation with Member State experts.

Table 65: Understanding of the term "brownfield" across the EU MS

Member State	Definition / understanding of the concept of "brownfield"	Comments
Austria	Previously used site or part of a site, which is presently derelict or underused. Owing to the site characteristics (e.g. dedication, status of its opening up for development, location) it offers a potential for reuse. The period, for which the site has been derelict, is not relevant. Source: *Austrian Standards Institute ON S2093*	Definition introduced in 2009. Previously there was no official definition in Austria (Oliver et al., 2005).
Belgium	Definition varies between the states: Flanders: Brownfield is a whole of neglected or insufficient used land, which is affected in such a manner that it can only be used or re-used by means of structural measures. Source: Decree of 30 March 2007 concerning brownfield agreements (Common Forum, 2010) Wallonia: Sites previously dedicated to economic activities and where the current condition is contrary to 'efficient land use' (*Sites d'activité économique désaffectés – SAED*) (Ferber et al. , 2006) Brussels: definition not identified	According to the Belgian definition, brownfield can be a site that is currently in use. The definition from Wallonia links brownfield to the concept of efficient land use.
Bulgaria	Areas where previous activities have ceased, but are still impacting neighbouring areas. (Oliver et al., 2005).	This definition has been identified by Project CABERNET (Oliver et al., 2005). No changes to this definition have been suggested during the consultation. Contamination is an indicator used for defining brownfield in Bulgaria (Petríková & Vojvodíková, 2012).
Croatia	There is no official/legal definition of brownfields in Croatia but these are abandoned industrial sites often with ownership issues. The Waste Management Strategy of the Republic of Croatia (OG 130/05) has identified 13 high risk locations ("hot spots") which have been created by long-term inappropriate management of industrial (technological) waste and whose existence presents a real danger to the environment and human health.	Understanding of the term is that brownfields are abandoned industrial sites. The priority in Croatia is to remediate heavily contaminated sites created as a result of inappropriate waste management practices.
Cyprus	No definition identified in the literature or through the MS consultation.	
Czech Republic	Properties (lands, objects, areas), that are underused, neglected, and can be contaminated. They are relics of industrial, agricultural, residential, military or other activities. They cannot be appropriately and effectively utilized without the regeneration process. Source: National Strategy for brownfield regeneration, Ministry of Industry and Trade, 2008	Understanding of the term is linked to the past use of land.
Germany	Based on information received following the MS consultation, there is no official definition of brownfields in Germany. However the following definitions were used to describe the	No common definition is applied however overall the term is linked to previously developed land. Other types of land

	infill development potential (IEP) for the purpose of data and knowledge gathering: - Brownfields are abandoned or temporarily used built-up sites, e.g. industrial wasteland, conversion wasteland (for which an entirely new function is foreseen), infrastructural and transportation brownfields, commercial brownfields, residential brownfields, abandoned buildings, post-agricultural sites as well as cultural and social brownfields. - Gap sites are non-built-up sites that offer potential for development (individual plots as well as several contiguous plots) which lie within established or newly built settlement areas. - Underutilized lots, in the sense adopted here, are parcels of land which are already built up, but which offer space for further development. Some examples are second row development, courtyard development as well as complementary buildings in residential, mixed-use and commercial areas.	available for recycling are also recognised.
Denmark	No definition of brownfield site (Common Forum, 2010). Project Cabernet (Oliver et al., 2005) stated that brownfield in Denmark is defined as land affected by contamination.	More recent information has not been provided through the consultation.
Estonia	Brownfields are deserted industrial areas (General Union Environment Action Programme to 2020 'Living well, within the limits of our planet' (legal translation in Estonian). Contaminated sites - former military and industrial sites. (The Operational Programme for the Development of the Living Environment 2007–2013 European Regional Development Fund and Cohesion Fund).	Both definitions have been provided through the consultation. Definition of brownfield appears to be limited to vacant industrial areas.
Finland	No definition of brownfield has been provided through the consultation. Literature suggests that definition is generally linked to contaminated land (Oliver et al., 2005). There are not many large brownfield areas in Finland. Most of the areas will be remediated due to land use change. Land recycling is taken place when areas of industrial and commercial activities and transport services are moved out from city centre and these areas are taken into residential and recreational use. This is happening especially in Helsinki metropolitan area and large cities with migration surplus.	Understanding of the terms was not corrected through the consultation.
France	Previously developed land (agriculture, harbour, industry, service, ore processing, military/defense, storage or transport) that has been temporarily or permanently abandoned following the cessation of activity and must be reclaimed for a future use (Common Forum, 2010)	France distinguishes between brownfield and contaminated sites.
Greece	There is no legal definition of a "brownfield" or of land suitable for recycling. The common understanding of the term is "abandoned land likely contaminated due to past industrial activity". There is no classification of brownfield sites into separate categories.	The information has been provided through the consultation.
Hungary	No legal definition exists (Common Forum, 2010). The common understanding of the term is that this is an abandoned, underused industrial, commercial and transportation area, which recovery / redevelopment is likely to be difficult due to contamination.	The definition has not been clarified through the consultation.
Ireland	Definition quoted by Project Cabernet states: Land which detracts, or is likely to detract, to a material degree from the amenity, character or appearance of land in the neighbourhood of the land in question because of ruinous structures, neglected condition or presence of waste (Oliver et al. , 2005). The other source (Government of Ireland, 2009) refers to brownfield as any land, which has been subjected to building, engineering or other operations, excluding temporary uses or urban green spaces.	No definition appears to be included in the existing legislation (Motherway, no date)
Italy	No legal definition is in place. Traditionally, the issue has been associated with land contamination; however a 2012	Further information on the approach to land recycling would be required to

	document from the Italian Ministry of Environment covering measures to support sustainable development in Italy, outlines some actions to enhance rehabilitation and valuation of abandoned industrial sites (Frantal et al., 2012).	understand current approach and thinking. Historically, approach to land recycling focused on contaminated sites.
Latvia	No official definition of brownfield exists; however the term is used by spatial planners referring to degraded areas, mainly construction areas or the territories of future development, contaminated and potentially contaminated sites, abandoned land and/or buildings, potential infrastructure territories etc. Contaminated and potentially contaminated sites are registered in a special register, which is publicly available, and are mapped in the local spatial plan.	Information has been provided through the consultation.
Lithuania	No definition of brownfield sites (Common Forum, 2010).	No further information has been obtained through the consultation.
Luxembourg	There is no legal definition of brownfield. Common understanding is a place that has been previously used or built up, but currently is derelict or abandoned. It can also be contaminated.	Information has been provided through the consultation.
Malta	No definition of brownfield sites identified.	No further information has been obtained through the consultation.
Netherlands	Brownfield is defined as (potentially) contaminated former industrial area where no spontaneous redevelopment will take place (Common Forum, 2010). Brownfields are not formally defined in the national policy, but the general policy is aiming on the reuse of sites. Still the following areas can be considered to fall under the Common Forum definition: - Sites closed to the public with aftercare to maintain technical measures to prevent dispersion, including controlled waste dump sites; however several sites with aftercare have been made into public green space (parks, golf courses) on the surface. - Areas with stagnation in site development due to presence of large/many low urgency sites that may cause human risk when a more sensitive new land use is affected, or similarly specific (large) single sites.	The definition is linked to contamination issue but also redevelopment perspective.
Poland	There is no common definition of brownfield in Poland. The concept is described differently across relevant legislative documents: 1) Areas designed for re-cultivation including degraded or desolated grounds, such as closed dumps, dumping grounds, depressions (hollows), post- industrial areas, post mining areas, post military training ground, for which the administrative bodies approved re-cultivation projects (Ministry of Infrastructure and Regional Development (former Ministry of Regional Development). 2) Study of the Conditions ad Directions for the Spatial Development and Land Use Development Plan." (*Ustawa o planowaniu i zagospodarowaniu przestrzennym*) 3)"Law of agriculture land and forests protection"- *Ustawa o ochronie gruntów rolnych i leśnych* 4) Environmental Protection Law (and its regulation concerning soil and ground standards – land surface protection article 10, point 5) presents three land categories: A- land under protection(according to the Nature protection and Water law) B-agriculture lands, forests, built-up and urbanized land C- land of industrial, coal mines and transportation activities This act imposes the land reclamation obligations for the user (manager) of the area.	In general, the term brownfield refers to post-industrial sites that have been designated for redevelopment purposes. The terms may also be associated with post-agricultural land.
Portugal	No definition identified.	No further information has been obtained

		through the consultation.
Romania	Definition used is based on ones from other European MS, specifically Germany and France. Most often, brownfield is described as land with past industrial activity; degraded by past activities and currently unused. The definition includes land that is contaminated.	The information has been provided through the consultation.
Slovakia	There appears to be no legal definition of the term, however a general understanding is that brownfield is "a site in an urbanized land which is not used effectively, abandoned, probably contaminated, it may be used efficiently only after reclamation and revitalization. It is a relic of industrial, agricultural, building or other activities" (Siebielec et al. ,2012)	The common understanding of the concept is that brownfield land can be either in use (but not used effectively) or not in use.
Slovenia	"Degraded area which is part of the village or area outside settlements, in which the technical, spatial design, housing, economic, social, cultural and ecological conditions are reduced to the state of uselessness and the renovation for revitalisation is needed, or is the area outside the village, where due to the human activity or inactivity has come to the degradation and its remediation is necessary Source: Ref: Official Gazette of the Republic of Slovenia, N° 33/07 (changes in 70/08 and 108/09) in Siebielec et al.(2012)	The approach is focused on land that is unusable, due to the previous use and other conditions.
Spain	In the Basque country, the understanding of the term is associated with contaminated sites and industrial ruins or derelict sites. The latter two terms refer to abandoned sites that may still have existing buildings and facilities in state inappropriate for re-use, where buildings have been demolished or inactive sites where the buildings are in good enough state to be re-used (Common Forum, 2010).	No further information has been obtained through the consultation.
Sweden	According to project Cabernet (Oliver et al., 2005), the term is interpreted as formerly used land which needs revitalisation (or remediation). However, another source (SEPA, 2012), states that brownfield sites are generally understood in Sweden as contaminated land, which are defined as "a well-defined area for which the level of contamination from one or more point sources significantly exceeds the relevant background level".	No further information has been obtained through the consultation.
United Kingdom	England: "Previously-developed land is that which is or was occupied by a permanent structure, including the curtilage of the developed land and any associated fixed surface infrastructure. The definition includes defense buildings, but excludes: – Land that is or has been occupied by agricultural or forestry buildings. – Land that has been developed for minerals extraction or waste disposal by landfill purposes where provision for restoration has been made through development control procedures. – Land in built-up areas such as private residential gardens, parks, recreation grounds and allotments, which, although it may feature paths, pavilions and other buildings, has not been previously developed. – Land that was previously developed but where the remains of the permanent structure or fixed surface structure have blended into the landscape in the process of time (to the extent that it can reasonably be considered as part of the natural surroundings). There is no presumption that land that is previously developed is necessarily suitable for housing development nor that the whole of the curtilage should be developed. " (Department for Communities and Local Government, 2011) Similar definition is used in Wales. In Scotland monitoring is undertaken for vacant and derelict land.	The meaning of the terms is previously developed land, definition of which excludes sites, which have been previously used for specific activities such as agriculture and forestry. Interestingly the definition in the UK has evolved from initially covering "previously developed but currently vacant land" to inclusion of the "currently used land" (Tang & Nathanail, 2012). Land does not have to be contaminated to be defined as brownfield in the UK. Contaminated land is defined separately.

Changes in the definition of previously developed land in the UK

The table below shows the evolution of the definition of "previously developed land" in England. The changes were introduced to prevent development of residential back gardens, which according to the initial definition could be classed as brownfield.

Table 66: Definition of "previously developed land" in England

Definition in the Planning Policy Guidance 3: Housing (2000)	Definition in the Planning Policy Statement 3 (2006)
"Previously-developed land is that which is or was occupied by a permanent structure (excluding agricultural or forestry buildings), and associated fixed surface infrastructure. The definition covers the curtilage of the development. Previously-developed land may occur in both built-up and rural settings. The definition includes defence buildings and land used for mineral extraction and waste disposal where provision for restoration has not been made through development control Procedures. The definition excludes land and buildings that are currently in use for agricultural or forestry purposes, and land in built-up areas which has not been developed previously (e.g. parks, recreation grounds, and allotments - even though these areas may contain certain urban features such as paths, pavilions and other buildings). Also excluded is land that was previously developed but where the remains of any structure or activity have blended into the landscape in the process of time (to the extent that it can reasonably be considered as part of the natural surroundings), and where there is a clear reason that could outweigh the re-use of the site - such as its contribution to nature conservation - or it has subsequently been put to an amenity use and cannot be regarded as requiring redevelopment".	"Previously-developed land is that which is or was occupied by a permanent structure, including the curtilage of the developed land and any associated fixed surface infrastructure. The definition includes defence buildings, but excludes: – Land that is or has been occupied by agricultural or forestry buildings. – Land that has been developed for minerals extraction or waste disposal by landfill purposes where provision for restoration has been made through development control procedures. – Land in built-up areas such as private residential gardens, parks, recreation grounds and allotments, which, although it may feature paths, pavilions and other buildings, has not been previously developed. – Land that was previously developed but where the remains of the permanent structure or fixed surface structure have blended into the landscape in the process of time (to the extent that it can reasonably be considered as part of the natural surroundings). There is no presumption that land that is previously developed is necessarily suitable for housing development nor that the whole of the curtilage should be developed. "

Categories of brownfield land based on the previous use of land

As part of project CircUse (2011), the following types of brownfield sites have been distinguished:

- Industrial brownfield – created as a result of changes to the industrial activity across Europe and decrease in the demand for land for industrial activities. Industrial brownfields are generally fully developed but often with not up-to-date infrastructure. Old structures often still exist on land.
- Military brownfield – changes in the political situation across Europe and downsizing of armed forces has meant that former military sites are no longer needed and often became abandoned without demolition of structures. Military brownfield sites include former housing and training camps. Depending on the local circumstances, military brownfields tend to be located outside urban areas.
- Commercial brownfield, also described as "greyfield" – abandoned or underused real estate or sites, including car parks and developments abandoned by investors before completion. Structures and buildings present on greyfields may be modern and reusable for the purpose of new use.
- Brownfield from infrastructure and traffic – created mainly as a result of re-organisation of transport infrastructure (also privatisation), which led to closure of railway tracks, stations and other transport infrastructure (e.g. warehouses)

- Residential brownfield – created mostly because of demographic changes, comprised of partly demolished or unused houses, often with historic architecture.
- Cultural and social brownfield – created as a result of demographic changes and comprised of cultural and social institutions that are no longer in use, for example schools, churches, and leisure areas.
- Agricultural brownfield – created as a result of changes in agricultural practices and farming methods. Comprised of abandoned agricultural buildings. These types of brownfield are likely to be located outside urban areas.

Impact of land recycling

The impacts of developing brownfield or an inner urban site will largely depend on the state of the site prior to redevelopment, the purpose of the redevelopment (e.g. a public green space, housing or commercial development) and location (e.g. deprived areas, shrinking cities etc.). Potential economic, social and environmental costs and benefits of land recycling are discussed below[181].

Economic impacts

Land recycling in the form of brownfield or further inner urban development, for example for housing or commercial development, is associated with a range of economic impacts, including the cost of redevelopment itself, site value benefits; increased neighbouring property values; benefits associated with the property market; employment and investment benefits; avoidance of greenfield infrastructure requirements; and agglomeration benefits (e.g. greater urban density). Some of these are discussed further in the sections below.

Cost of redevelopment

Brownfield development for commercial or soft-end uses[182] can be associated with costs of investigation and subsequent remediation if the land is contaminated in addition to the costs of development itself. Potential and actual contamination of such sites and associated environmental liabilities seem to represent a larger concern (and cost) than decommissioning existing facilities. Unclear or complex ownership status of the land, high investment, potential reputation risks, concerns over future marketability and a stigma associated with land dereliction may further hinder redevelopment potential (TECNALIA, 2013).

The category of a site (for example, according to the A-B-C model), i.e. attractiveness in the eyes of potential developer, is affected by the direct and indirect costs of development versus the anticipated return from this site (TECNALIA, 2013). Costs of 98 redevelopment projects were assessed as part of the EU funded FP7 research project Timbre (Frantal et al., 2012). Out of this sample, an average cost per project was calculated as EUR 147m, and average expenditure per hectare was EUR 3.4m. The costs of remediation in cases of land contamination are very site specific and depend on the area of land that requires clean-up, severity of contamination and technology used for treatment and disposal (often in hazardous waste facilities). The World Bank (2010) presented three cost scenarios for site

[181] Few studies frequently referenced in this section, specifically with regard to social impacts, were published in the United Kingdom. It should be noted that the evidence collected as part of these studies have not been limited to the UK alone and therefore impacts described on the basis of these documents are considered representative for the wider EU.

[182] "Soft re-use" involves an interim regeneration of a site to allow beneficial re-use of the land on a temporary basis. Examples of soft land usage include, among others, urban green-space or parkland, nature conservation areas and public open space, land cultivated for non-food crops. The land could then be further developed if the economic circumstances change (TECHNALIA, 2013).

remediation, varying from around EUR 110,000 to EUR 850,000 depending on the site. The average reported remediation cost of brownfield for contaminated land in the UK has been estimated to be around EUR 312,000 per hectare, reducing the attractiveness of some brownfield land for housing (Defra, 2012a). Anticipated returns from redevelopment of brownfields will depend on the type of final use such as residential, commercial, mixed-use, industrial developments or public open space such as urban parks or community gardens (Nikolić I., 2014) and the demand for that land use (TECNALIA, 2013).

Value of the site and neighbouring properties

A change in land use, for instance from an industrial site to residential housing, can substantially increase **site value**. The change in the value is dependent on location and market rates for similar land uses in the vicinity and may be sufficient to cover the costs of redevelopment (TECNALIA, 2013). In simplistic terms, for a brownfield redevelopment to make sense, the value of anticipated outcome should be higher than the investments made. For other categories where redevelopment of a brownfield site may proceed only at a loss, soft-end uses may provide opportunities for regeneration while benefiting the local community. Community initiatives or regulatory and non-regulatory measures already employed by a number of MS may be used to facilitate brownfield redevelopment at uneconomically viable sites (TECNALIA, 2013).

Available evidence suggests that brownfield development also has a positive impact on **neighbouring property values** (Defra, 2012b). In particular, in an urban residential neighbourhood, vacant and derelict land decreases property values and puts off development for both the actual site and the surrounding neighbourhood (Nikolić I. , 2014). On the other hand high-quality green spaces increase residential property values over identical properties in the same area (Defra, 2013a). A substantial negative impact of small brownfields on surrounding property values has been reported as well as evidence of a rebound in house prices when a clean-up of a closed and abandoned hazardous waste site is completed (Veermeer & Vermeulen, 2011). An analysis of house price data in England showed that all deprived neighbourhoods with residential brownfield development experienced a high level of house price inflation (an increase of over 110% of all house types) between 2001 and 2008, while the average figure for England was only 81% (Wong & Bäing, 2010). Furthermore some evidence from England suggests that brownfield redevelopment targets could lead to an imbalance in the nature of development delivered; specifically in the UK there was an imbalance between construction of blocks of flats (favoured by the brownfield target) and family homes with gardens.

Economic and property market growth

In instances where a brownfield is developed into an open green space, substantial evidence exists on its positive impact on neighbouring property values. In particular, the improved visual appearance and security has a knock on effect on businesses in the area and house prices (Defra et al., 2011) resulting in **economic and property market growth** (Defra, 2012b). The Impact Assessment accompanying the proposal for a National Policy Planning Framework in the UK (Defra, 2012a) identified that greater compactness and productivity of cities achieved by regenerating derelict land and remediating contaminated sites led to an increase in the overall economic competitiveness of the cities.

Brownfield development is also associated with **employment** related opportunities, as it would require labour to undertake the development works and maintenance of redeveloped sites (Defra, 2013a). Recycled derelict urban land encourages growth of businesses and services creating new jobs and brings economic improvement through stimulating additional private investment (Nikolić I., 2014).

Other economic impacts

Development of brownfield land and densification of urban areas also benefit from **existing infrastructure** and avoids a need to develop new infrastructure and services for a greenfield. The majority of brownfields are situated in urban areas providing access to transport infrastructure, energy and water supplies and amenities, thereby reducing further costs and land consumption, and improving the efficiency of city infrastructure and urban land resources (Defra, 2012a).

Redevelopment of brownfield sites may also contribute to welfare through **economies of agglomeration** and neighbourhood effects as areas of more dense population and activity (to which redevelopment of brownfield sites may contribute) are more productive than more sparsely settled and used urban areas (Defra, 2012b). Growth redirected from scattered fringe areas back to urban cores where people, services and infrastructure already exist increases population density, providing the critical mass to support local services and public institutions (Nikolić I., 2014). Furthermore, the advantages of scale and density matter not only for production but also for consumption, which may be particularly relevant for inner city areas where consumer amenities are mostly concentrated (Veermeer & Vermeulen, 2011).

In many cities and regions, high costs of brownfield redevelopment coupled with low market values constitute a significant challenge for recycling. Interim regeneration for “soft re-use” that allows beneficial re-use of the land on a temporary basis constitutes one of the feasible options. Examples of soft land usage include, among others, urban green-space or parkland, nature conservation areas, public open space and/or land cultivated for non-food crops. The land could then be further developed for commercial use if economic circumstances change (TECNALIA, 2013). Land recycling into open green spaces or de-naturalisation of land may, therefore, be particularly attractive for derelict sites in shrinking cities. In the context of soft re-use, key costs would include costs of remediation (if necessary) and creation of the open space along with the maintenance and operational costs. Key anticipated benefits would include increase in the neighbouring property values.

Social impacts

Land recycling in the form of brownfield or further inner urban development (e.g. gap filling, using underutilised lots) is associated with a wide range of potential social impacts. Available evidence suggests that land recycling can have an impact on human health and well-being, community cohesion and safety, visual and aesthetic landscape characteristics and historic heritage. These are discussed further in the sections below.

Impacts of brownfield redevelopment and using gap between buildings and underutilised lots

Existing evidence suggests that land recycling can have significant impacts on **human health**, both physical and mental. In instances where developed land has been contaminated and subsequently remediated, society may benefit from reduced health risks and improved health outcomes either from a reduction in direct exposure and ingestion to soil-borne contaminants or exposure to soil-borne contaminants transported into groundwater or air (Defra, 2012b) (Veermeer & Vermeulen, 2011).

Redevelopment of brownfield for commercial or housing use, as well as gap filling and increased use of underutilised lots, can however lead to an increase in densification and reduction in open spaces, which in turn may adversely impact quality of life and personal well-being. The move towards high density and compact urban development, therefore, raises concerns over **town-cramming and garden-grabbing** (Wong & Bäing, 2010).

Conversely land recycling has the potential to positively influence **community cohesion and safety**. Recycling derelict sites may result in fewer instances of vandalism, illegal dumping and drug use (Veermeer & Vermeulen, 2011) (Defra, 2012b). Available evidence suggests that new housing developed on brownfield in deprived areas resulted in **improved socioeconomic dynamics** in the areas, including population growth, improvements in **employment** and deprivation rankings in comparison to other similar areas not experiencing brownfield development for housing. While there is evidence that brownfield land reuse has supported urban containment and some regeneration in deprived neighbourhoods, an overall sustainability assessment is required when considering the costs and benefits of a brownfield development (Wong & Bäing, 2010).

Impacts of transforming brownfields into green areas

Where land recycling results in development of new urban green space, substantial human health benefits can be realised. In particular, there is a significant body of evidence on the importance attached by the public to green spaces within urban areas, including on physical health and mental well-being. Firstly, exposure to green space helps to improve **mental well-being** as it has a calming and restorative effect. The more frequent the visits to nearby green spaces, the lower the incidence of stress (Defra et al., 2011) (Defra (2010). The greatest positive effects of green surroundings were found for people with low levels of income and education. It was found that in urban zones where 90% of the area was green space, the incidence of anxiety was 18 people per 1,000 which rose to 25 per 1,000 in areas with only 10% greenery (Defra, 2013a). An increase in available urban green space also contributes to improvements in air quality and local climate conditions (e.g. reduction of urban heat island effect) thereby further benefiting **physical health** (Jacobs, 2008). Ecosystem services provided by urban green space are particularly important in densely populated areas and are explicitly associated with high quality and accessible parks and woodland, waterscapes, local nature reserves, playing fields and playgrounds (Defra, 2013a). Furthermore, recycling brownfield into an open green space can increase **community cohesion** and also lead to **reduced costs of crime**. This phenomenon is grounded in evidence that community cohesion acts as a form of social control which influences the behaviour of individuals within the community.

Environmental impacts

Redevelopment of brownfield land is one of the key measures to **reduce soil sealing** by limiting development of new land (Prokop et al., 2011). As such, land recycling could mitigate some of the negative impacts of soil sealing including, among others, pressure on water resources, biodiversity, carbon and other chemical and biological cycles (Prokop et al., 2011). Given brownfields are often located in areas with already well-developed infrastructure, requirements for new transport links and other amenities are reduced compared to greenfield. Furthermore by reducing demand for development on new land (i.e. land take), land recycling resulting in densification of urban areas could help **avoid loss of agricultural areas** (Eigenbrod et al., 2011),as well as green urban areas. This in turn may lead to reduced need for food imports (Eigenbrod et al., 2011).

By preventing development on new land of potential high ecological value, land recycling can contribute positively to **preservation of biodiversity** and **protection of valuable ecosystems**. However, evidence available suggests that in some instances brownfield land can also have high biodiversity value, for example if sites have been disused and left undisturbed for a longer period of time (Defra, 2013a). Some brownfield sites may have a higher environmental value than greenfield, due to a unique ecology and/or landscape which is considered worthy of preservation in its own right (TECNALIA, 2013). For example in the UK, many brownfield sites have been designated as Sites of Special Scientific Interest, Local Nature Reserves and County Wildlife Sites (Defra, 2012a).

Where brownfield redevelopment results in **remediation of contaminated land**, environmental and human health risks associated with tainted soils, polluted waters and airborne toxins are mitigated. Contaminated soil can negatively affect biodiversity, water, air and soil quality (for example through eutrophication and pollution of water bodies with toxic substances) and loss of habitats and species (Defra, 2012b). Remediation of contaminated soils may **increase quantities of hazardous waste** generated in the EU. Safe disposal needs to be ensured to mitigate potential risks of contamination of soil and water at different locations.

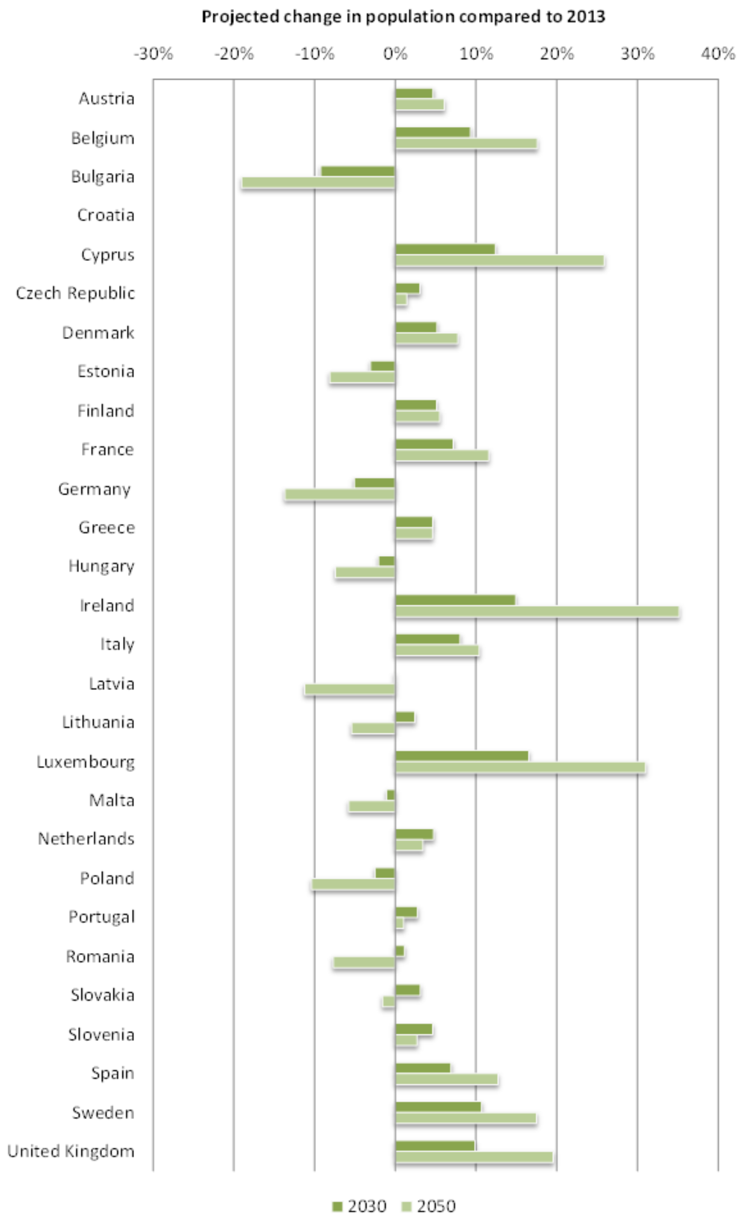
Brownfield redevelopment into soft uses or green spaces could be associated with a range of environmental benefits including **carbon sequestration**, **assimilation of soil contamination** and **air quality improvements** (Jacobs, 2008). In terms of densification measures, they lead to less land being turned over compared to development of new land (Eigenbrod et al., 2011). A case study for the UK demonstrated that 3.5 times more carbon stored in soil is released when developing new land, compared to densifying existing urban areas (Eigenbrod et al., 2011). New green infrastructure can also help **create habitats** for migrating birds and other species in urban and peri-urban areas (TECNALIA, 2013), however, in most cases there would be **limited biodiversity benefits** (Defra, 2013a). Establishment of recreational green spaces can also provide **flood management** and **water filtration** benefits.

Brownfield redevelopment can help prevent further urban sprawl. The EEA (2006a) stated that 20-45% in land resources, 15-25% in the construction of roads, and 7-15% in the provision of water and sewage facilities, can be saved through more compact city development compared to the development in the sub-urban areas In addition, it can reduce the requirements for travel and offer savings in associated **greenhouse gas emissions**. Land recycling could prevent further expansion of car-dependent and low-density developments, which overall would reduce dependence on vehicles (Nikolić I., 2014), and reduce associated negative impacts such as **air pollution, greenhouse gas emissions** and **traffic congestion**.

Some concerns have been raised in relation to the assessment and treatment of flood risk when reusing land. This may become more of a concern in MS where increased risk of floods may be experienced in the future due to climate change (Wong and Bäing, 2010). A case study for the UK comparing impacts of urban densification (minimising sprawl by increasing the density of housing within existing urban boundaries assuming conversion of approximately 948 km^2) and urban sprawl scenarios (favouring development in suburban areas and assuming conversion of approximately 3,302 km^2 of land), demonstrated that densification will result in decreased flood mitigation function of soil (Eigenbrod et al., 2011). The impacts of floods would also be greater due to more concentrated population. On the other hand development of suburban areas would not result in similar impacts as development of new land is usually sparser and includes more green areas and gardens. Overall, there is a need for careful and balanced consideration of brownfield development to ensure that the most sustainable approach is taken (Wong and Bäing, 2010).

Changes in relative importance of industry, manufacturing, construction and mining sectors to the economy of EU MS

Population statistics



Based on population projections from EUROPOP-2010 Database and population statistics from Eurostat
No projections available for Croatia

Figure 38: Projected change in population in 2013

Monitoring of land recycling in the EU

Table 67: Monitoring of land recycling in the EU and existing data on brownfields

MS	Number of brownfield sites	Area of brownfield sites	Comments
Austria	3,000 to 6,000 sites, approximately 85% with no or little contamination based on previous use data (Umweltbundesamt, 2013)	8,000-13,000 ha (Umweltbundesamt, 2013)	Large differences between the minimum and maximum estimates.
Belgium	5,528 (Wallonia)	9,000 hectares (Wallonia)	Data gathered as part of project Cabernet; collected in the early 2000s. At the moment in Flanders there is no estimation of the amount of brownfield sites. OVAM[183] is in the preliminary stages of collecting the information from relevant databases and cooperating with other Flemish governmental institutes to derive relevant estimates for the region.
Bulgaria	No estimates available. Consultation with Member State expert confirmed there is periodic monitoring undertaken at the national level but no data was provided. There are no initiatives at the regional level due to financial crisis.		
Cyprus	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Czech Republic	2,355 sites identified, however this figure did not take into account sites with less than 1 hectare, land used previously for mining and area of Prague (ECA, 2012) 50% of brownfield in the Czech brownfield dataset have no contamination and more than 70 % are in private ownership (Frantal et al., 2012)	10,326 ha (ECA, 2012) but experts estimate the actual number as 27,000 - 38,000 ha (ECA, 2012)	Data comes from two different sources therefore estimates may not be consistent. According to another source (CircUse, 2013), the total number of brownfield land in the Czech Republic is currently unknown, and the last data evaluation was undertaken over a decade ago. The figures have not been updated following recent financial crisis (CircUse, 2013). The consultation provided information on the land indicators monitored in the Czech Republic; however no brownfield or land recycling related indicator is currently monitored.
Germany	362,000 (Frantal et al., 2012). This estimate has not been confirmed through the consultation.	Based on the survey by the BBSR[184], the infill development potential (brownfield, gaps sites and underutilized lots) has been estimated as minimum of 120,000 ha (15 m2 per inhabitant). This accounts for around 5% of built-up land and open space within settlements. Following correction for underestimation it is estimated	There is no national database of brownfield sites in Germany; however many municipalities maintain such databases. The latest data available (for 2012) concern the infill development potential. The Federal States have started to develop land management tools and guidelines for the municipalities early on. They have also provided support to municipalities in setting up

[183] Openbare Vlaamse Afvalstoffenmaatschappij

[184] The Federal Institute for Research on Building, Urban Affairs and Spatial Development in Germany

		at around 160,000 ha. The previous assessments focused on brownfield land undertaken in Germany estimated that an area of around 63,000 hectares is available across municipalities (2006) (Grimski and Dosch, 2009). The German Federal Environment Agency (UBA) estimated around 150,000 hectares of brownfields in the whole country (Grimski and Dosch, 2009).	brownfield databases. For that reason, there are various approaches to collect data across Federal States. At the national level, support was provided by specific research programmes, e.g. the REFINA program of the Ministry for Education and Research (www.refina.info).
Denmark	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Estonia	Environmental register contains data on contaminated sites, total area of which is estimated at 4,545 ha. According to the response provided by Estonia to the consultation there is no data available on the area of brownfield sites. Monitoring activities are focused on contaminated soil.		
Greece	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Spain	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Finland	20,000 (Oliver et al., 2005)	Not available	Data gathered as part of project Cabernet; collected in the early 2000's.
France	200,200 Of which 3,900 potentially contaminated sites (unused and in use) were included in the BASOL database in 2009	20,000 ha 7,500 ha of industrial brownfield land were estimated to be located in the urban areas of France (Landforse and Valgo, 2014); however these are unofficial figures (private sector estimates). According to *Communautés Urbaines de France* (2010), in 2009 36% of municipalities in France had a list of brownfield sites which was regularly updated, 14% had such list but were not keeping it up to date, 21% were in the process of creating one and 29% did not have one.	Data quoted are from the early 2000s. More recently the French Environment and Energy Management Agency (ADEME) has been carrying out a study to evaluate the quantity of brownfields suitable for recycling. The results were not published in time for inclusion in this report and were not provided in the consultation. According to Landforse and Valgo (2014), regions of Île-de-France, Nord-Pas-de- Calais and Alsace et Lorraine have the highest density of industrial brownfields.
Croatia	Based on the response to the consultation there is no official identification of brownfields in Croatia.		
Hungary	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Ireland	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Italy	The only information has been identified for the Region of Lombardy, where information on brownfields (area, location, contaminants of concern) is collected and stored in a public database (EEA, 2013c). Information is published online to facilitate re-industrialisation. Information on the characteristics of brownfields can also be identified at regional level (EEA, 2013c).		
Lithuania	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Luxembourg	No estimates are available. The call of evidence provided information that a 120ha brownfield redevelopment project is currently in execution. Two projects with an area of 34 ha and 20 ha were being initiated.		
Latvia	Due to lack of definition of brownfield land in Latvia, brownfield sites are not fully identified. According to the		

	information provided in the consultation, the Land Management Law proposal defines degraded areas in order to identify them and to include them in the Spatial Development Planning Information System which is to be finalised by 2015. This information system will be used by local municipalities in the spatial development planning process. As soon as the degraded areas are identified and included in the Spatial Development Planning Information System, they can be quantified and monitored.		
Malta	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Netherlands	Not available	Project CABERNET (Ferber et a., 2006a) reported 9,000-11,000ha.	The consultation stated that information on the area of brownfield sites is not available. Information was provided on potentially contaminates sites but these sites may still be in use as such would not be in line with the definition of brownfield adopted in this study.
Poland	National figure: 3,230 (Oliver et al., 2005, quoted in Frantal et al., 2012) Silesian Voivodship: 700 (Frantal et al., 2012)	National figure: 800,000ha (Oliver et al., 2005) No national figures have been provided through the consultation. Silesian Voivodship: 11,300 ha of post-industrial, degraded areas (Frantal et al., 2012). Regional database contains more than 480 records of degraded areas (consultation).	No evidence of the national monitoring of brownfield sites have been identified in Poland.
Portugal	No estimates or information on the monitoring initiatives identified in the literature or provided through the consultation with Member State experts.		
Romania	The evidence provided in the consultation focused on identification and monitoring of contaminated sites. The national level database of contaminated sites is available on the National Agency for Environmental Protection website. No evidence of monitoring of brownfield sites has been identified for Romania.		
Sweden	40,000 (Oliver et al., 2005) The consultation provided information on the number of contaminated sites in different classes (1012 highest risk, 16000 second high risk) and the number of remediated areas (2000).	>5,000 ha (Oliver et al., 2005) According to the consultation, there is no information available at the national level on the area of contaminated sites.	Data quoted are based on unofficial figures from 2004 quoted in Oliver et al., (2005). Brownfields as defined in this study were not covered in the response to the call for evidence.
Slovakia	700 (Petríková & Vojvodíková, 2012)	Not available	Data from unofficial list of brownfield prepared in 2009.
Slovenia	According to the information in the EEA (2013), Slovenia does not have a comprehensive overview of brownfield sites nor the relevant register.		
UK	Not available	England: 68,910 ha (37,940 hectares identified as vacant; 30,980 identified as currently in use) Scotland: 11,114 ha. 402 hectares were brought back into use between 2012 and 2013. 2,355 ha were classified as urban vacant sites; 8,759 ha were classed as derelict sites.	Data for England is based on the National Database of Previously Developed Land 2010 Data for Scotland is based on the Scottish Vacant and Derelict Land Survey 2013. The Welsh Government currently does not have any programmes or initiatives to identify or quantify brownfield sites; however it has been indicated that the issue is being examined as part of an ongoing review of contaminated land in Wales.

Potential for land recycling in the EU – existing data and calculation of extrapolation factors

Table 68: Estimating the potential for land recycling in the EU – existing data and calculation of extrapolation factors

Member State	Total land cover ('000 ha)	Total brownfield area (ha)[185]		Brownfield as share of total land cover (%)		Total artificial area ('000 ha)	Brownfield as share of total artificial area (%)	
		Min	Max	Min	Max		Min	Max
AT	8,388	8,000	13,000	0.10	0.15	486	1.65	2.67
BE	3,053	7,200	10,800	0.24	0.35	410	1.76	2.64
CZ	7,887	10,326	38,000	0.13	0.48	313	3.30	12.16
DE	35,713	63,000	150,000	0.18	0.42	2,746	2.29	5.46
FR	54,397	16,000	24,000	0.03	0.04	3,146	0.51	0.76
NL	4,154	9,000	11,000	0.22	0.26	506	1.78	2.17
SE	43,858	4,000	6,000	0.01	0.01	789	0.51	0.76
SK	4,904	517	776	0.01	0.02	159	0.33	0.49
UK	24,853	64,019	96,029	0.26	0.39	1,625	3.94	5.91
Average (extrapolation factor)				0.10	0.19		1.79	3.43

[185] In the case of MS for which estimates of brownfield area were not provided as a range, the estimates were adjusted by +/-20% to provide a minimum and maximum value

Table 69: Estimation of brownfield area

Member State	Estimation of total brownfield area (ha)			
	Based on total land cover		Based on total artificial area	
	Min	Max	Min	Max
Existing data for MS				
AT	8,000	13,000	8,000	13,000
BE	7,200	10,800	7,200	10,800
CZ	10,326	38,000	10,326	38,000
DE	63,000	150,000	63,000	150,000
FR	16,000	24,000	16,000	24,000
NL	9,000	11,000	9,000	11,000
SE	4,000	6,000	4,000	6,000
SK	517	776	517	776
UK	64,019	96,029	64,019	96,029
Total	**182,062**	**349,604**	**182,062**	**349,604**
Estimated data for MS for which data on total brownfield area was not available				
BG	10,785	20,710	4,656	8,940
CY	900	1,728	1,218	2,339
DK	4,172	8,011	5,436	10,438
EE	4,398	8,446	1,422	2,730
EL	12,833	24,643	8,886	17,063
ES	48,482	93,096	35,219	67,630
FI	32,914	63,202	9,449	18,145
HR	5,495	10,551	5,495	10,551
HU	9,047	17,372	6,201	11,908
IE	6,788	13,035	4,808	9,232
IT	29,306	56,275	42,127	80,894
LT	6,351	12,195	3,050	5,856
LU	251	483	553	1,061
LV	6,279	12,057	1,815	3,486
MT	31	59	186	357
PL	30,409	58,392	22,020	42,283
PT	8,664	16,637	9,930	19,069
RO	23,184	44,520	10,152	19,495
SL	1,972	3,786	1,327	2,548
Total estimated (ha)	**242,259**	**465,198**	**173,949**	**334,026**
Total for the EU-28 (sum of actual and estimated brownfield area) (ha)	**424,322**	**814,802**	**356,012**	**683,630**

Table 70: Brownfield data for a sample of EU cities

MS	City	Total brownfield area (ha)[186]	Total area (ha)	Share of brownfield land (%)	Population (' 000 inhabitants)	Population density (inhabitants per hectare)	References
UK	London	1,245	157,215	0.8%	8,174	52	Homes and Communities Agency (2010) ONS (2011)
UK	Leicester	66	7,331	0.9%	330	45	
UK	Manchester	302	11,564	2.6%	503	44	
UK	Liverpool	544	11,184	4.9%	466	42	
UK	Birmingham	339	26,779	1.3%	1,073	40	
UK	Bristol	139	10,961	1.3%	428	39	
UK	Glasgow	1,159	17,468	6.6%	593	34	SVDLS (2013) ONS (2011)
UK	Coventry	105	9,864	1.1%	317	32	Homes and Communities Agency (2010) ONS (2011)
DE	Stuttgart	89	20,735	0.4%	598	29	Landeshauptstadt Stuttgart (2014) Statistisches Bundesamt (2013b)
DE	Essen	287	21,030	1.4%	567	27	Regionalverband Ruhr (RVR) (2011) IT.NRW (2013)
DE	Gelsenkirchen	458	10,494	4.4%	258	25	
DE	Duisburg	522	23,280	2.2%	487	21	
DE	Dortmund	725	28,071	2.6%	572	20	

[186] In the case of MS for which estimates of brownfield area were not provided as a range, the estimates were adjusted by +/-20% to provide a minimum and maximum value

MS	City	Total brownfield area (ha)[186]	Total area (ha)	Share of brownfield land (%)	Population (' 000 inhabitants)	Population density (inhabitants per hectare)	References
UK	Edinburgh	226	26,333	0.9%	477	18	SVDLS (2013) ONS (2011)
UK	Sheffield	456	36,795	1.2%	553	15	Homes and Communities Agency (2010) ONS (2011)
UK	Bradford	102	36,642	0.3%	522	14	
UK	Leeds	833	55,172	1.5%	751	14	
UK	Aberdeen	50	18,571	0.3%	223	12	SVDLS (2013) ONS (2011)

EU instruments supporting land recycling

Overview

Regulatory instruments

National spatial planning regulations provide an overall framework for development of land in a country. They inform regional and municipal development plans and actions. In the federal EU MS (e.g. Germany and Austria), a state level legislation determines general principles for planning and development strategies across the country (Difu, 2013).

Planning policies introduced in the MS to date have facilitated land recycling by:

- Restricting rate of development on greenfield land;
- Setting preference for development on brownfield land instead on greenfield;
- Introducing quantitative or qualitative targets; and
- Decreasing overall risks to prospective brownfield land developers by minimising legislative uncertainties.

Weakness of planning policies is named among the key barriers for efficient use of land as a resource, for example in Croatia (Sumpor, 2010) and Poland (Kowalewski et al., 2010).

Urban development plans and other national, regional and local level planning strategies have an important role to play in facilitating land recycling. A development plan is a document containing planning and development objectives and proposals for a given area. Such a plan in general contains information on the existing and planned built-up and green areas as well as transport and other infrastructure; and can be introduced either as legally binding or informal instruments (Difu, 2013). Development or land use plans can be created at various levels, from national and regional strategies to municipal plans, but they fit within the wider planning framework introduced in a country. In the context of land recycling, development plans and land use plans may include strategies, plans and targets to identify and redevelop brownfield sites. ECA (2012) recommended that "*brownfield regeneration projects should be part of an integrated development plan for the city or area concerned*".

Some urban development plans also consider overall potential for inner-city development. For example, the land use plan for the city of Stuttgart is based on the principles of primacy of the inner-urban development vs development on greenfield, on and providing inner-urban green areas (and connecting them to renaturated brownfields). In Estonia, Tallinn's plan is based on the goal to increase the usage intensity of existing land committed to housing and to re-use empty or insufficiently developed areas[187].

There is some evidence suggesting that in some MS, the potential benefits of introducing urban development plans or similar planning strategies has not yet been maximised. For example in Poland, preparing local development plans is not compulsory. Only 28% of the total area of the country is covered by development plans, with many urban areas are a lacking strategic vision for the location and functions of future developments (Kowalewski et al., 2010).

[187] Source: call for evidence

Other legislation and strategies influencing land recycling in the EU MS are related to:

- Dedicated brownfield regeneration strategies;
- Urban redevelopment, preservation of historic buildings and public space;
- Industrial activities and economic growth;
- Contaminated soil and its remediation; and
- Sustainable development.

Specifically with regard to the contaminated soil legislation, the European Court of Auditors (ECA, 2013) has highlighted wide differences between soil contamination screening values across MS and advised to implement common standards for contaminated soil across the EU.

Market- based instruments

Urban development funds focus on all forms of urban investment. These funds are usually set up as revolving loan funds, from which loans made are to be repaid with interest. This allows the fund to be maintained and money can continue to be lent (European Commission, 2008). Loans made from the urban development funds are generally low-interest (Medda et al., 2011). In the context of brownfield redevelopment, **revolving funds** are established to meet specific objectives in the city, region or country. They can be used for clean-up of a site, removal of existing structures etc. (Medda et al., 2011). In some MS (e.g. Bulgaria) a revolving loan fund is used to help local authorities and organisations to access money available from the EU Structural and Cohesion funds (e.g. support proposal writing). In general, revolving loan funds would not be used to fund projects which do not generate sufficient revenues to cover the required investment (these types of projects are likely to be funded through public sector grants). Urban development funds support brownfield regeneration projects as this offer diversification of the lending portfolio and long-term returns.

Unlike the urban development funds, **grants** do not need to be repaid, and therefore are usually offered to finance redevelopment of projects which are unlikely to bring sufficient returns on investment, for example contaminated brownfields. Grants have also been used to support the soft-end use redevelopment of brownfield land, including re-naturalisation. While such projects may not bring sufficient returns to attract private sector investment, they can benefit the local community by providing green urban spaces and improving quality of life, thus justifying use of public funds.

Box 15: Grants for brownfield redevelopment in France[188]

The French Environment and Energy Management Agency (ADEME) subsidises industrial brownfield redevelopment. The budget in 2014 was intended to be around EUR4m. In 2011, the total budget was EUR10m, in 2012 EUR8m and in 2013 EUR4m. 40% - 50% of the cost of soil remediation or of structural works can be financed through the subsidy, up to a maximum cost of EUR1.5m.

In 2011, 66 applications for grants have been received by ADEME. 26 projects have been selected, which were intended to deliver remediation of 133 hectares of land and construction of new buildings for mixed use, 60% of which was anticipated to be housing.

[188] Source: ADEME (2011), MS consultation

In the **land value finance (LVF)** model, the cost of redevelopment is recovered through an increase in the value of land resulting from an investment (Medda et al., 2011). The increase in land value is captured directly or indirectly by conversion into public revenues (received through fees, taxes or other fiscal instruments). This type of mechanism recoups the costs of the required investment, and returns the profits to the public by bringing the land into economic use. The LVF has been reported as particularly relevant in financing redevelopment of brownfield sites with wider public goals and can be used to finance broad range of projects, including transport infrastructure, housing, cultural amenities (Medda et al., 2011).

Land take / urbanisation or spatial development taxes can be introduced per area unit of previously undeveloped land taken up by a development, or can be applied as a one-off charge. Such taxes can be used to discourage building outside urban areas, thus supporting use of previously developed land. However, many European municipalities decide to keep land use taxes artificially low to compete for new investments (European Commission, 2013b). In order to provide incentive to develop a certain type of land, tax level needs to be set relatively high (EEA, 2010c). Overall, while taxes can be an effective add-on to the proper functioning of the planning system, alone they may be insufficient to guarantee that brownfield or previously developed land will be developed in place of greenfield (EEA, 2010c).

Tax on empty homes / underused property which introduce an additional or higher rate of tax on empty or underused property, have also been identified as supporting brownfield redevelopment. Such tax aims primarily to discourage dereliction of existing structures and support the efficient use of already developed land, thus decreasing demand for new development.

Non-regulatory instruments

Several MS have produced **guidelines on best practice in land recycling**. Guideline documents assist actors involved in brownfield redevelopment (for example potential investors, local authorities, community groups) in planning the redevelopment of brownfield sites. Depending on the local circumstances, national or local guidelines may contain information on the fundamentals of brownfield redevelopment, methods, benefits and costs of bringing brownfields back to beneficial use, regulatory framework, best practices and case studies etc. Furthermore information provision on the methods of valuation of previously developed land could help investors determine its real market value. Such standards can for example define the basic information required to establish the environmental status of a site, estimate the redevelopment costs or inform the design of the project.

Agencies aimed at facilitating investment in a region or a municipality have an important role in redeveloping brownfield sites. Such agencies identify brownfields, engage stakeholders and attract prospective investors for the site as well as identify possible sources of funding and assist the stakeholders in obtaining them. They may also have transitional ownership of land during its clean-up and promotion. Development agencies are often able to acknowledge the local communities' views on the redevelopment proposals and to act as a mediator between prospective investors and the public authority/owner.

Box 16: Role of *Etablissement Public Foncier* (EPF) in France[189]

EPFs bring together specialists in land related topics from a range of disciplines such as law, negotiation, rehabilitation, management, purchasing, etc. The first EPFs were created with an intention to deliver specific land tasks, for example redevelop post-industrial land abandoned as a result of crisis in the 1970s in the region of Lorraine. EPFs take temporary ownership of the land in order to prepare it for redevelopment. The extent of works required is site specific and may require for example demolition of existing structures, laying down the infrastructure, remediating soil, etc. EPFs bear the full risks associated this work. Their intervention does not depend on whether a pre-defined project for the land exists (development phase of the project is governed by the Local Planning and Development Agencies). The preparatory works undertaken by EPFs can take between 4-7 years.

Once the land is redeveloped, the EPF sells it back either to the municipality or to the private investor. EPFs are financed from special taxes, profits from sales of land and public grants (for example EPF Lorraine finances itself from a special tax on equipment which is no greater than EUR20 per capita, the sales proceeds and any grants received). In the region of Lorraine in 2013, the EPF Lorraine invested a total of EUR 12.2m in work related to redevelopment of brownfields. A total of 143 reconversions sites were active in 2013 (compared to 150 in 2012). Out of the 143 sites, in 82 cases actual work on site was undertaken (EUR 9.2m). Work on remaining 61 projects comprised of various desktop studies (EUR 2.2m).

Other example of activities undertaken by EPFs is preparing inventories of brownfield sites as was undertaken for example in the region of Normandie in 2011.

Public Private Partnership (PPP) is a public and private sector jointly owned entity set up to carry out regeneration works (ECA, 2012). PPPs are able to provide public authorities with the private investment they may lack, as well as means to promote the site once it is redeveloped. For private investors, PPPs allow sharing investment risk with other parties. PPPs are set up as new legal entities, with objectives and milestones set up in a way that benefits each party involved. Overall, PPPs ensure efficient transition between regeneration, reuse and profit generation from the redeveloped sites. On the other hand, according to Petríková & Vojvodíková (2012) PPPs can be perceived as having a negative impact on future cash flows of municipalities.

Box 17: Brownfield redevelopment using PPP in Poland[190]

The private party was the main investor in the project "*Manufaktura*" to redevelop a former cotton factory in the city of Lodz (total derelict area of 27 ha), into a multifunctional centre comprising entertainment, commercial and cultural activities. The total cost of the redevelopment was estimated at around EUR 120m. The public bodies (local authorities including the City Hall, Marshal Office, and Provincial Heritage Conservator) were involved in the design works and execution of the building renovation. 2,500 people were employed during the redevelopment phase, with around 3,500 currently employed by the centre.

[189] Sources: PWC (no date), EPFL (no date), MS consultation
[190] Source: Medda et al., (2011)

Table 71: Summary of EU instruments supporting land recycling

Type	Instruments and initiatives	General description	Comments/Examples
Regulatory	Industrial Emissions Directive (IED)	The provisions of Article 22 require the preparation of a baseline reports on soil quality at certain industrial sites covered by the IED (for both new sites and existing sites when permits are updated). Upon cessation of activities at the site, the operator is required to undertake examination of the soil quality, and ensure it is returned to its former state (if contamination has occurred).	Prevention of future land contamination; affecting future creation of contaminated sites.
	Environmental Liability Directive	Established a framework based on polluters pays principle to prevent and remedy environmental damage. Damage to soil is classified as environmental damage.	Mechanism to define liability for soil contamination and request operators of polluting activities to cover the costs of soil clean up
Market-based	European Regional Development Fund (ERDF) and Cohesion funds	ERDF and Cohesion Funds are used to correct economic disparities across the EU regions. ERDF has funded several Operational Programmes that listed redevelopment of different types of brownfield as their priorities. The national and regional Operational Programmes successfully target specific and the most relevant priorities in the regions. Cohesion funds are available to countries that have less than 90% of the EU average GDP. This includes all the new accession MS, Portugal, and Greece. Spain receives funds as part of a phase out transition.	Examples include industrial brownfield regeneration and 12 pilot urban brownfield regeneration projects (Petríková & Vojvodíková, 2012). Structural funds (ERDF and cohesion funds) funded projects for a total value of EUR2.3 billion in the period 2000-06 and EUR3.4 billion in the period 2007-2013. For the latter period it represented 1.3% of the total budget (ECA, 2012).
	Joint European Support for Sustainable Investment in City Areas (JESSICA) financing tool	EU special supporting tool developed from EC initiative in cooperation with the European Investment Bank (EIB) and the Council of Europe Development Bank (CEB). It supports sustainable urban development and regeneration through "soft" interest loans (Petríková & Vojvodíková, 2012). The tool is funded through ERDF and private sector investment. The projects are expected to generate revenue to repay the loan and amortise the private partners' investment.	The tool is flexible, which is particularly useful in the case of brownfield redevelopment projects due to unexpected events (e.g. discovered contamination). It combines public and private expertise. Loans are to be repaid and therefore the expenditure is expected to return to the EU (Petríková & Vojvodíková, 2012).
	Urban Development Fund	ERDFs specifically allocated to sustainable urban development. Also partially funded with cohesion funds	Examples are projects supported through URBACT - European exchange and learning programme supporting sustainable urban development. An example of such project is REPAIR, which focused on realising the potential of abandoned military sites as part of urban regeneration.
Non-regulatory	European Commission Guidelines on best practice to limit, mitigate or compensate soil sealing	Provides examples of best practice, impacts and current data on soil sealing in the EU	Brownfield redevelopment is listed as one of the measures that can be used to limit soil sealing.

Role of ERDF in financing brownfield redevelopment

One of the advantages of ERDF is that additional funding can be provided once the project commences. This is particularly useful in the case of brownfield redevelopment projects where unexpected problems (such as discovery of contamination) may lead to funding gaps. Some of ERDF funds are envisaged as loan funds that include investments from banks and the private sector.

One of the examples where ERDF funds have been used successfully to facilitate brownfield redevelopment is the region of Saxony in Germany, which introduced a specific programme to efficiently allocate the financing available from the ERDF[191]. The Regional Programme for Saxony (2007-2013) was dedicated to redevelopment of brownfield land (it formed a part of EUR109 million allocated to sustainable urban development along with EUR15 million funding from private investors). 23 urban brownfield sites were targeted, of a total area of approx. 35 km^2. Municipalities eligible for funding had to have at least 2000 inhabitants, a history of industrial past followed by a stage of industrial recession. Eligible projects had to demonstrate that areas put forward for redevelopment are affected by issues such as unemployment, lack of businesses, and emigration of young people. The redevelopment projects needed to be a part of a long-term, sustainable vision for the area. 75% of the project costs were funded with non-refundable subsidy, and the remaining costs were covered with other methods, with a compulsory 10% contribution from the local community. Low-interest loans were also provided.

Projects include:

- Old foundry transformed into a park (ERDF: EUR238,000 / Region: EUR210,000 / Local co-payment: EUR29,000)
- Re-development of a contaminated post-industrial area in Schoenberg (ERDF: EUR405,000 / Region: EUR288,000 / Local co-payment EUR117,000).

The region allocated additional funding for brownfield redevelopment of EUR10 million/year for the years 2013 and 2014.

Petríková & Vojvodíková (2012) suggest that EU funds may have reduced national actions on brownfield regeneration, as MS might have preferred to maximise use of EU funds, rather than develop their own initiatives. One view received from a land management expert, as part of the MS consultation, was that some structural funds allocated to support new development in MS may actually contribute to the emergence of brownfields (e.g. locating a new shopping centre at the outskirts of the city may mean that shops within city boundaries will go bankrupt, thus creating unused spaces within the urban areas; supporting development of new tourist accommodation or housing developments, which never become completed and thus emerge as brownfields as result of the recession). Then the EU funds are used again to redevelop brownfields. This suggests that there may be scope to introduce some improvements in the way that structural funds are allocated to projects, to ensure that new developments will not have an adverse impact on the land use within urban areas (for example through more market studies before allocating funds); however this issue has not been investigated specifically as part of this study.

[191] Source: Ferber, 2010; Lee-Pleuker and Klauer, 2010; Brachflächenrevitalisierung-Sachsen, 2013; Service Portal for Saxony, 2013; Urbact, 2013; B-team initiative, n.d., Kremling, 2013

Details per Member State

Table 72: Regulatory instruments supporting land recycling in EU MS

Instrument	Adoption and examples across MS
Spatial planning regulations	**Germany -** The recently revised German Building Code states that urban development should be primarily achieved through development in the inner cities, by redevelopment of existing brownfield sites, gaps and underutilised land lots as well as densification of existing urban areas (Difu, 2013). Given the recent implementation of that requirement, it is impossible to assess how successful it has been in supporting land recycling to date. **Estonia -** The aims of the national planning document "Estonia 2030" is to maintain compactness and to tighten the internal structures of urban areas, as well as to recycle marginalized areas of the cities and other major settlements in the process of planning (Source: MS consultation). **Ireland -** Guidelines 2009 on the national planning policies recommend that where substantial areas of brownfield or greenfield sites are to be (re)developed, a local area plan (LAP) should be prepared to ensure development of the area according to the principles of sustainable development, and to avoid it being developed in a piecemeal and incoherent fashion over a long period of time (Government of Ireland, 2009). In addition, opportunities for higher density developments in these locations should be promoted (subject to a number of safeguards or in accordance with local area plans). **Malta -** Strategic Plan for Environment and Development (SPED) (MEPA, 2014) issued for consultation in March 2014 is intended to regulate the sustainable management of land and sea resources in Malta, in the framework of the Environment and Development Planning Act of 2010. The SPED states that in preparing policies, plans and programmes the Government of Malta will apply the sequential approach to the use of land - development should be guided first to the re-use of existing developed land and buildings, then through a re-development of existing developed land and buildings and finally to the use of vacant land. The bulk of development is to be directed to urban areas. This rule applies to the National Spatial Framework (NSF). **Latvia -** The proposed new Land Management Law (not yet adopted) defines the general rules for locating new developments in Latvia. In the proposal, degraded areas are defined as areas with degraded or desolated grounds, as well as abandoned construction sites, post mining sites and ex- military training grounds etc. In the proposed legislation, these areas should be included in the local spatial plans and be recycled first before new greenfields are used for the purpose of new development. In addition, the objective to develop support tools for revitalization and re-naturalisation of degraded areas in Latvia is set in the national Guidelines for Landscape Policy. These tools are to be developed in 2017 (Source: MS consultation). **Slovenia** - The Ordinance on Spatial Planning Strategy of Slovenia includes some general recommendations concerning brownfields (no further details provided in the source document (Siebielec et al., 2012). **United Kingdom** - The green belt policy has been a simple instrument in the UK planning law aimed at containing urban growth. Green belt is a designated open area around the city, where in principle construction of new buildings cannot take place (exemptions from that rule are permitted under special circumstances). By limiting potential for growth at the outskirts of urban areas, green belt policies encourage recycling of derelict and other urban land across the country (Planning Portal, no date).
Urban development plans and other national, regional and local level planning strategies and land use plans	**Austria** - Vienna Stadtentwicklungsplan – STEP **Hungary** – National Rural Development Strategy includes measures for land protection such as development of greenfield versus brownfield (EEA, 2013c) **Belgium** - The Spatial Structure Plan for Flanders **Germany** - Land use plan 2010 for the city of Stuttgart **Estonia** - Comprehensive Plan for Tallinn City **Latvia** – Several municipalities have their own planning documents and action programmes aimed at redeveloping brownfield land. Riga municipality has introduced a Programme for Revitalization of Degraded Objects and Areas. In 2009, around 460 degraded areas were identified in Riga. As of 2012, 61

Instrument	Adoption and examples across MS
	of them were demolished or renovated (Source: MS consultation). **Poland -** The National Spatial Development Concept 2030 (NSDC 2030) introduces brownfield before greenfield development principle with a view to reduce urban sprawl and intensify urbanisation (EEA, 2013c)
Targets on the type of land for locating new development	**United Kingdom** - Targets for new housing built on brownfield land.
Other legislation and strategies influencing land recycling	**Austria -** Land re-use and revitalization activities are addressed by the Law of Preservation of Historic Centres, Law for Rehabilitation of Inherited Waste dealing with registration and identification of brownfields, and Law for Renovation of Towns, regulating the restoration of buildings (Act on Contaminated Soil (No. 1427 of 2009)). **Greece -** The main legislation influencing land recycling is related to contaminated soil. It concerns for example rehabilitation of improper/uncontrolled waste disposal sites and remediation of environmental damage caused to biodiversity, water and soil (Source: MS consultation). **Germany -** The problem of brownfield sites have officially been brought on the political agenda in Germany by the National Strategy on Sustainability (Source: MS consultation). The Federal Building Code in Germany sets out a formal framework for spatial planning and establishes instruments for urban rehabilitation and redevelopment. It is accompanied by sectorial legislation addressing specific aspects of land re-use and revitalization, e.g. Federal Soil Protection Law (Brachflächenrevitalisierung-Sachsen, 2013). **Czech Republic** - In 2005 a dedicated Brownfield Redevelopment Strategy has been published. The strategy fits within the wider policy framework set out by five strategic and planning documents: Sustainable Development Strategy of the Czech Republic, Economic Growth Strategy of the Czech Republic, Regional Development Strategy of the Czech Republic, Spatial Development Policy of the Czech Republic, State Environmental Policy of the Czech Republic (Frantal et al., 2012). **Finland -** Land recycling is indirectly encouraged by the rules set out in the Environmental Act, Land Use and Building Act and the Building Code. At the time of writing this report, both Environmental Act and Land Use and Building Act are being revised (Source: MS consultation). **France -** The new law for a renewed urbanism (ALUR law) allows for the remediation activity to be delivered by a party willing to re-use polluted industrial brownfield, rather than requiring the last operator to undertake the remediation. Before the Law was enacted, the last operator of an industrial site was required to remediate the soil, but the standards to which the remediation was done were often insufficient for the new use of a site. Thus developers had to remediate the soil again to a standard required for the intended use. The new Law is expected to speed up the redevelopment process of contaminated brownfield sites, as developers will now be able to remediate the site to their required standard in one rather than two steps (Source: MS consultation). **Croatia -** The Strategy for sustainable development of the Republic of Croatia 2009 established economic instruments supporting the utilisation of abandoned areas, revitalisation of derelict urban lands and transformation and remediation of industrial zones (e.g. where factories have shut down). The Strategy also supports better use of urban areas by promoting inner development. With regards to urban development, Croatia aims to reduce the growth of large cities by improving attractiveness of a medium-size and small towns (with 7,000 - 30,000 inhabitants) (Source: MS consultation). **Latvia -** The recultivation of mining and/or polluted sites is directly regulated by law. According to the Law On Subterranean Depths the users of land have a duty to recover damages caused as a result of their activity at their own expense. The local governments in the administrative territories supervise remediation of these sites. The “polluter pays” principle is incorporated in the Law On Pollution. Both laws are effective in remediating contaminated sites with the exception of the sites where polluter cannot be identified because the pollution occurred in the soviet times (Source: MS consultation). **United Kingdom** - In 2011 the UK Government published a Housing Strategy for England, which made publicly-owned brownfield sites available for private sector development. It has been estimated that total area of these sites could accommodate 100,000 new homes (HM Government, 2011).

Table 73: Market-based instruments supporting land recycling in EU MS

Instrument	Adoption and examples across MS
Urban / regional development funds and revolving loan funds	**Bulgaria -** Bulgarian Fund for Local Authorities and Governments (FLAG) is a regional development fund which since 2007 has been financing development and implementation of financially viable urban infrastructure projects. The fund also supports municipalities interested in benefiting from the EU Structural and Cohesion funds by providing low-interest finance during proposal writing (Browntrans, no date). **Netherlands -** A joint initiative entitled "Brownfields Beter Benut" (Brownfields Better Used) provides low-interest loans for brownfield projects developers (Medda et al., 2011)
Grants / subsidies	**Bulgaria** - On a case by case basis, some redevelopment can be funded from the national budget; however, overall this has to date had little influence on brownfield redevelopment in the country. State funded programmes in Bulgaria usually support sites still in economic use. **Czech Republic** - Grant financing for redevelopment of military brownfields is available from the Czech Ministry of Regional Development. The Czech Ministry of Culture offers grants to maintain properties of historical and cultural value to avoid their dereliction while the new use of these properties is being decided on (Petríková & Vojvodíková, 2012). **France** - The French Environment and Energy Management Agency (ADEME) subsidizes industrial brownfields redevelopment. The budget in 2014 was intended to be around EUR4m. In 2011 the total budget was EUR10m, in 2012 EUR8m and in 2013 EUR4m. From 40% to 50% of the cost of the remediation or of the architectural measures can be financed through the subsidy, up to a maximum cost of EUR1.5m (Source: MS consultation). **Germany** - Direct subsidies for redevelopment of brownfield sites has been successful in encouraging land recycling (Source: MS consultation). **Slovakia** - Grant schemes are focused on the re-development of public spaces and public buildings (Petríková & Vojvodíková, 2012). **Sweden -** Government subsidies are available for investigation and remediation of priority contaminated sites. The subsidy can cover up to 90% of the costs (Danish Ministry of the Environment, 2012). **United Kingdom -** The Contaminated Land Capital Grant Scheme has been subsidising identification and remediation of contaminated sites by the local authorities. In 2009/2010 £17.5m has been made available to the local authorities, decreasing to £2m in 2013/2014 and subsequently being withdrawn completely from April 2017 due to budget cuts. Between 2014 and 2017, £0.5m will be made available to local authorities for emergency and highest-priority projects (Defra, 2013c).
Land value finance (LVF)	Specific examples of the use of LVF for brownfield redevelopment projects have not been identified in the existing evidence for any of the EU MS. However, (Medda et al., 2011) provided example when LVF has been used for redevelopment of a heritage brownfield site in Turkey.
Land take / urbanisation / spatial development tax	**Czech Republic -** The land take tax introduced per hectare of agricultural land intended for development purposes is discouraging transition of agricultural land and facilitating development of brownfield land. Redevelopment of brownfields has been facilitated since the increase in tax in January 2014 and grading of the tax according to the quality of land (Source: MS consultation). **Portugal -** Municipal Urbanisation Tax in the city of Tomar. Following changes to the national law, Portuguese municipalities have been updating their municipal land use regulations (European Commission, 2013b). Tomar has increased the tax burden on development outside urban areas, in line with a strategy to forbid building outside urban areas. It is yet too early to conclude on how successful the tax has been in encouraging brownfield redevelopment in the city (European Commission, 2013b).
Tax on empty homes / underused property	**Luxembourg** - Tax on underused land has been introduced in one municipality (Source: MS consultation) **United Kingdom -** At regional level, local authorities can charge up to 50% extra in the Council Tax rates on dwellings that are left empty for more than two years. Council Tax in the UK is charged per household and depends on the results of property valuation. In case of empty properties, council tax has

Instrument	Adoption and examples across MS
	to be paid but owners can qualify for discounts at the discretion of the local authority. Approximately 850,000 homes are empty in the UK (1/3 long term), while the country has a shortage of 100,000 homes per year (Empty Homes Statistics, 2013). Mayor of London has been advocating increasing the rate of council tax paid on empty properties to discourage dereliction of properties.

Table 74: Other non-regulatory instruments supporting land recycling in EU MS

Instrument	Adoption and examples across MS
Guidelines on best practice in land recycling	Austria - Guidelines on brownfield redevelopment ("Bau Land in Sicht", Published by the Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management 2008 available online at http://doku.cac.at/bau_land_in_sicht.pdf) Germany - Municipalities and German Federal Governments have published best practice guidelines and developed tools to aid identification and management of brownfields. While provision of the national guidelines was not required (as this would repeat the efforts already undertaken at the regional level), numerous regional guidelines resulted in lack of consistency in the methodologies applied to estimate brownfield land across the German Federal States (Source: MS consultation). United Kingdom - Guidance on assessing the costs of preparing for redevelopment of sites affected by contamination or dereliction and on pre-acquisition site investigations, as part of due diligence ("Contamination and Dereliction Remediation Costs Best Practice Note 27" available from https://www.homesandcommunities.co.uk/ourwork/publications-and-data). - A best practice approach to brownfield redevelopment (The Brownfield Guide - available from https://www.homesandcommunities.co.uk/ourwork/publications-and-data).
Dedicated agencies facilitating recycling of land / land development agencies / revitalisation agencies	**Austria -** Land Management Agency Voitsberg (CircUse, no date) **Germany -** Land Development Agencies in Thuringia and North Rhine Westphalia have promoted and supported the brownfield redevelopment process (Grimski & Dosch, 2009). **Czech Republic -** CzechInvest (Frantal et al., 2012) **France -** Etablissement Public Foncier (EPF) (Source: MS consultation) **Latvia -** Investment and Development Agency of Latvia (http://www.liaa.gov.lv/lv)
Public Private Partnerships	**Bulgaria -** Local authorities participate with the property and private investors usually to redevelop old factories and industrial plants. Approximately 1/3 the PPP'S ownership is held by the Bulgarian local authorities (Petríková & Vojvodíková, 2012). Bulgaria adopted a new PPP law in 2012 but no evidence has been identified on how successful it has been to date in facilitating land recycling (The Sofia Globe, no date)**.** **Portugal -** Porto Vivo (SRU) is a public entity established in 2004 for the rehabilitation of the historic centre of Baixa Porto (Medda et al., 2011) **Poland -** The Manufaktura project in Lodz has been delivered through a PPP (Medda et al., 2011) **Latvia -** Redevelopment undertaken in the city of Riga (Solks, 2011) **Luxembourg -** The PPP Agora was established in early 2000s to redevelop former steel works (120ha). Agora since became a limited company specialising in urban redevelopment, with 50% owned by the state of Luxembourg and the remaining half by a private company. The company provides

Instrument	Adoption and examples across MS
	services across all stage of brownfield redevelopment from analysis and planning to marketing of the sites (http://www.agora.lu). **Slovakia -** PPPs are used for urban and regional development projects. Eurovea - a new international trading centre in Bratislava has been built on a former brownfield site and delivered by PPP. **United Kingdom -** Redevelopment of the former cast mine in Rotherham was delivered by a PPP. The private party contributed 30% to the PPP (the value of land) (ECA, 2012)
EIB investment in a brownfield redevelopment fund (private equity fund)	**France** – Brownfields, a private equity company specialising in the redevelopment of brownfields (http://www.brownfields.fr/), raised funds from several institutional investors including the EIB, the French *Caisse des Dépôts* and several other French institutional investors. Since its creation in 2006, the company has invested over 100 m EUR to clean up about 20 contaminated sites in France. The company conducts the preliminary environmental surveys, buys the site, carries out the clean-up works then sells the site with a 10-year guarantee on the clean-up works. The EIB participation's in Brownfields second fund is EUR 55.5m (out of a EUR 100m target for this second fund).

Annex 4.1: Objectives and targets related to land degradation in Member States

International level

In 2012, during the United Nations Conference on Sustainable Development ("Rio+20"), the United Nations Convention to Combat Desertification (UNCCD) formulated a target of "zero net land degradation". A dedicated working group is currently preparing a proposal for future targets dealing with land degradation to achieve this global goal. It includes sub-targets that namely address soil erosion and soil organic matter (Ehlers, Lobos, Montanarella, Muller, & Weigelt, 2013):

- Soil erosion: Reduce by 50% the amount of soil being eroded by wind and water;
- Soil organic matter: By 2030, countries that have completed their national ecosystem assessment, have tested quantifiable indicators for soil productivity, soil water storage capacity and soil organic matter content.

EU level

Since 2003, the Common Agricultural Policy (CAP) has introduced mandatory cross-compliance obligations. Amongst others, farmers must comply with requirements that aim at maintaining and encouraging good agricultural and environmental conditions (GAEC). Failure to respect these conditions may result in deductions from, or complete cancellation of, direct payments. These GAEC, adapted at national scale, include mandatory and optional standards that aim at addressing five issues[192], including soil erosion and soil organic matter. There are qualitative objectives associated with these issues:

- Soil erosion: Protect soil through appropriate measures;
- Soil organic matter: Maintain soil organic matter levels through appropriate measures.

Further details on how the implementation of GAEC contributes to addressing soil erosion and SOM loss are provided in Section 4.6.1.1.

In 2011, the Roadmap for a Resource Efficient Europe proposed two indicative quantitative targets with regard to soil degradation:

[192] Initially the GAEC included four issues. The issue related to the protection and management of water was added in 2008.

- The area of land in the EU that is subject to soil erosion of more than 10 t/ha per year should be reduced by at least 25% by 2020; and
- Soil organic matter levels do not decrease overall and increase for soils currently with less than 3.5% organic matter by 2020.

The target for soil erosion is based on EEA indicator "Soil erosion by water" based on data from the PESERA and/or RUSLE model of the JRC. The target for soil organic matter is based on the data from the LUCAS project (European Commission, 2011b).

MS level

Few MS have already formulated their own targets related to land degradation. Only few of them specifically focus on soil erosion and soil organic matter. Set at the national level, targets mostly remain indicative and are used as monitoring tools. A detailed presentation of existing national targets related to land degradation is available in Annex 4.1. Existing targets focus on:

- **Preventing and/or reducing erosion and SOM losses** (e.g. DE, HU, HR, UK, RO). In Germany for instance, the national target is to continuously reduce soil erosion by 2020. In the UK, the target is to reduce significantly the rate of loss of stored soil carbon by 2020. MS such as Croatia and Romania only have qualitative objectives at national level, mostly addressing land degradation in general. For instance, in Croatia the national target is to prevent and decrease forest soil degradation. In Romania, quantitative targets are proposed at the regional level.
- **Implementing measures to address soil erosion or SOM losses** (AT, EE, FR, LV, and SE). Three types of targets have been identified:
    - General targets on the implementation of measures to address erosion and/or SOM loss. In Austria, for example, soil erosion reduction measures are required to be taken up by 2020 (but the types of measures required are not specified).
    - Targets on the implementation of one or several specific measures to address erosion or SOM loss. Examples include the implementation of 100 km of hedgerows in 2013 in Estonia or the protection of wetland and peatland for France and Sweden (with a quantitative target for France).
    - Targets on the monitoring of land degradation. For example, Latvia has implemented targets on the classification of degraded areas by 2015 and the development of a land quality information system to assess agricultural land and forest soil quality.
- **Protecting the soil, in general.** Such targets may have been developed in relation to a more general objective than land degradation, or for another purpose such as the protection of biodiversity. For example: in Denmark, a national target is set to increase natural areas by at least 100,000 ha by 2020; in Bulgaria, 8% of arable land must be farmed organically in 2013.

The objectives and targets aiming to reduce land degradation were identified in the MS, through a review of literature (EEA, 2012c) (SoCo project team, 2009) and the stakeholder consultation conducted as part of the present study. These are summarised in the table below.

Table 75: Examples of objectives and targets in the MS, aiming to reduce land degradation

Member State	Preventing and /or reducing erosion of SOM loss	Implementing measures to address erosion of SOM loss	Other targets indirectly related to soil protection
Austria		Measures shall be taken to reduce insofar as possible losses caused by erosion and soil compaction by 2015 Natural nutrient depletion shall be compensated by appropriate fertilisation	Increase the share of organically farmed areas in the total agricultural area to 20% by 2010 (BMLFUW - Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft, 2005)
Bulgaria			8% of arable land to be farmed organically by 2013
Croatia	Qualitative targets at national level on land degradation. No target specific to erosion or SOM Prevent and decrease forestry soil degradation Prevent and decrease physical and chemical degradation of agricultural soil		
Denmark			Increase natural areas by at least 100,000 hectares by 2020
Estonia		Establish 100 km of hedgerows in 2013 to reduce wind and water erosion (and enhance biodiversity)	Increase organically farmed area from 72,800 ha to 120,000 ha
Finland	No target		
France	No target Marine erosion indicators are currently being developed (in 2014) (Ministère de l'écologie, du développement durable et de l'énergie, 2014)	20,000 hectares of wetlands should be acquired and protected	At least 2% of the national landmass should be placed under robust protection within 10 years, in particular by creating three new national parks By 2020–2030 one third of riverbanks should be protected Doubling the percentage of organically farmed land by the end of 2017
Germany	Continuously reduce soil erosion by 2020		
Greece	No target		
Hungary	Land users shall conserve topsoil and its organic matter content		
Latvia		Classify degraded areas by 2015 Develop the land quality information system to assess the agricultural land and forest soil quality	
Malta	Legislation under revision		
Romania	Qualitative targets at national level Quantitative targets at regional and local levels (no further details available)		

Member State	Preventing and /or reducing erosion of SOM loss	Implementing measures to address erosion of SOM loss	Other targets indirectly related to soil protection
Sweden		The ecological and water-conserving function of wetlands in the landscape must be maintained and valuable wetlands preserved for the future	The value of farmed landscape and agricultural land for biological production and food production must be protected, at the same time as biological diversity and cultural heritage assets are preserved and strengthened. This objective is intended to be achieved within one generation. The value of forests and forest land for biological production must be protected at the same time as biological diversity and cultural heritage and recreational assets are safeguarded. This objective is intended to be achieved within one generation.
The United Kingdom	Significantly reduce the rate of loss of stored soil carbon by 2020 (DEFRA, 2009)	Prohibition to plough the land in a certain way Prohibition to use certain land types as horticultural/agricultural land	No other explicit targets. Soil should be managed sustainably.

Annex 4.2: EU policies related to soil degradation

Overview

In 2006, the Commission adopted the Thematic Strategy for Soil Protection aiming to address the issue of soil degradation. The Strategy contained a proposal for a Soil Framework Directive which has been withdrawn since then. The Strategy aims to protect soil while using it sustainably, through the prevention of further degradation, the preservation of soil function and the restoration of degraded soils. Erosion is considered as soil degradation, as well as soil organic matter depletion.

Various other EU policies contribute to soil protection, and indirectly to soil erosion reduction and soil organic matter conservation, as shown in Table 76.

Table 76: Key EU policies contributing to soil protection

Policy	Soil erosion reduction	Soil organic matter conservation
Common Agricultural Policy (CAP)	x	x
Environmental Impact Assessment (EIA) Directive and Strategic Environmental Assessment (SEA) Directive	(x)	x
Alpine Convention and related Protocol on Soil Protection	x	x
Natura 2000 network and Habitats and Birds Directives	x	x
EU Biodiversity Strategy for 2020		x
Nitrates Directive		x

x Direct positive influence

(x) Indirect positive influence

The key aspects of the above policies are further described in Annex 4.2. Measures included in the CAP have a particularly important role in addressing soil erosion and SOM loss. The measures to protect soil from degradation are clearly stated in the GAEC, as described below:

- Soil coverage: Soil cover consists in covering the soil throughout the year to stabilise soil elements. The soil can be covered by crops such as winter crops, or by grass such as in orchards and vineyards.
- Minimum soil management according to site-specific conditions: This may include elements such as the use of specific machinery while harvesting root crops such as sugar beet that induces important soil removal (DEFRA, 2005a and b). Other measures include grass cutting once a year at least, channelling of surface water for sloping ground, minimum tillage in non-cropped land, or specific timing for ploughing or tillage after spreading.

- Conservation of terraces: Elimination of existing terraces is prohibited to avoid the creation of sloping grounds that foster water erosion.

The AEM also include actions targeting soil erosion such as tillage techniques (injection, band spreading, etc.), green cover, conservation agriculture and mulching. Other measures that do not aim at protecting soil from erosion may indirectly affect soil erosion, e.g. regarding the management of landscape and pasture, actions to maintain habitats favourable to biodiversity and afforestation.

GAEC contributing to the conservation of soil organic matter include:

- Management of crop residues: The management of crop residues from cereals (straw or stubble) has significant positive effect on soil organic matter: it increases carbon storage and the immobilisation of N by crops. MS with a high cereal production such as Belgium, the Netherlands, Ireland, Denmark, the United Kingdom, Germany, Luxembourg and France have a higher potential for sequestering carbon into the soil than the average for EU-27 at 0.86 tonnes carbon/ha for all straw incorporated and at 0.44 tonnes carbon/ha for all straw harvested (Gobin, 2011)
- Reduced and no tillage: Tillage increases degradation of organic matter and hence can decrease soil carbon stores. Since conservation tillage also involves specific practices such as avoiding the burning of residues, incorporation of residues and cover crops, it contributes to increasing soil organic matter.
- Crop rotation: Crop rotation creates better nutrient management, thanks to the addition of nitrogen-fixing crops and thus decreases the need for nitrogen fertilisers by up to 100 kg N/ha/year and up to 65-70% according to Wyland (1996) (Wyland, Jackson, Chaney, Klonsky, Koike, & Kimple, 1996). It also leads to higher soil carbon content through increased crop cover periods (using catch crops), and reduced tillage intensity and frequency (Friends of the Earth Europe, IFOAM EUGroup and PAN and APRODEV, 2012).

Actions required by GAEC may also have indirect effects on soil organic matter. For example, crop coverage that firstly aims at protecting soil from erosion plays a role in increasing carbon sinks since the vegetation enriches soil with carbon. Measures to control soil structure such as reduced or no tillage may also have an effect on soil organic matter since they can increase nitrogen immobilisation.

Several measures under AEM also play an important role in the preservation of SOM:

- Promotion of extensification and organic farming: Organic farming includes measures that maintain and potentially increase SOM and SOC of soil. The carbon content of land is typically higher than for conventional farming due to the use of green and animal manure, crop rotations and cover-cropping (Frelih-Larsen, Leipprand, Naumann, & Beucher, 2008).
- Soil management measures: these measures are similar to the measures for cross compliance, i.e. soil cover, residue management, crop rotation, and tillage.
- Promotion of agroforestry and afforestation: Afforestation can have a significant positive impact on carbon sequestration by creating new carbon sinks through tree growth and by maintaining carbon stocks in soil through high and regular inputs of soil organic matter. Conversion of arable land to forest has a high potential for increasing carbon storage. At the EU-27 level there is on average 47 t/ha of SOC stock gain due to conversion of utilised agricultural area to forest land (European Commission, 2011b).
- Protection of High Nature (carbon) Value areas: Organic soils contain a high density of carbon accumulated over many years, because soil decomposition stopped due to the absence of oxygen under flooded conditions. If these soils are used for agriculture, the aeration of soil will induce carbon dioxide and nitrous oxide emissions. The creation of pasture through the conversion of arable land

into grassland and its management, such as late mowing, can have a strong positive influence on carbon sequestration.

Relevant provisions of key EU policies

Common Agricultural Policy (CAP)

The CAP aims to ensure a fair standard of living for farmers and to provide a stable and safe food supply at affordable prices for consumers by providing agricultural subsidies and setting specific requirements. Since 1999, the CAP has been based on two pillars. The first pillar is dedicated to income support by providing payments to farmers decoupled from yield. To obtain the integral payment, farmers have to comply with Statutory Management Requirements (SMR), linked with EU policies and Good Agricultural and Environmental Conditions (GAEC). The second pillar is dedicated to rural development. It provides subsidies for actions such as sustainable agricultural practices (agri-environmental measures, AEM), investment or installation of young farmers.

Moreover, the CAP reform in 2003 has introduced important modifications that may have stimulated the decrease of soil erosion after 2006. Indeed, the introduction of cross-compliance obligations, linked with good agricultural and environmental practices (GAECs) have enhanced the implementation of measures against land degradation. Protection of soil from erosion and soil organic matter depletion are explicitly targeted. Farmers must comply with GAECs in order to obtain full direct subsidies. Moreover, the implementation of “decoupled” aid, which refers to a subsidy system where payments to farmers are independent from the obtained yields, participates to an extensification of crop production and thus decreases land degradation. The CAP also proposes additional subsidies or the implementation of agri-environmental measures (AEM) that go beyond the GAECs. According to Gobin et al. (2011), an increase of the afforestation rate by 2% compared to business as usual would result in a 10% increase in carbon stock levels by 2030 (Gobin, 2011). Moreover, peatland protected from conversion would avoid 0.13% to 0.36% of carbon loss per year (European Commission, 2011b).

Nitrates Directive

The Nitrates Directive (91/676/EEC) was adopted in 1991. It aims to protect water quality across Europe by preventing nitrates from agricultural sources from polluting ground and surface waters and by promoting the use of good farming practices. While the Directive mainly focuses on water, some requirements may affect – negatively or positively – carbon sequestration and thus SOM. The Nitrates Directive is the main Directive that relates to manure and requires the implementation of an action plan that implements actions targeting inter alia manure.

The Nitrates Directive requires limiting the source of pollution and avoiding surplus use of fertilisers. In so doing, farmers must balance their use of fertilisers and quickly incorporate the manure spread to reduce the volatilisation of nitrogen. In addition to the intrinsic advantage of using manure, this measures increases organic matter content in soils.

The Nitrate Directive have indirect effects on soil erosion by aiming, amongst other, at limiting leaching that can affect soil erosion by water.

Alpine Convention and related Protocol on Soil Protection

The Alpine Convention[193] and related protocols have increased public awareness of the environmental problems, in particular with regard to practices enhancing soil erosion. The contracting parties have to:

- Design and protect areas threatened by erosion and landslide, by quantifying and mapping erosion within the territory (using the same quantification techniques).
- Control and limit erosion, including water erosion. In particular, the Protocol also requires that agriculture practices (crop, livestock and pasture farming, and forestry) be adapted to local conditions. The parties must also take measures to control surface run-offs.
- Rehabilitate damaged areas.
- Take measures to control water erosion and surface run-offs.

This is an important step forward to integrate environmental issues, specifically soil protection, into sectoral policies. The Alpine Convention is mainly applied through an EIA procedure.

Soil organic matter is not directly mentioned but the Protocol encourages practices that contribute to its conservation. In particular, the contracting parties have to:

- Conserve soils in wetlands and moors through restricted use and drainage schemes;
- Enhance the use of ecological/biological and integrated methods of cultivations, and minimise the use of mineral fertilisers.

Biodiversity and green infrastructure policies

In 2011, the European Commission adopted an **EU Biodiversity Strategy to 2020** (COM(2011) 244). Among the targets to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity, the strategy sets an objective of “Restoration of at least 15% of degraded ecosystems”. This objective may help restore forests, wetland and rewet peatland in particular, which contribute to storing carbon in soils. To do so, the EU Biodiversity Strategy promotes the development of green infrastructure and has launched some work to establish by 2015 a ‘No net loss initiative’[194] that aims to contribute to the no net loss of carbon-rich soils.

Soil protection is one of the elements considered under habitat protection and taken into account in the delineation of the **Natura 2000 network**.

The **Habitats and Birds Directives** (92/43/EEC and 2009/147/EC) have an indirect effect on:

- Soil erosion - through the protection of landscapes that contribute to maintaining soil and hence limit erosion
- Soil organic matter - by avoiding the conversion of forests and high value areas into cropland and hence contributing to the maintenance of carbon storage.

These Directives also contribute to preserving agricultural and semi-natural areas from the development of infrastructure and artificial areas, thus indirectly tackling soil erosion.

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[193] Protocol on the implementation of the Alpine Convention of 1991 in the field of soil conservation (http://www.alpconv.org/en/convention/pages/default.aspx?AspxAutoDetectCookieSupport=1)

[194] http://ec.europa.eu/environment/nature/biodiversity/nnl/index_en.htm

The **Green Infrastructure Strategy** (COM(2013) 249 final) highlights the benefits of green infrastructure in adapting and reducing the impacts of climate change. It also aims to streamline green infrastructure in agriculture and forestry policies. The EU Biodiversity Strategy also calls for the establishment of green infrastructure to maintain and enhance ecosystems and their services, one of which could be carbon storage.

Environmental Impact Assessment (EIA) Directive and Strategic Environmental Assessment (SEA) Directive

The Environmental Impact Assessment (EIA) Directive (2011/92/EU, amended by 2014/2/EU) was adopted in 1985 and revised in 2014. The Directive aims to ensure that environmental implications of individual large-scale projects such as the construction of highways and airports are taken into account before decisions are made. It is combined with procedure for gaining permissions for urban developments, for example. The Strategic Environmental Assessment (SEA) Directive (2001/42/EC) is similar to the EIA Directive except that it relates to public plans and programmes. The projects and programmes co-financed by the EU (Cohesion, Agricultural and Fisheries Policies) have to comply with the EIA and SEA Directives to receive approval for financial assistance.

Both assessment requirements directly consider the environmental impacts of land use. However, until now soil was not the core issue of an EIA or SEA and quantitative thresholds related to land were missing (Bory, 2009). In 2013, a guidance document for each Directive was published to provide recommendations on the integration of climate change and biodiversity into EIA (European Union, 2013a) and into SEA (European Union, 2013b) carried out across EU.

In these guidance documents, erosion is tackled through the conservation of landscape, forests and plants that stabilise soils and reduce the risk of landslides and erosion. The protection of soil organic matter is tackled through the conservation of carbon sinks mostly induced by the protection of habitats. Both guidance documents encourage the implementation of measures such as the protection and/or restoration of natural carbon sinks including peat soils, woodlands, wetland areas and forests, as well as tree plantation.

Both guidance documents also specifically mention the Green Infrastructure Strategy (European Commission, 2013a). Green Infrastructure refers to a network of high quality green spaces. Managed in an ecosystem-based approach and in a spatial context, the network aims at creating and maintaining valuable landscape and the associated ecosystem services. This Strategy benefits the prevention of erosion since it enhances the preservation and restoration of habitats and land that can sequester a high amount of carbon and the preservation of landscapes that help maintain soil.

EU freshwater policy

Because soil degradation has been identified in many river basins as a pressure on the water bodies and as an obstacle to achieve good water quality, the **Water Framework Directive** (2000/60/EC), its **daughter Directives** on quality standards for groundwater and for surface waters (such as the Nitrate Directive) and its sister **Directive on flood management** contribute to mitigating soil erosion and contamination by pesticides or overload by nutrients. They encourage good practices such as natural buffering areas, carbon sequestration and accurately balanced fertilisation of soils. Implementation of the EU freshwater policy can lead to placing restrictions on land take or land use change at specific locations.

Annex 4.3: Overview of Member States' policies related to soil degradation

Overview

Policy framework in the Member States

Few EU MS have implemented policies specifically addressing soil erosion and soil organic matter issues at the national level. However, as described below, MS have implemented several types of policies aiming at soil protection in general, with a direct or indirect link to soil erosion and soil organic matter.

An overview of relevant national policies is provided in Annex 4.3, while some key examples are discussed hereafter.

Legislative instruments

These instruments require or encourage the implementation of measures to address the impacts of human activities on soil. Few of them are specifically dedicated to the protection of soil from degradation factors, including soil erosion and loss of organic matter. Existing regulations are often not well enforced and monitoring is often insufficient or lacking (Bory, 2009). Some examples are presented in **Box 1**.

Box 1: Examples of national policies dedicated to soil protection[195]

Austria has implemented a Soil Enhancement Act that tackles land degradation, including soil erosion and soil organic matter losses. For instance, authorities can ask land users to elaborate a plan containing soil enhancement measures within a determined period if negative impacts on erosion are identified. The measures proposed that may have an impact on soil erosion include: crop rotation, technical measures to enhance soil structure, usage of less harmful machines, planting of shrubs or windbreakers, ban of soil usage, etc. A soil protection consultation centre was also established to help farmers plan and implement these measures. This plan is very flexible, cheap and adapted to all users since it asks farmers to elaborate their own measures. However, the plan is rarely executed.

In Slovakia, the regulation for the protection and use of agricultural soil provides rules regarding topsoil removal, reuse of topsoil and recultivation process for taken soils. These rules are often applied and contribute to avoiding agricultural land reduction and protecting soil from several threats, including erosion and soil organic matter losses.

After having established erosion plans at regional level (or river basin level), **France** has launched

[195] Sources: Bory, 2009; stakeholder consultation; French Environment Ministry, 2012

in 2012 a national action plan against coastal erosion. It aims at increasing the knowledge on erosion, developing monitoring processes and implementing strategies to address this issue.

Some MS have implemented policies that do not specifically aim at protecting soil from degradation, but may indirectly contribute to this aim. In particular, policies aiming to manage agricultural land in a more sustainable way are often related to soil quality and soil pollution. They can have a significant positive contribution to the reduction of soil erosion and soil organic matter losses, indirectly or through specific measures such as crop rotation, reduced tillage, afforestation and other plantation (in particular, wind breakers). Some examples are presented in **Box 2**.

Box 2: Examples of national policies indirectly contributing to soil protection[196]

Policies for nature protection

Germany has implemented the Nature Protection Act and the Nature Protection Act of the Federal Land Baden-Württemberg. These Acts aim at safeguarding soil functionality and performance. To do so, users have to implement measures in order to compensate soil losses by encroachments, or to pay if they are not able to implement measures. This involves performing a soil functions assessment and implementing compensatory measures. Although this Act is considered to be an effective instrument, it faces administrative issues due to differing responsibilities of authorities: the nature protection authorities in charge of enforcing the Act, and the soil conservation authorities, that provide guidance, may have different goals.

In the **Czech Republic,** the Environmental Law sets the environmental protection principles, including erosion and soil organic matter against damage caused by corporations or individuals. The document identifies the types of impacts and proposes measures to address them. Fines can be applied in the case of non-compliance with the environmental principles.

Policies for agricultural lands

Czech Republic has implemented the Act 334/1992 on protection of agricultural land resource. This instrument determines the goals in terms of soil protection, land use regulation, permissions and taxes, and brownfield use aiming at enhancing soil quality and rationale use of soil. All authorities, from the local level to the national level, can apply it. Erosion aspects are well covered since the legislation mostly addresses soil extraction. It also addresses soil organic matter losses but only to a lesser extent. However, only agricultural soil is covered by the legislation, and corresponding fines for non-compliance have not been updated since 1994, which lessens the impact of the instrument.

In **Slovenia,** the Agricultural Land Act is applied by the Ministry of Agriculture, Forestry and Food and implemented in municipalities for preparing land planning. It encourages good practices, particularly with regard to addressing land degradation. Nonetheless, the Act is not very detailed and there is a lack of monitoring with regard to its enforcement.

In **Croatia,** the 2013 Agricultural Land Act regulates the protection, the use and management of agricultural land owned by the Republic of Croatia.

[196] Source: Bory, 2009; stakeholder consultation

Economic instruments

In addition to CAP subsidies, some MS use economic instruments to encourage the conservation of soil organic matter. Nonetheless, subsidies may not be a long-term option as they are efficient only as long as farmers receive their money. Once farmers no longer receive funding, there is a risk that they may stop implementing soil protection measures if the measures are too stringent and/or expensive. Examples of such policies are presented in **Box 3**.

Box 3: Examples of economic instruments implemented in the Member States[197]

> **Poland** has established a law on agricultural and forest land protection that aims at protecting agricultural and forest soil from degradation as a result of non-agricultural activities. The regulation applies the "polluter pays" principle by specifying that any entity that causes the degradation of agricultural land function must implement measures for it to be recovered. Moreover, transformation of high quality land requires a decision from the Ministry of Agriculture and Rural Environment (if the area exceeds 0.5 ha) and the payment of compensation fee, as a function of soil quality. The user must also reuse top soil (including for peatland) to improve soil quality in the vicinity. Since 2008, there have been no compensation fees for the transformation of agricultural land within urban areas, where most changes take place, making the regulation less efficient than it could be.
>
> Similarly, in **Slovakia,** there is a fee to convert agricultural land into non-agricultural purposes. The fees are fixed by a decree. Although the decree does not directly tackle soil organic matter losses, the fee is related to soil fertility: the more fertile the soil is, the higher the fee is.
>
> In **Flanders**, the Soil Erosion Decree (2001) provides subsidies to municipalities (12.5 EUR/ha and 75% of subsidies for implementation of measures) as well as subsidies for sowing cover crops (50 EUR/ha), grass strips (0.13 EUR/m^2), afforestation (850 EUR/ha for popular and 3,700 EUR/ha for oak), and set-aside (298-424 EUR/ha) (in the context of the CAP).
>
> Since the 19th century, **Denmark** had proposed free plants to create windbreaks. This support has been replaced by subsidies.
>
> **France** has established subsidies and other economic incentives such as a coupled aid to promote leguminous introduction in the rotation (in the context of the CAP). France has also strengthened the support to the agri-environment-climate measures and organic production promotion measures, as well as areas facing natural and other specific constraints (which are mainly pasture areas). Lastly, public support encourages farmers to convert to and maintain ecological farming practices ("agro-ecological project for France").

Information and support

Some MS have implemented measures that go beyond the requirements of the EIA and SEA Directives, including measures related to soil erosion or soil organic matter depletion. Some examples are provided in **Box 4**.

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[197] Sources : Bory, 2009; stakeholder consultation; Verstaeten et al., 2003

Box 4: Examples of national information and support instruments[198]

> **Germany** has established a guideline for the assessment of soils according to their performance (1995, currently being revised). Five soil functions are considered, including natural soil fertility. Hence, high quality soil can be identified and taken into account in planning processes. Although the guideline is not a binding instrument, this instrument can be combined with soil protection regulation to define a protection status.
>
> **Austria** has elaborated a framework for the assessment of soil-related impacts relating to development projects, including soil erosion and soil organic matter. The impact assessment is necessary to obtain necessary permissions to carry out the project. The linkage with the grant of permission is essential to ensure the implementation of soil protection measures. The assessment of soil is systematic, which makes the instrument effective. However, the quality of the assessment is heterogeneous since the guidelines proposed are not very precise (Institute of Technology Assessment, 2011). In 2007, Upper Austria also created the Soil Protection Festival where information on soil and soil protection is provided in a playful and educational way.
>
> **Italy** has elaborated a Protocol of Soil Conservation of the Alpine Convention that provides guidelines to protect soil functions, including soil erosion and soil organic matter losses. It can be applied at national scale and adopted by planers, on a voluntary basis.
>
> **Slovakia** has implemented Law 24/2006 on EIA. It considers that the law is efficient with regard to soil protection (in particular the prevention of erosion and contamination) only in combination with the refusal of a building permit. The law focuses on non-agricultural activities; it provides good recognisable indicators and a comprehensive methodology.

Details on policies implemented in Member States

An overview of EU MS' policies related to land degradation is provided in Table 77. This complements the list of objectives/targets addressing land degradation presented in Annex 4.1. The instruments identified here are those which go beyond EU legislation directly or indirectly related to land degradation. For instance, the implementation of a National Programme for Rural Development is not described here since it is required by the CAP, except if this program proposes additional ambitious mandatory standards. The table is based on the information available in (Bory, 2009) (SoCo project team, 2009) and from the stakeholder consultation conducted as part of this project.

Table 77: MS' policies related to soil degradation[199]

MS	Instruments		
	Legislation and action plans	Economic instruments	Information and support
Austria	*Measures related to soil degradation:* Soil Enhancement Plan under Soil protection Act at regional level: •The Soil Enhancement Act tackles land degradation, including soil erosion and soil organic matter losses. Authorities can ask land users to elaborate a plan containing soil enhancement measures within a determined period if negative impacts on erosion are identified. The measures proposed that may have an impact on soil erosion include crop rotation, technical	Agricultural subsidies though the Rural Development Programme (RDP) for measures such as soil cover in vineyards and orchards or conservation tillage in farmland that tackles soil erosion Permissions within protected areas (Nature Conservation Law)	Soil reporting (National State of the Environment Report, Regional Soil information reports of some federal provinces) Soil protection festival (Upper Austria) to raise awareness on soil and soil protection

[198] Sources: Bory, 2009; SoCo project team, 2009; stakeholder consultation

[199] Sources: (Bory, 2009) (Hubert, S., 2007) (SoCo project team, 2009) (Environment Agency Austria, 2010) (Dutch Ministry of Infrastructure and the Environment, 2013) (Verstaeten, Poesen, Govers, Gillijns, Van Rompaey, & Van Ost, 2003), and stakeholder consultation

MS	Instruments		
	Legislation and action plans	**Economic instruments**	**Information and support**
	measures to enhance soil structure, usage of less harmful machines, planting of shrubs or windbreakers, ban of soil usage, etc. A soil protection consultation centre was also established to help farmers plan and implement these measures. The plan is very flexible, cheap and adapted to all users since it asks farmers to elaborate their own measures. However, the plan is rarely executed. Measures going beyond EIA/SEA Directives *Other measures:* Development program - rules for the land plan Federal Forest Act Soil Protection Protocol of Alpine Convention Nature Conservation Law		
Belgium	*Flanders:* Flemish Environmental Action Plan (2003-2007) and Flemish Plan for Rural Development (2004) *Wallonia:* there is no specific regulation, except several agri-environmental measures (AEM) (crop cover, buffer strips) (Bielders, 2003) but regulations are expected to be established soon.	*Flanders:* Soil Erosion Decree (2001) that provides subsidies to municipalities in addition to CAP subsidies related to erosion (subsidies to municipalities (12.5 EUR/ha and 75% of subsidies for implementation of measures) as well as subsidies for sowing cover crops (50 EUR/ha), grass strips (0.13 EUR/m2), afforestation (850 EUR/ha for popular and 3700 EUR/ha for oak), and set-aside (298-424 EUR/ha) (in application of the CAP))	*Flanders:* development of an erosion risk map
Bulgaria	Soil Protection Act National Action Programme for sustainable land management and combating desertification in the Republic of Bulgaria (2007 - 2013)	Subsidised and compensatory measures to conserve soil introduced in the National Programme for Rural Development 2007 - 2013	
Croatia	No specific national legislation. National Environmental Action Plan (OG 46/2002) regarding the prevention and decrease of forestry soil degradation and the prevention and decrease of physical and chemical degradation of agricultural soil. Agricultural Land Act (OG 39/2013) regulates the protection, use and change of use of agricultural land and the management of agricultural land owned by the Republic of Croatia.		
Cyprus	*No information collected*		
Czech Republic	Environmental Law: Environmental Law, Act 334/1992 on Protection of Agricultural Land Resources sets the environmental protection principles, including erosion and soil organic matter against damage caused by corporations or individuals. The document identifies the types of impacts and proposes measures to address them. Fines can be applied in the case of non-compliance with the environmental principles. The Act 334/1992 determines the goals in terms of soil protection, land use regulation,		

MS	Instruments		
	Legislation and action plans	**Economic instruments**	**Information and support**
	permissions and taxes, and brownfields use aiming at enhancing soil quality and rational use of soil. All authorities, from the local level to the national level, can apply it. Erosion aspects are well covered since the legislation mostly addresses soil extraction. It also addresses soil organic matter losses to a lesser extent. However, only agricultural soil is concerned and fines have not been updated since 1994, which lessens the impact of the instrument.		
Denmark		Free plants to establish windbreaks (since 19th century), now replaced by subsidies.	Research project (ex: FAIR3 (1997))
Estonia	Estonian Rural Development Plan 2007–2013 National Environmental Action Plan of Estonia for 2007-2013 that encourages environmentally sustainable use of soil.		
Finland			Guidelines and recommendations for soil preparation in forest management practices (as part of regeneration process)
France	National action plan against coastal erosion 2012-2015 Erosion plans at regional level (or river basin level) No specific policy for SOM An assessment of French regulations concerning soils is being made in order to improve coherence between the current pieces of legislation.	Subsidies and other economic incentives such as: - A coupled aid to promote leguminous introduction in the rotation (in the context of the CAP) - Strengthening of the support to the agri-environment-climate measures and organic production promotion measures, as well as areas facing natural and other specific constraints (which are mainly pasture areas) - Public support to encourage farmers to convert to and maintain ecological farming practices (“agro-ecological project for France”)	Programmes: “Produisons autrement” and the “agro-ecological project for France” to display information, training, etc.
Germany	*Measures related to soil degradation:* Soil Protection and Contaminated Sites Act *Other measures:* Nature Protection Act: The Nature Protection Act and the Nature Protection Act of the Federal Land Baden-Württemberg aim at safeguarding soil functionality and performance. To do so, users have to implement measures in order to compensate soil losses by encroachments, or to pay if they are not able to implement measures. This involves performing an assessment of soil functions and implementing compensatory measures. Although this Act is considered as an effective instrument, it faces administrative issues due to the different responsibilities of the authorities: the nature protection authorities, in charge of enforcing the Act, and the soil conservation authorities, that provide guidance, may have different goals.		Best practice guidelines: - Guideline for the assessment of soils according to their performance - Guideline for the soil environmental compartment in the compensation regulation Classification of agricultural land according their erosion risks
Greece	No instrument that goes beyond the EU legislation		

MS	Instruments		
	Legislation and action plans	Economic instruments	Information and support
Hungary	Chapter VI of Law 55 (1994) on cultivated soil.		
Ireland	*No information collected*		
Italy	*Measures related to soil degradation:* Law 97 (1994) and the National Programme to Combat Drought and Desertification (NAP) (1999) *Other measures:* Single Act (Law) of the Environmental/Law in environmental matter		
Latvia	*Measures related to soil degradation:* National development plan of Latvia for 2014-2020 Sustainable development strategy of Latvia until 2030 Environmental Policy Strategy 2014-2020 (wind and water erosion and SOM loss) Latvian Rural Development Programme 2007-2013 Law On Subterranean Depths Land Management Law proposal Regulations regarding soil and ground quality standards Procedure for obtaining and summarising information regarding fertility level and changes of the agricultural land *Other measures:* Sustainable development strategy of Latvia until 2030	Compensatory payments for environmental friendly management and implementation of measures, including on agricultural land and forest land located in specially protected nature territories The purpose of the Natural Resources Tax Law is to promote economically efficient use of natural resources, restrict pollution of the environment, reduce manufacturing and sale of environment polluting substances, promote implementation of new, environment-friendly technology, support sustainable development in the economy, as well as to ensure environment protection measures financially. Natural resources tax is applied also to the use of soil. The Latvian Rural Development Programme 2007-2013 comprised measures for the improvement of environment and rural landscapes. Compensatory payments are granted for environmentally friendly management and implementation of the specific provisions of each particular measure (including also agricultural land and forestland located in specially protected nature territories	Classification of degraded areas by the end of 2015 Land quality information system to assess the agricultural land and forest soil quality (under development)
Lithuania	*No information could be collected*		
Luxembourg	*No information could be collected*		
Malta	Strategic Plan for the Environment and Development, Floriana		
The Netherlands	Environmental Protection Act National Integrated Soil Policy Framework (in preparation?) National Soil Protection Act and Soil Remediation Circular 2009, Soil Quality Decree and Soil Quality Regulation (do not		Information dissemination Soil+ program (information and subsidies) National Soil Protection Guidelines (tackle

MS	Instruments		
	Legislation and action plans	Economic instruments	Information and support
	address soil erosion and SOM) Regional legislation on water erosion in Limburg		industrial activities but do not mention soil erosion and SOM) Limburg Soil Conservation Project, in collaboration with government Research on the fertility of agricultural land by the National Institute of Public Health and Environment (RIVM)
Poland	Law on agricultural and forest land protection Law on environmental damages and their alleviation Law on excavation wastes (SOM only)	The law on Agricultural and Forest Land Protection applies the “polluter pays” principle by specifying that any entity that causes the degradation of agricultural land function must implement measures to recover this function. Moreover, transformation of high quality land requires a decision from the Ministry of Agriculture and Rural Environment (if the area exceeds 0.5 ha) and the payment of compensation fees, as a function of soil quality. The user must also reuse the top soil (including for peat land) to improve soil quality in the vicinity. Since 2008, there have been no compensation fees for transformation of agricultural land within urban areas, where most changes take place, making the regulation less efficient than it could be.	Best practices detailed in the law of agricultural and forest land protection
Portugal	*No information could be collected*		
Romania	No remarkable policy instrument identified		
Slovakia	*Measures related to soil degradation:* Law 220/2004 on protection and use of agricultural soils (complemented by law 219/2008) Regulation 508/2004 executing the law on protection and use of agricultural soils (re-cultivations): •Regulation for the protection and use of agricultural soil provides rules regarding topsoil removal, reuse of topsoil and recultivation process for taken soils. These rules are often applied. They contribute to avoiding agricultural land reduction and protecting soil from several threats, including erosion and soil organic matter losses. *Other measures:* Regulation on land protection through urban planning and zoning, and through forest land functions restriction	Decree setting the amount of payment and specifications of payment for agricultural land consumption. Although the decree does not directly tackle soil organic matter losses, the fee is related to soil fertility: the more fertile the soil is, the higher the fee is.	
Slovenia	*Measures related to soil degradation:* Decree on Spatial order of Slovenia (Soil erosion only) Spatial planning Act (SE only) Water Act (SE only) Agricultural Land Act: It encourages good practices, in particular with regard to addressing land degradation. Nonetheless, the act is not very detailed and there is a lack		

MS	Instruments		
	Legislation and action plans	**Economic instruments**	**Information and support**
	of monitoring with regard to its enforcement. *Other measures:* Decree on the maximum input concentration values in soil (SOM only)		
Spain	The National Plan of Hydrological Forest Restoration and Erosion Control	Decree 6/2001: Aid Programme for the afforestation of former agricultural lands	Forest and Soils Guidelines, with a focus on forest and woodlands
Sweden	*No information could be collected*		
The United Kingdom	The First Soil Action Plan for England 2004-06' *Wales*: Glastir agri-environment scheme	Environmental Stewardship (funding for land management, in transition according the next RDP)	

Annex 5: Overview of existing targets related to Land Use Functions

LUF1: Provision of work

Employment, and especially rural employment, is a core objective of many regional and rural development policies; as well as there is a clear linkage to overall employment policies. Rural development policies often aim at strengthening the valorisation of land based products to generate rural income and stimulate rural development. Subsidies and incentives provide options to better promote and valorise land use functions. Although rural development policies are complementary to land related policies, their analysis is outside the scope of this study.

LUF2: Provision of leisure and recreation

EU level

A target for the provision of cultural ecosystem services is included in the Biodiversity Strategy: "To halt biodiversity and ecosystem service loss by 2020 (…)" and "By 2050, EU biodiversity and the ecosystem services it provides – its natural capital – are protected, valued and appropriately restored for biodiversity's intrinsic value and for their essential contribution to human wellbeing and economic prosperity, and so that catastrophic changes caused by the loss of biodiversity are avoided"[200]. This is further elaborated in Target 2: "By 2020, ecosystems and their services are maintained and enhanced by establishing Green Infrastructure and restoring at least 15% of degraded ecosystems" and in the context of the No Net Loss Initiative as mentioned in Action 7b: "The Commission will carry out further work with a view to proposing by 2015 an initiative to ensure there is NNL of ecosystems and their services (e.g. through compensation or offsetting schemes)."

The Bathing Water Directive (2006/7/EC) was designed to protect the public from accidental and chronic pollution incidents, which could cause illness from recreational water use.

The Landscape Convention (Council of Europe, 2000) acknowledges the importance of landscape heritage for people to e.g. recreate. The convention promotes landscape protection, management and planning, and organises European co-operation on landscape issues (Council of Europe, 2010). According to its Article 5, each Party signing the Convention undertakes to "recognise landscapes in law as an essential component of people's surroundings, an expression of the diversity of their shared cultural and natural heritage, and a foundation of their identity" and to "to integrate landscape into its regional and town planning policies and in its cultural, environmental, agricultural, social and economic policies. Other specific measures that are promoted include awareness-raising, training and education, identification and assessment. In this respect, one of the major innovations of the European Landscape Convention is the definition, by each country that signed the Convention, of "landscape quality objectives", meaning, for a specific landscape, the formulation by the competent authorities of the aspirations of the public with regard to the landscape features of their surroundings. In this respect, the Guidelines associated to the Convention cover the rehabilitation of

[200] COM(2011) 244 final

degraded land (mines, quarries, landfills, so that they meet the stipulated landscape objectives. Despite reporting by countries that signed the Convention, in 2003, 2007 and 2009, it is difficult to assess the reality of public participation to tackle landscape issues. All MS are members of the European Landscape Convention. Implementation reports, which are submitted by a limited number of members, reveal that countries are very attached to their own land stewardship, which is in line with the flexibility of implementation allowed by the Convention. The guidelines associated to the landscape convention aim to clarify how to implement general and specific measures (Jones and Stenseke, 2011).

MS level examples

The Netherlands have designated 20 National Landscapes[201], which demonstrate a unique combination of cultural heritage and natural elements, while telling the story of Dutch landscapes' development in general. Within the National Landscapes, socio-economic development is possible, as long as the special qualities of the landscapes are maintained. Expansion of built-up areas is only allowed to accommodate natural population growth; no migration into the National Landscapes is allowed.

In Spain, building activities within the first 100 m from the sea were strictly controlled under the 1988 Coastal Law until recently. In 2013 a reform, through the law 2/2013 of 29 May[202], reduces the protection of coastal areas by modifying the protection zone to 20 m from the sea under specific conditions (e.g. high urban pressure)[203]. France also adopted a coastal legislation ('Loi Littoral'[204]) which limits construction within 100 m from the coast or banks of interior waters of more than 1000 ha. Its implementation, however, is still controversial, as highlighted by the recent report from the French Parliament of the 21 January 2014[205].

In the Walloon region of Belgium, any new zone to be urbanised must be compensated, since 2005. This may help mitigate further fragmentation of (semi)natural habitats and could influence the provision of recreational functions of the landscape (Tucker et al., 2013).

LUF3: Provision of land-based products

EU level

The main objective of the EU Soil Thematic Strategy is to protect soil quality by ensuring a sustainable utilization of soil functions. This has to be achieved by integrating soil protection policy into other EU environmental policies and other EU policy areas, among which agriculture (Toth et al., 2009). The soil functions referred to by the Soil Strategy and which are relevant to LUF3 include food and biomass production.

The Common Agricultural Policy (CAP) aims at increasing productivity, securing the availability of food supply, and providing consumers with food at reasonable prices. A CAP target related to LUF3 is that EU agriculture should maintain its production capacity[206].

According to the Renewable Energy Directive (2009/28/EC), the EU aims to get 20% of its energy from renewable resources. As part of this total effort, at least 10% of each Member State's transport fuel use must

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[201] http://www.synbiosys.alterra.nl/natura2000/gebiedendatabase.aspx?subj=gebnatlandschappen&groep=0

[202] Ley 2/2013, de 29 de mayo, de protección y uso sostenible del litoral y de modificación de la Ley 22/1988, de 28 de julio, de Costas: www.magrama.gob.es/es/costas/temas/modificacion-de-la-ley-de-costas/ley-de-proteccion-y-uso-sostenible-del-litoral-y-de-modificacion-de-la-ley-de-costas/default.aspx

[203] http://marenostrumproject.eu/news-events/blog/new-spanish-law-threatens-protection-of-coastal-areas

[204] www.legifrance.gouv.fr/affichTexte.do?cidTexte=LEGITEXT000006068963&dateTexte=20110510

[205] www.maire-info.com/upload/files/Rapport_senat_loi_littoral.pdf

[206] COM (2010) 672

come from renewable sources (including biofuels). In June 2014, the EU Energy Council reached political agreement on the draft Indirect Land-Use Change (ILUC) Directive[207] to amend the Renewable Energy Directive and the Fuel Quality Directive, so as to reflect concerns over the sustainability and GHG-reduction benefits of some biofuels. This agreement involves, in particular, the mitigation of indirect land-use change emissions through a threshold of 7 % of the final consumption of energy in transport in 2020 for conventional biofuels to count towards the renewable energy directive target.

The EC Forest Strategy aims at "contributing to balancing various forest functions, meeting demands, and delivering vital ecosystem services"[208].

The Biodiversity Strategy's target to maintain and enhance the provision of ecosystem services includes the provision of food from cropland and livestock, timber and other fibres[209].

The RISE foundation is investigating interpretations of the "sustainable intensification" concept, by characterizing the intensity and sustainability of EU agricultural systems, and exploring the potential for EU agriculture policy of to contribute to sustainable intensification[210]. Although no policies have been proposed so far, the concept of sustainable intensification is seen as an option to increase sustainability of European agricultural production. Sustainable intensification is defined as simultaneously improving the productivity and the environmental functioning of the land. The goal is to achieve a resource efficient agriculture with a significantly higher environmental performance. EU agriculture is among the most intensive in the world, both in input levels and in output levels. Further increase in agricultural productivity is assumed very difficult (Bommarco et al., 2012), which means that in the EU there is mainly potential for increasing the environmental functioning of the land without decreasing the productivity too much. Based on a land evaluation scheme, 37.2% of EU arable land seems to be suitable for sustainable intensification. However, each farm system or location has a specific combination of economic and environmental challenges and contributions, meaning that each will have a specific combination of provisioning and non-provisioning services. Consequently, different development paths would be needed to operationalize the concept of sustainable intensification into EU policies for different catchments, natural zones or regions. Nevertheless, sustainable intensification is a useful concept where an EU-level aim for agricultural productivity improvement can be combined with the consideration of environmental performance.

MS level examples

In the UK, best and most versatile land is mapped to identify land with the potential for high yields. This aims to ensure this land is used for agriculture. This mapping is intended to provide a rationalised assessment of the economic and environmental benefits of land use in planning decisions.

In Poland, the 1995 law on the protection of agricultural land strictly protects top agricultural land in rural regions[211]. Only 14% of the total agricultural land in Poland is of high quality. A key objective of the law is to give fallow lands priority for urbanisation purposes. The law distinguishes between six soil classes. The conversion of high quality soils is charged and the amount of the fee depends on the soil class and on surface area of the given land.

LUF4: Provision of housing and infrastructure

Please refer to Chapter 2 (Land take).

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[207] 2012/0288 (COD)

[208] COM(2013) 659 final

[209] COM(2011) 244 final

[210] http://risefoundation.eu/activities/areas-of-work/131

[211] Ustawa o Ochronie gruntow rolnych i leśnych z 3 02. 1995 / translation: Act on agricultural and forestry land protection, 3.02.1995.

LUF5a: Provision of abiotic resources

International level

The Global Environmental Flow Network[212] is a global scale network of the IUCN, NGO's and water knowledge institutes that aims to integrate the eFlow concept into standard practices for the management of river basins. As a global action agenda with regards to environmental flow, the network calls in their Brisbane Declaration[213] for immediate quantification of eFlow worldwide, integrating eFlow management into every aspect of land and water management, and implementation and enforcement of environmental flow standards. The network suggests accounting for eFlow in Strategic Environmental Assessments and Environmental Impact Assessments.

EU level

In the 7th Environmental Action Plan (EAP), the EU reiterated its objective to achieve good status for all Union waters, including freshwater (rivers and lakes, groundwater), by 2015, in accordance with the Water Framework Directive. It puts forward the following vision: "*the Union and its MS should take action to ensure that citizens have access to clean water and that water abstraction respects available renewable water resource limits, by 2020, with a view to maintaining, achieving or enhancing good water status in accordance with the Water Framework Directive, including by improving water efficiency through the use of market mechanisms such as water pricing that reflects the true value of water, as well as other tools, such as education and awareness raising*". Finally, the 7th EAP shall ensure that by 2020, "*water stress in the Union is prevented or significantly reduced*".

The EU Water Framework Directive contributes to the provision of sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use. The Water Framework Directive prescribes the designation of river management plans. In these plans, a balance between the abstraction and the recharge of water has to be ensured.

MS level examples

In line with the Water Framework Directive, groundwater abstraction and protection in the Netherlands is managed at the province level, following the Dutch Water Law. The provinces specify in their Water Plans targets to ensure long-term, sustainable and responsible supply of groundwater, i.e. groundwater needs to be available in sufficient quantity and in sufficient quality to be used as drinking water without intensive and costly water treatment. To achieve this, provinces have designated groundwater protection areas where activities potentially damaging for groundwater quality are prohibited. This includes for example the use of pesticides or manure, construction of built-up areas, infrastructure, cemeteries or recreation areas, or deep tillage (Provincie Gelderland, 2009).

LUF5b: Regulation by natural physical structures and processes

International level

The 2013 Warsaw conference acknowledged the importance of LULUCF and REDD, but prescribed no tangible actions or target.

EU level

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[212] www.e**flow**net.org

[213] http://www.eflownet.org/download_documents/brisbane-declaration-english.pdf

The EU Soil Thematic Strategy refers to several land functions that are relevant to LUF5a, i.e. storing, filtering and transformation of materials.

Biodiversity strategy: Maintaining and enhancing ecosystem services is included in several targets and actions in the Biodiversity Strategy, including the No Net Loss action. Target 2 of the Biodiversity Strategy ("By 2020, ecosystem services are maintained and enhanced (…)") specifies that the ecosystem services included in LUF5b should be maintained and enhanced. Secondly, Target 2 ("(…) by establishing Green Infrastructure and restoring at least 15% of degraded ecosystems") has to be measured with the land cover based indicators for this LUF. This target is repeated in the 7th Environmental Action Plan (European Union, 2014).

Under the Floods Directive (2007/60/EC), MS have to establish flood risk management plans by December 2015. These need to focus on the reduction of potential adverse consequences of flooding for human health, the environment, cultural heritage and economic activities, and on the reduction of the likelihood of flooding. Flood risk management plans shall address all aspects of flood risk management, including prevention. The plans need to account for the characteristics of each river basin. The management plans may include promotion of sustainable land use practices, improvement of water retention and controlled flooding of certain areas in the case of flood events.

The Roadmap for a Low Carbon Europe 2050[214] states that: "Improved agricultural and forestry practices can increase the capacity of the sector to preserve and sequester carbon in soils and forests. This can be achieved, for instance, through targeted measures to maintain grasslands, restore wetlands and peat lands, low- or zero-tillage, to reduce erosion and allow for the development of forests. Agricultural and forestry are also providing the resources for bio-energy and industrial feedstocks, and this contribution is bound to increase further." Measures to achieve this are included in the CAP. The Roadmap sets targets for carbon sequestration, which is only one component of LUF5b. However, the proposed measures ("maintain grasslands, restore wetlands and peat lands, low- or zero-tillage, to reduce erosion and allow for the development of forests") are likely to positively affect other components of LUF5b.

The CAP states that European agriculture has to improve its environmental performance through more sustainable production methods. Farmers also have to adapt to challenges stemming from climate change by pursuing climate change mitigation and adaption actions (e.g. by developing greater resilience to disasters such as flooding, drought and fire) (European Union, 2013c). Greening measures of the CAP involve per-hectare payments for respecting agricultural practices that are beneficial to the climate and environment, including maintaining permanent grassland, ensuring an ecological focus area of at least 5% of the agricultural holding, and crop diversification[215]. The first two can have profound effects on regulating services included in LUF5b. Also, strengthened or streamlined support through grants and annual payments for forestry is foreseen.

The Natural Water Retention Measures Initiative aims at building knowledge and promoting best practices on natural water retention measures in Europe. Natural Water Retention Measures (NWRM) are measures that aim to safeguard and enhance the water storage potential of landscape, soils and aquifers, by restoring ecosystems, natural features and characteristics of water courses, and by using natural processes. They are green infrastructure solutions and they support adaptation, reducing vulnerability of water resources.

MS level examples

The Dutch government adopted the following targets: the Rhine / Meuse river basin is protected against high water levels by 2015; 16,000 m^3 of Rhine discharge and 3,800 m^3 of Meuse discharge can be safely taken up and discharged. To achieve this, river embankments are heightened and strengthened, areas for

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[214] COM/2011/0112 final

[215] http://europa.eu/rapid/press-release_MEMO-13-937_en.htm

temporarily storing extreme discharges are being designated, floodplains are planned to increase the water storage capacity, and built-up expansion in areas with risk of flood is being limited[216].

In Germany, in order to confine sealed surfaces in the Dresden region and to contribute to flood prevention, the city of Dresden requires that new developments on undeveloped land are compensated by de-sealing or "greening" measures somewhere else but within the city boundaries. Developers have the opportunity to carry out compensation measures by themselves or to pay a compensation fee to the Environment Authority of the City, who is in charge of several de-sealing projects.

Examples of actual "soil sealing" targets are rare and limited to the local level. For instance, in Vienna (Austria) 10% of new construction sites larger than 500 m² must stay unsealed and up to 2/3 for new constructions in residential areas. In France, parking areas are restricted to 75% of the floor area of commercial facilities of more than 1000 m^2 (see Annex 2.3).

In Ireland, Green City Guidelines (2008) are designed to provide practical guidance for planners and developers on how to integrate biodiversity into new medium and high-density developments to compensate increases in soil sealing (see Annex 2.3).

Examples of national policies which may help reduce fragmentation are as follows:

- A project of joint spatial concept for the Walloon region and the Brussels region may introduce stricter zoning for land development, so that new development zones are only developed along large public transport routes.
- In the Walloon region, since 2005, any new zone to be urbanised must be compensated (Tucker et al., 2013).
- In France and in the Netherlands, designated "green and blue" landscapes are protected from infrastructure development. In particular, in the Netherlands, red contour lines were introduced through the Fifth national policy document on spatial planning which aims to limit urban sprawl in the vicinity of cities (issued by the Ministry of Housing, Spatial Planning and Environment).

According to information reviewed, targets for restricting the degree of land fragmentation have only been suggested in one Member State (Germany) and it was dropped because of the difficulty encountered in its practical implementation.

The Flanders Soil Erosion Decree (2001) specifies subsidies to municipalities (12.5 EUR/ha and 75% of subsidies for implementation of measures), and subsidies for sowing cover crops (50 EUR/ha), grass strips (0.13 EUR/m^2), afforestation (850 EUR/ha for popular and 3700 EUR/ha for oak), and set-aside (298-424 EUR/ha).

LUF6: Provision of biotic resources

Under the Habitats Directive, each MS has the obligation to contribute to the creation of Natura2000 by designating sites to be included in the Natura2000 network. At EU level, about 10% of the terrestrial area is designated under the Birds Directive and approximately 13% under the Habitats Directive. Many sites are designated under both Directives.

Habitats of European Interest are habitats which are listed in Annex I of the Habitats Directive, i.e. "Habitats which are in danger of disappearance in their natural range, or have a small natural range following their

[216] http://www.rijksoverheid.nl/onderwerpen/water-en-veiligheid/ruimte-voor-de-rivier

regression, or by reason of their intrinsically restricted area, or present outstanding examples of typical characteristics of one or more of the biogeographical regions" (EEA, 2013a).

The biodiversity targets require frequent monitoring and update to ensure they are in line with actual conservation needs. Overall, monitoring species distribution throughout Europe is essential for being able to properly assess the impact of policies on LUF6 and to set and monitor targets.

The Habitats and Birds Directives set requirements for the protection of habitats and species and specify reporting obligations to MS (Article 17). The Natura2000 network aims to protect 17% of the terrestrial EU area.

Maintaining and enhancing ecosystem services is included in several targets and actions of the Biodiversity Strategy, including the No Net Loss action. Target 2 of the Biodiversity Strategy ("*By 2020, ecosystem services are maintained and enhanced by establishing Green Infrastructure and restoring at least 15% of degraded ecosystems*") provides a specific target related to both land cover based and ecosystem service based indicators for this LUF. This is an EU scale target in line with the Aichi Targets set by the international Convention on Biological Diversity.

The CAP greening measures include per-hectare payments for implementing agricultural practices that are beneficial for the climate and environment: maintaining permanent grassland, ensuring an ecological focus area of at least 5% of the agricultural holding, and crop diversification[217]. The first two can have profound effects on regulating services included in LUF6. Also, strengthened or streamlined support through grants and annual payments for forestry is foreseen.

As presented in the previous sections, there are a number of EU-scale strategies, Directives and other policies that include objectives or targets relevant to one or more land use functions.

An overview of the identified policies relevant for LUFs is provided in the table below. It shows that, for each of the LUFs discussed in this chapter, EU-scale policies exist that often contain a relevant objective or target. However, for several LUFs only specific components are addressed and the policies and targets often do not specifically address the LUF in question but indirectly influence the LUF. These policy measures can be less effective for ensuring sustainable provision of the LUFs.

[217] http://europa.eu/rapid/press-release_MEMO-13-937_en.htm

Annex 6.1: Environmental and social impacts related to consumption

Environmental degradation is the deterioration of the natural environment through human activities and natural disasters (United Nations, 1994). Environmental impacts as a result of global tele-connections between consumption and production are manifested at global, regional and national level. Global environmental impacts are being referred to as 'systemic' forms of environmental change, such as global climate change, desertification and sea-level rise (Kate et al., 1990; Lambin and Meyfroidt, 2011b). Regional level impacts are more specific to a particular locality and are, generally speaking, not transported to other areas, e.g. eutrophication of water bodies, soil nitrate pollution (Briassoulis, 1994).

Furthermore, environmental impacts can be categorized into physical and social impacts. According to (Briassoulis, 2000)_ENREF_8, physical and social impacts are closely interrelated with the former impacts causing the latter which then feeds back to physical impacts again, causing successive rounds of spatio-temporal land-cover changes. The close relation between physical and social impacts is also shown by the differentiation between direct and indirect impacts, a concept used by (Fons Esteve, 2003), where direct impacts are manifested in changes in the physical environment (e.g. vegetative losses) and indirect impacts being the consequential effects on the human population (e.g. reduced food security, price rises)

The consumption perspective covers the global environmental pressures, caused directly and indirectly along the production chains of all products consumed domestically (produced domestically and imported). In this report, we focus on the environmental impacts of global land use and land use changes related to consumption, i.e. the total amount of land needed domestically and in third countries to supply the goods and services to be consumed in the EU. In principle, imports of embodied land (land displacement) is driven by differences in (1) land productivity between regions, (2) differences in climatic differences allowing for the production of different products and harvest seasons (Northern and Southern hemisphere) and, (3) most importantly, as a result of leakage effects related to a lack of governance to protect the natural environment in one region compared to the other (FAO, 2006). It is the 3rd argument that is gaining importance as a negative impact from trade liberalisation and globalisation.

In this section, an overview of the global pressures and related environmental impacts as a result of global tele-connections between consumption and production is given with the aim to identify the most pressing environmental impacts on a global scale. These identified impact categories will then also be taken up in the review of indicators and the related feasibility assessment in the context of future target setting.

From land use and land use change to environmental impacts

The UNEP International Resource Panel (UNEP 2014) identify land use change as the most important driver of alteration of land cover and a deprivation of natural capital. Land use change mainly involves the expansion of agricultural land and urban areas at the expense of grasslands, savannahs and forests (Holmgren 2006). In addition, intensification of land use is one of the most profound mechanisms that can be related to degradation of soil functions, including soil fertility (land management). Hence, the relation between land use and environmental impacts is both driven by demand (land use change) and by production (changes in land management).

It should be emphasised that environmental pressures and impacts are part of an adaptive system with complex feedback mechanisms which prevent a direct or linear relation between pressures, the state of the environment and impacts. For example, land use change and climate change are strongly interlinked: ca. 20% of global carbon emissions have been related to land use change in the 1990s (IPCC 2001). At the same time, climate change can induce soil degradation, causing agriculture to expand in other regions (IPCC 2007). In addition, the impact of environmental pressures may differ according to the local circumstances, e.g. erosion (pressure) may or may not affect land productivity, depending on the depth of the top soil and/or the fertility of the deeper soil (Eurostat, 2013).

Impacts of globalisation and trade on land use concentrate on degradation or depletion of natural resources and on environmental pollution. UNEP (2014) summarises the main environmental issues related to LULUC as follows: (1) soil degradation, (2) nutrient pollution, (3) biodiversity loss and (4) GHG emissions and climate change. Social environmental impacts may then involve adverse effects on food security and food prices, large scale land investments, largely in Sub Saharan Africa, which may affect large groups of people that are dependent on natural resources. These rural poor are largely dependent on the natural resource base which is under pressure of both quantitative threats (less land availability) and qualitative threats (pollution of natural resources) (De Schutter 2011). IEEP and GHK Consulting (2005) summarised the environmental pressures and impacts related to LULUC from global trade and globalisation as follows (see also

Table 78):

- Expansion of agricultural land at the expense of natural habitats through clearance of forests or other natural land, with consequences for biodiversity, landscape and ecosystem functions, as well as social impacts on local people losing their land use rights;
- Substitution between different forms of agricultural land use, e.g. pastures and arable land, between crops (e.g. citrus and sugarcane) and, most importantly, intensification of agricultural production through the use of high-yielding crop varieties, fertilisation and pesticides and (local) irrigation which may involve a loss in soil organic content, deteriorated ecosystem functions such as water filtering and absorption and a general increase in GHG emissions;
- Pressure on natural resources from export oriented agriculture and processing activities, e.g. monocultures of soy, maize palm oil, which reduces local genetic variety, increases price volatility (world markets) and reduces self-sufficiency of subsistence farmers. Potential environmental impacts include the functioning of ecosystems, e.g. through water pollution (nitrate and/or phosphorous) or increased water demand, or higher risk of erosion (e.g. in maize monocultures);
- Shifts of production between areas with lower and higher environmental and/or animal welfare standards, generally in less developed markets with biodiversity rich ecosystems (leakage);
- Land abandonment through, for example, land degradation or a contraction of a specific sector in marginal areas, e.g. the dairy sector in Central & Eastern Europe. In some world regions, e.g. in the EU, an apparent positive environmental impact occurs as a result of scaling back agricultural land management as a result of e.g. contraction of livestock production in marginal areas (IEEP and GHK Consulting 2005). This effect, however, is likely to cause an indirect land use change (iLUC) within or outside the EU, thus displacing a potential negative environmental effect elsewhere.

Table 78: Summary of environmental issues related to land use and land use change

Pressure	Degradation process	Potential environmental impacts
Expansion of agricultural land	Deforestation Degradation of ecosystem functioning	Global warming Biodiversity loss Soil degradation Social impacts
Substitution between different forms of agricultural land use, e.g. intensification or extensification	Reduced soil organic content Increased emissions/ pollution	Soil degradation Biodiversity loss Nutrient pollution/water quality
Expansion of commodity crops (specialisation/monocultures)	Soil organic content Ecosystem functioning Water pollution Erosion iLUC/ Deforestation	Soil degradation Nutrient pollution /water quality Global warming Biodiversity loss (farmland birds) Social impacts
Shifts of production between areas (to areas with less environmental protection)	Displacement, deforestation and concentration of all possible environmental pressures	Soil degradation Biodiversity loss Nutrient pollution/water quality
Land abandonment	Negative: iLUC/ Deforestation Positive: Afforestation, nature expansion	Positive and negative environmental impacts Social impacts

Source: IEEP (2005), EC (2006), Würtenberger et al. (2005), UNEP (2014)

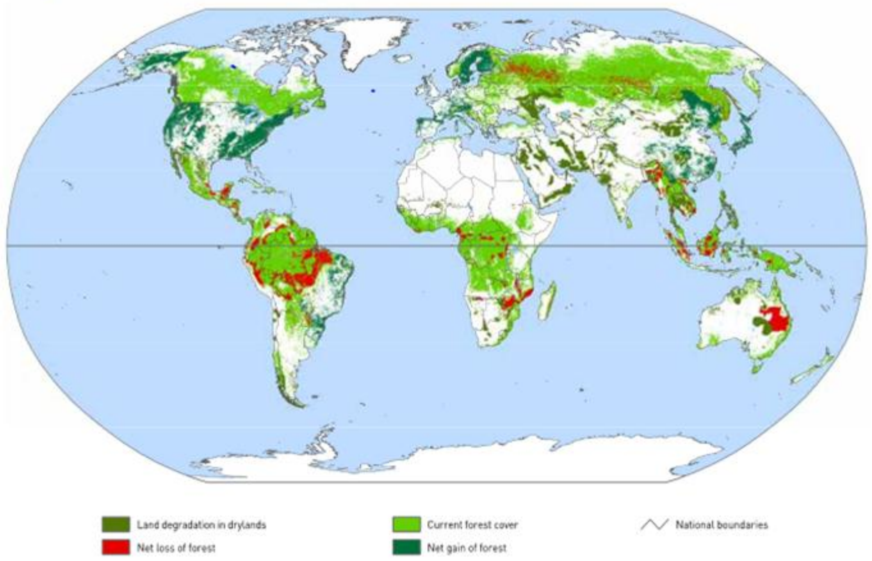
Although local environmental issues may cover a much wider range of impacts, five key environmental impacts can be identified from

Table 78 (1) soil degradation, (2) nutrient pollution, (3) biodiversity loss, (4) global warming and the related (5) social impacts. These key environmental impacts are highly interrelated, and will be analysed in the following sections. Deforestation seems to be the most profound environmental degradation process as a result from land use change and land displacement and will therefore be discussed at the beginning of the following section.

Deforestation

Over the last five decades, deforestation has occurred at a rate of about 13 Mha per year, mainly as a result of converting forests to agricultural land, but also due to expansion of settlements and infrastructure, often for logging (Gibbs et al. 2010, Barker et al. 2007). The main regions with gross deforestation are South America, (33% of global deforestation), Sub Saharan Africa (31%) and tropical Asia (19%) (EC, 2013). While these regions continue to see high rates of net forest loss, North America, the EU, China and a hand a handful of tropical developing countries have been through a forest transition from net deforestation to net reforestation (Lambin and Meyfroidt, 2009). According to the land use transition concept (Foley et al., 2005), forest change follows two distinct stages (Lambin and Meyfroidt, 2010): in an initial stage natural systems, which in most relevant environments are forests, are changed into extensive agricultural systems at a relatively fast rate. Later on, with increasing population numbers, agriculture intensifies and becomes market oriented, pushing subsistence back into niches, the conversion rate of forests slows down and eventually forest recovery sets in. This transition largely involves the use of plantation forestry in response to the growing local demand of urban and industrial markets, as well as for exports (Zobel et al., 1987; FAO, 1999), supported by national reforestation policies (Lambin and Meyfroidt, 2009).

In the globalization era, however, national strategies aimed at forest protection and sustainable use of forest resources may have displacement effects of land use across countries. In a recent study (EC, 2013), it is shown that of the 239 Mha of worldwide deforestation, 55% has been attributed to the conversion of forest land to cropland, ruminant livestock production and industrial roundwood production (logging). Furthermore, it was shown that one third (22.4 Mha) of deforestation is embodied in international trade, mainly soy beans, palm oil, stimulants and fibre crops. These products were both used in the country of origin and exported for consumption elsewhere. With 36% of global embodied deforestation, the EU was the largest importer of deforestation embodied in crop and (ruminant) livestock products over the period 1990-2008 (EC 2013). When looking at the world map of forest transitions (Figure 39), it can be seen that the main areas with forest loss are tropical South America, in Sub Saharan Africa, in Russia, in southeast Asia and in Australia. It can also be seen that deforestation is related to both forests in tropical regions and Russia, and to extensive grazing areas in Brazil and Australia.



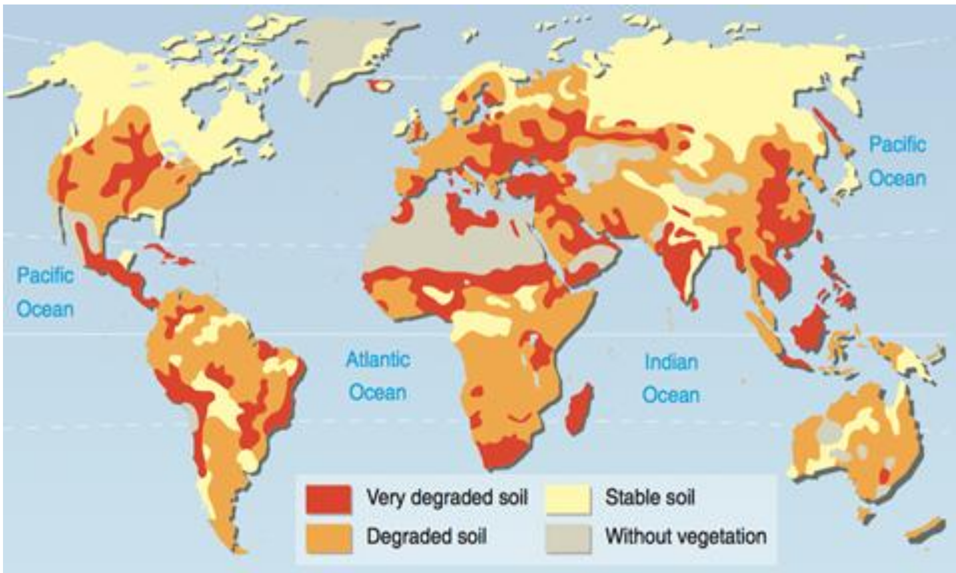
Source: UNEP (2014), based on FAO (2006) and MEA (2005)

Figure 39: Forest transition and land degradation in drylands

Furthermore, urbanisation and international demand for agricultural products are important drivers for deforestation in the humid tropics (DeFries et al., 2010). Cattle ranching is thought to be the most important driver of deforestation in Brazil (Barona et al., 2010), but they also found evidence that expansion of soy acreage has displaced pasture for cattle grazing further north, leading to deforestation elsewhere. Gasparri et al. (2013) also found a strong link between soybean expansion and deforestation, and argued that macro-economic incentives can be a much stronger driver for deforestation than domestic legal frameworks to protect deforestation.

Soil degradation

Soil degradation is widely recognised as a global problem having implications for agronomic productivity and the environment as well as effects of food security and quality of life (Eswaran et al. 2001). Soil degradation of the world's land resources is of particular concern as it reduces the productive capacity of land which in turn leads to expansion of agricultural land elsewhere (iLUC) (ISRIC 1991). It has been estimated that 23% of all useable land has been affected to a degree sufficient to reduce its productivity, the majority (2 Mha per year) being eroded as a result of human activities (Lambin & Meyfroidt, 2011b). Environmental implications of soil degradation are multiple. Among the most critical issues are erosion and the expansion of drylands and deserts (see Figure 40), biodiversity losses (through habitat destruction or pollution of aquifers), climate change (through deforestation and the loss of soil organic matter releasing carbon to the atmosphere) and depletion of water resources (through alteration of the soil texture or removal of vegetation cover affecting water cycles) (FAO 2006). Very degraded soils are found especially in semi-arid areas (Sub-Saharan Africa, Chile), areas with high population pressure (China, Mexico, India) and regions undergoing severe deforestation (Indonesia) (Rekacewicz 2009). In general, soil degradation is negatively correlated with affluence as nutrient and water input tends to increase with the development stage of a country. However, the EU is importing a large share of global land degradation, in particular from Southeast Asia (palm oil) and from North and South America (grains). Chapter 4 of the present report explores the aspects of soil erosion and soil organic matter as the underlying indicator for territorial land degradation processes. The analysed indicators and proposed targets could also serve as a basis for the EU's global use of land resources.

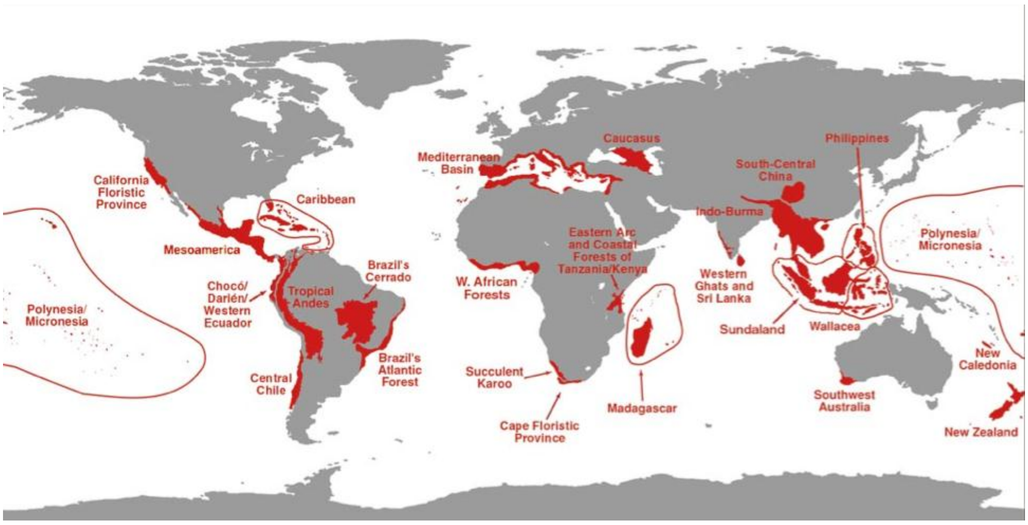


Source: Rekacewicz, 1997

Figure 40: World map of soil degradation according to the global soil atlas of desertification, 1997

Biodiversity

The most important direct drivers of biodiversity loss and ecosystem service changes are habitat change (such as land use changes, physical modification of rivers or water withdrawal from rivers, climate change, invasive alien species, overexploitation, and pollution (Millennium Assessment, 2005). Several studies support the link between consumers in developed countries and biodiversity threats in exporting countries, e.g. coffee growing in Mexico and Latin America, soy and beef production in Brazil, forestry and fishing in Papua New Guinea and palm oil plantations in Malaysia and Indonesia (Lenzen et al. 2012). A pragmatic approach to global biodiversity loss identified 25 biodiversity hotspots that capture 44% of all plant species and 35% of all vertebrate species, while featuring several habitat types at a global scale (Myers et al. 2000) (see Figure 41). Predominant are tropical forests and Mediterranean-type zones. This approach allows for potential monitoring and regulation of biodiversity hotspots with the aim to protect and preserve genetic species and variation. As for the EU, deforestation is the single most important degradation process to link EU consumption to biodiversity losses elsewhere. As such South America, Sub Saharan Africa and Southeast Asia are the key production hotspots of biodiversity loss related to EU consumption. In South America, the Cerrado – an extensive woodland savannah ecosystem – is threatened by both cattle ranching and soy area expansion; two products imported by the EU (Carey and Oettli 2006).



Source: Myers et al., 2000

Figure 41: Global map of 25 biodiversity hotspots

Water scarcity and quality

Water scarcity is one of the most urgent food security issues. Agriculture, accounting for about 70% of global water withdrawals (International Water Management Institute 2006), is in increasing competition for water resources and increasingly turns to irrigation to support productivity in dry or semi-dry regions. Globally, food production from irrigated cropland represents >40% of the total food crops produced and uses only about 17% of the land area devoted to food production (Fereres and Connor 2004). Nevertheless, irrigated agriculture is still practiced in many areas in the world with complete disregard to basic principles of resource conservation and sustainability (Fereres and Auxiliadora Soriano 2006). However, irrigated agriculture is projected to increase only marginally as a result of limited water resources (Bruinsma 2009) and because crop water requirements in warm and dry climates require considerably more water than crops in temperate climate zones (Hoekstra and Hung 2002).

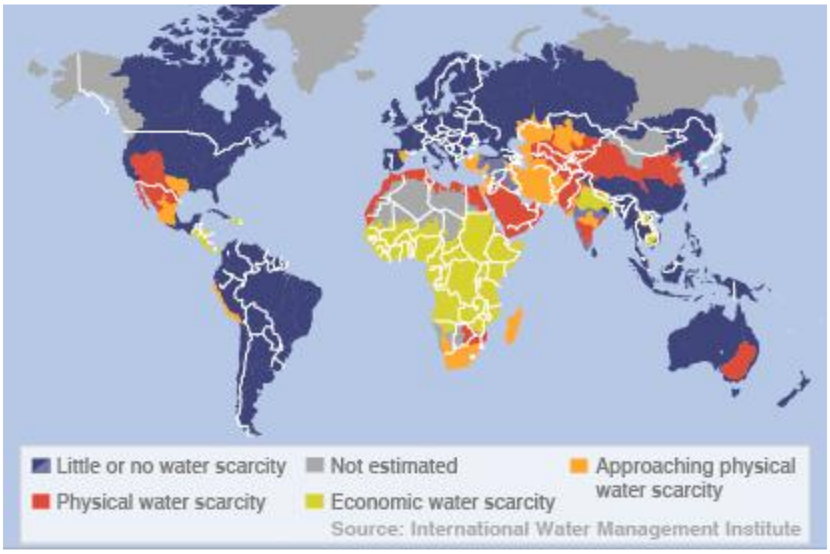


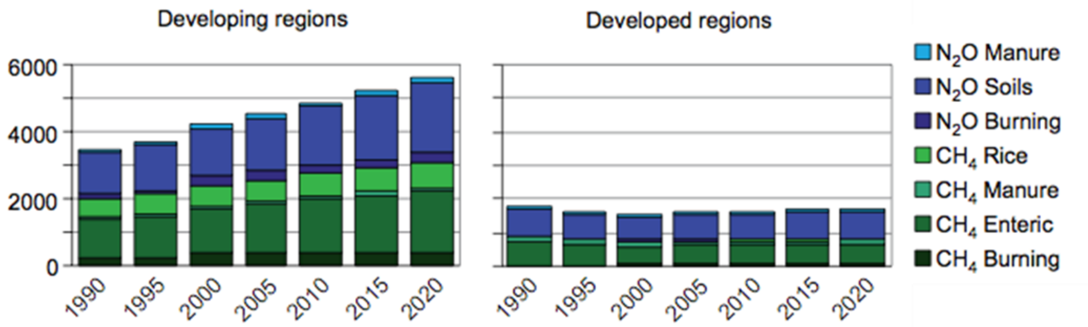
Figure 42: Global water scarcity map, 2006

Furthermore, human activity has greatly accelerated the cycles of both nitrogen (N) and phosphorous (P) at global land regional level, mainly as a result of increased use of fertilizer (FAOSTAT 2014)(Howarth et al. 2005). Excessive N and P use, largely in developed regions but increasingly seen in new production areas in developing countries, cause eutrophication which may severely impact water ecosystems (Smith et al. 1998). In particular, nitrogen has numerous and diverse impacts on the environment, leading to increased greenhouse gases, including N_2O and atmospheric ozone, as well as acidification of surface waters (biodiversity loss). The general problem related to nutrient pollution is the inefficiency in the uptake of soil nutrients by agricultural crops, which shows a strong relation with the level of soil organic content and micro-organisms in the soil. Land use management (knowledge and extension) and research into this area are key to reduce the high level of nutrient loss along the production process of agricultural crops (Roberts 2008).

Global warming potential and climate change

Land use, land use change and forestry, especially deforestation in tropical nations, accounted for 21% of global greenhouse gas emissions. Of the total (>10 Pg. of carbon per year), 14% is related to the management of agricultural soils, livestock and biomass burning, whereas 17% is related to land use change and forestry, primarily deforestation, land clearing for agriculture and fires or decay of peat soils (McCarthy, 2009). This is also confirmed in a recent study (BIOIS et al. 2014) showing that CO_2 balances are being disturbed by deforestation as a result of land use changes, especially in Sub Saharan Africa and Latin America, where forest ecosystems are increasingly managed or transformed into wood plantations, grassland or cropland.

Globally, agricultural CH_4 and N_2O emissions have increased by nearly 17% from 1990 to 2005, with a stable to slightly decreasing trend in developed regions, including the EU and North America and a strong increase in developing regions, in particular in East Asia (China), Latin America and Sub Saharan Africa (see Figure 43). In general, land related emissions are higher in warmer climate regions (e.g. CH_4 from wetlands and rice cultivation) and the largest share of land is located in the warmer southern hemisphere. However, the strong increase shows the global warming potential which is largely related to burning of wood resources, deforestation of tropical forests and changes in land use management (increased fertilisation of cropland) (Barker et al. 2007). However, per hectare, emissions related to land use largely come from fertiliser use and animal husbandry and are highest in developed regions such as the EU.



Source: IPCC, 2007

Figure 43: GHG emissions from agriculture as an indicator for the global warming effect

Conversely, the impact of climate change on agriculture is projected to be high as well. The most likely impacts are a general increase in thermal and water stress, with net favourable effects for the cooler climate zones, in particular the EU, Boreal non-EU, Boreal North America and temperate South America, and adverse effects in warmer, semi-arid zones as a result of longer and more severe periods of droughts (Easterling et al. 2007). Sub Saharan Africa is the region most vulnerable to climate change: water stress and scarcity, desertification, crop yield decreases up to 50% of current levels, and the distribution of diseases are a number of potential impacts from climate change that may severely affect the functioning of ecosystems and human health in Sub Saharan Africa (Dieng et al. 2009). As such, increased embodied land imports from the southern hemisphere to the EU may significantly contribute to global warming, especially in combination with deforestation related to e.g. expansion of palm oil plantations in tropical Asia.

Social impacts in third countries related to EU consumption

In general, a contribution to food insecurity in third countries, either through reduced availability of food crops for the domestic population in the country of origin or through increased prices on world markets, would probably be the most significant social impact of increased land demand from the EU. In addition, social impacts may involve a deterioration of wellbeing as a result of environmental impacts, e.g. groundwater pollution threatening human health. However, social impacts of land displacement related to EU consumption are hard to identify and to quantify. Social impacts generally are subject to more complex factors than environmental impacts (Brioussalis 2000) and highly context specific. Contexts differ between countries or between localities within a country. For example, turning land over to biofuel when pressure on land resources is high, or when food prices are rising, may increase food insecurity. When land resources are available, biofuel production can offer an alternative source of income to farmers and create jobs in the agricultural sector, thus reducing poverty (Ehrensperger et al. 2013).

Increased land demand and economic globalization are likely to connect remote production areas to the world market for commodities more intensively. This may lead to higher and, most likely, more volatile prices of commodity crops. Higher prices may lead to larger areas dedicated to a single crop with potential environmental impacts related to monocultures and land use intensification, whereas social impacts relate to reduced access to food (higher prices) and to local people getting deprived of their right to use the land and the related social and environmental services (De Schutter 2011).

Economic globalization also increases the influence of large agribusiness enterprises and international financial flows on local land use decisions in countries with weak governance structures, thus posing a threat to the public good (Lambin and Meyfroidt 2010). 'Land grabbing' is defined as large scale land acquisitions or long-term leases for the benefit of the investor and/or the country of end-consumption (other than the country where the land is located). Globally, more than 200 Mha is being reported to be subject to land grabbing, of which an estimated 130 Mha in Africa. Investors are (1) emerging economies like the BRICs, (2) Gulf states and (3) OECD countries. Both marginal / idle land and productive land is purchased, resulting in competition and conflicts over land use. In countries affected by land grabbing, most of the land is owned by the state. Land acquisition is consequently generally arranged between large private-sector investors that are supported by public government in the target country (Messerli et al., 2013). The German government emphasises that these numbers are highly uncertain which adds to the problem of in transparency surrounding the land grabbing phenomenon (BMZ 2012).

International trade also carries the potential to increase global land use efficiency by allowing for regional specialization in land use and productivity increases. Furthermore, higher prices may allow farmers to use fertilisers and other inputs to improve yields and reduce land expansion. And globalization of agribusiness may support innovation in agriculture. All these developments have the potential of generating economic development increasing access to food through higher levels of affluence (Ehrensperger et al. 2013).

As shown by the feedback mechanisms above, international trade and land displacement may have both positive and negative social impacts in third countries. Although qualifying and weighing these impacts into an aggregated indicator may not be possible, measuring and monitoring the most relevant impacts is an important step. In some certification schemes, e.g. fair trade, social aspects of global supply chains are included. With respect to land use, e.g. a 'fair share' concept which measures the domestic availability of key food crops, no such international schemes exist.

Summary environmental and social impacts per region

Based on the analysis of the environmental and social impacts from agricultural production related to consumption of goods and services worldwide, we have summarized the impacts per region, relative to each other. The impact map (Table 79) only serves illustrative purposes and is based on a rough analysis of global impact maps per theme. Note that the numbers in the individual cells on the environmental impacts only serve the purpose of generating the respective colours in the matrix. In order to provide a robust assessment of the various environmental impacts by world region, more spatial data work and evaluation is required.

Furthermore, actual local environmental impacts within a region may be much stronger than the regional average. Social impacts are based on reported occurrences of land conflicts (Africa, South America), conflicts related to high food prices (mainly North Africa and Middle East) and a general poor protection of social and labour conditions (Africa, Asia).

The map shows a concentration of social and environmental impacts in the southern hemisphere regions, in particular in Sub Saharan Africa, China and the tropical regions of South America and Asia. This is partly related to climatic conditions (warmer and drier periods) and the fact that the southern hemisphere contains the majority of land resources. For the other part, it is related to the development stage: southern hemisphere countries tend to develop natural areas (land use change) whereas developed regions have stabilized their land use and management.

In Sub Saharan Africa, impacts are likely to occur at all levels, mainly related to a lack of protection of natural resources (governance) whereas in Asia, the impacts are largely resulting from the - already - intensive land management systems in combination with the transformation from natural to production forests. In tropical South America, impacts can be related to an intensification of land management, in combination with agricultural area expansion in ecologic hotspots such as the Cerrado.

Boreal regions in North America and Europe seems to have been affected least, whereas the impacts in the EU show to be mostly related to its large share of intensively used cropland areas.

Table 79: Summary of (indicative) environmental and social impacts per region

	Deforestation	Soil degradation	Biodiversity	Water scarcity	Global warming	Social impacts	Overall
EU	1	2	2	1.5	2	1	9.5
Rest of Europe	2	1	2	1	1	1.5	8.5
EurAsia	1	3	1	2	1	2	10
N-Africa/M-East		4	2	3	1	2.5	12.5
Sub Saharan Africa	3	3	2	2	3	3	16
China	1.5	3	3	3	3		13.5
Tropical Asia	2	2	3	1.5	3	2	13.5
South Asia	1	3	1	2.5	2	3	12.5
Boreal N-America	2	1.5	1	1	2	1	8.5
USA	1	2	2	2	2	1	10
Tropical South America	3	1.5	4	1	2	2	13.5
Temperate Souith America	2	1.5	2	1	2	2	10.5
Oceania	3	1.5	1	1.5	2	1	10

Highest impact from land use change and/or land management
Medium impact
Least impact
No data available

Annex 6.2: The global cropland footprint for key world regions and countries

The global cropland footprint, as calculated by BIO IS et al. (2014), shows the teleconnected production regions related to final consumption within a specific region. The figure should be read from column (consumption of a country or region in Mha) to row (the producer of the original products for end-consumption in Mha). For example, 12 Mha of the land footprint related to EU consumption originates from tropical America (Brazil). On the other hand, the EU exported 3 Mha to North Africa & Middle East in 2007.

	EU	Boreal non-EU Europe	Temperate Eur-Asia	Boreal America	USA	Tropical America	Temperate South America	North Africa & Middle East	Sub-Saharan Africa	Temperate Asia	China	South Asia	Tropical Asia	Oceania	Exports
EU	100	2	2	0	1	0	0	3	1	1	0	0	0	0	10
Boreal non-EU Europe	2	61	2	0	0	0	0	5	0	0	0	1	0	0	13
Temperate Eur-Asia	6	3	71	0	1	0	0	5	0	0	0	1	0	0	17
Boreal America	3	0	0	11	7	3	0	2	1	3	1	2	1	0	24
USA	6	1	1	2	90	11	0	6	2	8	7	1	2	0	47
Tropical America	12	1	0	1	6	70	1	3	1	2	5	0	1	0	33
Temperate South America	7	1	1	0	2	6	12	3	2	1	5	1	1	0	31
North Africa & Middle East	3	0	0	0	1	0	0	41	0	0	0	0	0	0	6
Sub-saharan Africa	8	0	1	0	2	0	0	2	165	1	1	1	1	0	17
Temperate Asia	0	0	0	0	0	0	0	0	0	8	0	0	0	0	1
China	7	1	1	1	7	1	0	2	1	7	92	1	2	1	30
South Asia	5	0	1	0	3	0	0	3	1	1	1	188	2	0	19
Tropical Asia	4	1	0	0	4	1	0	2	3	3	3	3	65	1	24
Oceania	2	0	0	0	3	0	0	2	0	6	2	0	4	27	20
Cropland in 3rd countries (Mha)	65	11	9	5	36	23	1	38	12	34	28	13	14	3	
Cropland in 3rd countries (%)	39%	15%	11%	32%	29%	24%	11%	48%	7%	81%	23%	6%	18%	10%	

Figure 44: The global cropland footprint for world regions or major countries in 2007 (based on own MRIO calculations and GTAP data)

The global cropland footprint indicates several land related issues:

- 65 Mha (39%) of the EU cropland footprint is located in third countries. This share is only surpassed by North Africa/Middle East (48% from third countries) and temperate Asia (Japan and South Korea) with a record foreign land footprint of 81%.
- Other regions with large foreign land footprints are the USA, North Africa & Middle East, China and temperate Asia (Japan, South Korea), but all show smaller embodied land areas than the EU area.
- The largest area for the EU (in third countries) is located in Latin America. A total of 19 Mha (which amounts to 15.8% of the total EU arable land) is directly and indirectly used for EU consumption.
- Other considerable cropland areas embodied in EU final consumption are located in Sub Saharan Africa, China and temperate Eur-Asia.
- Major exporters of embodied land are Latin America with 64 Mha embodied in exports, the USA with 47 Mha and China with 30 Mha. The EU exports a relatively small embodied land area to third countries (10 Mha).
- Although being among the largest exporters of food & agricultural products in monetary value, it can be seen that there is relatively little land embodied in EU exports (10 Mha).

Annex 6.3: Details of the three methodological approaches in land flow accounting

In the following, we give an overview on the basic methodological approaches used for the calculation of land footprints, i.e. (1) economic accounting (input-output analysis), (2) physical accounting and the coefficients approach, and (3) hybrid methods (combinations of both). We describe their key properties, advantages and shortcomings.

Economic accounting

Economic accounting models apply the technique of input-output analysis to trace monetary flows through the economy. Input-output economics was founded by the Russian-American economist Wassily Leontief, who investigated how changes in one economic sector affect other sectors (Leontief 1936; Leontief 1986). Leontief was the first to use a matrix representation of a national economy. These input-output tables represent the structure and interdependencies between different branches of a national economy, thus comprehensively depicting all supply chains through an economy in a specific year.

Input-output models allow integrating environmental data such as land use as a production input equal to e.g. labour or capital and tracing land flows along monetary inter-industry flows of the IO table. This technique is called environmentally extended input-output analysis (EE-IOA) and has become increasingly popular with improving data availability and computational power in the past 15 years.

A review by Hoekstra undertaken in 2010, available as a conference paper (Hoekstra 2010), provides one of the most comprehensive historical analysis in the field of environmental input-output analysis. He tracked close to 360 papers in the refereed literature between 1969 and 2010. Some important conclusions from this meta-review include the following:

- The main scientific production in the EE-IOA field occurred after 1995; just 50 out of the 360 papers were published before that date.
- Papers published before 1995 focused almost exclusively on energy use, whereas more recent studies take into account a large variety of environmental issues.
- About 90% of the papers focused on single countries.
- Issues related to pollution embodied in trade have been discussed in only a few papers before 1995, whereas the number of papers increased significantly between 2005 and 2010 (20% of the 100 publications).

How to calculate land footprint indicators with economic accounting

Input-output analysis allows tracing monetary flows and embodied environmental factors from its origin to its final consumption. The Leontief inverse, a matrix generated from an input-output table, shows, for each commodity or industry represented in the model, all direct and indirect inputs required along the supply chain. When this model is extended by environmental data, e.g. on land use, the total upstream requirements of land to satisfy final consumption of a country can be determined.

Multi-regional input-output (MRIO) models link together input-output tables of several countries or regions via bilateral trade flows. These models have major advantage compared to single region models, e.g. that they trace global supply chains using country specific information on technologies and economic structures (Feng et al. 2011) instead of the commonly applied domestic technology assumption and thus allow taking into account the different resource intensities (e.g. yields) in different countries (Tukker et al. 2013). The disadvantage is that MRIO systems are highly data intensive and require specific technical skills to be used in the calculation of footprint-type indicators.

Key advantages of economic accounting

Input-output analysis, in particular in a multi-regional form, brings along a number of key advantages over other methodological approaches (Wiedmann et al. 2011). The main advantage of input-output models is that they allow calculating the footprints for all products and all sectors, also those with very complex supply chains, as the whole economic system is included in the calculation system (Chen and Chen 2013). Input-output analysis thus avoids so-called "truncation errors" often occurring in coefficient-based approaches, i.e. errors resulting from the fact that the whole complexity of production chains cannot be fully analysed based on Life Cycle Assessments, so certain up-stream chains have to be "cut off".

Input-output analysis thus avoids imprecise definition of system boundaries, which is one key advantage over coefficient approaches (Bruckner et al. 2012b). Input-output models also avoid double counting, as different supply-chains are clearly distinguished from each other in the monetary input-output tables. Thus, a specific land input can only be allocated once to final consumption, as the supply and use chains are completely represented (Daniels et al. 2011).

Another advantage of the input-output approach is that the accounting framework is closely linked to standard economic and environmental accounting (United Nations 2003), which ensures that, at least at the national level, a continuous process of data compilation and quality check takes place.

Key disadvantages of economic accounting

The major disadvantage of input-output analysis is the fact that most input-output models work on the level of economic sectors and product groups, assuming that each sector produces a homogenous product output (Bruckner et al. 2012b; Wiedmann et al. 2011). For the application on land footprints this implies that in one sector, a number of different products with potentially very different land use intensities are mixed together. This assumption limits the level of disaggregation that can be achieved with that approach and leads to distortions of results, for example, when crops with widely diverging mass-value-ratios are aggregated into one sector. This is the case even for the most detailed IO data sets available, where e.g. spices and fodder crops are mingled into one aggregate product group. But even for apparently homogenous products like rice, price differences by a factor of ten and more can be observed.

However, a number of recent EU research projects have been devoted to the consistent integration and/or the refinement of input-output tables and multi-regional input-output systems to calculate footprint-type indicators (Tukker and Dietzenbacher 2013; Dietzenbacher et al. 2013).[218] The intention is to create consistent systems with a higher level of disaggregation, in particular in environmentally-sensitive primary sectors, thus avoiding mistakes resulting from the high level of aggregation of the input-output tables. Also input-output systems developed outside Europe such as the Eora database (Lenzen et al. 2012; Lenzen et al. 2013) point in the same direction.

[218] Examples of European research projects include the 6th Framework Programme projects EXIOPOL, FORWAST and OPEN-EU, and the 7th Framework Programme projects CREEA, DESIRE and WIOD.

Other disadvantages that are emphasised in the literature related to footprint-type calculations based on input-output analysis are:

- the large time-lag for the publication of input-output tables, in particular those harmonised for MRIO models and those tables with a high level of disaggregation: input-output tables are often published with a delay of several years, sometimes even a delay of 6-10 years;
- the high sensitivity of input-output models to relatively small errors in the trade data, in cases where imports and exports of a country are large relative to its domestic production. Relatively small errors in the estimates of imports and exports can then suddenly translate into relatively large errors in the footprint estimate (Mekonnen and Hoekstra 2011);
- the uncertainties and discussions arising from the differences between agricultural statistics and input-output statistics, with the latter reporting bigger shares of agricultural production going into manufacturing industries than the former (Kastner et al. in press);
- the use of monetary economic structures for the allocation of physical flows and the applied proportionality assumption, i.e. that a flow from a specific sector has the same land use intensity disregarding the receiving country and sector, may cause high discrepancies (Bruckner et al. 2012b) – it is likely that trade of western countries with high value-to-weight ratios is overestimated by such a model;
- the high sensitivity of results to potential incompatibilities of the environmental data with the economic accounts (e.g. differing system boundaries). Sector classifications often vary between countries, which cannot be fully considered in the available IO databases. Therefore, some countries for example include non-market fodder crops by estimating their economic value, while other countries do not. These inconsistencies pose problems when allocating physical flows to the monetary IO framework.

Including physical information on the detailed product level into land flow input–output models, in particular for the first steps of processing, could significantly improve the robustness of the results (Buyny et al. 2009; Weinzettel et al. 2014) and would solve many of the described problems (see section on hybrid accounting).

Physical accounting

While footprint models based on economic accounting use monetary data on economic structures and international trade to allocate natural resource inputs (such as land areas) to final use, physical accounting models aim at reflecting the global production and trade structures in physical units, e.g. tonnes of biomass, in order to trace embodied land areas through international supply chains.

How to calculate land footprint indicators with physical accounting approaches

Physical accounting models follow a top-down framework starting from the total biomass production (and the related land areas) and allocating the physical quantities to the consuming country. The approach applies the concept of apparent consumption, where consumption is defined as domestic production + imports – exports.

Information on the supply and utilization of food products is available from agricultural statistics. FAOSTAT, the statistical service of the FAO, is the only agricultural database with global coverage. The supply utilization accounts (SUA) published by FAOSTAT provide time series data on the supply and utilization of agricultural commodities which are balanced in terms of physical quantities by matching supply (domestic production and imports) with uses (food, feed, etc.; see Figure 3). The total quantity of agricultural commodities produced in a country (i.e. domestic production) added to the total quantity imported and adjusted for any change in stocks gives the supply available during a certain period. The utilization side comprises the quantities exported, food supplies used for human consumption (‘food’), fed to livestock (‘feed’), further manufacturing for food use (‘processing’), seed use (‘seed’), industrial and other uses (‘other use’ or ‘other utilization’), losses during storage and transportation (‘waste’), and changes in stocks (‘stock change’). Some studies consider flows of unmanufactured or only slightly processed products such as soybeans and soybean cake, while others also examine more complex supply chains of highly processed food and non-food products from biotic sources.

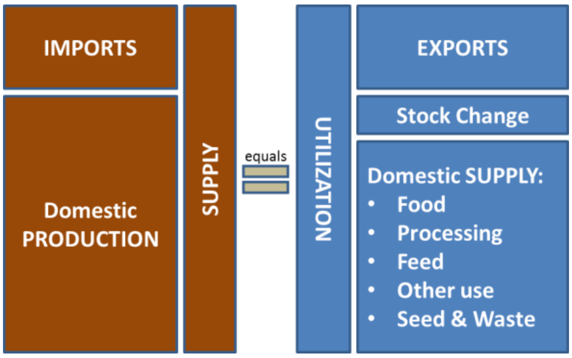


Figure 45: Items in supply utilization accounts (SUA)

The SUA database structure of agricultural statistics is designed to cover each country’s entire agricultural sector. Over 200 different primary and processed crop and livestock commodities are linked by a consistent commodity tree structure and balanced annually for each country. Intermediate or processed commodities may be included in a particular SUA commodity in their primary equivalent. For example the SUA commodity wheat includes in its supply of imports not only the import of raw wheat but also all imported wheat products converted into primary wheat equivalents.

For non-food products from biotic sources, such as wood and paper products, textiles, leather products, bio-fuels and bio-chemicals, no such information is disposable. Some studies therefore integrate additional information to capture also these products and their supply chains and use land intensity coefficients via a bottom-up approach. These land intensity coefficients inform about the supply chain wide land requirements for a certain product or activity and can be sourced from life cycle assessments.

Key advantages of physical accounting

The most important advantage of physical in comparison to economic accounting is the possibility to apply mass allocation or other physical allocation forms (e.g. according to energy content), while pure economic accounting is restricted to economic allocation. High-priced rice, for example, can be imported by country A, while country B rather consumes low-priced rice. Assuming that land intensity of both types of rice measured in hectares per tonne are equal, the country importing higher-priced rice will be allocated a bigger share of the rice cultivation area than what actually was needed to grow the crop. For this reason, mass allocation can be considered to produce more robust results, in particular in the case of unmanufactured crop commodities.

Moreover, physical accounting operates at a high level of detail and transparency. The physical accounting approach only faces few restrictions of the definition of sectors or product groups and thus allows performing very specific comparisons of footprints down to the level of single products or materials (Dittrich et al. 2012).

This approach therefore allows for illustrating the composition of footprints by commodity or product category in a very straightforward and transparent manner, as the overall numbers are summed up from the bottom, which is more difficult to assess with input-output analysis (Mekonnen and Hoekstra 2011).

The top-down approach of physical accounting fully and consistently covers global biomass flows and avoids double counting. More complex supply chains are either disregarded or considered applying a bottom-up method (see disadvantage section below). Finally, this approach can also specify the main areas of use of biomass-based products, i.e. food, feed or other purposes.

Key disadvantages of physical accounting

Physical accounting models are very data intensive and require huge efforts to be implemented. This is particularly true for calculating or gathering solid land use coefficients for a large number of especially higher processed products. Physical accounting models are therefore often applied to assess the resource requirements of raw materials and basic products, but the availability of coefficients for finished products with highly complex supply chains is generally very restricted (Dittrich et al. 2012).

Physical accounting techniques also produce truncation errors, as based on the available data indirect land requirements are not traced along the entire industrial supply chains. Supply utilization accounts report all flows up to the consumer, except for industrial (non-food) uses of biomass. For the products not covered with SUAs, land intensity coefficients are often taken from various sources including life cycle assessments. Since these studies are technically detailed but rely on assumptions and data from certain representative industries the regional specificity and consistency with national and global land use statistics will usually be impaired.

Hybrid accounting

In the past few years, hybrid accounting became increasingly popular in footprint-type calculations. These methods combine elements from input-output analysis with physical accounting or process-based coefficients (e.g. land use coefficients from life cycle assessments) and aim at exploiting the advantages of both methods.

How to calculate footprint-type indicators with hybrid accounting

Hybrid accounting methods apply a differentiated perspective to the calculation of footprint-type indicators for different products and product groups, depending on the processing stage. Typically, they apply physical accounting and process-based coefficients for raw materials and products with a low level of processing, as these data allow taking into account specific aspects with regard to different products, applied technologies and countries of origin at a very detailed product level. Processed commodities and finished goods with more complex production chains are treated with the input-output methodology, which allows considering the full upstream resource requirements and thus illustrating all indirect effects (Buyny et al. 2009; Ewing et al. 2012; Schoer et al. 2012b; Vringer et al. 2010).

This combination of different methods is realised in various ways. Some studies integrate detailed statistics in mass units into monetary input-output tables, thereby creating mixed-unit IO tables (Buyny et al. 2009; Schoer et al. 2012a; Schoer et al. 2013). Other approaches apply input-output analysis to derive land intensity coefficients for highly processed products to complement the physical land flow accounts (Meier and Christen 2012; Meier et al. 2014). A third type of hybrid accounting sets up physical accounts to model crop flows and related embodied land flows from agricultural production to the first use stage (Weinzettel et al. 2011; Ewing et al. 2012; Steen-Olsen et al. 2012; Weinzettel et al. 2013; Weinzettel et al. 2014). The resulting information, i.e. environmental extensions representing the intermediate consumption of primary products distinguished by region of origin, is then allocated to the monetary IO model, which is used to cover all supply chains from the first processing step onwards. This enables the application of a different sales structure for each primary product, irrespective of the product groups within the IO model. For example, wheat is partly allocated to the food processing sector (food use) and partly to livestock sectors (feed use).

Key advantages of hybrid accounting

The key advantage of the hybrid approach is that the applied detailed physical data allow compensating the disadvantages normally faced with input-output analysis, in particular the problems of aggregation and economic allocation. This especially enhances the assessment of products with a low level of manufacturing (Schaffartzik et al. 2009; Schoer et al. 2012a; Wiedmann 2011). Food products typically undergo only a few processing steps, thus, this type of models is particularly relevant for the case of land flow accounting. At the same time, the above-mentioned advantages of input-output analysis, in particular regarding the full reflection of all supply chains, are kept for products with a higher level of manufacturing. Therefore, hybrid approaches are most promising for the analysis of land flows embodied in non-food land-based products such as textiles, leather, paper and wood products, biofuels, cosmetics, pharmaceuticals, and lubricants.

Key disadvantages of hybrid approaches

Some of the disadvantages described for the two basic approaches also apply for hybrid approaches. These include the time lag to publication of input-output tables and the low sector detail, albeit applied only to upstream flows of higher processed products. Furthermore, comparability of results generated with existing hybrid approaches is low as the various models apply different types of hybridisation as briefly described above.

Annex 6.4: Structured list of literature considered for the review of existing approaches for the quantification of land footprints

The literature list was structured according to authors, research institutions and the applied models/methodologies, identifying more than 20 teams working and publishing in the field of land flow accounting.

Table 80: Structured list of existing methods for the quantification of land footprints and related publications

Method	IO-data set[219]	Research institution(s) / model name[220]	Publications
Economic Accounting	GTAP	Netherlands Environmental Assessment Agency (PBL)	Wilting and Vringer (2009)
		Sustainable Europe Research Institute (SERI)	Lugschitz et al. (2011), Bruckner et al. (2012a)
		Center for International Climate and Environmental Research (CICERO)	Karstensen et al. (2013)
		University of Maryland (UMD)	Yu et al. (2013)
		Vienna University of Economics and Business (WU)	BIO Intelligence Service et al. (2014)
	WIOD	University of Groningen (RUG) and others[221]	Arto et al. (2012), Dietzenbacher et al. (2013)
	OECD	Global Resource Accounting	Bruckner et al. (2012b), Wiebe et al. (2012)

[219] We specify the used source of input-output tables and trade data for studies applying multi-regional input-output (MRIO) analysis.

[220] Many studies have been conducted in co-operation of researchers from more than one organisation. For simplicity, we assigned each reviewed publication only to the organisation where the first author was affiliated at the time of publication. In a few cases, where the first authors were affiliated to more than one university, we list publications twice. Where available, we give the model name instead of the name of the involved research institution(s).

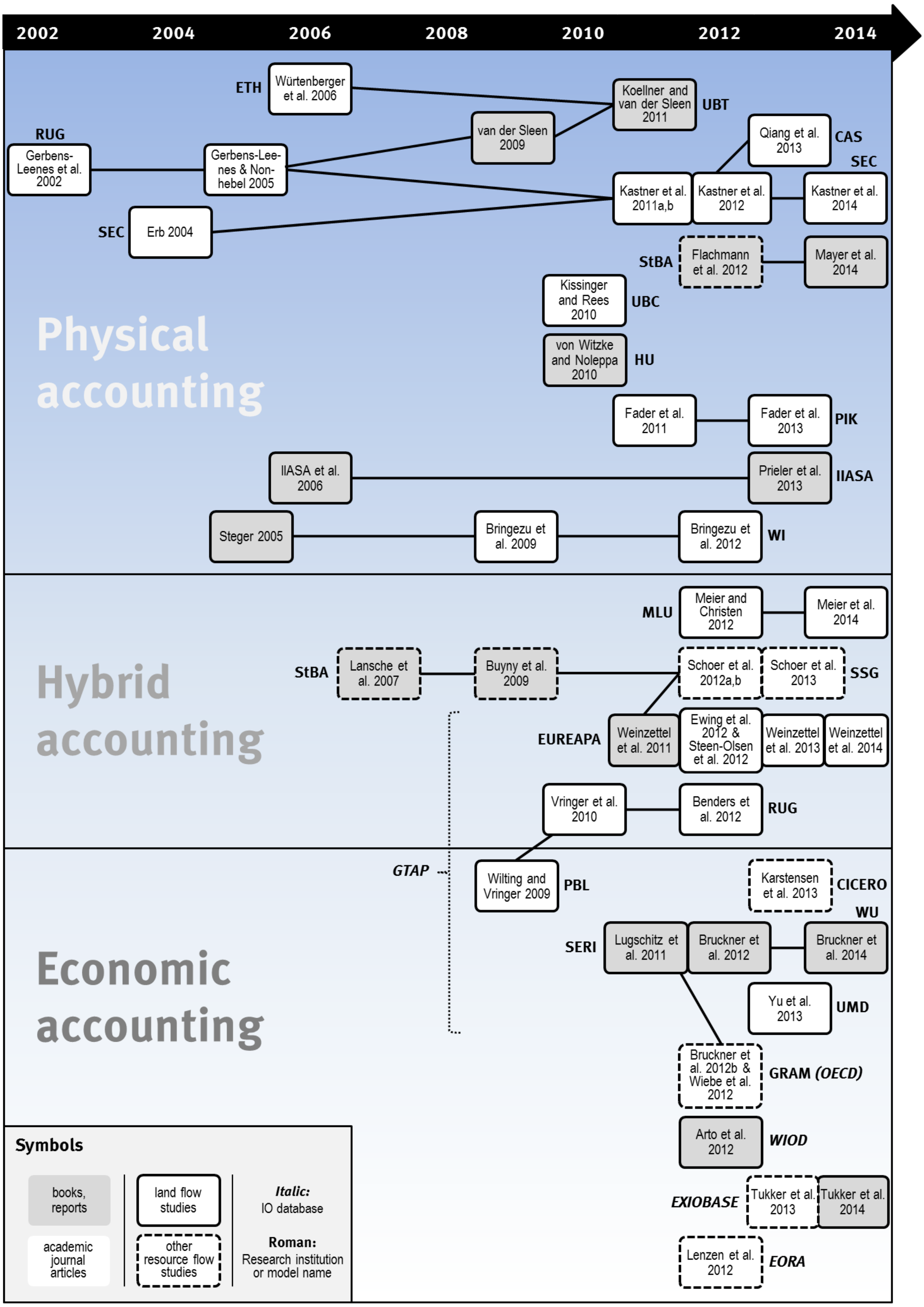
[221] See http://www.wiod.org/new_site/project/participants.htm.

Method	IO-data set[219]	Research institution(s) / model name[220]	Publications
		Model (GRAM)[222]	
		OECD	Nakano et al. (2009)
	EXIOBASE	Netherlands Organisation for Applied Scientific Research (TNO) and others[223]	Tukker et al. (2013), (Tukker et al. 2014)
	EORA	University of Sydney (USyd)	Lenzen et al. (2012), Lenzen et al. (2013a)
Physical Accounting	University of Groningen (RUG)		Gerbens-Leenes et al. (2002), Gerbens-Leenes and Nonhebel (2005), van der Sleen (2009), Kastner et al. (2011b), Kastner et al. (2011a), Kastner et al. (2012)
	Institute for Social Ecology (SEC)		Erb (2004), Kastner et al. (2011b), Kastner et al. (2012), Kastner et al. (2014)
	Chinese Academy of Sciences (CAS)		Qiang et al. (2013b)
	Swiss Federal Institute of Technology (ETH)		Würtenberger et al. (2006), van der Sleen (2009)
	Potsdam Institute for Climate Impact Research (PIK)		Fader et al. (2011), Fader et al. (2013)
	Humboldt University Berlin (HU)		von Witzke and Noleppa (2010)
	International Institute for Applied Systems Analysis (IIASA)		IIASA et al. (2006), Prieler et al. (2013)
	Statistisches Bundesamt (StBA)		Flachmann et al. (2012), Mayer et al. (2014)
	University of British Columbia (UBC)		Kissinger and Rees (2010)
	Wuppertal Institut (WI)		Steger (2005), Bringezu et al. (2009), Bringezu et al. (2012)
Hybrid Approaches	GTAP	Netherlands Environmental Assessment Agency (PBL)	Nijdam et al. (2005), Vringer et al. (2010)
		EUREAPA model[224]	Weinzettel et al. (2011), Ewing et al. (2012), Steen-Olsen et al. (2012), Weinzettel et al. (2013), Weinzettel et al. (2014)
	Martin Luther University of Halle-Wittenberg (MLU)[225]		Meier and Christen (2012), Meier et al. (2014)
	Eurostat		Schoer et al. (2012a), Schoer et al. (2012b)
	Statistisches Bundesamt (StBA)		Lansche et al. (2007), Destatis (2009)

[222] Developed by GWS and SERI within the petrE project, see http://www.petre.org.uk/
[223] See http://exiobase.eu/about-us/partners.
[224] Developed within the OPEN: EU project, see http://eureapa.org/.
[225] Not yet considered in the review.

The development of land flow accounting methodologies is a very dynamic and rapidly expanding field. The following figure shows the genesis of the field of research on global land flows using physical accounting, which has seen a larger number of recent publications compared to economic accounting. The boxes represent publications (white boxes for peer-reviewed journal papers; grey boxes for project reports and non-scientific publications) arranged along a time line and connected via solid lines representing personal or institutional relations, indicating that one or more co-authors and/or research institutions were involved in both studies. Publications from fields other than land flow accounting (e.g. deforestation, biodiversity or material flow accounting) are framed in dashed lines. The applied IO databases are mentioned in italic letters, where applicable, while institution or model names are written in roman letters.

Table 81: Genesis of the various research strands in land flow accounting



This illustration, although likely incomplete, shows that some of the first studies applying physical accounting and the coefficient approach for the calculation of national or international land flows were developed in the early 2000s. Pioneering Universities and research organisations were the University of Groningen (RUG), the Institute of Social Ecology (SEC), the International Institute for Applied Systems Analysis (IIASA), the Wuppertal Institute for Energy, Climate, Environment (WI), and the Swiss Federal Institute of Technology (ETH). Some years before that, Ecological Footprint studies addressed a similar research question, quantifying the biocapacity embodied in trade (Wackernagel and Rees 1996). In the last few years, the field became more diverse and vivid. Two thirds of the reviewed studies were published as from 2010. By now, 2013 was the year with the highest record of publications in this field.

Annex 6.5: Review results and recommendations for the further development of land flow accounting approaches

In this chapter we provide a comparative analysis of the various methodological and data options for land footprint calculations, discussing key aspects of the calculation procedures with significant impacts on the overall result. The numerous aspects are discussed as part of the two overarching steps in the calculation: first, how land areas are attributed to primary production and second, how embodied land is tracked along global supply chains. Recommendations regarding the best available options are provided for both calculation steps.

Land attribution to primary production

Tracking land along global supply chains starts from the primary production in the countries of origin. Thus, global land use data and land intensities of primary commodities, i.e. the extents of the total physical land in the agricultural and forestry systems of each country as required to produce a commodity, are key inputs for tracking land along supply chains. Since land intensities (yields) among crops and across countries vary widely, it is essential for land accounting to retain, to the extent possible, both the commodity and geographical details of the supply chains. The same applies to wood and livestock products, in particular for grassland productivity and resulting land intensity of ruminant livestock herds.

Yet, despite the wealth of data and statistics available, the integration of land data into the socio-economic accounting framework remains a major challenge (Erb et al. 2007), particularly for economic accounting methods. Land use information can be inferred from land cover data only to a limited extent, as no unambiguous correlation between land use and land cover can be observed. Furthermore, national land use statistics refer to land use but may not coincide with the actual geography of countries due to reporting inconsistencies. In the following, we describe data sources and specific shortcomings for different land use types.

Disaggregation of land use

The agriculture and forestry sectors are the largest users of land. Other sectors such as mining, manufacturing or transport may result in large environmental impacts but they require much less physical land for their production activities, albeit with largely irreversible consequences for the land. Agriculture utilizes arable land for the production of food, feed and fibre from annual crops, keeps land under permanent crops and uses grassland and permanent pastures for grazing and producing feed for ruminant livestock herds. Forests are used for the harvest of industrial round wood and for wood fuel collection.

The Food and Agriculture Organization of the United Nations (FAO) compiles various annual agricultural land use and production statistics (FAOSTAT 2014). This database contains data on agricultural areas and yields for around 180 crops and is the only available land use database with global coverage. The data are collected from FAO member nations primarily based on questionnaires. Although these data may involve problems due to intentional over- or underreporting or problems owed to a lack of resources and survey capacities, especially in developing countries (Ramankutty 2004), FAO is regarded as an authoritative source for agricultural data and indeed, is the only source available for large-scale global studies related to biomass and land. The FAO online database[226] contains annual agricultural statistics from 1961 to t-2 (i.e. 2012, as of 2014). Printed statistics are available also for earlier years. In 2011, global cropland amounted to 1,550 million hectares (Mha) (of which 1,396 Mha was arable land and 154 Mha was land under permanent crops) and was distributed over the world's favourable climatic zones and most fertile soils. Permanent pastures and forests covered respectively 3,356 Mha and 4,027 Mha (FAOSTAT 2014).

There are many potential problems associated with the interpretation of FAO cropland statistics (Ramankutty 2004). Member nations are asked to report harvested areas, which exclude both non-cropped arable land and cropped but not harvested areas (e.g. due to flooding or draught losses). Temporary grassland and fallow land are not reported by all member nations and seem to vary widely in their proportional extent. Small-scale subsistence agriculture is often not accounted for. Correct reporting of intercropping, i.e. crops that are interplanted with others, poses a challenge to the national reporting authorities. Reported extents of grassland and forests are often even less reliable compared to cropland area statistics due to various reasons including differences in definitions across countries. Also, grassland and forest ecosystems cover a very wide range of land productivity, from conditions in sparsely vegetated semi-arid climates to tropical forests with very high productivities. In addition, area extents of current actually used grass- and forest lands are not or incompletely reported in the available global databases.

To account for these differences in accuracy, sharpness and availability of land data and to improve the interpretation of results, it is strongly recommended to calculate land footprints separately for cropland, grassland and forests.

Recommendation:

- It is strongly recommended to calculate land footprints separately for cropland, grassland and forest land in order to account for differences in accuracy, sharpness and availability of land use data by broad primary sectors (crops, livestock, wood production) and to facilitate better impact oriented interpretation of the results.
- Meaningful land accounting requires to differentiate among feed sources and land inputs of different livestock types and to treat ruminants (e.g. cattle, sheep – feed sources from cropland and grassland) separately from other livestock (mainly pigs and poultry – feed sources from cropland only) production.
- The Food and Agriculture Organization (FAO) of the United Nations compile national statistical data. Data are checked and where relevant estimates included. It is the only available consistent global dataset on land use and agricultural and forestry production and thus the only available source for large-scale global studies related to biomass production and land use. We recommend using these publicly available country-level, time series databases for the agricultural and forestry sector in land footprint accounting.

Land intensities of cropland

Interpretation problems of cropland statistics arise from crop rotations that happen within a single year (multi-cropping). Multi-cropping is an important issue in countries such as Bangladesh, where farmers often reap two or more harvests per year. Yields of 6 tons of rice per harvested hectare thus could actually conceal real

[226] http://faostat.fao.org

annual yields of 12 or 18 tons per physical hectare. Bruckner et al. (2012a), IIASA et al. (2006) and Prieler et al. (2013) adjust land use data for multi-cropping by scaling down harvested areas to the physical areas, in cases where multi-cropping practices increase harvested areas above the level of physical (actual) cropland areas. In the case of Bangladesh, for example, applying this procedure increases all yields of temporary crops by about 60%, thus implying that each physical hectare is harvested 1.6 times a year. This approach can be considered conservative and will still underestimate the actual yields for many countries.

Furthermore, economic activities might not only depend on the land areas they directly use. One can argue that fallow land, although it is out of production and thus out of use for a certain period, forms part of the agricultural production system as fallow periods are a necessary element in many traditional crop rotation systems. Therefore, fallow land should be added to cropland for the correct representation of land resources required for crop production.

Other sources such as Eurostat or national statistical institutes also provide data sets of good quality, but the use for global analyses is limited, as only cropland inventories of one or a few countries are depicted.

Cropland productivity depends on the land's biophysical endowment (climate, soils, terrain), access to agro-research knowledge through education and extension services, availability of agro-inputs, land management objectives and practices, and local land tenure as well as socio-economic circumstances. Biophysical characteristics of land and land management practices determine crop rotation schemes including the use of multi-cropping and fallow periods. Multi-cropping is the practice of growing two or more crops per year on the same piece of land. Yields of 6 tons of rice per harvested hectare thus could actually conceal real yields of 12 or 18 tons per physical hectare. Crop rotation cycles may include fallow periods, e.g. to accumulate soil moisture and for maintaining soil fertility. Occasionally extreme events, drought or flooding, may decrease the amount of sown or harvested areas.

FAOSTAT as well as most national statistics report physical cropland areas (usually separately for arable land and land under permanent crops) as well as sown or harvested areas of individual crops. The multi-cropping index (MCI) is a commonly used measure of cropping intensity. Multiple use of physical land can be calculated as the ratio of the sum of harvested areas of all individual crops and the physical cropland area. This measure of multiple use of cropland varies considerably across countries and has been increasing at the global level from 0.90 in 2000 to 0.97 in 2011 (FAOSTAT 2014), which reflects an intensification trend of agricultural production systems and indicates rising land productivity.

A key input for land footprint calculations are so-called land intensities, which describe the amount of physical land area associated with the production of primary crops. In previous studies, some land footprint methodologies have applied land intensities calculated for individual crops as the ratio of reported harvested areas (in ha) and production (in tonnes) in each country. Alternatively, the inverse of average global crop yields was sometimes used for calculating land footprints, for example in studies where the country of origin of imported commodities was not tracked.

To reflect these obvious differences between physical cropland used in agriculture and reported harvested areas, and between cultivation cycles of annual and perennial crops, we recommend accounting for multi-cropping and fallow periods when attributing physical cropland to primary crop production. From the literature considered in this report, Bruckner et al. (2012a), IIASA et al. (2006) and (Prieler et al. 2013) go beyond harvested areas as basis for the calculation of land intensities and also account for multi-cropping and fallow periods.

Land intensities differ between annual crops and permanent crops in accordance with their agronomic characteristics. Perennial crops include for example orchards, vineyards, olive groves and oil palm, coffee, tea and natural rubber. These crops occupy the land for long periods and reported harvested areas refer to the annual production cycle. Annual crops are sown each year and in sub-humid and humid conditions of the sub-tropical and tropical regions two or three rain-fed crops per year are possible. In the case of Bangladesh, for example, a MCI of 1.6 was determined, implying that each physical hectare is harvested 1.6 times within a year on average.

For the purpose of cropland attribution to primary crops FAO data permit computing average land intensities in each country separately for annual crops and permanent crops. .Applying these factors evenly to the harvested areas of individual crops of each group ensures that all cropland is attributed to the primary production and the attribution respects agronomic knowledge and practice in each country.

Recommendation:

- Since yields (land intensities) among crops and across countries vary widely, it is essential for the land accounting to retain in the tracking procedures both the commodity and geographical details of land-based production and commodity flows and avoid aggregation at an early stage in the supply chain to the extent possible.
- Realistic and consistent accounting of land actually embedded in the consumption and trade of agricultural products requires using country-specific technology and land use information (i.e. country-specific crop yields, livestock herds, feeding practices, etc.)
- Account for multi-cropping and fallow periods when attributing physical cropland to primary crop production.
- Apply agronomic logic and data to differentiate in the calculation of multi-cropping and land intensities among annual and perennial crops.
- Calculate average multi-cropping intensities, separately for annual and perennial crops, across all crops cultivated in a country and apply respective intensities to harvested areas of individual crops to estimate physical land associated with production.

Land intensities of grassland and forests

While reported cropland areas can be considered as being fully utilized by the agricultural systems for accomplishing the reported annual crop production volumes, the grassland and forest area statistics are usually less detailed and incomplete regarding the extent of areas, which are actually utilized for rearing livestock or for wood harvesting.

FAOSTAT land use data report grassland and forests defined as follows:

- Permanent meadows and pastures is the land used permanently (five years or more) to grow herbaceous forage crops, either cultivated or growing wild (wild prairie or grazing land).
- Forest area is the land spanning more than 0.5 hectares with trees higher than 5 metres and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use. Forest is determined both by the presence of trees and the absence of other predominant land uses.

Lacking data on actual use of grassland and forest land, land footprint methodologies have often assumed reported grassland and forest land areas as the underlying physical land base required for the production of the primary produce. However, such simple approaches overestimate land requirements and disregard differences in land productivity of used versus unused grass- and forest land. Therefore, more refined estimation methods are needed.

Grassland

There is a lack of reliable data on the extent of land used for grazing. This has mainly two reasons. On the one hand, remote sensing data provide only a poor basis for the establishment of grazing data, due to the physical heterogeneity of grazing areas (Harris 2000; Erb et al. 2007). On the other hand, irregularities in available census data (Asner et al. 2004) point to discrepancies in statistical reporting. Large uncertainties in the FAO data on pasture land result from inconsistent definitions of this land use category across countries.

Statistics do not correspond with real grazing areas. The case of Saudi Arabia, where about 80% of the land surface is reported to be permanent pastures, underpins the problem. This can result in large differences between countries in the derived grazing areas per animal and may have considerable effects on the results.

Grazing areas constitute the largest fraction of global human land appropriation and its expansion is a major driver of deforestation in the tropics, highlighting the importance of overcoming these obstacles. One way to overcome them is to estimate grassland use by calculating the grass demand (in tonnes) of the reported livestock herd (Krausmann et al. 2008) and deriving the respective grassland areas based on global grassland productivities obtained, e.g., from the detailed grid-cell based bio-geographical GAEZ model (Global Agro-Ecological Zoning, IIASA/FAO 2012).

Forest areas

A differentiation between managed forest land, which is harvested for wood fuel or timber and undisturbed natural forests is not trivial. Forest statistics show the area covered by trees and almost never separately report actually productive or harvested areas.

The TBFRA-2000 report on "Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand" (UN-ECE/FAO, 2000) includes estimates for actual forest lands available for wood supply. In contrast to the FAOSTAT database TBFRA-2000 data is available for selected countries and for the year 2000 only.

Many studies such as Bringezu et al. (2012), Bruckner et al. (2012a), Erb (2004), and Prieler et al. (2013) therefore adopt a sustainable yield approach calculating the forest area required to harvest the reported timber production according to the net annual increment of forests in the country of origin, i.e. assuming that each year the increment is harvested and stocks remain constant. This can be done based on productivity estimates from biophysical models such as GAEZ (IIASA/FAO 2012), or based on increment rates reported by the FAO Forest Resource Assessment (FRA, see FAO 2010).

Recommendation:

- For countries where data is not available or data are unreliable, grassland and forest land actually used for livestock and wood production should be estimated rather than assuming all reported grassland and forest land as being part of the production cycle. For instance, regional data or model-based simulations of grassland productivity, net annual forest increments, etc. together with estimated livestock feed balances and reported timber harvests can be used to fill information gaps needed for enhancing estimates of forest and grassland utilization of livestock and wood production.
- Since land intensities among livestock and forestry products and across countries vary, it is essential for the land accounting to retain in the tracking procedures both the commodity and geographical details of land-based production and commodity flows and avoid aggregation at an early stage in the supply chain to the extent possible.
- Realistic and consistent accounting of land actually embedded in the consumption and trade of ruminant livestock products and forestry products requires using country-specific technology and land use information (i.e. country-specific livestock herds, feeding practices, timber harvesting).

Consistency with the System of National Accounts

According to the current standards and guidelines, both National Accounts (as the source of IO tables) and land use statistics capture all market activities as well as non-commercial or non-market production such as kitchen garden production and all kinds of subsistence agriculture. The share of non-market activities can be particularly high for land-based parts of the economy. In some countries subsistence agriculture and forestry cover large parts of the provision of food and wood. The consistency between these two statistical sources cannot be ensured, especially for developing countries. Thus, accounting methods that directly combine IO tables and land use statistics (i.e. economic accounting approaches) could substantially under- or overestimate virtual land flows.

Recommendation:

- Errors resulting from inconsistencies between the National Accounts and land use statistics can only be avoided applying physical or hybrid accounting methods.
- A physical accounting approach based on detailed commodity production and trade data should therefore be used for the first stages of the supply chains. When industrial uses cannot be tracked further by the physical accounting methods due to data limitations economic accounting of flows from these sectors based on monetary IO tables should be applied to extend supply chains to final consumption.

Tracking land flows along global supply chains

IO tables depict the inter-sectoral flows within and between economies. Based on these data, all global supply chains can be traced. Physical accounting models are based on production and trade statistics reporting quantities such as FAOSTAT; yet, consistent statistics comprising physical data on inter-sectoral flows are lacking. Therefore, physical accounting approaches either use land intensity coefficients for processed products or they convert these products into their raw material equivalents for which land intensity coefficients (yields) are available from statistical sources (see chapter 2 above).

Overview of sources for supply chain data

The following table shows the main characteristics of the currently available datasets used for economic and physical accounting of global resource flows along supply chains. It includes all currently available and expected multi-regional input-output databases (namely Eurostat, EXIOBASE, WIOD, OECD, GTAP and EORA) contrasted with FAOSTAT, which is the most widely used data source for physical land accounting models. The table provides a comprehensive and compact overview on the available data sources and their limitations for the application in land flow accounting.

Table 82: Global data sets for the construction of land flow accounting models[227]

	Eurostat	EXIOBASE	WIOD	OECD	GTAP	EORA	FAOSTAT
Regions	28 EU countries, Norway, candidate countries, EU aggregate	44 + 5 RoW	27 EU countries, 13 other major economies + RoW	48 countries (all OECD countries and other major economies)	66, 87, 113, 134 (number increasing for later versions)	187	239 countries
Agricultural & forestry sectors	2	18	1	1	13	~1-20	~200c
Food / non-food biomass processing sectors	5	10 / 10	1 / 4	1 / 3	8 / 5	~1-40	~100c
Total number of sectors	60i	200c, 163i	35i	36i	57c	20-500c/i	~300c
Time series	for most countries 2008, 2009	1995-2011	1995-2011	1995, 2000, 2005	1997, 2001, 2004, 2007	1990-2011	1961-2011

[227] Note: i = industries, c = commodities, ITA = industry technology assumption, PTA = product technology assumption.

	Eurostat	EXIOBASE	WIOD	OECD	GTAP	EORA	FAOSTAT
Update frequency	SUTs annually, IOTs every five years	unknown	unknown	5 year steps, time lag 5 years	3 year steps, time lag 5 years	unknown	annually, time lag 2 years
Units	values	values	values	values	values	values	quantities, values
Sector classification & technology assumption	i x i	i x i with FPA; c x c with ITA	i x i with FPA	i x i with FPA	mixed	mixed	n.a.
Type of data source	official EU statistics	academics	academics	official OECD statistics	academics	academics	official UN statistics
Availability	free	not yet available	free	free	$215-$5,550	free (CC)	free

As illustrated in the table, the different data sets have complementary strengths. Eurostat's IO database is an official statistical database available for Europe, but has its deficits in particular in terms of sectoral disaggregation and does not include data for non-EU countries, thus only capturing a fraction of the global economy. GTAP has its major strength in the number of countries and the disaggregation of a large number of sectors in the agricultural and food production areas, while not providing fully transparent documentation. WIOD and OECD have the closest link to national statistics and the least degree of data manipulation. However, sector detail is lowest for these two databases. EXIOBASE has its main advantage in providing a high sectoral detail, but is so far only available for the years 2000 and 2007, with differing sector classification, and is lacking transparent and comprehensive documentation. The largest number of countries and a long time series is provided by the EORA system, which also provides long-time series data, but involves significant modelling to generate data. Moreover, sector detail is low for the globally consistent version of EORA (26 sectors) and varying for the full version (between 20 and 500 sectors).

Yet, some global IO datasets are contested for quality or transparency issues. A recently published paper discusses some implausibilities of land footprint calculations for China based on MRIO analysis (Kastner et al. in press). Physical accounting approaches revealed significant net imports of embodied land (Qiang et al. 2013b), while MRIO-based calculations show net exports (Weinzettel et al. 2013; Yu et al. 2013). This effect might be partly explained through distortions introduced by the assumption for constructing the IO tables (e.g. Industry-Technology versus Product-Technology Assumption). It may also be a result of the significant uncertainties related to the data and assumptions applied in the disaggregation procedures applied for the construction of detailed IO data sets. Both MRIO studies considered in the comparison by Kastner et al. (in press) use GTAP, which effectively shows significant intermediate flows of about 20% of agricultural outputs (even higher for animal products) to various manufacturing industries, while according to the SUAs only about 10% of all agricultural commodities used in China are utilised for non-food purposes. In a MRIO-framework, large countries have a relatively big influence on the overall results. Assuming that the IOT for China used in the GTAP database might contain errors, e.g. stemming from deficient disaggregation methods, this could eventually explain the effect revealed by Kastner and colleagues.

FAO provides one of the most comprehensive sets of global agricultural and forestry statistics. These are collected through annual questionnaires, national/international publications, and information gathered during country visits or provided by the local FAO representatives. The FAO's supply utilization accounts (SUA) provide statistics on the supply and utilization of over 200 different primary and processed crop and livestock commodities and are linked by a consistent commodity tree structure representing physical supply chains. However, for non-food products from biotic sources, such as wood and paper products, textiles, leather products, bio-fuels and bio-chemicals, no such information is disposable.

FAO acknowledges several shortcomings of the data it receives. Notably, these include data gaps and incomplete reporting by countries, sometimes questionable reliability and inconsistent definitions (George and Nachtergaele 2002). The Statistics Division of the FAO endeavours to overcome these shortcomings.

Most uncertainties are expected for some developing countries, while for developed countries the overall picture can be regarded as reliable (see George and Nachtergaele 2002).

Recommendation: On the one hand, detailed IO data sets such as GTAP and EXIOBASE struggle with uncertainties related to the data and assumptions applied in the disaggregation procedures. For more aggregate IO data sets such as Eurostat, WIOD, OECD and EORA, on the other hand, the homogeneity assumption for product groups is considered to produce significant errors, particularly for the case of agricultural commodities and related land flows. Therefore, we recommend applying a detailed physical attribution scheme for tracking land flows along the supply chains based on FAOSTAT to the extent possible. In other words, detailed commodity flows should be tracked via their physical quantities (tonnes) and associated land areas should be attributed in proportion to physical volumes.

Assumptions for the construction of Input-Output Tables

In most cases, Input-Output Tables (IOTs) are derived from supply-use tables (SUTs). Different assumptions for constructing IOTs from SUTs can be applied:

- The **industry technology assumption** (ITA), on the one hand, assumes the same input structure for each product being produced by a specific industry. For example, radios and TVs, are produced by the NACE sector 26.4 (Manufacture of consumer electronics).[228] Although different raw materials and technologies are used to manufacture a radio or a TV, the ITA would assume equal inputs for the two production processes.
- The **product technology assumption** (PTA), on the other hand, is assuming that a product has the same input structure in whichever industry it is produced. For example, a specific electronic appliance will be regarded equal, albeit produced by sector 26 (Manufacture of computer, electronic and optical products) or by sector 27 (Manufacture of electrical equipment).

The choice of a specific technology assumption might significantly influence the land footprint results generated with an IO model. For instance, when farmers produce not only agricultural products but also manufacturing goods or certain services, as it is the case to varying extents all over the world (say, for example, farm holidays), an IOT derived using the ITA, which is probably the most widely used assumption for constructing product-by-products IOTs, would allocate agricultural products as an intermediary input to the production of these services and manufacturing goods. In other words, the tourism services offered by the farm eventually appear to require substantial amounts of cereals, vegetables or raw milk in their production processes. Moreover, the exports of these goods and services may as a consequence incorrectly shift land use to a third country. This error is of course most relevant for regions where farmers traditionally generate a significant share of their income producing manufactured goods and services.

The application of the PTA would avoid the problems related with the described example, as farm holidays would be considered to have the same input structure as hotels and other businesses in the tourism sector. However, if input-output analysis is only applied for non-food products as part of a hybrid accounting approach, as proposed above, the effect will be less important than in the case of pure economic accounting.

ITA can be implemented straight-forward and is only producing non-negative values, which is a pre-condition for a meaningful economic interpretation, while PTA may produce negative values which need to be dealt

[228] NACE is the statistical classification of economic activities in the European Community, see http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-RA-07-015/EN/KS-RA-07-015-EN.PDF.

with separately, e.g. applying the approach presented by Almon (2000). This procedure is technically more elaborate and has not yet been applied to global IO datasets.

Recommendation: PTA can be assumed to be more appropriate than ITA. However, no MRIO data set currently available was constructed applying PTA. This is less relevant for hybrid than for economic accounting approaches, as hybrid models use IO information only for a fraction of the supply chains.

Allocation of products in the supply chain

An important difference between economic and physical accounting methods is whether supply chain flows (and embedded land uses) are tracked in terms of monetary values or physical quantities. This is on one hand relevant for joint production processes (e.g. crushing of soybean resulting jointly in soybean oil and soybean cake) requiring rules to attribute the land embedded in the raw material to the jointly produced commodities. On the other hand, land embedded in products needs to be allocated to different utilization categories or sectors, which can be done assuming heterogeneity or distinguishing different qualities and prices.

Joint products

A consistent treatment of joint products such as oil and cake from soybeans needs to be ensured in order to avoid double counting. Many studies already do so by allocating land areas to joint products in relation to their weight (Bringezu et al. 2009), energy content (Kastner et al. 2011b), carbon content (Kastner et al. 2011a) or value shares (Prieler et al. 2013; Statistisches Bundesamt 2013a). Furthermore, the protein content was discussed by Kastner et al. (2011b) as another weighting scheme for allocation. Economic allocation, i.e. allocation of joint production according to the value share of each component, is often used in life cycle assessments and is recommended by the Dutch Handbook on LCA (Guinée JB et al. 2002) as a baseline method, as it reflects the economic incentives of producers. Economic allocation is the standard form of land flow attribution in economic accounting models and can also be applied in physical accounting approaches, when using prices to convert physical quantities into monetary values (see, e.g., Prieler et al. 2013; Statistisches Bundesamt 2013a). It can be argued that agricultural production decisions in many cases are not (only) driven by economic incentives. Allocating land according to energy or protein content would be problematic for the case of energy-rich oil and protein-rich feed production from oil seeds. Either of the two joint products would be attributed the lion's share of the embodied land. And finally, in cases where the main product incorporates only a small share of the total weight of the starting product, while the major part of the physical quantity is going into a low-value by-product supply chain, weight based forms of allocation

Recommendation: Ensure consistent treatment of joint production processes along the supply chain. We argue that the consistent use of economic allocation for attributing land to joint products is an appropriate compromise, as it can be applied to all joint products consistently, while other allocation logics could only be implemented very specifically on a case-by-case basis. Economic allocation can either be achieved by applying monetary supply use structures (as in economic accounting) or by translating physical quantities into values using price information (in physical accounting).

Product heterogeneity

Product flows within countries are often assumed to be homogeneous, regardless of its utilization, while in fact a crop used for domestic consumption, exports, or processing might differ in quality and price. For example, a comparison of global trade flows of rice has shown that rice import flows to high-income countries may increase up to an order of magnitude allocating flows according to prices as opposed to a weight-based allocation, while for low-income countries imports are lower using economic allocation. As a reason we therefore assume quality and related price differences between rice imports of high- vs. low-income countries. This error is discussed extensively by Schoer et al. (2013). Physical allocation of primary product flows can only be realised in a physical accounting framework.

Recommendation: Land embodied in a country's supply of a certain crop or commodity should be allocated according to physical quantities as far as possible, as price variations for different utilisations otherwise impair the results. This implies that a physical accounting approach should be applied for these supply chains.

Supply chains of plant-based products

Input-output tables depict the inter-sectoral flows within and between economies. Based on these data, all global supply chains can be tracked. Data in the input-output tables, however, are highly aggregated to only a few agricultural product groups and are reported in monetary units, which do not allow applying physical allocation logic, as discussed before.

In contrast, physical accounting models are based on very detailed production and trade statistics reporting quantities for several hundreds of products. Yet, statistics providing physical data of inter-sectoral commodity flows are limited. Therefore, the derived processed products are converted into crop equivalents using technical knowledge and coefficients. The most widely used source for such conversion factors is the FAO report "Technical Conversion Factors for Agricultural Commodities" (FAO 2003). However, regional or temporal differences due to differences in technologies or nutritional preferences are not captured by the technical conversion factors, which are only available as a global average.

Recommendation: Retain commodity detail and accounting based on physical volumes along the supply chains to the extent possible by applying a physical or hybrid accounting approach.

Supply chains of non-food products

Not for all commodities and their supply chains conversion factors are provided by the FAO, so that product trees are truncated at a certain stage of processing. That is particularly the case for non-food biomass products such as biofuels and other bio-materials and the derived products (e.g. soap from oil crops, textiles from fibre crops, tobacco products, and tires from natural rubber). These processed products can be considered using bottom-up coefficients, mainly from LCA studies. This procedure produces uncertainties related to the use of various data sources which often include grey literature and unpublished sources. Since these studies are technically detailed but rely on assumptions and data from certain representative industries the regional specificity and consistency with national and global land use statistics is usually impaired.

As data domain boundaries for physical accounting do not allow tracking the full supply chains of non-food products, economic accounts (IO tables) can be applied in order to track secondary products from processing industries to final uses. The development of the EUREAPA model, so far applied to the cases of the ecological, water and carbon footprints (Weinzettel et al. 2011; Steen-Olsen et al. 2012; Ewing et al. 2012; Weinzettel et al. 2014), as well as the work done by Meier and colleagues (Meier and Christen 2012; Meier et al. 2014) and Vringer and colleagues (Vringer et al. 2010; Benders et al. 2012) contributed significantly to the development of hybrid accounting by integrating detailed physical biomass and land accounts and input-output analysis.

Recommendation: Use a hybrid accounting approach extending the physical accounting model using monetary flows from IO tables for processing industries/economic sectors where processing industries/economic sectors. This is particularly the case for non-food use of crops and derived products (recorded as "Other Utilization" item in FAOs agricultural supply chains) and manufactured forestry products.

Supply chains of animal products

In Germany around 60% of the overall land footprint of food is due to the consumption of animal products (Statistisches Bundesamt 2013a). Thus, the treatment of livestock production has a particularly important role in land flow accounting models. Economic accounting is not well suited for the tracking of land in the supply chains of animal products due to the low sectoral detail of IOTs. In most IOTs agriculture is represented as one aggregated sector, which does not allow deriving any specific information, for instance, on feed use. This results in one average land use intensity factor for aggregate agricultural production even though in reality the land intensities of, for example, ruminants and pigs or chicken are very different and need to be considered separately in the land accounting model.

Therefore, available agricultural statistics should be used to compute appropriate and specific land intensities for livestock products. This can be realised either in a top-down approach, starting from feed supply statistics, livestock herds and permissible diets and apportioning recorded market and non-market feed to different livestock types and production. The second option is a bottom-up calculation, using feed conversion ratios for different animal products. Due to its consistency with land use data, top-down accounting approaches are preferable. Interesting methodologies were developed by Mayer et al. (2014) based on German statistics and by IIASA et al. (2006) (see also Prieler et al. 2013) based on global FAO statistics.

Recommendation: Avoid the 'domestic technology assumption' and apply a top-down approach in order to maintain global consistency of land attribution along supply chains. Apply a detailed physical accounting approach for achieving high detail and robustness of the results.

Top-down vs. bottom-up

We argue that top-down approaches are in any case preferable as compared to bottom-up approaches, as they ensure consistency with national or global land use statistics, i.e. total in-flows equal total out-flows. Furthermore, in a top-down accounting approach, physical supply chain information can be integrated with monetary input-output data constructing mixed-unit input-output tables (IOTs). This integration has the advantage of consistently adding together all parts of the model into one matrix framework, which can be solved using basic linear algebra. However, a full integration maintaining the detail of the base data would result in a matrix of the dimension of about 40,000 by 40,000 and has not yet been realised.

Recommendation: Follow a 'top-down' approach, starting with land attribution to the production of primary products and following the supply chain to final consumption. If technically feasible, a consistent top-down accounting model can be realised by full matrix integration of all physical and monetary supply chain data.

Trade

Globalization and increasing trade in agricultural and forestry products is an essential element of development strategies in many countries resulting in substantial cross-country flows of primary and manufactured products. In order to track land embodied in products, huge sets of bilateral trade data need to be employed, raising questions of data quality and consistency, which are discussed below. However it should be noted that consistent bilateral trade data are mandatory for tracking global supply chains.

Consistency of trade data

It has long been recognized that the international trade data reported by importers and exporters often do not match for a variety of reasons (Hertel and Binkley, 1992; Gelhar, 2013). Bilateral trade flows are reported separately by importers and exporters, often resulting in large discrepancies in reported trade flows.

Reasons for inconsistencies are manifold, including:

- time lags (e.g. exports reported in one year could reach a destination only in the following year);
- loss and shrinkage (exported quantities could be destroyed or lost on the way to the destination, e.g. due to physical evaporation);
- type of trade reported (some countries report general trade including re-exports, while other report special trade, i.e. imports for the domestic use);
- data gaps in the reporting of one of the trading partners;
- misreporting, e.g. customs tax avoidance by misrepresenting a commodity on import or not reporting a trans-shipment;
- inconsistencies in reporting of place of origin/final destination (e.g. some countries may report final destination and omit intermediate trade via a third country);
- mismatches between the imports reported by one country and the exports reported by another are not reconciled. An exception is, for instance, trade between the US and Canada, two countries which share and harmonize trade data.

Globally consistent natural resource flow accounting requires consistency between imported and exported commodities. There is no commonly accepted method for reconciling differences in bilateral trade statistics. For example, the bilateral trade data of agricultural commodities in 2010 recorded in FAOSTAT amount to more than 600,000 data records, which are harmonized in LANDFLOW by constructing a symmetric trade matrix using the largest value of each pair of recorded trade flows. The trade data in the GTAP database are based on the UN COMTRADE database, which are reconciled according to a methodology described in Gelhar (1996).

Recommendation: Maintain global consistency of land attribution along supply chains by setting up a fully consistent representation of bilateral trade flows.

Re-exports

One main challenge of land flow accounting is posed by the fact that in bilateral trade statistics the country of origin is the country where the last value added step occurred. Thus, the true origin in the case of re-exports is lost in this information. For the purpose of land accounting, re-exports have to be defined more widely than is commonly done. For tracking embedded land a re-export occurs also if a country imports a primary commodity (e.g. soybeans) and exports secondary products derived from this raw material (such as soybean cake or livestock products based on soybean cake). We consider this flow of secondary products to be a re-export, as we are interested in linking environmental factors at the place of primary production to the place of final consumption.

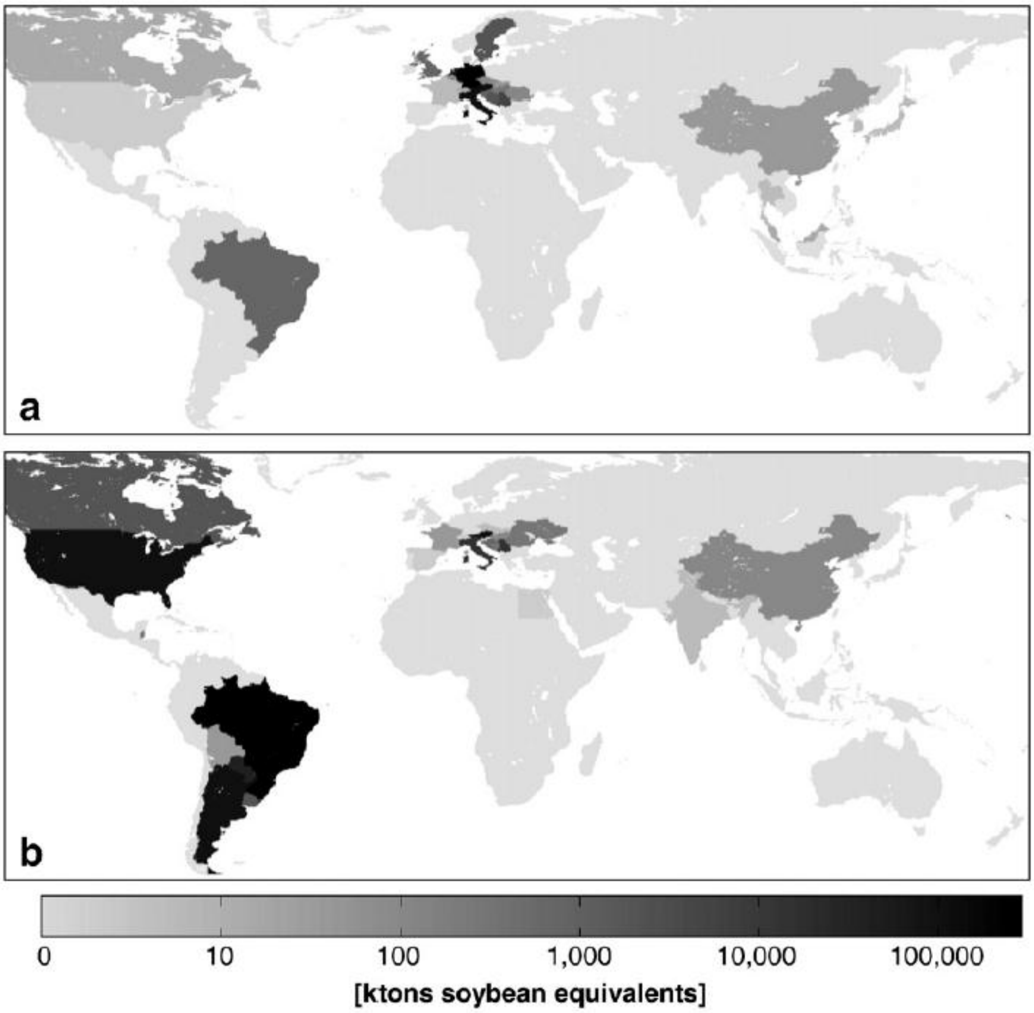
One approach taken in some land flow studies applying physical accounting was to assume the exporting country to be the producing country. This assumption is problematic: For instance, take country A importing large amounts of a good from country B, which country B does not produce or only in very small quantities. The assumption that such a product originated from country B necessarily results in accounting errors. Clearly, country B must have imported the product (and its embedded land) from elsewhere. Some studies apply global average yields (and implied land intensity coefficients) when encountering the problem that the country of origin cannot be the producer of the respective crop (see e.g. Kissinger and Rees 2010). Yet, this may still cause poor estimation because yields of the world's largest exporters will usually exceed the global average.

A thorough approach is used in the LANDFLOW model, where the land intensity of commodity utilization items (various domestic use categories and exports) of a processed commodity is calculated from land embedded in the production of domestic raw materials as well as in the imported raw materials and the estimated processed commodity. This allows for estimating land and adjusting for re-exports by recalculating land in global trade flows in an iterative process until convergence is reached and a stable solution is found. This approach ensures that transit trade flows and production based on imported primary raw materials are accounted for and treated as such.

The German Statistical Office (StBA) manually adjusted trade data for re-exports for the most important crops and trade volumes by back-tracking flows to producing countries using COMTRADE data (Mayer et al. 2014). Re-exports in a wider sense, i.e. exports of processed products produced with imported raw materials (e.g. chocolate produced with imported cocoa), were considered by building specific supply accounts for exports (i.e. distinguishing exports from imports and from domestic production) under the assumption that imported raw products are not exported without processing, i.e. exported raw products originate from domestic production.

A study by Kastner et al. (2011b) proposes a mathematical approach using matrix algebra to track in physical terms the origin of a product. Using this technique, a major advantage of economic accounting can also be implemented in physical accounting approaches. The following figure shows a comparison of the origin of the soybeans contained in soy products consumed in Austria when using officially reported trade data for 2005 (part a of the figure below, based on FAOSTAT) without accounting for re-exports as compared to the results of calculation considering re-exports using the approach by Kastner et al. (part b of the figure below). Bilateral trade data list Germany, Italy and The Netherlands as principle countries of origin for soy products imported into Austria. Two of these trade partners, Germany and the Netherlands, do not grow soybeans on their own (at a relevant scale). The example illustrates that re-exports have to be addressed in a systematic manner with consistent calculation steps and transparent assumptions. When considering re-exports, the single largest source of soy products imported by Austria becomes Brazil, followed by Argentina and the United States. These are also the top three producers at the global level.

Origin of the soybeans in soy products consumed in Austria in 2005; according to (a) the reported bilateral trade links without considering re-exports; and (b) the result of the calculations by Kastner et al. (2011b) considering re-exports.



Source: Kastner et al. (2011b)

Figure 46: (a) the reported bilateral trade links without considering re-exports; and (b) the result of the calculations considering re-exports

Recommendation: Account for re-exports of primary and processed commodities. Tracking the origin of raw materials for processed commodities is required for calculating meaningful (and fully consistent) product land intensities.

Consumer demand and final utilization

The aim of land flow accounting is to attribute all observed land uses to various categories of consumption. In input-output analysis, used in economic accounting, final demand is used as a proxy variable for consumption. This assumes that the paying agent (country or industry) equals the consuming agent (country or industry). However, in some cases this assumption does not hold true. For instance, food aid that is provided to another country is not represented in trade statistics[229]. Another example is caterings and company-subsidised canteens, where the eventual consumer is not the payer and land embedded in

[229] However, according to Kastner et al. (2014) food aid shipments only account for 0.7% of the total global production for export (on average between 2007 and 2009).

canteen food will be incorrectly attributed to the company's customers, which may be a firm or a household in a third country.

Physical accounting approaches face yet another problem, namely that supply chains may end in the utilization item 'Other Utilization[230]' of the Supply Utilization Accounts (SUAs) explained in chapter 2.4.2. Further processing steps, trade of these processed goods and their end uses cannot be tracked because of limitations in the tracking depths of the respective data system. In this case the embedded land is attributed to the country where the last recorded use occurred, which may differ from the actual consuming country when such processed goods are traded.

The table below indicates for 2007 that the attribution of cropland to final utilization, assuming no further trade of commodity flows to 'Other Utilization', as done in the LANDFLOW model, is fairly robust for five out of eight crop groups, namely cereals, roots and pulses, fruits/vegetables/nuts, stimulants and fodder crops. For these commodities the share of embodied cropland attributed to 'Other Utilization' is relatively low (below 6%). Also only 10% of ruminant livestock products are associated with 'Other Utilization' (e.g. leather).

Land in global production, trade and 'Other Utilization' of crops in 2007

Table 83: Attribution of cropland to final utilization

	Embodied cropland in global production (Mha)	Embodied cropland associated with international trade (%)	Embodied cropland associated with 'Other Utilization' (%)
Cereals	749.0	15.0	2.6
Roots and pulses	128.7	6.9	2.8
Sugar crops	29.7	26.2	11.3
Oil crops	243.0	39.8	11.8
Fruit, nuts, vegetables	121.4	10.5	0.8
Stimulants	23.0	61.7	5.3
Non-food fibre crops	42.4	43.2	100.0
Fodder crops	190.0	0.0	0.0
All crops	1527.2	17.8	6.6

Source: LANDFLOW calculations based on FAOSTAT 2011

This limitation is most relevant for the group of non-food fibre and rubber products, where all raw materials are processed into industrial goods. In this case physical accounting of cropland based on agricultural Supply Utilization Accounts tracks the trade of raw materials (45% of land in total fibre and rubber production) to the destination of industrial use but cannot track the trade and final use of these industrial products (e.g. when Germany imports rubber for tire production the land consequently embodied in the rubber tires is not accounted for when these tires are traded). Note, however, that non-food fibre and rubber products are associated with only 3% of total global cropland.

LANDFLOW calculations show that globally an estimated 30 Mha or about 12% of the total cropland attributed to the production of oil crops concerns the use in non-food/non-feed industrial products (e.g. soaps, cosmetics, biofuel, etc.). For comparison, cropland in oil crops attributed to feed use in 2007 is about 80 Mha, i.e. roughly threefold. Finally for sugar crops (total global cropland in sugar crops in 2007 was about 30 Mha), the share of land attributed to 'Other Utilization' was 11.3%.

[230] This utilization category refers to quantities of commodities used for non-food purposes, e.g. oil for soap.

Although a large share of the products dedicated to 'Other Utilization' is consumed in the region/country of industrial processing, trade of processed industrial goods should be accounted for and the data system boundaries of FAOSTAT result in some uncertainty of the attributed cropland to final uses especially for the product groups of plant-based fibres, natural rubber and oil crops.

The uncertainty (due to data system limitations for tracking highly processed industrial commodities) of attributing land embodied in crop products using the SUA-based physical accounting approach, applied for example by the LANDFLOW model, is estimated to be less than 7% of global cropland. This estimate would materialize to the full extent only if all industrial products with embodied cropland were traded and consumed outside the country/region of industrial production.

Hybrid accounting approaches as recommended in this report could extend the tracking analysis using monetary information for situations where the "Other Utilization" item is subject to further trade and processing before final consumption.

Recommendation: Use a hybrid accounting approach tracking physical flows to final consumption as far as possible and extend supply chains for processing industries using monetary IO tables, where SUAs are cut-off at industrial uses (recorded as 'Other Utilization' in FAOSTAT).

Detail of reporting

The level of commodity detail reported for land embedded in consumer demand and utilization depends on the type of data used for tracking embedded land along the supply chain. The FAOSTAT databases allow physical accounting of flows and a disaggregation of supply and utilization according to food, feed, export, seed/waste and other (non-food) utilization. Economic accounting is limited in detail, though it allows tracking flows through all sectors of an economy and allocating it to different final demand categories (e.g. household consumption, government consumption, capital fixation, stock changes, and exports).

Recommendation: Depending on the purpose of the analysis, economic accounting is more appropriate if information on the land footprint is required distinguishing different final demand categories. Physical accounting, on the contrary, is able to distinguish different categories of designated end use such as food, feed, and non-food uses.

Annex 6.6: Descriptions of the reviewed resource flow accounting approaches and studies

In this section, we provide descriptive evaluation summaries for all reviewed accounting approaches and related literature.

Studies based on economic accounting

In recent years, a number of Land Footprint studies have been published, which are based on economic accounting, most of them applying multi-regional input-output (MRIO) analysis. Currently only few datasets for the construction of global multi-regional input-output models are available, namely GTAP, WIOD, OECD, EXIOBASE and EORA. As the properties, advantages and limitations of these models are tightly related to the applied data base, the following evaluation is structured along these global input-output data sets.

In MRIO databases in general it is not (yet) possible to disaggregate the various primary uses of crops produced on certain land areas (e.g. food, feed, bio-energy, etc.), as input-output sectors and product groups do not disaggregate the various use types. For example, in the GTAP database, there is only one product group covering all “oil seeds”, independently whether they are used as animal feed, for energy production or for material uses, e.g. in the chemical industry.

In contrast to physical accounting approaches (see below), all MRIO-based methods possibly allow identifying the industry or product group, which is the last stage in the supply chain before delivering a product to final demand. The full structure of inter-industry deliveries is illustrated in the IO tables, thus the supply chains can be analysed using additional analytical methods (tools such as Structural Path Analysis allow quantitative assessments of the supply-chain structures). All existing MRIO databases allow separate calculations of the land footprints of private household consumption as well as for government consumption, investments, inventory changes and exports as well as imports.

Compatibility with the system of national accounts is generally high across all MRIO approaches, as the establishment of input-output tables is closely connected with the set-up of national economic accounts and by definition takes a sector perspective, which is also the basis of e.g. the NAMEA system.

The land modules of MRIO based calculations are simple. In most cases, land use data on the level of single crops is retrieved from the FAO database and then aggregated to the sector classification of the respective MRIO database. For this first step, it is important to note that only in a minority of cases (for example, Bruckner et al. 2012a; Prieler et al. 2013), an approach for correcting crop production statistics for multi-cropping as well as for adjusting FAO pasture area data with data on the actual amounts of grazed biomass has been implemented, while most studies applied the original FAO data without further corrections.

After aggregation of the land use data to the available sector detail of the MRIO database, the sum of the land areas for all products produced in a sector is divided by the monetary production value of that sector in each country, in order to calculate the land intensity of production in each sector. The unit used is hectares per monetary unit (EUR or $). The vector of land intensity per sector then enters the further calculation steps of environmentally-extended input-output analysis (see Miller and Blair 2009).

Global Trade Analysis Project (GTAP)

The Global Trade Analysis Project (GTAP) database is the MRIO database most widely applied for land-related assessments so far (Wilting and Vringer 2009; Vringer et al. 2010; Lugschitz et al. 2011; Bruckner et al. 2012a; Ewing et al. 2012; Karstensen et al. 2013; Weinzettel et al. 2013; Yu et al. 2013). GTAP is an economic database of harmonized input-output tables and bilateral trade data established and maintained at Purdue University, Indiana, USA[231]. The latest version 8 of GTAP disaggregates 129 countries / world regions and thus represents a very high geographical coverage. GTAP8 contains information for 57 product groups, of which 8 refer to primary crop production and one to timber production. This disaggregation level also determines the extent to which land use data linked to agricultural and forestry activities can be disaggregated. In addition to these primary production sectors, a number of food production and processing sectors are being distinguished, including various types of meat and animal products.

GTAP data exist for various points in time, the latest data referring to the year 2007, and is updated every 3 to 4 years.

Regarding transparency, GTAP has some clear deficits, as the data manipulation procedures necessary to transform original IO tables into the standardized GTAP format are not well documented. In many cases, the quality of the underlying IO data cannot be properly evaluated. National tables are collected from uncountable sources and provided by experts from all over the world. Data quality varies and cannot be assured. Furthermore, type and structure of the underlying national tables are not consistent (e.g. following different industry or commodity classifications and applying different technology or sales assumptions). It is furthermore not clear how the relatively high sectoral detail for agricultural activities is obtained. Since the data and assumptions used for disaggregating the agriculture sector from the original input-output data are crucial for the calculation of land footprints, this lack of knowledge leaves uncertainties regarding the robustness of land footprint results generated with the GTAP database.

Land use data for GTAP-based land footprint assessments were almost exclusively taken from FAO. The land use data on the level of single crops is first aggregated to the 13 agriculture and forestry sectors in GTAP and then linked to the monetary tables in each country.

World Input-Output Database (WIOD)

The second MRIO database, which has been explicitly applied to calculate land footprints of EU-27 countries (see Arto et al. 2012) is the World Input-Output Database (WIOD)[232]. In comparison to GTAP, WIOD disaggregates a smaller number of countries (40 countries plus Rest of the World), with only a few important agricultural production countries outside the OECD being covered (e.g. Brazil, Indonesia). Compared to GTAP, WIOD also has a lower resolution regarding sectors and product groups (35 industries, 59 products).

With regard to Land Footprints, a particularly weak point is the limit to only one sector, containing all agricultural and forestry production, and two product groups (agricultural products and forestry products) in the product perspective. This also puts a severe constraint to the number of land categories, which can be distinguished in the assessments. In the study for the EU-27, four types of land areas were separately analysed (temporary crops, permanent crops, permanent pastures, and forestry). However, as only one agricultural sector is distinguished in the WIOD database, an identical economic structure has to be applied to allocate e.g. temporary crops and permanent crops. As a result, the same percentage share of temporary versus permanent crops ends up in the different categories of final demand.

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[231] See https://www.gtap.agecon.purdue.edu/databases/v8.

[232] For a description of the WIOD see (Dietzenbacher et al. 2013).

Differences to other MRIO data bases can particularly be observed for the availability of time series with WIOD data being available for each year between 1995 and 2010. Also the transparency and quality of the underlying data is higher for WIOD compared to GTAP, as official national IO tables were the starting point of the data harmonisation procedures.

In the land footprint study (Arto et al., 2012), arable land and pasture data was sourced from FAOSTAT, forest areas used for production purposes from the FAO Forest Resource Assessment.

OECD input-output database

Another potential source for MRIO-based Land Footprint assessments is the OECD input-output database (OECD 2009). This database has not yet been explicitly applied to the case of land, but has been used for the calculation of Carbon and Material Footprints (Nakano et al. 2009; Wiebe et al. 2012; Bruckner et al. 2012b). The OECD database is very close to the officially published IO tables, with a transparent documentation of the required steps taken to transform the IO tables into a harmonised format. Therefore, the OECD database is characterised by high transparency and good data quality. Regarding the sector breakdown, OECD is comparable to WIOD, with only one aggregated agriculture/forestry/fishing sector, which significantly limits the potential use of this database for the case of Land Footprints. OECD MRIO data are so far only available for only three years: 1995, 2000 and 2005.

EXIOBASE

The EXIOBASE system was developed in various European research projects and particularly designed for environment-related applications (Tukker et al. 2013). Therefore, in EXIOBASE, national IO tables were further disaggregated in order to provide a higher industry/product detail in environmentally sensitive sectors, including agriculture and food industries. It was applied to the calculation of the carbon, water, land and material footprint (Tukker et al. 2014). The EXIOBASE has a total of 169 industrial sectors and almost 200 product groups. In the agricultural area, EXIOBASE is oriented towards the GTAP classification with eight primary crop production sectors plus one sector for timber production. EXIOBASE distinguishes a similar number of products and thus land use categories as GTAP. EXIOBASE data are so far only available for two years, 2000 and 2007, but time series (1995-2011) are currently being built in the ongoing FP7 project "DESIRE"[233]. The transparency of data manipulation procedures required to disaggregate standard IO tables to the EXIOBASE classification is not satisfying, but currently being improved. Additionally, a larger number of auxiliary data is being used, which cannot always be judged regarding the data quality.

EORA

Another available option for MRIO-based Land Footprint assessments is the EORA MRIO system (Lenzen et al. 2013). EORA has not been directly used for the calculations of Land Footprints so far, but studies exist for the issues of drivers for biodiversity (Lenzen et al. 2012) and Material Footprint of nations (Wiedmann et al. 2013). With 187 countries and country groups, EORA provides the highest spatial resolution of all MRIO systems presented so far. The number of sectors and product groups disaggregated in EORA differs from country to country, depending on the officially available data. This also determines the number and type of land use data that can be attached to an EORA-based land model. In case no official IO table is available, a mathematical optimisation algorithm creates IO tables with 26 industries from national accounts and other economic production data. This algorithm is applied for 69 of the 187 countries disaggregated in EORA and concern mainly developing countries. According to the authors, several routines are applied, which shall assure quality and consistency of the resulting IO tables (Lenzen et al. 2013). EORA so far delivers a time series of IO tables from 1990 to 2011.

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[233] See www.fp7.desire.eu

Studies based on physical accounting

The following evaluation is clustered along the organisations the researchers were affiliated to at the time their work was published. Where researchers from more than one organisation have been contributing, we considered only the affiliation of the first author. In one case, we group more than one organisation together, as the first author changed his affiliation and published together with researchers from other organisations.

University of Groningen (RUG)

The first consumption-based calculations of the land requirements of a country were done by Gerbens-Leenes et al. (2002) with a predecessor study published in Dutch language (Gerbens-Leenes 1999). Gerbens-Leenes et al. calculated land intensity coefficients in m^2 year kg-1 for different food items. The study covers animal and crop products and is based mostly on data from Statistics Netherlands (CBS) and FAO. The researchers first examine the land requirements per kg crop as a weighted average of Dutch crop production and imports. Then, information on the amounts of basic agricultural commodities needed for the manufacturing of food items were used to compute land intensity coefficients for food items. These coefficients are then multiplied with the amounts of food consumed by an average Dutch household. Food consumption per food item was derived from the CBS expenditure survey and data on food prices. A shortcoming of this approach is that it does not take into account consumption outside the house, e.g. at work or in bars and restaurants.

IIASA (LANDFLOW model)

The LANDFLOW model, developed by the International Institute for Applied Systems Analysis (IIASA), so far is the only existing model for assessing land embodied in international trade and national consumption, which realises a purely physical accounting approach on the global level (IIASA et al. 2006; Prieler et al. 2013). LANDFLOW uses the large harmonized time series country data from different domains of the FAOSTAT agriculture and forestry databases (FAOSTAT 2014). They include i) land use data; ii) primary crop production (harvested area, production, yields); iii) livestock production (animal stock numbers, off-take, carcass weight); iv) commodity supply and utilization accounts (SUA) of primary and derived products; vii) production of raw timber materials and wood-based products; vi) bilateral commodity trade data in physical units and dollar values.

LANDFLOW first attributes physical land areas separately for cropland, pastures and forest land to primary commodities. Land intensities (ha/ton of produce) are deter-mined by reporting biomass production for crops and supplemented by modelled biomass productivity from the Global Agro-Ecological Zones (GAEZ) database (IIASA/FAO, 2012) for grassland and forest land where data is missing. Cropland attribution accounts for multi-cropping and fallow periods. Second, FAO's supply utilization accounts (SUA) for agricultural products and wood balances for the forestry sector are connected with harmonized trade matrices to track physical quantities and embodied land areas from primary production via intermediate products (notably animal feed), joint products (e.g. livestock producing milk, meat and hides; soybean producing soy oil and soy cake) and cross-country trade to final (apparent) utilization.

LANDFLOW generates consistent trade matrixes for all SUA commodities using the FAO bilateral trade statistic data reported in physical quantities (tons). For the purpose of reconciling imports and exports to achieve consistency across all partner pairs LANDFLOW uses the larger of each pair of reported trade volumes.

LANDFLOW calculates and adjusts for re-exports by solving for all reported agricultural and forestry commodities a system of linear equations that determines by an iterative process the land content of traded products.

The LANDFLOW livestock module treats ruminants (e.g. cattle, sheep) separately from other livestock (mainly pigs and poultry) according to their feed requirements and associated land utilization. Feed requirements together with feed use of different sources form the basis for attributing cropland use and pastures to the two animal groups. Feed sources are allocated to livestock categories in proportion to energy requirements of the respective livestock herds and according to suitability of feed sources for use in animal diets, i.e. while respecting dietary characteristics of animal types and the total amounts of recorded feed types, the feed energy balance of each animal type is satisfied as closely as possible.

The LANDFLOW model shows a particularly high product detail, especially of food products, as over 100 primary and processed crop commodities (using land use data from some 190 primary crops), and 27 livestock products are distinguished and tracked in the model.

As harvested areas are available for each primary product and country, the level of detail with regard to agricultural land data is very high. In addition, multi-cropping and fallow periods are accounted for in a way that land attributed to primary crop production matches the FAO country statistics of crop land (i.e. arable land and land under permanent crops). Almost all other reviewed land footprint studies fail to account for these agricultural management practices, which differ across countries.

Land attribution in LANDFLOW consistently deals with joint products such as vegetable oil and cake from oil crops, sugar and molasses from sugar crops as well as several joint animal products (e.g. meat, milk, offals, fats and hides from cattle; meat & eggs from poultry).

Coverage of supply chain depth is somewhat limited for some product groups (e.g. fibres, rubber, non-food use of vegetable oils) due to the domain boundaries of the FAOSTAT databases, where trade of highly processed agricultural and forestry goods and hence ultimate final uses of such highly processed commodities cannot be tracked within the LANDFLOW system. LANDFLOW tracks flows of raw materials to non-food industrial uses (as reported in FAO's utilization category 'Other uses') but cannot track the trade of highly processed industrial commodities coming from these industries. For instance, once animal fats enter the industrial sector to produce cosmetics, or tanned leather from skins and hides are turned into leatherwear or shoes, the trade of cosmetics or respectively shoes is not recorded in the FAOSTAT data. Other examples of trade that cannot be tracked on the basis of FAO data include biofuels produced from vegetable oils, clothes produced from fibres (cotton), or furniture made from wood.

LANDFLOW operates on an annual basis and FAOSTAT reports data with a one to three year time lag. LANDFLOW calculations are on a detailed commodity level. For reporting, commodities are summed up and commonly presented in terms of the following main commodity aggregates: First, *crop products* from cropland include eight sub-categories: 1) Cereals; 2) Roots & tubers; 3) Sugar crops; 4) Oil crops; 5) Fruits/Veg/Spice; 6) Stimulants; 7) Industrial crops; 8) Fodder crops. Second, two sub-categories of *livestock products*: i) Ruminants (e.g. cattle, sheep) using cropland and pastures, ii) other livestock (mainly pigs and poultry) relying on cropland for feed only. Third, *forestry products* from forest land include three sub-categories: 1) Wood products (sawnwood and panels); 2) Pulp and Paper; 3) Wood fuel.

LANDFLOW differentiates between the utilization categories food use, separate for vegetarian and livestock diets, 'other use' (mainly industrial), exports and equivalents for seeds and wastes (from field to farm gate). The LANDFLOW model provides clear and comprehensive descriptions of the model structure and the underlying assumptions.

German Federal Bureau of Statistics (StBA)

StBA developed a methodology to calculate Germany's land footprint in the time frame of 2000 to 2010 (Statistisches Bundesamt 2013a; Mayer et al. 2014). The methodology is oriented at the approach developed for the German water footprint (Statistisches Bundesamt 2012; Flachmann et al. 2012). It specifies Germany and its 48 main trading partners plus one rest of the world region. The approach calculates land footprints for cropland and grassland for overall agricultural production including the livestock sector, i.e. 160 crops plus 8 categories of live animals, plus processing activities for 14 2-digit product groups from trade statistics. Calculations were undertaken for the time period of 2000 to 2010, base data would be available for an update with a time lag of 2 years (t-2). A number of technical reports clearly describe the applied methodology in high detail.

The StBA methodology is the only methodology among all reviewed approaches, which is fully compatible both with the German agricultural statistics, as trade data were adapted to be consistent with the special trade system. Another distinct feature of this methodology is that it allows disaggregating the results by main areas of use, i.e. 14 commodities made of crop products and 4 categories of animal products (meat, sausage products, dairy products separate for drinking milk, butter and cheese, and eggs).

Land use data for the StBA model were sourced from agricultural statistics for Germany and from FAO crop production statistics for imports. Land use for joint crop products was allocated according to the prices of the joint products following the principle of economic allocation. A detailed livestock module traces flows of feed from market-crops and grazing through the livestock system to the consumers. Requirements of cropland for feed and fodder production were calculated summing up inland production and feed imports as reported in foreign trade statistics. Significant efforts were made to allow allocating total feed supply to eight animal types, using information on the feed intake per animal and year, calculated based on livestock data and adjusted for the average lifetime of animals. Imported animal products were multiplied with land use coefficients derived for Germany, except for beef, where information from a WWF study was used.

Processed or manufactured products were converted back to their raw material equivalents using conversion factors from the FAO report on Technical Conversion Factors for Agricultural Commodities (FAO 2003). The approach on average reaches 70% product coverage. Due to the complexity of supply chains, only 70% of processed food products could be considered. This was complemented with additional estimates, hence attaining 92% product coverage.

Trade data are adjusted for re-exports for the most important crops and trade volumes by back-tracking flows to producing countries using COMTRADE data (manually implemented iterative procedure similar to LANDFLOW). This approach is probably still overestimating imports from European countries. However, it is an important correction to the raw data. Countries of origin were identified for 75.8% of the overall land requirements of imported products.

Re-exports in a wider sense, i.e. exports of processed products produced with imported raw materials (e.g. chocolate produced with imported cocoa), were considered building specific supply accounts for exports (i.e. distinguishing exports from imports and from domestic production) under the assumption that imported raw products are not exported without processing, i.e. exported raw products originate from domestic production.

Institute of Social Ecology (Erb 2004)

One of the very first coefficient approaches applied to the case of land footprints was presented by Erb (2004) at the Alpen-Adria University's Institute of Social Ecology (SEC). He developed a model for one country (Austria) to quantify the actual demand for domestic and foreign land for a very long time period (1926 to 2000). The model disaggregates 207 trading partners of Austria and a total of 61 agricultural products, of which 39 are primary products and 22 processed products. Erb distinguishes between a large number of land use categories, including pasture area, arable land area including permanent crops, forest area, as well as built-up area and energy land, the latter calculated as the corresponding CO2 equivalents of energy use multiplied with the average global sink-capacity of forests for carbon. The model is particularly strong with regard to the transparency of the methodology as well as the quality of the data sources, as official Austrian statistical data was combined with FAO and UN statistics.

Land area data were sourced from the FAO database for agricultural production, however without corrections for multi-cropping. Another, however, not specified, source was used for grassland data. For forest areas, two approaches were applied: 1) a production approach (using actual felling rates) based on FAO and UN statistics and 2) a sustainable yield approach, which calculated the hypothetical area needed according to the net annual increment of forests in the country of origin.

How processed products were transformed into primary equivalents is not specified, but presumably FAO conversion factors were applied. Also it was not documented in detail, how animal products were modelled. Re-exports were not considered on the import side, for exports, a weighted mix of domestic production and imports was calculated.

University of Groningen – Institute of Social Ecology – Chinese Academy of Sciences (Kastner et al.)

Kastner and colleagues set up global models to trace embodied agricultural land (Kastner et al. 2011b; Qiang et al. 2013b; Kastner et al. 2014) as well as embodied forest land (Kastner et al. 2011a). This work is based on earlier work done at the University of Groningen (Gerbens-Leenes et al. 2002; Gerbens-Leenes and Nonhebel 2005) and integrates experiences gained earlier at the Institute of Social Ecology. The main novelty of the model developed by Kastner et al., which are well documented and described in the publications, is that they set up detailed bilateral trade matrices for various products and apply matrix algebra (similar to the use of a Leontief inverse matrix in input-output analysis, see above) in order to model international supply chains and thus trace direct and indirect linkages between producing and consuming countries. This approach is particularly designed to allow for a consistent accounting of re-exported agricultural and forestry products, both processed and raw.

FAO also serves as the main data provider for this approach, which uses production and trade statistics, Food Balance Sheets as well as Technical Conversion Factors from FAO. Also land data stem from FAO, but are not corrected for multi-cropping. For the forestry-related study, data was taken from the FAO Forest Resource Assessment.

The model disaggregates 172 countries and covers all primary agricultural products along with a number of processed products, however, the latter not being specified in detail. Processed products are transformed into equivalents of primary products according to the energy content in the agricultural studies and the carbon content in the forestry-related study. This approach is also used for the allocation of coupled products. Animal products are not considered in these models but are accounted for via national level feed balances in a more recent and yet unpublished work.

The approach has first been applied to a case study on Austrian soy consumption (Kastner et al. 2011b) and then been used to investigate embodied land related to China’s crop trade (Qiang et al. 2013b). Lately, it was also extended to all 255 countries covered in the FAO database (Kastner et al. 2014). Time series calculations for the Austrian soy case have been presented for 1986-2005, and for Chinese external trade for 1986-2009, and for all countries globally for 1986-2009. The calculations depend on FAO statistics on the supply and utilization of crops and food commodities that are available for the period of 1986-2009 and are published with a time lag of 4 years.

As with most physical land footprint accounting methods, this approach does not allow distinguishing the main areas of final use of a certain product, nor can the industry be specified, which delivered a certain product to the final user.

Swiss Federal Institute of Technology (ETH)

A model to assess embodied land of Switzerland’s international trade relations was established by Würtenberger and colleagues (2006). The study investigated the virtual land trade related to arable crops for Switzerland and its 125 main trading partners. The analysis was undertaken for the year 2001, but can also be applied to more recent years. With all products being aggregated into 8 product groups, the aggregation level of this model is relatively high compared to other coefficient-based approaches. The model also includes processed products, which were converted to primary product equivalents with the help of “transfer coefficients”. However, the source and quality of these coefficients cannot be judged, as no further information is provided by the authors. Animal products were defined out of scope in this study. Also coupled production was not specifically treated.

Land use data were taken from the FAO database without adjusting for multi-cropping. Trade data were obtained from Swiss national sources. Re-exports have not received consideration in this methodology.

Potsdam Institute for Climate Impact Research (PIK)

Applying the hydrology and agro-biosphere model LPJmL, a research group from PIK (Fader et al. 2011; Fader et al. 2013) primarily investigated the blue and green virtual water as well as virtual land trade of all countries world-wide, for 11 crops of global importance (temperate cereals, maize, rice, tropical cereals, temperate roots, tropical roots, rapeseed, groundnuts, soybeans, pulses, and sunflower). Additionally, they also calculate the land savings through international trade. Compared with other studies using physical accounting, this model only treats a very small number of primary crops and completely disregards higher processed products.

Using a grid classification (of 0.5° resolution) instead of a country approach, this approach stands out regarding the geographical detail from all other reviewed land footprint models. The authors apply yield data from the LPJmL model instead of FAO data used for most other methods. UN Comtrade is the main source for trade data, , which are a kind of bottleneck for the grid cell-based analysis, as they are only available on the national level. Re-exports of agricultural crops are not considered. Calculations were so far only undertaken for the average of the period 1998-2002.

Humboldt University Berlin (HU)

Trade of "virtual land" of the EU with the rest of the world was the focus for the analysis undertaken by von Witzke and Noleppa (2010). The authors aimed to assess how much agricultural land outside Europe was required to satisfy European consumption and how international trade of virtual land would change under alternative policy and technology assumptions. Calculations were done for the year 2007/08, but base data would be available to update the approach for more recent years.

The study considered a large number of products, i.e. 40 primary crops and 240 processed plant- and animal-based products, accounting for roughly 80% of the overall EU external trade with agricultural products. Main agricultural data sources used to set up the model include the Eurostat Agricultural Statistics, the FAPRI US and World Agricultural Outlook database and FAOSTAT. Corrections for multi-cropping are not applied. Regarding international trade, the authors use the Eurostat External Trade data set and do not consider re-exports.

Processed products were converted into agricultural raw products using a broad spectrum of processing parameters. Various weights, measures and conversion factors, based on e.g. FAO and U.S. Department of Agriculture (USDA) publications, were updated using additional sources. Meat and dairy products were converted into crops using feed ratios and feed mix percentages. Approaches on dealing with coupled products and information on crushing factors were used to avoid double counting of land areas.

The main weakness of this approach is that based on the existing documentation, the study is non-reproducible, in particular as the applied land intensity coefficients stem from a large variety of sources, i.e. reports, statistics and other mostly not peer-reviewed publications. Not all of these sources are referred, a more detailed description of own assumptions or estimations is omitted. It is therefore impossible to evaluate the quality and consistency of the coefficients. Furthermore, consistency of the coefficients-based results with official land use statistics (bottom-up vs. top-down) is not cross-checked.

Wuppertal Institute for Climate, Energy, Environment (WI)

Two recent studies on land embodied in international trade were published by the Wuppertal Institute. One study assessed the global land area required to meet the German consumption of agricultural products for food and non-food use (in particular biofuels) for the years 2004 to 2006 and potential changes until 2030 under various scenario assumptions (Bringezu et al. 2009). A later study focused on the global land use related to European consumption in the year 2007 (Bringezu et al. 2012).

The Wuppertal model is characterised by a very high product detail, with calculations being done for a total of 773 commodities (primary crops, plant based products and animal based products according to the 6-digits HS classification) in the European study. A further positive characteristic of the approach as carried out for the German case is that primary areas of use of biomass products are represented in great detail, being separated into material use (pharmaceutical plants, dye plants, fibres, starch, sugar, plant oils and fats, lubricants and additives), energetic use (biodiesel, plant oils as direct fuel, bioethanol, BtL, biogas as fuel, plant oils for electricity/heat, biogas for electricity/heat), plant-based nutrition and animal-based nutrition.

Land use data were taken from the German Ministry for Agriculture and various other data sources for processed and traded products. Animal products are based on feedstuff and production statistics of the German Ministry for Agriculture, thus implicitly assuming all imports coming from intensively managed systems. This represents one main weakness of this approach, as no regional specificity is adopted, i.e. for many commodities German productivity levels are assumed. Eurostat is used as the main source for international trade data in physical units; re-exports are not considered for European imports; for exports a weighted mix of domestic production and exports is calculated.

Generally, also the Wuppertal approach is difficult to assess with regard to its quality and consistency with official land use statistics, as the applied land intensity coefficients are taken from a large number of sources, including reports and other not peer-reviewed publications.

University of British Columbia (UBC)

In their study on the US external trade, Kissinger and Rees (2010) investigate the ecosystem area embodied in US imports of renewable resources. This model disaggregates the US and its 59 major import partners and covers 169 primary and manufactured products, including animal products such as live cattle, beef and lamb products (but not fowl or pork). The products are aggregated into 10 product groups. Calculations were done for the period from 1995 to 2005 and could be updated based on the described data sources. The methodology is generally clearly described, but further explanations of the used coefficients (see below) are missing.

For land use data, this approach applies FAO and USDA data for croplands, FAO data for pastures and the Canadian National Forestry Database for data on annual growth rates of forests. The conversion of processed or manufactured products back to their raw/fresh material equivalent is done using information from USDA, FAO (Technical Conversion Factors Guide) and industry sources e.g. for sugar, coffee and juices. For pasture land, the authors relate FAO grassland statistics to meat production and derive pasture requirement coefficients. Coupled production is not addressed in this approach.

Trade data is sourced from US databases (USDC, USDA). The authors do address the issue of re-exports and when encountering the problem that the country of origin is not a producer of the respective crop (but a re-exporter), they apply global average yield values. Imports to the US that are re-exported to other countries are also separately identified and excluded from the US land footprint.

Land Footprint studies based on hybrid accounting

Acknowledging the limitations of economic and physical accounting approaches, several studies have tried to integrate elements of physical accounting into IO assessments of land footprints or vice versa.

RUG-PBL model

In order to assess the global land use and GHG emissions related to private consumption in the Netherlands, Vringer and colleagues (2010) and Benders et al. (2012) construct a hybrid IO model (RUG-PBL model). They build on experiences from previous hybrid energy models and apply this method to calculate the environmental load of Dutch consumption in terms of global warming potential, acidification, eutrophication, summer smog, and land use. In the model, the product life-cycles are split into two parts: major processes, i.e. those that have a significant impact on the overall results such as mining and energy sectors, are modelled using physical process analysis, while all remaining processes are modelled with a simplified, 4-region input-output model (Netherlands plus three other world regions) based on GTAP. Therefore, the processes of a product life cycle are partly described in physical terms and partly in financial terms. The basic goods, packaging materials, transport, direct consumption in the households, and waste processing are described in physical terms by means of process analysis. Capital and residual goods, manufacturing, and trade are described in economic terms by means of input-output analysis. Land use data are obtained from FAOSTAT. For all calculations, the assumption is made that imports are produced with the same technology and environmental load as in the Netherlands. An incomplete documentation of the method and a lack of specifications for the sources data impede a full evaluation.

EUREAPA model

The EUREAPA model has been developed and tested for the case of the Ecological, Water and Carbon Footprint ("Footprint Family") (Weinzettel et al. 2011; Ewing et al. 2012; Steen-Olsen et al. 2012; Weinzettel et al. 2013; Weinzettel et al. 2014)_ENREF_72. The authors state that in order to fully consider a higher product detail in the MRIO framework, the IO tables would need to be disaggregated and all bilateral trade relations would need to be adjusted accordingly. As this is a very laborious task, the authors suggest an alternative procedure with less effort: they create physical satellite accounts, which illustrate to which countries and sectors primary agricultural products are delivered in the first step. Using FAO data, the physical use structures of primary agricultural products can be modelled in a detail of single products. But instead of linking agricultural products (and their related land area) to the MRIO system at the point of primary production, the environmental data are allocated to the first recipient of this primary production, either in the domestic or a foreign economy. This allows keeping the full product detail, without changing the overall MRIO sector structure.

Therefore, this approach reaches a very high detail in the distinguished products and related land areas. The underlying MRIO system is based on the GTAP database, so the limitations of this database also apply to the EUREAPA model.

German Federal Bureau of Statistics – RME

The German Federal Bureau of Statistics (StBA) developed a detailed and comprehensive approach for calculating the imports, exports and material consumption for Germany in raw material equivalents (RME), including the indicators RMI and RMC. The StBA RME approach, unless developed for the calculation of material flows, could be extended by land use and serve as a basis for land flow accounts with only small efforts.

The methodology consists of three main elements (Destatis 2009):

- National input-output tables for Germany (73 x 73 sectors),
- The calculation of the RME of selected imports to Germany with the help of LCA-based coefficients,
- And the establishment of specific hybrid input-output tables, i.e. tables that include both monetary and physical units in the technology matrix (A matrix), for each considered raw material ("physical material flow tables").

The German approach thus addresses several shortcomings of other approaches. First, the use of detailed additional information on the physical flow of certain raw materials allows implementing a deeper level of disaggregation than the standard IO table would enable, which only separates 3 extractive industries and 8 extraction products. Through this additional modelling, a total of 39 abiotic and 16 biotic raw materials can be separately considered in the calculations. For each of the 55 raw materials, detailed supply-use accounts in physical units (i.e. tonnes) were established, in order to model the first stages of each production chain in detail (from extraction via processing to intermediate products). This is done for the first stages of production, because the potential errors originating from allocating several different materials to only one sector in the input-output model are much larger at the first stages of processing than at later stages of the production chain where various materials are incorporated in higher manufactured products and the allocation more closely follows the monetary flows. In order to create these physical supply-use accounts on the level of single materials, detailed German supply-use data (3000 products by 120 production activities) plus additional data (e.g. physical supply-use tables for wood products) are used, partly from non-published StBA-internal sources.

Second, the indirect material flows related to imports are generally calculated applying the modified German input-output tables and applying the Domestic Technology Assumption, i.e. assuming that imports from other countries were produced with the same input factors as applicable in Germany. In order to avoid mistakes for goods that are produced differently in Germany or not at all, an exemption to this general procedure is made for a number of raw materials, which are separately modelled applying LCA-based factors. The factors have been compiled from various literature sources and partly modelled with the LCA software "Umberto". A detailed technical report informing about the approach and results concerning the material intensity coefficients is available (Lansche et al. 2007).

For wheat, for example, Canadian yields and production system properties have been assumed for all imported quantities; Italian conditions for rice imports; Egypt was taken for potato imports. As crop yields differ greatly between countries, a robust land flow accounting method should consider the respective yields of the country of origin.

The results for the German hybrid model published so far (Destatis 2009) cover the time period from 2000 to 2005, however, longer time series could be calculated, as German supply-use tables are currently available for 1995-2010.

Eurostat – RME

In a series of projects, carried out by external consultants, Eurostat developed a methodology for assessing the indirect material flows related to European imports and exports and calculated the RMI and RMC indicators. The Eurostat RME approach, unless developed for the calculation of material flows, could be extended by land use and serve as a basis for land flow accounts with only small efforts.

Aggregate results for the EU-27 have been presented in a time series of 2000-2011. For the Eurostat methodology, a number of publications and detailed technical reports (Schoer et al. 2012a; Schoer et al.

2012b; Schoer et al. 2013) as well as a range of online material and data sets are available[234], making this methodology very transparent.

As for the StBA RME calculation approach, imports into the EU-27 are calculated using the "Domestic Technology Assumption". An exception are 62 selected products and product groups, mainly metal ores and energy carriers, for which specific material intensity coefficients of imports were calculated (here called "LCA products"). The main data source for these coefficients was the ecoinvent 2.0 database (see www.ecoinvent.org). However, as the authors state, ecoinvent is not very reliable regarding metal ores, therefore additional research was undertaken using data from USGS and mining reports to derive appropriate ore grades for metal imports into the EU-27. Although metal ore grades significantly differ between countries of origin, it was decided to apply global average ore grades, because huge variations in ore grades between years and countries were observed, with a potentially distorting effect on the overall results.

As with the StBA RME approach, the original aggregated IO table for the EU-27 was significantly modified, in order to adapt it to the requirements of assessing embodied material flows. While the StBA RME model keeps to original sector structure (73 x 73 sectors) and provides additional detail through implementing physical input-output structures on the level of single raw materials (see above), the Eurostat RME model disaggregates the whole input-output table. Starting from the original 60 x 60 products tables from Eurostat, the IO table was expanded to a 166 x 166 products table by using additional information, such as total output of more detailed product groups and detailed German supply and use structures, which are not publicly available. With this method, more than 50 product categories, 48 different material extraction sectors (15 biomass, 10 fossil fuels, 18 metal ores, 5 minerals), and ten categories of final demand can be specified.

In addition to detailing the sectors, in order to allow separating a larger number of single materials, a mixed-unit input-output table was created by replacing the monetary information for some sectors in the IO table with data in physical units. This was done, e.g., for biomass products, for sectors containing abiotic raw materials and basic metals as well as for energy carriers. The authors argue that for these products physical use structures are more appropriate for depicting the flows of materials through an economy compared to monetary structures. In reality, different users of a certain raw material or energy carrier, pay different prices for the same product (Schoer et al. 2012b) and thus monetary use structures are not simply a unit conversion from the underlying physical structure (see also Hubacek and Giljum 2003).

The Eurostat RME model can thus be regarded a very advanced approach, applying a highly detailed, mixed-unit input-output model, where a number of imported products are calculated with specific material coefficients. However, except for a range of metals and metal products, domestic technology assumption is used. Therefore, the method would need to be further developed for the calculation of robust land flow indicators.

[234] See http://epp.eurostat.ec.europa.eu/portal/page/portal/environmental_accounts/documents/.

Annex 6.7: Data availability for impact-oriented indicators

In this Annex, we describe the current status of data development underlying the various impact-oriented indicators in detail and list the most important currently available data sources as well as major on-going efforts to improve the data basis. We also elaborate on the geographical specification of the impact-oriented data, i.e. whether data are only available on the national level or on a more spatially explicit level (e.g. grid cell data). The level of geographical specification determines to what extent the impact-oriented data can be allocated to land used for the production of specific commodities and thus linked to specific supply chains, which is a requirement for calculating impact-oriented land footprint indicators. In the table underneath, we list the main sources of available datasets in relation to the current quality/useability in relation to EU consumption of biomass.

Deforestation

Data availability on worldwide deforestation is relatively good. FAO's Forest Resource Assessment (FRA) 2010 (FAO 2010) provides forest area changes, including net change in forest area, for the three periods of 1990 to 2000, 2000 to 2005 and 2005 to 2010 for all countries worldwide. This data was applied in the DG ENV study on embodied deforestation (VITO et al. 2013) as well as in other studies on the links between trade and deforestation (for example, Meyfroidt et al. 2010). In 2012, the FRA 2010 Remote Sensing Survey (RSS) (FAO and JRC 2012) was published, accompanying the main report and providing findings on forest land use and land-use change between 1990 and 2005 based on satellite imagery data. More detailed deforestation data on the sub-national level can also be obtained from national sources, such as the data set used by Karstensen et al. (2013) for their study on deforestation and related emissions in Brazil.

However, it must be emphasised that there are significant discrepancies between estimates on forest area (change) based on national forest inventories and country questionnaires (as applied in the FRA 2010) and results from satellite survey data (as applied in the RSS) (VITO et al. 2013; FAO and JRC 2012). Efforts therefore need to be put into improving the forest inventory data in particular in developing countries (most notably: Africa), in order to reduce uncertainties and differences in results.

Soil degradation

Soil degradation occurs in various ways, for example, through the loss of soil organic matter (SOM), wind and water erosion or salinization. A common and very robust measurement of soil quality is its organic matter content (Frischknecht et al., 2013). Because that content consists to more than half of carbon, the content of soil carbon is an appropriate proxy for such a measurement.

On a European scale, the mapping of soil quality is already advanced and geographically very detailed information is available[235]. On a global scale, the mapping is still under development. However, large-scale projects have produced representative data. For example, the International Soil Reference and Information Centre (ISRIC) has developed a global database on soil information covering recent decades. This is

[235] See information available at the JRC European Soil Portal (http://eusoils.jrc.ec.europa.eu).

currently the only comprehensive repository of global primary data on soil profiles (FAO, 2013). However, the more than 3500 soil profiles do not cover the entire world and algorithms have been developed to derive secondary datasets. Furthermore, a global consortium has been working on the creation of a global soil map since 2009, in collaboration with the European Joint Research Centre (JRC) and ISRIC. These efforts are further supported by the Global Soil Partnership (GSP).

Biodiversity loss

Biodiversity is a very complex issue and there is no single best approach or indicator to measure and monitor biodiversity. A variety of indicators exists of which each provides very specific information. For the target setting of the United Nations Convention on Biodiversity (UN CBD) for the year 2020 almost 100 indicators were proposed (Pereira et al., 2013). Many indicators face problems regarding, for example, missing geographical coverage, the fact that information applies only for a location and not to the associated region, that data is not monitored on a regular basis, or that standards for the collection of data are different. Furthermore, at the moment there is no global, harmonized system which monitors changes in biodiversity on a regular basis (Marquez et al., 2013; Pereira et al., 2013).

The Group on Earth Observations Biodiversity Observation Network (GEO BON, see www.earthobservations.org/geobon.shtml) has proposed a set of Essential Biodiversity Variables (EBVs) which form the minimum biodiversity aspects that should be used in order to study and monitor biodiversity change, based on their suitability across taxa and ecosystems, their temporal sensitivity and their feasibility.

In 2005, several European Institutions (among them EEA and DG Environment) launched the SEBI (Streamlining European Biodiversity Indicators) initiative which has elaborated a set of 26 indicators in order to monitor progress towards European and global biodiversity targets (EEA, 2013a).
The extent to which several of these biodiversity indicators correlate with the impacts from land use is different for each indicator. This would justify a selection of those which respond most directly to changes in land use. However, currently available SEBI data focus on European data and thus are not suitable to calculate global footprint-type indicators.

Other approaches apply the abundance of species as an indicator for biodiversity, which has the advantage of being available on a disaggregated level and can be easily quantified and therefore linked to land use. For example, Lenzen et al. (2012) used information from the International Union for Conservation of Nature Red List on threatened animal species.

The GLOBIO3 model uses the mean species abundance (MSA) as an indicator for biodiversity (Alkemade et al., 2009). The model has been developed to assess human impacts on biodiversity with the single driver in the model being land use.

Similarly, an approach based on life cycle assessment (LCA) by de Baan et al. (2012a) directly addresses land occupation impacts, quantified as a biodiversity damage potential (BDP), i.e. the biodiversity losses related to a broad selection of different plants and animals.

Global warming

Parties included in Annex I to the United Nations Framework Convention on Climate Change (UNFCCC) are required to report on emissions/removals of direct greenhouse gas (GHG) emissions from six accounting sectors, i.e. Land Use, Land Use Change and Forestry (LULUCF), Agriculture, Energy, Industrial processes, Solvents and Waste. LULUCF includes all human management of vegetation and soils – but it does not include emissions from, for example, livestock and biofuels which are part of Agriculture as well as non-CO2 emissions from agricultural soils. LULUCF accounting rules were set at the Durban Climate Change Conference 2011 and divide landscapes into the following categories: Forest management; Afforestation; Deforestation; Reforestation; Re-vegetation; Cropland and grazing land management; and, Wetland rewetting and drainage. LULUCF is linked with Agriculture, Forestry and Other Land Use (AFOLU), which is a term from the 2006 IPCC Guidelines (IPCC 2006) describing a category of activities that combines the two previously distinct sectors LULUCF and Agriculture. It must not be confused with the climate mitigation funding mechanism: Reducing Emissions from Deforestation and Forest Degradation (REDD), which applies to developing countries and aims at creating incentives for them to reduce emissions from forested lands and invest in low-carbon paths for development.

GHG emissions are calculated by the MS based on the extent of human activities in combination with coefficients that quantify the emissions or removals for a given activity (emission factors). This provides the basis of national GHG inventories. Reporting is required under UNFCCC and includes the compilation and availability of national data and statistics for information in the GHG inventory.

The emission factors provided by the IPCC involve a great amount of uncertainty. Higher and lower boundaries of emission factors are indicated by the IPCC good practice guidance. Particularly the wood and forest databases in developing countries are sources of large uncertainties. Sequestration is a function of the total forested area, but depends heavily on local circumstances such as forest types.

Besides IPCC, also FAOSTAT provides a global inventory of land use related GHG emissions and removals for the land use categories cropland, forest land, and grassland, collectively called emissions/removals from the Forestry and Other Land Use (FOLU) sector (FAOSTAT 2014). FOLU emissions consist of CO_2 (carbon dioxide), CH_4 (methane) and N_2O (nitrous oxide) associated with land management activities. Estimates are available by country, with global coverage and relative to the period 1990 to present, with annual updates. However, the procedure for estimating emissions differ from the UNFCCC procedures.

A study commissioned by the European Commission, DG CLIMA, recently calculated the AFOLU related carbon emissions embodied in the EU's consumption, i.e. the land related carbon footprint of the EU, based on the IPCC emission factors (BIO Intelligence Service et al. 2014).

Water scarcity

Within Europe, the EEA has been measuring human water use in relation to available water resources for many years, using the Water Exploitation Index (WEI) (EEA, 2009). So far, the WEI is applied mainly on the national level for European countries using Eurostat data on water availability and water abstraction. However, for analysing water scarcity as well as for designing effective water management options, the geographical unit of "watershed" – also known as water catchment area, river basin or river system – is most appropriate. This was already recognised in the Water Framework Directive (European Parliament and Council 2000). As a consequence, there are attempts ongoing to (1) calculate the WEI for the watershed level as well as (2) to make the indicator even more specific by taking into account not water abstraction as a whole but rather those quantities of water which are abstracted and not returned to the same watershed due to evaporation or incorporation into products.

While the WEI could also be applied for countries and watersheds outside the EU, on the global level, other indicators on water scarcity and water stress are just being developed. For example, Pfister and colleagues (2009) developed a "Water Stress Index (WSI)" by calculating the ratio of total annual freshwater withdrawals to hydrological availability in more than 10,000 watersheds on the planet, assuming that – in accordance to the WEI – moderate and severe water stress occur above a ratio of 20 and 40%, respectively. The WSI not only compares water use with water availability in general, but it takes a step further by translating the information on water scarcity (expressed by the WSI) into damage assessment according to the framework of the Eco-indicator-99 assessment methodology (Goedkoop and Spriensma 2001), identifying three areas of protection: human health, ecosystem quality and resources (Pfister et al. 2009).

Alternatively, the WEI and WSI indicators could be based on another well-known water scarcity measure, which is per capita renewable water availability, where threshold values of 500, 1000 and 1700 m3 per person and year are used to distinguish between different levels of water stress (Falkenmark and Widstrand, 1992; UN-Water, 2006; UN-Water, 2008). On this criterion, countries or regions are considered to be facing absolute water scarcity if renewable water resources are <500 m^3 per capita, chronic water shortage if renewable water resources are between 500 and 1000 m3 per capita, and regular water stress between 1000 and 1700 m3 per capita. This crude approach to measuring water scarcity was primarily based on estimates of the number of people that can reasonably live with a certain unit of water resources (Falkenmark, 1984). This indicator is widely used because it can be easily calculated for every country in the world and for every year, based on water resources data (FAO-AQUASTAT, 2012) and available population data (UN, 2009).

Water quality

Regarding water quality issues, especially two aspects are of key importance when evaluating the impacts of agricultural production on water: diffuse emissions of nitrogen (N) and phosphorous (P) into water bodies resulting in eutrophication, as well as pollution as a result of pesticide application (and further infiltration into groundwater).

The EEA holds a comprehensive data base on emissions to water (Waterbase, see http://www.eea.europa.eu/data-and-maps/data/waterbase-emissions-4) which comprises diffuse as well as point source emissions of nutrients as well as of hazardous substances, some of which are also included in pesticides. The assessment of balances of N and P is also well-established for the global level. Annual soil nutrient balances, i.e. inputs and outputs have been estimated on a detailed spatial resolution (5 by 5 arc minute grid cells) and disaggregated by crop type, for example in the context of the FP7 CREEA project (see www.creea.eu).

Furthermore, the UNEP GEMS/Water Programme provides a composite index of water quality by country (UNEP GEMS/Water, 2006; UNEP GEMS/Water, 2008). The method used is based on the 2010 Environmental Performance Index (http://epi.yale.edu).

Food availability

Food availability can be described through various indicators, such as average dietary supply adequacy, average value of food production or average protein supply (FAO, 2013). However, even though there is a significant correlation between undernourishment and the availability of food, those indicators do not adequately describe the resulting problem caused, i.e. famine and malnutrition. The quantity of a certain food uptake (e.g. calories from sugar) does not describe the quality of the diet.

Therefore, the Global Hunger Index (GHI) is considered a more appropriate indicator in this regard. Developed by the International Food Policy Research Institute (IFPRI, 2013), it reflects several dimensions of hunger (undernourishment, child underweight, child mortality) in one index. Data is available only on a national scale, for around 120 countries (in 2013) and for regular points of time since 1990. It is not reported annually.

Working conditions

Several sources are available for global data on child labour and forced labour. However, it is difficult to draw the causality between land use and the working situation of people in the associated country. Therefore it is desirable to have an indicator with a clear relation to land use.

One feasible option is to use a list of products which can be believed to be produced by child labour and forced labour, and to link those products to land use and specific supply chains. Such a list is provided by the US Bureau of International Labour Affairs (ILAB). It lists 342 products, differentiating by countries on a worldwide scale. The majority of goods are primary agricultural products (often cotton, sugarcane, coffee, cattle, rice, fish and cocoa) (ILAB, 2013).

Alternative approaches could use data on a national scale. UNICEF (2013) provides data on child labour for more than 100 out of nearly 200 countries in their statistical tables, illustrating the share of children aged 5-

14 engaged in labour. A system of surveys and data collection exists by the International Labour Organization (ILO), but data and results are not summarized for quantitative uses. ILO also provides data on forced labour, showing that agriculture is one the primary sectors where labour exploitation can be found. However, this data is only available by world regions.
One indicator with a good coverage (139 countries), but no clear link to land use, is the Global Rights Index by the International Trade Union Confederation, illustrating violations of worker's rights (with regards to international standards of labour rights) per year (ITUC, 2014).

Land conflicts

As access to land and food are often distributed very unequally and interests of land owners and land users do not necessarily consider the well-being of the local population, it should be measured how much land is taken away from the possibility to serve the local population for subsistence purposes.
Data on so-called land grabbing is available on a global scale, showing transnational acquisitions of land per country in total hectares. The LAND MATRIX database is regularly updated, contains more than 1200 entries on land grabs larger than 200 hectares since 2000. The entries in the database currently add up to about 57 million hectares worldwide (Land Matrix Global Observatory, 2014). The entries show the purpose of the investments, e.g. agriculture or forestry in most cases, and the investor country. The Land Matrix Global Observatory comprises well-established international research and development organizations, which attempts to regularly improve the process of data collection on land grabbing, also involving governments and investors.

Annex 6.8: Considerations with respect to target setting aiming at a reduction of global impacts related to EU land use

Targets and complementing policy options may support the implementation of sustainability criteria at supply chain level, of which the most important ones are listed in Table 84. The table summarises the main socio-economic impacts related to each (policy) option. If relevant, the cost aspects and ecological synergy effects with other impact areas are taken into account.

Positive impacts generally concern the increased awareness about scarce land resources, the related environmental and social impacts and the fairness aspect of resource use worldwide, the transition of a carbon and land intensive consumption pattern towards lower carbon food products (e.g. from meat to plant based protein), the support of waste reduction and cascading strategies, and the general resource efficiency improvements that are likely to be promoted by potential or indicative land targets. Furthermore, international supply chains may benefit from product labelling with environmental criteria to distinguish positive products and supply chains. For developing countries supplying the EU, targets or policy options are likely to support an increase in environmental standards and the necessary financial and governance support to help developing countries implementing these standards.

On the negative side, the most important potential negative impact for the EU relates to the likely restrictions related to the use of land for its bio-economy and other strategic policies that involve biomass and/or land. For the rest of the world, the general assumption that global demand is increasing will most likely counterbalance a potential adverse economic effect of a stabilising or reduced demand from the EU. Further potential negative impacts relate to the necessary costs to implement global tracking and tracing systems of biomass and land flows, of measuring and monitoring costs of environmental impacts (e.g. soil samples) and to the complex governance challenge to motivate government, NGO and private stakeholders to support efforts of measuring and monitoring environmental and social impacts related to biomass use worldwide. This motivation, both within and outside the EU, will be largely influenced by the possibilities to label and distinguish products and supply chains in international trade in the WTO context. The WTO challenge is further enhanced by the fact that environmental impacts largely occur in developing countries (related to land use changes and intensification of agriculture), which may interfere with WTO's development goals. In general, the WTO is reluctant to allow a plethora of environmental criteria and labels in international trade relations, urging the need of global governance to concentrate on key issues in relation to global sustainable land use and to provide a strong evidence base for the relation between (EU) consumption and its environmental or social impacts.

Table 84: Assessment of targets and policy options to support global responsible supply chains

(Policy) option	EU	Rest of the World	Other comments
1. Indicative target in relation to env/social impact-oriented indicators at consumption level, e.g. a reduction of embodied CO2 emissions	Impact-oriented indicator target only accepted if EU helps (developing) countries to meet criteria; Need to share in (global) costs of database development; Increase awareness domestic stakeholders and consumers; Reduced exports of products with high environmental impacts.	Development support in measuring and monitoring programs environmental criteria; Impact-oriented indicators may boost domestic knowledge development; Enhanced access of env./social responsible products to developed markets; Potential reduction in exports of certain (land intensive) products/ industries.	Relevance of env./social impact may differ with local context and not be accepted in WTO context; Target may only indirectly affect land use (no clear relation with EU land use) and may thus increase global land use; Impact-oriented target (esp. the embodied GHG emission footprint) may have strong synergy effects with other env. Impacts.
2. Mandatory tracking and tracing systems related to the consumption of end-products in the EU, or in supply chains;	Costs related to the development of tracking and tracing systems; Mandatory system requires a global tracking & tracing system and thus requires agreement external governments and other stakeholders (bureaucracy).	High costs may be barrier; Lack of clear benefit RoW.	High costs related to voluntary (supply chain) tracking & tracing systems may be considered a trade barrier.
3. Development of relevant impact-oriented databases (soil organic content, land degradation, water pollution etc.)	Costs related to the measuring and monitoring systems.	Costs related to the measuring and monitoring systems; Could benefit from improved land use and land management data and knowledge (e.g. less degraded land, higher yields).	A large number of initiatives and efforts exist, but building consistent global environmental databases is hindered by a lack of governance, financial sources and by unclear benefits in relation top-down approaches/benefits.
4. Mandatory labelling of the embodied env./social impact footprint of (food and non-food) products, e.g. a biodiversity (loss/gain) footprint at product level;	Mandatory labelling will only be possible with well-established tracking and tracing systems and cooperation of countries of origin.	Environmental impact in developing countries larger than in developed countries; may be perceived as a barrier to trade Probably not obligatory in countries where impact is not considered significant (considered an unnecessary barrier to trade).	Requires evidence of connection consumption-impact (in WTO context).
5. Increase share of imports of socially/ environmentally labelled products in the EU (target)	Need to support countries of origin to meet environmental criteria; Resistance domestic (EU) private sector; Likely to increase costs of imports (feed, food).	Will raise environmental standards in exporting countries.	Implemented at EU level; Sensitive in WTO context (but increasingly likely on basis of strong evidence base, e.g. in bioenergy).
6. Mandatory reporting on the monitoring and mitigation mechanisms to reduce global environmental and social impacts	Positive to support transparency; Positive to report on environmental 'profits'; Generally benefits larger, multinational companies.	Lack of reporting standards/ skills, disadvantageous SMEs and developing countries (also in agriculture).	Implemented at supply chain or company level (difficult to develop/maintain a standard).

Note: Impacts are differentiated for the EU and the rest of the world (RoW)

Table 85: Assessment of targets and policy options to support natural areas and ecosystem functioning worldwide.

(Policy) option	EU	Rest of the World	Other comments
1. Indicative target on embodied deforestation in imported products and goods	Likely to support intensification of land and forest area management; Likely to prevent further reduction or increase expansion of domestic cropland; Could halt domestic afforestation trend; Likely to increase domestic land related emissions and to reduce sequestration; Likely to support certified global supply chains.	Likely to support intensification of land and forest area management instead of agricultural area expansion; Limitation on development of agricultural areas (e.g. in areas with large available land areas such as Sub Saharan Africa and South America); Could support re- or afforestation; Protected forests support indigenous livelihoods; Safeguards fresh water supplies.	EU's total deforestation footprint should decrease; Positive synergy effects with biodiversity, water quality, land related emissions/global warming; Indicator measured at national and supply chain level (supply chains can certify to be deforestation free).
2. Mandatory tracking and tracing systems related to the consumption of wood products in the EU	Costs related to the development of tracking and tracing systems; Mandatory system requires a global tracking & tracing system and thus requires agreement & cooperation external governments and other stakeholders (governance).	Most wood consumption for domestic use (energy purposes); tracking & tracing would increase price	Current traceability of wood and embodied forest area flows intransparent, especially for fuel wood. Important in light of EU bioenergy policies; Costs for mandatory global tracking & tracing system may be high and considered a trade barrier.
3. Label products associated with embodied deforestation (e.g. 5 year average deforestation that can be allocated to certain products or supply chains);	Likely to impact certain crop or product categories, e.g. soy, maize, beef, palm oil; Could support a transformation towards land extensive (plant based) supply chains.	Labelling and sanctioning of deforestation affects certain crops in developing countries only; may be perceived as a non-tariff barrier to trade Will enhance development towards certified (deforestation free) global supply chains	Requires clear land cover and land use categories (e.g. distinction of pristine and production forests, lignocellulose crops etc.); Requires a standardised and globally committed and accepted principles of allocation of deforestation to crop categories and supply chains, including indirect effects.
4. Increase import tariffs on commodities that are associated with deforestation,	See 1 & 3	See 3 May be conflicting with developing goals developing countries; requires cooperation and solving issue of costs to maintain common pool resources/lost revenues.	Requires strong evidence of connection consumption-impact (better tracking and tracing systems, clear land cover and land use categories, widely accepted principles of allocation of deforestation to supply chains, including indirect effects).
5. Increase share of certified products (free from embodied deforestation) (target)	Positive approach: reward good practices; Requires active support (financial, managerial) to build responsible supply chains, public-private partnerships.	Will support an increase in environmental standards	Sensitive in WTO context (but increasingly likely on basis of strong evidence base, e.g. in bioenergy) Requires advanced tracking & tracing systems and accepted principles of allocation of deforestation to supply chains/products
6. Import products from countries with a certain (or	Lower operational and system costs (than using	No (direct) positive impact on environmental standards in	End-goal approach;

(Policy) option	EU	Rest of the World	Other comments
increasing) area protected (e.g. protected area/agricultural area indicator)	impact-oriented targets); Dependent on government and governance in countries of origin (less direct relation with EU consumption/land requirements).	agricultural production/supply chains; Protected forests support indigenous livelihoods; Safeguards fresh water supplies.	Relatively simple indicator; Safe operating space is not defined; Requires additional indicators supporting evidence regarding the quality of the protected area (e.g. biodiversity); No relation with end-consumption or supply chains (cause of pressure persists).

Note: Impacts are differentiated for the EU and the rest of the world (RoW).

Table 86: Assessment of targets and policy options to support a fair land and/or biomass use worldwide, for both the EU and the rest of the world (RoW)

(Policy) option	EU	RoW	Other comments
1. Indicative target: Global average weighted bio-productivity footprint to be reduced in the direction of global average	When level is above global average, a target will limit expansion opportunities for countries/supply chains/industries; Increasing awareness about fairness aspect of resource use; Likely to benefit public health in relation to overconsumption; Potential limitation of available land/biomass for EU strategies (e.g. bio-energy/ bio-economy).	Increased awareness fairness aspect resource use; Increased food/biomass availability, also for energy purposes; Potential reduction of food riots/hunger rates.	Target alone is suppressive, requires communication strategy; Target can be set at EU or at member state level; Positive synergy effects major global env. impacts; Biomass (carbon) target not necessarily a (positive) effect on land use (normalised land footprint may be preferred).
2. Support development and marketing of innovative, healthy products that embody below average (weighted) resources per kg output	Business development and employment (potential job losses traditional sectors).	Signals countries with below average biomass or land appropriation.	Requires tracking and tracing systems for (embodied) biomass and land flows; Weighted indicators are suitable to calculate and implement on a global scale
3. Development of mandatory food waste prevention practices and targets;	Will reduce demand for primary biomass and land resources; Will stimulate cascading activities.		
4. Higher end-user taxes on e.g. livestock products;	Effect on total meat/ animal protein consumption levels unclear (like with price increases of fossil fuels); May impact productivity of EU livestock production (and land).	Reduced demand for animal feed, especially soy and maize	

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