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LUISA Dynamic Land Functions Catalogue of Indicators – Release I

EU Reference Scenario 2013
LUISA Platform - Updated Configuration 2014

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LUISA Dynamic Land Functions Catalogue of Indicators – Release I

EU Reference Scenario 2013
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Abstract

The concept of 'dynamic land function' is a new notion for cross-sector integration and for the representation of complex system dynamics. A land function can be societal (e.g. provision of housing, leisure and recreation), economic (e.g. provision of production factors - employment, investments, energy – or provision of manufacturing products and services – food, fuels, consumer goods, etc.) or environmental (e.g. supply of ecosystem services). Land functions are temporally and spatially dynamic, and are constrained and driven by natural, socio-economic, and techno-economic processes.

Based on the concept of 'land function' and beyond a traditional land use model, the Land-Use based Integrated Sustainability Assessment (LUISA) modelling platform adopts a new approach towards activity-based modelling based upon the endogenous dynamic allocation of population, services and activities. The ultimate product of LUISA is a set of territorial indicators that can be grouped and combined according to the 'land function' of interest and/or to the sector under assessment.

The herein presented indicators measure the provision of land functions in the period 2010-2050, according to the EU Reference Scenario (LUISA, updated configuration 2014), consistent with settings (economic and demographic in particular) and policies in place in 2013 (hence including the 2020 renewable energy targets). The indicators are aggregated by Member States and Regions (Administrative Units NUTS-2) and can be employed as benchmark to monitor sectorial and territorial evolutions of alternative scenarios (e.g. to simulate policy options or specific measures), and for future updates of the reference scenario, to capture policy impacts (for example when changing energy targets) and their territorial effects.

This catalogue aims to provide the description of the land functions and the list of related indicators and an indicator factsheet (metadata). 30 indicators, out of the more than 50 currently produced by LUISA, are included in the first release of the catalogue.

The catalogue is periodically up-dated, following the updates of the configurations of the LUISA modelling platform and the definition, computation and validation of new indicators. Indicators and basic spatial layers used for the simulations will be made available in the frame of the framework for the management of knowledge and dissemination of information being set up by the Pilot Knowledge Centre on Territorial Policies.

1. Introduction

The 'Land-Use-based Integrated Sustainability Assessment' modelling platform (LUISA) is primarily used for the ex-ante evaluation of EC policies that have a direct or indirect territorial impact. It is based on the concept of 'land function' for cross-sector integration and for the representation of complex system dynamics. Beyond a traditional land use model, LUISA adopts a new approach towards activity-based modelling based upon the endogenous dynamic allocation of population, services and activities.

The ultimate product of LUISA is a set of territorial indicators that can be grouped and combined according to the 'land function' of interest and/or to the sector under assessment. A land function can, for example, be physical (e.g. related to hydrology or topography), ecological (e.g. related to landscape or phenology), social (e.g. related to housing or recreation), economic (e.g. provision of production factors - employment, investments, energy – or provision of manufacturing products and services – food, fuels, consumer goods, etc.) or political (e.g. the consequence of policy decisions). Land is commonly perceived to exercise many functions. Land functions are temporally dynamic, they depend on the characteristics of land parcels, and are constrained and driven by natural, socio-economic, and technological processes (Lavalle et al, submitted).

This document presents the 'Land Function' (LF) indicators developed within LUISA. The modelled LF indicators are grouped in six themes of land provision of goods and services (Figure 1). Other indicators such as, population density and GDP (which are not land function proxies) were also included in the list as auxiliary data to support the interpretation of other indicators.

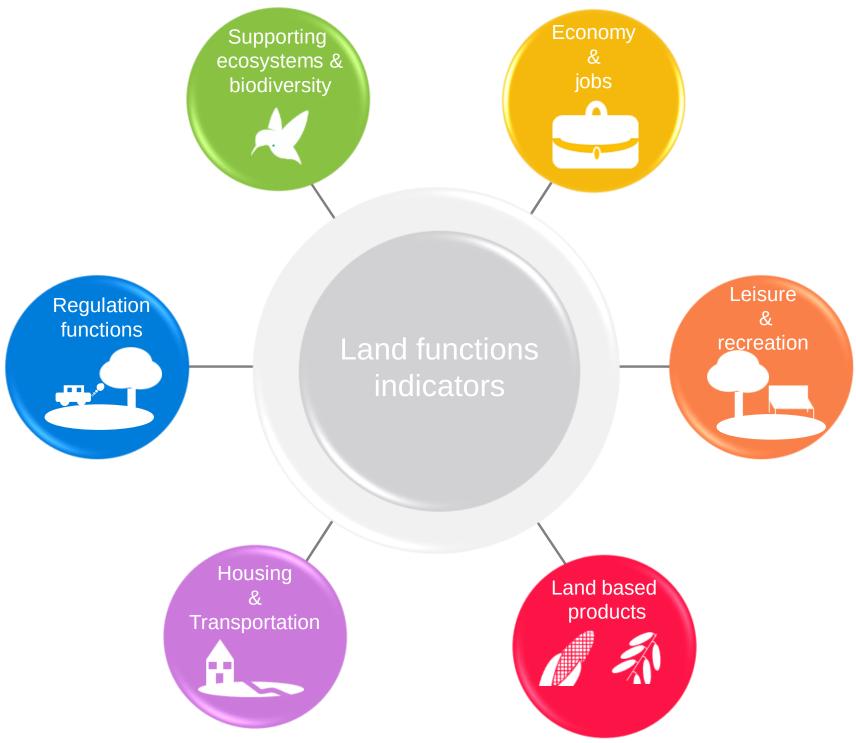

Figure 1. LUISA Indicators framework - land functions.

The indicators were projected according to the LUISA Updated Configuration 2014 of the EU Reference Scenario (Baranzelli et al., 2014) which is fully compliant with the "EU Energy, Transport and GHG emission trends until 2050 – Reference Scenario 2013". The

Updated Reference scenario 2014 includes the Cohesion Policy's current legislation (regional and infrastructural investments at regional scale), CAP related measures, biodiversity and habitat protection.

The land function indicators inform on the status of the LF for each Member States (NUTS 0) and regions (NUTS 2) in Europe, at time interval of 10 years (from 2010 to 2050).

As future developments, the indicators will also be aggregated following other administrative and geographical units, such as river basins, Global Agro-ecological zones, Local Administrative Unit (LAUx), Large Urban Zones (LUZ) and Cities.

This document is structured following the LF indicators framework, i.e. one section per Land Function. Each land function is divided in two sub-sections:

1. **A brief description of the land function and a list of related indicators**. Each land function is based on a set of indicators used to observe the provision of goods and services according to the Reference scenario. The same list of indicators will be used for the assessment of potential policies measures. Some indicators are still "under development" and most of them are expected to be computed and integrated in the visualization tool in the coming months. The classification of the indicators has the following structure: land function; division; sub-division; indicator; unit of the indicator. A number of indicators are developed in collaborations with other projects at the JRC.

2. An **indicator factsheet** is compiled for each indicator of an initial set of 30. The factsheet is structured according to the format proposed by the Europe Environmental Agency (EEA, 2014). The format includes the indicator definition; the key message; the policy context and policy questions; the assessment text, and the figures supporting the assessment. A factsheet for each indicator presents the detailed indicator specification. This part includes information related to the identification of the indicator (title, code); classification according to the DPSIR; the justification for the selection of this indicator and scientific references; the indicator definition; the policy context and targets; the policy questions; the methodology; the data specifications; uncertainties of the method and the data used; responsibility, ownership and further work.

2. Land function 1 – Provision of work

The land function provision of work refers to the employment provision for the economic activities related to agriculture and industrial/commercial/services. The indicators used as a proxy to evaluate the provision of work are confined to the data available: the projected employment for the industrial/commercial/services and agriculture activities as % of total population, both under development. The GDP and GDP per capita were also integrated in this list as an auxiliary indicator.

Table 1. List of land function 'provision of work' indicators.

Land function	Division	Sub-division	Indicator	Indicator Code	Unit
LF 1 Provision of work	Employment	Industrial / Commercial/ Services	Employment in Industrial, commercial, Services *(Under development)*	LF_111	% of total population
		Agricultural	Employment in Agriculture *(Under development)*	LF_112	% of total population
	Economy	GDP	GDP	LF_113_a	(million EUR)
			GDP / capita	LF_113_b	(million EUR/capita)

LF 113 – GDP and GDP/capita

1. Identification (title; code) and classification (DPSIR; typology)

LUISA framework: LF_113 a – GDP (million EUR); LF_113 b GDP/Capita (million EUR/pc);

DPSIR typology: Driver, Pressure

2. Rationale — justification for indicator selection; scientific references

GDP estimates are commonly used to measure the economic performance of a whole country or region. The GDP is currently used to calculate the annual growth of a country or region. While GDP is the single most important indicator to capture these economic activities, it is not a good measure of societies' well-being and only a limited measure of people's material living standards (OECD, 2014).

References

OECD (2014). Domestic product - Gross domestic product (GDP) - OECD Data. Retrieved April 14, 2015, from https://data.oecd.org/gdp/gross-domestic-product-gdp.htm

3. Indicator definition — definition; units

Gross Domestic Product (GDP) is defined by the Organisation for Economic Co-operation and Development (OECD) as standard measure of the value of final goods and services produced by a country during a period minus the value of imports.

The projected GDP in Million EUR for the EU-28 Member States was extracted from GEM-E3 model and disaggregated at NUTS 2 level. The GDP per capita is the country or regional total annual projected GDP derived from GEM-E3 divided by the total annual projected population from EUROPOP2010. The higher the value of the indicator, the higher the productivity per person. The indicator is given in million euros per capita (person).

4. Policy context and targets — context description; targets; related policy documents

GDP is commonly used as an indicator of the economic health of a country. The GDP and GDP per capita itself does not have a specific goal. However one of the 5 targets for the EU in 2020, propose to invest 3% of the EU's GDP in R&D. Similar to other goals, this target is translated into national targets in each EU country, reflecting different situation and circumstances.

5. Policy questions — key policy questions; specific policy questions

NA

6. Methodology (indicator calculation; gap filling; references)

The projected Gross Domestic Product (GDP) was derived by a computable general equilibrium (CGE) macro-economic model 'GEM-E3' (General Equilibrium Model for Energy-Economy-Environment), run by the National Technical University of Athens, and provides annual GDP national detail (National Technical University of Athens, 2010). The national GDP was disaggregated at regional level (NUTS 2). The GDP per capita is the gross domestic product divided by the population of a country/ region.

The projected population was obtain from the EUROPOP2010 (European Commission/ DG Economic and Financial Affairs, 2011).

References used:

European Commission/ DG Economic and Financial Affairs. (2011). The 2012 Ageing Report: Underlying Assumptions and Projection Methodologies. Retrieved from ec.europa.eu/economy_finance/publications/.../2012/.../ee-2012-2_en.pdf

National Technical University of Athens. (2010). General Equilibrium Model for Economy – Energy – Environment - GEM-E3 MODEL MANUAL. Athens, Greece.

7. Data specifications — data references; external data references; data sources in latest figures

- Projected GDP – GEM-E3: National Technical University of Athens. (2010). General Equilibrium Model for Economy – Energy – Environment - GEM-E3 MODEL MANUAL. Athens, Greece.
- Projected population - EUROPOP2010: European Commission/ DG Economic and Financial Affairs. (2011). The 2012 Ageing Report: Underlying Assumptions and Projection Methodologies. Retrieved from ec.europa.eu/economy_finance/publications/.../2012/.../ee-2012-2_en.pdf

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

NA

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

NA

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C, Batista e Silva, F (2015): LF113 - b - GDP/capita – disaggregated at NUTS2 (LUISA Platform REF2014). European Commission - Joint Research Centre.

3. Land function 2 - Provision of leisure

The land function provision of leisure refers to the access to nature based recreational services including cultural landscapes. The indicator "recreation potential" reflects the potential opportunities for nature based recreation activities in Europe.

Table 2. List of land function 'provision of leisure' indicators.

Land function	Division	Sub-division	Indicator Code	Indicator	Unit
LF2 Provision of leisure and recreation	Recreational and cultural services	Physical and experiential interactions	LF_211	Recreation potential	Dimensionless

LF 211 – Recreation potential

1. Identification (title; code) and classification (DPSIR; typology)

LUISA framework: LF_211 - Recreation potential

DPSIR typology: Impact.

2. Rationale — justification for indicator selection; scientific references

Public, local, nature-based, outdoor recreational activities include a wide variety of practices ranging from walking, jogging or running in the closest green urban area or at the river/lake/sea shore, riding bike in nature after work, picnicking, observing flora and fauna, organizing a daily trip to enjoy the surrounding beauties of the landscape, among a myriad of other possibilities. These activities have an important role on the human well-being and health, since they provide physical, aesthetic, cultural benefits and offer an opportunity to experience directly a relationship with nature. In addition, fruition of nature-based recreational activities may induce people's support for ecosystem protection. The model estimates the capacity of ecosystems to provide recreational opportunities.

References

Zulian, G., Paracchini, M.-L., Maes, J., & Liquete Garcia, M. D. C. (2013). ESTIMAP: Ecosystem services mapping at European scale (p. 54). doi:10.2788/64713 (print); 10.2788/64369 (online)

Paracchini, M. L., Zulian, G., Kopperoinen, L., Maes, J., Schägner, J. P., Termansen, M., Bidoglio, G. (2014). Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. Ecological Indicators, 45, 371–385. doi:10.1016/j.ecolind.2014.04.018

3. Indicator definition — definition; units

Potential opportunities for nature based recreation activities. Dimensionless.

4. Policy context and targets — context description; targets; related policy documents

The model was built in the context of EU biodiversity strategy Improve the knowledge of ecosystems and their services in the EU; it is part of Action 5: Mapping and Assessing Ecosystems and their services.

According to Action 5: "*Member States, with the assistance of the Commission, to map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020*".

Action 5 is one of the keystones of the strategy providing a knowledge base for Europe's green and blue infrastructure, the restoration of 15% of degraded ecosystems and the No Net Loss of biodiversity and ecosystem services initiative.

5. Policy questions — key policy questions; specific policy questions

The indicator aims at answering the following question:

- What is the spatial pattern of nature-based recreation opportunities in Europe

6. Methodology (indicator calculation; gap filling; references)

The model quantifies the recreational opportunities according to presence and importance of the following components: degree of naturalness; presence and distance from water bodies; presence of natural protected areas.

References used:

Zulian, G., Paracchini, M.-L., Maes, J., & Liquete Garcia, M. D. C. (2013). ESTIMAP: Ecosystem services mapping at European scale (p. 54). doi:10.2788/64713 (print); 10.2788/64369 (online)

Paracchini, M. L., Zulian, G., Kopperoinen, L., Maes, J., Schägner, J. P., Termansen, M., Bidoglio, G. (2014). Mapping cultural ecosystem services: A framework to assess the potential for outdoor recreation across the EU. Ecological Indicators, 45, 371–385. doi:10.1016/j.ecolind.2014.04.018

7. Data specifications — data references; external data references; data sources in latest figures

- Baseline Scenario projected land use maps (LUISA)
- Nature 2000, CDDA areas
- Water bodies

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The mapping of recreation potential does not take into account user preferences.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

The recreation potential model is continuously being updated and refined with new inputs and configurations. New inputs: geomorphology of coast, water clarity, refined data about green urban areas, semi natural vegetation in grassland, natural riparian areas. New configuration includes the changes in the land.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C; Zulian, G (2015): LF211 - Recreation potential map (LUISA Platform REF2014). European Commission - Joint Research Centre.

4. Land function 3 - Provision of land and water based products

The third land function addresses the provision of land and water based products. This function is divide in three groups: the capacity of water to deliver safe drinking-water and to support economic activities; the capacity of the land to deliver food and feed products; and to deliver energy and timber products.

The water has two proxy indicators, one reflects the consumption and the second reflects the water use efficiency (productivity). The provision of food and feed, energy crops and forest products are represented in terms of production (tonnes) and energy content produced (Mj or GJ).

The 'food and feed production', 'biomass harvested for material' and 'energy uses and energy content of wood production' are still under development, thus they were not yet integrated in the visualization tool.

Table 3.List of land function 'provision of land and water based products' indicators.

Land function	Division	Sub-division	Indicator Code	Indicator	Unit
LF 3 Provision of land and water based products	Water	Water flows	LF_311	Water consumption	(m3)
			LF_312	Water productivity	(EUR per m3)
	Food and Biofuels	Food and Feed Crops	LF_321	Food and feed production (under development)	(1000t/ha/a)
			LF_322	Energy content of produced food and feed	(MJ/ha/a)
		Energy Crops	LF_331	Biomass harvested from energy crops	(1000t/ha/a)
			LF_332	Energy content of dedicated energy crops	(GJ/ha/a)
	Wood Biomass	Forest	LF_351	Biomass harvested for material and energy uses (*Under development*)	(t/ha/a)
			LF_352	Energy content of wood production (*Under development*)	(MJ/ha/a)

LF 311 - Water Consumption

1. Identification (title; code) and classification (DPSIR; typology)

LUISA framework: LF_311 – Water Consumption

DPSIR typology: Pressure.

2. Rationale — justification for indicator selection; scientific references

In the framework of different European directives, like the EU Water Framework Directive or the resource efficiency milestones, we see understanding the current and future trends in the amount of water we use as the first step towards sustainable water quantity management. The sectorial water use model was built in order to study the consumption/use trends under different scenarios for the EU Blueprint to safeguard Europe's water project (http://ec.europa.eu/environment/water/blueprint/index_en.htm).

References

Vandecasteele, I., Bianchi, A., Batista e Silva, F., Lavalle, C., Batelaan, O., 2014. Mapping Current and Future European Public Water Withdrawals and Consumption. Hydrology and Earth System Sciences, 18, 407-416, doi: 10.5194/hess-18-407-2014.

Vandecasteele, I., Burek P., Bianchi, A., Mubareka S., De Roo A., Bouraoui F., Lavalle, C., Batelaan, O., 2014. Sectoral water withdrawal and consumption in Europe 2006 - 2030, submitted to Journal of Hydrology - Regional Studies Europe.

3. Indicator definition — definition; units

Water consumption per sector is the result of the water use model which allocates sectorial statistical data on freshwater consumption to the correspondent land use class and projects the base line year's consumption (2006) to 2050. The unit of measurement is cubic meters.

4. Policy context and targets — context description; targets; related policy documents

The water use model's outputs are the sectorial water consumption maps. The model was built in the context of the EU Blueprint to safeguard Europe's water project.

5. Policy questions — key policy questions; specific policy questions

The indicator aims at answering the following question:

- Are the different sectors (public, industry, energy, agriculture and livestock) reducing the amount of water used over time or improving the efficiency of the water they use?

6. Methodology (indicator calculation; gap filling; references)

The total annual freshwater use was calculated for the base year 2006 and forecasted to 2010, 2020 and 2050 using the Water Use Model. The model quantifies water use in the public, industry, energy (cooling water), irrigation, and livestock sectors. Country-level aggregated statistics on water use per sector were derived from EUROSTAT and verified with the FAO AQUASTAT dataset. These values were disaggregated using proxy data (mostly land use) to produce sectorial water use maps up to 100m resolution. The total country-level sectorial water use is forecasted based on additional proxy data specific to each sector, including, amongst others, population growth, industrial productivity, and energy consumption.

The public water use is computed for 2006 and then projected until 2050. For 2006 the water used per user is computed, with the population density (people going abroad and coming to the area) corrected by the tourism densities. The total water used is disaggregated to the user density maps and then allocated to the urban land use class (Vandecasteele et al. 2014).

Industry and energy statistics are extrapolated for the projections taking in account the efficiency factors. Per year the statistics are disaggregated for the total amount of industrial land or energy points and allocated to the correspondent land use (Vandecasteele et al. 2013)..

Irrigation use maps are calculated per crop based on the averages of water used per crop type from FAO and the irrigated areas map (Global Map of Irrigated Areas, FAO). The total amount of water used per crop type is disaggregated to their area (amount of pixels) and then allocated to the correspondent agricultural land use.

Livestock water use is calculated for 2006 and kept constant for the following years. The methodology is explained in Mubareka et al. 2013.

References used:

Mubareka, S., Maes, J., Lavalle, C., & de Roo, A. (2013). Estimation of water requirements by livestock in Europe. Ecosystem Services, 4, 139-145.

Vandecasteele, I., Bianchi, A., Batista e Silva, F., Lavalle, C., Batelaan, O., 2014. Mapping Current and Future European Public Water Withdrawals and Consumption. Hydrology and Earth System Sciences, 18, 407-416, doi: 10.5194/hess-18-407-2014.

Vandecasteele, I., Bianchi, A., Mubareka, S., De Roo, A., Burek, P., Bouraoui, F., Lavalle, C., Batelaan, O., 2013, Mapping of current and projected Pan-European water withdrawals, UNCCD 2nd Scientific Conference, proceedings, 9-12 April 2013

7. Data specifications — data references; external data references; data sources in latest figures

- Baseline Scenario projected land use maps (LUISA, urban, industrial and agricultural land uses classes)
- Freshwater abstractions by source and sector (EUROSTAT)
- Water withdrawals (FAO - AQUASTAT)
- Thermal power stations (EPRTR dataset)
- Projected energy consumption (POLES model)
- Projected GVA for industry (GEM-E3 model)
- Population density maps (Batista et al., 2013)
- Tourism statistics (EUROSTAT), and forecasts (UNWTO, 2014)
- Irrigation water requirements (FAO, EUROSTAT)
- Irrigated areas (Global Map of Irrigation Areas –GMIA-, FAO)
- Livestock density map (FAO)
- EU-28 administrative regions

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The mapping of sectoral water use requires input from several models (LUISA, POLES, GEM-E3) which all have their own uncertainties. The projection of water use per sector assumes that water use will increase linearly with specific 'driving forces' per sector. Although we do take into account that there will be a certain degree of improvement in water use efficiency over time for all sectors, there may be additional factors which are not taken into account.

9. Responsibility and ownership (indicator manager; ownership) Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)
10. Further work (short-term work; long-term work) The water use model is continuously being updated and refined to improve dynamic computation of sectoral water use and to reduce uncertainties. In particular, livestock water maps need to be projected over time and energy water use will be linked to the Land Use Model when it incorporates the energy land use class.
11. Publisher: European Commission - Joint Research Centre Lavalle, C, Vandecasteele, I (2015): LF311 - Water Consumption (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 312 - Water Productivity

1. Identification (title; code) and classification (DPSIR; typology)

LUISA framework: LF_312 – Water Productivity

Resource efficiency > Dashboard indicators > Water > Water Productivity (t2020_rd210)

DPSIR typology: Pressure.

2. Rationale — justification for indicator selection; scientific references

The indicator reflects productivity in terms of water use, so gives a measure of a country's water use efficiency.

References

European Commission (a) (2011). COM (2011) 571 - Roadmap to a Resource Efficient Europe, European Commission, Documentation and data. [http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf] (accessed 10/11/2014).

Eurostat (2013). Productivity of built-up areas metadata. [http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/EN/t2020_rd210_esmsip.htm] (accessed 10/11/2014).

3. Indicator definition — definition; units

Water productivity is a measure of the monetary value produced by a country per unit of water used. It is essentially the country total annual GDP (GEM-E3) divided by the total annual freshwater use for all sectors. The higher the value of the indicator, the higher the productivity. The indicator is given in euros per m^3 of water used.

4. Policy context and targets — context description; targets; related policy documents

Water Productivity is a 'Resource Efficiency indicator' It has been chosen as a dashboard indicator presented in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency (Eurostat - metadata, 2013).

5. Policy questions — key policy questions; specific policy questions

The indicator aims at answering the following question:

- How efficiently is water used for productive purposes?

6. Methodology (indicator calculation; gap filling; references)

The total annual freshwater use was calculated for the base year 2006 and forecasted to 2010, 2020 and 2050 using the Water Use Model. The model quantifies water use in the public, industry, energy (cooling water), irrigation, and livestock sectors. Country-level aggregated statistics on water use per sector were derived from EUROSTAT and verified with the FAO AQUASTAT dataset. These values were disaggregated using proxy data (mostly land use) to produce sectoral water use maps up to 100m resolution. The total country-level sectoral water use is forecasted based on additional proxy data specific to each sector, including, amongst others, population growth, industrial productivity, and energy consumption. The GDP per region is divided by the total water used in all sectors to give the final indicator, which is presented here at country level.

References used:

Vandecasteele, I., Bianchi, A., Batista e Silva, F., Lavalle, C., Batelaan, O., 2014.

Mapping Current and Future European Public Water Withdrawals and Consumption. Hydrology and Earth System Sciences, 18, 407-416, doi: 10.5194/hess-18-407-2014.

Vandecasteele, I., Bianchi, A., Mubareka, S., De Roo, A., Burek, P., Bouraoui, F., Lavalle, C., Batelaan, O., 2013, Mapping of current and projected Pan-European water withdrawals, UNCCD 2nd Scientific Conference, proceedings, 9-12 April 2013

De Roo, A., Bouraoui, F., Burek, P., Bisselink, B., Vandecasteele, I., Mubareka, S., Salamon, P., Pastori, M., Zambrano, H., Thiemig, V., Bianchi, A., Lavalle, C., 2012. Current water resources in Europe and Africa - Matching water supply and water demand - JRC Technical Report EUR 25247 EN.

7. Data specifications — data references; external data references; data sources in latest figures

- Baseline Scenario projected land use maps (LUISA, urban, industrial and arable land uses classes)
- Freshwater abstractions by source and sector (EUROSTAT)
- Water withdrawals (FAO - AQUASTAT)
- Thermal power stations (EPRTR dataset)
- Projected energy consumption (POLES model)
- Projected GVA for industry (GEM-E3 model)
- Population density maps (Batista et al., 2013)
- Tourism statistics (EUROSTAT), and forecasts (UNWTO, 2014)
- Irrigation water requirements (FAO)
- Livestock density map (FAO)
- EU-28 administrative regions
- GDP in Million Euros from the GEM-E3 model (National Technical University of Athens, 2010)

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The mapping of sectoral water use requires input from several models (LUISA, POLES, GEM-E3) which all have their own uncertainties. The projection of water use per sector assumes that water use will increase linearly with specific 'driving forces' per sector. Although we do take into account that there will be a certain degree of improvement in water use efficiency over time for all sectors, there may be additional factors which are not taken into account.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

The water use model is continuously being updated and refined to improve dynamic computation of sectoral water use and to reduce uncertainties.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C, Vandecasteele, I (2015): LF311 - Water Productivity (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 321 - Food and feed production

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_321

DPSIR typology: Pressure

2. Rationale — justification for indicator selection; scientific references

The food and feed production indicator aims to assess the intensity of the agricultural production in Europe.

3. Indicator definition — definition; units

The indicator is defined as the amount of food and feed production over the total surface area.

The unit of measurement is thousands of tons per hectare.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

The indicator aims at answering the following question:

- Is the agricultural production increasing or decreasing across different European regions?

6. Methodology (indicator calculation; gap filling; references)

The indicator is computed as the amount of food and feed produced in the administrative unit (NUTSx) divided by the total surface of the administrative unit itself. The agricultural production considered takes place on land classified as arable, permanent crop or pasture.

7. Data specifications — data references; external data references; data sources in latest figures

- CAPRI - Britz W and Witzke HP. (2012) Capri model documentation 2012: Version 2. Bonn: Institute for Food and Resource Economics, University of Bonn.
- EU Reference Scenario 2014 projected land use maps from LUISA (arable land, permanent crops and pastures)
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The production levels are projected at regional level by the CAPRI model, which has its own uncertainties. The thematic detail (crops types) of the CAPRI model is higher than in LUISA, where aggregations of the CAPRI commodities are simulated (cereals, maize, root crops and other arable; permanent crops; pastures).

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

The LUISA platform is continuously being updated and refined to improve the allocation of agricultural commodities according to the suitability characteristics of the land.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C, Baranzelli, C (2015): LF321 – Food and Feed production (LUISA Platform REF2014). European Commission - Joint Research Centre

LF 331 - Biomass harvested from energy crops

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_331

DPSIR typology: Pressure

2. Rationale — justification for indicator selection; scientific references

The biomass harvested from energy crops indicator aims to assess the production level of dedicated energy crops in Europe.

References

Perpiña Castillo, C., Lavalle, C., Baranzelli, C., Mubareka, S. (2015). Modelling the spatial allocation of second-generation feedstock (lignocellulosic crops) in Europe. International Journal of Geographical Information Science 29, 1807-1825

3. Indicator definition — definition; units

The indicator is defined as the amount of biomass produced from dedicated energy crops over the total surface area.

The unit of measurement is thousands of tons per hectare.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

The indicator aims at answering the following question:

- What is the spatial distribution of dedicated energy crops across the European landscape?

6. Methodology (indicator calculation; gap filling; references)

The indicator is computed as the amount of biomass harvested from dedicated energy crops in the administrative unit (NUTSx) divided by the total surface of the administrative unit itself. Dedicated energy crops are lignocellulosic crops, either herbaceous or woody (short rotation coppice). Dedicated energy crops are allocated taking into account favourable location characteristics (climate, soil properties, terrain morphology, etc.), relevant legal provisions and policy incentives.

References used

European Commission. Directive 2009/28/EC of the European Parliament and of the Council on the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. 23 April 2009

Future Crops for Food, Feed, Fiber and Fuel - 4CROPS. Webpage: http://www.4fcrops.eu/

Fisher G. et al. (2010). Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures. Part I: Land productivity potentials. Biomass and Bioenergy 34, 159- 172

Best practice guide lands. Growing Short Rotation Coppice. For applicants to DEFRA'S Energy Crops Scheme. DEFRA Department for Environment, Food and Rural Affairs, England

Report on Energy crops options for Ontario power generation. The research park, London. May 2009

Bioenergy: Environmental impact and best practice. Final report, 2007

Fiorese G., Guariso G. (2010). A GIS-based approach to evaluate biomass potential from energy crops at regional scale. Environmental modelling and software 25, 702-711

Fisher G. et al. (2010). Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures, Part II: Land use scenarios. Biomass and Bioenergy, Volume 34, Issue 2, Pages 173-187

Perpiña Castillo, C., Lavalle, C., Baranzelli, C., Mubareka, S. (2015). Modelling the spatial allocation of second-generation feedstock (lignocellulosic crops) in Europe. International Journal of Geographical Information Science 29, 1807-1825

7. Data specifications — data references; external data references; data sources in latest figures

- CAPRI - Britz W and Witzke HP. (2012) Capri model documentation 2012: Version 2. Bonn: Institute for Food and Resource Economics, University of Bonn.
- EU Reference Scenario 2014 projected land use maps from LUISA (energy crops)
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The production levels are projected at regional level by the coupled models CAPRI (agricultural sector) and PRIMES (energy), which have their own uncertainties. Dedicated energy crops (lignocellulosic crops) are simulated as one unique class, whose properties refer to the following perennial crops:

- Herbaceous lignocellulosic crops: Miscanthus (Miscanthus spp.), Switchgrass (Panicum virgatum), Reed canary grass (Phalaris arundinacea), Giant reed (Arundo donax) and Cardoon (Cynara cardunculus);
- Woody lignocellulosic tree crops: Willow (Salix spp.), Poplar (Populus spp.) and Eucaliptus (Eucaliptus spp.)

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

The LUISA platform is continuously being updated and refined to improve the allocation of dedicated energy crops according to the suitability characteristics of the land.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C, Perpiña, C (2015): LF331 – Biomass harvested form energy crops (LUISA Platform REF2014). European Commission - Joint Research Centre

LF 332 - Energy content of dedicated energy crops

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_332 – Energy content of dedicated energy crops

DPSIR typology: Pressure

2. Rationale — justification for indicator selection; scientific references

The biomass harvested from energy crops indicator aims to assess the production level of dedicated energy crops in Europe.

References

Perpiña Castillo, C., Lavalle, C., Baranzelli, C., Mubareka, S. (2015). Modelling the spatial allocation of second-generation feedstock (lignocellulosic crops) in Europe. International Journal of Geographical Information Science 29, 1807-1825

3. Indicator definition — definition; units

The indicator is defined as the amount of energy content of the biomass harvested from dedicated energy crops over the total surface area.

The unit of measurement is Giga Joules per hectare.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

The indicator aims at answering the following question:

- What is the spatial distribution of dedicated energy crops across the European landscape?

6. Methodology (indicator calculation; gap filling; references)

The indicator is computed as the energy content of the biomass harvested from dedicated energy crops in the administrative unit (NUTSx) divided by the total surface of the administrative unit itself. Dedicated energy crops are lignocellulosic crops, either herbaceous or woody (short rotation coppice). Dedicated energy crops are allocated taking into account favourable location characteristics (climate, soil properties, terrain morphology, etc.), relevant legal provisions and policy incentives.

References used

European Commission. Directive 2009/28/EC of the European Parliament and of the Council on the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. 23 April 2009

Future Crops for Food, Feed, Fiber and Fuel - 4CROPS. Webpage: http://www.4fcrops.eu/

Fisher G. et al (2010). Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures. Part I: Land productivity potentials. Biomass and Bioenergy 34, 159- 172

Best practice guide lands. Growing Short Rotation Coppice. For applicants to DEFRA'S Energy Crops Scheme. DEFRA Department for Environment, Food and Rural

Affairs, England

Report on Energy crops options for Ontario power generation. The research park, London. May 2009

Bioenergy: Environmental impact and best practice. Final report, 2007

Fiorese G., Guariso G. (2010). A GIS-based approach to evaluate biomass potential from energy crops at regional scale. Environmental modelling and software 25, 702-711

Fisher G. et al (2010). Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures, Part II: Land use scenarios. Biomass and Bioenergy, Volume 34, Issue 2, Pages 173-187

Perpiña Castillo, C., Lavalle, C., Baranzelli, C., Mubareka, S. (2015). Modelling the spatial allocation of second-generation feedstock (lignocellulosic crops) in Europe. International Journal of Geographical Information Science 29, 1807-1825

7. Data specifications — data references; external data references; data sources in latest figures

- CAPRI - Britz W and Witzke HP. (2012) Capri model documentation 2012: Version 2. Bonn: Institute for Food and Resource Economics, University of Bonn.
- Average conversion factor for herbaceous and woody lignocellulosic crops - De Wit, M., Faaij, A., 2010. European biomass resource potential and costs. Biomass and Bioenergy, 34, 188-202.
- EU Reference Scenario 2014 projected land use maps from LUISA (energy crops)
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The production levels are projected at regional level by the coupled models CAPRI (agricultural sector) and PRIMES (energy), which have their own uncertainties. Dedicated energy crops (lignocellulosic crops) are simulated as one unique class, whose properties refer to the following perennial crops:

- Herbaceous lignocellulosic crops: Miscanthus (Miscanthus spp.), Switchgrass (Panicum virgatum), Reed canary grass (Phalaris arundinacea), Giant reed (Arundo donax) and Cardoon (Cynara cardunculus);
- Woody lignocellulosic tree crops: Willow (Salix spp.), Poplar (Populus spp.) and Eucaliptus (Eucaliptus spp.)

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

The LUISA platform is continuously being updated and refined to improve the allocation of dedicated energy crops according to the suitability characteristics of the land.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C, Perpiña, C (2015): LF331 – Biomass harvested form energy crops (LUISA

Platform REF2014). European Commission - Joint Research Centre

5. Land function 4 - Provision of housing and transport

The provision of housing function refers to the provision of space where residential, social and economic activities takes place. The indicators presented here are divided in residential, industrial including commercial and services, and built-up areas which groups the residential and industrial areas together.

The provision of transportation reflects the capacity of land to deliver transportation services. The indicators proxy used are the potential accessibility, travel time to nearest city, amount of people reached within 4 hours and efficiency of the network.

Table 4. List of land function 'provision of housing and transports' indicators.

Land function	Division	Sub-division	Indicator Code	Indicator	Unit
LF 4 Provision of housing and transport	Settlements	Residential areas	LF_411	Share of residential areas over the total land area	% of total land
			LF_412	Residential areas per inhabitant	(m^2/person)
			LF_415	Population Density	Inhabitants /Km^2
		Industrial areas	LF_421	Share of industrial/commercial/services areas	km and %
			LF_422	Industrial economic output per unit of industrial/ commercial area	(euro/ha)
		Built-up areas	LF_431	Share of built-up areas over the total land	km and %
			LF_432	Productivity of built-up areas	(EUR per km^2)
			LF_433	Built-up per person	(m^2/capita)
		Transport	LF_441	Potential accessibility	(dimensionless)
			LF_442	Network efficiency	(dimensionless)
			LF_443	Local accessibility (Travel time to nearest city)	(dimensionless)
			LF_444	Daily accessibility (Amount of people reached within 4 hours)	(dimensionless)

LF 411 - Share of residential areas over the total land area

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_411

DPSIR typology: descriptive indicator of Pressure.

2. Rationale — justification for indicator selection; scientific references

The share of residential areas over the total land area indicator aims to assess the proportion of land used for residential, sport and leisure purposes and green urban areas over the total surface area.

3. Indicator definition — definition; units

Share of residential areas measures the total urban fabric area (including continuous and discontinuous residential areas, sport and leisure, and green urban areas) as a proportion of the total surface area of land in the country expressed in percentage.

The indicator presents data for the year 2010, 2020, 2030, 2040 and 2050 at NUTS 2 and NUTS 0 for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

The indicator aims at answering the following question:

- In which proportion is the share of residential areas increasing in Europe?

6. Methodology (indicator calculation; gap filling; references)

The share of residential area is the result of the division of the residential area in Km^{2}' by the total surface of the administrative unit (NUTSx). As residential areas we include the urban fabric land uses classes (CLC11X residential (continuous and discontinuous), and CLC 14X green urban areas, sport and leisure facilities.

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 - Batista e Silva, F., Lavalle, C., & Koomen, E. (2013). A procedure to obtain a refined European land use/cover map. Journal of Land Use Science, 8(3), 255–283. http://doi.org/10.1080/1747423X.2012.667450
- EU Reference Scenario 2014 projected land use maps from LUISA (urban land use classe)
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, only residential areas with a minimum width of 100 meters were considered in the indicator.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban - rural topology (NUTS3 3 category levels);
- Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%

11. Publisher:

European Commission - Joint Research Centre Lavalle, C, Barbosa, A (2015): LF411 - Share of residential areas over the total land area (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 412 - Residential areas per inhabitant

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_412 – Residential area per inhabitant

DPSIR typology: descriptive indicator of Pressure.

2. Rationale — justification for indicator selection; scientific references

The 'residential areas per inhabitant', measures the residential land used by comparing the size of the urban fabric areas with the population expressed in sq. m per inhabitant (m^2 per person). It provides useful information on the efficiency of land used for residential, sport and leisure. The higher the area per inhabitant, the lower the land use efficiency.

References

Lavalle, C., Barbosa, A. L., Mubareka, S., Jacobs-Crisioni, C., Baranzelli, C., Perpiña Castillo, C. (2013). Land Use Related Indicators for Resource Efficiency - An analytical framework for the assessment of the land milestone proposed in the Roadmap for Resource Efficiency. http://doi.org/10.2788/94223

Prokop, G. (2011). Report on best practices for limiting soil sealing and mitigating its effects. http://doi.org/10.2779/15146

3. Indicator definition — definition; units

The 'residential areas per inhabitant' measure the land consumption by comparing the size of the urban fabric with the population expressed in sq. m per inhabitants (m^2 per person).

The indicator presents data for the year 2010, 2020, 2030, 2040, 2050, for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

The 'residential areas per inhabitant' indicator aims to answer the following questions:

- Are Europe using residential areas more efficiently?
- Do the residential use intensities improve or follow an unsustainable trend?

6. Methodology (indicator calculation; gap filling; references)

The residential areas per inhabitant (m^2 per person) is the total sum of the land uses classified as urban fabric including, CLC11X residential (continuous and discontinuous), and CLC 14X green urban areas, sport and leisure facilities divided by population of the region (NUTSx).

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 - Batista e Silva, F., Lavalle, C., & Koomen, E. (2013). A procedure to obtain a refined European land use/cover map. Journal of Land Use Science, 8(3), 255–283. http://doi.org/10.1080/1747423X.2012.667450
- EU Reference Scenario 2014 projected land use maps from LUISA (urban & industrial/commercial land uses classes)

- EUROPOP2010, population projections from Eurostat.
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, only residential areas with a minimum width of 100 meters were considered in the indicator.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban - rural topology (NUTS3 3 category levels);
- Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C, Barbosa, A (2015): LF412 - Residential areas per inhabitant (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 415 - Population density

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_415 Population density

DPSIR typology: descriptive indicator of state and pressure.

2. Rationale — justification for indicator selection; scientific references

Population density measures the number of people (in average) per NUTSx regions.

References used:

Batista e Silva, F., Lavalle, C., Jacobs-Crisioni, C., Barranco, R., Zulian, G., Maes, J., Mubareka, S. (2013). Direct and Indirect Land Use Impacts of the EU Cohesion Policy Assessment with the Land Use Modelling Platform Contact information. http://doi.org/10.2788/60631

Jacobs-Crisioni, C., Batista, F., Lavalle, C., Baranzelli, C., Barbosa, A., Perpiña Castillo, C. (n.d.). Accessibility and territorial cohesion in a case of transport infrastructure improvements with endogenous population distributions. Submitted to European Transport Research Review, 1–24.

3. Indicator definition — definition; units

Population density is calculated by dividing the number of people by land area in a region.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

NA

6. Methodology (indicator calculation; gap filling; references)

The population density at $100m^2$ is an output of the LUISA model. The average population density per NUTSx region was estimated using the administrative boundaries and then converted from sq. meters into sq. kilometres.

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA population density maps for the year 2010, 2020, 2030, 2040 and 2050
- Administrative boundary maps (NUTS, Large Urban Zones, etc.).

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

NA

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)
NA
11. Publisher:
European Commission - Joint Research Centre Lavalle, C; Jacobs-Crisioni, C (2015): LF415 - Population density (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 421 - Share of ICS areas over the total land area

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_421 - Share of industrial/commercial/services areas (ICS) over the total land area

DPSIR typology: descriptive indicator of Pressure.

2. Rationale — justification for indicator selection; scientific references

The share of industrial/commercial/services areas over the total land area indicator aims to assess the proportion of land used for economic activities over the total surface area.

3. Indicator definition — definition; units

Share of industrial/commercial/services areas measures the total industrial/commercial/services area as a proportion of the total surface area of land in the country expressed in percentage (% of total land).

The indicator presents data for the year 2010, 2020, 2030, 2040 and 2050 at NUTS 2 and NUTS 0 for all EU 28 Member States based on LUISA model projected land use maps.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

The share of industrial/commercial/services areas over the total land area aims to answer the following questions:

- In which proportion is the share of industrial/commercial/services areas increasing in Europe?

6. Methodology (indicator calculation; gap filling; references)

The share of industrial/commercial/services areas over the total land area is the total sum of the land uses classified as urban fabric including, CLC121 industrial and commercial land.

The share of industrial/commercial/services area is the result of the division of the industrial/commercial/services area Km^{2}' by the total surface of the administrative unit (NUTSx).

References:

Batista E Silva, F., Koomen, E., Diogo, V., & Lavalle, C. (2014). Estimating demand for industrial and commercial land use given economic forecasts. PloS One, 9(3), e91991. http://doi.org/10.1371/journal.pone.0091991

Batista e Silva, F., Lavalle, C., Jacobs-Crisioni, C., Barranco, R., Zulian, G., Maes, J., Mubareka, S. (2013). Direct and Indirect Land Use Impacts of the EU Cohesion Policy Assessment with the Land Use Modelling Platform Contact information. http://doi.org/10.2788/60631

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 - Batista e Silva, F., Lavalle, C., & Koomen, E. (2013). A procedure to obtain a refined European land use/cover map. Journal of Land Use Science, 8(3), 255–283. http://doi.org/10.1080/1747423X.2012.667450
- EU Reference Scenario 2014 projected land use maps from LUISA (urban land use class)
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, only industrial and commercial areas with a minimum width of 100 meters were considered in the indicator.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban - rural topology (NUTS3 3 category levels);
- Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C., Barbosa, A. (2015): LF421 - Share of ICS areas over the total land area (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 422 - ICS economic output per unit of ICS area

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_422 – Industrial/Commercial/Services economic output per unit of ICS area

DPSIR typology: descriptive indicator of Pressure.

2. Rationale — justification for indicator selection; scientific references

The industrial/commercial/services (ICS) economic output measures the productivity of the ICS land. The projected ICS land in combination with the projected GVA, give more detailed information on whether ICS areas within a region/ country has been efficiently used to generate economic value added.

3. Indicator definition — definition; units

The 'industrial/commercial/services (ICS) economic output per unit of ICS area' is the ratio of the Gross Value Added (GVA) of the industrial, commercial and services sectors by the industrial, commercial and services land use, and it is expressed as million EUR per hectare. The higher the ICS GVA in million EUR/hectare, the higher the level of productivity. The indicator is computed for the years 2010, 2020, 2030, 2040 and 2050 at NUTS 2 and NUTS 0 for all EU 28 Member States based on LUISA model projected land use maps.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

The trend of the ICS economic output per ICS unit aims to answer the following questions:

- How efficient is the industrial, commercial and services land use?
- How will the ICS productivity change under the Reference scenario in the EU-28?

6. Methodology (indicator calculation; gap filling; references)

The ICS economic output per unit of ICS area is computed by diving the projected annual GVA by the projected industrial/commercial/services areas.

The industrial, commercial and services GVA is derived from the macro-economic model 'GEM-E3' (General Equilibrium Model for Energy-Economy-Environment), run by the National Technical University of Athens, and which provides annual GVA growth rates with national and sector detail, respecting the long term economic forecast by EC DG ECFIN (Ageing Report 2012). The growth rates from GEM-E3 are used to project GVA from 2009, and generate a trajectory of future GVA.

The ICS areas are derived from the projected land use maps from LUISA platform.

References:

Batista E Silva, F., Koomen, E., Diogo, V., & Lavalle, C. (2014). Estimating demand for industrial and commercial land use given economic forecasts. PloS One, 9(3), e91991. http://doi.org/10.1371/journal.pone.0091991

Batista e Silva, F., Lavalle, C., Jacobs-Crisioni, C., Barranco, R., Zulian, G., Maes, J., Mubareka, S. (2013). Direct and Indirect Land Use Impacts of the EU Cohesion Policy Assessment with the Land Use Modelling Platform Contact information.

http://doi.org/10.2788/60631

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 - Batista e Silva, F., Lavalle, C., & Koomen, E. (2013). A procedure to obtain a refined European land use/cover map. Journal of Land Use Science, 8(3), 255–283. http://doi.org/10.1080/1747423X.2012.667450
- EU Reference Scenario 2014 projected land use maps from LUISA (urban land use class)
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, only industrial and commercial areas with a minimum width of 100 meters were considered in the indicator.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban - rural topology (NUTS3 3 category levels);
- Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Batista e Silva, F (2015): LF422 - ICS economic output per unit of ICS area (REF2014 LUISA Platform). European Commission - Joint Research Centre.

LF 431 - Share of built-up area over the total land

1. Identification (title; code) and classification (DPSIR; typology)

EUROSTAT: Eurobase > Tables on EU policy> Europe 2020 Indicators > Resource efficiency > Dashboard indicators > Land > Built-up areas as a share of total land (t2020_rd110)

LUISA Framework: LF_431- Share of built-up area over the total land

EEA (related indicator): Biodiversity/Threats to biodiversity: habitat loss and degradation/Land take

DPSIR typology: descriptive indicator of Pressure.

2. Rationale — justification for indicator selection; references

The built-up areas indicator was selected in the context of the RERM to reflect the production of land as resource. This indicator aimed to be used in conjunction with the lead indicator and has the advantage that it focused on built-up stock and flows of the land as a resource. Thus, it can be easily understood, measured and communicated.

References:

European Commission. (2011a). COM (2011) 571 - Roadmap to a Resource Efficient Europe. European Commission, Documentation and data. European Commission. Retrieved from http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf

European Commission. (2011b). SEC (2011) 10 67 - Commission Staff Working Paper. Analysis associated with the Roadmap to a Resource Efficient Europe Part II. System (Vol. 147). Retrieved from http://ec.europa.eu/environment/resource_efficiency/pdf/working_paper_part2.pdf

Eurostat/ European Commission. (2013). Built-up areas (tsdnr510). Retrieved April 9, 2015, from http://ec.europa.eu/eurostat/cache/metadata/FR/tsdnr510_esmsip.htm

Lavalle, C., Barbosa, A. L., Mubareka, S., Jacobs-Crisioni, C., Baranzelli, C., Perpiña Castillo, C. (2013). Land Use Related Indicators for Resource Efficiency - An analytical framework for the assessment of the land milestone proposed in the Roadmap for Resource Efficiency. http://doi.org/10.2788/94223

3. Indicator definition — definition; units

Built-up areas measures the total built-up area as a share of the total surface area of land in the country expressed in percentage.

The indicator presents data for the year 2010, 2020, 2030, 2040 and 2050 at NUTSx for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents

The indicator of 'built-up areas' has been included in the Dashboard indicators of the Resource Efficiency Scoreboard to measure progress towards the efficient use of land (European Commission (a) (2011). The 'built-up areas' indicator itself does not have a specific goal. However, the average annual land take indicator, which measures the net changes of the built-up areas in time in km^2 has a policy goal proposed in the 2020 land milestone of the RERM. This target is measurable and has a specific time limit to achieve: 'no net land take by 2050' (EC, 2011).

5. Policy questions — key policy questions; specific policy questions

The built-up area indicator aims to answer the following policy questions:

- By how much and in which proportions are built-up areas increasing in Europe?

6. Methodology (indicator calculation; gap filling; references)

The 'built-up area in km^2 is the total sum of the land uses classified as urban fabric including, CLC11X residential (continuous and discontinuous), CLC121 industrial/commercial land, and CLC 14X green urban areas, sport and leisure facilities.

The 'share of built-up area' is the result of the division of the 'built-up area in Km^2' by the total surface of the administrative unit (NUTSx).

References:

Batista E Silva, F., Koomen, E., Diogo, V., & Lavalle, C. (2014). Estimating demand for industrial and commercial land use given economic forecasts. PloS One, 9(3), e91991. http://doi.org/10.1371/journal.pone.0091991

Batista e Silva, F., Lavalle, C., Jacobs-Crisioni, C., Barranco, R., Zulian, G., Maes, J., … Mubareka, S. (2013). Direct and Indirect Land Use Impacts of the EU Cohesion Policy Assessment with the Land Use Modelling Platform Contact information. http://doi.org/10.2788/60631

Lavalle, C., Barbosa, A. L., Mubareka, S., Jacobs-Crisioni, C., Baranzelli, C., Perpiña Castillo, C. (2013). Land Use Related Indicators for Resource Efficiency - An analytical framework for the assessment of the land milestone proposed in the Roadmap for Resource Efficiency. http://doi.org/10.2788/94223

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 - Batista e Silva, F., Lavalle, C., & Koomen, E. (2013). A procedure to obtain a refined European land use/cover map. Journal of Land Use Science, 8(3), 255–283. http://doi.org/10.1080/1747423X.2012.667450
- EU Reference Scenario 2014 projected land use maps from LUISA (urban land use class)
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, only industrial and commercial areas with a minimum width of 100 meters were considered in the indicator.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban - rural topology (NUTS3 3 category levels);

- Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%

LF 432 - Productivity of built-up areas

1. Identification (title; code) and classification (DPSIR; typology)

EUROSTAT: Eurobase > Tables on EU policy> Europe 2020 Indicators > Resource efficiency > Dashboard indicators > Land > Productivity of built-up areas (t2020_rd110)

LUISA Framework : LF_432

DPSIR typology: Pressure.

2. Rationale — justification for indicator selection; references

The 'built-up areas' in combination with the GDP, gives more depth information on whether that built-up areas within a region/ country has been efficiently used to generate economic value added.

References:

European Commission. (2011a). COM (2011) 571 - Roadmap to a Resource Efficient Europe. European Commission, Documentation and data. European Comission. Retrieved from:

http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf

European Commission. (2011b). SEC (2011) 10 67 - Commission Staff Working Paper. Analysis associated with the Roadmap to a Resource Efficient Europe Part II. System (Vol. 147). Retrieved from:

http://ec.europa.eu/environment/resource_efficiency/pdf/working_paper_part2.pdf

Eurostat/ European Commission. (2013). Productivity of artificial land (t2020_rd100). Retrieved April 9, 2015, from:

http://ec.europa.eu/eurostat/cache/metadata/DE/t2020_rd100_esmsip.htm

3. Indicator definition — definition; units

Land productivity compares the total economic output (GDP) to the size of the built-up areas (this includes residential area, industrial/commercial land, green urban areas, sport and leisure facilities). The indicator presents data for the year 2010, and the net changes in a short term period (2010 -2020) and in a long term period (2010 - 2050), for all EU 28 Member States in GDP Million euros (volumes in constant prices of year 2010) per Km^2.

4. Policy context and targets — context description; targets; related policy documents

Productivity of built-up areas is a 'Resource Efficiency indicator'. It has been chosen as a dashboard indicator presented in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency (Eurostat/ European Commission, 2013).

5. Policy questions — key policy questions; specific policy questions

The productivity of the built-up areas indicator aims to answer the following policy questions:

- How well the built-up areas are used for productive purposes?
- How much the land productivity is expected to increase or decrease according to the Reference scenario In EU-28?

6. Methodology (indicator calculation; gap filling; references)

The 'productivity of the built-up areas' is defined as the Gross Domestic Product divided by the surface of built-up areas (Km^2). Built-up areas are the sum of the land uses classified as urban fabric, including CLC11X residential (continuous and discontinuous), CLC121 industrial/commercial land, and CLC 14X green urban areas, sport and leisure facilities. Ideally, the productivity of land should be expressed in purchasing power standards (PPS) to facilitate comparisons of productivity of built-up area between countries during one time period. However, the projected GDP figures were available only expressed in GDP Million euros (volumes in constant prices of year 2010) and the conversion of the GDP was not possible with the projected data available.

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 - Batista e Silva, F., Lavalle, C., & Koomen, E. (2013). A procedure to obtain a refined European land use/cover map. Journal of Land Use Science, 8(3), 255–283. http://doi.org/10.1080/1747423X.2012.667450
- EU Reference Scenario 2014 projected land use maps from LUISA (urban land use classes)
- GDP in Million Euros from the GEM-E3 model (National Technical University of Athens, 2010) - National Technical University of Athens. (2010). General Equilibrium Model for Economy – Energy – Environment - GEM-E3 MODEL MANUAL. Athens, Greece.
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main limitation from this indicator arises from the fact that we use the GDP in Million Euros instead of the GDP in PPS as suggested by Eurostat (Eurostat - productivity of built-up areas metadata, 2013) which would not allow for comparisons in time nor between member states. In addition, the spatial resolution of the source data is 100 m2. Therefore, only built-up areas with a minimum width of 100 meters were considered in the indicator.

This indicator can be limited because it only compares total output to the size of the built-up areas ignoring factors such as urban density, i.e. a highly productive regions might have low urban density and settlements are scattered.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban - rural topology (NUTS3 3 category levels);
- Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%

LF 433 - Built-up area per person

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_433 - Built-up area per person

DPSIR typology: descriptive indicator of Pressure.

2. Rationale — justification for indicator selection; scientific references

The 'built-up area per inhabitant', also commonly called 'land use intensity', measures the built-up land used by comparing the size of the built-up areas with the population expressed in sq. m per inhabitant (m^2 per person). This indicator is not part of the RE indicators. It was included in this study since it provides useful information on the efficiency of land used for residential, sport and leisure, and economic activities. Thus it can be easily understood, measured and communicated.

References:

Kasanko, M., Barredo, J. I., Lavalle, C., McCormick, N., Demicheli, L., Sagris, V., & Brezger, A. (2006). Are European cities becoming dispersed?. A comparative analysis of 15 European urban areas. Landscape and Urban Planning, 77, 111–130. http://doi.org/10.1016/j.landurbplan.2005.02.003

Lavalle, C., Barbosa, A. L., Mubareka, S., Jacobs-Crisioni, C., Baranzelli, C., & Castillo, C. P. (2013). Land Use Related Indicators for Resource Efficiency - An analytical framework for the assessment of the land milestone proposed in the Roadmap for Resource Efficiency. http://doi.org/10.2788/94223

Prokop, G. (2011). Report on best practices for limiting soil sealing and mitigating its effects. http://doi.org/10.2779/15146

3. Indicator definition — definition; units

The built-up area per inhabitant measure the land consumption by comparing the size of the built-up areas with the population expressed in sq. m per inhabitants (m^2 per person).

The indicator presents data for the year 2010 and the net changes in a short term period (2010 -2020) and in a long term period (2010 - 2050), for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents

There is no target associated with this indicator.

5. Policy questions — key policy questions; specific policy questions

The built-up area per inhabitant indicator aims to answer the following policy questions:

- Are Europe using land more efficiently?
- Do the land-use intensities improve or follow an unsustainable trend?

6. Methodology (indicator calculation; gap filling; references)

The 'built-up areas' in km^2 is the total sum of the land uses classified as urban fabric including, CLC11X residential (continuous and discontinuous), CLC121 industrial/commercial land, and CLC 14X green urban areas, sport and leisure facilities divided by population of the region (NUTSx).

7. Data specifications — data references; external data references; data sources in latest figures

- Refined CORINE land cover 2006 - Batista e Silva, F., Lavalle, C., & Koomen, E. (2013). A procedure to obtain a refined European land use/cover map. Journal of Land Use Science, 8(3), 255–283. http://doi.org/10.1080/1747423X.2012.667450
- EU Reference Scenario 2014 projected land use maps from LUISA (urban & industrial/commercial land uses classes)
- EUROPOP2010, population projections from Eurostat (European Commission/ DG Economic and Financial Affairs, 2011) - European Commission/ DG Economic and Financial Affairs. (2011). The 2012 Ageing Report: Underlying Assumptions and Projection Methodologies. Retrieved from ec.europa.eu/economy_finance/publications/.../2012/.../ee-2012-2_en.pdf
- EU-28 administrative regions: EuroBoundaryMap v81

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, only residential areas with a minimum width of 100 meters were considered in the indicator.

9. Responsibility and ownership (indicator manager; ownership)

Joint research Centre, Institute for Environment and Sustainability, Sustainability Assessment Unit (H08)

10. Further work (short-term work; long-term work)

Short-term: built-up by NUTS3 , LAU 1 and 2, Large Urban Zones (LUZ) and other relevant classification groups such as:

- Urban - rural topology (NUTS3 3 category levels);
- Less developed regions (GDP per capita < 75% of EU average), transition regions (GDP per capita between 75% and 90%) and more developed regions (GDP per capita > 90%

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Barbosa, A (2015): LF433 - Built-up area per inhabitant (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 441 - Potential accessibility

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_441- Potential Accessibility

2. Rationale — justification for indicator selection; scientific references

Potential accessibility can be considered as one of the key outputs of a transport system. It has its source in spatial interaction models and measures the amount of interactions that may be originating or terminating at one point if there would be no competition for interactions. Key publications for this indicator are (Hansen, 1959; Geurs and Van Wee, 2004; Gutiérrez and Urbano, 1996). The indicator is commonly associated with economic welfare and economic opportunities. This indicator has been used as one of four indicators to explore cohesion effects of TEN-T policies (López et al., 2008; Jacobs-Crisioni et al., 2014).

References used:

Geurs KT and Van Wee B. (2004) Accessibility evaluation of land-use and transport strategies: Review and research directions. Journal of Transport Geography 12: 127-140.

Gutiérrez J and Urbano P. (1996) Accessibility in the European Union: The impact of the trans-European road network. Journal of Transport Geography 4: 15-25.

Hansen WG. (1959) How accessibility shapes land use. Journal of the American Institute of Planners 25: 73-76.

Jacobs-Crisioni C, Batista e Silva F, Lavalle C, et al. (2014) Accessibility and territorial cohesion in a case of transport infrastructure improvements with endogenous population distributions.

López E, Gutiérrez J and Gómez G. (2008) Measuring regional cohesion effects of large-scale transport infrastructure investments: An accessibility approach. European Planning Studies 16: 277-301.

3. Indicator definition — definition; units

Potential accessibility measures the potential amount of interactions one may have at different points in space. Crucial are the amount of potential interaction destinations, which in the presented indicator is observed as number of people in destination zones, and the degree of geographic separation, which in the presented indicator is observed by travel times. The higher the amount of people in destination zones or the lower the travel times to those zones, the higher the level of potential accessibility in this indicator.

4. Policy context and targets — context description; targets; related policy documents

This indicator is particularly useful in the evaluation of transport network investments such as the TEN-T project, and is in the LUISA framework used to explore reciprocities between population developments and accessibility improvements due to transport network investments. It can be used to some degree to assess impacts on economic opportunities for services and industries, to assess opportunities for specialization, and even to assess urbanization pressures on open space.

5. Policy questions — key policy questions; specific policy questions

The potential accessibility indicator is useful to answer the following policy questions:

- How will population developments and/or infrastructure investments affect economic opportunities?
- What is the impact of population developments and/or infrastructure investments on urbanization pressures?

6. Methodology (indicator calculation; gap filling; references)

The potential accessibility measure is computed as in the following equation:

$$\boldsymbol{A_i} = \sum_{i=1}^{n} \frac{\boldsymbol{P_j}}{\boldsymbol{f}(\boldsymbol{c_{ij}} + \boldsymbol{c_j})},$$

in which accessibility levels A for each origin point *i* are computed using current population counts *P* in destination zones *j,* the results of a function of traveltime *c* between *i* and *j*, and a zone-specific internal traveltime $\boldsymbol{c_j}$. The origin points are equally distributed throughout Europe with roughly 15km intervals. The destination points are currently the centroids of the finest available zonal units in an area, in most cases either LAU-1 or LAU-2 units.

No penalties on potential cross-border interactions are currently imposed on accessibility values. Traveltimes are obtained from the TRANS-TOOLS road network (Rich et al., 2009) using a shortest path algorithm assuming free-flow traveltimes. To account for the unknown distribution of destinations within zones an additional traveltime is added that essentially depends on a destination zone's geographical area. It uses the Frost and Spence (1995) approach to approximate internal Euclidean distances; thus, internal distance $\boldsymbol{d_j}$ is assumed to be $\boldsymbol{d_j = 0.5\sqrt{AREA_j/\pi}}$. Subsequently, internal travel times $\boldsymbol{c_j}$ are computed from $\boldsymbol{d_j}$ by means of a function in which effective travel speeds in km/h are obtained with the fitted function $\boldsymbol{10.66 + 13.04\ln(d_j)}$, with a minimum of 5 km/h imposed on very small zones. For details on the fitted function we refer to Jacobs-Crisioni and Koomen (2014). Lastly the distance decay function $\boldsymbol{f(c_{ij})}$ in the model is of the form $\boldsymbol{c_{ij}}^{\mathbf{1.5}}$. The form of the distance decay function was chosen among many tested in a data fitting exercise for LUISA because, in terms of explained variance, it fits best on observed population distributions. The measure is computed for all origin points and subsequently spatially interpolated to a 100m raster using an inverse distance weighting method to obtain an accessibility value for each grid cell.

References used:

Frost ME and Spence NA. (1995) The rediscovery of accessibility and economic potential: the critical issue of self-potential. Environment and Planning A 27: 1833-1848.

Jacobs-Crisioni C and Koomen E. (2014) The influence of national borders on urban development in border regions: An accessibility approach.

Rich J, Brõcker J, Hansen CO, et al. (2009) Report on scenario, traffic forecast and analysis of traffic on the TEN-T, taking into consideration the external dimension of the union - TRANS-TOOLS version 2; model and data improvements. Copenhagen.

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios population distributions: year 2010, 2020, 2030, 2040 and 2050
- Roads: Trans-Tools roads network
- Hybrid sets of smallest available zones for all modelled countries

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Methodological uncertainty:

With the method here presented to assess accessibility it is important to consider some methodological limitations for a correct interpretation. One important aspect is that for many types of interactions such as job commutes, resources are limited and competition is relevant. For such types of interactions an accessibility indicator that takes competition into account is more suitable. Another important aspect is the selection of the distance decay function used for the indicator. Currently a distance decay function is used that is selected because of its usefulness in explaining urban patterns; but ideally such a function is estimated from observed trips of European citizens. One last methodological uncertainty is related to the selection of so-called free-flow travel times (e.g., the travel times if a car continuously travels at the recorded maximum speed). The used travel times do not take congestion into account, and may thus cause a slight overestimation of accessibility in crowded areas. On the other hand, congestion is a phenomenon that happens only a small proportion of the day, so that the effect of congestion on average daily travel times must not be overestimated.

Dataset uncertainty:

The largest source of uncertainty is that only the links observed in the Trans-Tools network are relevant for potential interactions, while in reality the European road network has a much finer grain. The underlying road network is only simulated as connectors to the Trans-Tools network. Discrepancies in interaction opportunities that may in reality exist due to locally more or less efficient network structures are therefore not observed.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

NA

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Jacobs Crisioni, C (2015): LF441 - Potential accessibility (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 442 - Network efficiency

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_442 – Network Efficiency

2. Rationale — justification for indicator selection; scientific references

Network efficiency can be considered as one of the key outputs of a transport system. The indicator indicates the degree of connectivity a transport system offers, compared to an ideal transport system. This indicator has been used as one of four indicators to explore cohesion effects of TEN-T policies (López et al., 2008; Jacobs-Crisioni et al., 2014).

References used:

Jacobs-Crisioni C, Batista e Silva F, Lavalle C, et al. (2014) Accessibility and territorial cohesion in a case of transport infrastructure improvements with endogenous population distributions.

López E, Gutiérrez J and Gómez G. (2008) Measuring regional cohesion effects of large-scale transport infrastructure investments: An accessibility approach. European Planning Studies 16: 277-301.

3. Indicator definition — definition; units

Network efficiency is an index that indicates the distance between the connectivity offered by an existing, planned or modelled transport network and the connectivity offered by an ideal network. A network efficiency value of 1 indicates that the network connectivity is ideal. The further away from 1, the less efficient the network is.

4. Policy context and targets — context description; targets; related policy documents

This indicator is particularly useful in the evaluation of transport network investments such as the TEN-T project, and is in the LUISA framework used to explore reciprocities between population developments and accessibility improvements due to transport network investments. It can be used to in particular to assess the usefulness of transport network investments.

5. Policy questions — key policy questions; specific policy questions

The network efficiency indicator is useful to answer the following policy questions:

- How efficient is the existing transport network, and where are improvements obtainable?
- What is the efficiency increase of a planned transport network extension?

6. Methodology (indicator calculation; gap filling; references)

The network efficiency index is computed as follows:

$$E_i = \sum_{j=1}^{n} \frac{c_{ij}}{\acute{c}_{ij}} P_j \Big/ \sum_{j=1}^{n} P_j,$$

in which network efficiency value E for each origin point *i* is computed using current population counts *P* in destination zones *j*, travel time *c* between *i* and *j*, and a zone-specific internal traveltime c_j. Ideal traveltimes $\acute{c}_{ij}$ are based on Euclidean distances between *i* and *j* and the fastest maximum speed (130 km/h) recorded in the road network data. The origin points are equally distributed throughout Europe with roughly 15km intervals. The destination points are currently the centroids of the finest available zonal units in an area, in most cases either LAU-1 or LAU-2 units. No penalties on potential cross-border interactions are currently imposed on accessibility values. Traveltimes are obtained from the TRANS-TOOLS road network (Rich et al., 2009) using a shortest path algorithm assuming free-flow traveltimes. The measure is computed for all origin points and subsequently spatially interpolated to a 100m raster using an inverse distance weighting method to obtain an accessibility value for each grid cell.

References used:

Rich J, Brõcker J, Hansen CO, et al. (2009). Report on scenario, traffic forecast and analysis of traffic on the TEN-T, taking into consideration the external dimension of the union - TRANS-TOOLS version 2; model and data improvements. Copenhagen.

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios population distributions: year 2010, 2020, 2030, 2040 and 2050
- Roads: Trans-Tools roads network
- Hybrid sets of smallest available zones for all modelled countries

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Methodological uncertainty:

With the method here presented to assess network efficiency it is important to consider some methodological limitations for a correct interpretation. One important aspect is that origin-destination relationship relations are weighted by population at the destination, so that a travel time improvement to population centres has a larger impact on network efficiency than a travel time improvement to a rural area. Thus other activities such as employment and recreation are not accounted for. Another important aspect is that the method assumes straight lines with very high maximum speeds as an ideal situation. It must be abundantly clear that such a network design is only ideal in a very limited sense, and safety and environmental aspects related to network design are ignored here. One last methodological uncertainty is related to the selection of so-called free-flow travel times (e.g., the travel times if a car continuously travels at the recorded maximum speed). The used travel times do not take congestion into account, and may thus cause a slight overestimation of network efficiency in particular because crowded areas have a bigger impact on values of the indicator. On the other hand, congestion is a phenomenon that happens only a small proportion of the day, so that the effect of congestion on average daily travel times must not be overestimated.

Dataset uncertainty:

The largest source of uncertainty is that only the links observed in the Trans-Tools network are relevant for network efficiency, while in reality the European road network has a much finer grain. The underlying road network is only simulated as connectors to the TRANS-TOOLS network. Discrepancies in network efficiency that may in reality exist due to locally more or less efficient network structures are therefore not observed.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work) NA
11. Publisher: European Commission - Joint Research Centre Lavalle, C.; Jacobs-Crisioni, C (2015): LF442 - Network efficiency (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 443 - Location accessibility

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_443 – Location accessibility

2. Rationale — justification for indicator selection; scientific references

Location accessibility can be considered as one of the key provisions of a transport system. The indicator indicates how well the transport system connects an area to main cities. This indicator has been used as one of four indicators to explore cohesion effects of TEN-T policies (López et al., 2008; Jacobs-Crisioni et al., 2014).

References used:

Jacobs-Crisioni C, Batista e Silva F, Lavalle C, et al. (2014) Accessibility and territorial cohesion in a case of transport infrastructure improvements with endogenous population distributions.

López E, Gutiérrez J and Gómez G. (2008) Measuring regional cohesion effects of large-scale transport infrastructure investments: An accessibility approach. European Planning Studies 16: 277-301.

3. Indicator definition — definition; units

Location accessibility indicates the travel times to the largest cities in the country or neighbouring countries. Only very large cities that are economically dominant in a region are selected.

4. Policy context and targets — context description; targets; related policy documents

This indicator is particularly useful in the evaluation of transport network investments such as the TEN-T project, and is in the LUISA framework used to explore reciprocities between population developments and accessibility improvements due to transport network investments. It can be used to in particular to assess the connectivity impacts of transport network investments.

5. Policy questions — key policy questions; specific policy questions

The location accessibility indicator is useful to answer the following policy questions:

- To what degree are places connected to key national economic centres?
- What is the connectivity impact of proposed infrastructure investments?

6. Methodology (indicator calculation; gap filling; references)

The location accessibility indicator is computed as follows:

$$L_i = \sum_{j=1}^{n} c_{ij} P_j S_j \Big/ \sum_{j=1}^{n} P_j S_j,$$

with

$$S_j = \begin{cases} 1 \text{ if } j \text{ is in a capital or large city} \\ 0 \text{ if not} \end{cases},$$

so that location access for each origin point *i* is computed using current population counts *P* in destination zones *j* and travel time *c* between *i* and *j*. The origin points are equally distributed throughout Europe with roughly 15km intervals. The destination points are currently the centroids of the finest available zonal units in an area, in most cases either LAU-1 or LAU-2 units. No penalties on potential cross-border interactions are currently imposed on accessibility values. Traveltimes are obtained from the TRANS-TOOLS road network (Rich et al., 2009) using a shortest path algorithm assuming free-flow traveltimes. The measure is computed for all origin points and subsequently spatially interpolated to a 100m raster using an inverse distance weighting method to obtain an accessibility value for each grid cell. Only a limited set of cities is used as destinations. The full list of destinations is: Amsterdam, Ankara, Athens, Barcelona, Belgrade, Berlin, Birmingham, Bucharest, Budapest, Copenhagen, Dublin, Hamburg, Helsinki, Istanbul, Lisbon, Ljubljana, London, Lyon, Madrid, Manchester, Milan, Munich, Naples, Oslo, Paris, Prague, Riga, Rome, Rotterdam, Ruhr area, Sarajevo, Sofia, Stockholm, Tallinn, Turin, Vienna, Vilnius, Warsaw, Zagreb

References used:

Rich J, Brõcker J, Hansen CO, et al. (2009) Report on scenario, traffic forecast and analysis of traffic on the TEN-T, taking into consideration the external dimension of the union - TRANS-TOOLS version 2; model and data improvements. Copenhagen.

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios population distributions: year 2010, 2020, 2030, 2040 and 2050
- Roads: Trans-Tools roads network
- Hybrid sets of smallest available zones for all modelled countries

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Methodological uncertainty:

With the method here presented to assess location accessibility it is important to consider some methodological limitations for a correct interpretation. One important aspect is that the selected destination zones in S are based on arbitrary choices, so that the set may miss particular important cities or rather include cities that are not very relevant for the location at hand. The list of selected cities must therefore be taken into account when interpreting the indicator. Another important aspect is that the used travel times do not take congestion into account, and may thus cause a slight overestimation of location accessibility in particular because crowded areas have a bigger impact on values of the indicator. On the other hand, congestion is a phenomenon that happens only a small proportion of the day, so that the effect of congestion on average daily travel times must not be overestimated.

Dataset uncertainty:

The largest source of uncertainty is that only the links observed in the Trans-Tools network are relevant for location accessibility, while in reality the European road network has a much finer grain. The underlying road network is only simulated as connectors to the TRANS-TOOLS network. Discrepancies in location accessibility that may in reality exist due to locally more or less efficient network structures are therefore not observed.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

NA
11. Publisher: European Commission - Joint Research Centre Lavalle, C.; Jacobs-Crisioni, C. (2015): LF443 - Location accessibility (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 444 - Daily accessibility

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_444 - Daily accessibility

2. Rationale — justification for indicator selection; scientific references

Daily accessibility can be considered as one of the key provisions of a transport system. The indicator indicates how many people are resident within a limited travel time. The selection of a maximum travel time is based on the criterion that it must be possible to make a round trip on a working day. This indicator has been used as one of four indicators to explore cohesion effects of TEN-T policies (López et al., 2008; Jacobs-Crisioni et al., 2014).

References used:

Jacobs-Crisioni C, Batista e Silva F, Lavalle C, et al. (2014) Accessibility and territorial cohesion in a case of transport infrastructure improvements with endogenous population distributions.

López E, Gutiérrez J and Gómez G. (2008) Measuring regional cohesion effects of large-scale transport infrastructure investments: An accessibility approach. European Planning Studies 16: 277-301.

3. Indicator definition — definition; units

Daily accessibility indicates the amount of people that live within four hours of driving from the location at hand.

4. Policy context and targets — context description; targets; related policy documents

This indicator is particularly useful in the evaluation of transport network investments such as the TEN-T project, and is in the LUISA framework used to explore reciprocities between population developments and accessibility improvements due to transport network investments. It can be used to in particular to assess the social and economic opportunity impacts of transport network investments and population changes.

5. Policy questions — key policy questions; specific policy questions

The daily accessibility indicator is useful to answer the following policy questions:

- To what degree do transport infrastructure and land-use patterns enable social and economic opportunities?
- How are social and economic opportunities affected by a proposed transport infrastructure investment or by projected land-use changes?

6. Methodology (indicator calculation; gap filling; references)

The daily accessibility indicator is computed as follows:

$$D_i = \sum_{j=1}^{n} P_j \hat{c}_{ij},$$

with

$$\hat{c}_{ij} = \begin{cases} 1 \; if \; c_{ij} \leq 240 \; minutes \\ 0 \; if \; c_{ij} > 240 \; minutes \end{cases},$$

so that location access for each origin point *i* is computed using current population counts *P* in destination zones *j* and travel time *c* between *i* and *j.* The origin points are equally distributed throughout Europe with roughly 15km intervals. The destination points are currently the centroids of the finest available zonal units in an area, in most cases either LAU-1 or LAU-2 units. No penalties on potential cross-border interactions are currently imposed on accessibility values. Traveltimes are obtained from the TRANS-TOOLS road network (Rich et al., 2009) using a shortest path algorithm assuming free-flow traveltimes*.* The measure is computed for all origin points and subsequently spatially interpolated to a 100m raster using an inverse distance weighting method to obtain an accessibility value for each grid cell. A maximum of 4 hours of travel time is imposed on *c* through $\hat{c}_{ij}$ because this maximum travel time would allow anybody to make a roundtrip to the destination in the course of a regular working day.

References used:

Rich J, Brõcker J, Hansen CO, et al. (2009) Report on scenario, traffic forecast and analysis of traffic on the TEN-T, taking into consideration the external dimension of the union - TRANS-TOOLS version 2; model and data improvements. Copenhagen.

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios population distributions: year 2010, 2020, 2030, 2040 and 2050
- Roads: Trans-Tools roads network
- Hybrid sets of smallest available zones for all modelled countries

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Methodological uncertainty:

With the method here presented to assess daily accessibility it is important to consider some methodological limitations for a correct interpretation. One important aspect is that the selected maximum travel time in $\hat{c}_{ij}$ is based on an arbitrary choice, so that the set may overestimate or underestimate the amount of opportunities that one may experience if daily trips are in fact less or more limited in terms of travel time. The four hour maximum value must therefore be taken into account when interpreting the indicator. Another important aspect is that the used travel times do not take congestion into account, and may thus cause a slight overestimation of daily accessibility in particular because crowded areas have a bigger impact on values of the indicator. On the other hand, congestion is a phenomenon that happens only a small proportion of the day, so that the effect of congestion on average daily travel times must not be overestimated.

Dataset uncertainty:

The largest source of uncertainty is that only the links observed in the Trans-Tools network are relevant for daily accessibility, while in reality the European road network has a much finer grain. The underlying road network is only simulated as connectors to the TRANS-TOOLS network. Discrepancies in daily accessibility that may in reality exist due to locally more or less efficient network structures are therefore not observed.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

NA

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Jacobs-Crisioni, C. (2015): LF444 - Daily accessibility (LUISA Platform REF2014). European Commission - Joint Research Centre.

6. Land function 5 - Provision of regulation by natural physical structures and processes

The land function 5 – provision of regulation by natural physical structures and processes refers to the capacity of ecosystem to remove air pollutants, prevent soil erosion, the capacity for retention of water in the landscape, habitat and gene pool protection, soil formation composition and global/local climate regulation. The indicators proxy presented here are part of the Total ecosystem Service Index (TESI8). The TESI is a composite indicator that measure aggregated capacity to deliver ecosystem services (Maes, Paracchini, & Zulian, 2011).

The 'urban population exposed to PM10 concentrations', 'the urban population exposure to air pollution by particulate matter', 'the capacity and demand for coastal protection' and the Micro climate regulation indicators are still under development, thus they were not yet integrated in the visualization tool.

Table 5. List of land function 'provision of regulation by natural physical structures and processes' indicators.

<table>
<tr><th>Land function</th><th>Division</th><th>Sub-division</th><th>Indicator Code</th><th>Indicator</th><th>Unit</th></tr>
<tr><td rowspan="8">LF 5 b Provision of regulation by natural physical structures and processes</td><td rowspan="3">Mediation of waste, toxics and other nuisances</td><td rowspan="3">Mediation by ecosystems (Capacity of ecosystem to remove air pollutants)</td><td>LF_511</td><td>NO2 removal by urban vegetation</td><td>(t/ha/year)</td></tr>
<tr><td>LF_512</td><td>Urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year (under development)</td><td>%</td></tr>
<tr><td>LF_513</td><td>Urban population exposure to air pollution by particulate matter (under development)</td><td>Micrograms per cubic meter</td></tr>
<tr><td rowspan="4">Mediation of flows</td><td rowspan="2">Mass flows (Capacity of the Land Cover to prevent soil erosion)</td><td>LF_521</td><td>Capacity of ecosystems to avoid soil erosion</td><td>(dimensionless)</td></tr>
<tr><td>LF_522</td><td>Soil retention</td><td>(t/ha)</td></tr>
<tr><td>Liquid flows (Capacity of coastal ecosystem to protect against inundation and erosion from waves, storm or sea level rise)</td><td>LF_523</td><td>Ratio between capacity and demand for coastal protection (under development)</td><td>(dimensionless)</td></tr>
<tr><td>Liquid flows (Capacity for retention of water in the landscape)</td><td>LF_524</td><td>Water Retention</td><td>(dimensionless)</td></tr>
<tr><td>Maintenance</td><td>Lifecycle</td><td>LF_531</td><td>Relative pollination</td><td>(dimensionle</td></tr>
</table>

	of physical, chemical, biological conditions	maintenance, habitat and gene pool protection		potential	ss)
		Soil formation composition	LF_532	C- Stock changes	(t/ha)
	Atmospheric composition and climate regulation	Global climate regulation by reduction of GHG concentrations	LF_541		
		Micro climate regulation (Capacity of ecosystems to regulate urban)	LF_542	Colling effect	NA

LF 511 - NO2 Removal by urban vegetation

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_511 NO_2 Removal by urban vegetation

CICES classification of ecosystem services: the NO_2 Removal by urban vegetation is classified as follows: Section: Regulation & Maintenance of ecosystem services, Division: Mediation of waste, toxics and other nuisances, Group: Mediation by ecosystem, Class: Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals.

DPSIR typology: descriptive indicator of Response

2. Rationale — justification for indicator selection; scientific reference

Air quality is the principal environmental factor linked to preventable illness and premature mortality in the EU and still has significant negative effects on much of Europe's natural environment. NO_2 is one of the main pollutants emitted by road vehicles, shipping, power generation industry and households. Over a quarter of EU's Air Quality Management Zones exceed the limit values for nitrogen dioxide (NO_2) (EC, 2013).

On the other hand, urban green spaces and green infrastructures provide ecosystem services that sustain and promote human health: vegetation traps air pollution playing an important role for air quality regulation. Many studies (Escobedo and Nowak. 2009, Litschke and Kuttler, 2008, Nowak et al. 2006, Nowak et al., 2013) had assessed the removal capacity of pollutants by vegetation, focusing mainly in urban areas, where concentrations due to human activities are expected to be higher.

Removal capacity is calculated as the product of dry deposition velocity and pollutant concentration (Wesely and Hicks, 2000), derived on the context of the LUISA modelling platform. The development of a spatially explicit indicator, allows the development of removal capacity maps that can be used as tools for management plans to improve air quality and to make projections on future scenarios.

References

Escobedo F.J., Nowak D.J., 2009. Spatial heterogeneity and air pollution removal by an urban forest. Landscape and Urban Planning 90, 102-110.

Litschke T., Kuttler W., 2008. On the reduction of urban particle concentration by vegetation – a review. Meteorologische Zeitschrift 17(3), 229-240.

Nowak D.J., Crane D.E., Stevens J.C., 2006. Air pollution removal by urban trees and shrubs in the United States. Urban Forestry & Urban Greening 4, 115-23.

Nowak D.J., Hirabayashi S., Bodine A., Hoehn R., 2013. Modelled PM2.5 removal by trees in ten U.S. cities and associated health effects. Environmental Pollution 178, 395-402.

Wesely ML, Hicks BB (2000) A review of the current status of knowledge on dry deposition. Atmospheric Environment 34, 2261-2282.

3. Indicator definition — definition; units

Removal capacity (RC) is calculated as the product of deposition velocity (mainly dry) (DV) and pollutant concentration (C) (Wesely and Hicks, 2000) according to equation 1:

$$RC\left[\frac{T}{Ha \times y}\right] = \boldsymbol{Dry\ deposition\ velocity}\ \left[\frac{m}{s}\right] \times \boldsymbol{NO2\ concentration}\left[\frac{\mu g}{m3}\right] \times \boldsymbol{0.365} \quad \text{(Equation 1)}$$

References

Wesely ML, Hicks BB (2000) A review of the current status of knowledge on dry deposition. Atmospheric Environment 34, 2261-2282.

4. Policy context and targets — context description; targets; related policy documents

The EU Air Quality Directive (2008/50/EC) have set forth legally binding limit values for ground-level concentrations of NO_2, for hourly and annual exposure: the short-term limit establishes a limit value on daily mean concentrations of 200 μg/m3 not to exceeded more than 18 times per year. The annual mean limit value is set to 40μg/m^3.This Directive declared that this limit value should have been met by January 1st, 2010. The World Health Organisation (WHO) set the same average limit values within the Air Quality Guideline.

References

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (Offic J EU, L 152, 11 June 2008, 1–44), 2008.

5. Policy questions — key policy questions; specific policy questions

The NO_2 Removal by urban vegetation indicator aims to answer the following policy questions:

- Does vegetation and in particular urban vegetation provide ecosystem services to improve air quality?
- How air quality may change in response to future land use scenarios specifically those related to the existence of vegetation?
- Which functional group may be more affected the future land use changes: forest or farmland species? And where?

6. Methodology (indicator calculation; gap filling; references)

According to equation 1, NO2 Removal by urban vegetation was calculated as the product of deposition velocity and NO2 concentration.

Air pollutant deposition velocity was assessed following the approach proposed by Pistocchi et al. (2010) that estimates deposition velocity (DV) as a linear function of wind speed at 10 m height (w) and land cover type:

$$\boldsymbol{DV = \alpha j + \beta j \times w} \quad \text{(Equation 2)}$$

where α and β are, respectively, the intercept and slope coefficients corresponding to each broad land cover type j (namely forest, bare soil, water or a combination of the previous).

NO2 concentration levels were estimated from a concentration map derived from Land Use Regression (LUR) models, a computation approach widely used for assessing air pollution at different scales (Beelen et al. 2013, Brauer et al., 2008, Briggs et al., 1997, Hoek et al., 2008, Jerrett et al, 2005). The LUR model was built using NO_2 concentration for 2010 from the monitoring sites included in the AirBase database (dependent variable) and several parameters (independent variables) defined within a Geographic Information System (GIS). Some of these variables reflect sources or sinks for air pollution such as the road network, different types of land use and population density. Furthermore, factors such as elevation, topographical exposure (from Farr et al., 2007), distance to sea, and climatic data as annual mean temperature and annual mean wind speed (from also influence the spatial concentration of pollutants and were included for the modelling. The Land Use Regression model was developed using Random Forest regression techniques (Breiman, 2001). The land use and population data parameters were taken from the LUISA outputs (Baranzelli et al, 2015) allowing to spatially allocate current and future land uses for EU28 countries. The same LUR model was used to for the different scenarios of land use to predict evolution of concentrations and deposition velocity of NO_2 according to the changes in land use and population density.

Results of both, concentration and deposition velocity levels, were developed as GIS maps, allowing the calculation of removal flux map with a simple map algebra multiplication of both factors. The final map of annual removal capacity was obtained multiplying the estimated removal flux map by a map of share of vegetation within pixel. Areas covered by vegetation were calculated by combination of detailed maps of urban vegetation and forest, aggregated to 100-meter resolution. For urban vegetation, the green layers of the Global Human Settlement Layer were used (Florczyk et al., 2014, Pesaresi et al, 2013).

Hansen. For forests, the High Resolution Global Forest map developed by Hansen (2014) was used. In overlapping areas, the maximum value of both maps was applied. Final map of vegetation had values between zero (no vegetation) and one (totally covered by vegetation).

Final results of removal capacity were averaged within different EU-28 administrative regions.

References

AirBase - The European air quality database: http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-7. Accessed October 2014.

Beelen R, Hoek G, Vienneau D, Eeftens M, Dimakopoulou K, Pedeli X et al., 2013 Development of NO2 and NOx land use regression models for estimating air pollution exposure in 36 study areas in Europe: The ESCAPE project. Atmos Env 72: 10–23.

Brauer, C. Lencar, L. Tamburic, M.   Koehoorn, P. Demers, C. Karr, 2008. A cohort study of traffic-related air pollution impacts on birth outcomes. Environ Health Perspect, 116 (5), pp. 680–686.

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European Commission, 2013: Communication form the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Clean Air Programme for Europe. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0918&from=EN

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Florczyk A., J., Ferri S., Syrris V., Kemper, T., Halkia, M., Soille, P., Pesaresi, M., (2014) A New Global Human Settlement Layer Of Europe From Optical HR/VHR RS Data. IGARSS 2014.

Hansen MC, et al. 2013 High-resolution global maps of 21st-century forest cover change. Science 342, 850–853. (doi:10.1126/science.1244693).

Hoek G, Beelen R, de Hoogh K, Vienneau D, Gulliver J, Fischer P et al. 2008: A review of land-use regression models to assess spatial variation of outdoor air pollution. Atmos Env; 42: 7561–7578.

Jerrett M., Burnett R.T., Ma R.J., Pope C.A., Krewski D., Newbold K.B., Thurston G., Shi Y.L., Finkelstein N., Calle E.E., and Thun M.J. (2005). Spatial analysis of air pollution and mortality in Los Angeles. Epidemiology: 16(6): 727-736.

Baranzelli C., Jacobs-Crisioni C., Batista e Silva F., Perpiña Castillo C., Barbosa A., Arevalo Torres J, Lavalle C. 2014. The Reference scenario in the LUISA platform – Updated configuration 2014. Towards a Common Baseline Scenario for EC Impact Assessment procedures. EUR 27019 EN. Luxembourg: Publications Office of the European Union, (2015).

Pesaresi et al. (2013) A global human settlement layer from optical hr/vhr rs data: Concept and first results. IEEE JSTAR 6(5):2102–2131.

Pistocchi A, Zulian G, Vizcaino P, Marinov D (2010) Multimedia Assessment of Pollutant Pathways in the Environment, European Scale Model (MAPPE-EUROPE). EUR 24256 EN. Luxembourg (Luxembourg): Publications Office of the European Union; 2010. JRC56335.

Wesely ML, Hicks BB (2000) A review of the current status of knowledge on dry deposition. Atmospheric Environment 34, 2261-2282.

7. Data specifications — data references; external data references; data sources in latest figures

- Data of measured concentrations of NO_2 were taken from the monitoring stations within the AirBase database.
- Topographical exposure and elevation data were taken from the Global digital elevation data based on the NASA Shuttle Radar Topographic Mission (SRTM) of 3 arc-second resolution (Farr, 2007)
- Climatological data were taken from data developed by JRC-Ispra (European Commission)
- High-resolution data on forest cover were taken from Hansen (2013).
- High-resolution data on urban vegetation were taken from the New Global Human Settlement Layer Of Europe (Florczyk et al, 2014, and Pesaresi el al, 2013).
- LUISA scenarios: year 2010, 2020, 2030, 2040 and 2050
- **EU-28 administrative regions: NUTS0, NUTS2, NUTS3**

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Deposition velocity was considered as fixed average values for the different land uses considered in the formula (forest, soil and water). However, specifically for the case of forest where dry deposition plays a major role, dry deposition of NO2 is dependent on tree cover, structure of vegetation, length of in-leaf season, and amount of precipitation and other climatic variables (Nowal et al, 2006). Only data on tree cover was available and included on the calculations.

We estimated the uncertainty derived from the use of LUR models. Uncertainty was expressed in relative terms by relating the RMSE to the mean NO2 concentration value for all the monitoring stations. The result value is 39%, which fulfils the data quality objectives for models as set in the Annex I of the Air Quality set to 50% for hourly and eight-hour average concentrations.

Data availability and homogeneity of data in terms of either spatial distribution, or temporal and geographical resolution, are the main limitation when modelling at European scale:

- Regarding the air quality data used as predicted parameters within the LUR model, we found high discrepancies between the level of representation between the different EU-28 countries, and within countries, between different types of monitoring stations. Regarding the quality of data, they are officially submitted by the national authorities. It is expected that data has been validated by the national data supplier and it should be in compliance with the data quality objectives as described in the Air Quality Directives (EU, 2004, 2008). There are different methods in use for the routine on monitoring of pollutants. Station characteristics and representativeness are in some cases insufficiently documented.
- Regarding the climatic data used as input parameters, the resolution of original data is 0.25x0.25o, and from this original resolution, data were resampled to 100m resolution as used in the LUR model.
- Regarding traffic intensity data, which is the main responsible of NO2 emissions to the atmosphere, no data were available for all the different road types at European scale. Consequently, we developed a proxy of traffic intensity based on population density and road type.

Rationale uncertainty:

The indicator is calculated as yearly average value of removal capacity, without considering daily or not even seasonal changes of the parameters used to derive the indicator. Considering that exceedance of daily NO_2 concentration limits occurs more frequently than exceedance of average yearly values, it should be more useful to estimate the ecosystem service provided by vegetation at this time step. However, most of the data necessary to develop the model are not available at such temporal resolution.

Another important limitation of the model for the prediction of removal capacity by vegetation under future scenarios of land use and population density changes is that the landuse related to green urban areas is considered as static, and consequently in cities, were air quality is more problematic, the regulation of urban vegetation is constant.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

- Include traffic intensity data (Under development within the IES- Sustainability Assessment Unit (H-08)) to improve LUR input parameters.
- Evaluate different future scenarios of urban development considering different models of urban planning in terms of development of green urban zones in order to evaluate the efficiency of this measure to improve air quality.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Vizcaino, P. (2015): LF511 - NO_2 Removal by urban vegetation (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 512 - Urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year

1. Identification (title; code) and classification (DPSIR; typology)

The Urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year is included as a Land Function Indicator (LF 512). It is included in the Core Set of Indicators developed by the EEA corresponding to the indicator CSI-4, (exceedance of air quality limit values in urban areas), where it has been classified as a performance indicator. It has also been included as one of the Resource efficiency scoreboard indicators as part of the theme specific indicators, in the thematic area of safeguarding clean air

According to the DPSIR typology it is classified as a descriptive indicator of Pressure (P) and Impact (I)

2. Rationale — justification for indicator selection; scientific reference

Particulate Matter (PM) exposure is the first responsible on health problems mainly those related to cardiovascular and lung diseases. According to what EEA reports (EEA, 2014), epidemiological studies attribute the most important health impacts of air pollution to PM and in particular to particulates up to 2.5 micrometres. However, $PM_{2,5}$ is monitored yet in much less stations across Europe so for this study PM_{10} was selected.

Emissions of PM_{10} are dominated by household and (to a lower extent) commercial and institutional fuel combustion, followed by industrial activities and transport. The high density of population and economic activities in urban areas result in increased emissions of air pollutants and consequently ambient concentrations and population exposure.

The air quality directives (EU, 2004 and 2008c) and the WHO (2006), set daily and mean annual limit and target values for PM_{10} that should be considered acceptable and achievable objective to minimise health effects. For both WHO set stricter air quality guidelines. The PM_{10} daily limit value and the number of days that it can be exceeded are more stringent than the annual limit value and are more frequently exceeded.

The EU urban population exposed to PM_{10} concentrations exceeding the daily limit value on more than 35 days in a year indicator takes part of the RE indicators. This indicator provides useful information on the percentage of European urban population exposed to pollutant concentrations above the regulated thresholds, which urban areas are the most affected by population, and what are the future tendencies related to the implementation of resource efficiency policies.

References

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3. Indicator definition — definition; units

The EU urban population exposed to PM_{10} concentrations exceeding the daily limit value on more than 35 days in a year measures the percentage of population in urban areas exposed to PM_{10} concentrations exceeding the daily limit value (50 µg/m3) established by the Air Quality Directive (2008/50/EC) on more than 35 days in a calendar year.

The indicator presents data for the year 2010 and the net changes in a short-term period (2010 -2020) and in a long-term period (2010 – 2050), for all EU 28 Member States.

References

EU, 2008c, Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

4. Policy context and targets — context description; targets; related policy documents

The EU Air Quality Directive (2008/50/EC) have set forth legally binding limit values for ground-level concentrations of PM_{10}, for daily and annual exposure: the short-term limit establishes a limit value on daily mean concentrations of 50 µg/m3 not to exceeded more than 35 times per year. This Directive declared that this limit value should have been met by January 1st, 2005.

The World Health Organisation (WHO) set the Air Quality Guideline level for annual mean concentrations of PM_{10} on 20 µg/m^3 much more restrictive than the limits imposed by European legislation.

References

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (Offic J EU, L 152, 11 June 2008, 1–44), 2008.

5. Policy questions — key policy questions; specific policy questions

The Urban population exposure to air pollution by particulate matter indicator aims to answer the following specific policy questions:

- What progress is being made in reducing concentrations of air pollutants in urban areas to below the limit values defined in air quality legislation?
- What is the percentage of European urban population exposed to pollutant concentrations above the regulated thresholds?

6. Methodology (indicator calculation; gap filling; references)

Annual mean concentrations of PM_{10} were calculated using Land Use Regression (LUR) Models. The LUR model was built using annual mean PM_{10} concentration for 2010 from the monitoring sites included in the AirBase database (dependent variable) and several parameters (independent variables) defined within a Geographic Information System (GIS). Some of these variables reflect sources or sinks for air pollution such as the road network, different types of land use and population density. Furthermore, factors such as elevation, topographical exposure, distance to sea, annual mean temperature and annual mean wind speed also influence the spatial concentration of pollutants and were included for the modelling. Land Use Regression model was developed using Random Forest regression techniques (Breiman, 2001) and results of concentration were presented in GIS maps.

Although PM_{10} daily concentration limit are more stringent, not all the stations included in the AirBase database provide daily data on the 36th highest value, that would correspond to the time limit stablishe by the Directive. However Kiesewetter et al (2014) analyzed relations between annual mean level concentrations and the limit on daily exceedances, finding that there is a good correlation between the 36th highest daily mean and annual mean. Specifically the daily limit value 50 μgm−3 is well represented by an annual mean limit of 30 μgm−3. This value was used within the map of annual mean concentrations to specify areas over the limit whenever annual concentrations overcome 30 μgm−3.

References

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7. Data specifications — data references; external data references; data sources in latest figures

- Annual mean data of measured concentrations of PM_{10} for the year 2010 were taken from the monitoring stations within the AirBase database.
- Topographical exposure and elevation data were taken from the Global digital elevation data based on the NASA Shuttle Radar Topographic Mission (SRTM) of 3 arc-second resolution (Farr, 2007)
- Climatological data were taken from data developed by JRC-Ispra (European Commission)
- High-resolution data on forest cover were taken from Hansen (2013).
- High-resolution data on urban vegetation were taken from the New Global Human Settlement Layer Of Europe (Florczyk et al, 2014, and Pesaresi el al, 2013).
- LUISA scenarios: year 2010, 2020, 2030, 2040 and 2050
- **EU-28 administrative regions: NUTS0, NUTS2, NUTS3**

References

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Farr, T.G.; Rosen, P.A.; Caro, E.; Crippen, R.; Duren, R.; Hensley, S.; Kobrick, M.; Paller, M.; Rodriguez, E.; Roth, L., et al. The shuttle radar topography mission. Reviews of Geophysics 2007, 45, RG2004.

Florczyk A., J., Ferri S., Syrris V., Kemper, T., Halkia, M., Soille, P., Pesaresi, M., (2014) A New Global Human Settlement Layer Of Europe From Optical HR/VHR RS Data. IGARSS 2014.

Hansen MC, et al. 2013 High-resolution global maps of 21st-century forest cover change. Science 342, 850–853. (doi:10.1126/science.1244693).

European Commission Joint Research Centre (JRC). MARS daily data http://mars.jrc.ec.europa.eu/mars/About-us/AGRI4CAST/Data-distribution/AGRI4CAST-Interpolated-Meteorological-Data (accessed february 2013).

Baranzelli C., Jacobs-Crisioni C., Batista e Silva F., Perpiña Castillo C., Barbosa A., Arevalo Torres J, Lavalle C. 2014. The Reference scenario in the LUISA platform – Updated configuration 2014. Towards a Common Baseline Scenario for EC Impact Assessment procedures. EUR 27019 EN. Luxembourg: Publications Office of the European Union, (2015).

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the use of regression models to assess mean annual concentrations. Uncertainty was expressed in relative terms by relating the RMSE to the mean PM_{10} concentration value for all the monitoring stations. The result value is 18% that fulfils the data quality objectives for models as set in the Annex I of the Air Quality.

Data availability and homogeneity of data in terms of either spatial distribution, or temporal and geographical resolution, are the main limitation when modelling at European scale:

- Regarding the air quality data used as predicted parameters within the LUR model, we found high discrepancies between the level of representation between the different EU-28 countries, and within countries, between different types of monitoring stations. Regarding the quality of data, they are officially submitted by the national authorities. It is expected that data has been validated by the national data supplier and it should be in compliance with the data quality objectives as described in the Air Quality Directives (EU, 2004, 2008). There are different methods in use for the routine on monitoring of pollutants. Station characteristics and representativeness are in some cases insufficiently documented.
- Regarding the climatic data used as input parameters, the resolution of original data is $0.25x0.25^{o}$, and from this original resolution, data were resampled to 100m resolution as used in the LUR model.
- Regarding traffic intensity data that is one of the main responsible of PM_{10} emissions to the atmosphere, no data were available for all the different road types at European scale. Consequently, we developed a proxy of traffic intensity based on population density and road type.

The model was developed considering only the anthropogenic sources of PM10 and consequently results of concentrations reflect only this emissions but not natural sources sea salt, naturally suspended dust, pollen and volcanic ash, that can be of high importance at local scale.

Rationale uncertainty:

The indicator estimates proportion of urban population exposed to concentrations over the limits established by the Air Quality Directive (EU, 2008c). However WHO cautioned that the levels for the PM limit and target values set by this Directive are not sufficient to adequately protect human health (WHO, 2013a). Thus, even in the event of full compliance with the existing limit and target values, substantial health impacts would remain.

WHO set stricter air quality guidelines (AQGs) than the EU air quality standards. The recommended AQGs should be considered as an acceptable and achievable objective to minimise health effects. However, the final aim would be to achieve the lowest concentrations possible, as no threshold for PM has been identified below which no damage to health is observed (WHO, 2014b).

References

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WHO, 2013a, Review of evidence on health aspects of air pollution — REVIHAAP Project, Technical Report, World Health Organization, Regional Office for Europe, Copenhagen, Denmark.

WHO, 2014b, 'Ambient (outdoor) air quality and health, Fact sheet N°313', Updated March 2014, World Health Organization (http://www.who.int/mediacentre/factsheets/fs313/en/) accessed 18 August 2014.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

- Include traffic intensity data (Under development within the IES- Sustainability Assessment Unit (H-08)) to improve LUR input parameters.
- Evaluate different air quality guidelines (i.e. WHO AQGs) to define more strict scenarios in terms of air quality that would evidence areas at risk to present health problems related to PM_{10} exposure

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Vizcaino, P. (2015): LF512 - Urban population exposed to PM10 concentrations exceeding the daily limit value on more than 35 days in a year (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 513 - Urban population exposure to air pollution by particulate matter

1. Identification (title; code) and classification (DPSIR; typology)

The Urban population e exposure to air pollution by particulate matter is included as a Land Function Indicator (LF 513). The indicator is a Sustainable Development Indicator (SDI). It has been chosen for the assessment of the progress towards the objectives and targets of the EU Sustainable Development Strategy. It is also a Resource Efficiency Indicator, as it has been chosen as a lead indicator presented in the Resource Efficiency Scoreboard for the assessment of progress towards the objectives and targets of the Europe 2020 flagship initiative on Resource Efficiency.

According to the DPSIR typology it is classified as a descriptive indicator of Pressure (P) and Impact (I)

2. Rationale — justification for indicator selection; scientific reference

Fine and coarse particulates (PM10) are particulates whose diameters are less than 10 micrometres. Fine particulates (PM2.5) are those whose diameters are less than 2.5 micrometres. Particulate Matter (PM) exposure is the first responsible on health problems mainly those related to cardiovascular and lung diseases. According to what EEA reports (EEA, 2014), epidemiological studies attribute the most important health impacts of air pollution to PM and in particular to particulates up to 2.5 micrometres. However, $PM_{2,5}$ is monitored yet in much less stations across Europe so for this study PM_{10} was selected.

Emissions of PM_{10} are dominated by household and (to a lower extent) commercial and institutional fuel combustion, followed by industrial activities and transport. The high density of population and economic activities in urban areas result in increased emissions of air pollutants and consequently ambient concentrations and population exposure. The EU Air Quality Directive (EU, 2008c) has imposed daily and annual limits of concentration of PM10 that entered into force in 2005.

The EU urban population exposure to air pollution by particulate matter indicator shows the population weighted annual mean concentration of PM_{10} in agglomerations. This indicator takes part of the RE indicators and provides useful information on the levels of concentration of PM10 in urban areas, allowing to identify the most exposed areas. It also provides information of the progress made towards the targets imposed by legislation for reducing the concentration of particulate matter and the level of achievement of different regions along Europe.

References

EU, 2008c, Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

European Commission (a) (2011). COM (2011) 571 - Roadmap to a Resource Efficient Europe, European Commission, Documentation and data. Retrieved from: [http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf] (accessed 30.07.2014).

European Environment Agency, 2014. Air quality in Europe. EEA Report No 5/2014. 80 pp. ISBN 978-92-9213-489-1. doi:10.2800/22775

3. Indicator definition — definition; units

The EU urban population exposure to air pollution by particulate matter indicator shows the population weighted annual mean concentration of PM_{10} in agglomerations expressed in ug/m^3

The indicator presents data for the year 2010, and the net changes in a short term period (2010 -2020) and in a long term period (2010 – 2050), for all EU 28 Member States.

4. Policy context and targets — context description; targets; related policy documents

The EU Air Quality Directive (2008/50/EC) have set forth legally binding limit values for ground-level concentrations of PM_{10}, for daily and annual exposure. The short-term limit establishes a limit value on daily mean concentrations of 50 µg/m3 not to exceeded more than 35 times per year, and the long term limit establishes and annual mean concentration limit of 40 ug/m^3 . This Directive declared that these limit values should have been met by January 1st ,2005.

The World Health Organisation (WHO) set the Air Quality Guideline level for annual mean concentrations of PM_{10} on 20 µg/m3 much more restrictive than the limits imposed by European legislation.

References

Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe (Offic J EU, L 152, 11 June 2008, 1–44), 2008.

WHO, 2006a, Air quality guidelines. Global update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide, World Health Organization, Regional Office for Europe, Copenhagen, Denmark.

5. Policy questions — key policy questions; specific policy questions

The Urban population exposure to air pollution by particulate matter indicator aims to answer the following specific policy questions:

- What progress is being made in reducing concentrations of air pollutants in urban areas to below the limit values defined in air quality legislation?

6. Methodology (indicator calculation; gap filling; references)

Annual mean concentrations of PM_{10} were calculated using Land Use Regression (LUR) Models. The LUR model was built using annual mean PM_{10} concentration for 2010 from the monitoring sites included in the AirBase database (dependent variable) and several parameters (independent variables) defined within a Geographic Information System (GIS). Some of these variables reflect sources or sinks for air pollution such as the road network, different types of land use and population density. Furthermore, factors such as elevation, topographical exposure, distance to sea, annual mean temperature and annual mean wind speed also influence the spatial concentration of pollutants and were included for the modelling. Land Use Regression model was developed using Random Forest regression techniques (Breiman, 2001) and results of concentration were presented in GIS maps.

Population weights were calculated with GIS techniques estimating the ratio of population per cell by the total population within the cities. Cities boundaries were taken from the Urban Audit 2012 data. Results if weighted mean concentrations were aggregated within different administrative units

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European Commission, 2013: Communication form the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Clean Air Programme for Europe. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0918&from=EN

GISCO - Urban Audit 2012. GISCO Urban Audit 2012 geographical data set: http://www.eea.europa.eu/data-and-maps/data/external/gisco-urban-audit. Accessed March 2015.

Lavalle, C.; Barbosa,A.; Mubareka S.; Jacobs C.; Baranzelli C.; Pernina C. (2013) Land Use Related Indicators for Resource Efficiency - Part I Land Take Assessment. An analytical framework for assessment of the land milestone proposed in the road map for resource efficiency. Luxemboug, Publications Office of the European Union. .[http://bookshop.europa.eu/pt/land-use-related-indicators-for-resource-efficiency-pbLBNA26083/

7. Data specifications — data references; external data references; data sources in latest figures

- Annual mean data of measured concentrations of PM_{10} for the year 2010, were taken from the monitoring stations within the AirBase database.
- Cities boundaries were taken from the Urban Audit 2012 data
- Topographical exposure and elevation data were taken from the Global digital elevation data based on the NASA Shuttle Radar Topographic Mission (SRTM) of 3 arc-second resolution (Farr, 2007)
- Climatological data were taken from data developed by JRC-Ispra (European Commission)
- High-resolution data on forest cover were taken from Hansen (2013).
- High-resolution data on urban vegetation were taken from the New Global Human Settlement Layer Of Europe (Florczyk et al, 2014, and Pesaresi el al, 2013).
- LUISA scenarios: year 2010, 2020, 2030, 2040 and 2050
- EU-28 administrative regions: NUTS0, NUTS2, NUTS3

References

AirBase - The European air quality database: http://www.eea.europa.eu/data-and-maps/data/airbase-the-european-air-quality-database-7. Accessed October 2014.

Farr, T.G.; Rosen, P.A.; Caro, E.; Crippen, R.; Duren, R.; Hensley, S.; Kobrick, M.; Paller, M.; Rodriguez, E.; Roth, L., et al. The shuttle radar topography mission. Reviews of Geophysics 2007, 45, RG2004.

GISCO - Urban Audit 2012. GISCO Urban Audit 2012 geographical data set: http://www.eea.europa.eu/data-and-maps/data/external/gisco-urban-audit. Accessed March 2015.

Florczyk A., J., Ferri S., Syrris V., Kemper, T., Halkia, M., Soille, P., Pesaresi, M., (2014) A New Global Human Settlement Layer Of Europe From Optical HR/VHR RS Data. IGARSS 2014.

Hansen MC, et al. 2013 High-resolution global maps of 21st-century forest cover change. Science 342, 850–853. (doi:10.1126/science.1244693).

European Commission Joint Research Centre (JRC). MARS daily data http://mars.jrc.ec.europa.eu/mars/About-us/AGRI4CAST/Data-distribution/AGRI4CAST-Interpolated-Meteorological-Data (accessed february 2013).

Baranzelli C., Jacobs-Crisioni C., Batista e Silva F., Perpiña Castillo C., Barbosa A., Arevalo Torres J, Lavalle C. 2014. The Reference scenario in the LUISA platform – Updated configuration 2014. Towards a Common Baseline Scenario for EC Impact Assessment procedures. EUR 27019 EN. Luxembourg: Publications Office of the European Union, (2015).

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The main uncertainty from this indicator arises from the use of regression models to assess mean annual concentrations. Uncertainty was expressed in relative terms by relating the RMSE to the mean PM_{10} concentration value for all the monitoring stations. The result value is 18% that fulfils the data quality objectives for models as set in the Annex I of the Air Quality.

Data availability and homogeneity of data in terms of either spatial distribution, or temporal and geographical resolution, are the main limitation when modelling at European scale:

- Regarding the air quality data used as predicted parameters within the LUR model, we found high discrepancies between the level of representation between the different EU-28 countries, and within countries, between different types of monitoring stations. Regarding the quality of data, they are officially submitted by the national authorities. It is expected that data has been validated by the national data supplier and it should be in compliance with the data quality objectives as described in the Air Quality Directives (EU, 2004, 2008). There are different methods in use for the routine on monitoring of pollutants. Station characteristics and representativeness are in some cases insufficiently documented.
- Regarding the climatic data used as input parameters, the resolution of original data is 0.25x0.25°, and from this original resolution, data were resampled to 100m resolution as used in the LUR model.
- Regarding traffic intensity data that is one of the main responsible of PM_{10} emissions to the atmosphere, no data were available for all the different road types at European scale. Consequently, we developed a proxy of traffic intensity based on population density and road type.

The model was developed considering only the anthropogenic sources of PM10 and consequently results of concentrations reflect only these emissions but not natural sources sea salt, naturally suspended dust, pollen and volcanic ash, that can be of high importance at local scale.

For the calculation of the population weighting factor, not all the population living within the administrative unit of concern was considered for the statistical calculations, but only population living in agglomerations as defined in the Urban Audit 2012. Therefore result values are higher than those expected if all urban population was included, and this has to be taken into account for the comparison of data.

References

EU, 2008c, Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe.

WHO, 2013a, Review of evidence on health aspects of air pollution — REVIHAAP Project, Technical Report, World Health Organization, Regional Office for Europe, Copenhagen, Denmark.

WHO, 2014b, 'Ambient (outdoor) air quality and health, Fact sheet N°313', Updated March 2014, World Health Organization (http://www.who.int/mediacentre/factsheets/fs313/en/) accessed 18 August 2014.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

- Include traffic intensity data (Under development within the IES- Sustainability Assessment Unit (H-08)) to improve LUR input parameters.
- Evaluate different air quality guidelines (i.e. WHO AQGs) to define more strict scenarios in terms of air quality that would evidence areas at risk to present health problems related to PM_{10} exposure

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Vizcaino, P. (2015): LF513 - Urban population exposure to air pollution by particulate matter (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 521 - Capacity of ES to avoid soil erosion

1. Identification (title; code) and classification (DPSIR; typology)

Capacity of ecosystems to avoid soil erosion

DPSIR: indicator of state

2. Rationale — justification for indicator selection; scientific references

Soil erosion by water is one of the major and most widespread forms of soil degradation in Europe, being highly affected those countries located in the Mediterranean region. This circumstance is due to the dry climate, intense rainfall periods, soil characteristics and low vegetation cover (EC, 2013a).

Despite the fact that erosion is a natural process, it can however be significantly accelerated by human activities such as agricultural practices, deforestation, overgrazing and construction activities. The major impacts are on the topsoil layer destroying the capability of the soil to provide economic or environmental services (EC, 1995). Moreover, future variations in the rainfall patterns due to climate change will also have an influence on soil erosion processes (IPCC, 2007).

In this context, soil erosion control is a key service supply by terrestrial ecosystems, mainly provided by vegetation cover.

3. Indicator definition — definition; units

Erosion control assessment is performed under the conceptual framework of the Revised Universal Soil Loss Equation (RUSLE) (Wischmeier, 1978), which is a simple empirical model that is widely used for assessing long-term annual soil losses.

The indicator measures the capacity of ecosystems to avoid soil erosion assigning values ranging from 0 to 1 at pixel level, covering the EU-28 territory from 2010 up to 2050. This indicator is related to the capacity of a given land cover type to provide soil protection.

4. Policy context and targets — context description; targets; related policy documents

The European Commission adopted a Soil Thematic Strategy (COM (2006) 231) and a proposal for a Soil Framework Directive (COM (2006) 232) in 2006. The main objective is ensuring sustainable use of soils and soil protection from a series of key threats, including soil erosion.

5. Policy questions — key policy questions; specific policy questions

- Does the vegetation cover protect soils?
- Does changes in land use affect the ecosystem service?

6. Methodology (indicator calculation; gap filling; references)

Pan-European data sources, spatial analysis technics and LUISA (Land Use Integrated Sustainability Assessment) modelling platform have been used to model the soil retention and the capacity of ecosystems to avoid soil erosion at European from 2006 to 2050. The base map in LUISA for the simulation is the Corine Land Cover 2006 (refined version). Arable lands, permanent crops, pastures, natural vegetation and forest are the land uses/covers that are considered to have a major influence when assessing erosion control service of ecosystems.

In order to assess erosion control service of ecosystems it is needed an adaptation of the empirical USLE equation to provide four outputs under a conceptual ecosystem services framework (Guerra et al., 2014). Specifically, these four concepts are:

- Structural Impact (Y) is defined as the total soil erosion impact when any ecosystem service is provided. In soil erosion context, it is referred to the potential soil erosion including rainfall erosivity, soil erodibility and topography.
- Capacity for Ecosystem service provision (e) is the fraction of the structural impact that is mitigated by the ecosystem service and it correspond to a dimensionless gradient varying from 0 to 1. It is denominated as capacity of ecosystems to avoid soil erosion.

$$\boldsymbol{e = 1 - C}$$

- Ecosystem service mitigated impact (β_e) is referred to the remaining soil erosion after the ecosystem service provision, that is, the ecosystem capacity to provide a specific service (soil protection).
- Actual ecosystem service provision (E_s) corresponds to the total amount of ecosystem service provided measured in ton ha^{-1} $year^{-1}$ (tons of soil not eroded). It is called as soil retention understood as the modelled soil erosion with and without the presence of vegetation.

The capacity of ES to avoid soil erosion is represented by the C factor of the RUSLE equation (Wischmeier and Smith, 1978). The procedure to compute this factor has certain complexity. To estimate the vegetation cover per land cover class, Corine Land Cover Map for 2006 was used (EEA, 2013)) as a reference year .This was reclassified to a smaller number of land cover classes to be combined with the outputs from LUISA. Then, vegetation cover was monthly estimated using the relation between the Normalized Difference Vegetation Index (NDVI; calculated from 2009 MODIS 16 days NDVI composites with a 250 meters pixel resolution) and the USLE C Factor (Wischmeier & Smith, 1978) proposed by Van der Knijff *et al.* (1999). Afterwards, using the environmental zones from Metzger et al. (2005) to stratify the original *C* Factor data, zonal statistics were calculated to obtain the average monthly value of *C* present in each land cover class. Then, a monthly snow cover data set (Dosio, 2011; Dosio, 2012) was included to mask the obtained C factor. Finally, a yearly average of C factor was obtained for each year, by averaging for each pixel the results obtained for every month, obtaining a composite spatial representation of vegetation cover for Europe.

Methodology references:

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7. Data specifications — data references; external data references; data sources in latest figures. Data Sources:

- NDVI index calculated from MODIS 250 m pixel images
- Corine Land Cover 2006 refined
- LUISA outputs (land use map)
- Snow cover data set
- Environmental Zones: Metzger et al., 2005

References:

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Guerra, C. A., Metzger, M. J., Maes, J., & Pinto-Correia, T. (2015). Policy impacts on regulating ecosystem services: Looking at the implications of 60 years of landscape change on soil erosion prevention in a mediterranean silvo-pastoral system. Landscape Ecology, doi:10.1007/s10980-015-0241-1

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Renard K.G., Foster G.R., Weesies G.A., McCool D.K., Yoder D.C. (1997). Predicting Soil

Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). US Dept Agric., Agr. Research Service. Agr. Handbook No. 703

Wischmeier W.H. and Smith D.D. (1978). Predicting Rainfall Erosion Losses – A Guide to Conservation Planning. Agriculture Handbook, No. 537, USDA, Washington DC.

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

This indicator is implemented in the LUISA modelling platform and this poses a certain degree of uncertainty not only due to the temporal simulation (from 2006 up to 2050) itself, but also to the limitations and uncertainties of the sectorial models used as inputs (e.g. to assess land demand) in the platform. Modelling land use/cover changes require a set of spatial explicit data and statistical data whose availability and resolution are limited. Data harmonization is required to make consistent the inputs and outputs in the model.

Therefore, the uncertainty of the modelled erosion indicator is high, due to the limitations of the applied methodology, data used and the uncertainty related to future projections with a high time frame. However, the assessment can offer valuable qualitative information at the European scale about the areas where erosion mitigation and prevention measures should be implemented.

9. Responsibility and ownership (indicator manager; ownership)

Joint Research Centre (JRC), Institute for Environment and Sustainability

10. Further work (short-term work; long-term work)

The limited availability of high-resolution data related to the different biophysical phenomena that are considered within the soil erosion model is furthermore hampering the calculation of its indicators at higher resolution.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Perpiña Castillo, C (2015): LF521 - Capacity of ecosystems to avoid soil erosion (LUISA Platform REF2014). European Commission - Joint Research Centre. http://data.jrc.ec.europa.eu/dataset/jrc-luisa-lf521-capacity-of-ecoystems-to-avoid-soil-erosion-ref-2014

LF 522 - Soil Retention

1. Identification (title; code) and classification (DPSIR; typology)

Soil retention

DPSIR: indicator of state

2. Rationale — justification for indicator selection; scientific references

Soil erosion by water is one of the major and most widespread forms of soil degradation in Europe, being highly affected those countries located in the Mediterranean region. This circumstance is due to the dry climate, intense rainfall periods, soil characteristics and low vegetation cover (EC, 2013a).

Despite the fact that erosion is a natural process, it can however be significantly accelerated by human activities such as agricultural practices, deforestation, overgrazing and construction activities. The major impacts are on the topsoil layer destroying the capability of the soil to provide economic or environmental services (EC, 1995). Moreover, future variations in the rainfall patterns due to climate change will also have an influence on soil erosion processes (IPCC, 2007).

In this context, soil erosion control is a key service supply by terrestrial ecosystems, mainly provided by vegetation cover.

3. Indicator definition — definition; units

Erosion control assessment is performed under the conceptual framework of the Revised Universal Soil Loss Equation (RUSLE) (Wischmeier, 1978), which is a simple empirical model that is widely used for assessing long-term annual soil losses.

Soil retention, is calculated as soil loss without vegetation cover minus soil loss including the current land use/cover pattern. Specifically, this indicator takes into account climate data (observed measurements for rainfall and modelled for snow), topographic aspects, soil properties and the presence or not of the vegetation cover.

4. Policy context and targets — context description; targets; related policy documents

The European Commission adopted a Soil Thematic Strategy (COM (2006) 231) and a proposal for a Soil Framework Directive (COM (2006) 232) in 2006. The main objective is ensuring sustainable use of soils and soil protection from a series of key threats, including soil erosion.

5. Policy questions — key policy questions; specific policy questions

- How much European soils are being and will be protected from water soil erosion?

6. Methodology (indicator calculation; gap filling; references)

Pan-European data sources, spatial analysis technics and LUISA (Land Use Integrated Sustainability Assessment) modelling platform have been used to model the soil retention and the capacity of ecosystems to avoid soil erosion at European scale from 2006 to 2050. The base map in LUISA for the simulation is the Corine Land Cover 2006 (refined version).

The indicator was implemented in LUISA according to the Revised Universal Soil Loss Equation (USLE/RUSLE) (Wischmeier, 1978; Renard, 1997). The parameters included in the USLE equation combine data on precipitation, soil properties, topography and land use/cover. USLE equation provides the conceptual framework for the estimation of soil losses and soil retention by applying the following equation:

$$A = R \times K \times L\,S \times C \times P$$

where:

A = (Annual) soil erosion by water (t ha-1 yr-1)

R = Rainfall Erosivity Factor (MJ mm ha-1 h-1 yr-1)

K = Soil Erodibility Factor (t ha h ha-1 MJ-1 mm-1)

L = Slope length Factor (dimensionless)

S = Slope Factor (dimensionless)

C = Vegetation Cover Factor (dimensionless)

P = Conservation and management Practices aimed at erosion control (dimensionless)

C and R factor are considered dynamic factors since they will be projected to future time. However, P, LS and the K factors will keep static, as the studied period is not temporarily long enough to detect changes on the erodibility parameters and topography (driven by geological erosion). The lack of information of P factor leads us to keep this factor as static as well.

To estimate the rainfall erosivity parameter was needed two different climate datasets: observables and future projections. Year 2010 represents the observed precipitation values from the European Climate Assessment and Dataset (E-OBS; http://eca.knmi.nl/; Haylock et al., 2008), and for the remaining time slices (2020, 2030, 2040, 2050) were considered projections related to five regional climatic models (RCA3HAD, ALADIN, HIRHAM, CLM, RCA3BCM) corrected for biases in temperature and precipitation (Dosio, 2011; Dosio, 2012).

The R-factor was estimated based on the MedREM model proposed by Diodato and Bellocchi (2010) for Mediterranean conditions. For each time slice, the rainfall erosivity factor was calculated using the following expression:

$$\boldsymbol{R_y = b_0 * P_y * \sqrt{d_{ymax}} * (\alpha + b_1 * L)}$$

Where, Ry (MJ mm ha^{-1} h^{-1} y^{-1}) corresponds to the yearly rainfall erosivity, $\boldsymbol{b_0}$ (MJ ha^{-1} h^{-1}) is a constant equal to 0.117, b_1 ($d^{0.5}$ $mm^{-0.50-1}$) is a constant equal to 2, α ($d^{0.5}$ $mm^{-0.50}$) is a constant equal to -0.015, L corresponds to the site longitude, P_y (mm y^{-1}) to the total amount of precipitation in a given year, and d_{ymax} (mm d^{-1}) to the annual maximum daily precipitation for year y averaged over a multi-year period of 10 years.

Due to the methodology followed, the climatic data has more influence on the results than the other factors. Therefore, the results of the indicator are driven in some countries by this data. In the Figure 2 is shown the rainfall per country and year. For 2030 and 2040 most of the countries have a low rainfall compared with the other years, meaning that the soil retention – service- will be reduced (as the erosion –impact- will be lower).

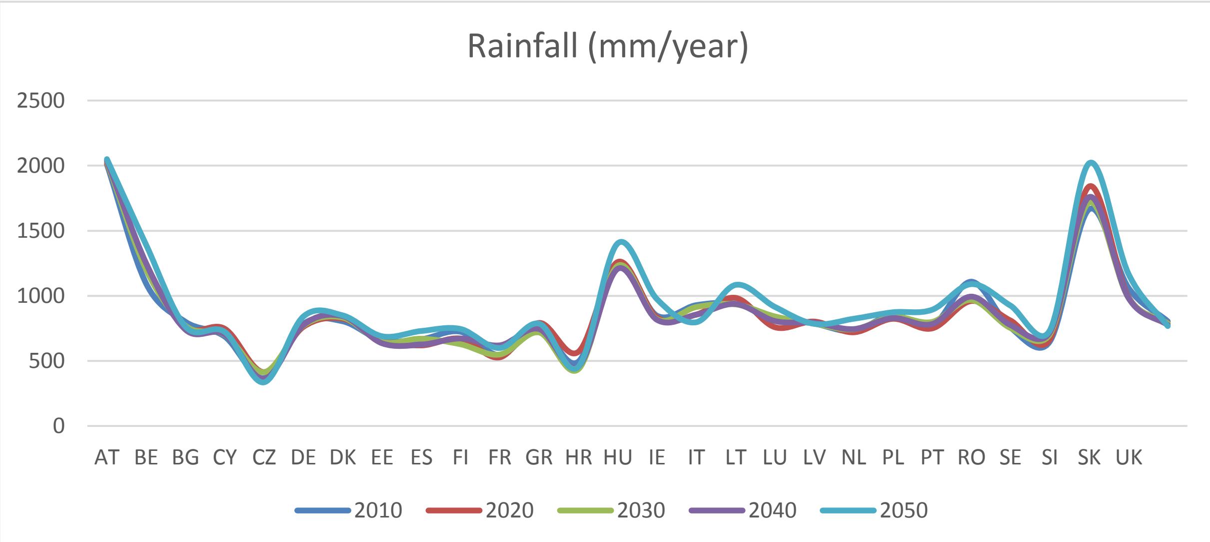

Figure 2. Rainfall data used to compute R factor per country and year

The C factor is based on the combination of the land cover map provided by LUISA for a given year, the dataset for the Environmental Zones of Europe (Metzger, 2005; Metzger, 2008), specific calculated vegetation curves for each land cover class (Van der Knijff, 1999), and the snow cover dataset of each given year (Dosio, 2011; Dosio,2012).

In order to assess erosion control service of ecosystems it is needed an adaptation of the empirical USLE equation to provide four outputs under a conceptual ecosystem services framework (Guerra et al., 2014). Specifically, these four concepts are:

- Structural Impact (Y) is defined as the total soil erosion impact when any ecosystem service is provided. In soil erosion context, it is referred to the potential soil erosion including rainfall erosivity, soil erodibility and topography.
- Capacity for Ecosystem service provision (e) is the fraction of the structural impact that is mitigated by the ecosystem service and it correspond to a dimensionless gradient varying from 0 to 1. It is denominated as capacity of ecosystems to avoid soil erosion.
- Ecosystem service mitigated impact (β_e) is referred to the remaining soil erosion after the ecosystem service provision, that is, the ecosystem capacity to provide a specific service (soil protection).
- Actual ecosystem service provision (E_s) corresponds to the total amount of ecosystem service provided measured in ton ha^{-1} $year^{-1}$ (tons of soil not eroded). It is called as soil retention understood as the modelled soil erosion with and without the presence of vegetation.

$$\boldsymbol{E_s = Y - \beta_e}$$

Methodology references:

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Metzger, M.J., Bunce, R.G.H., Leemans, R., Viner, D. (2008). Projected environmental shifts under climate change: European trends and regional impacts. Environ.

Conserv. 35, 64–75.

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7. Data specifications — data references; external data references; data sources in latest figures

Data Sources:

- LUISA outputs (land use map): years 2010 , 2020, 2030, 2040, 2050
- Corine Land Cover 2006 refined
- Observed climate data (precipitation for 2006 and 2010): ENSEMBLES project, E-OBS gridded dataset.
- Projections of rainfall data (from 1990 to 2050): JRC
- Projections of snow data (from 1990 to 2050): JRC
- K erodibility factor: JRC
- LS factor: JRC
- Environmental Zones: Metzger et al., 2005
- NDVI index calculated from MODIS 250 m pixel images

References:

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Renard K.G., Foster G.R., Weesies G.A., McCool D.K., Yoder D.C. (1997). Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). US Dept Agric., Agr. Research Service. Agr. Handbook No. 703

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8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

This indicator is implemented in the LUISA modelling platform and this poses a certain degree of uncertainty not only due to the temporal simulation (from 2006 up to 2050) itself, but also to the limitations and uncertainties of the sectorial models used as inputs (e.g. to assess land demand) in the platform. Modelling land use/cover changes require a set of spatial explicit data and statistical data whose availability and resolution are limited. Data harmonization is required to make consistent the inputs and outputs in the model.

The methodology is based on an empirical equation (RUSLE) in order to estimate long-term soil erosion by water. This model contains different factors, which individually incorporate high uncertainties to the model outputs, especially at local level. One of the most influent factors in the equation is a projected rainfall erosivity factor (R-factor) whose spatial and temporal resolution may not be adequated to represent the impact of extreme rainfall. Other complex factor is the land cover factor (C-factor) due to two main reasons. Firstly, land use/cover maps are outputs modelled from LUISA and, secondly, the C-factor has been calculated using spatial data (e.g. snow cover projections) that might increase its degree of uncertainty.

Therefore, the uncertainty of the indicator is high, due to the limitations of the applied methodology, data used and the uncertainty related to future projections with a high time frame. However, the assessment can offer valuable qualitative information at the European scale about the areas where erosion mitigation and prevention measures should be implemented.

9. Responsibility and ownership (indicator manager; ownership)

Joint Research Centre (JRC), Institute for Environment and Sustainability

10. Further work (short-term work; long-term work)

The limited availability of high-resolution data related to the different biophysical phenomena that are considered within the soil erosion model is furthermore hampering the calculation of its indicators at higher resolution.

Furthermore, the management practices factor (P-factor) needs further investigation due to the difficulty to find data on sustainable agriculture and soils conservation practices that are suitable to be modelled and projected for future conditions.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C.; Perpina Castillo, C (2015): LF522 -Soil retention (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 524 - Water Retention Index

1. Identification (title; code) and classification (DPSIR; typology)

LUISA framework: LF_ 524 - WRI

DPSIR: indicator of state

2. Rationale — justification for indicator selection; scientific references

In order to assess the potential amount of water retained in the landscape a complex soil-plant-atmosphere system model is needed. A composite indicator was developed to assess the capacity of the landscape to regulate and retain water passing through it. This indicator shows where there could be a deficit in the capacity of the landscape to retain water which, combined with rainfall extremes, could lead to higher flood risk or water scarcity.

References

Vandecasteele I., Mari Rivero I., Dreoni I., Becker W., Vizcaino P., Maes J., Lavalle C., Batelaan O., 2014: Potential Landscape Water Retention as an indicator for Water Quantity Regulation in Europe, submitted to Ecosystem Services Journal.

3. Indicator definition — definition; units

The indicator shows the spatial and temporal distribution of the landscape's capacity to capture water, reducing runoff. The Water Retention Index is a composite indicator, dimensionless, which takes into account the role of interception by vegetation, the water-holding capacity of the soil, and the relative capacity of both the soil and the bedrock to allow percolation of water. The influence of soil sealing and slope gradient are additionally considered.

4. Policy context and targets — context description; targets; related policy documents

Action 5 of the EU Biodiversity Strategy to 2020 calls Member States to map and assess the state of ecosystems and their services in their national territory with the assistance of the European Commission. In this framework, the development of a coherent analytical framework to be applied by the EU and its Member States in order to ensure consistent approaches are used (MAES project). The WRI is used to assess the provision of liquid flows regulation (CICES classification).

The WRI is part of the Total Ecosystem Services Index (TESI), used in the OpenNESS project, which aims to translate the concepts of Natural Capital (NC) and Ecosystem Services (ES) into operational frameworks that provide tested, practical and tailored solutions for integrating ES into land, water and urban management and decision-making.

The Floods Directive requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas, and to take adequate and coordinated measures to reduce this flood risk. The WRI could be used to evaluate the measures related to land use management and to identify hotspots where measures to reduce flood risks are more needed.

5. Policy questions — key policy questions; specific policy questions

The water retention index aims to answer the following policy questions:

- Where are the more vulnerable areas for water scarcity and flood risk in Europe?
- Do the current environmental policies reduce the areas of flood risk?
- Will current measures be effective to increase water retention and thus reduce?

6. Methodology (indicator calculation; gap filling; references)

The Water Retention Index (WRI) is a composite indicator which takes into account the retention (or storage) of water throughout the landscape. We assume the total landscape potential for water retention to be a function of the retention in vegetation (Rv), soil (Rs) and groundwater (Rg). We in addition take into account the impact of slope on the capacity to retain water, and correct the overall indicator for the share of sealed area (assumed to be impermeable). Both slope and soil sealing are limiting factors of the natural retention capacity, as actual retention should decrease with increasing share of sealed area and with increasing slope gradient. The WRI is computed as shown in Figure 3, where grey boxes indicate the dynamic components. All parameters are given scores and combined in the composite indicator according to the available literature.

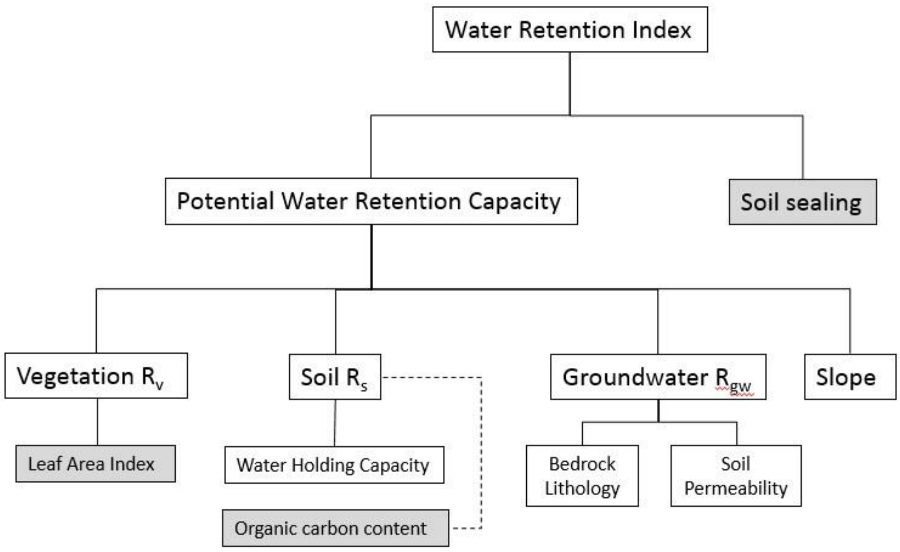

Figure 3. Schematic overview of the structure of the composite indicator. Parameters in grey are dynamic and updated based on land use.

All parameters are standardized and combined in the composite indicator. We performed a sensitivity analysis using an approach similar to that in Paruolo et al, 2013. We further adopted an optimisation procedure which iteratively adjusted the weights until the desired importance of each parameter was reached. The influence of each parameter on water retention capacity was taken to be equal, except for the slope factor, which was assumed to have a relatively lower impact. For this reason, the desired impact was assigned as half that of the other parameters. The structure of the WRI is:

$$WRI = (w1.Rv + w2.Rgw + w3.Rs + w4.Rslope).w5.(1- SS/100\ )$$

With w1 = 1.81; w2 = 0.22; w3 = 1.51; w4 = 0.2; w5 = 1.16

Processing is carried out at 100 m resolution and then aggregated to 1 km resolution, according to the lowest resolution of the input data.

To forecast the index from the base year 2006 to 2050, the Leaf Area index, the organic carbon content and the sealed areas are updated each 5 years. As in Van Dijk and Bruinzeel (2001), we assume that the canopy capacity, and therefore the potential amount of water intercepted, is linearly related to the leaf area index (LAI). The forecasted LAI (R_v) is re-computed directly from the average LAI values per land use class and per climatic zone (Metzger et al., 2005).

Both the soil organic carbon content and bulk density are influenced by changing land use typology over time (Bormann, 2007). We estimated the average expected changes in both parameters with land use conversions between cropland - grassland, and forests based on an extensive review of available literature (Bauer & Black, 1981; Bewket & Stroosnijder 2003; Breuer et al. 2006; Bronson et al. 2004; etc.). The resulting assumed changes are given in **Table 6**. We therefore only used the changes in organic carbon content over time to update the Rs parameter, assuming a soil with a higher organic carbon content to have a proportionally higher water retention capacity.

Table 6. *Estimated changes in soil bulk density and organic carbon (OC) content each 20 years.*

Land use	Assumed change in bulk	Assumed change in OC
Crops to grassland	↓ 6.5%	↑ *5%*
Crops to forest	↓ 15%	↑ 15%
Grassland to crops	↑ 7%	↓ 20%
Grassland to forest	↓ 9%	↑ *10%*
Forest to crops	↑ 17%	↓ 35%
Forest to grassland	↑ 10%	↓ 15%

The soil sealing layer used is computed based on the average percentage soil sealing per land use class and per country. This means that the parameter can be calculated directly based on the simulated land use. The WRI can therefore be calculated for any year up to 2050 based on the updated land use map.

The relative permeability (Rgw) and the slope are static parameters. The first is based on the type of lithology present and its relative permeability. We assign estimated permeability scores for each major lithology based on the average of the range of permeabilities given by Domenico and Schwartz (1990), Gleeson et al. (2011), and Lewis et al. (2006). The European slope map we use is consistent with that used in the EUClueScanner model, as derived from the Global Digital Elevation Model (SRTM, NASA) (http://srtm.csi.cgiar.org/).

References used:

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Paruolo P., Saisana M., and Saltelli A. Ratings and rankings: voodoo or science? Journal of the Royal Statistical Society: Series A (Statistics in Society), 176(3):609–634, 2013.

Van Dijk A.I.J.M., Bruijnzeel L.A., 2001, Modelling rainfall interception by vegetation of variable density using an adapted analytical model. Part 1. Model description, Journal of Hydrology 247, p.230-238

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios: years 2010, 2020 and 2050
- CLC 2006 refined
- Leaf Area Index: H08 IES-JRC
- Environmental Zones: Metzger et al., 2005
- Total Available Water Capacity: European Soil database (ESDB)
- Parent Material: ESDB
- Hydrological Class: ESDB
- One Geology dataset
- Cyprus and Austria geological surveys
- Slope: SRTM, NASA (used as DEM for the Land Use Model)
- Soil sealing: European Soil Sealing Map (EEA).

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Methodological uncertainty:

The main limitation of the indicator is the lack of measured data to validate it. The methodology implies a certain degree of uncertainty. A composite indicator is a statistical representation of the studied phenomena and all data sets used will add errors to the final result. The forecasting methodology adds the uncertainties coming from the EUClueScanner model (LU maps), the assumptions taken to forecast the Rv and the soil sealing and the errors and limitations to forecast the total available water capacity in soil.

Dataset uncertainty:

Each data set brings uncertainty. The land use scenarios, leaf area index and soil sealing lookup tables are at 100 m resolution, and are based on the outputs of the EUClueScanner model.

The data sets used from the ESDB contain high uncertainty. These maps are computed by interpolating the measured points (LUCAS project) at 1km resolution.

The One Geology project data sets used are also highly uncertain. However, it is the most complete lithology data available to date at European scale.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

Possible further work is based on the improvement of the input data sets and the sensitivity analysis, done currently at NUTS3 level.

Another line of future work is the use of the indicator for flood protection by crossing the indicator with climate indicators (such as SPI) to highlight the hotspots where water flow regulation measures are needed.

LF 531 – Relative pollination potential

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_531 - Pollination

DPSIR typology: Impact.

2. Rationale — justification for indicator selection; scientific references

Pollination by wild insects is an important ecosystem service with high natural and economic value.

Insect pollinators contribute to the pollination of 84% of European crop species (Williams, 1994) and are responsible for an estimated 35% of world food production (Klein et al., 2007).

Several attempts have estimated the global economic value of pollination (Gallai et al., 2009, Lautenbach et al., 2012) and these studies make clear that ecosystem services such as crop pollination are fundamental for human well-being.

The model estimates the capacity of land use parcels to sustain wild pollinators.

References

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Zulian, G., Maes, J., & Paracchini, M. (2013). Linking Land Cover Data and Crop Yields for Mapping and Assessment of Pollination Services in Europe. Land, 2(3), 472–492. doi:10.3390/land2030472

Gallai, N., Salles, J. M., Settele, J. & Vaissière, B. E. 2009. Economic Valuation Of The Vulnerability Of World Agriculture Confronted With Pollinator Decline. Ecological Economics, 68, 810-821.

Klein, A.-M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C. & Tscharntke, T. 2007. Importance Of Pollinators In Changing Landscapes For World Crops. Proceedings Of The Royal Society B: Biological Sciences, 274, 303-313.

Lautenbach, S., Seppelt, R., Liebscher, J. & Dormann, C. F. 2012. Spatial And Temporal Trends Of Global Pollination Benefit. Plos One, 7, E35954.

3. Indicator definition — definition; units

Capacity of ecosystems to sustain wild pollinators. Dimensionless.

4. Policy context and targets — context description; targets; related policy documents

The model was built in the context of EU biodiversity strategy Improve the knowledge of ecosystems and their services in the EU; it is part of Action 5: Mapping and Assessing Ecosystems and their services.

According to Action 5: "*Member States, with the assistance of the Commission, to map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020*"

Action 5 is one of the keystones of the strategy providing a knowledge base for Europe's green and blue infrastructure, the restoration of 15% of degraded ecosystems and the No Net Loss of biodiversity and ecosystem services initiative.

5. Policy questions — key policy questions; specific policy questions

The indicator aims at answering the following question:

- Where wild pollinators can be active?

6. Methodology (indicator calculation; gap filling; references)

The model quantifies capacity of ecosystems to sustain wild pollinators according to presence and importance of the following components: Land use, road network, and seminatural vegetation in agricultural areas; temperature and solar irradiance; foraging distance.

References used:

Zulian, G., Maes, J., & Paracchini, M. (2013). Linking Land Cover Data and Crop Yields for Mapping and Assessment of Pollination Services in Europe. Land, 2(3), 472–492. doi:10.3390/land2030472

Klein, A.-M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C. & Tscharntke, T. 2007. Importance Of Pollinators In Changing Landscapes For World Crops. Proceedings Of The Royal Society B: Biological Sciences, 274, 303-313.

7. Data specifications — data references; external data references; data sources in latest figures

- Baseline Scenario projected land use maps (LUISA)
- High Nature Value Farmlands (HNV)
- AGRI4CAST interpolated grid (temperature, irradiance)
- Teleatlas Multinet 2007

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

The mapping of pollination potential estimates the capacity of the ecosystems to sustain insect activity, it doesn't take species distribution or abundance into account.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

The pollination potential model is continuously being updated and refined, in order to focus on pollination from different point of view: maintenance of biological conditions (regulation), nutrition (provision), intellectual interactions with ecosystems (cultural). Furthermore, a new model that focus on bumble bees is under development.

LF 532 – C- Stocks

(Soil organic carbon-stock changes in mineral soils 0-30cm)

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_532 – C-stocks

DPSIR typology: Impact.

2. Rationale — justification for indicator selection; scientific references

At EU level, emissions from the agricultural sector represent about 11% of the total greenhouse gas emissions (GHG) emissions of 4.7 Gt CO_2 eq in 2010 (include CH_4 and N_2O emissions from livestock, fertilization and manure management), while the removals from the Land Use, Land Use Change and Forestry (LULUCF) sector compensates about 8% of EU GHG emissions. Thus, the land use and management may play a role in climate mitigation and offers synergies with climate adaptation.

Globally, soil present the largest pool of terrestrial carbon (over 70 Gt C in EU28). Changes in land use and cover may cause significant changes in the amount of organic material in the soil. Thus, soil can act as either a sink or a source for atmospheric carbon, mainly in form of carbon dioxide (CO_2).

A method of estimating changes in CO_2 from the effect of changes in land use and cover on soil organic carbon (SOC) stocks is detailed by the Intergovernmental Panel on Climate Change (IPCC, 2006). For estimating GHG emissions resulting from anthropogenic activities leading to changes in land use IPCC distinguishes three levels or Tiers with increasing complexity. The most generic method is defined by Tier 1.

References

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IPCC (2006) 2006 IPCC guidelines for national greenhouse gas inventories, volume 4: agriculture, forestry, and other land use. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

3. Indicator definition — definition; units

The C-stocks change indicator estimates the change in the stocks of carbon in organic compounds in mineral soils (Mt C $year^{-1}$) and CO_2 emissions or removals (Mt CO_2 equivalent $year^{-1}$) from land use and management changes for mineral soils.

4. Policy context and targets — context description; targets; related policy documents

The 2020 land milestone proposed in the RERM has as main purpose to control and reduce the rate of artificial land take in the European territory. Land take by artificial surfaces can resulted in substantial negative impacts on the environment. One of the indicators used to evaluate the impact of land take is the change in the stocks of carbon in organic compounds in the soil. The target of the roadmap for 2020 the indicator is that soil organic matter (SOM) levels do not decrease overall and increase for soils currently with less than 3.5% organic matter (equivalent to 2.0% organic carbon) (European Commission, 2011).

References:

European Commission. (2011). COM (2011) 571 - Roadmap to a Resource Efficient Europe. European Commission, Documentation and data. European Commission. Retrieved from http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf

5. Policy questions — key policy questions; specific policy questions

The indicator aims to answer the following question:

- How much CO_2 emission or removal from the soil can be expected from changes in land use and management according to the Reference?

6. Methodology (indicator calculation; gap filling; references)

The most generic method to estimate the CO2 emissions and removals through C-Stocks changes in mineral soils is defined by the IPCC Tier 1 method. The Tier 1 method is based on the supposition that the flux of carbon between the atmosphere and the soil has a propensity towards a state of equilibrium. Following changes in land use and cover the state of equilibrium is reached after 20 years. Under Tier 1 general default values for SOC density are defined depending on soil type and climatic conditions. These default values are varied by a set factors for land use and management.

The method of Tier 1 starts with defining a default reference value for the (SOC) stock as they are typical for a soil type under native vegetation, i.e. without anthropogenic influence. Under Tier 1 the factors considered to lead to deviations from the reference SOC stocks are changes in land use type (F_{LU}), management (F_{MG}) and input (F_I). The C-stock is calculated by applying the factors to the default reference C-stock as:

$$SOC_a = \sum (SOC_{REF} * F_{LU} * F_{MG} * F_I * A)$$

where

SOC_a	SOC stock in year a
SOC_{REF}	default reference C-stock under native vegetation
F_{LU}	land use factor
F_{MG}	management factor
F_I	input factor
A	area

These SOC stocks are established for a base year and for the conditions after n years. For mineral soils changes in C-stocks, and as a consequences in CO_2 emissions, are then calculated as the difference in SOC stocks between the two points in time. The IPCC Tier 1 method assumes that after a change in any of the factors SOC stocks reach an equilibrium after 20 years with a fixed annual rate of change (IPCC, 2006). The difference in SOC stocks after n years is thus calculated as:

$$\Delta SOC_n = (SOC_{a+20} - SOC_a) * \frac{n}{20}$$

where

SOC_n	change in C-stock from year *a* to year *a+n*
SOC_a	SOC stock for LUS in year *a*
SOC_{a+20}	SOC stock for LUS in year *a+n, n* < 20 years

For organic soils a different approach is used. Instead of calculating changes in C-stocks annual default emissions factors are defined by climate region. The factors are applied as long as the conditions for managed organic soils are met.

Definition of Default Reference Soil Organic C-Stock The Tier 1 default reference soil organic carbon stock (SOCREF) for mineral soils is the SOC density under conditions of native vegetation. The values are defined for the topsoil layer from 0 to 30 cm, where most of the changes in SOC are expected to be found. Values are specified for a combination of 6 soil types of mineral soils and 9 climate regions.

Factors Defining the Land Use System

The factors considered under Tier 1 to modify SOC stocks are:

- land use category (F_{LU});
- management practice (F_{MG});
- level of input (F_I).

The combination of the conditions form the *Land Use System* (LUS). The factor values can be combined to form a Land Use System Factor (F_{LUS}). Changes in any of the defining factors lead to subsequent changes in SOC stocks.

A schematic presentation of the Tier 1 factors defining a LUS is given in Figure 4.

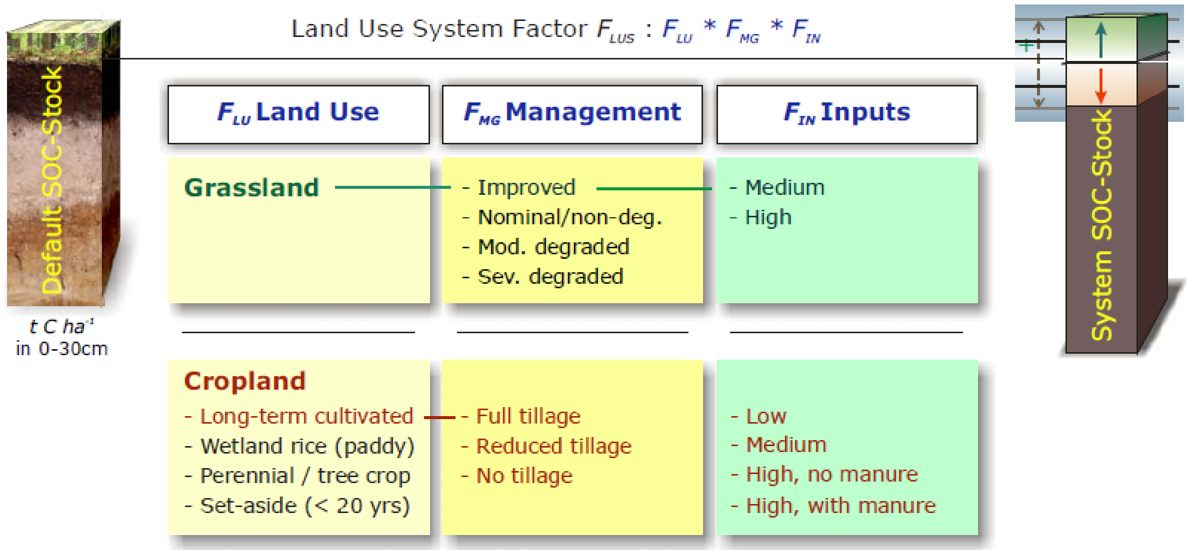

Figure 4. Schematic Presentation of Factors Defining Land Use System

The land use type "Grassland" is not further subdivided. For the management factor four conditions describing the status of the grassland are distinguished. Grassland classified as "improved" it is characterized by one of the two conditions of input.

Cropland is sub-divided into four land use types. For the type "*long-term cultivated*" the management factor relates to the degree to which soil tillage is applied. The level of input of organic material to the soil is divided into four classes. No differentiation in management or input is made for the other cropland types.

Reference used:

Beyer, L., P. Kahle, H. Kretschmer and Q. Wu (2001) Soil organic matter composition of man-impacted urban sites in North Germany. Journal of Plant Nutrition and Soil Science 164(4). p. 359-364.

Hiederer, R. (2013) Mapping Soil Properties for Europe --- Spatial Representation of Soil Database Attributes. European Commission, EUR 26082 EN. pp. 47. doi:10.2788/94128.

https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/mapping-soil-properties-europe-spatial-representation-soil-database-attributes

IPCC (2003) Good practice guidance for land use, land-use change and forestry. Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe K. and Wagner, F. (eds.). The Institute for Global Environmental Strategies for the IPCC and IPCC National Greenhouse Gas Inventories Programme. Hayama, Kanagawa, Japan. http://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf.html

IPCC (2006) 2006 IPCC guidelines for national greenhouse gas inventories, volume 4: agriculture, forestry, and other land use. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). IGES, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

Pouyat, R., P. Groffman, I. Yesilonis and L. Hernandez (2002) Soil carbon pools and fluxes in urban ecosystems. Environmental Pollution 116(2002), p. S107-S115.

7. Data specifications — data references; external data references; data sources in latest figures

- Baseline Scenario projected land use maps (LUISA)
- European Soil Database (ESDB) - Download page: http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDBv2/index.htm
- Additional spatial layers derived from the European Soil Database http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDB_Data_Distribution/derived_data.html
- Climate region data: Support to Renewable Energy Directive http://eusoils.jrc.ec.europa.eu/projects/RenewableEnergy/
- EUROSTAT data for themes agriculture and agri-environmental indicators http://ec.europa.eu/eurostat/data/database

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Uncertainties of factors for IPC Tier 1 as given in IPCC 2006 Guidelines for national GHG inventories.

9. Responsibility and ownership (indicator manager; ownership)

Joint Research Centre, Institute for Environment and Sustainability, Unit (H05), Roland Hiederer

10. Further work (short-term work; long-term work)

Setting baseline for soil organic carbon changes from land use and management practices for 20 years of historic period 1990 – 2010.

Estimating the effect on CO_2 emissions and removals by the soil from varying land use and management based on scenarios.

7. Land function 6 – Supporting ecosystems and biodiversity

The land function 6 refers to the land capacity for the conservation of biodiversity and maintenance of ecosystems. The selected indicators to monitor the biodiversity conservation are the habitat conservation and the habitat quality based on the species distribution.

The indicators chosen for observing the maintenance of ecosystems were the green infrastructure and landscape fragmentation. All the indicators were integrated in the visualization tool, with the exception of the 'Landscape fragmentation by artificial areas' which has been computed only for Large Urban Zones.

Table 7. List of land function supporting ecosystems and biodiversity' indicators.

Land function	Division	Sub-division	Indicator Code	Indicator	Unit
LF 6 Land supporting ecosystems and biodiversity	Biodiversity conservation	Habitat conservation	LF_611	Habitat conservation Status	(dimensionless)
		Habitat quality indicator	LF_612a	Habitat quality based on the species distribution of all common birds included in the Common Bird Index	(dimensionless)
			LF_612b	Habitat quality based on the species distribution of forest birds included in the Common Bird Index	(dimensionless)
			LF_612c	Habitat quality based on the species distribution of farmland birds included in the Common Bird Index	(dimensionless)
	Maintaining ecosystems	Structural Green Infrastructure	LF_621	Proportion of land area covered by green infrastructure (Structural)	%
		Green Infrastructure fragmentation	LF_622	Effective mesh density (Number of meshes per 1000)	(Nm/1000 km²)

		Landscape fragmentation by artificial areas	LF_623	Effective mesh density (Number of meshes per 1000) (Under development)	(Nm/1000 km²)

LF 612 - Habitat Quality Indicator (HQI a,b,c)

1. Identification (title; code) and classification (DPSIR; typology)

The Habitat Quality Indicator (HQI) is included as a Land Function Indicator (LF 612) and has been developed for the subset of common birds in Europe (i.e. those considered in European Common birds' indicator (Gregory *et al.*, 2005; Eurostat, 2013)), thus providing the HQI for all common birds (LF 612a), for common forest species (LF 612b) and for common farmland species (LF 612c).

According to the CICES classification of ecosystem services, the HQI is classified as follows:

Section: Regulation & Maintenance, Division: Maintenance of biological conditions, Group: Lifecycle maintenance, habitat and gene pool protection, Class: Maintaining nursery populations and habitats; and more concretely the habitat quality for the reproduction of a subset of indicator species of common birds.

2. Rationale — justification for indicator selection; scientific references

Common species are determinant of the structure, function and service provision by ecosystems, playing a key role in the regulation and maintenance of biological processes (Gaston, 2010). Common birds in particular are considered good proxies to measure the diversity and integrity of ecosystems as they tend to be near the top of the food chain, have large ranges and the ability to move elsewhere when their environment becomes unsuitable (Sekercioglu, 2006). Therefore, they are responsive to changes in their habitats and ecosystems at different spatial scales.

In this context, tools such as species distribution models (SDM) allow to spatially explicitly assess the main environmental drivers determining species distributions and to make projections on future scenarios. Based on empirical occurrence data, SDM provide maps determining where the species is more likely to find suitable habitat. Combined maps of SDM for a subset of indicator species are used to develop the habitat quality indicator. The HQI will be useful to identify areas at large spatial scale where common bird species find the best habitat conditions to maintain their communities in the long term, and therefore, identify areas where the role of these species maintaining biological process are more important. In addition, the projections on different scenarios will allow to identifying potential up- and downgrades of habitat quality in response to land use changes.

The methodology applied for the HQI is part of an unpublished work (Vallecillo *et al.*, Manuscript in preparation).

3. Indicator definition — definition; units

The habitat quality indicator (HQI) is a measure of the capacity of ecosystems to provide suitable habitat for common bird communities, that are determinant of the structure, function and service provision by ecosystems; playing therefore a key role in the regulation and maintenance of biological processes. The HQI is calculated according to equation 1:

$$\boldsymbol{HQI} = \frac{\textit{Local species richness}}{\textit{Average species richness within a 250 km radius}} \quad \text{(Equation 1)}$$

Since the HQI is expressed in relative terms (see justification in the methodology section), the indicator has not related units. Values larger than 1 represent areas where the habitat quality is larger than in the neighbourhood area, and thus with larger species richness. On the contrary, values smaller than 1 show areas with local habitat quality below the average conditions in the neighbourhood area.

A total of 148 species were modelled to calculate the habitat quality indicator for common birds, split in three function groups: forest species, farmland species and other common species (**Table 8**).

Table 8. *Common bird species modelled for the Habitat Quality Indicator*

Farmland species		Forest species	
1	*Alauda arvensis*	38	*Accipiter nisus*
2	*Alectoris rufa*	39	*Anthus trivialis*
3	*Anthus campestris*	40	*Bombycilla garrulus*
4	*Anthus pratensis*	41	*Bonasa bonasia*
5	*Burhinus oedicnemus*	42	*Carduelis spinus*
6	*Calandrella brachydactyla*	43	*Certhia brachydactyla*
7	*Carduelis cannabina*	44	*Certhia familiaris*
8	*Ciconia ciconia*	45	*Coccothraustes coccothraustes*
9	*Corvus frugilegus*	46	*Columba oenas*
10	*Emberiza cirlus*	47	*Cyanopica cyanus*
11	*Emberiza citrinella*	48	*Dendrocopos medius*
12	*Emberiza hortulana*	49	*Dendrocopos minor*
13	*Emberiza melanocephala*	50	*Dryocopus martius*
14	*Falco tinnunculus*	51	*Emberiza rustica*
15	*Galerida cristata*	52	*Ficedula albicollis*
16	*Galerida theklae*	53	*Ficedula hypoleuca*
17	*Hirundo rustica*	54	*Garrulus glandarius*
18	*Lanius collurio*	55	*Nucifraga caryocatactes*
19	*Lanius minor*	56	*Parus ater*
20	*Lanius senator*	57	*Parus cristatus*
21	*Limosa limosa*	58	*Parus montanus*
22	*Melanocorypha calandra*	59	*Parus palustris*
23	*Miliaria calandra*	60	*Phoenicurus phoenicurus*
24	*Motacilla flava*	61	*Phylloscopus bonelli*
25	*Oenanthe hispanica*	62	*Phylloscopus collybita*
26	*Passer montanus*	63	*Phylloscopus sibilatrix*
27	*Perdix perdix*	64	*Picus canus*
28	*Petronia petronia*	65	*Pyrrhula pyrrhula*
29	*Saxicola rubetra*	66	*Regulus ignicapilla*
30	*Saxicola torquata*	67	*Regulus regulus*
31	*Serinus serinus*	68	*Sitta europaea*
32	*Streptopelia turtur*	69	*Tringa ochropus*

	33	*Sturnus unicolor*	70	*Turdus viscivorus*
	34	*Sturnus vulgaris*		
	35	*Sylvia communis*		
	36	*Upupa epops*		
	37	*Vanellus vanellus*		
	Other habitat species			
	71	*Acrocephalus arundinaceus*	111	*Lullula arborea*
	72	*Acrocephalus palustris*	112	*Luscinia luscinia*
	73	*Acrocephalus schoenobaenus*	113	*Luscinia megarhynchos*
	74	*Acrocephalus scirpaceus*	114	*Luscinia svecica svecica*
	75	*Actitis hypoleucos*	115	*Merops apiaster*
	76	*Aegithalos caudatus*	116	*Motacilla alba*
	77	*Anas platyrhynchos*	117	*Motacilla cinerea*
	78	*Apus apus*	118	*Muscicapa striata*
	79	*Ardea cinerea*	119	*Numenius phaeopus*
	80	*Buteo buteo*	120	*Oenanthe oenanthe*
	81	*Carduelis carduelis*	121	*Oriolus oriolus*
	82	*Carduelis chloris*	122	*Parus caeruleus*
	83	*Carduelis flammea*	123	*Parus major*
	84	*Carpodacus erythrinus*	124	*Passer domesticus*
	85	*Cettia cetti*	125	*Phoenicurus ochruros*
	86	*Circus aeruginosus*	126	*Phylloscopus trochilus*
	87	*Cisticola juncidis*	127	*Pica pica*
	88	*Columba palumbus*	128	*Picus viridis*
	89	*Corvus corax*	129	*Pluvialis apricaria*
	90	*Corvus corone*	130	*Prunella modularis*
	91	*Corvus monedula*	131	*Pyrrhocorax pyrrhocorax*
	92	*Cuculus canorus*	132	*Streptopelia decaocto*
	93	*Cygnus olor*	133	*Sylvia atricapilla*
	94	*Delichon urbica*	134	*Sylvia borin*
	95	*Dendrocopos major*	135	*Sylvia cantillans*
	96	*Dendrocopos syriacus*	136	*Sylvia curruca*
	97	*Emberiza cia*	137	*Sylvia hortensis*
	98	*Emberiza schoeniclus*	138	*Sylvia melanocephala*
	99	*Erithacus rubecula*	139	*Sylvia nisoria*
	100	*Fringilla coelebs*	140	*Sylvia undata*
	101	*Fringilla montifringilla*	141	*Tetrao tetrix*
	102	*Fulica atra*	142	*Tringa glareola*
	103	*Gallinago gallinago*	143	*Tringa totanus*
	104	*Gallinula chloropus*	144	*Troglodytes troglodytes*
	105	*Hippolais icterina*	145	*Turdus iliacus*
	106	*Hippolais polyglotta*	146	*Turdus merula*
	107	*Hirundo rupestris*	147	*Turdus philomelos*
	108	*Jynx torquilla*	148	*Turdus pilaris*
	109	*Locustella fluviatilis*		
	110	*Locustella naevia*		

4. Policy context and targets — context description; targets; related policy documents

The EU 2020 Biodiversity Strategy has as main target to halt the loss of biodiversity and the degradation of ecosystem services in the EU by 2020. A necessary requirement for implementing the Biodiversity Strategy is gathering comprehensive and robust information concerning the status of biodiversity, ecosystems and ecosystem services across the EU. In this sense, the scope of the Action 5 aiming at mapping and assessing ecosystems and their services becomes one of the keystones of the EU 2020 Biodiversity Strategy. Therefore, development of new indicators providing information about the quality of ecosystems to provide habitat for different species was required.

5. Policy questions — key policy questions; specific policy questions

The habitat quality indicator aims to answer the following policy questions:

- Which areas provide better habitat quality for the maintenance of common bird communities' at large spatial scales?
- How habitat quality may change in response to future land use scenarios?
- Which functional group may be more affected by future land use changes: forest or farmland species? And where?

6. Methodology (indicator calculation; gap filling; references)

To develop the HQI, we modelled species distribution of common birds, including the species listed in the European Common birds' indicator (Gregory et al., 2005; Eurostat, 2013). Data on bird species occurrences were obtained from the EBCC Atlas of European Breeding Birds (Hagemeijer & Blair, 1997). Species distribution models (SDM) were built by means of the maximum entropy method implemented in Maxent (Phillips *et al.*, 2006) and downscaled at 10-km^2 resolution relying on an ecological basis. Within each polygon of the species range defined by the EBCC Atlas, we refined the species occurrence at grid cells of 10-km^2 resolution based on the species preferences for breeding habitats. It will allow a more detailed assessment of the land uses as drivers of species distribution changes. The methodology used is part of an unpublished work (Vallecillo *et al.*, Manuscript in preparation).

Explanatory variables of species distributions included in the models are described in **Table 9**:

Table 9. *Environmental variables included in the species distribution models*

	Variables	Predictive role
Climate	Mean temperature of the coldest month	static
	Mean temperature of the warmest month	static
	Mean precipitation of the wettest month	static
	Mean precipitation of the driest month	static
Land uses (in %)	Artificial	dynamic
	Arable	dynamic
	Permanent crops	dynamic
	Pastures	dynamic
	Natural land	dynamic
	Transitional woodland-shrub	dynamic

	Forests	dynamic
	Other nature	static
	Wetlands	static
	Water bodies	static
Miscellaneous	Distance to big artificial areas (squared)	dynamic
	Simpson land use diversity	dynamic

Since species richness maps, obtained from the overlay of SDM, show inherent spatial patterns due to the biogeography of the species considered in the analysis, we defined the species richness in relative terms as the ratio between the local species richness and the average species richness in the neighbourhood (i.e. in a 250 km radius). This will allow overcoming the influence of the naturally heterogeneous patterns of species distributions at large spatial scales. Therefore, the relative species richness will be indicative of the capacity of ecosystems to provide suitable habitat for common bird communities and is interpreted as a 'habitat quality indicator' (HQI). The HQI, as expressed in relative terms, allows making direct comparisons between regions. Those areas showing large values of the HQI are indicative of places with high relative species richness, becoming of special concern for the maintenance of nursery habitats for common birds.

References used:

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Wiley, E.O., McNyset, K.M., Peterson, A.T., Robins, C.R. & Stewart, A.M. (2003) Niche modeling and geographic range predictions in the marine environment using a machine-learning Algorithm. *Oceanography*, 16, 120-127.

7. Data specifications — data references; external data references; data sources in latest figures

- Bird occurrence data from the EBCC Atlas of European Breeding Birds (Hagemeijer & Blair, 1997)
- Worldclim database (Hijmans et al., 2005)
- Corrected version of Corine Land Cover 2000

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

In order to reduce methodological uncertainty, different approaches were applied:

- In order to make more robust predictions, each species was modelled 10 independent times, taking for each time one random occurrence at 10 km2, where the proportion of suitable breeding habitat was above the percentile 50. Each species was considered to be present in those areas where agreement among the 10 replicates was met.
- Model performance was measured by means of the Area Under the receiver operating characteristic Curve (AUC), using 70% of the data to train the model and the remaining 30% for model evaluation. We averaged the model performance of the 10 replicates done per species. Since with presence-only data the maximum AUC achievable is lower than one (maximumAUC = 1 - area occupied/2), Wiley et al. (2003)), we expected for very common and widespread species included in the Common birds' indicator, to get low discriminatory performance. Therefore, for the species distribution models with average AUC below 0.7, we built a set of null models (10 per species) to be compared with. In the null models the species occurrences are replaced by random locations keeping the same number of observations (Raes & ter Steege, 2007). Only when the average AUC was significantly higher than the average of the 10 null models, the species was included for the final HQI.

Methodological uncertainty:

- Inherent uncertainty of species distribution model: among the main limitations of SDM it is important to consider that this tool do not account for the lack of equilibrium between the species occurrence and the underlying environmental conditions, undervaluing the role of historical factors as drivers of species distributions. In addition, models are based on single species response without considering likely species interactions
- Although we considered the most recommended algorithm for only-presences data (maximum entropy) (Elith et al., 2006), predictions may change when other algorithm for SDM is used.
- Habitat quality is a measure at large spatial scale and the interpretation should be

limited to the role of climate and landscape composition (i.e. land uses) as drivers of species distribution. It represents areas where conditions at large spatial scale are suitable for the target species. Hence, habitat conditions at local scale are not analysed with this approach. This means for instance that, for farmland species we could find an area with good habitat quality at large spatial scale, but this does not necessarily mean that local habitat conditions (at small spatial scale) also offer good conditions. Intensive agriculture practices with high pesticide loads in these areas might favour the degradation of local conditions endangering the species persistence in the long term, even when at large spatial scale offers suitable habitat and appears as high habitat quality. Therefore, the indicator here described should be understood as a way to identify hotspot at large spatial scale where potential impacts endangering the species persistence in the long term should be reduced in order to maintain the community of species driving the regulation and maintenance of many ecosystem services.

Dataset uncertainty:

Bird occurrence data from the EBCC Atlas of European Breeding Birds presents the limitation of the spatial resolution provided in polygons of 50 km^2. This spatial resolution is especially problematic when modelling the species response to land use changes. To reduce this uncertainty, data were downscaled at 10-km^2 resolution relying on an ecological basis. Within each polygon of the species range defined by the EBCC Atlas, we refined the species occurrence at grid cells of 10-km^2 resolution based on the species preferences for breeding habitats. It allows a more detailed assessment of the land uses as drivers of species distribution changes.

Given to the spatial scale used, values calculated for Malta, with a very small extent, cannot be considered as representative.

Rationale uncertainty:

The indicator is focussed in a subset of indicator species that are used at European level as the European Common birds' indicator (Gregory et al., 2005; Eurostat, 2013). Even when this group of species is quite representative of common species, other groups might be considered in further works (i.e. amphibians, reptiles, mammals). However, bird species are a really well-known group of species and are considered good proxies to measure the diversity and integrity of ecosystems as they tend to be near the top of the food chain, have large ranges and the ability to move elsewhere when their environment becomes unsuitable.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work)

- Consider the HNV farmland layer (Paracchini et al., 2008) to identify hotspots of habitat quality for farmland species where areas of intensive agriculture (not considered as HNV) might endanger the species persistence in the long term. This would be a further step to reduce some methodological uncertainties about local habitat conditions (see section 8).
- Consider a subgroup of species with preference for artificial uses (urban areas) as indicators of the response to urban sprawl. Since this group of species is rather generalist in the selection of habitats this approach should be limited to buffered areas around large urban zones.

LF 621 - Structural Green Infrastructures

1. Identification (title; code) and classification (DPSIR; typology)

LUISA Framework: LF_621structural

2. Rationale — justification for indicator selection; scientific references

Green Infrastructure (GI) is defined as a strategically planned and delivered network of high quality green spaces and other environmental features (EC, 2012) that are structurally and functionally "interconnected and therefore bring added benefits and are more resilient". GI includes natural and semi-natural areas, features and green spaces in rural and urban, terrestrial, freshwater, coastal and marine areas. GI aims to promote ecosystem health and resilience, contribute to biodiversity conservation and benefit human populations through the maintenance and enhancement of ecosystem services (Naumann et al., 2011). In this sense, there is a need to quantify the share of GI at regional level.

References:

European Commission (2012) Green infrastructure (GI)—enhancing Europe's Natural Capital. COM (2013) 249. Brussels

Naumann S, McKenna D, Kaphengst T, Pieterse M, Rayment M (2011) Design, implementation and cost elements of green infrastructure projects. Final Report to the European Commission, DG Environment, Contract 070301/2010/577182/ETU/F.1. Ecologic Institute and GHK Consulting

3. Indicator definition — definition; units

The indicator presented here measures the share of GI at different regional levels (in %). For the definition of the GI network we considered the following land uses:

LU Classes	GI category	Modelled
Urban	Never	Simulated
Industry	Never	Simulated
Other arable	GI Only if HNV	Simulated
Permanent crops	GI Only if HNV	Simulated
Pastures	GI Only if HNV	Simulated
Forests	GI	Simulated
Transitional	GI	Simulated
Cereals	GI Only if HNV	Simulated
Maize	GI Only if HNV	Simulated
Root crops	GI Only if HNV	Simulated
Abandoned arable	GI Only if HNV	Simulated
Abandoned	GI Only if HNV	Simulated
Abandoned pastures	GI Only if HNV	Simulated
Abandoned urban	Never	Simulated
Abandoned Industry	Never	Simulated
New Energy Crops	Never	Simulated

Natural land	GI	Non-simulated
Infrastructure	Never	Non-simulated
Other Nature	GI	Non-simulated
Wetlands	GI	Non-simulated
Water Bodies	GI	Non-simulated
Urban green leisure*	GI	Non-simulated

*Urban green leisure areas of LUISA maps have been refined adding information from the Global Human Settlement Layer (GHSL). Since available information of this layer is at 10m resolution, only those pixels of 100m resolution with a coverage of green urban areas above 50% were considered. This layer provides information about green covers in urban areas independently of the use, so, vegetation from private

4. Policy context and targets — context description; targets; related policy documents

EU biodiversity strategy to 2020 aims under target 2 to maintain and enhance ecosystems and their services by establishing GI and restoring at least 15 % of degraded ecosystems (EC 2011).

So, the first step to achieve this target is defining the likely land uses that define the GI network. The next step will be the functionality assessment for the provision of ecosystem services and biodiversity conservation. This will be useful to assess the quality of GI and identify degraded ecosystems to stablish restoration priorities.

References

European Commission (2011) Our life insurance, our natural capital: an EU biodiversity strategy to 2020. COM (2011) 244. Brussels

5. Policy questions — key policy questions; specific policy questions

- What proportion of the land correspond to the GI network?
- How the share of GI is expected to change according to the simulated scenarios?

6. Methodology (indicator calculation; gap filling; references)

Selection of land uses as indicated in section 3 and quantification of the area (tabulated areas) for the GI layers at different regional levels.

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios: year 2010, 2020, 2030, 2040 and 2050
- Global Human Settlement Layer (GHSL)
- NUTS 0, NUTS 2, NUTS 3 and Large Urban Zones (v 8)

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

We used the High Natural Value Farmland (HNV) layer and we assumed that all agriculture uses not included in these layers were intensive agriculture. This is a quite coarse generalization, but for the moment, this is the best data available at European level. Furthermore, this layer is not modelled in the simulated scenarios; it is kept fixed. So, when assessing the share of GI at regional level we do not account for changes in the patterns of intensive agriculture because we took this factor as static between scenarios.

Other limitation of this approach is that it does not reflect information about the quality or functionality of the land uses shaping the GI network.

9. Responsibility and ownership (indicator manager; ownership)

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10. Further work (short-term work; long-term work)

We will also work on the assessment of the functionality of GI by analysing its capacity to deliver ecosystem services and provide important habitats for biodiversity conservation (multi-functionality approach based on the EEA 2014).

References:

European Environment Agency. 2014. Spatial analysis of green infrastructure in Europe. European Environment Agency.

11. Publisher:

European Commission - Joint Research Centre

Lavalle, C, Vallecillo Rodriguez, S (2015): LF621 - Structural Green Infrastructures (LUISA Platform REF2014). European Commission - Joint Research Centre.

LF 622 - Landscape Fragmentation

1. Identification (title; code) and classification (DPSIR; typology)

EUROSTAT: Resource Efficiency Scoreboard > Natural capital and ecosystem services > Biodiversity > Landscape fragmentation (Resource Efficiency Framework: t2020_rn110, LUISA Framework: LF_622)

EEA: Biodiversity/Ecosystem integrity and ecosystem goods and services/Fragmentation of natural and semi-natural habitats. DPSIR typology: descriptive indicator of pressure.

2. Rationale — justification for indicator selection; scientific references

Landscape fragmentation, usually also associated to habitat loss, is becoming a central issue in land and conservation planning since is a key process with negative impacts on biodiversity. Habitats which are highly degraded or fragmented are less likely to be able to support species in the long term or provide the same level of ecosystem services as by intact habitats. In this sense, an indicator of landscape fragmentation is required to assess likely changes and provide support to policy development. The effective mesh density is the indicator of landscape fragmentation included in the Resource efficiency Scoreboard given the advantages it presents over other landscape metrics (Jaeger, 2000; Moser *et al.*, 2007).

References used:

EEA - European Environmental Agency (2012) Urban adaptation to climate change in Europe: Cities' challenges, opportunities, and supportive national and European policies. In:

EEA - European Environmental Agency & FOEN - Swiss Federal Office for the Environment (2011) Landscape fragmentation in Europe. In. European Environmental Agency. , Luxembourg.

Forman, R.T.T., Sperling, D., Bissonette, J.A., Clevenger, A.P., Cutshall, C.D., Dale, V.H., Fahrig, L., France, R., Goldman, C.R., Heanue, K., Jones, J.A., Swanson, F.J., Turrentine, T. & Winter, T.C. (2003) Road Ecology. Island Press, Covelo, CA.

Jaeger, J. (2000) Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. Landscape Ecology, 15, 115-130.

Moser, B., Jaeger, J.G., Tappeiner, U., Tasser, E. & Eiselt, B. (2007) Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem. Landscape Ecology, 22, 447-459.

Paracchini, M.L., Petersen, J.E., Hoogeveen, Y., Bamps, C., Burfield, I. & van Swaay, C. (2008) High Nature Value Farmland in Europe: An estimate of the distribution patterns on the basis of land cover and biodiversity data. In: JRC Scientific and technical reports. JRC, EEA, Luxembourg.

3. Indicator definition — definition; units

The indicator presented here measures the degree to which species movements between different parts of the landscape are interrupted by barriers. The more barriers fragmenting the landscape, the more difficult will be the species movement through the landscape. This is measured by the effective mesh density (S_{eff}) and includes the so called 'cross-boundary connections' procedure that eliminates the bias arising from the patches shared by two or more reporting units (i.e. administrative boundaries) (Jaeger, 2000; Moser et al., 2007; EEA & FOEN, 2011). It is expressed in number of meshes per 1,000 km² - the more fragmented is the landscape, the higher is the effective mesh density of a given region.

4. Policy context and targets — context description; targets; related policy documents

The indicator of 'Landscape fragmentation' has been included in the Resource Efficiency Scoreboard as indicator for the assessment of the progress towards the objectives of the Roadmap to a Resource Efficient Europe.

In addition, the 'Aichi Biodiversity Target' number 5, established by the parties to the Convention on Biological Diversity, states that '*by 2020, the rate of loss of all natural habitats, (…), is at least halved, (…), and degradation and fragmentation is significantly reduced*'. However, specific targets would be needed to implement measurements towards a better protection of the environment. As discusses in the report 'Landscape Fragmentation in Europe' benchmarks and limits could be distinguished for different types of landscapes. In this sense, priority habitats which have strategic national or global ecological importance should be identified for the implementation of specific fragmentation targets.

5. Policy questions — key policy questions; specific policy questions

The landscape fragmentation indicator aims to answer the following policy questions:

- To what extent are natural and semi-natural lands fragmented in Europe?
- How may landscape fragmentation change in future scenarios in response to urban and industrial sprawl and bioenergy crops?

6. Methodology (indicator calculation; gap filling; references)

The 'Landscape fragmentation' indicator based on the effective mesh density (number of meshes per 1,000 km^2) is based in the methodology described by Jaeger (2000) and Moser et al. (2007). First, we calculated the effective mesh size (m_{eff}), which estimates the probability that two points chosen randomly in a region are connected. We also accounted for the 'cross-boundary connections' of the habitat patches that are shared by two different regions (i.e. countries, regions, provinces) applying equation 1 (Moser et al., 2007):

$$\mathbf{m_{eff}^{CBC}} = \frac{\mathbf{1}}{\mathbf{Atotal}} \sum_{\mathbf{i=1}}^{\mathbf{n}} \left(\mathbf{Ai \ x \ Ai^{cmpl}}\right) \qquad \textit{(Equation 1)}$$

where $\mathbf{n}$ is the number of patches in a given study region, $\mathbf{Ai}$ is the size of the patch inside the region and $\mathbf{Ai^{cmpl}}$ is the complete area of the patch including also the area outside the study region. $\mathbf{Ai}$ will be equal to $\mathbf{Ai^{cmpl}}$ when the patch is completely located in the study region. Then, the effective mesh size was converted to effective mesh density (S_{eff}) according to equation 2 (Jaeger, 2000):

$$\mathbf{S_{eff}} = \frac{\mathbf{1}}{\mathbf{m_{eff}^{CBC}}} \qquad \textit{(Equation 2)}$$

The interpretation of this indicator largely depends on the definition of the elements that are considered as being habitat areas (i.e. natural and semi-natural habitats for the species movement) and what are considered barriers (i.e. physical obstacles to species movement). The land uses that are considered as landscape and barrier are shown in **Table 10**:

Table 10. Definition of land uses and other features as habitat or barriers for the calculation of landscape fragmentation

Land uses	Classification
Artificial (Urban, ICS and infrastructures)	Barrier
Agriculture (crops, pastures, arable land)	Barrier if it is not included as High Natural Value Farmlands[1] Habitat if it has HNV
Forests	Habitat
Transitional woodland-shrub	Habitat
Abandoned farmland	Barrier if it is not included as High Natural Value Farmlands[1] Habitat if it has HNV
Abandoned artificial	Barrier
New energy crops	Barrier[2]
Natural land	Habitat
Other nature	Habitat
Wetlands	Habitat
Water bodies	Habitat
Urban green leisure	Habitat[3]
Roads (TeleAtlas)	
Motorways	Barrier
National roads	Barrier

[1]As suggested in EEA - European Environmental Agency and FOEN - Swiss Federal Office for the Environment (2011)

[2] Immerzeel, D.J., Verweij, P.A., van der Hilst, F. & Faaij, A.P.C. (2014) Biodiversity impacts of bioenergy crop production: a state-of-the-art review. GCB Bioenergy, 6, 183-209.

[3] Since this land use may contribute to favour landscape connectivity (EEA - European Environmental Agency, 2012)

Only main roads were included as barriers, assuming to be 100 m wide, since this is the minimum information unit (pixel resolution). See also 'Uncertainties' section. Although motorways and national roads do not always reach 100 m wide, their impact on both sides of the road could easily have a significant impact on this distance (Saunders *et al*., 2002). In this context, regional and local roads were not included as barriers for two main reasons. First, since the pixel resolution of the source data (LUISA scenarios) was 100 m, including elements that might have a barrier effect at smaller spatial resolution would result in a mistreatment of the source data and an overestimation of the landscape fragmentation. Secondly, the role of secondary roads as barriers in the landscape appears not to be so important since they show permeability for the movement of many species (Forman *et al.*, 2003).

References used:

EEA - European Environmental Agency & FOEN - Swiss Federal Office for the Environment (2011) Landscape fragmentation in Europe. In. European Environmental Agency. , Luxembourg.

Jaeger, J. (2000) Landscape division, splitting index, and effective mesh size: new measures of landscape fragmentation. Landscape Ecology, 15, 115-130.

Moser, B., Jaeger, J.G., Tappeiner, U., Tasser, E. & Eiselt, B. (2007) Modification of the effective mesh size for measuring landscape fragmentation to solve the boundary problem. Landscape Ecology, 22, 447-459.

Saunders S.C., Mislivets M.R., Chen J. & Cleland D.T. (2002) Effects of roads on landscape structure within nested ecological units of the Northern Great Lakes Region, USA. Biological Conservation, 103, 209-225.

7. Data specifications — data references; external data references; data sources in latest figures

- LUISA scenarios: year 2010, 2020, 2030, 2040 and 2050
- High Natural Value farmland (Paracchini et al., 2008)
- Roads: Tele Atlas
- **EU-28 administrative regions: NUTS0, NUTS2, NUTS3**

8. Uncertainties — methodology uncertainty; data set uncertainty; rationale uncertainty

Methodological uncertainty:

With the method here presented to assess landscape fragmentation it is important to consider some methodological limitations for a correct interpretation. The method used assumes all barriers to have the same role limiting the species movement. It is based on a binary classification of 'habitat' and 'non-habitat'. However, this is an oversimplification of the complex patterns of species movement though the landscape. For instance, for a given species the barrier effect might be larger in urban areas than in intensive agricultural areas, or in high traffic density roads as opposed to national roads less frequented. In addition, this indicator addresses the fragmentation of the landscape as a whole, looking at the spatial structure of the habitat patches, without focusing in a specific group of habitats or species (e.g. forest habitats and species). Landscape fragmentation will have a different impact on the biodiversity depending on their ecological requirements (type of habitats used) and dispersal distances of the species considered. Finally, the impact and relevance of the landscape fragmentation will depend on the ecological importance of the area affected. Landscape fragmentation should be of especial concern in key habitats for the maintenance of biodiversity and ecosystems.

Dataset uncertainty:

The main uncertainty from this indicator arises from the spatial resolution of the source data (100 m^2). Therefore, landscape fragmentation taking place at smaller spatial scale cannot be measured with the available data at European level. The role of agricultural intensification as a landscape barrier presents also some limitations given the available data. The High Natural Value Farmlands used to split the agricultural uses into habitat or non-habitat is static. Therefore, temporal changes of this factor cannot be integrated.

9. Responsibility and ownership (indicator manager; ownership)

IES- Sustainability Assessment Unit (H-08)

10. Further work (short-term work; long-term work) NA
11. Publisher: European Commission - Joint Research Centre Lavalle, C.; Vallecillo Rodriguez, S (2015): LF622 - Landscape Fragmentation (LUISA Platform REF2014). European Commission - Joint Research Centre.

Conclusions

Land functions are instrumental to better understand territorial processes and to better inform on the impacts of policy options. A land function can, for example, be physical (e.g. related to hydrology or topography), ecological (e.g. related to landscape or phenology), social (e.g. related to housing or recreation), economic (e.g. related to employment or production or to an infrastructural asset) or political (e.g. consequence of policy decisions). Commonly, one portion of land is perceived to exercise many functions. Land functions are temporally dynamic, depend on the characteristics of land parcels, and are constrained and driven by natural, socio-economic, and technological processes.

The Land-Use-based Integrated Sustainability Assessment (LUISA) modelling platform has been developed based upon this concept of 'Land Functions' aiming at contributing to the evaluation of impacts of policies and socio-economic trends on European cities and regions. LUISA has been configured in compliancy with the "EU Energy, Transport and GHG emission trends until 2050 – Reference Scenario 2013" (LUISA Updated Configuration 2014) assuming socio-economic trends as set by ECFIN and E-STAT. It includes the Cohesion Policy's current legislation (regional and infrastructural investments at regional scale), CAP related measures, biodiversity and habitat protection (Baranzelli et al., 2014).

LUISA simulates land functions described by means of spatially explicit indicators. The indicators are grouped according to six themes, projected in time until typically year 2030 or 2050, and can be represented at various levels (national, regional or other). The main goal of the exercise is to provide a set of 'indicators of land functions' that can be used as benchmark for alternative scenarios (e.g. to simulate policy options or specific measures), and for future updates of the reference scenario, to capture policy impacts (for example when changing energy targets) and their territorial effects.

Methodology, data sources, uncertainties and other characteristics of each indicators have been fully described in this report in order to provide an indicator definition as detailed as possible.

The implementation of the reference scenario with the LUISA platform will follow an annual up-date. Indicators and basic spatial layers used for the simulation will be made available in the frame of the framework for the management of knowledge and dissemination of information being set up by the Pilot Knowledge Centre on Territorial Policies.

References

Baranzelli, C., Jacobs-Crisioni, C., Batista e Silva, F., Perpiña Castillo, C., Barbosa, A., Arevalo Torres, J., Lavalle, C. 2014. The Reference scenario in the LUISA platform – Updated configuration 2014. Towards a Common Baseline Scenario for EC Impact Assessment procedures. EUR 27019 EN. Luxembourg: Publications Office of the European Union, (2015).

European Environment Agency (EEA), 2014. Digest of EEA indicators 2014. Luxembourg. Retrieved from http://www.eea.europa.eu/publications/digest-of-eea-indicators-2014.

Lavalle, C., Barbosa, A. L., Mubareka, S., Jacobs-Crisioni, C., Baranzelli, C., Perpiña Castillo, C. (2013). Land Use Related Indicators for Resource Efficiency - An analytical framework for the assessment of the land milestone proposed in the Roadmap for Resource Efficiency. http://doi.org/10.2788/94223.

Other references for each indicator developed were allocated in their associated indicator factsheet.

List of abbreviations

AUC	Area Under the receiver operating characteristic Curve
AQG	Air Quality Guidelines
CDDA	Common Database on Designated Areas
CLC	Corine Land Cover
CO_2	Carbon dioxide
DG	CLIMA Directorate-General for Climate Action
DG	ECFIN Directorate-General for Economic and Financial Affairs
DG	ENER Directorate-General for Energy
CAPRI	Common Agricultural Policy Regionalised Impact model
CAP	Common Agricultural Policy of the European Union
DEM	Digital elevation model
DPSIR	Driving forces - Pressures - State - Impact – Responses
EBCC	European Breeding Birds atlas
EC	European Commission
EEA	European Environmental Agency
EPRTR	European Pollutant Release and Transfer Register
ESDB	European soil database
EU28	European Union (28 countries)
EUR	Euros
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GEM-E3	General equilibrium model for economy – energy – environment
GHG	Green House Gases
GHSL	Global Human Settlement Layer (GHSL)
GI	Green Infrastructure
GMIA	Global Map of Irrigation Areas
GVA	Gross Value Added
ha	Hectares
HNV	High Nature Value farmland areas
HQI	Habitat quality index
IPPC	Intergovernmental Panel on Climate Change
kha	Thousands of hectares
km^2	Square kilometres
ICS	Industry, commerce and services
LAI	Leaf area index
LAU	Local Administrative Unit
LCF	Land cover/use flows
LF	Land functions
LU	Land use
LUCAS	Land Use/Cover Area frame statistical Survey
LUISA	Land Use-based Integrated Sustainability Assessment platform
LULUCF	Land use, land-use change and forestry
LUZ	Large urban zones
m^2	Square metres
m^3	Cubic metres
Mt	Million tonnes
MAES	Mapping and assessment of ecosystem and their services
MJ/GJ	Megajoule/Gigajoule
MS	Member State
NA	No answer
NASA	National Aeronautics and Space Administration
NDVI	Normalized Difference Vegetation Index
NO_2	Nitrogen dioxide
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organization for Economic Cooperation and Development

OpenNESS	Operationalisation of natural capital and ecosystem services
PM10	Particulate Matter up to 10 micrometres in size
PPS	Purchasing power standard
POLES	Prospective Outlook on Long-term Energy Systems model
PRIMES	Price Induced Market Equilibrium System model
RED	Renewable Energy Directive
RERM	Resource efficiency road map
REF2014	Updated Reference Scenario configuration 2014 in LUISA platform
RUSLE	Revised Universal soil loss equation
R&D	Research and development
SDM	Species distribution model
SOC	Soil organic carbon
SRTM	Shuttle Radar Topography Mission
t	tonnes
TENT-T	Trans-European Transport Networks
TESI	Total Ecosystem Service index
TRANS-TOOL	TRansport Forecasting ANd Scenario testing tool
UNWTO	United Nations - The World Tourism Organization
WHO	World Health Organization
WRI	Water retention index
µgm	Micrograms

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