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Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment

Supplement (Indicator fact sheets)

Joint Research Centre, European Environment Agency, DG Environment, European Topic Centre on Biological Diversity, European Topic Centre on Urban, Land and Soil Systems

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Contents

Abstract

This report is a supplement to the EU Ecosystem Assessment (Maes et al., 2020). The assessment is carried out by Joint Research Centre, European Environment Agency, DG Environment, and the European Topic Centres on Biological Diversity and on Urban, Land and Soil Systems. This supplement contains a series of indicator fact sheets with information of the indicators, data, and metadata used in this ecosystem assessment.

Reference:

Maes, J., Teller, A., Erhard, M., Condé, S., Vallecillo, S., Barredo, J.I., Paracchini, M.L., Abdul Malak, D., Trombetti, M., Vigiak, O., Zulian, G., Addamo, A.M., Grizzetti, B., Somma, F., Hagyo, A., Vogt, P., Polce, C., Jones, A., Marin, A.I., Ivits, E., Mauri, A., Rega, C., Czúcz, B., Ceccherini, G., Pisoni, E., Ceglar, A., De Palma, P., Cerrani, I., Meroni, M., Caudullo, G., Lugato, E., Vogt, J.V., Spinoni, J., Cammalleri, C., Bastrup-Birk, A., San Miguel, J., San Román, S., Kristensen, P., Christiansen, T., Zal, N., de Roo, A., Cardoso, A.C., Pistocchi, A., Del Barrio Alvarellos, I., Tsiamis, K., Gervasini, E., Deriu, I., La Notte, A., Abad Viñas, R., Vizzarri, M., Camia, A., Robert, N., Kakoulaki, G., Garcia Bendito, E., Panagos, P., Ballabio, C., Scarpa, S., Montanarella, L., Orgiazzi, A., Fernandez Ugalde, O., Santos-Martín, F., Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment, EUR 30161 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-17833-0, doi:10.2760/757183, JRC120383.

Fact sheet 3.0.100: Area of MAES ecosystem types and extended ecosystem layers 2018

1. General information

This fact sheet contains area estimates for the different MAES ecosystem types, EU marine regions and extended ecosystem types used the EU ecosystem assessment.

2. Data sources

- Data holder: EEA
- Weblinks:
  - Corine Land Cover https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data
  - Natura 2000 data - the European network of protected sites https://www.eea.europa.eu/data-and-maps/data/natura-10
  - State of Nature in the EU. Results from reporting under the Nature Directives 2013-2018 Version: 6.0
  - Marine protected areas: ETC/ICM - Spatial Analysis of Marine Protected Area Networks in Europe's Seas II, Volume A, 2017. Data from Table 3.6 p.34 and Table 3.8 p.37 (Agnesi et al., 2017)
- Year or time-series range: 2018 (land area), 2016 (marine area)
- Versions
  - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
  - Natura 2000 End 2018 – Shapefile
  - Art.17 data still to be published on 15/07/2020

3. Data

Table 1 presents estimates for the year 2018 based on the Corine Land Cover data 2018, the . The table contains information on the total extent of ecosystem types on the EU land area, the total Area of Annex 1 habitat (protected under the Habitats Directive), the total area of Natura 2000 and the total area of Annex 1 habitat inside Natura 2000. Romania overestimated for certain habitat types the total area of Annex 1 habitat. Therefore, table 1 also includes statistics on the different area estimates for Romania and for the EU-28 without Romania.

Table 2 contains area estimates for extended ecosystem layers. These extended layers overlap with other ecosystem types and should therefore not be used for accounting purposes.

Table 3 lists the total area of the EU marine regions, the area of coastal and marine Annex 1 habitats and the area of marine protected areas.

Table 1. Ecosystem extent on the EU land area using Corine Land Cover 2018 as reference.

MAES ecosystem types (EU land area, Corine Land Cover)	Area (EU-28, km2)	Area (Romania, km2)	Area (EU-28 excl. Romania, km2)	Area Annex 1 habitat (EU-28, km2)	Area Annex 1 habitat (EU-28 excl. Romania, km2)	Area Natura 2000 (km2)	Area of Annex 1 habitat within Natura 2000 (km2)
Urban ecosystems	222 189	12 504	209 685	0	0	6 777	0
Cropland	1 596 051	111 476	1 484 575	0	0	135 185	0
Grassland	500 566	30 668	469 898	247 328	218 504	94 056	73 253
Forest	1 597 533	75 473	1 522 060	494 392	429 961	361 505	157 588
Inland wetlands	98 003	3 080	94 922	138 437	109 337	36 623	29 191
Heathland and shrub	181 814	739	181 074	128 894	125 602	73 926	61 642
Sparsely vegetated land	67 986	241	67 744	128 452	36 272	35 764	18 532
Rivers and lakes	109 261	3 346	105 915	127 754	68 050	35 383	27 769
Marine inlets and transitional waters	24 776	785	24 701				
Coastal wetlands (Annex 1)				84 487			
Total area	**4 398 178**	**238 313**	**4 160 575**	**1 349 745**	**987 727**	**779 219**	**367 975**

Table 2. Extent of extended ecosystem layers on the EU land area using Corine Land Cover 2018 as reference.

Extended layers	**Area (EU-28, km2)**
Rivers, lakes and riparian land	329 637
Functional urban areas (full)	991 759
Functional urban areas (core)	169 236
Potential floodplains	370 740
Extended wetlands	377 888
Total area of terrestrial ecosystems covered by soil	4 153 047
Total area of terrestrial ecosystems covered by organic soil	269 948
Total area of terrestrial ecosystems covered by mineral soil	3 883 099

Calculations for the area of soil: Soil is arguably the largest terrestrial habitat in the EU. In extent, soil in one form or other covers 4,398,178 km2 (i.e. the total EU land area; see Table 1). Excluding rivers and lakes, and marine inlets and transitional waters and minus a nominal 50% of the urban area, soil extends over 4,153,047 km2 of the EU's terrestrial ecosystems (or 94.4%). Organic soils, more commonly referred to as peatlands, are a distinctive soil ecosystem in their own right (see chapter 3.4 on inland wetlands) and account for around 6.5% of the soil area. The remaining 93.5% are mineral soils.

Table 3. Extend of the EU marine regions, coastal and marine Annex 1 habitat and marine protected areas

EU marine regions	**Area (EU-28, km2)**	**Area Annex 1 habitat (EU-28, km2)**	**Marine Protected Areas (km2)**
Baltic Sea	368 720	42 158	60 839
Black Sea	64 384	121	9 143
Mediterranean Sea	1 274 892	34 803	149 162
North East Atlantic Ocean	4 082 719	433 159	404 189
Total area	**5 790 715**	**510 241**	**623 333**

Reference

Agnesi, S., Mo, G., Annunziatellis, A., Chaniotis, P., Korpinen, S., Snoj, L., Globevnik, L., Tunesi, L., Reker, J. 2017, Spatial Analysis of Marine Protected Area Networks in Europe's Seas II, Volume A, 2017, ed. Künitzer, A., ETC/ICM Technical Report 4/2017, Magdeburg: European Topic Centre on inland, coastal and marine waters, 41 pp.

Fact sheet 3.1.100: Reporting units for urban ecosystems

1. General information

- Reporting units for the urban ecosystems

2. Data sources

- Data holder: EUROSTAT – Urban Audit
- Weblink: https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/urban-audit#ua11-14
- Version: Urban Audit 2018
- Access date: January 2019
- Reference: (Eurostat 2017)

The study focused on 706 European cities and their surroundings. As basic mapping boundaries and spatial reporting units the Spatial system for city statistic, version 2018[1], was used as recommended by EUROSTAT (Dijkstra and Poelman, 2012; EuroStat, 2016; Eurostat, 2017). The system is structured as follow:

- **Functional Urban Areas**, defined as the core city (with at least 50,000 inhabitants) and the commuting zone. It is based on commuters, employed persons living in one city that work in another city. It represents an 'operational urban spatial extent' that allows mapping and evaluating the city and its surroundings. The commuting area is an area of transition, from agricultural or semi-natural land uses to urban land use and is very important when considering ecosystem services. There are cities that never had a commuting zone or that lost its commuting zone.

- **Core cities** are cities with at least 50,000 inhabitants. One FUA includes one or more core cities. As reporting unit for core cities, we aggregated all core cities within the same FUA.

- **Commuting zone (or sub city districts),** it represents the commuting zone around the core city; occasionally FUAs do not include a commuting zone (15% of the cases).

- **'Greater city',** are urbanized areas that stretch far beyond their administrative boundaries. The greater city can overlap completely the FUA and includes one or more urban centres (Eurostat, 2017).

For reasons of consistency, *Greater cities* have been considered as the core city for the respective FUAs (eg. Naples, Paris, London, Athens, see Eurostat, 2017).

[1] https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units/urban-audit

Table 1: The spatial system for city statistic, number and share of FUAs per Country. 15% of the cities lack of a commuting zone (they never had one or lost it).

Country code	Number of		Country code	Number of	
	Commuting zone and aggregated core cities	Disaggregated core cities		Commuting zone and aggregated core cities	Disaggregated core cities
AT	6	6	**IE**	5	5
BE	11	11	**IT**	84	92
BG	17	18	**LT**	6	6
CY	2	2	**LU**	1	1
CZ	15	18	**LV**	4	4
DE	96	127	**MT**	1	1
DK	4	4	**NL**	35	47
EE	3	3	**PL**	58	68
EL	14	14	**PT**	13	25
ES	81	132	**RO**	35	35
FI	7	9	**SE**	12	13
FR	64	68	**SI**	2	2
HR	7	7	**SK**	8	8
HU	19	19	**UK**	96	171
			EU	706	916

Table 2. Spatial system for greater cities in the EU-28.

Country code	Number of greater cities	City name	Number of core cities
DK	1	Copenhagen	1
EL	1	Athens	1
ES	2	Barcelona, Bilbao	13
FI	1	Helsinki; Espoo; Vantaa	3
FR	1	Paris	1
IE	1	Dublin	1
IT	2	Naples; Milan	4
NL	2	Amsterdam; Rotterdam	8
PL	1	Katowice	8
PT	2	Lisbon, Porto	11
SE	1	Stockholm	1
UK	10	London; West Midlands urban area; Liverpool; Greater Manchester; Tyneside conurbation; Leicester; Portsmouth; Greater Nottingham; Southend-on-Sea; Reading; Preston	63

Figure 1: Distribution of Functional Urban Areas, Core cities and Greater cities in Europe (EU-28).

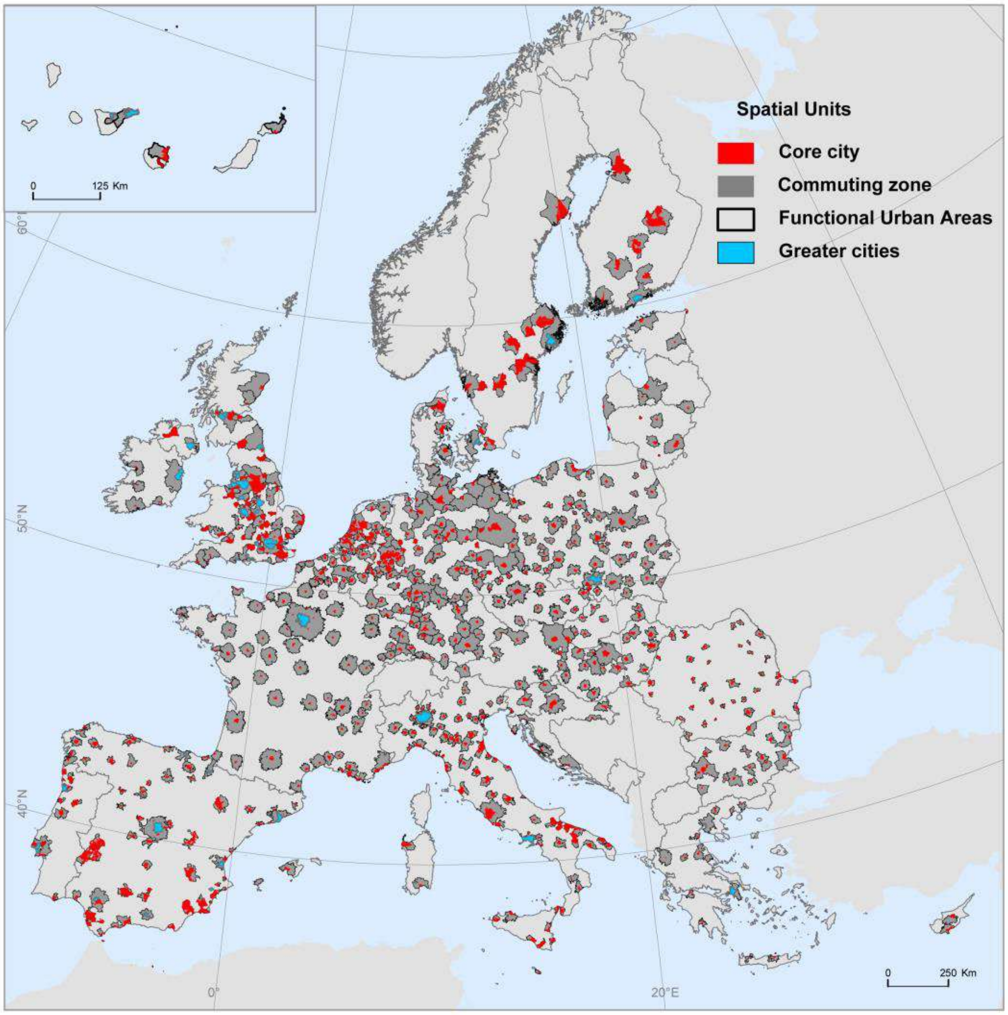
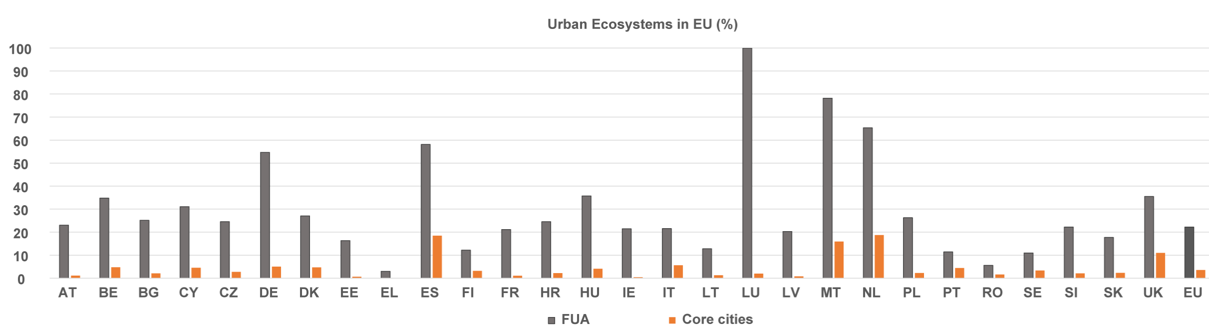


Figure 2: Proportion of surface area of FUA and core cities in EU countries territory (%)



Size of European cities

According to the Organization for Economic Co-operation and Development (OECD), population density and commuting patterns correctly reflect the economic function of cities in addition to their administrative boundaries[2]

Urban areas in OECD countries are classified as:

- large metropolitan areas with population > 1.5 million or more;
- metropolitan areas if their population is between 500,000 and 1.5 million;
- medium-size urban areas if their population is between 200,000 and 500,000;
- small urban areas if their population is between 50,000 and 200,000.

If we classify FUAs according to the size of the respective core cities, we find that almost 70% of European cities are small urban areas, 20% medium size cities, almost 8% metropolitan size and only 2.8% are large metropolitan areas. Large metropolitan areas host more than 27 % of EU urban citizens (see Table 2) and half of urban population in Europe lives in 75 functional urban areas (10.8 % of the FUAs).

Table 4: proportion of cities per size group and relative population (%)

Type of FUA	%	
	Fuas per size class	**Population within FUAs**
large metropolitan areas	2.89	27.40
metropolitan areas	7.95	23.68
medium-size urban areas	20.09	20.57
small urban areas	69.08	28.36

The size of administrative boundaries (of FUA and core cities) on the other hand, reflects well the structure of urban ecosystems. The size of Functional urban areas and core cities varies considerably in the different European countries (see Figure 1).

All reporting units used in this assessment are compliant with EUROSTAT- Urban Audit structure. The reporting unit chosen to describe each indicator varies according to the data available (nature of the data, spatial accuracy and precision), the type of indicator (for structural ecosystem attributes we try to disaggregate as much as possible to provide a clear overview of European Urban Ecosystems), the type

2 https://data.oecd.org/popregion/urban-population-by-city-size.htm

of policy support requested and the type of stakeholders that potentially can be interested in the indicator.

Table 2: indicators resolution and key reporting units used in the assessment.

Class	Indicator	Reporting unit	
Pressure	Air pollutants emissions	FUA	
	Imperviousness	Core city	Densely built
			Not-densely built
	Municipal waste generated	Aggregate municipalities per MS	
Condition-Environmental quality	Air pollutant concentrations	FUA	
	Bathing water quality		
	Population exposed to road noise pollution	Agglomerations with more than 100000 inhabitants	
	Population	Core city	
		FUA	
Condition-Structural ecosystem attributes	Share of dominant land types	FUA	
	Urban structure	FUA	
	Trends in vegetation cover within Urban Green Infrastructure (UGI)	Core city	Densely built
			Not-densely built
		Commuting Zone	Densely built
			Not-densely built

References

Eurostat (2017) Methodological manual on city statistics – 2017 edition. Luxembourg: Publications Office of the European Union, 2017

Fact sheet 3.1.101: Air Pollution Emission within urban areas

1. General information

- Thematic ecosystem assessment: Urban
- Indicator class: Pressure
- Name of the indicator: Air pollution emissions
  - NOx National Total (generated: 31.05.2019)
  - PM 10 National Total (generated: 03.06.2019)
  - PM 2.5 National Total (generated: 03.06.2019)
  - NMVOCs National Total (generated: 04.06.2019)
  - SOx National Total (generated: 04.06.2019)
- Units: tonne/year
- Spatial resolution: 0.1° x 0.1° (long-lat)

2. Data sources

The indicator is based on readily available data.

- Data holder (EMEP)
- Data source: EMEP/CEIP 2019, Spatially distributed emission data as used in EMEP models; Terms of reference: CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/deed.en)
- Weblink: http://www.ceip.at/ms/ceip_home1/ceip_home/new_emep-grid/01_grid_data
- Year or time-series range: 1990- 2000- 2010 - 2017
- Access date: October 2019
- Reports:
  - "NEC Directive reporting status" [3] (the report doesn't provide statistic at FUA level)
  - "EU Member States make only mixed progress in reducing emissions under UN convention, latest air pollution data shows"[4]

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Emissions is the term used to describe the gases and particles which are put into the air or emitted by various sources. The amounts and types of emissions change every year. These changes are caused by changes in the nation's economy, industrial activity, technology improvements, traffic, and by many other factors.

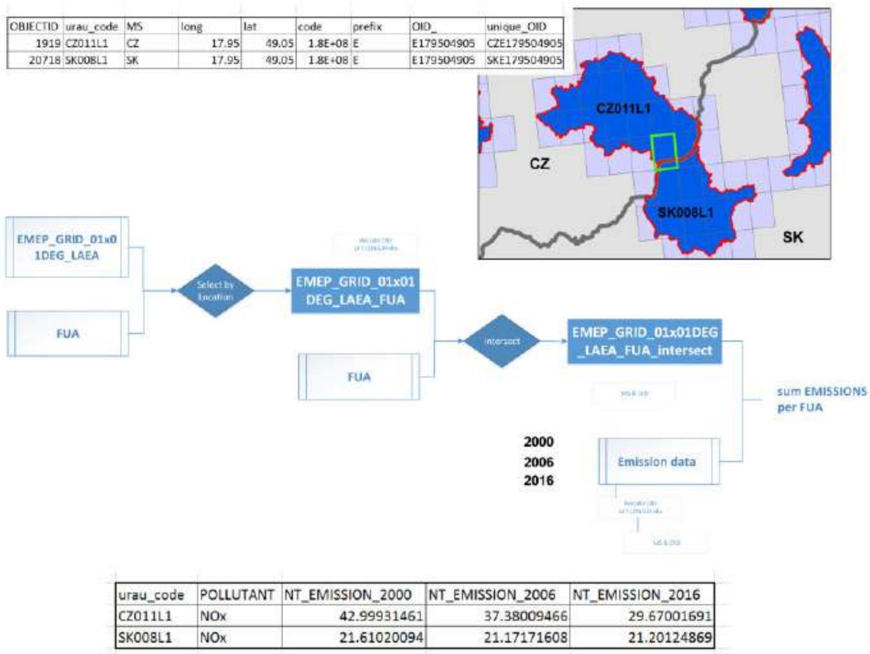
The National Emission Ceilings (NEC) Directive[5] sets national emission reduction commitments for Member States and the EU for five important air pollutants: nitrogen oxides (NOx), non-methane

[3] https://www.eea.europa.eu/publications/nec-directive-reporting-status-2019
[4] https://www.eea.europa.eu/highlights/eu-member-states-make-only
[5] https://www.eea.europa.eu/themes/air/national-emission-ceilings/national-emission-ceilings-directive

volatile organic compounds (NMVOCs), sulphur dioxide (SO2), ammonia (NH3) and fine particulate matter (PM2.5). These pollutants contribute to poor air quality, leading to significant negative impacts on human health and the environment.

In this study we used spatially explicit data of emission retrieved from the EMEP database. The emission grid (in the resolution 0.1°x0.1° long-lat) was intersected with the FUAs boundaries. An unique OID based on latitude and longitude was created to account for transboundary emissions (see figure 1).

Figure 1: workflow to connect FUA grid to emission data.



Directive 2001/81/EC of the European Parliament and of the Council of 23 October 2001 on national emission ceilings for certain atmospheric pollutants

3.2. Maps

Figure 2: NOx within FUAs, Status map (2017)

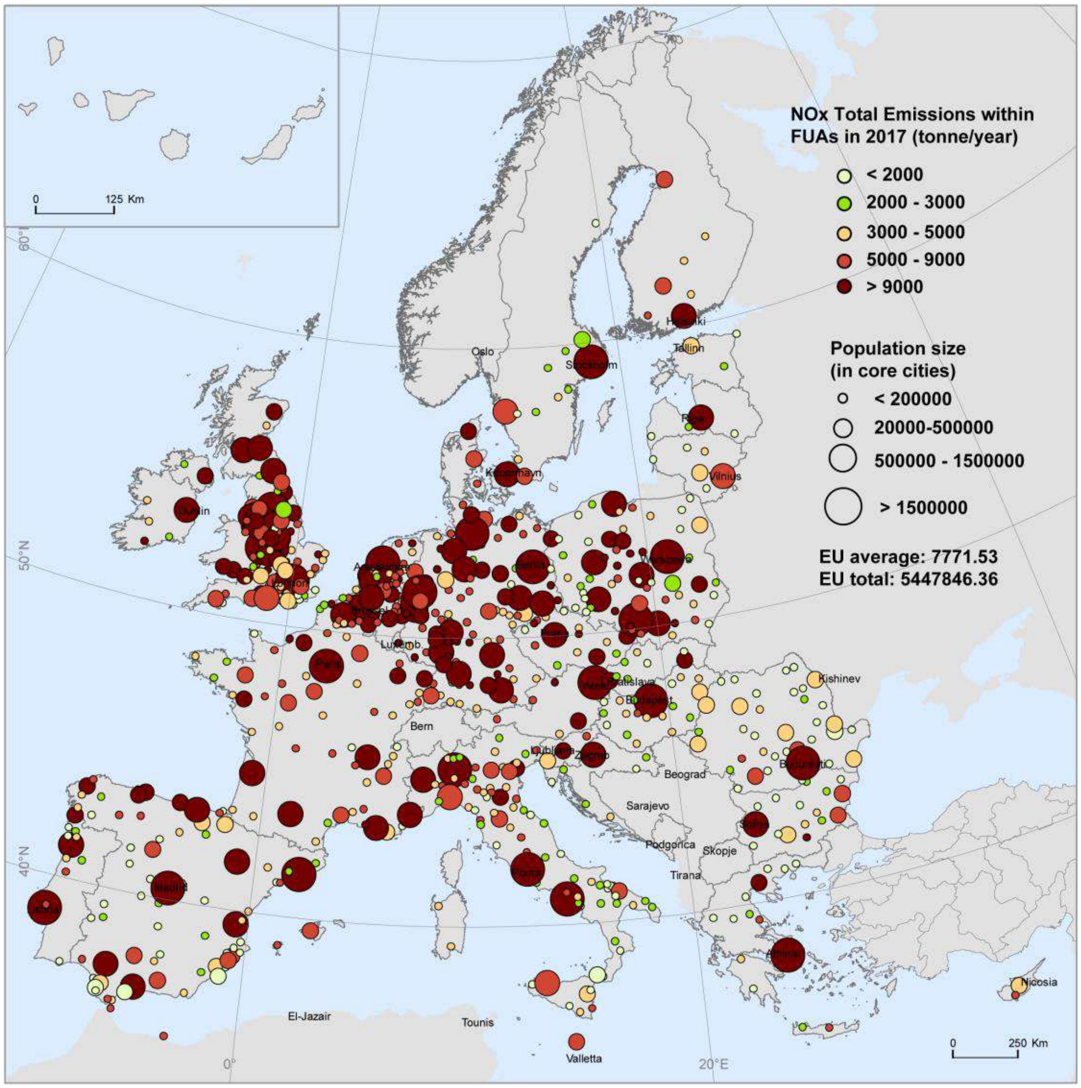


Figure 3: NOx emissions. NOx within FUAs in the Short and Long Term (source: EMEP model); National emission by sectors (source EEA)

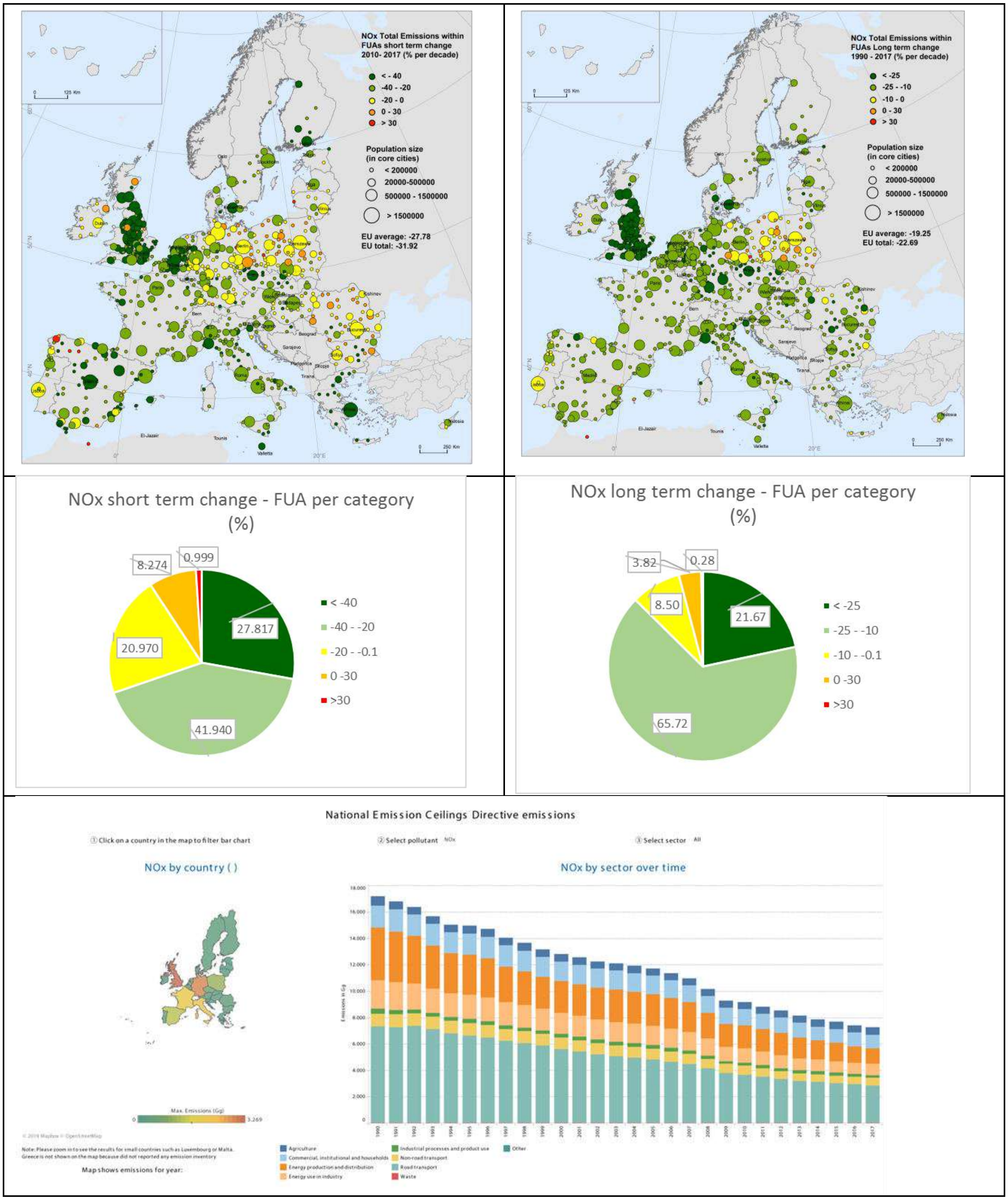


Figure 4: PM10 emissions registered within FUAs, Status map (2017)

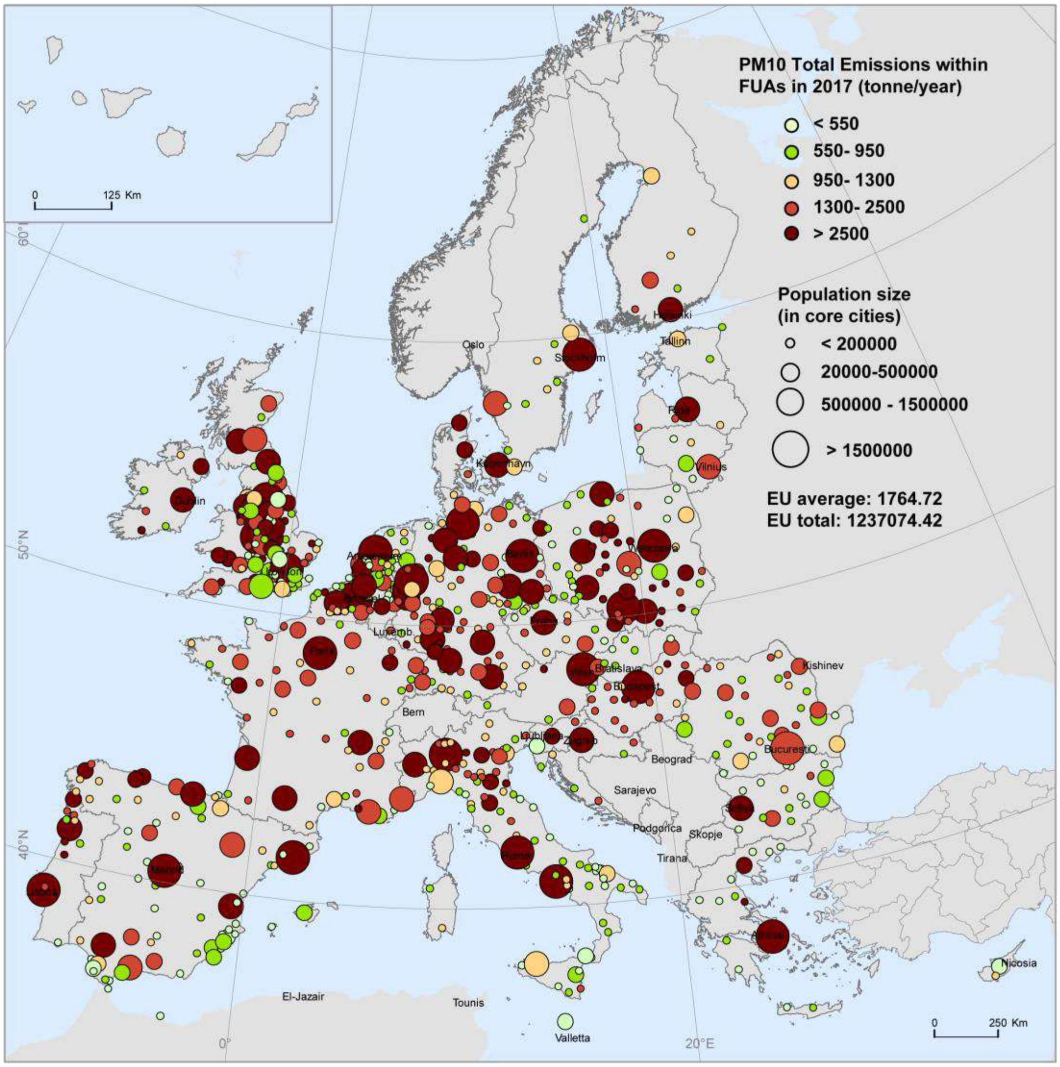


Figure 5: PM_{10} emissions. PM_{10} within FUAs in the Short and Long Term (source: EMEP model).

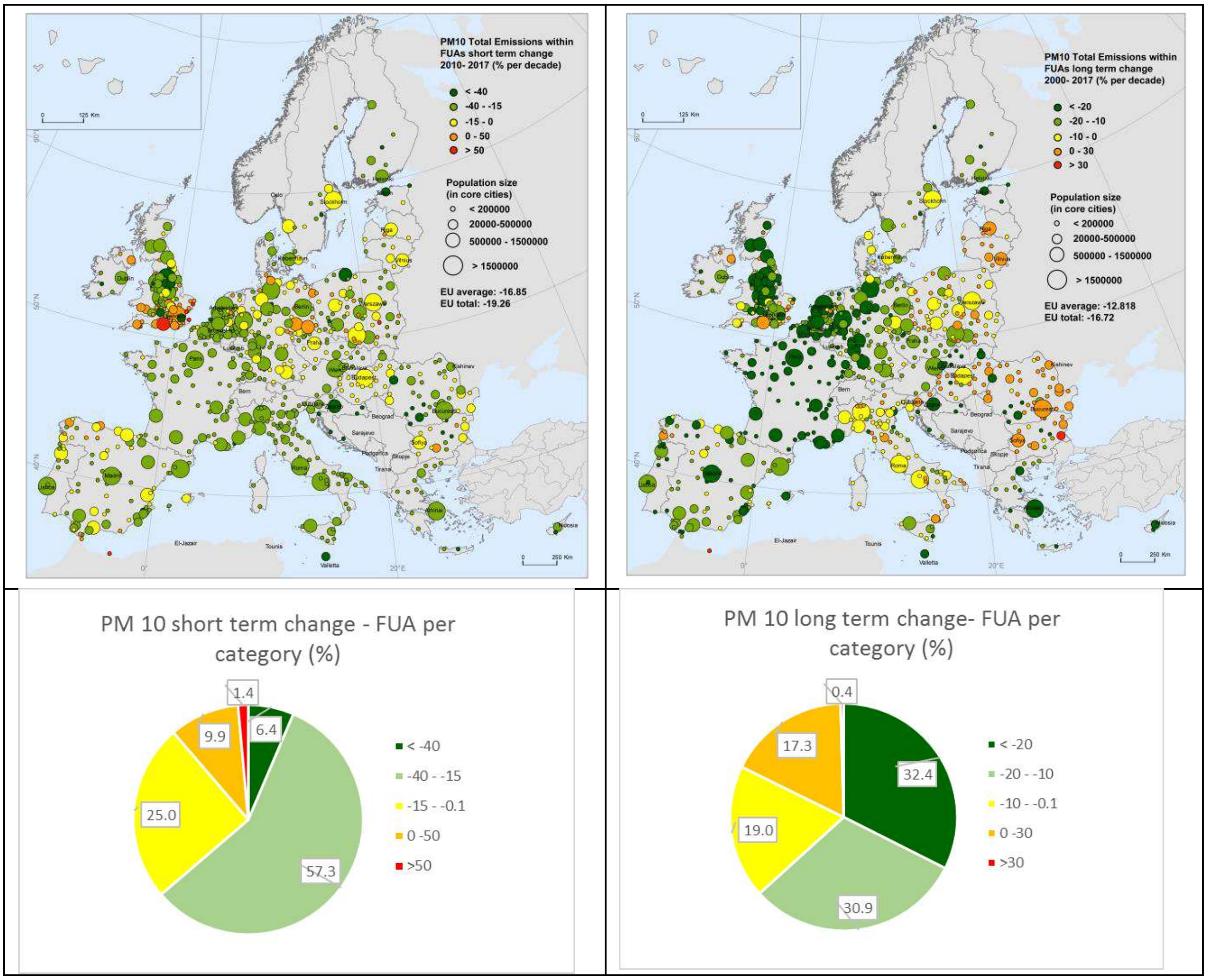


Figure 6: PM2.5 emissions registered within FUAs, Status map (2017)

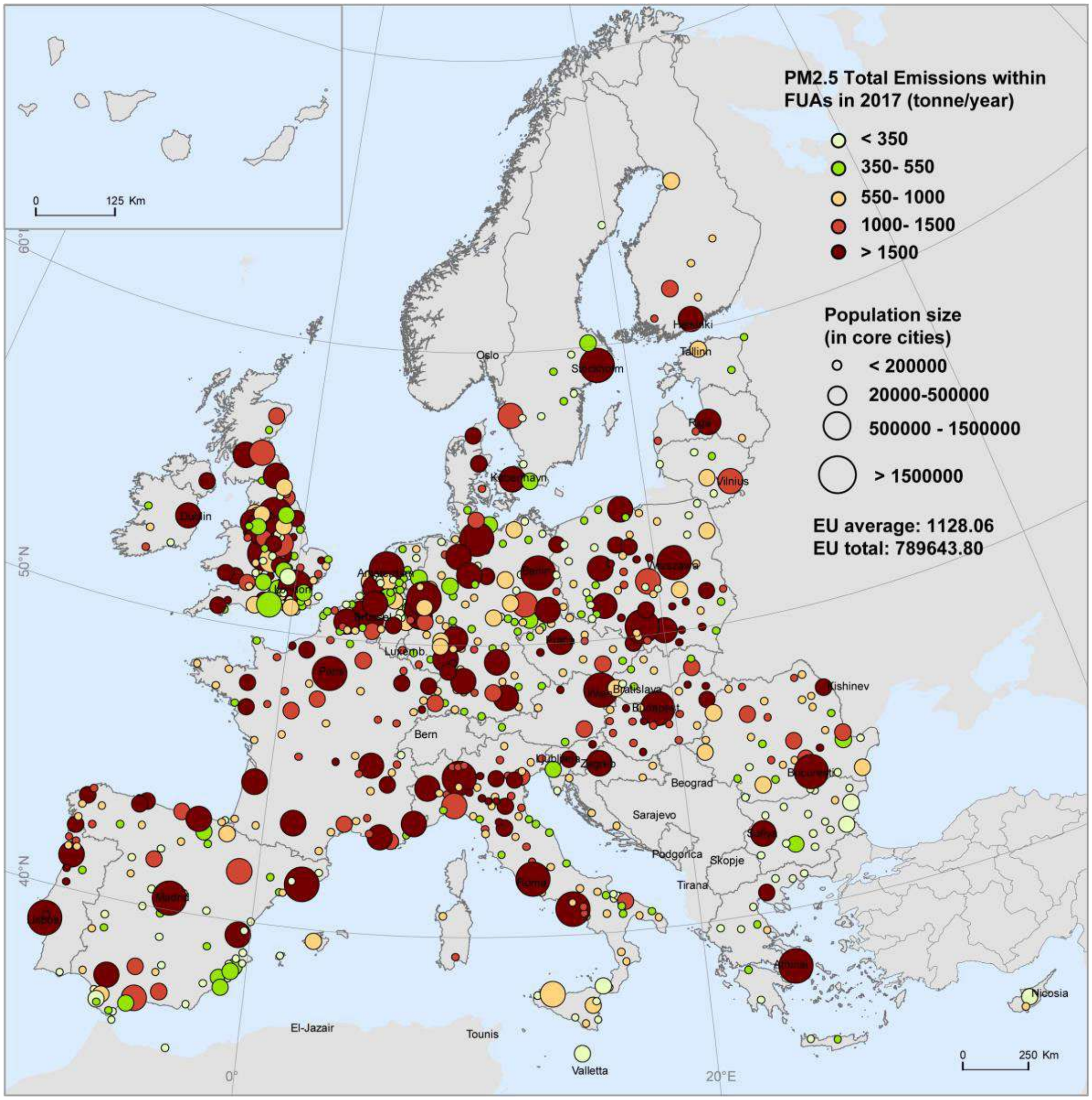


Figure 7: PM $_{2.5}$ emissions. PM $_{2.5}$ within FUAs in the Short and Long Term (source: EMEP model); National emission by sectors (source EEA)

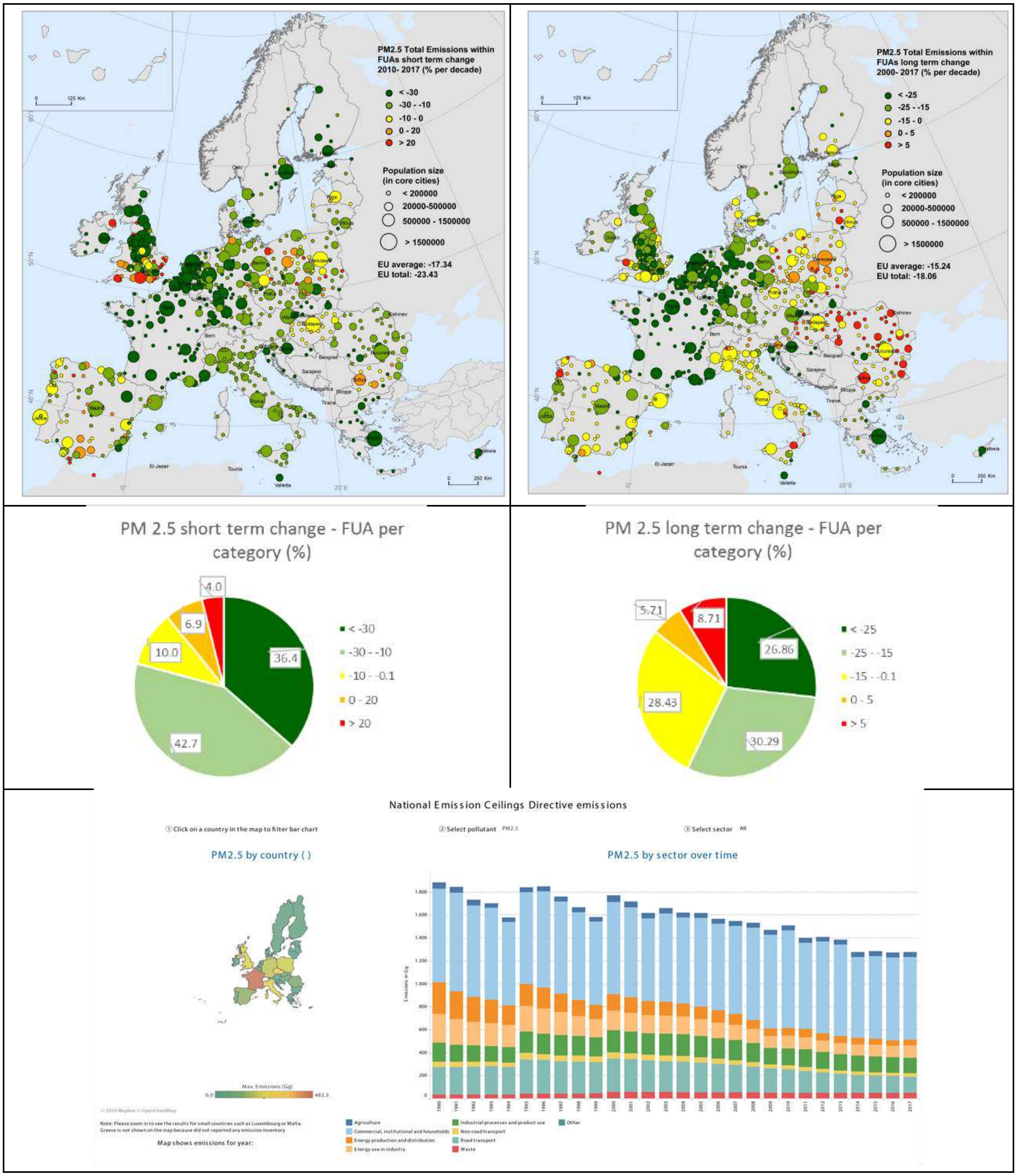


Figure 8: NMVOCs emissions registered within FUAs, Status map (2017)

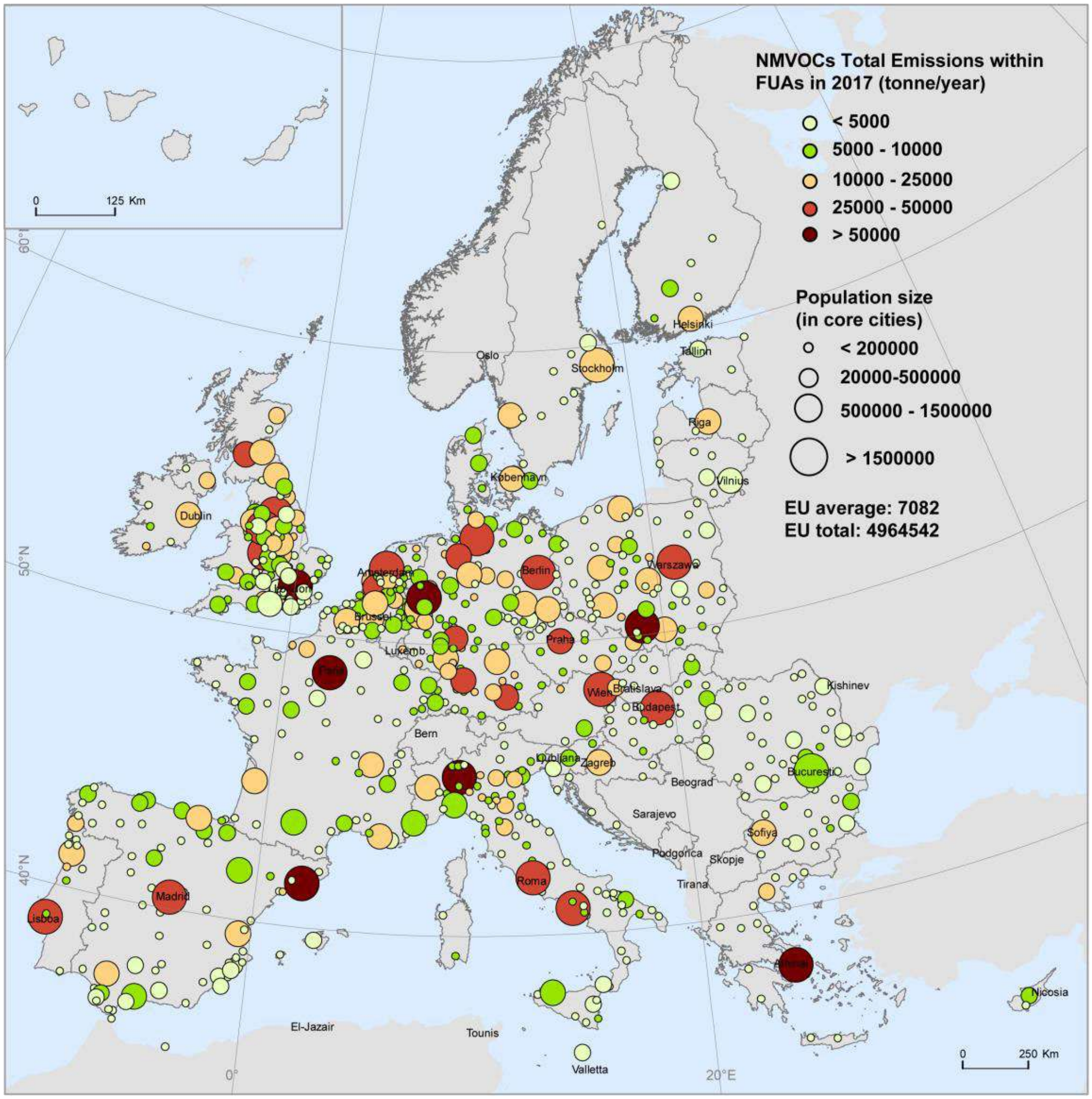


Figure 9: NMVOCs emissions. NMVOCs within FUAs in the Short and Long Term (source: EMEP model); National emission by sectors (source EEA)

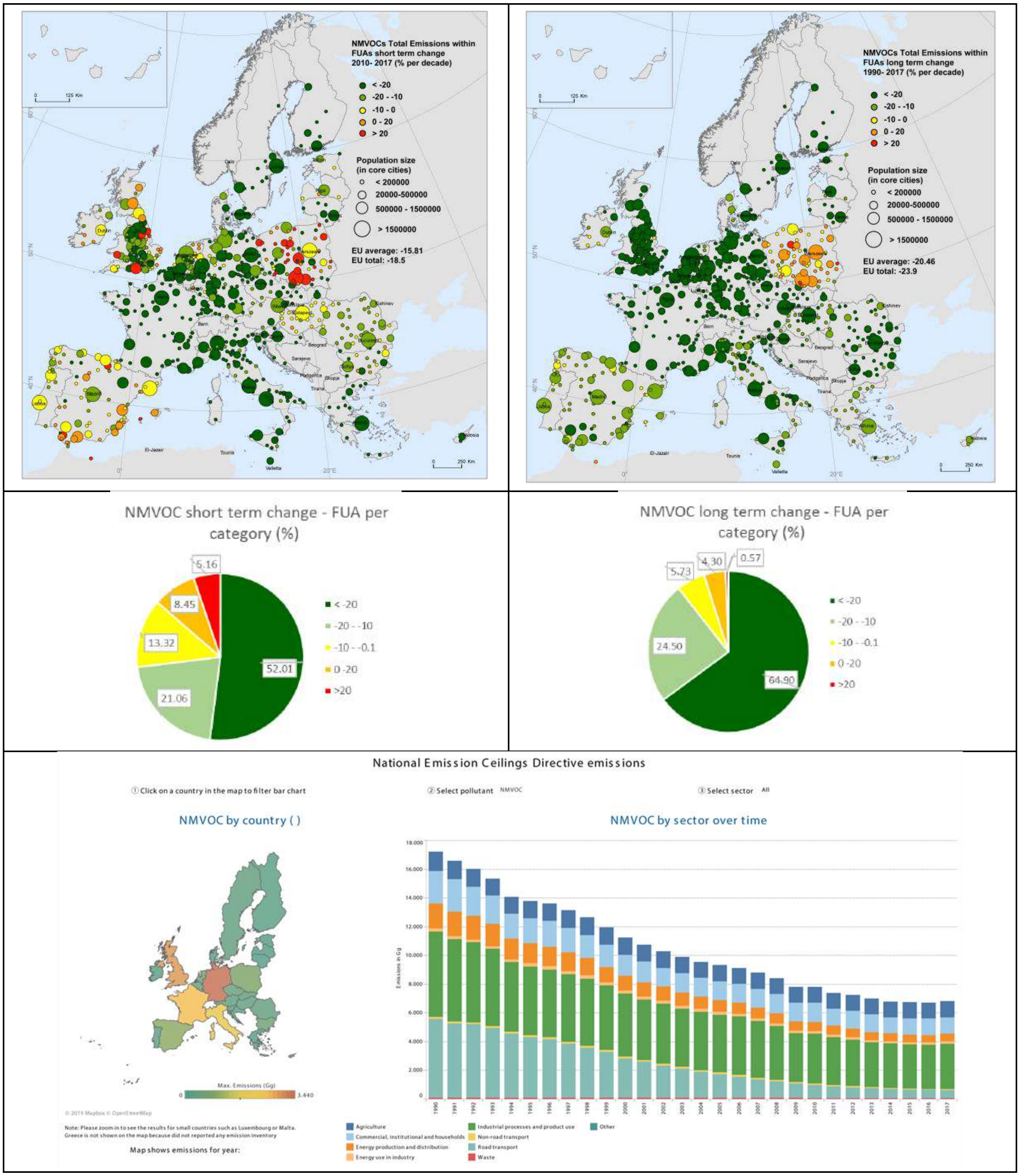


Figure 10: SOx emissions registered within FUAs, Status map (2017)

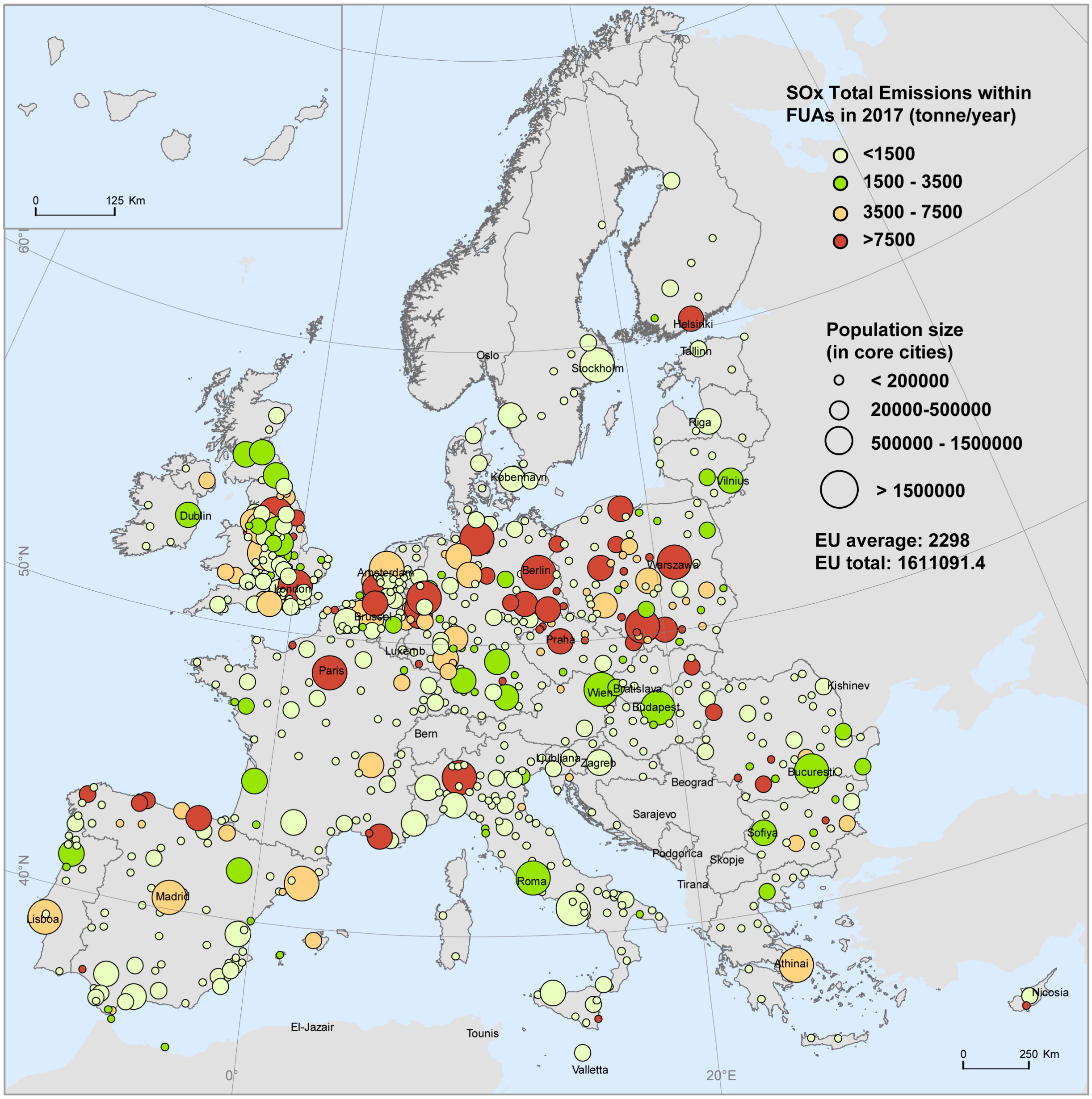
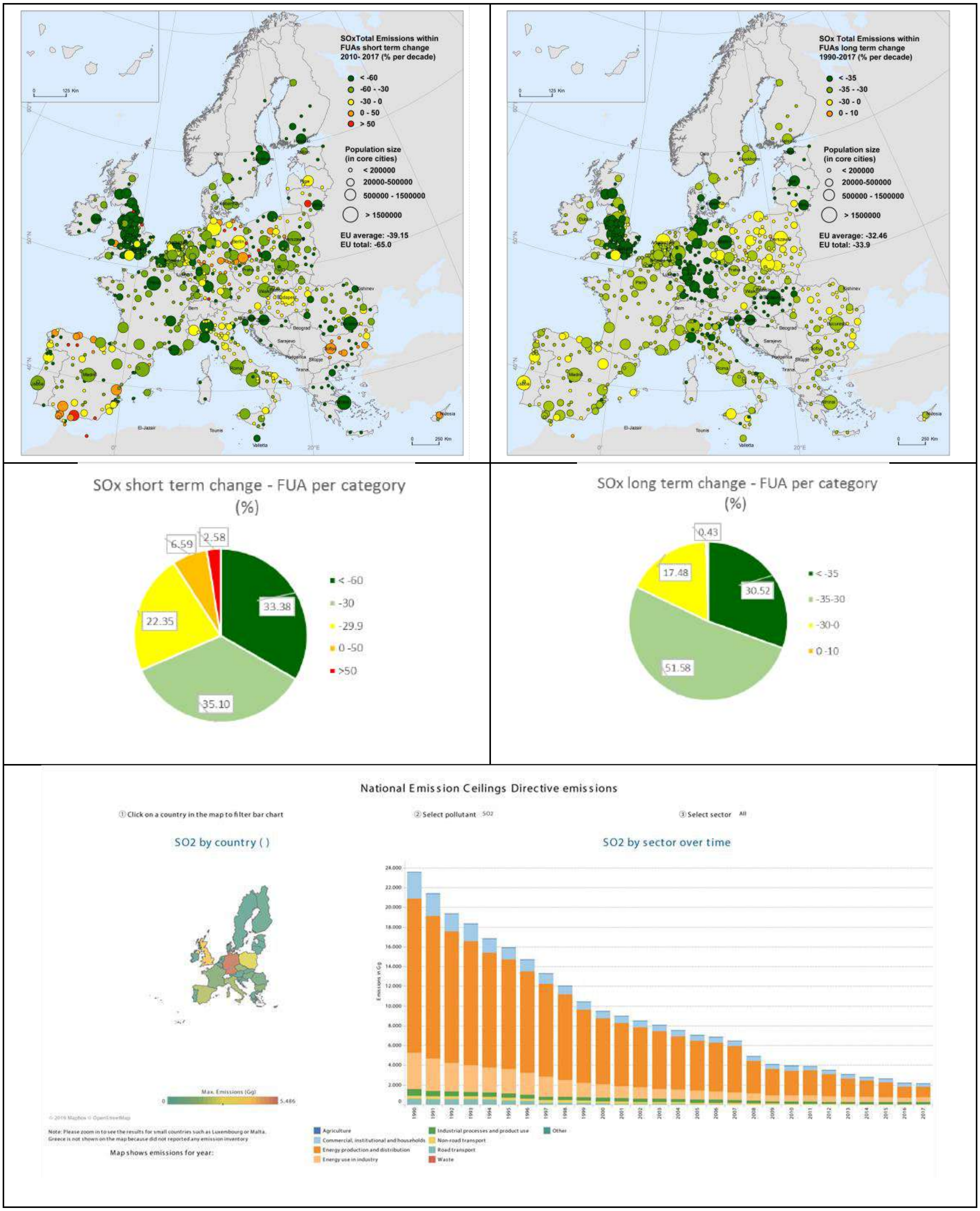


Figure 11: SOx emissions. SOx within FUAs in the Short and Long Term (source: EMEP model); National emission by sectors (source EEA)



3.4. Key trend at EU level

Table 2: air pollutant emission within FUA. Long trends and short trends.

Pressure and condition class	Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score	Long-term trend (% per decade)	Long-term trend (change)	Long-term trend confidence score
Air pollutants emission (Source: EMEP)	NOx	Million tonne/ year	7.01	-31.92	↑	5	-22.69	↑	5
	PM10		1.42	-19.25	↑	5	-16.72	↑	5
	PM2.5		0.94	-23.43	↑	5	-18.0	↑	5
	NMVOC		5.7	-18.5	↑	5	-23.9	↑	5
	SOx		2.95	-65.0	↑	5	-33.9	↑	5

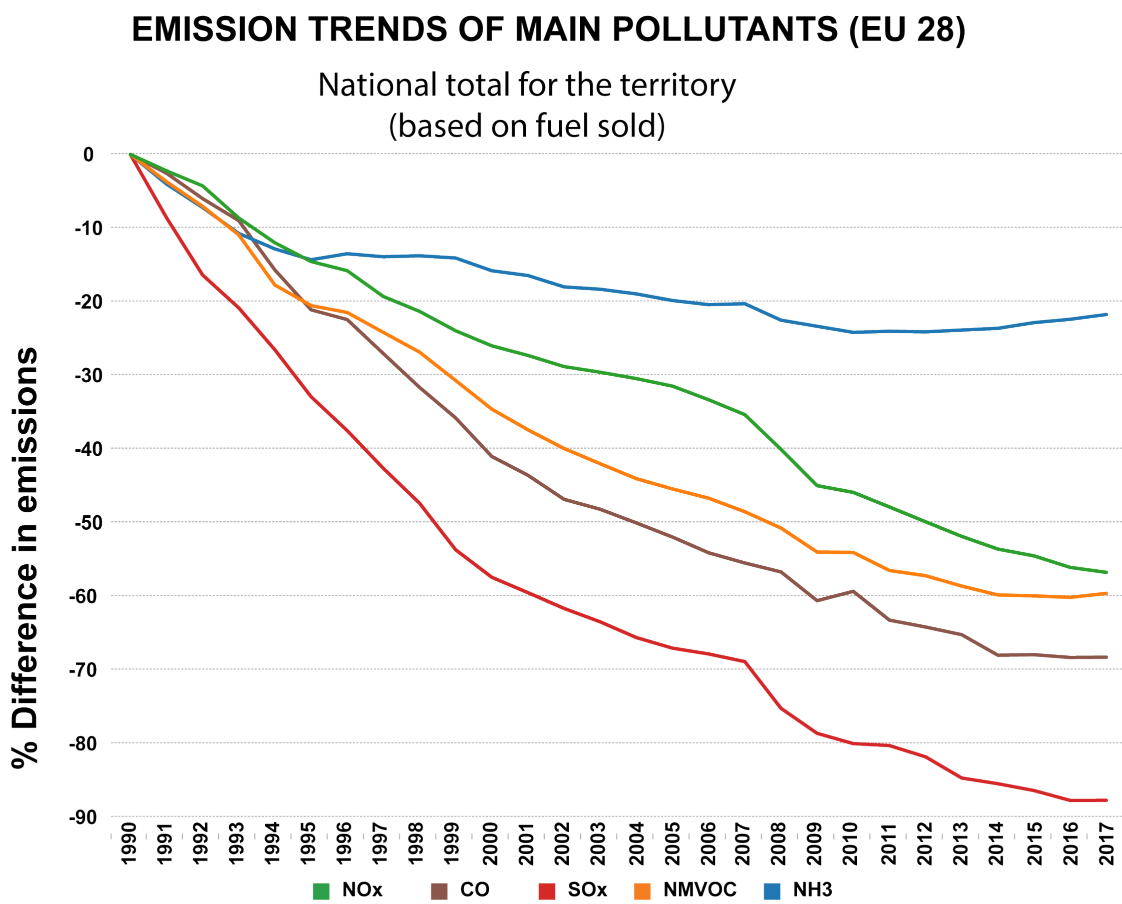
At Functional urban area level we register a general decrease in the total emission of the main air pollutants, that can be translated as a general positive progress of MS on the reduction of national emissions of certain atmospheric pollutants. The trend is confirmed from statistics compiled at a national level[6] and reported by Member States (EEA 2019) see Figure 12.

[6] https://www.eea.europa.eu/data-and-maps/dashboards/necd-directive-data-viewer-2

The assessment of the trends using data collected within the FUAs confirm that in 2017, the most recent year for which data were reported, the total emissions of four main air pollutants - nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulphur dioxide (SO_2) and ammonia (NH_3)- were below the respective ceilings set for the EU as a whole (EEA 2019). Specifically within FUAs:

- NO_x (Figure 2 and Figure 3)
  - in the long term the downward trend is stable in 97% of European urbanized areas. Poland is the only region with slightly increased emissions within FUAs (or a slower downward trend);
  - in the short-term the downward trend remains constant in 90% urbanized areas. Nevertheless in some cities the downward trend is turning into a slightly upward one (north east Spain, Romania, Poland, UK)
- NMVOCs (Figure 8, Figure 9)
  - in the long term trend the downward trend is stable in 90% of European urbanized areas. Poland is the only Member State where emissions increase within Urban Areas.
  - in the short-term trend, the downward trend remains constant in 73% urbanized areas. Nevertheless in Poland, Spain and some cities in UK we register an upward trend
- PM10 (Figure 4 and Figure 5)
  - in the long term the downward trend persist in 82% of European urbanized areas. Nevertheless we register an upward trend in some cities in Romania, Italy, Spain (north east), Poland, Bulgaria, Latvia and Lithuania.
  - in the short-term the downward trend remains constant in 88% urbanized areas. Nevertheless in some cities the downward trend is turning into an upward one (north east Spain, South UK, few German cities)
- PM 2.5 (Figure 6 and Figure 7)
  - in the long term trend the downward trend persist in 85.5% of European urbanized areas. Nevertheless we register an upward trend in some cities in Romania, Italy, Spain (north east), Poland, Bulgaria, Latvia and Lithuania.
  - in the short-term the downward trend remains constant in 89% urbanized areas. Nevertheless: in some cities the downward trend is turning into an upward one (north east Spain, South UK, few German cities); in other areas (Romania, Italy, some Spanish and Polish cities) the emission decreased.
- SOx (Figure 10 and Figure 11)
  - in the long term trend the downward trend persist in all European urbanized areas.
  - in the short-term the downward trend remains constant in 82% urbanized areas. Nevertheless in some urbanized regions we registered an inversed tendency (Bulgaria, Spain, Germany)

Figure 12: National total emission trends (source: EEA)



Source: The air pollutant emissions data viewer (LRTAP Convention) provides access to the data contained in the EU emission inventory report 1990-2017 under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP)

3.3. Statistical analysis of the trend

The non-parametric Wilcoxon test was applied using bootstrapping (sampling 1% of the reference units, 1000 times). Table 1 presents the Wilcoxon test results.

Table 1: Wilcoxon test results

Indicator	Range	Trend at EU level (per decade)	Statistical significance
NOx (tonne / year)	Long trend 1990-2017	Min. :-32.12 1st Qu.:-24.44 Median :-21.58 Mean : **-19.25** 3rd Qu.:-16.81 Max. : 64.98	**Significant** AvgP: 0.03065599
	medium trend 2000-2017	Min. :-48.62 1st Qu.:-30.62 Median :-26.76 Mean :**-22.28** 3rd Qu.:-18.63 Max. :134.58	**Significant** AvgP: 0.04540754
	Short trend 2010-2017	Min. :-89.12 1st Qu.:-41.31 Median :-33.02 Mean : **-27.78** 3rd Qu.:-14.97 Max. :263.97	**Not significant** AvgP: 0.0581033
PM10 (tonne / year)	Long trend 2000-2017	Min. :-54.285 1st Qu.:-22.826 Median :-14.050 Mean **:-12.818** 3rd Qu.: -4.436 Max. :123.523	**Not significant** AvgP: 0.1196508
	Short trend 2010-2017	Min. :-127.77 1st Qu.: -27.89 Median : -18.58 Mean : **-16.85** 3rd Qu.: -10.43 Max. : 291.38	**Not significant** AvgP: 0.104699
PM2.5 (tonne / year)	Long trend 2000-2017	Min. :-50.680 1st Qu.:-25.518 Median :-18.216 Mean :-15.249 3rd Qu.: -6.506 Max. :147.672	**Not significant** AvgP: 0.08481084
	Short trend 2010-2017	Min. :-122.47 1st Qu.: -34.67 Median : -23.43	**Not significant** AvgP: 0.1468903

		Mean : -17.34 3rd Qu.: -13.41 Max. :2846.42	
NMVOC (tonne / year)	Long trend 1990-2017	Min. :-34.51 1st Qu.:-26.74 Median :-22.48 Mean : **-20.47** 3rd Qu.:-18.07 Max. : 37.76	**Significant** AvgP: 0.0350674
	Short trend 2000-2017	Min. :-42.07 1st Qu.:-29.10 Median :-23.33 Mean **:-21.04** 3rd Qu.:-16.17 Max. : 47.44	**Significant** AvgP: 0.04805504
	Short trend 2010-2017	Min. :-94.924 1st Qu.:-27.411 Median :-20.237 Mean : **-15.813** 3rd Qu.: -8.909 Max. :304.063	**Not significant** AvgP: 0.1147921
SOx (tonne / year)	Long trend 1990-2017	Min. :-36.92 1st Qu.:-35.35 Median :-33.52 Mean : **-32.46** 3rd Qu.:-31.59 Max. : 10.66	**Significant** AvgP: 0.02362566
	Short trend 2000-2017	Min. :-58.11 1st Qu.:-48.02 Median :-42.46 Mean : **-39.76** 3rd Qu.:-35.05 Max. :164.18	**Significant** AvgP: 0.03389309
	Short trend 2010-2017	Min. :-135.55 1st Qu.: -69.02 Median : -44.53 Mean : **-39.16** 3rd Qu.: -24.52 Max. :1804.89	**Not significant** AvgP: 0.1021846

Fact sheet 3.1.102: Municipal waste generated

1. General information

- Thematic ecosystem assessment: Urban
- Indicator class: Environmental quality
- Name of the indicator: Municipal waste generated
- Units: tonnes-thousands

2. Data sources

Data on municipal waste area available on the EUROSTAT dissemination database and on the OECD data catalog. In both database data are provided aggregated at MS level.

EUROSTAT

- Data holder: EUROSTAT
- Data source: EUROSTAT dissemination database
- Weblink: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190123-1
- Year or time-series range: 1995- 2018
- Access date: January 2020
- Last update: January 2020
- Data aggregated at national level (28 Member States represented)
- https://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics#Municipal_waste_generation

OECD

- Data holder: OECD
- Data source: OECD (2019), "Waste: Municipal waste", OECD Environment Statistics (database), https://doi.org/10.1787/data-00601-en (accessed on 20 November 2019).
- Weblink: https://stats.oecd.org/index.aspx?r=686948
- Year or time-series range: from 1995 to 2017
- Access date: October 2019
- Last update: March 2019
- Data aggregated at national level (23 Member States represented)

This dataset contains data provided by Member countries' authorities through the questionnaire on the state of the environment (OECD/Eurostat). They were updated or revised on the basis of data from other national and international sources available to the OECD Secretariat, and on the basis of comments received from national Delegates. Selected updates were also done in the context of the OECD Environmental Performance Reviews. The data are harmonised through the work of the OECD Working Party on Environmental Information (WPEI) and benefit from continued data quality efforts in OECD member countries, the OECD itself and other international organizations. In many countries systematic collection of environmental data has a short history; sources are typically spread across a range of agencies and levels of government, and information is often collected for other purposes. When interpreting these data, one should keep in mind that definitions and measurement methods vary among countries, and that inter-country comparisons require careful interpretation. Data presented here refer to national level and may conceal major subnational differences (https://stats.oecd.org/index.aspx?r=686948).

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Municipal waste is defined as waste collected and treated by or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, as well as yard and garden waste, street sweepings, the contents of litter containers, and market cleansing waste if managed as household waste. The definition excludes waste from municipal sewage networks and treatment, as well as waste from construction and demolition activities. This indicator is measured in thousand-tonnes and in kilograms per capita[7].

This dataset presents data in amounts of municipal (including household) waste. The amount of waste generated in each country is related to the rate of urbanization, the population density, the types and pattern of consumption, household revenue, size and lifestyles.

In the long term, there has been a slight increase of municipal waste generated at EU scale, nevertheless the value cannot be considered statistically different from 0, and has been recorded as stable in the EU level assessment (Figure 1 and Table 1).

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[7] https://data.oecd.org/waste/municipal-waste.htm
https://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics#Municipal_waste_generation

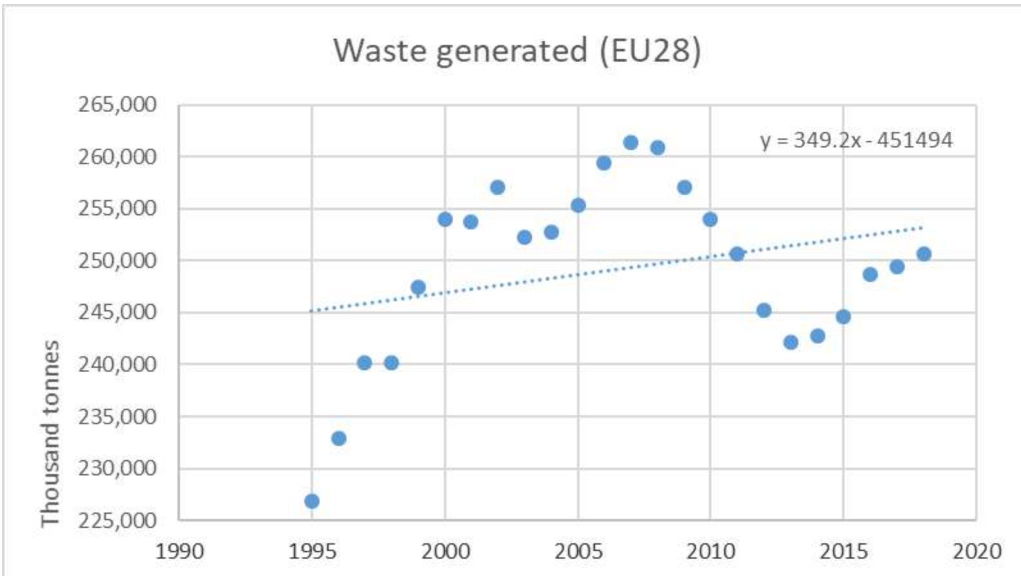


Figure 1: Municipal waste generated at EU level.

Table 1: statistic result OLS. Slope is not significantly different from zero, the change is not significantly different from 0 % per decade.

Regression Statistics	
Multiple R	0.287212
R Square	0.082491
Adjusted R Square	0.040786
Standard Error	8419.954
Observations	24

ANOVA

	df	*SS*	*MS*	*F*
Regression	1	140228942.4	140228942.4	1.977963
Residual	22	1559703754	70895625.19	
Total	23	1699932697		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-451494.1	498198.6503	-0.906253099	0.374621
X Variable 1	349.1965	248.2908974	1.40640082	0.173574
% change per decade	1.394605			

The picture varies a lot at the national level. In ten Member States, we denote a decrease in the amount of municipal waste produced. In Spain, Germany, United Kingdom and The Netherlands however the direction of change cannot be considered statistically significant. Eighteen Member states on the contrary show a clear upward trend, and only in Poland and Belgium the change cannot be considered statistically significant.

Figure 2: Municipal waste generated per MS (1995-2018), change per decade (%). Black dots represent the MS for which the change cannot be considered statistically significant.

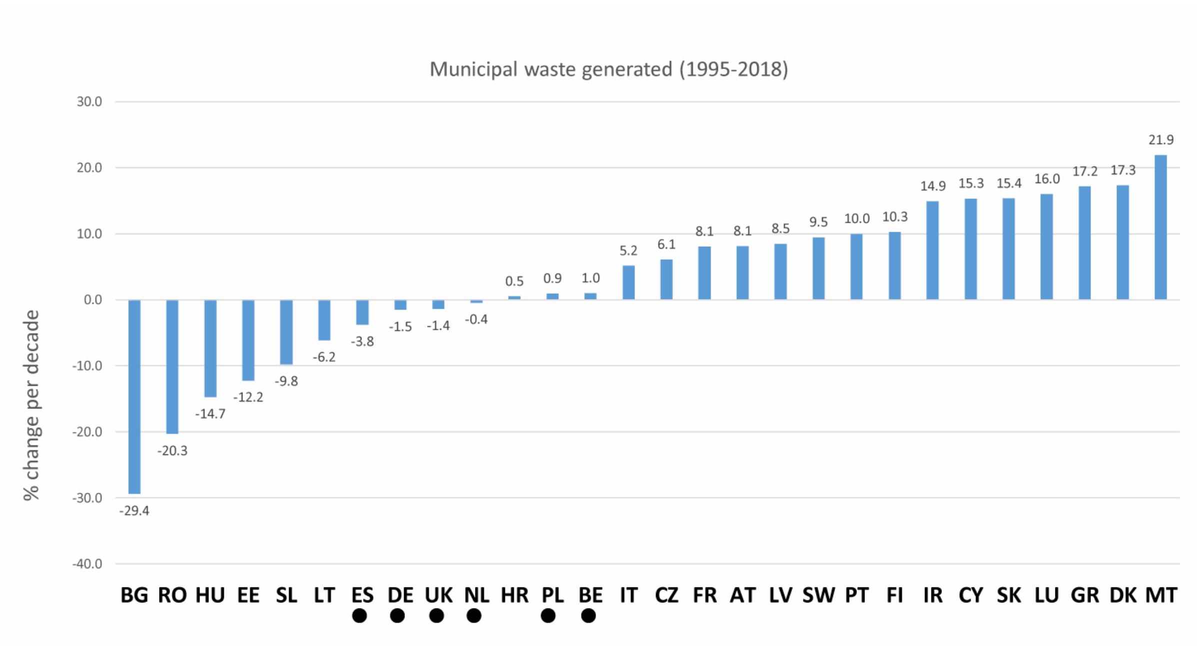
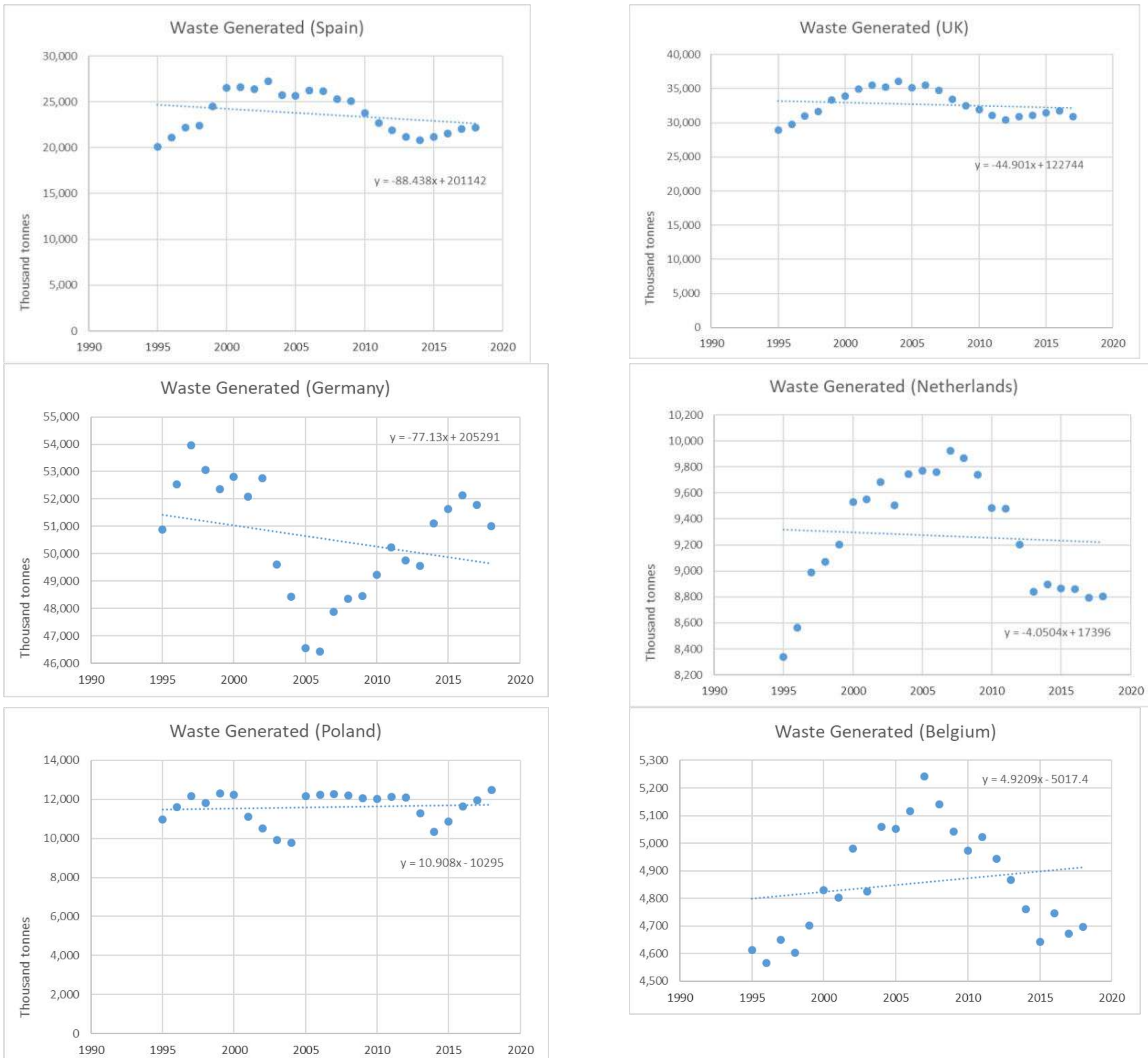


Table 2 shows the graphs for the Member states where the change is not statistically significant

Table 2: Waste generated per MS where a decrease in thousand –tonnes was recorded but not statistically significant.



As reported by EUROSTAT the variations among member States, which are confirmed by the values expressed in kg per capita, "…reflect differences in consumption patterns and economic wealth, but also depend on how municipal waste is collected and managed. There are differences between countries regarding the degree to which waste from commerce, trade and administration is collected and managed together with waste from households"[8].

[8] https://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics#Municipal_waste_generation

Fact sheet 3.1.103: Soil sealing

1. General information

- **Urban** ecosystem assessment
- Indicator class : **Structural ecosystem attributes**
- Name of the indicator: **soil sealing**
- Units:
    - Share of sealed soil in artificial land (%)

2. Data sources

- Data holder : EEA -Imperviousness
- Weblink: https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness
  Year or time-series range: 2006-2009-2012-2015
  Resolution: 20 m
- Access date: April 2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

"***Soil sealing** is the covering of the soil surface with materials like concrete and stone, as a result of new buildings, roads, parking places but also other public and private space. Depending on its degree, soil sealing reduces or most likely completely prevents natural soil functions and ecosystem services on the area concerned*" (EEA 2011).

This indicator measures the **percentage of land covered by surfaces** that do not allow water to soak into the soil. The values are calculated within the core cities, using two reporting units: densely built areas (areas where there is a dominance of artificial land) and not-densely built areas or interface zones (areas where artificial land is prevalent but it coexists with other ecosystem types, such as urban forest or agricultural land).

A high proportion of impervious surfaces exposes urban areas to several risks connected to local climate regulation, flood protection and water regulation.

3.2. Maps

Figure 1: percentage of sealed soil in core cities in 2015 within densely and not densely built areas. Pie charts show the proportion of core cities per sealed soil class (%)

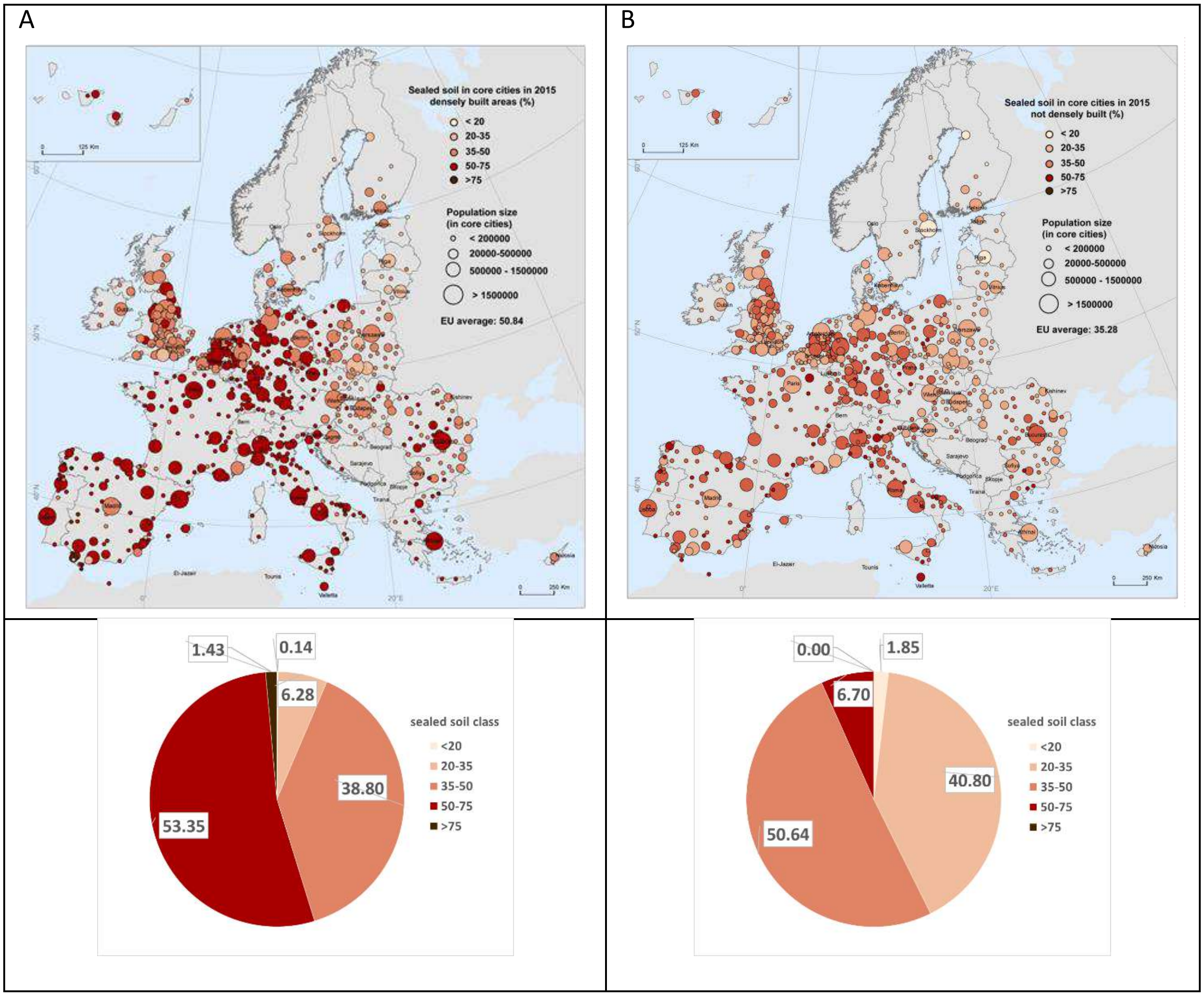
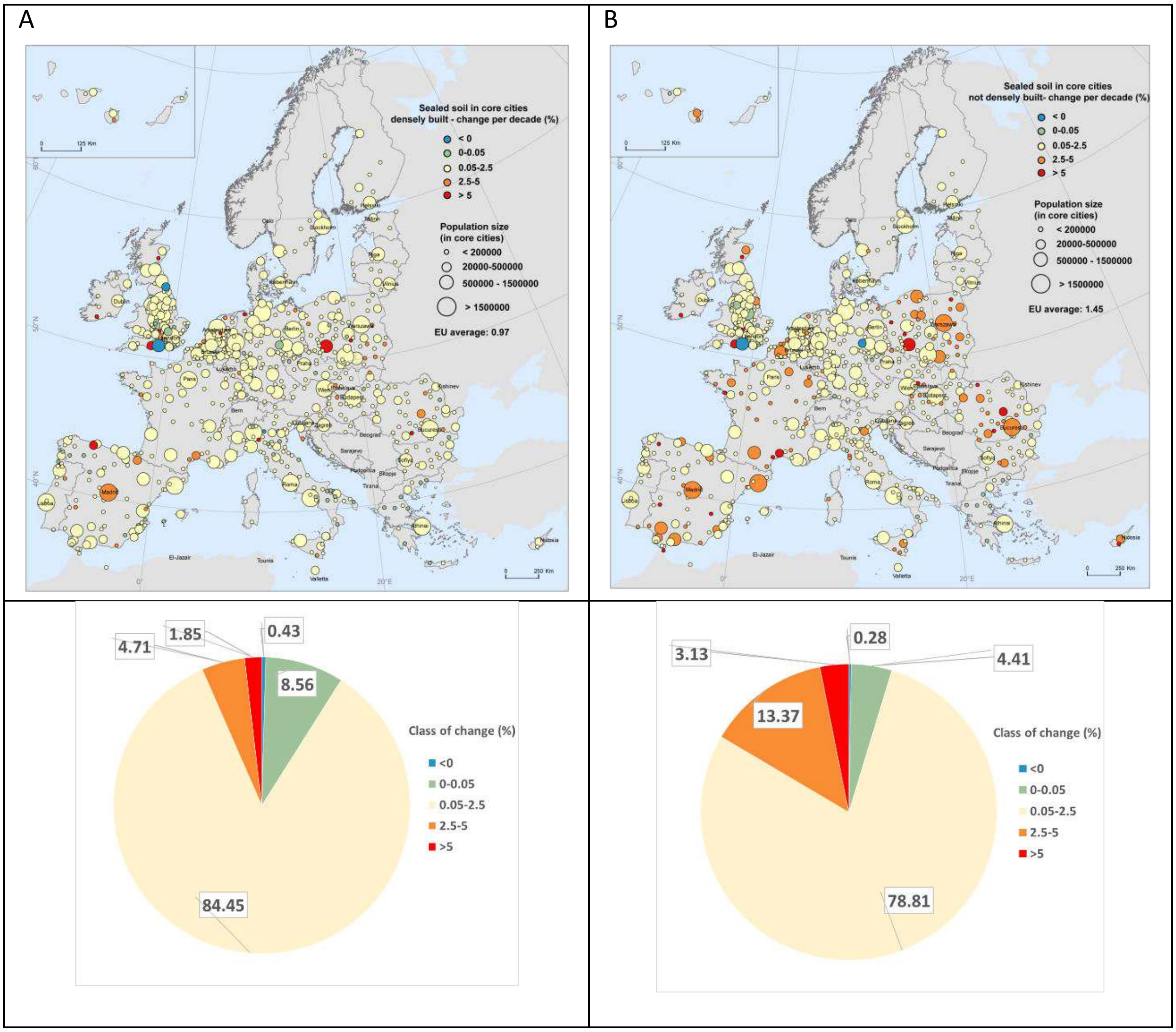


Figure 1 shows the percentage of sealed soil in core cities. Within densely built areas (Map A, Figure 1) more than 50% of the land is sealed in 55% of the core cities. This condition exposes urban areas to several risks connected to local climate regulation, flood protection and water regulation. Concerning flood protection and water regulation, as an example, an impervious cover greater than 50% implies a decrease of deep and shallow infiltration and conversely an increase of surface run-off in case of rain (Chithra S. V., Harindranathan Nair M. V., Amarnath A. 2015). The increase of surface run-off requires more infrastructure to minimize flooding and exposes people and artefact to risks.

The trend is relatively steady in the short term (Figure 2, Map A and B). Within core cities-densely built areas, the percentage of sealed soil remained almost stable, showing a very light upward trend. In 85%

of the cities, there was an increase of sealed soil ranging by 0.05 and 2.5%. This pattern is consistent in almost all European core cities, with few exceptions where a more intense increase is registered.

Figure 2: percentage of sealed soil in core cities, changes in the short term per decade. Pie charts show the proportion of core cities per class of change (%)



3.3. Key trend at EU level

Table 1: trend at EU level for urban soil sealing within core cities. Baseline values and changes are reported using the AVERAGE value for FUAS in the sample dataset.

Indicator	Unit	Baseline value (2010)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score
Imperviousness in densely built areas	%	50.84	0.97	↓	6
Imperviousness in interface zone	%	35.28	1.46	↓	6

Statistical significance

The non-parametric Wilcoxon test was applied using bootstrapping (sampling 1% of the reference units, 1000 times). The random sampling was stratified by country to make sure all countries are repre sented in the subsampling (it depends on the number of observations available within each country).

Table 2: results of the Wilcoxon test

Type of indicator: Structural ecosystems attributes Soil sealing		Data source : IMPERVIOUSNESS (EEA)	
		Spatially explicit : YES	Spatial resolution: 20 m
Indicator	Range	Trend at EU level (per decade) Average (min-max)	Statistical significance
Soil sealing in densely built areas	Short trend 2006-2015	2.28 (-29.2679-111.6)	Significant AvgP: 0.0327782
Soil sealing in not densely built areas	Short trend 2006-2015	4.6 (-4.307 - 154.05)	Significant AvgP: 0.02563347

References

EEA (2011) Urban soil sealing in Europe.

M. Munafò, F. Assennato, L. Congedo, T. Luti, I. Marinosci, G. Monti, N. Riitano, L. Sallustio, A. Strollo, I. Tombolini e M. Marchetti, 2015. Il consumo di suolo in Italia - Edizione 2015. ISPRA, Rapporti 218/2015.

Fact sheet 3.1.104: Noise Pollution

1. General information

- Thematic ecosystem assessment: Urban
- Indicator class: Environmental quality
- Name of the indicator: Noise Pollution from roads
- Units:
  - Percentage of population exposed to noise pollution from roads (>55dB) (Lden)

2. Data sources

- Data holder: EEA
- Data source: https://www.eea.europa.eu/data-and-maps/data/data-on-noise-exposure-7
- Weblink: https://www.eea.europa.eu/data-and-maps/data/data-on-noise-exposure-7
- Year or time-series range: 2012-2017
- Access date: 4 December 2019
- Last update: 21 November 2019
- Data reported at agglomerations level (cities with more than 100000 inhabitants).
- Reference: (Fons-esteve, 2018)
  - https://www.eea.europa.eu/airs/2018/environment-and-health/environmental-noise

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Noise pollution

The Directive related to the assessment and management of environmental noise (the Environmental Noise Directive – END, 2002/49/EC) is the main EU instrument to identify noise pollution levels and to trigger the necessary action both at Member State and at EU level. Environmental noise is defined as: "*unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity which have negative effects on human health*". The Directive applies to environmental noise to which humans are exposed in particular in built-up areas, in public parks or other quiet areas in an agglomeration, in quiet areas in open country, near schools, hospitals and other noise sensitive buildings and areas (END, 2002/49/EC).

The 7th EAP (EU, 2013) includes an objective to significantly decrease noise pollution by 2020, moving closer to WHO[9] recommended levels. The WHO (2011) has identified noise from transport as the second most significant environmental cause of ill health in Western Europe, the first being air pollution from fine particulate matter (AIRS_PO3.1, 2018[10]). Environmental noise exposure can lead to annoyance, stress reactions, sleep disturbance, poor mental health and wellbeing, impaired cognitive function in

[9] http://www.euro.who.int/en/health-topics/environment-and-health/noise/policy
[10] https://www.eea.europa.eu/airs/2018/environment-and-health/air-pollutant-emissions#tab-based-on-indicators

children, and negative effects on the cardiovascular and metabolic system[11]. Road traffic is the most widespread source of environmental noise. Railways, air traffic and industry are other major sources of noise

Methodology and limitations

Noise exposure information are reported under the END Directive (2002/49/EC) per agglomerations (cities with more than 100000 inhabitants). The database (updated regularly by the EEA) contains information on the number of people exposed to 55 decibel (dB) bands for two indicators "Lden : 55-59, 60-64, 65-69, 70-74, >75" and "Lnight. : 50-54, 55-59, 60-64, 65-69, > 70". The database covers the noise sources specified in the END (major roads, major railways, major airports and urban agglomerations) and the corresponding number of people exposed to each of the noise sources inside urban areas and outside urban areas.

In this assessment, for comparative purposes, we use the percentage of people exposed to harmful noise levels derived from roads. Unfortunately the assessment is not completely representative of European cities but represents the best data available.

Only data for 284 cities were used for this assessment. Cities represented in 2012 were 431 (82.5% of the agglomerations for which data were requested), in 2017 there were data for 303 cities (57.2% of the agglomerations for which data were requested).

There are comparability problems between the 2012 and 2017, due to differences in data collection and mapping. Changes across years may not be strictly related to a real increase/ decrease in noise or population exposed. In addition to this when comparing countries it should be clear that results also depend of the mapping methodology of the countries (e.g. in some cities major roads are only mapped and in other cities all streets are mapped).

Due to the importance of noise pollution the indicator has been included in the assessment having clear in mind that the results have to be considered as a first estimate for the agglomerations for which data were available for 2012 and 2017.

[11] https://www.eea.europa.eu/airs/2018/environment-and-health/environmental-noise

Table 1: summary table of Noise pollution within 242 agglomerations.

Pressure and condition class	Indicator	Unit	Baseline value (2012)	Short-term trend (% per decade)	Short-term trend (change)	Short-term trend confidence score
Noise pollution (Source: EEA)	noise pollution from roads	Percentage of population exposed to noise pollution from roads (>55dB) (Lden)	37.01	3.82	➔	6

Reference

Fons-esteve, J. (2018) 'Analysis of changes on noise exposure 2007 – 2012 – 2017', (November).

Fact sheet 3.1.205: Bathing Water quality within Functional Urban Areas

1. General information

- Thematic ecosystem assessment: Urban
- Indicator class: Environmental quality
- Name of the indicator: Status of Bathing Water quality within Functional Urban Areas
    - Percentage of bathing water in good status
    - Percentage of bathing water in poor status
- Units: %

2. Data sources

The indicator is based on readily available data.

- Data holder (EEA)
- Data source: Bathing Water Directive - Status of bathing
- Weblink: https://www.eea.europa.eu/data-and-maps/data/bathing-water-directive-status-of-bathing-water-11
- Year or time-series range: from 1990 to 2018 (comparable from 2000 to 2018)
- Access date: June 2019
- Report: "European Bathing Water Quality in 2018" EEA Report No 3/2019 [12] (European Environment Agency EEA, 2019)

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

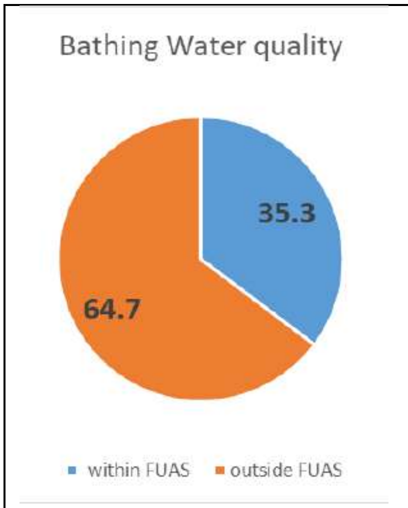
The EU Bathing Waters Directive requires Member States to identify popular bathing places in fresh and coastal waters and monitor them for indicators of microbiological pollution (and other substances) throughout the bathing season, which runs from May to September. The EU's efforts to ensure clean and healthy bathing water began 40 years ago with the first Bathing Water Directive [13]. Today, Europe's bathing waters are much cleaner than in the mid-1970s, when large quantities of untreated or partially treated municipal and industrial waste water were discharged into clean water. Polluted water can have impacts on human health, causing stomach upsets and diarrhea if swallowed. Depending on the levels of bacteria detected, the bathing water quality is classified as 'excellent', 'good', 'sufficient' or 'poor'. (European Environment Agency EEA, 2019).

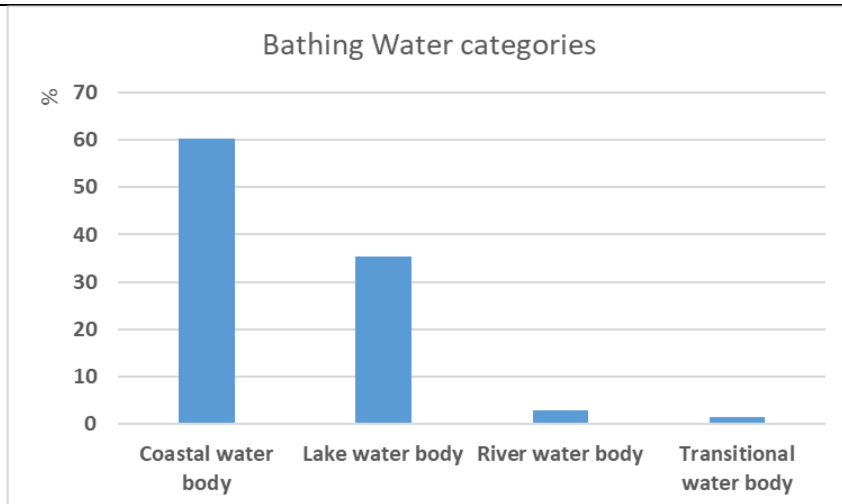
A total of 21831 locations are monitored in EU-28, 35.3% of the sample points are within FUAs, most of them in coastal water bodies and lake water bodies (Figure 1). Bathing areas within FUAs are potentially more exposed to pollution and, on the other side, are closer to potential users interested in open water recreation and sports activities.

[12] https://www.eea.europa.eu//publications/european-bathing-water-quality-in-2018

[13] http://ec.europa.eu/environment/water/water-bathing/index_en.html European

Figure 1: on the left: share of bathing water quality sampling locations within and outside FUA (%); one the right proportion of sampling locations , within FUA, classified per water categories (%).





Data were considered from 2000 to 2018; Quality classes *Good*, *Good or sufficient* and *Sufficient* were merged for comparability purposes, see the original classes in Table 1

Table 1: quality status classes.

Quality status (1990-2018)	Quality status classes used in this assessment
Excellent	Excellent
Good	Good or sufficient
Good or sufficient*	
Sufficient	
Poor	Poor
Not classified	Not classified
*Quality classes "Good" and "Sufficient" are merged for comparability with classification of the preceding Bathing Water Directive 76/160/EEC.	

The quality of monitored bathing water locations within FUAs generally improved in the long and short term, especially concerning bathing water locations in poor and excellent status. Figure 2 and 3 present the graphs of the trends and Table 2, 3, 4, 5 show the statistical tests. Locations in poor status declined during the last 19 year by 27.4% per decade (and by 31% in the short term. On the contrary the share of locations in Excellent status increased by 13.2% in the long term (and 19.7 % in the short term).

Areas classified as in good status remained, in general, stable or did not present a clear pattern, see Figure 3 and Table 6.

Figure 2: share of bathing water locations classified as in Poor status over the total bathing water locations (EU-28 within FUA) between 2000 and 2018.

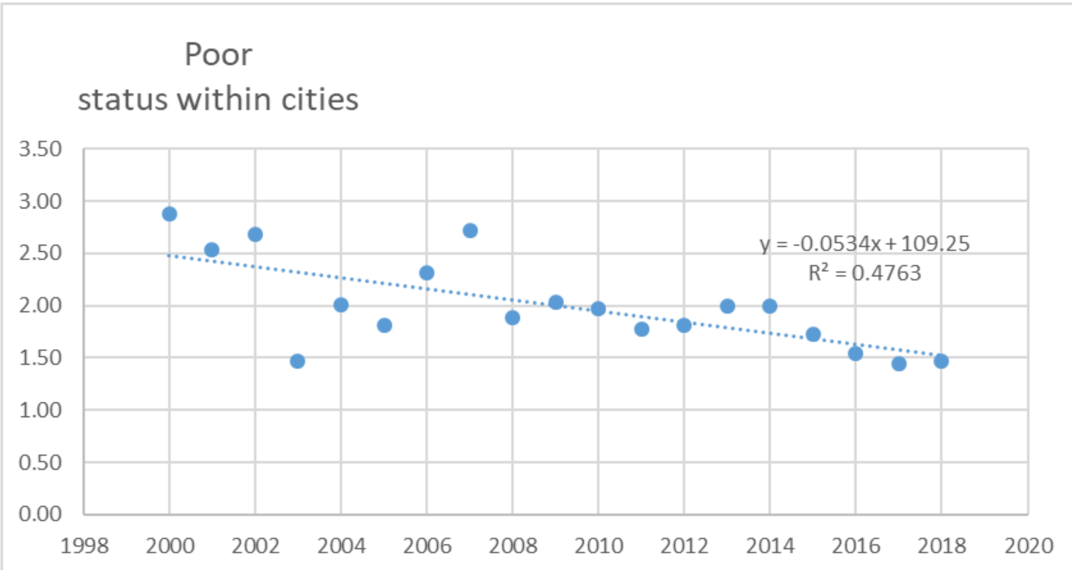


Table 2: summary statistic - long term analysis of Bathing Water quality in poor status

Regression Statistics	
Multiple R	0.690133
R Square	0.476284
Adjusted R Square	0.445477
Standard Error	0.324154
Observations	19

ANOVA

	df	*SS*	*MS*	*F*
Regression	1	1.624505	1.624505	15.46034
Residual	17	1.786285	0.105076	
Total	18	3.41079		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	109.2541	27.2769	4.005371	0.000916
X Variable 1	-0.05339	0.013577	-3.93196	0.001075
% change per decade	-27.3866			

Table 3: summary statistic - short term analysis of Bathing Water quality in poor status.

Regression Statistics	
Multiple R	0.788817
R Square	0.622232
Adjusted R Square	0.568265
Standard Error	0.145417
Observations	9

ANOVA

	df	*SS*	*MS*	*F*
Regression	1	0.243814	0.243814	11.52988
Residual	7	0.148024	0.021146	
Total	8	0.391837		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	130.1329	37.80949	3.441804	0.010811
X Variable 1	-0.06375	0.018773	-3.39557	0.011512
% change per decade	-31.8214			

Figure 3: proportion of bathing water locations classified as in Excellent status over the total bathing water locations (EU-28 within FUA) between 2000 and 2018

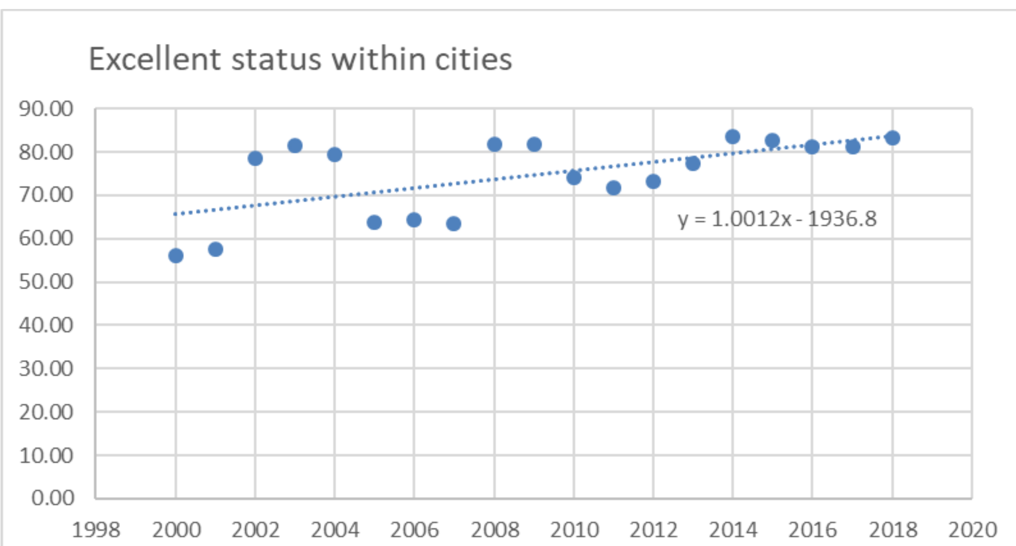


Table 4: summary statistic - long term trend of Bathing Water quality in Excellent status

Regression Statistics	
Multiple R	0.617551
R Square	0.381369
Adjusted R Square	0.344979
Standard Error	7.383485
Observations	19

ANOVA

	df	*SS*	*MS*	*F*
Regression	1	571.3273485	571.3273485	10.48002
Residual	17	926.7693427	54.51584369	
Total	18	1498.096691		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-1936.79	621.3059201	-3.117289575	0.006268
X Variable 1	1.001164	0.309260135	3.237286513	0.004843
% change per decade	13.25193			

Table 5: summary statistic - short term trend of Bathing Water quality in Excellent status

Regression Statistics	
Multiple R	0.842476
R Square	0.709765
Adjusted R Square	0.668303
Standard Error	2.68925
Observations	9

ANOVA

	df	*SS*	*MS*	*F*
Regression	1	123.8014083	123.8014083	17.1184
Residual	7	50.62445429	7.232064899	
Total	8	174.4258626		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-2814.29	699.2224363	-4.024889869	0.005028
X Variable 1	1.436439	0.347180666	4.137439298	0.004363
% change per decade	19.69102			

Figure 3: proportion of bathing water locations classified as in Good or sufficient status over the total bathing water locations (EU-28 within FUA) between 2000 and 2018

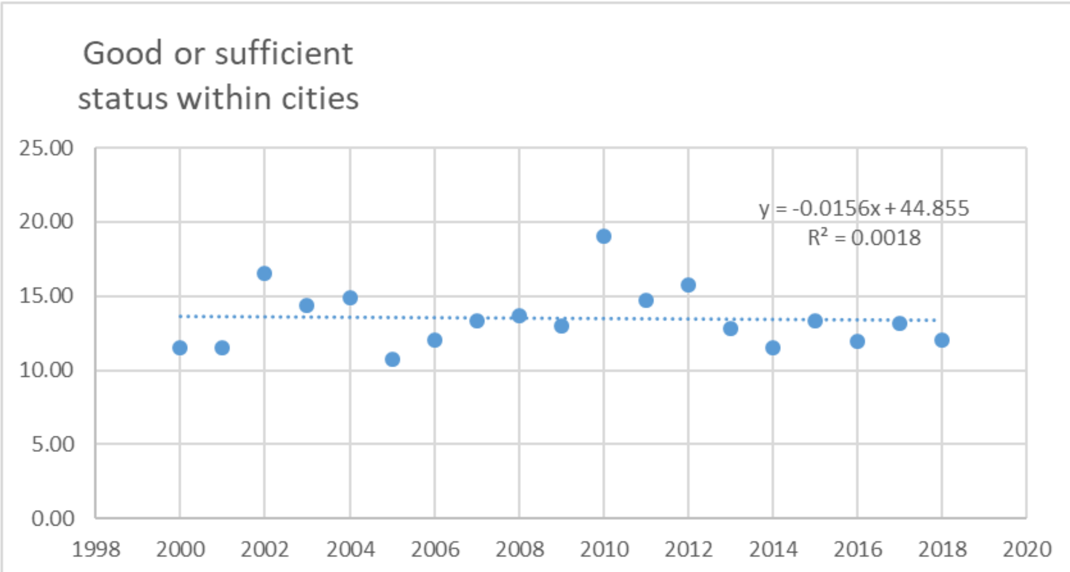


Table 6: summary statistic - long term trend of Bathing Water quality in in Good or sufficient status

Regression Statistics	
Multiple R	0.042690274
R Square	0.00182246
Adjusted R Square	-0.056893866
Standard Error	2.116623459
Observations	19

ANOVA

	df	*SS*	*MS*	*F*
Regression	1	0.13905488	0.139055	0.031038
Residual	17	76.1616128	4.480095	
Total	18	76.3006676		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	44.85495813	178.109764	0.251839	0.804185
X Variable 1	-0.015619088	0.0886556	-0.17618	0.862236
% change per decade	-1.160356874			

Fact sheet 3.1.206: Population

1. General information

- Thematic ecosystem assessment: Urban
- Indicator class: Environmental quality
- Name of the indicator: Population
- Units:
  - total inhabitants within CORE CITIES
  - total inhabitants within FUA

2. Data sources

The indicator is based on readily available data.

- Data holder: EUROSTAT
- Data source: EUROSTAT-URBAN AUDIT
- Weblink: https://ec.europa.eu/eurostat/web/cities/data/database
  - Population on 1 January by age groups and sex - cities and greater cities (Code: urb_cpop1)
  - Population on 1 January by age groups and sex - functional urban areas (Code: urb_lpop1)
- Year or time-series range Core cities:
  - 2010-2015 (850 CORE CITIES)
- Year or time-series range FUAs:
  - 2010-2016 (444 FUA)
  - 2010-2017 (58 FUA)
  - 2011-2014 (44 FUA)
  - 2013-2018 (5 FUA)
- Access date:
  - Core cities: Access date: 4/11/2019 (Last update of data: 21/10/2019 ; Last table structure change: 02/09/2019)

3. Assessment of the indicator

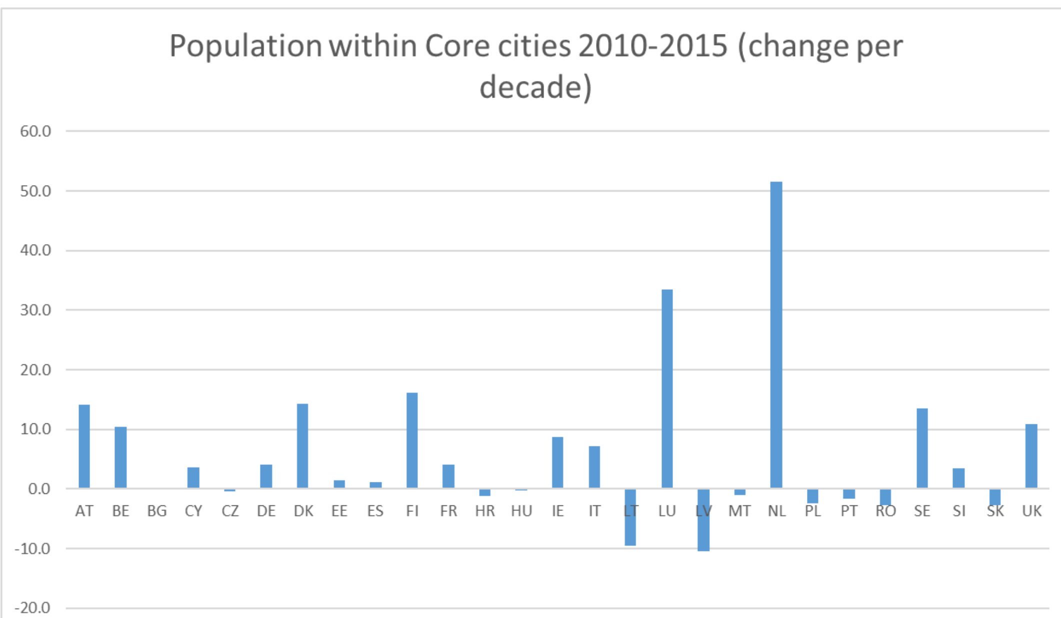
3.1. Short description of the scope of the indicator.

Population dynamics (e.g., population size, growth, density, age and sex composition, migration, distribution) are one of the main drivers of environmental impact of urbanized areas (Newman, 2006).

The intensity of population impact is strongly related to the type of resource management and to lifestyle (de Sherbinin *et al.*, 2007).

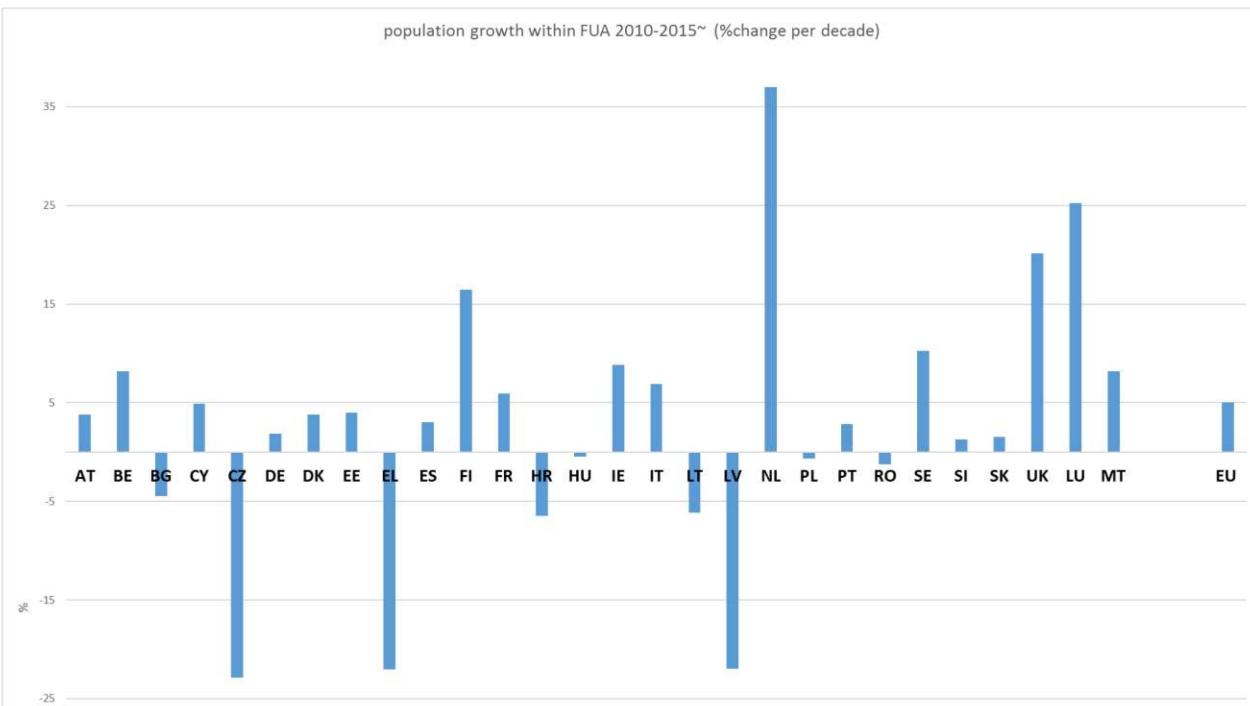
Core cities

Time-series range	Core cities represented	%	time y1	y2	Population population Y1	population Y2	change per decade
EU-2010-2016	723	78.93	2010	2016	183844963	191851000	7.26
EU-2010-2017	42	4.59	2010	2017	10906486	11045417	1.82
EU-2011-2013	4	0.44	2011	2013	1239931	1275352	14.28
EU-2013-2018	5	0.55	2013	2018	1259742	1252608	-1.13
EU-2011-2014	69	7.53	2011	2014	12936179	12842766	-2.41
EU-2011-2019	1	0.11	2011	2019	94,034	119,214	33.47
EU-2013-2014	6	0.66	2013	2014	2562304	2598407	14.09
EU-Core cities	850	92.79	2010.126	2015.874	212843639	220984764	6.65
TOT_Core cities	916						



FUA

Time-series range	represented FUA number	%	y1	y2	population Y1	Y2	change per decade
EU-2010-2016	443	62.75	2010	2016	243164088	253544832	7.12
EU-2010-2017	44	6.23	2010	2017	15893891	16543883	5.84
EU-2011-2014	58	8.22	2011	2014	21276231	21329243	0.83
EU-2013-2018	5	0.71	2013	2018	2072737	2045816	-2.60
EU-2011-2013	4	0.57	2011	2013	5560628	5602628	3.78
EU-2013-2014	6	0.85	2013	2014	5564652	5606655	7.55
EU-2011-2019	1	0.14	2011	2019	3,828,434	3,154,152	-22.02
EU-FUA	561	79.46	2010.17	2015.85	297360661	307827209	6.20
TOT_FUA	706						



Fact sheet 3.1.207: Land composition

1. General information

- **Urban** ecosystem assessment
- Indicator class : **Structural ecosystem attributes**
- Name of the indicator: **Land composition**
- Units:
  - Land Types (%)
  - Direction of land Types change (%)
  - Magnitude of change : K statistic

2. Data sources

- Data holder : EEA
- Weblink: https://land.copernicus.eu/pan-european/corine-land-cover
- Year or time-series range: 2000 – 2006 – 2012 - 2018
- Version: Corine Land Cover (CLC) 2000-2018, Version 20
- Access date: June 2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

In this study, we used CORINE Land Cover (CLC) as land use map despite its relatively low resolution (100 m) compared to other sources (e.g. urban atlas) but we were interested in trend analysis for different years available for an higher number of possible cities. Urban Atlas covers two time-steps (2006-2012) for 300 cities with a resolution of 50 m, for artificial land use classes and 100 m for agricultural, forest and semi-natural. Moreover, the comparison between 2006 and 2012 is complicated by the fact that some categories semantically differ (e.g. Class 3.1 from UA2012 is included into class 3 in UA2006; and classes 3.2 and 3.3 are included into class 2 in UA2006). CLC is available for 1990-2000-2006-2012-2018 and allows including 700 cities.

Land composition is a measure of the spatial distribution of elements or components of a landscape. It is used to consider the co-occurrence of land types within each FUA. It represents the arrangements of ecosystem types within and around cities. To quantify land composition we use the *Landscape Mosaic* (LM), model available in GuidosToolbox[14] (Vogt and Riitters 2017). Additional technical details can be found in the fact sheet 4.3.201_LandscapeMosaic and chapter 4.3.The model measures all possible land type combinations and allows to consider trade-offs occurring between intra-land type changes (i.e., modification of the area of a given land type) and inter-land types changes (i.e., direction of change). It provides a measure of the relative contributions of land types within a given neighborhood/observation area.

[14] https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/

Table 1: Land Mosaic parameters implemented in the Urban application

Dominant land types			
Dominant type	Corine Land Cover	notes	
A = Agricultural	[12 -> 22]	all agricultural land types included in CLC	
N= Natural	[23-36]	for cities we exclude lakes	
D = Developed	[1 -> 11]	Urban green is classified as artificial	
Spatial parameters			
resolution (m)	moving window	observation zone (km^2)	
100	15 pixels	2.25	

Figure 1: type of output derived from the model.

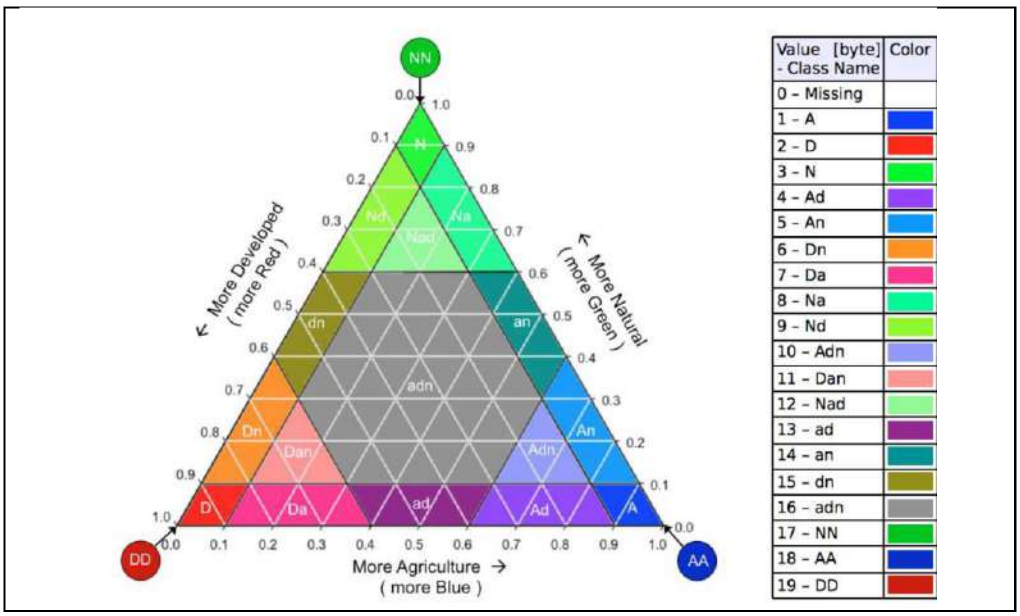


Table 1 presents a synthesis of parameters used to run the Land Mosaic within FUAs. Corine Land Cover was classified in three dominant classes: Agricultural, Natural, Developed (or Artificial). The first includes all agricultural land types; the second represents all forest types, Semi-natural vegetation and grassland and does not include water. The third consists of all artificial land types (including urban-green).

Figure 2: Example of Land Mosaic maps in Helsinki (FI) and Naples (IT). A = Agriculture; D = Developed; N = natural; Mix = mixed presence of all land classes.

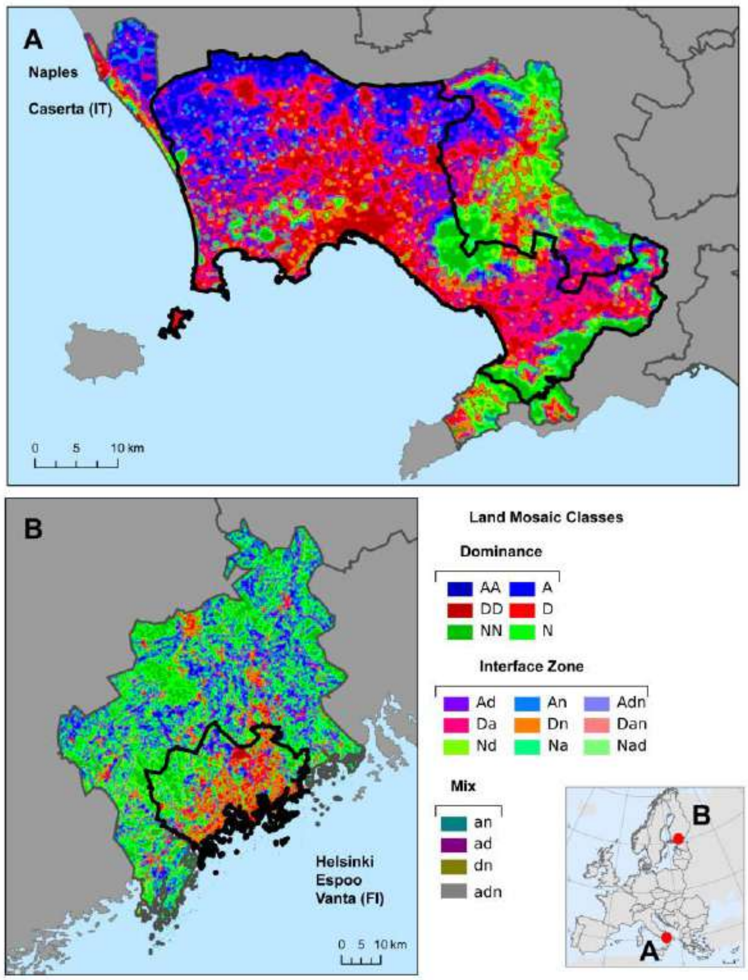


Figure 2 show the type of output derived from the model. The main output is a 19 classes categorical map which represents the co-occurrence of the three main land types within a given zone. A location being composed of a single land cover type only (100%) is labelled with a double upper letter (i.e. DD = 100% developed-artificial). Upper-class letter denotes a respective contribution of at least 60% but less than 100% (D => 99% artificial; Dn => 10-40 % natural and 60-90% artificial). Lower-case letter denotes a respective land cover type proportion of at least 10% but less than 60% (Nad =>60-80% natural and 10-30 % agricultural and 10-20 % artificial). A letter does not appear if the respective land cover proportion is less than 10% (Dn has no agriculture).

Figure 3 describes the workflow of the land composition analysis and how the land mosaic types have been used to focus on specific zones within core cities and commuting zone.

A. CLC (originally 44 land types) is re-coded in 3 main classes: Agricultural; Artificial; natural
B. Land Mosaic model run within a zone of 2.25 km2.

C. The 19 classes are reclassified in 4 main categories representing Dominance and prevalence of Agricultural, Artificial and Natural plus the situation where there is not a clear prevalence.

D. Land composition analysis

   1. Magnitude of land cover change is evaluated using the kappa statistic (Hagen-Zanker 2006; Research Institute for Knowledge Systems 2008; Hagen-Zanker 2009). The Kappa comparison method is based on a straightforward cell-by-cell map comparison, which considers for each pair of cells on the two maps whether they are equal or not. It is defined as the goodness of fit between two categorical maps. Values range between 0 and 1, where 0 indicates no agreement at all and 1 indicates a perfect fit.
   2. Direction of land cover change, evaluated considering in each FUA the proportion of cells that from one land type transited to the others.
   3. Combination of the two metrics were combined in a hierarchical cluster and EU FUA

E. Land types were used to classify core cities and commuting zone in densely built and interface zone. This zonation has been used to analyze imperviousness and urban green infrastructure trends in order to have a more exhaustive overview of what is happening within part of the cities with different characteristics in terms of land combinations. This method allows to focus on areas within the city boundaries where the soil in almost completely sealed (> 60% artificial) and where there is still a proportion of land covered by agriculture or natural vegetation). **Table 2** shows examples of aggregated land mosaic types used in the urban assessment.

Table 2: examples of aggregated land mosaic types used in the urban assessment

Land class		
Densely built		
Not-densely built		
		

Figure 3: workflow for the land composition analysis.

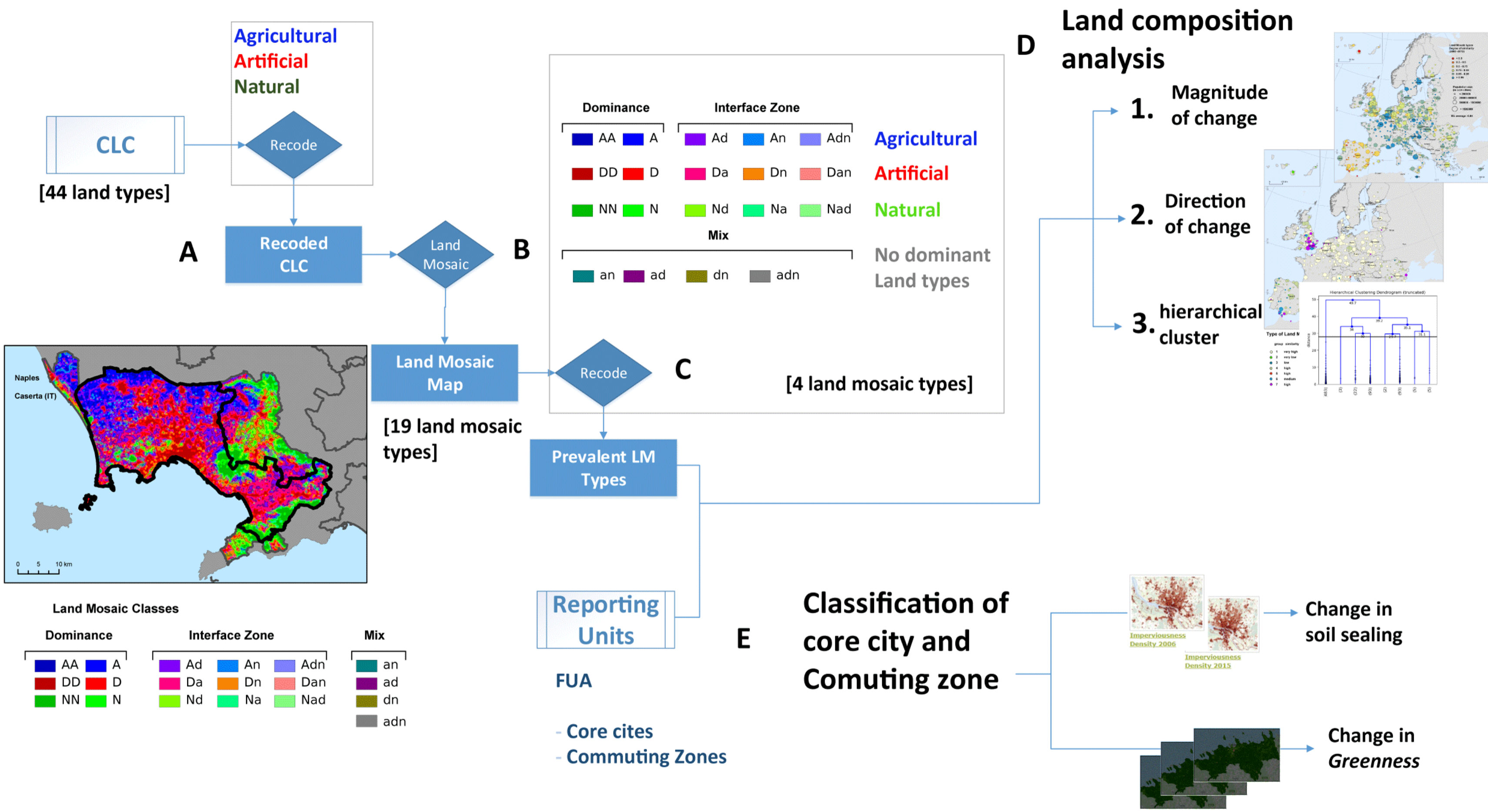


Table 2: EU scale trends of land composition within FUA.

			Short-term trend			Long-term trend		
Indicator	**Unit**	**Baseline value (2012)**	**%**	**change**	**c.s**	**%**	**change**	**c.s**
Dominant Artificial	%	5.84	0.3	➔	4	0.49	➔	4
Dominant Agriculture	%	51.68	-0.87	➔	4	-1.57	➔	4
Dominant Natural and Semi-natural	%	27.0	-0.15	➔	4	0.23	➔	4
No dominant Land Type	%	15.4	0.55	➔	4	0.75	➔	4

Table 2 presents short-term and long-term trends aggregated at EU scale expressed in percentage per decade. At EU-28 scale we register a variation in the total share of dominant artificial areas within FUAs, that varies between 5.13% in 2000 to 6.02% in 2018. Together with artificial areas, also land characterized by "No dominant land type", increases. This land type represents all interface zones that (in different measure) overlap with sprawled urbanization.

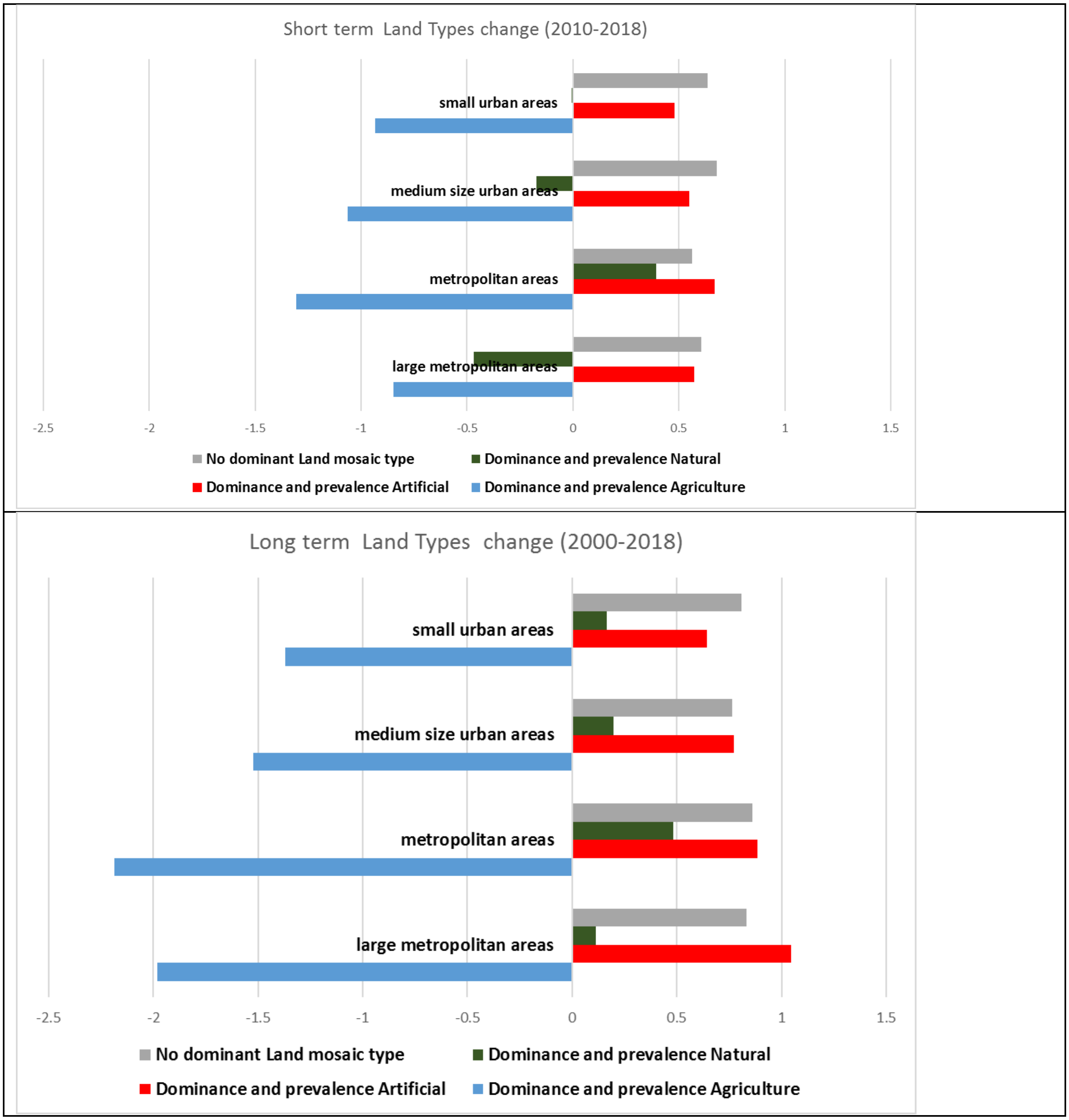
The total share of Natural and semi-natural vegetation varies between 26.49%, in 2000 to 26.90% in 2018. Proportionally we register a more intense decline in agricultural land compared to Urban Forest. Dominant agricultural land decreases from 54% in 2000 to 51% in 2018.

Size, structure and composition of European FUAs varies a lot, both in terms of land type co-occurrence and population dynamics (Maes et al. 2019). The EU wide general pattern varies a lot among cities. As an example, we register an average change (% per decade) in Natural Land Types of -0.04% with a minimum of -12.5 and a maximum value of 19.00.

Despite the fact that the indicators were not statistically significant, we note an increase in the total share of areas dominated by the presence of artificial land types and of land characterized by no specific land type. This last category represents all interface zones; areas which, in different degrees, overlap with a sprawled urbanization and tend to fragment the remaining, relatively natural or rural ecosystems. In parallel, there has been a generalized decrease in areas with a dominance of agriculture and areas with a dominance of natural and semi-natural vegetation.

Direction and magnitude of changes vary according to the size of cities and the land type considered, however, all FUA are characterized by a decrease in agricultural land and an increase in artificial areas and land with no dominant land type(see Figure 5).

Figure 5: short-term and long-term land type change (% per decade) classified per FUA size[15].



[15] The methodology applied to classify cities is described in the fact sheet on Reporting Units.

The magnitude of change

Land composition trends are highly stable, Figure 6 quantifies the magnitude of change among land types between 2000 and 2018 within FUAs.

Figure 6: Land use types, magnitude of change between 2000 and 2018.

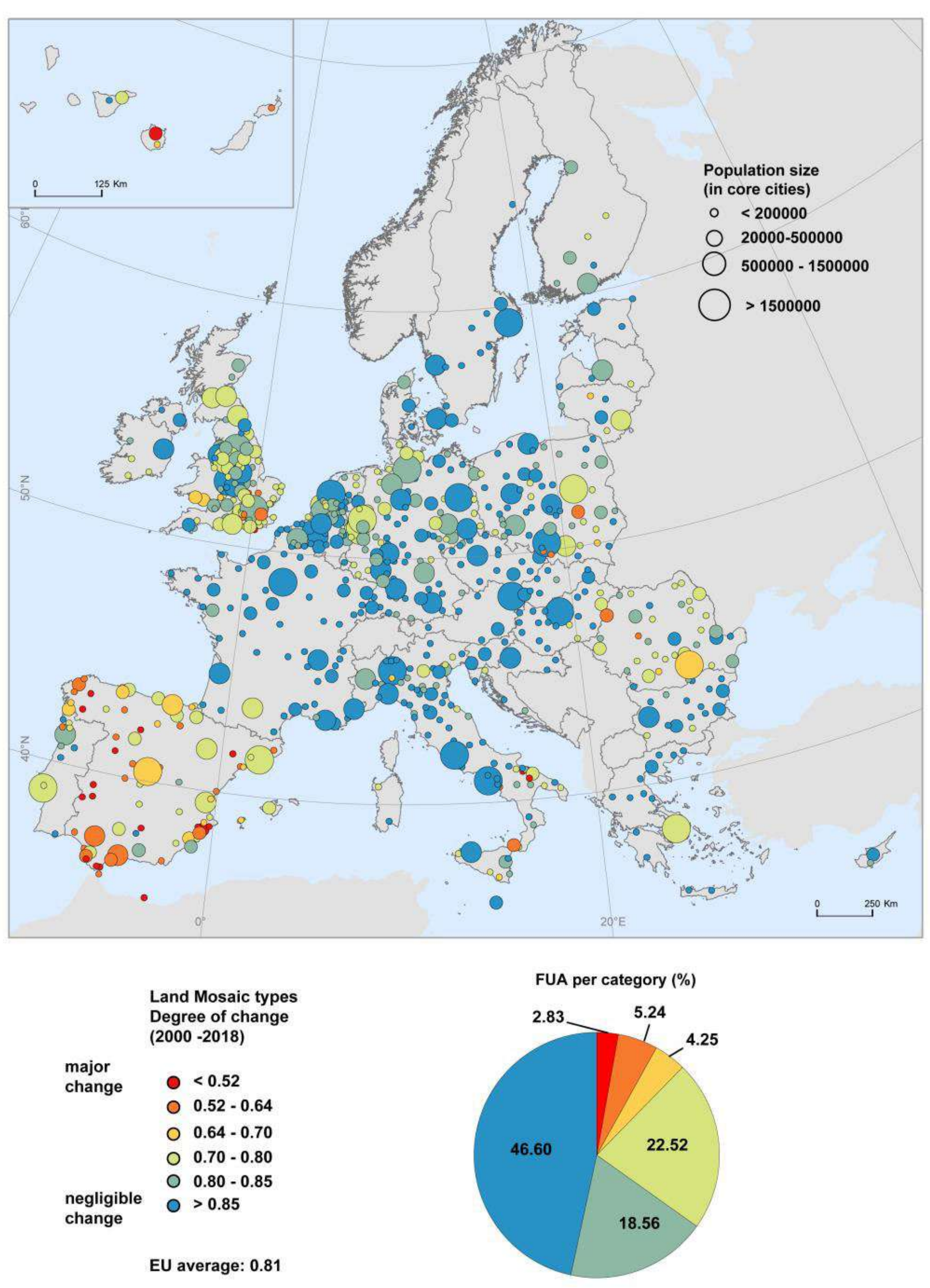
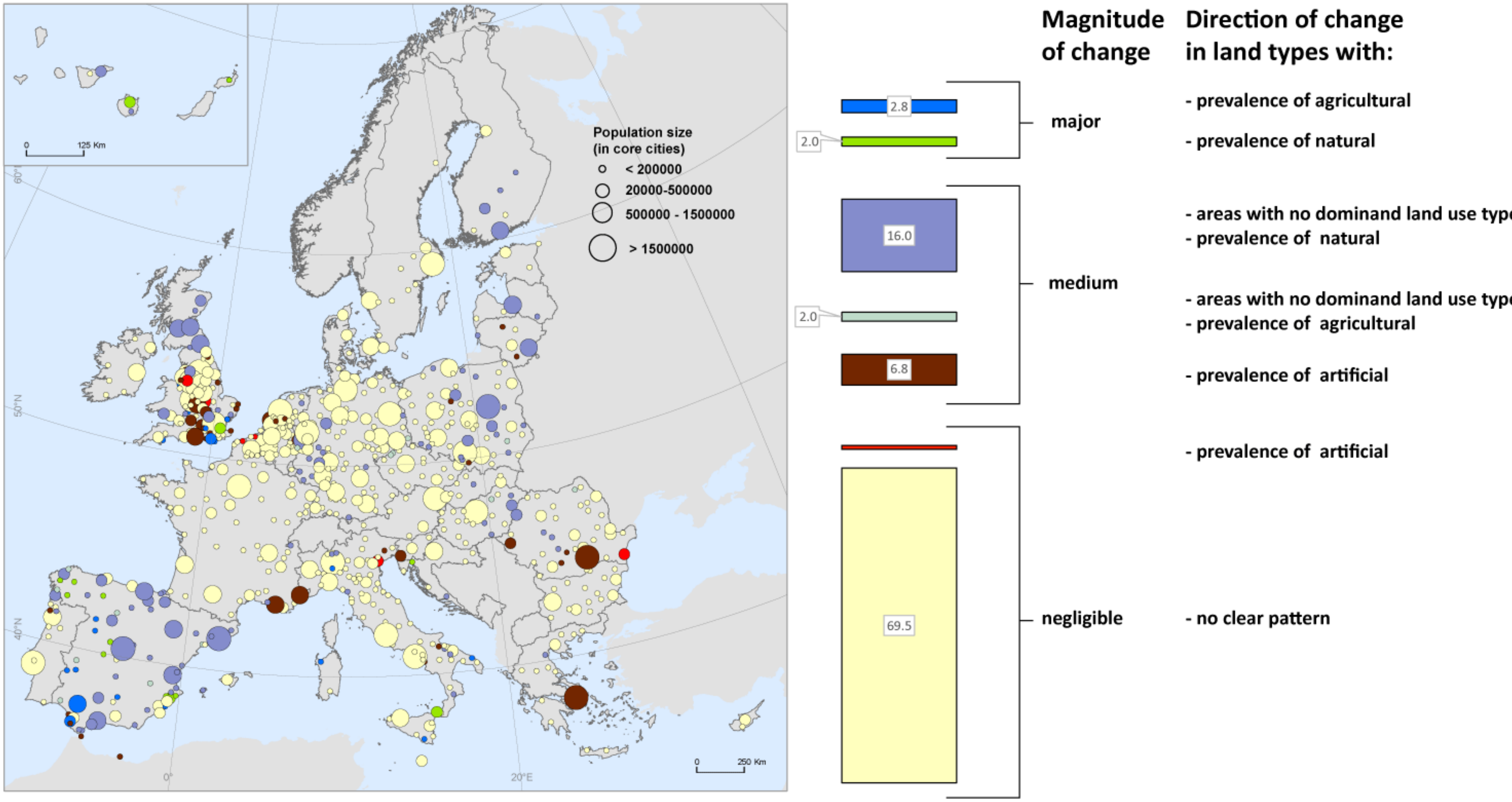


Figure 7: FUAs classified in terms of magnitude and direction of change.



Changes in share of dominant land types are relatively stable. Figure 14 presents FUA classified according to magnitude of change and direction of change (the main direction of transition in case of change of land type). In 70.4 % of FUA land type changes were negligible (meaning that it was not detectable using CLC). A medium magnitude of change characterized 24.8% of FUA. The main direction of change in this case has been versus "Land with do dominant land use types", which represents an areas with mixed uses. In 4.8% of the FUA there was a major change, with a slightly inverse tendency, signaling an increase in areas primarily occupied by agricultural or natural land types

References

Acosta-Alba I, Van der Werf MH (2011) The Use of Reference Values in Indicator-Based Methods for the Environmental Assessment of Agricultural Systems. Sustainability 3:

Hagen-Zanker A (2006) Map comparison methods that simultaneously address overlap and structure. J Geogr Syst 8(2): 165–185. doi: 10.1007/s10109-006-0024-y

Hagen-Zanker A (2009) An improved Fuzzy Kappa statistic that accounts for spatial autocorrelation. Int J Geogr Inf Sci 23(1): 61–73. doi: 10.1080/13658810802570317

Maes J, Zulian G, Günther S, Thijssen M, Reynal J (2019) Enhancing Resilience Of Urban Ecosystems through Green Infrastructure (EnRoute) Final Report. Luxembourg.

Research Institute for Knowledge Systems (2008) Assessment and scenarios of land use change in Europe. Maastricht, The Netherlands

Vogt P, Riitters K (2017) GuidosToolbox: universal digital image object analysis. Eur J Remote Sens 50(1): 352–361. doi: 10.1080/22797254.2017.1330650

Fact sheet 3.1.208: Urban Form

1. General information

- **Urban** ecosystem assessment
- Indicator class : **Structural ecosystem attributes**
- Name of the indicator: **Urban Form**
- Units:
  - Urban Form [dimensionless]
  - Share of FUA grid classified as:
    - Highly compact (%)
    - Compact (%)
    - Continuous (%)
    - Not-built (%)

2. Data sources

- Data holder (JRC) GHS built-up grid, derived from Landsat, multitemporal R2018A, 30-m (EPSG:3857).
- Weblink JRC Open Data repository: https://data.jrc.ec.europa.eu/dataset/jrc-ghsl-10007
- Year or time-series range: 1975-1990-2000-2014
- Resolution: 30 m
- Version: Version 2.0
- Access date: April 2019
- Reference :
  - Dataset: Corbane Christina; Florczyk, Aneta; Pesaresi, Martino; Politis, Panagiotis; Syrris, Vasileios (2018): GHS built-up grid, derived from Landsat, multitemporal (1975-1990-2000-2014), R2018A. European Commission, Joint Research Centre (JRC) doi: 10.2905/jrc-ghsl-10007 PID: http://data.europa.eu/89h/jrc-ghsl-1000
  - Concept & Methodology: (Corbane et al. 2019)

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Urban Form provides a spatially explicit metric to describe the built-up area pattern within a given zone.

The indicator has been derived, and adapted at European scale, from the sprinkling (SPX) index. The SPX index is defined as the "mean Euclidean nearest neighbor distance" and measure the degree of fragmentation of urban settlements through a purely geometric point of view (Romano et al. 2017; Saganeiti et al. 2018). Assuming the circular form as the most "compact" possible, the index is based on the calculation of distances between different built-up areas on a 2 km buffer around each 1 km grid cell within each Functional Urban Areas. The distance buffer of 2 km around each sub-reporting unit (1 km cell) was chosen following previous works on urban sprawl developed at European scale (Aurambout et al. 2018).

The Urban Form index is defined as follow:

$$Urban_{Form} = \frac{(Max_{-\,bld-dist})}{R}$$

where:

Max(**bld-dist**) = the maximum distance between all built up areas extracted within a 2 km horizon (2 km buffer around each 1 km cell); the distance is measured within the target FUA and the adjacent FUAs in order to take the edge effect into consideration. The analysis is carried on at 30 m resolution and the final indicator is represented within a 1 km grid.

R= ray of a hypothetical built-up zone with and area equal to the sum of all the built up areas in the considered horizon

The Urban Form Index is a dimensionless metric. The higher the value the higher the degree of fragmentation of land due to the presence of built-up infrastructures within the FUA. Values greater than 100 represents no-built up areas. In terms of changes negative values represent a progressive densification of built-up areas. To make the interpretation easier the indicator has been classified in six classes which represent categories of urban form having an impact on city performance in terms of mobility, urban resilience, ecosystem services and biodiversity (Cortinovis et al. 2019). **Figure 1** shows an example of urban form measured in Padova (north-east of Italy). We note a progressive increase of compactness within the core city and a progressive densification of settlements in the commuting zone, at the expenses of agricultural areas and of a Natura 2000 site (the Colli Euganei regional park) (south east).

Figure 1: example of urban form index applied to the Functional Urban Area of Padova (Italy). Maps at this resolution are available for the all 700 European cities.

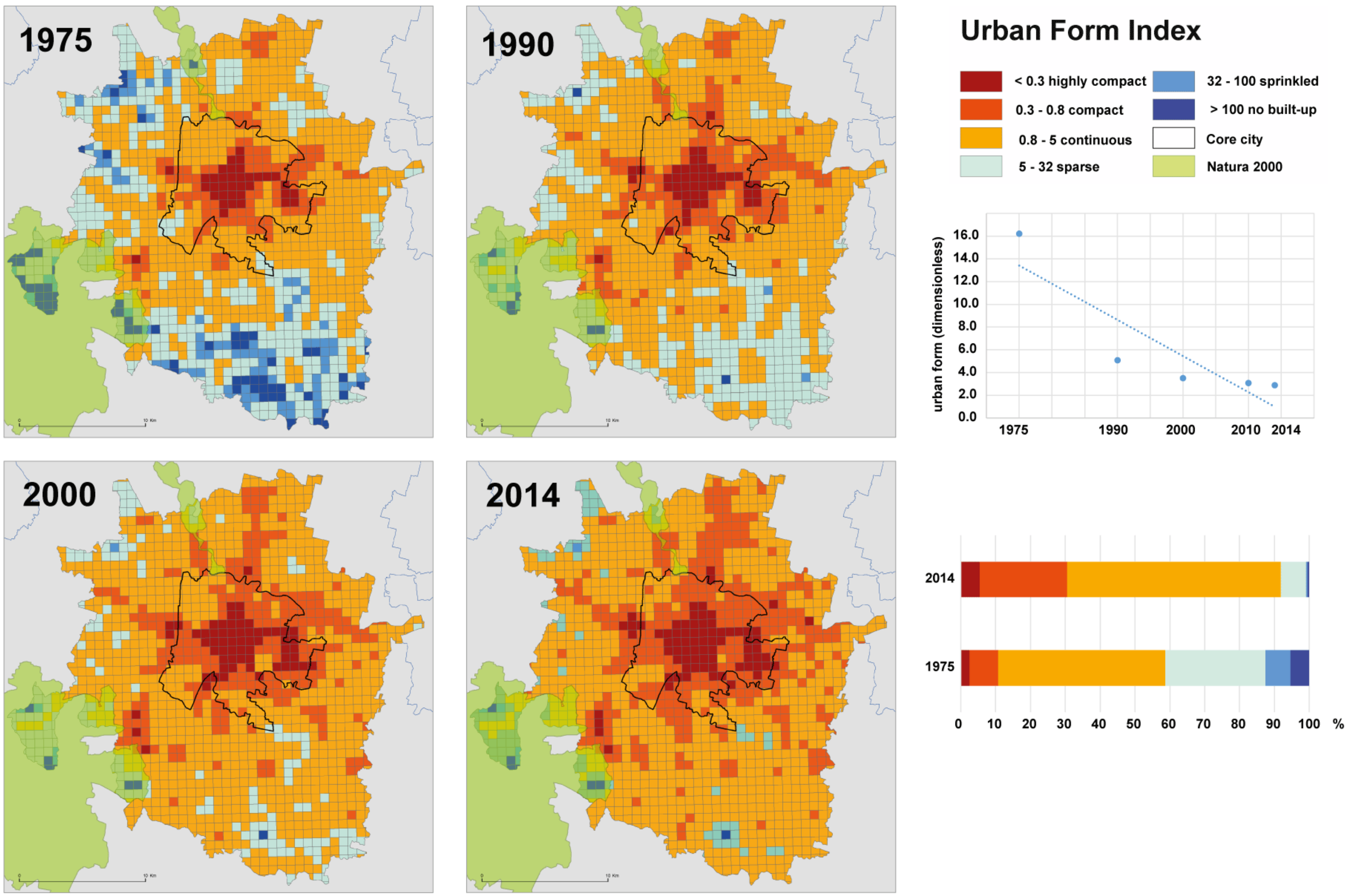


Figure 2: share of urban structure classes in few European cities. Highly compact and compact were collapsed in one class.

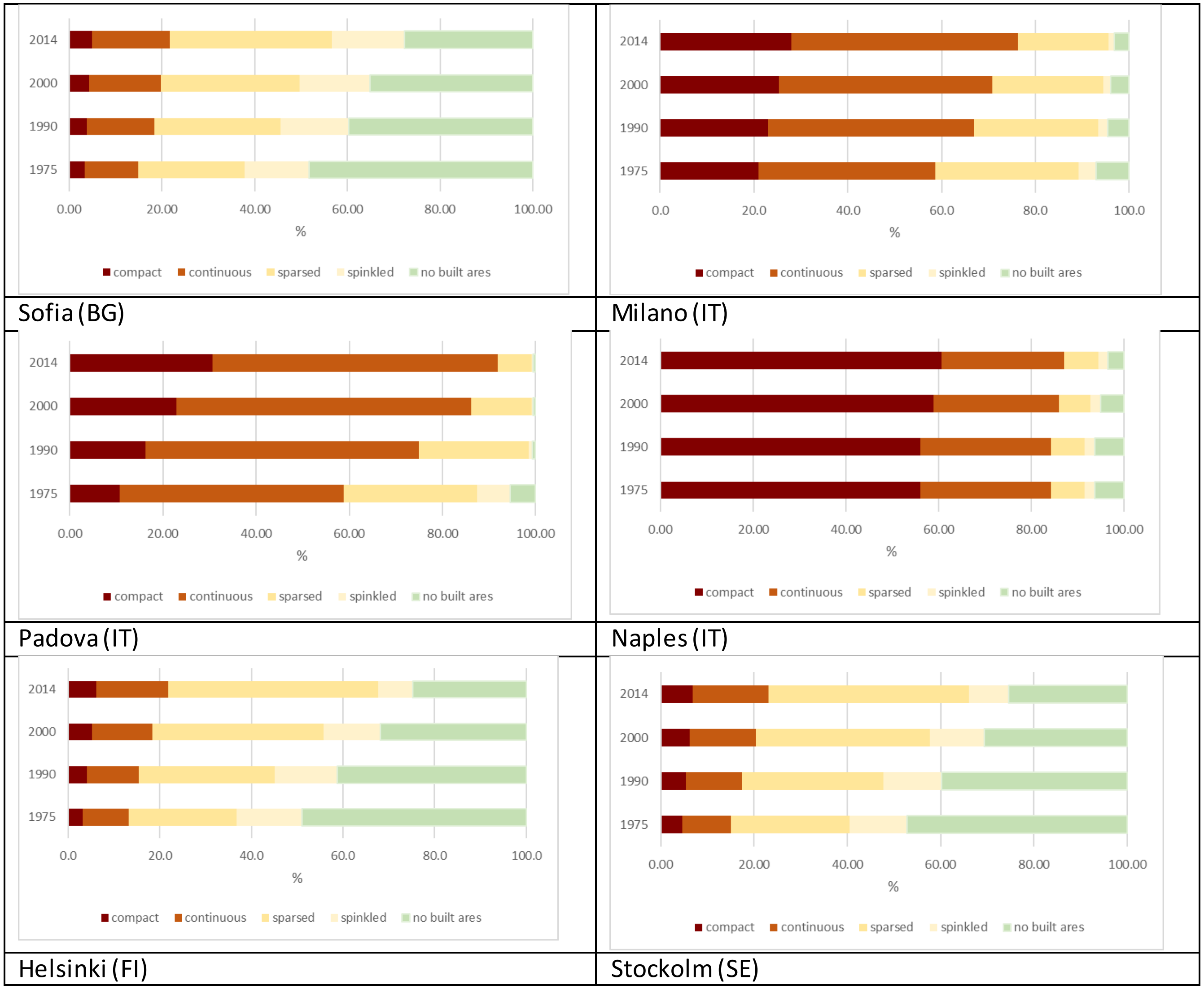
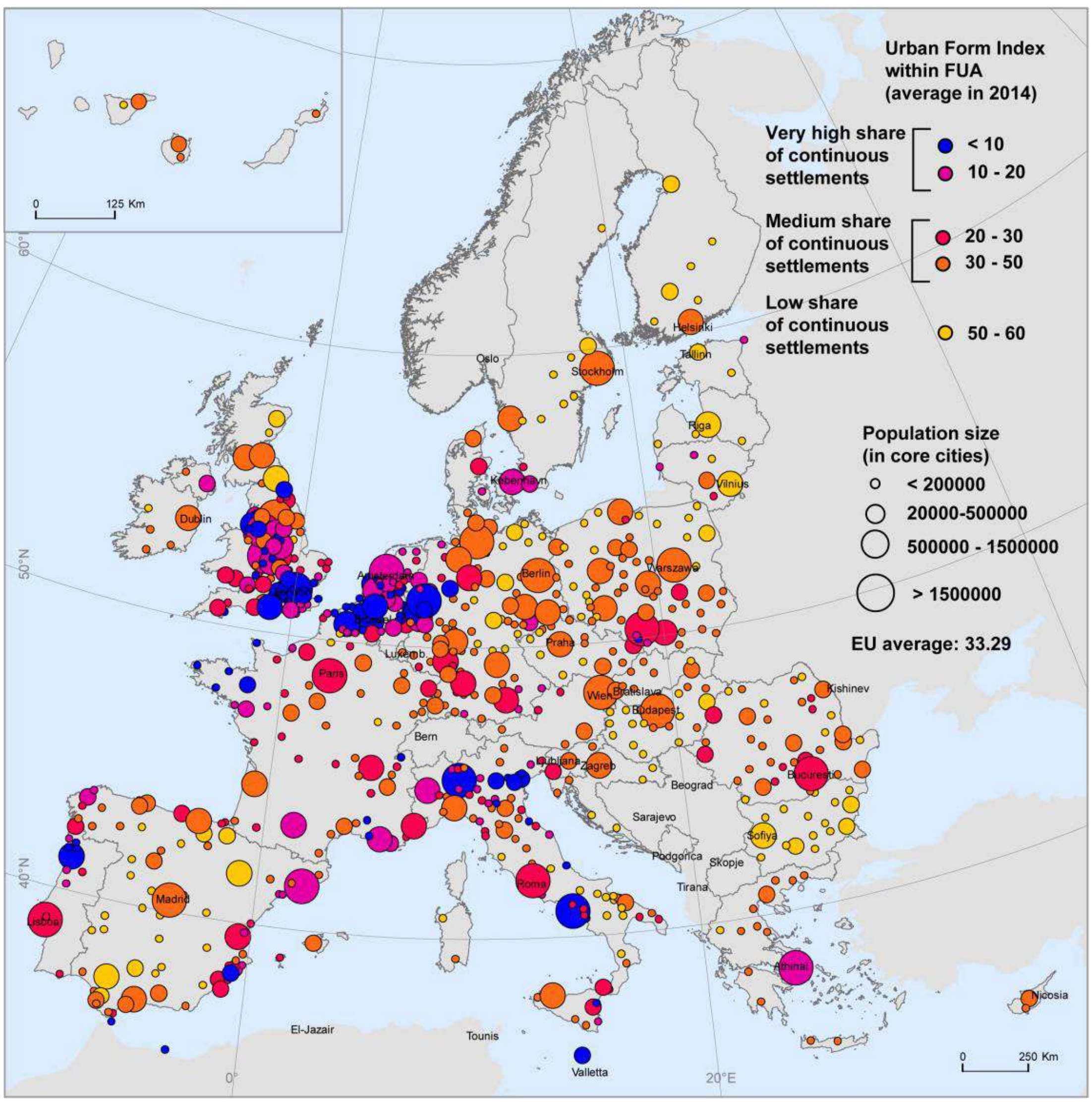


Figure 2 shows the structure of the FUA in six European cities. It represents the share of five structure classes over the FUA surface. Helsinki (FI), Stockholm (SE) and Sofia (BG) have a very similar structure with a relatively low share of FUA occupied by compact and continuous settlements. However “no built areas” in Helsinki and Stockholm are covered by peri-urban forest and inland water whereas in Sofia no built areas are mainly occupied by agricultural land (Maes et al. 2019). On the contrary, the FUA of Naples, Padova and Milano (IT) are almost totally built and no built space areas essentially no longer exist.

3.2. Maps

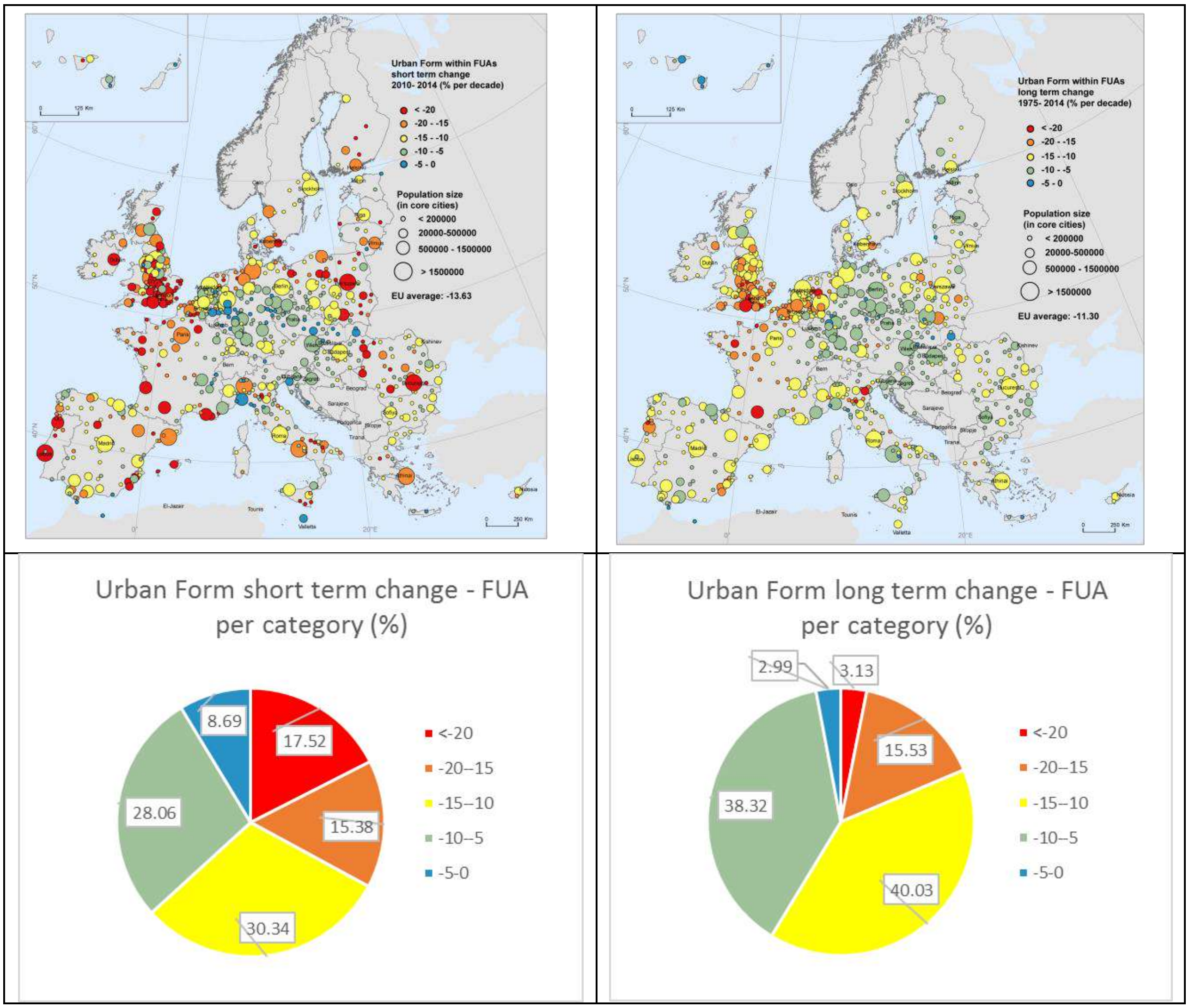
Figure 3: Status maps of Urban Form, average value per FUAs (2014).



The map provides a spatially explicit pattern of regions with a dominance of compact and continuous settlements within the overall FUA surface.

Figure 3 shows the different degree of settlement dispersion in FUA in 2014. A very high share of dense settlements, i.e. in Naples or Milano, evidence a situation where the commuting zone (or the cluster of municipalities around the core city) is assuming the characteristics of a conurbation (or of an extended urban area).

Figure 4: Urban Form short and long term trends



In the long term, a progressive densification process is reported (**Figure 4** Map B) at EU level. An intense transition versus a very dense structure (red and orange dots) characterizes FUAs in England, Belgium and The Netherlands. In the short term, (**Figure 4** Map A) the process demonstrates a relatively rapid urbanization in eastern, Nordic and Mediterranean cities, probably connected with the stage of economic development of European cities. However, additional socio-economic data are needed to fully understand the trend.

Statistical significance

The non-parametric Wilcoxon test was applied using bootstrapping (sampling 1% of the reference units, 1000 times). The random sampling was stratified by country to make sure all countries are represented in the subsampling (it depends on the number of observations available within e ach country).

Table 2: results of the Wilcoxon test

Type of indicator: Structural ecosystems attributes Urban structure		**Data source : GHSL (JRC)**	
		Spatially explicit : YES	**Spatial resolution: 30 m (aggregated at 1 km)**
Indicator	**Range**	**Trend at EU level (%per decade) Mean (min-max)**	**Statistical significance**
Structure of built-up areas (dimensionless)	Long trend 1975-2014	**-11.30** (-22.63 - -0.27)	**Significant** AvgP 0.02248707
	Short -term trend 2010*-2014	**-13.63 (**-56.35; -0.44)	**Significant** **AvgP** 0.02248755
Structure of built-up areas-type **highly compact** (%)	Long trend 1975-2014	**0.37** (0.0; 4.68)	**Significant** AvgP 0.02949552
	Short -term trend 2010*-2014	Mean **0.28 (0.0 – 4.95)**	**Significant** AvgP 0.04598709
Structure of built-up areas-type **compact** (%)	Long trend 2010-2014	**0.60 (**-0.69 – 5.29)	**Significant** AvgP 0.048718
	Short -term trend 2010*-2014	**0.46 (**-2.08; 5.08)	**Significant** AvgP 0.04928846
Structure of built-up areas-type Dense (%)	Long trend 1975-2014	**2.44 (**-5.13; 14.05)	**Significant** AvgP 0.03870777
	Short -term trend 2010*-2014	2.11 (-6.04 ;15.52	**Not Significant** AvgP 0.05523742
Structure of built-up areas-type Sparsed (%)	Long trend 1975-2014	1.49 (-10.05 ;11.72)	**Not Significant** AvgP 0.3407279
	Short -term trend 2010*-2014	0.69 (-14.25; 13.67)	**Not Significant**
Structure of built-up areas-type Sprinkled (%)	Long trend 1975-2014	-0.78 (-4.16; 3.99)	**Not Significant** AvgP 0.2196815
	Short -term trend 2010*-2014	-0.84 (-6.09; 5.95)	**Not Significant**
Structure of built-up areas-type No built areas (%)	Long trend 1975-2014	**-4.25 (**-13.1 ; 0.0)	**Significant** AvgP 0.0259339
	Short -term trend 2010*-2014	**-2.82 (**-18.46; 0.0)	**Significant** AvgP 0.0290268

References

Aurambout J-P, Barranco R, Lavalle C (2018) Towards a Simpler Characterization of Urban Sprawl across Urban Areas in Europe. Land 7(1): 33. doi: 10.3390/land7010033

Corbane C, Pesaresi M, Kemper T, Politis P, Florczyk AJ, Syrris V, Melchiorri M, Sabo F, Soille P (2019) Automated global delineation of human settlements from 40 years of Landsat satellite data archives. Big Earth Data 3(2): 140–169. doi: 10.1080/20964471.2019.1625528

Cortinovis C, Haase D, Zanon B, Geneletti D (2019) Is urban spatial development on the right track? Comparing strategies and trends in the European Union. Landsc Urban Plan 181(August 2018): 22–37. doi: 10.1016/j.landurbplan.2018.09.007

Romano B, Zullo F, Fiorini L, Ciabò S, Marucci A (2017) Sprinkling: An approach to describe urbanization dynamics in Italy. Sustain. doi: 10.3390/su9010097

Saganeiti L, Favale A, Pilogallo A, Scorza F, Murgante B (2018) Assessing urban fragmentation at regional scale using sprinkling indexes. Sustain 10(9): 1–23. doi: 10.3390/su10093274

Fact sheet 3.1.209: Annual trend of vegetation cover in Urban Green Infrastructure (UGI)

1. General information

- **Urban ecosystems**
- **Indicator class** : Structural ecosystem attributes
- **Name of the indicator**: Annual trend of vegetation cover within Urban Green Infrastructure (UGI)
- Units of measure:
  - % change per decade
  - Greening-Browning balance (difference between share of UGI where there has been a major upward and downward trend in vegetation cover)
- Spatial Reporting Units:
  - Core cities and Commuting zone:
    - They represent the administrative boundaries (or aggregated administrative boundaries in the case of Commuting zones)
  - Densely built areas and Interface zones:
    - Densely built areas: where artificial areas cover more than the 60% of a 2.25 km^2 neighborhood[16]
    - Interface zones: where artificial areas are mixed with urban forest, semi-natural vegetation or urban fringes

2. Data sources

- Data holder : Earth Engine's public data catalog
- Weblink:https://developers.google.com/earth-engine/datasets/catalog/LANDSAT_LE07_C01_T1_ANNUAL_GREENEST_TOA
- These composites are created from all the scenes in each annual period beginning from the first day of the year and continuing to the last day of the year. All the images from each year are included in the composite, with the greenest pixel as the composite value, where the greenest pixel means the pixel with the highest value of the Normalized Difference Vegetation Index (NDVI).
- Year or time-series range: 1996 - 2018
- Resolution: 30 m
- Access date: January 2019

[16] See metadata Lan Mosaic model for more information

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

This indicator examines how and in which direction vegetation cover changes within the Urban Green Infrastructure. Trend detection in Normalized Difference Vegetation Index (NDVI) time series can help to identify and quantify recent changes in ecosystem properties. The greenness values are derived from Landsat annual Top-of-Atmosphere (TOA) reflectance composites available in the Google Earth Engine (GEE) platform for the period 1996–2018. These composites are created by considering the highest value of the NDVI as the composite value. The analysis is based on the greenest pixel value, i.e. the pixel with the highest value of NDVI of the year.

Vegetation trends tend to be highly stable and changes are gradual. In anthropized ecosystems instead, they are not always monotonic (or gradual) but can have what is called an *"Abrupt"* character (Forkel et al. 2013; Yu et al. 2017). Gradual and abrupt changes have different meanings and origins (Zhu et al. 2016; Novillo et al. 2019):

- <u>Gradual changes:</u>
  - generally caused by vegetation growth, climate change, land degradation, extended drought, pests as well as other factors;
  - develop over a relatively long time periods (5+ years);
- <u>Abrupt changes:</u>
  - generally induced by land cover change (e.g. housing development) or intensive urban green space management;
  - can have an impact on greenness within a short time period (1~2 years);

We examined the greenness trend within UGI in core cities and commuting zone of all European Functional Urban Areas (FUA)[17]. Indicators were extracted using two zones, extracted from the Land Mosaic Model (Guids Toolbox[18]): the densely built up areas and the interface zones (see Figure 1).

[17] See metadata on reporting units for a detailed definition
[18] See metadata Land Mosaic model for more information

Figure 1: examples of urban green infrastructure in densely built up areas and not- densely built areas.

Densely built-up areas		where artificial areas cover more than 60% within a 2.25 km^2 neighbourhood.
Not- densely built areas		where artificial areas cover the 40% of a 2.25 km^2 neighbourhood; and the rest of the land can be covered by: urban forest, seminatural vegetation or agro-ecosystems.

Similar methodologies were applied by Corbaine et al. 2018, which examined greenness in built-up areas in comparison to the non-built-up areas and, which evaluated greenspace change along a gradient outward from city centers.

The approach used here allows identifying the trend direction and the magnitude of change in core city and commuting zone. Results are reported at EU level but maps and analysis are available at 30 m resolution for the 700 FUAs. The second indicator "*Greening-Browning balance*" reports on the difference between share of UGI where major upward and downward trend in vegetation cover took place.

- A negative balance occurs in case of vegetation loss. This phenomenon is called "*Abrupt browning change*", generally caused by a relatively fast land use change or by land take with no compensation policies in place.
- A positive balance occurs in case of vegetation growth. In urban areas an "*Abrupt greening change*", generally is caused by the implementation Nature Based Solutions (e.g. Intensive urban green space management) or sustainable compensation strategies in case of land take.

This indicator can help identifying possible policy actions to restore degraded ecosystems or compensate the loss of UGI. In fact, several Nature based Solutions (NBS) are available to achieve a sustainable urbanization (Somarakis et al. 2020) and the type of NBS to be put in place depends also on the area where the problems occur. Table 1 presents a synthesis of possible NBS classified according to the land configuration type of the area of intervention.

Table 1: NBS classified according to the land configuration of the Urban Area and the Typology NBS. The table was compiled following (Somarakis et al. 2020, chapter 2 and Annex 1)**.**

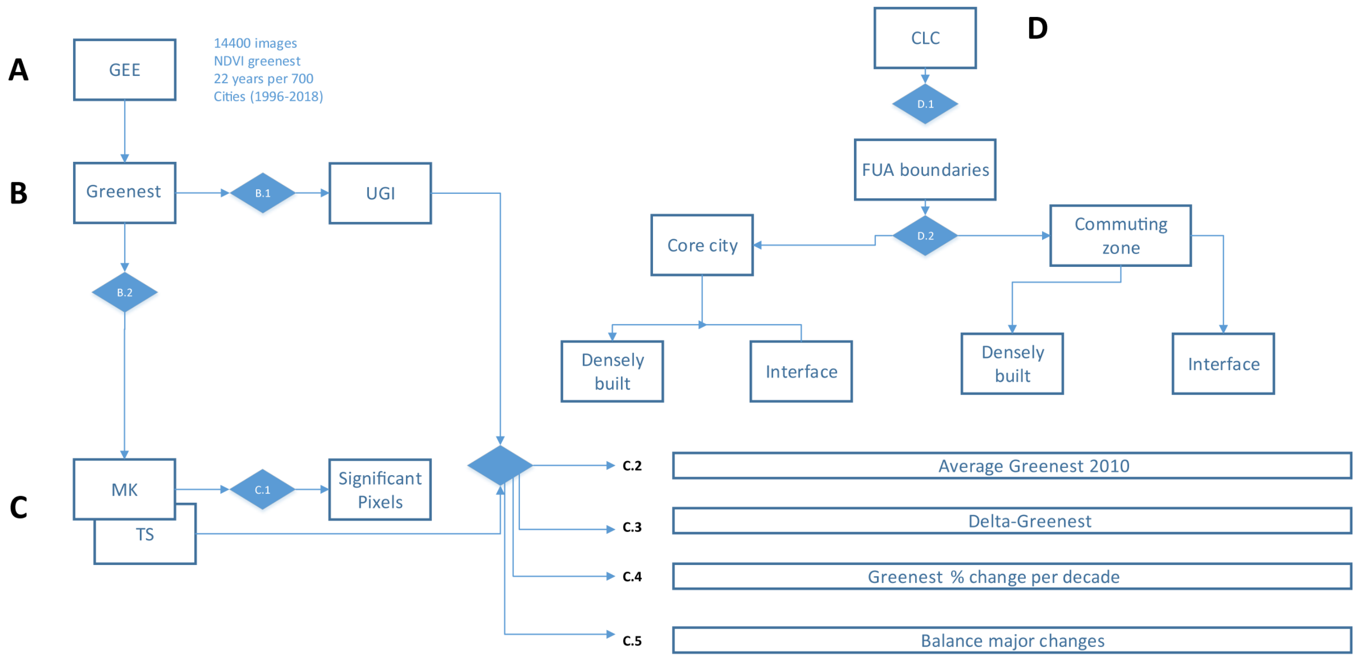
Land configuration type	NBS Type	NBS-sub-type	Examples
Densely built areas	Type 3 – Design and management of new ecosystems.	Intensive urban green space management	Integrated and ecological management - spatial aspects Choices of plants Structure of urban parks system (Large urban park; Pocket garden/park; Community gardens) Flower field Street trees Green roof Green wall system
		Urban water management	Sustainable Urban Drainage Systems
		Ecological restoration of degraded terrestrial ecosystems	Soil and slope revegetation Plant trees/ hedges/perennial grass strips to intercept surface run-off
		Restoration and creation of semi-natural water bodies and hydrographic networks	Re-vegetation of riverbanks Constructed wetlands and built structures for water management
Interface zones	Type 1 – Better use of protected/natural ecosystems	Protection and conservation strategies in terrestrial and marine Protected Areas (e.g. Natura2000 or MPA	Limit or prevent specific uses and practices Ensure continuity with ecological network Protect forests from clearing and degradation from logging, fire, and unsustainable levels of non-timber resource extraction
	Type 2 – NBS for sustainability and multifunctionality of managed ecosystems	Agricultural and Forest landscape management	Agro-ecological practices Agro-ecological network structure Forest patches Hedge and planted fence Flower strips

		Extensive urban green space management	Ensure continuity with ecological network Planning tools to control urban expansion Historical urban green network structure Choices of plants Heritage park Urban natural protected areas Introduced vs. local plants Vegetation diversification Green corridors and belts Planning tools for biodiversity, green infrastructure, and ecosystem services

The methodology

Figure 2 provides a synthesis of the complete data processing.

Figure 2: Data processing. TS refers to the Theil-Sen slope data and MK refers to the Mann-Kendal test.



A. Data were physically downloaded from Google earth engine (GEE)
    - Using a javascript code, 22 maps (i.e. one per year) per 700 cities (for a total of 14400 maps) were downloaded

B. From the original greenest maps (greenest pixel means the pixel with the highest value of NDVI) the Urban green Infrastructure (UGI) mask was created:
    - B.1. This map represents the areas where at least once between 1996 and 2018 the highest-NDVI was greater than 0.4. The UGI mask was used to focus on changes which affected the urban green infrastructure, minimizing the impact of mixed pixels on the analysis. A similar methodology was used by Dobbs et al. 2018, which analyzed urban ecosystem services in Bogota'.

C. The Trend analysis employed a non-parametric approach, namely the Theil–Sen regression. The slopes of the regression approach were tested for their statistical significance using the p-value of the Mann–Kendall[19] test for slopes (Forkel et al. 2013; Teferi et al. 2015; Corbane et al. 2018; Wang et al. 2018; Novillo et al. 2019; Jin et al. 2019).

[19] Mann–Kendall is a temporal trend estimator that is more robust than the least-squares slope because it is much less sensitive to outliers and skewed data (https://clarklabs.org/terrset/).

- C.1 Only pixels where the p-value (Mann–Kendall) was less than 0.05 (95% confidence interval) have been considered to have a significant medium-term trend and used as a mask to extract all the indicators
- C.2 we reported the average greenest value in 2010 as reference value
- C.3 From the Theil–Sen positive or negative slope we extracted the Delta Greenest, which represent the change direction over the 22 years of analysis
- C.4 To make the interpretation easier the annual trends were reported in terms of percentage of change per decade (using the equation proposed by Teferi et al. 2015 .
- C.5 The TS-Slope was reclassified in 5 classes representing key gradual to abrupt change types. They were defined using the minimum measurable change (+-0.001) as thresholds for areas with no changes (Jin et al. 2019; Verbyla 2008; Guan et al. 2018). Table 2 provides a description of the downward and upward trends recognised.
    i. The difference between major greening and major browning represents a "compensation indicator", if it is positive the upward trend was higher than the downward trend and greening areas compensated the loss of green spaces. If it is negative the land development pattern didn't include any solution to compensate the green loss.

D. CLC map was reclassified using the land mosaic model in Densely built up and interface zone
- D.1 land Mosaic Model (GuidosToolbox[20]) was run at EU scale using a neighborhood of 2.25 km^2; the Land Mosaic was reclassified and two classes (densely built and interface zone) were used to analyze the urban vegetation trend (see also fact sheet 3.1.107 and chapter 4.3).
- D.2 for each FUA data were extracted within the core city and the commuting zone
- Indicators (C1-C2-C3-C4-C5) were extracted in Core cities and Commuting zone within Densely built up and interface zone **only for significant pixels of UGI**.

Table 2: change thresholds used in the study.

Class	description
≤ -0.015 → major browning	Downward trends (Browning) due to housing policies, development of industrial and commercial areas, new grey infrastructures
-0.015 < x ≤ -0.0001 → light browning	
-0.0001 < x ≤ 0.0001 → no changes	
≤ 0.007 → light greening	Upward trend (Greening) due to green infrastructure management; vegetation growth; climate change
> 0.007 → major greening	

Percentage of pixels with significant positive and significant negative trends were used as accuracy indicator, see Table 3.

Figure 3 shows a spatially explicit example of upward major trend detected within the core city – not densely built area of the city of Padova (Italy). The Abrupt greening change is due to intensive urban

[20] https://forest.jrc.ec.europa.eu/en/activities/lpa/gtb/

green space management. In 1996 the “Parco degli Alpini” was opened and new trees were planted, picture A in Figure 3 shows the park in 2001 and picture B in 2018.

Figure 3: example of abrupt greening (upward trend) due to due to green infrastructure management in Padova core city - not densely built zone (Italy). A. represents the NDVI change between 1996-2018; B represents the park in 2001 and C represents the park in 2018.

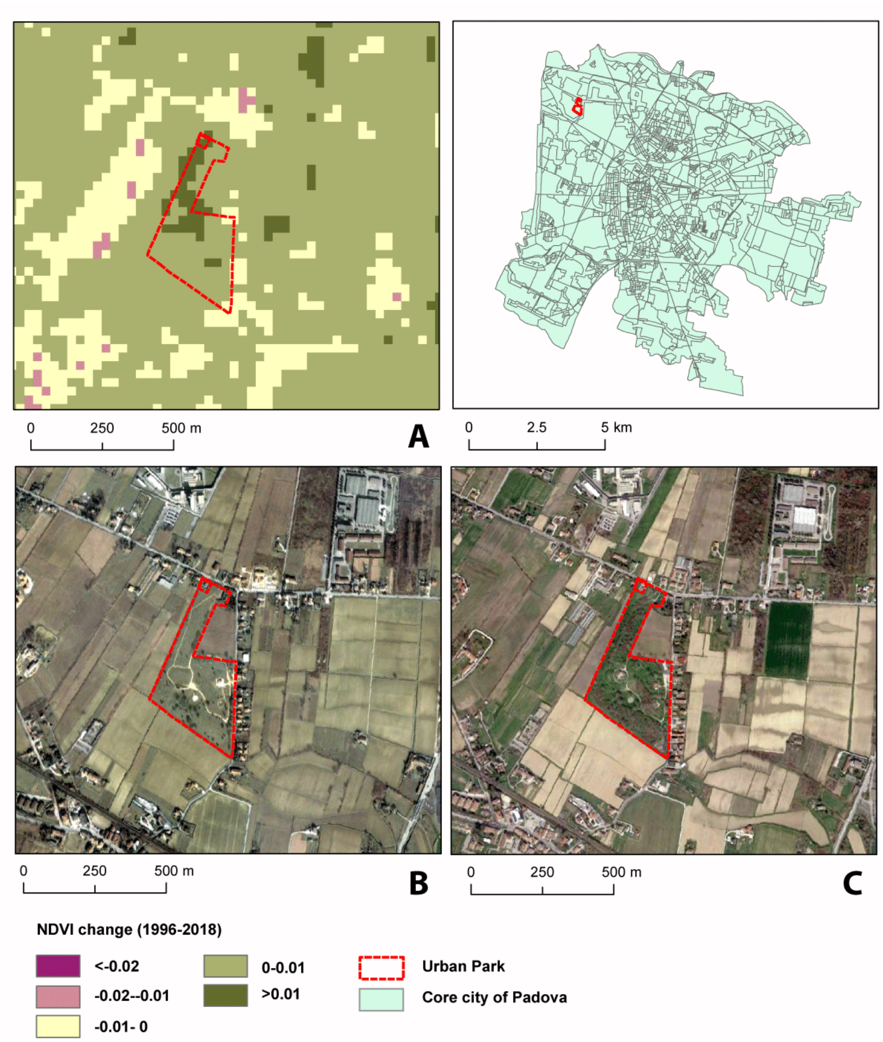
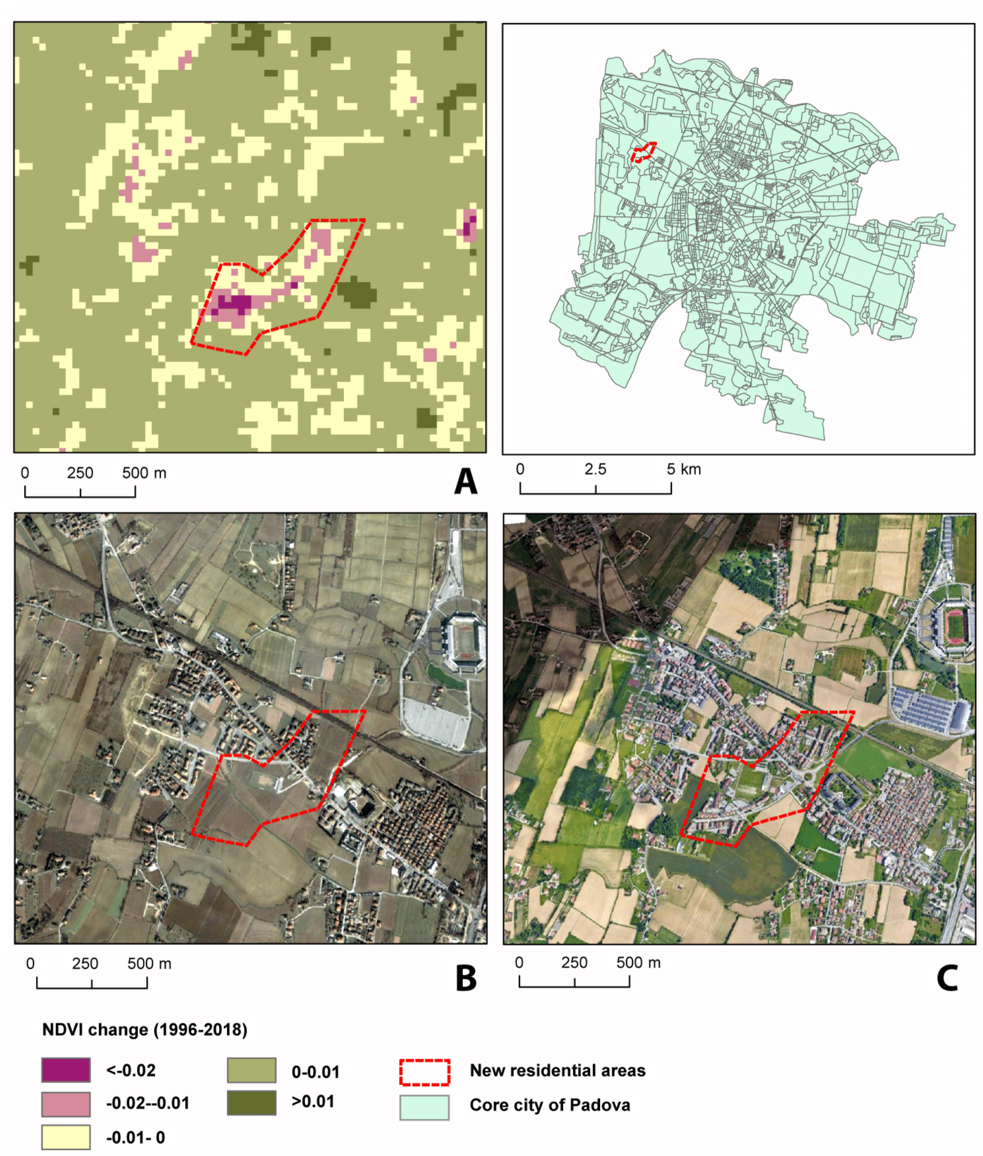


Figure 4 shows a spatially explicit example of downward major trend detected within the core city – not densely built area of the city of Padova (Italy). The Abrupt browning change is due the recent housing and commercial development of the city.

Figure 4: example of abrupt browning (downward trend) due to housing policies in Padova core city - not densely built zone (Italy). A. represents the NDVI change between 1996-2018; B represents the area in 2001 and C represents the area with a new residential zone in 2018.



Results at European scale

Table 3 shows the percentage of pixels, within the core cities and commuting zones, with significant trend. The core cities had, in total, 49.56% of significant pixels. The average value among the 696 cities for which data were available was 54.12% with a maximum of 90% and a minimum of 6%. The commuting zones (608 because there are Functional Urban Areas which do not have a commuting zone) had in total 52.4 % of significant pixels, with an average value of 54.18%, a maximum of 92.43 and a minimum of 10.18%.

Table 3: Percentage of significant pixels, per core cities and commuting zones. The average between all cities and the total share is reported.

MK Z trend		
	Core city (696 cities)	Commuting zones (608)
Significant pixels (%) total	49.56	52.38
Significant pixels (%) average within EU FUA	average (min-max)	average (min-max)
	54.12 (5.9 – 90.1)	54.18 (10.98-92.43)

Table 4 reports the average NDVI (greenest) value per reporting unit in 2010 (the reference year). The average value within core cities is, as expected, slightly lower but remarkably the values reported in densely built areas and interface zone are very similar in core cities and commuting zone. Figure 4 shows the values per Member States,

Table 4: NDVI (greenest) status map 2010. The average in European cities is reported, within core cities and Commuting zone in densely built areas and interface zones.

Status map	NDVI (greenest)			
	Core city (696)		Commuting zone (608)	
	Densely built	Not-densely built	Densely built	Not-densely built
	average (min-max)		average (min-max)	
Average greenest value in 2010	0.44 (0.21 - 0.5)	0.58 (0.26 - 0.7)	0.45 (0.0 - 0.63)	0.59 (0.29 - 0.7)

There are countries, such as Italy, Greece, Luxemburg, Slovak Republic, Czech Republic where NDVI average values are practically equal in UGI situated within densely built up zones both in core cities and commuting zones. In Portugal and Spain the values are slightly higher within densely built up areas of core cities. It would be very interesting to explore the reasons of this pattern.

During the last 22 years a general slight upward trend in urban vegetation cover is observed in European cities. Table 5 shows the EU scale average for the four reporting units. The upward trend is extremely gradual. This is more clearly reported by the indicator, "*Balance between major changes*" which measure the difference in share of land with upward and downward trends. Although the very aggregated scale of observation (average of nearly 700 cities) a negative balance is expressed in all the reporting units.

This indicator depends on abrupt changes, so changes generally due to intensive urban green management (in case of vegetation growth) or and land use change (in case of vegetation loss). When it is so clearly negative means that in general European cities did not take the indispensable initiatives to maintain an efficient urban green infrastructure.

Table 5: results of the linear trend analysis based on Theil-sen (TS) slope for yearly greenest NDVI. Average, minimum average and maximum average is reported for : Delta Greenest/year (TS slope); %Greenest change; % Greenest change/decade within core cities and Commuting zone in densely built areas and interface zones. The average in European cities is reported.

Trend estimator	Slope			
	Core city (696)		Commuting zone (608)	
	Densely built	Not densely built	Densely built	Not densely built
	average (min-max)		average (min-max)	
Delta Greenest/year (absolute)	0.0016 (-0.009 - 0.007)	0.0033 (-0.0053 -0.009)	0.0008 (-0.025 - 0.008)	0.0035 (-0.0035 - 0.007)
% Greenest change (relative)	0.216 (-3.33 - 1.43)	0.500 (-1.44 - 2.01)	0.030 (-5.81 - 2.05)	0.52 (-0.92 - 1.61)
% Greenest change/decade (relative)	0.098 (-1.51 - 0.65)	0.227 (-0.65 - 0.91)	0.013 (-2.64 - 0.93)	0.24 (-0.42 - 073)
Balance between major changes	-4.36 (-47.42-23.41)	-0.48 (-34.16 – 41.43)	-6.36 (-78.54-42.85)	-0.07 (-18.83 - 22.71)

A part from Cyprus, where a downward trend is reported also in interface zones of core cities, normally negative values characterized urban green infrastructure located within the densely built areas. In Spain, Italy, Ireland, Portugal, Slovenia, Austria and Slovakia the downward trend characterizes also the densely built up areas in commuting zone.

A negative balance between abrupt changes characterizes almost all Member States, with the exception of Romania, Latvia, Lithuania and Bulgaria. Again we remark higher values within densely built areas in commuting zones compared with core cities (Figure 7).

Those findings are clearly evident in the maps. Figure 10-11 presents the Percentage of change per decade and Figure 12, which shows the prevalent direction of change in European cities. In core cities, densely built 26.3% of the cities had a downward trend in percentage per decade. The share of cities which present a downward trend increases within commuting zones densely built (32%).

Figure 5: annual trend in vegetation cover in urban GI, per Member states. % Greenest change per decade is reported within core cities and Commuting zone in densely built areas and interface zones.

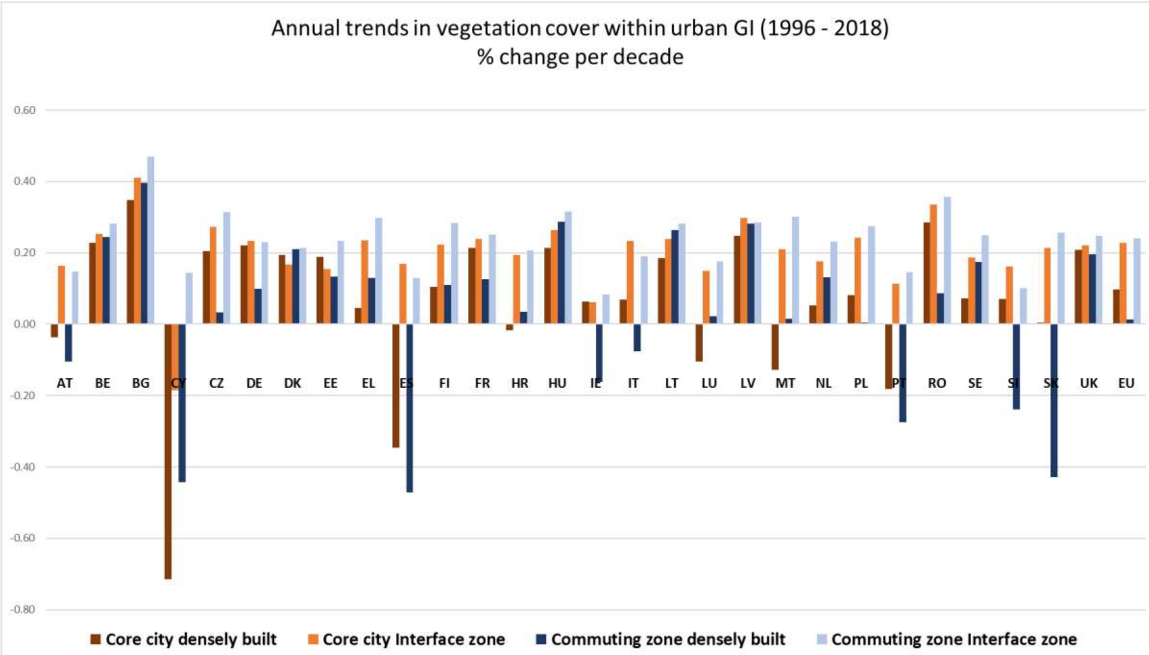
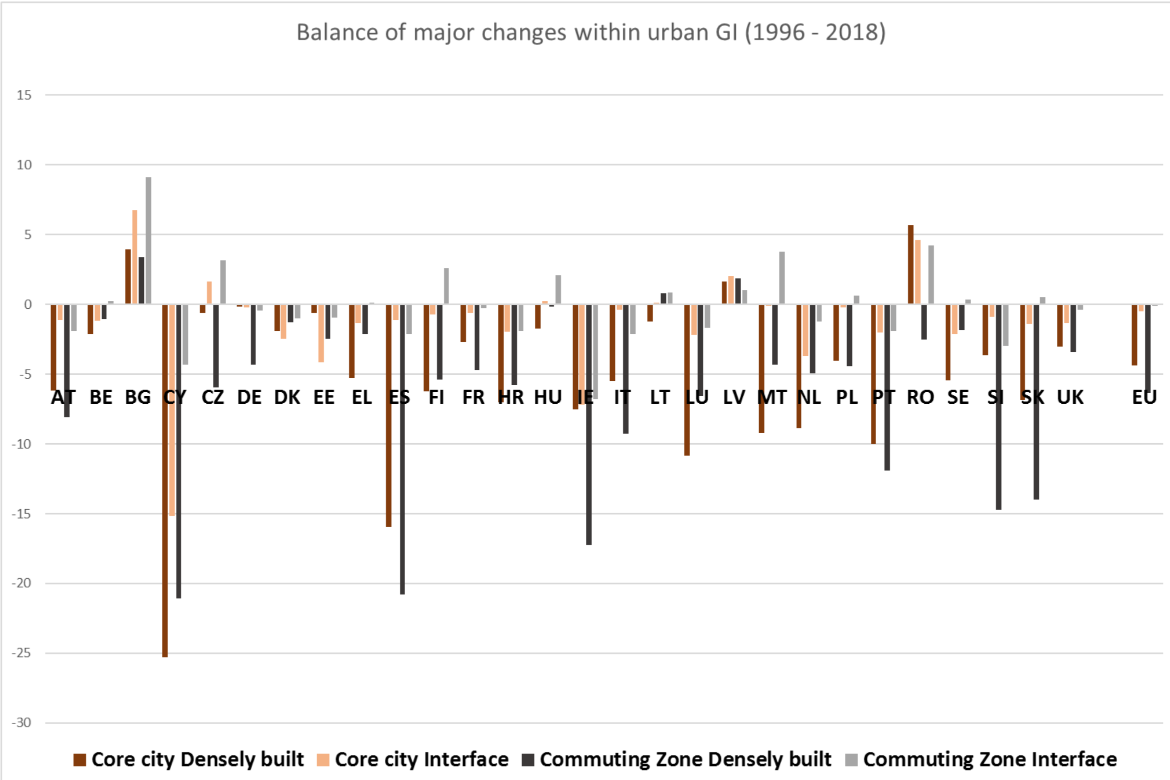


Figure 6: Balance between major changes within urban GI, per Member states. The indicator is reported within core cities and Commuting zone in densely built areas and interface zones.


Balance of major changes within urban GI (1996 - 2018)
15
10
5
0
-5
-10
-15
-20
-25
-30
AT BE BG CY CZ DE DK EE EL ES FI FR HR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK EU
Core city Densely built
Core city Interface
Commuting Zone Densely built
Commuting Zone Interface

3.2. Map

Figure 7: status maps: Average greenest value in 2010 within densely built areas.

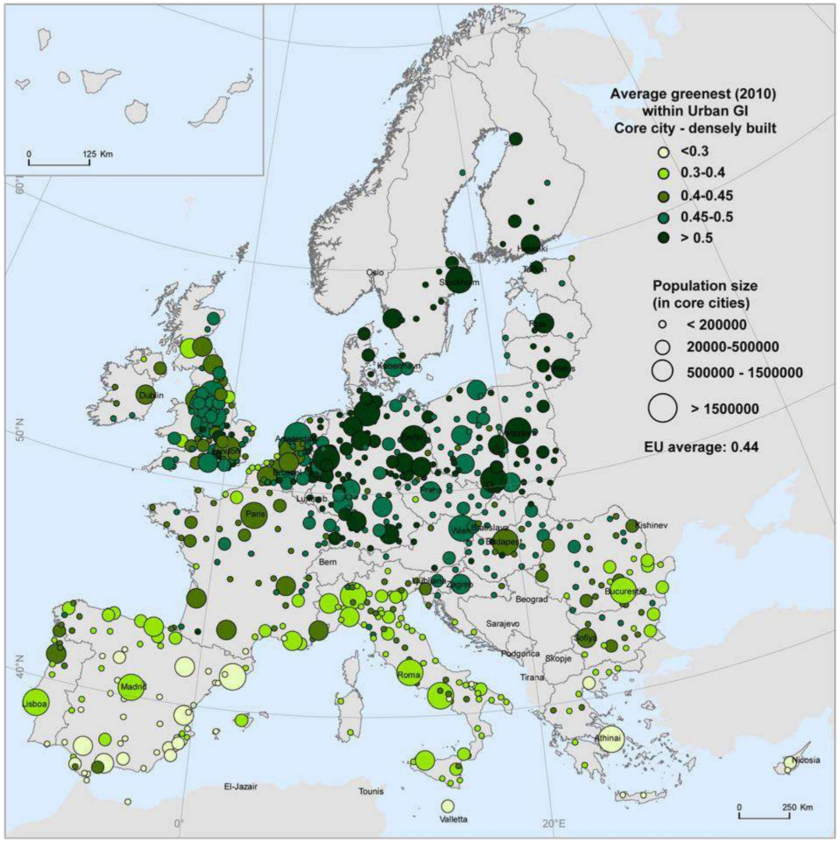
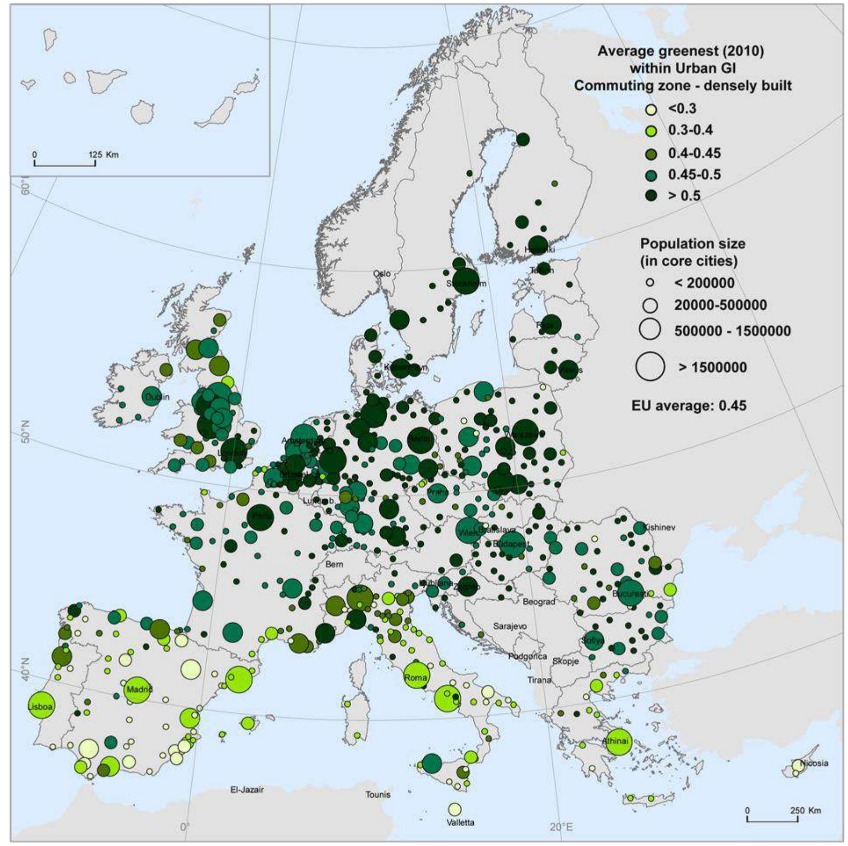
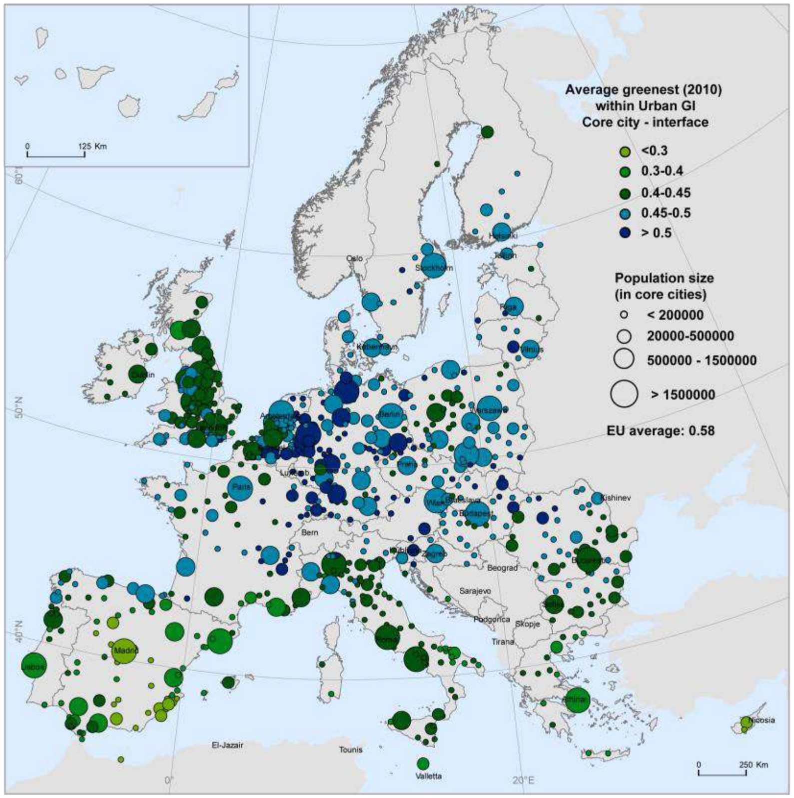
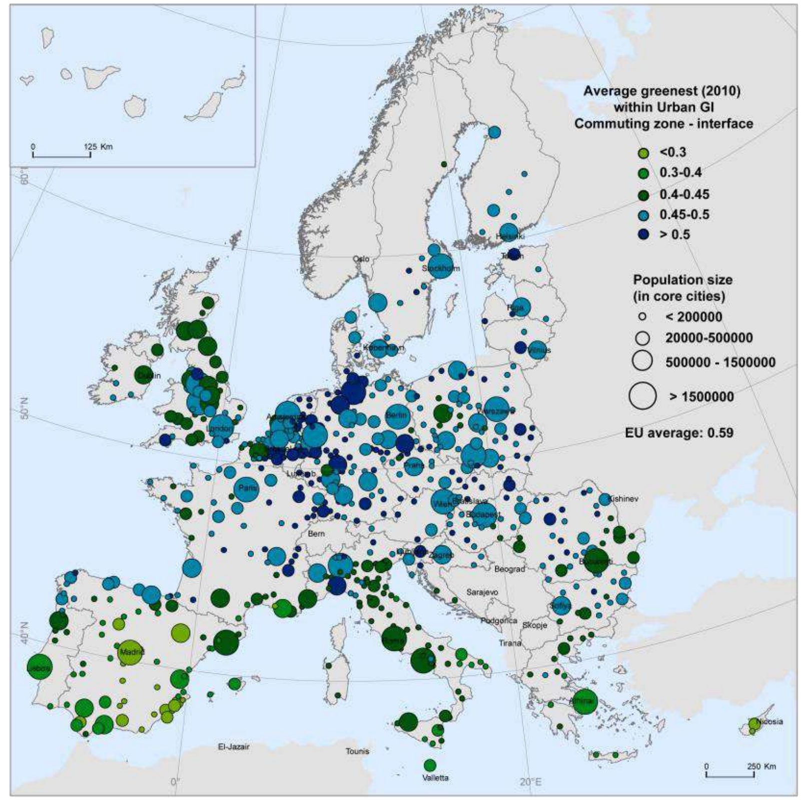
A-Core Cities	B-Commuting zone
	

Figure 8: status maps 2010, average of urban greenness, within interface zones

A-Core Cities



B-Commuting zone



3.3. Key trend at EU level

Figure 9: Trends in vegetation cover (% change/decade), within densely built areas in core cities and commuting zones..

A-Core Cities | B-Commuting zone

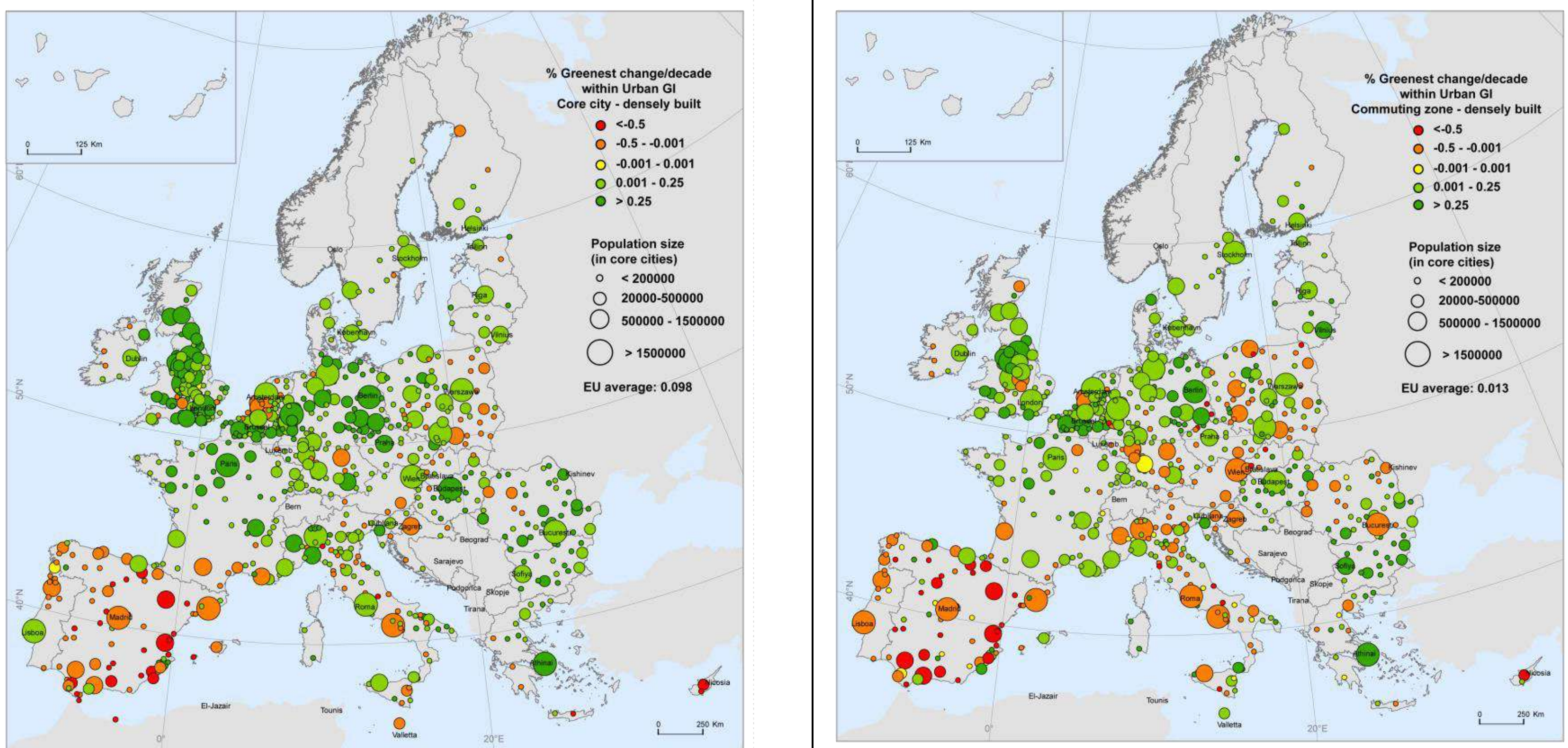
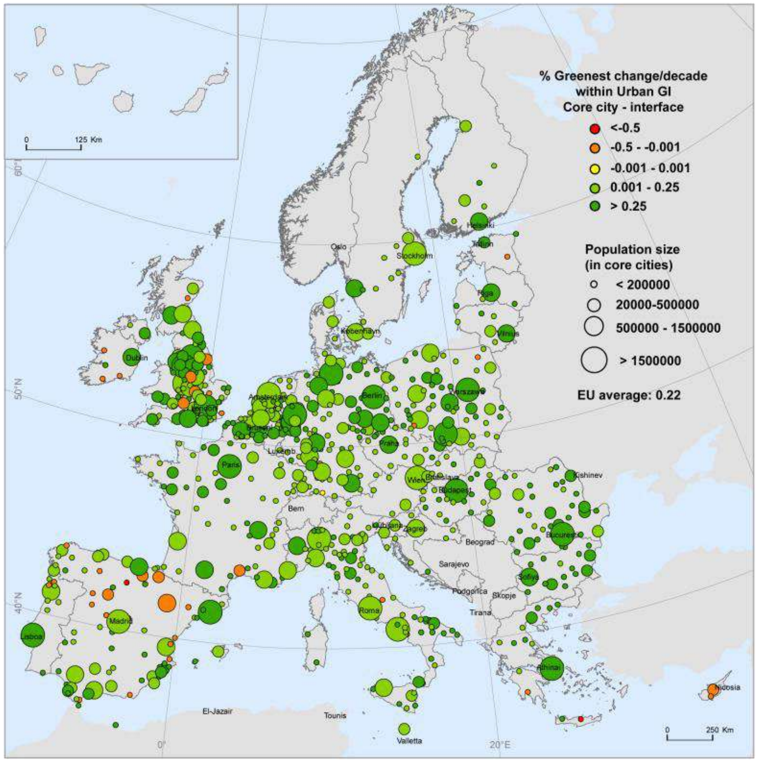


Figure 10: Trends in vegetation cover (% change/decade), within not densely built areas in core cities and commuting zones.

A-Core Cities



B-Commuting zone

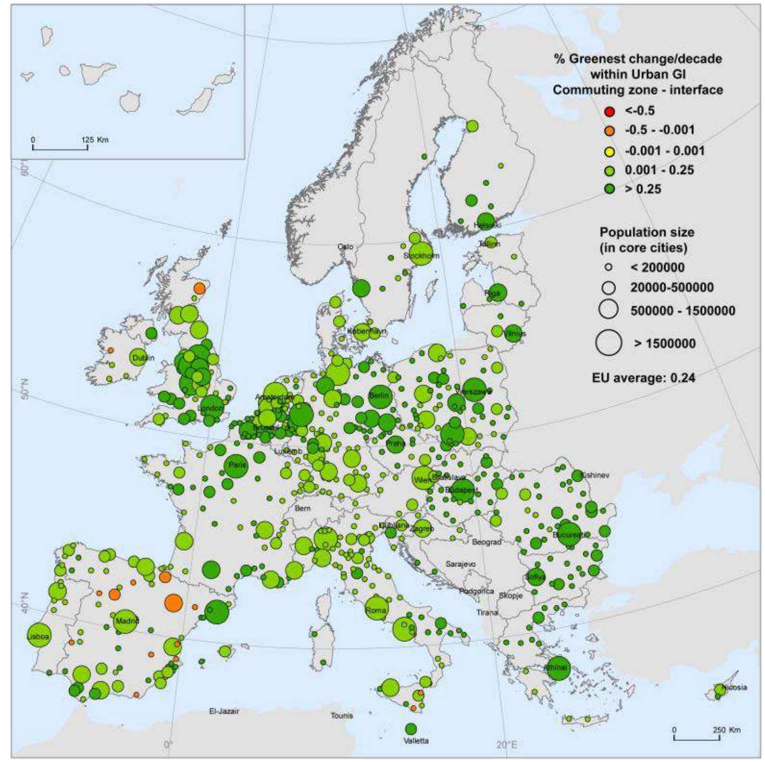


Figure 11: prevalent direction of change in European cities. Pie charts show the proportion of reporting units per class of change (%).

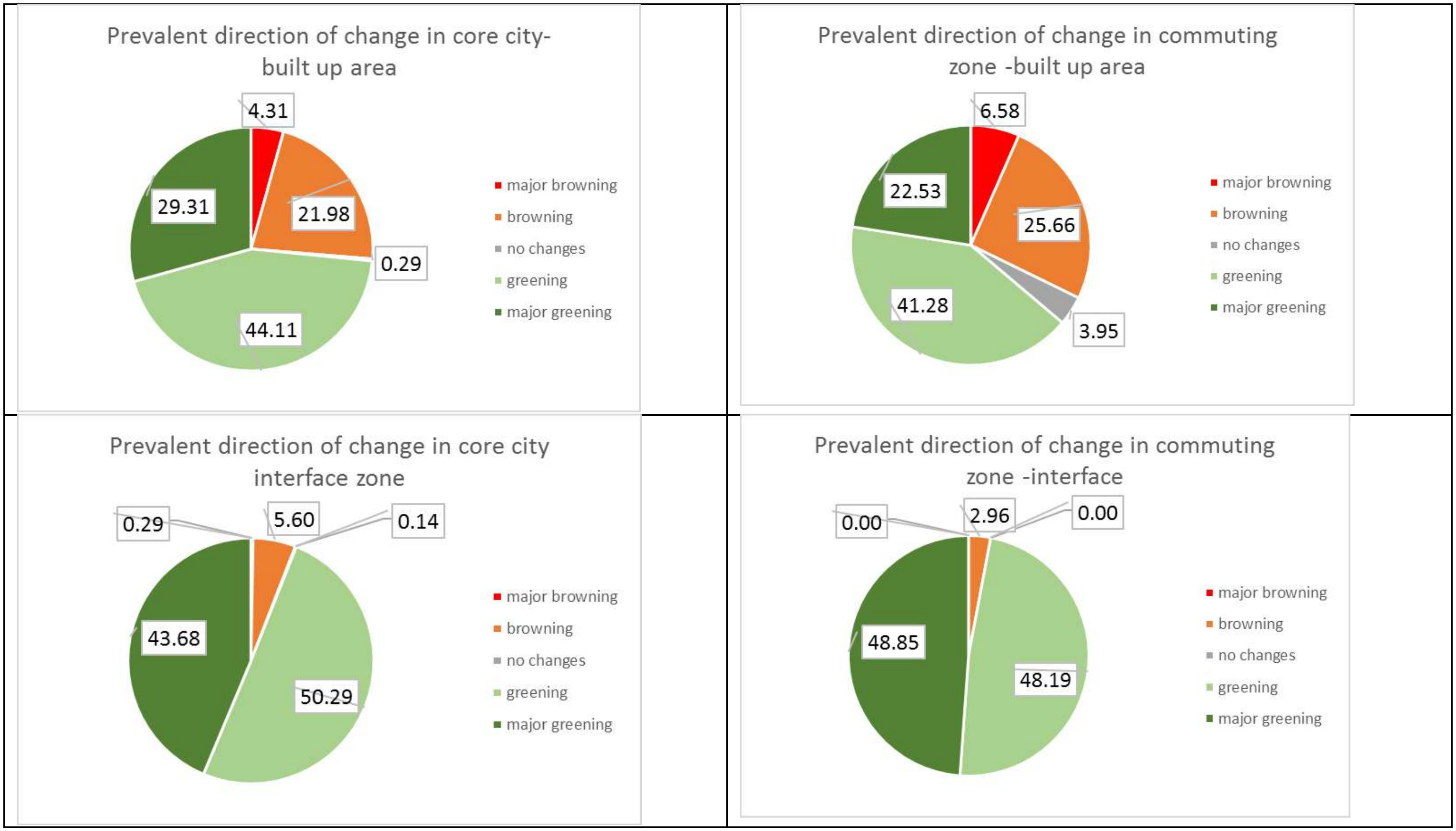
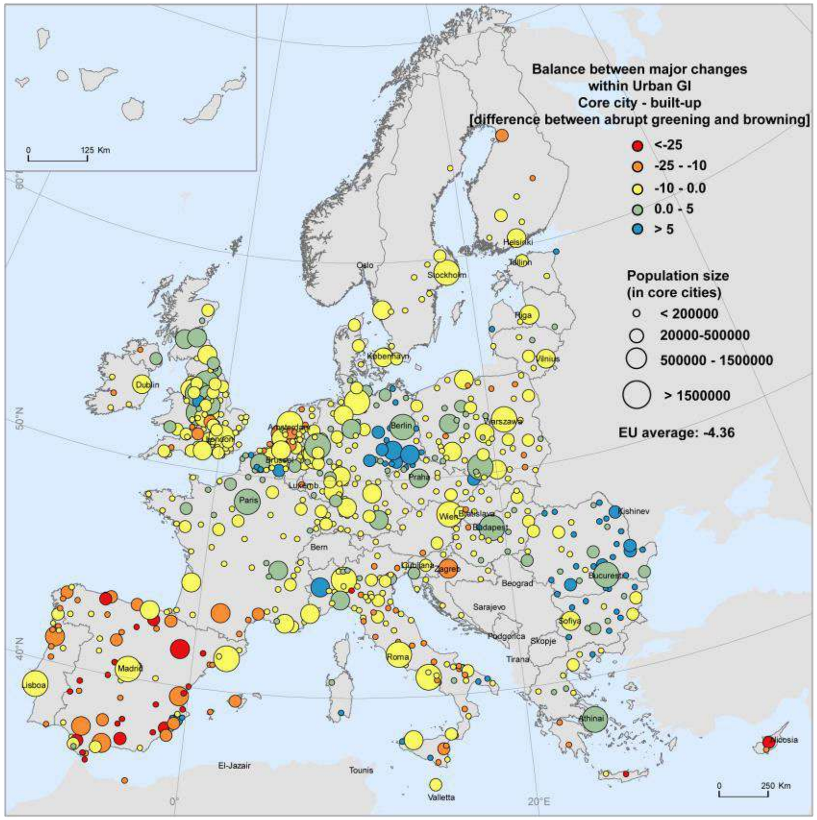


Figure 12: Balance between abrupt greening and browning changes within densely built areas in core cities and commuting zones.

A-Core Cities



B-Commuting zone

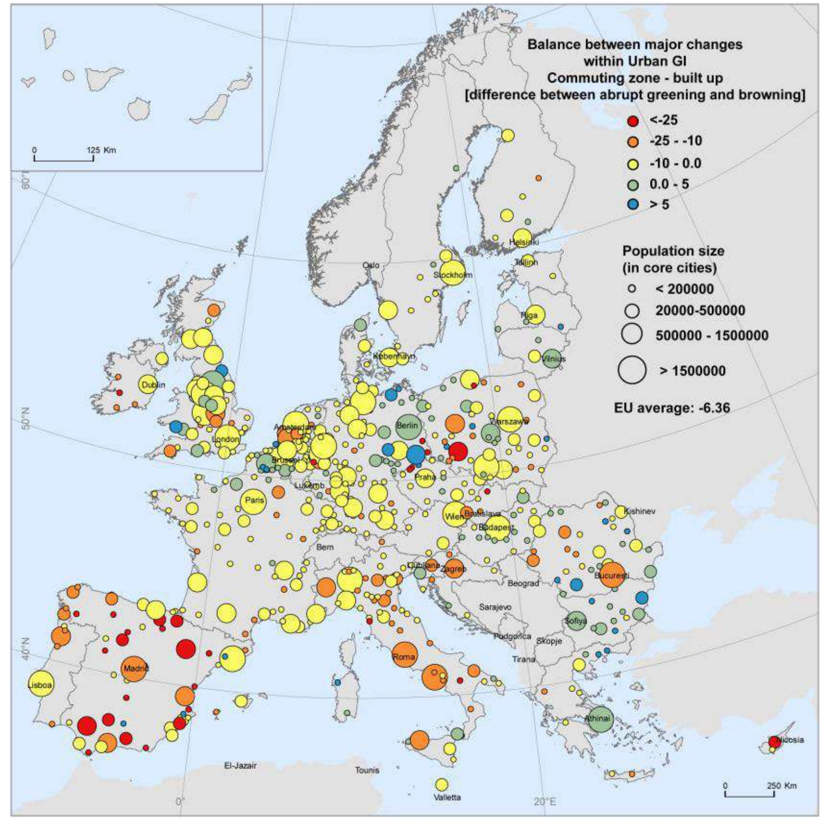
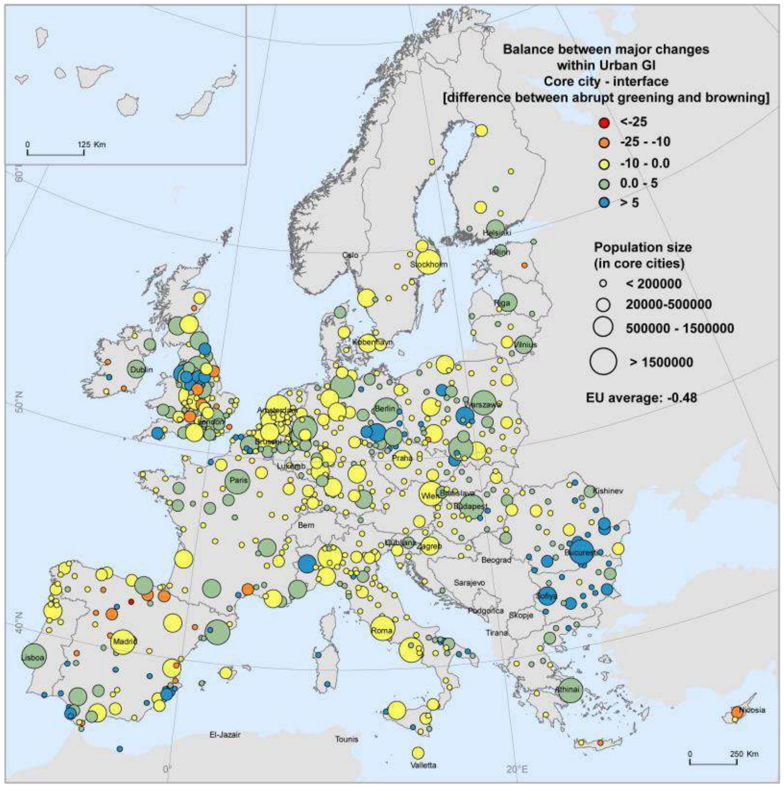
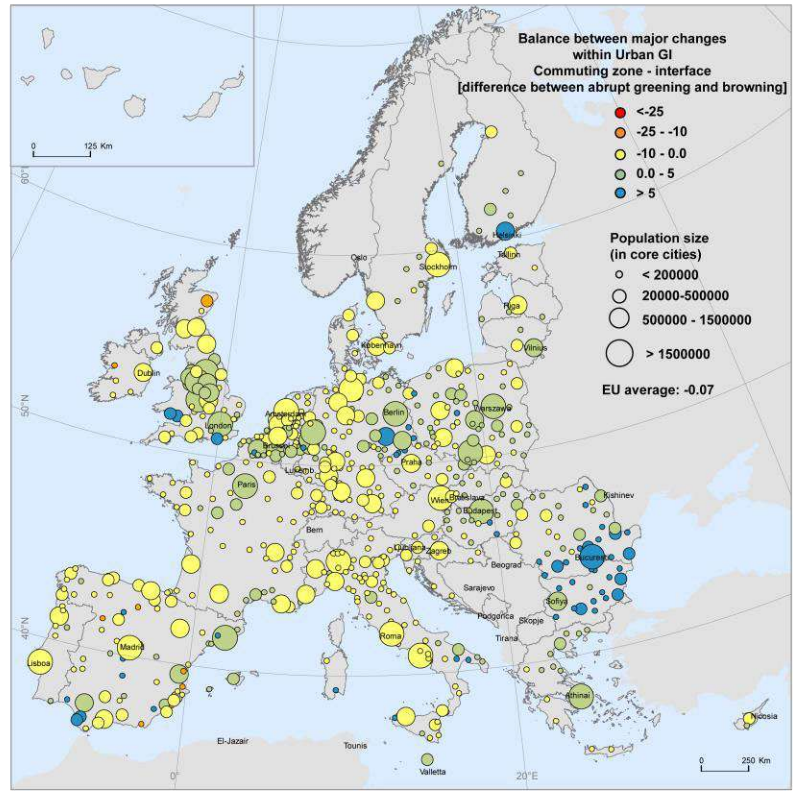


Figure 13: Balance between abrupt greening and browning changes within not densely built areas in core cities and commuting zones.

A-Core Cities



B-Commuting zone



References

Corbane C, Pesaresi M, Politis P, Florczyk J. A, Melchiorri M, Freire S, Schiavina M, Ehrlich D, Naumann G, Kemper T (2018) The grey-green divide: multi-temporal analysis of greenness across 10,000 urban centres derived from the Global Human Settlement Layer (GHSL). Int J Digit Earth 0(0): 1–18. doi: 10.1080/17538947.2018.1530311

Forkel M, Carvalhais N, Verbesselt J, Mahecha MD, Neigh CSR, Reichstein M (2013) Trend Change detection in NDVI time series: Effects of inter-annual variability and methodology. Remote Sens 5(5): 2113–2144. doi: 10.3390/rs5052113

Jin J, Gergel SE, Lu Y, Coops NC, Wang C (2019) Asian Cities are Greening While Some North American Cities are Browning: Long-Term Greenspace Patterns in 16 Cities of the Pan-Pacific Region. Ecosystems. doi: 10.1007/s10021-019-00409-2

Novillo C, Arrogante-Funes P, Romero-Calcerrada R (2019) Recent NDVI Trends in Mainland Spain: Land-Cover and Phytoclimatic-Type Implications. ISPRS Int J Geo-Information 8(1): 43. doi: 10.3390/ijgi8010043

Somarakis G, Stagakis S, Chrysoulakis N (2020) NATURE-BASED SOLUTIONS HANDBOOK.

Teferi E, Uhlenbrook S, Bewket W (2015) Inter-annual and seasonal trends of vegetation condition in the Upper Blue Nile (Abay) Basin: Dual-scale time series analysis. Earth Syst Dyn 6(2): 617–636. doi: 10.5194/esd-6-617-2015

Wang J, Zhou W, Qian Y, Li W, Han L (2018) Quantifying and characterizing the dynamics of urban greenspace at the patch level: A new approach using object-based image analysis. Remote Sens Environ 204(September 2017): 94–108. doi: 10.1016/j.rse.2017.10.039

Yu Z, Wang Y, Deng J, Shen Z, Wang K, Zhu J, Gan M (2017) Dynamics of Hierarchical Urban Green Space Patches and Implications for Management Policy.

Zhu Z, Fu Y, Woodcock CE, Olofsson P, Vogelmann JE, Holden C, Wang M, Dai S, Yu Y (2016) Including land cover change in analysis of greenness trends using all available Landsat 5, 7, and 8 images: A case study from Guangzhou, China (2000–2014). Remote Sens Environ 185: 243–257. doi: 10.1016/j.rse.2016.03.036

https://link.springer.com/article/10.1007/s10021-019-00409-2

Fact sheet 3.2.101: Land take

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Pressures - Habitat conversion and degradation (Land conversion)
- Name of the indicator: Land take
- Units: ha/year

2. Data sources

- Data holder, data source: EEA
- Weblink: https://tableau.discomap.eea.europa.eu/t/Landonline/views/Landtakeindicator/Landtakeandnetlandtakeindicator
- Year or time-series range: 2000 - 2018
- Access date: 01/07/2019
- Reference: https://www.eea.europa.eu/data-and-maps/indicators/land-take-2/assessment-1

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The main objective of this indicator is to measure the pressure from the development of urban and other artificial land use on natural and managed landscapes that are necessary 'to protect and restore the functioning of natural systems and halt the loss of biodiversity' (Sixth Environment Action Programme (6th EAP, COM(2001)31)).

Land use in Europe is driven by a number of factors such as the increasing demand for living space per person, the link between economic activity, increased mobility and the growth of transport infrastructure, which usually result in urban expansion.

The impact of urbanisation depends on the area of land taken and on the intensity of land use, for example, the degree of soil sealing and the population density. Land take by urban areas and infrastructure is generally irreversible and results in soil sealing, i.e. the loss of soil resources due to the covering of land for housing, roads or other construction work. Converted areas become highly specialised in terms of land use and support few functions related to socio-economic activities and housing. Urban land take consumes mostly agricultural land, but also reduces space for habitats and ecosystems that provide important services such as the regulation of the water balance and protection against floods, particularly if soil is highly sealed. Land occupied by man-made surfaces and dense infrastructure connects human settlements and fragments landscapes. It is also a significant source of water, soil and air pollution.

This indicator looks at the change in the amount (in ha per 6 years) of cropland and grassland taken by urban and other artificial land development. It includes areas sealed by construction and urban infrastructure, as well as urban green areas, and sport and leisure facilities. The main drivers of land take are grouped in processes resulting in the extension of:

- housing, services and recreation;
- industrial and commercial sites;
- transport networks and infrastructures;
- mines, quarries and waste dumpsites;

- construction sites.

3.2. Maps

The long-term change in the amount of croplands taken by artificial land use (Table 1, Figure 1, Figure 3) has increased at a rate higher than 5% in five countries and lower than 5% in 19 countries. The long-term change in the amount of grasslands (Table 2, Figure 2, Figure 4) taken by artificial land use has increased at a rate higher than 5% in nine countries and lower than 5% in 16 countries.

The short-term change in the amount of croplands taken by artificial land use has increased at a rate higher than 5% in six countries and lower than 5% in 19 countries. The short-term change in the amount of grasslands taken by artificial land use has increased at a rate higher than 5% in eight countries and lower than 5% in 16 countries.

Table 1 The amount of cropland taken in different periods, short-term and long-term changes.

	2000-2006	2006-2012	2012-2018	2000-2018	% change per 10 year (long-term change)	% change per 10 year (short-term change)
Austria	4450	3207	3386	10804	-13.28	4.65
Belgium	2273	2563	2291	6727	0.44	-8.84
Bulgaria	2520	2556	2403	7449	-2.58	-4.99
Croatia	2226	1136	1572	4937	-16.32	31.98
Cyprus	7697	2088	1389	11145	-45.53	-27.9
Czechia	8242	10353	5108	23040	-21.12	-42.22
Denmark	10277	8450	4397	22414	-31.79	-39.97
Estonia	1832	671	558	3022	-38.63	-14.03
Finland	2044	1332	710	4050	-36.26	-38.91
France	62150	60785	32602	152487	-26.41	-38.64
Germany	49489	26837	16402	91157	-37.14	-32.4
Greece	14299	9548	3780	26959	-40.87	-50.34
Hungary	12179	7501	5851	24235	-28.87	-18.33
Ireland	6607	366	634	7557	-50.22	61.02
Italy	45463	31916	10295	86548	-42.98	-56.45
Latvia	381	981	277	1619	-15.16	-59.8
Lithuania	2888	2862	698	6277	-42.13	-63.01
Luxembourg	67	263	400	716	276.12	43.41
Malta	-	-	87	87	-	0
Netherlands	21606	15022	5059	38368	-42.55	-55.27
Poland	14958	36458	32591	82666	65.49	-8.84
Portugal	11490	3420	1246	15865	-49.53	-52.97
Romania	6997	8773	12131	27838	40.76	31.9
Slovakia	3011	6039	3083	12045	1.33	-40.79
Slovenia	402	157	449	998	6.5	154.99
Spain	94480	71806	5852	168121	-52.11	-76.54
Sweden	5957	4069	1500	10887	-41.57	-52.61
United Kingdom	10115	8026	30847	46968	113.87	236.95
EU-28	**404100**	**327185**	**185598**	**894986**	**-45.06**	**-72.12**

Table 2 The amount of grassland taken in different periods, short-term and long-term changes.

	2000-2006	2006-2012	2012-2018	2000-2018	% change per 10 year (long-term change)	% change per 10 year (short-term change)
Austria	2240	814	1650	4696	-14.63	85.59
Belgium	252	483	427	1101	38.58	-9.66
Bulgaria	1140	1090	1071	3287	-3.36	-1.45
Croatia	2113	861	828	3763	-33.79	-3.19
Cyprus	775	87	156	1015	-44.37	66.09
Czechia	3690	1524	804	5407	-43.45	-39.37
Denmark	80	58	277	363	136.81	314.66
Estonia	416	1198	438	1966	2.94	-52.87
Finland	28	55		83	-55.56	-83.33
France	14215	15190	6492	34690	-30.18	-47.72
Germany	7756	9359	9644	24288	13.52	2.54
Greece	1959	2495	1503	5789	-12.93	-33.13
Hungary	2848	1546	1968	5468	-17.17	22.75
Ireland	12336	1974	1723	15906	-47.8	-10.6
Italy	1290	1437	561	3244	-31.4	-50.8
Latvia	286	914	633	1821	67.4	-25.62
Lithuania	366	420	1926	2631	236.79	298.81
Luxembourg	300	174	123	556	-32.78	-24.43
Malta	-	-	-	-	-	-
Netherlands	13509	7741	3110	23175	-42.77	-49.85
Poland	2218	7265	5526	14506	82.86	-19.95
Portugal	1270	654	318	2203	-41.64	-42.81
Romania	1244	2188	4037	7459	124.73	70.42
Slovakia	72	173	85	354	10.03	-42.39
Slovenia	18	6	14	38	-12.35	111.11
Spain	11585	23207	5324	34005	-30.02	-64.22
Sweden	835	206	80	1066	-50.23	-50.97
United Kingdom	11382	7743	19796	37367	41.07	129.72
EU-28	**94223**	**88862**	**68514**	**236247**	**-15.16**	**-38.16**

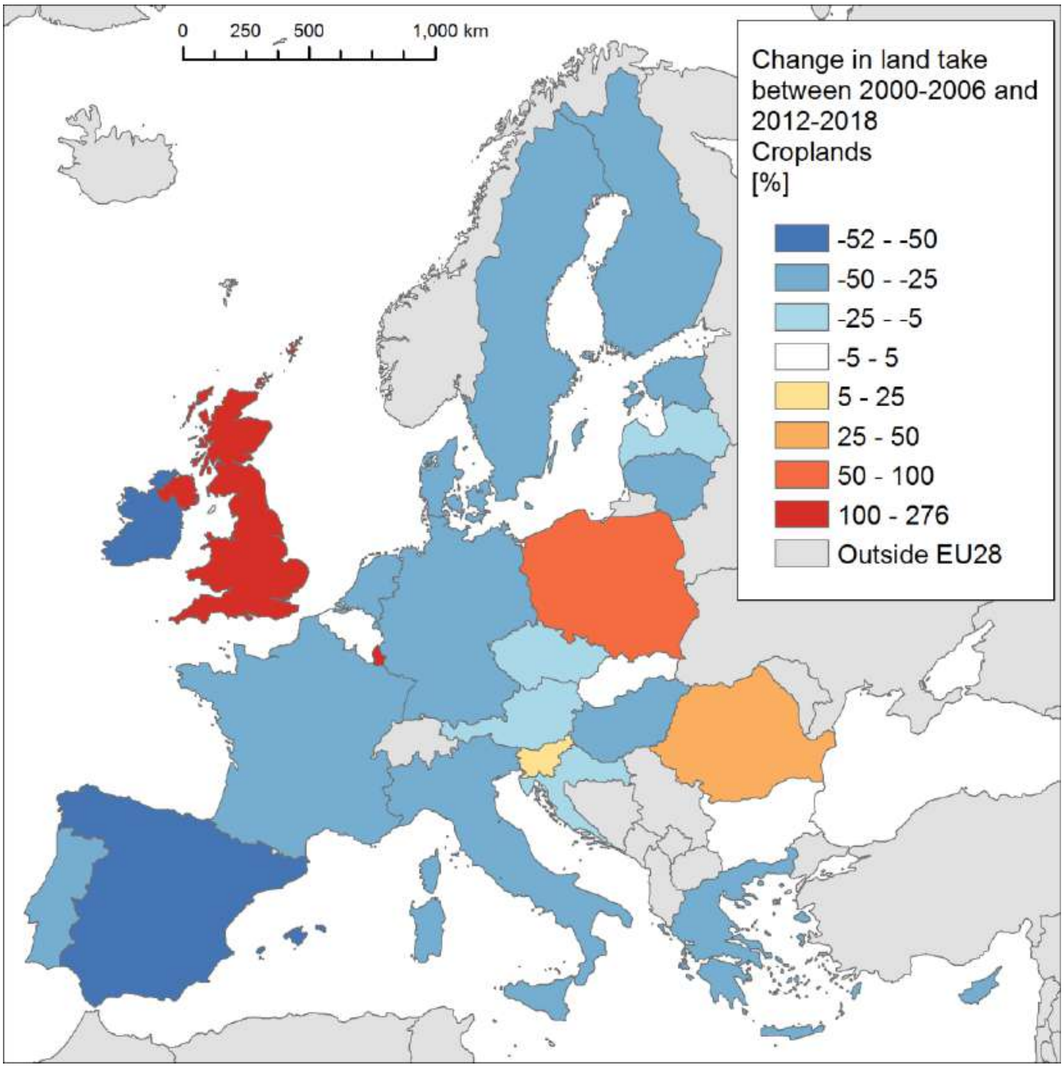


Figure 1 Percentage change in land take per 10 years for cropland, calculated from the change between 2012-2018 and 2000-2006.

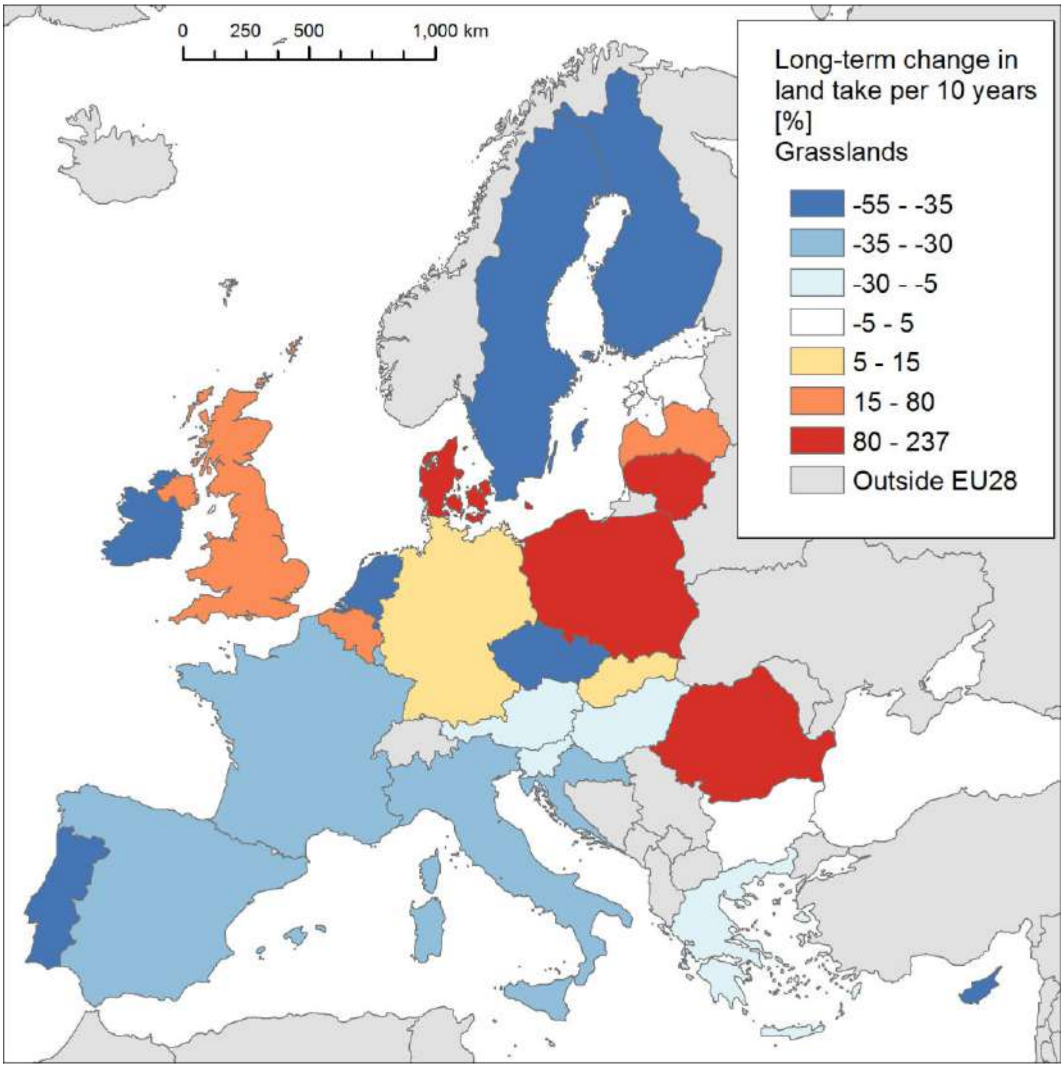


Figure 2 Percentage change in land take per 10 years for grassland, calculated from the change between 2012-2018 and 2000-2006.

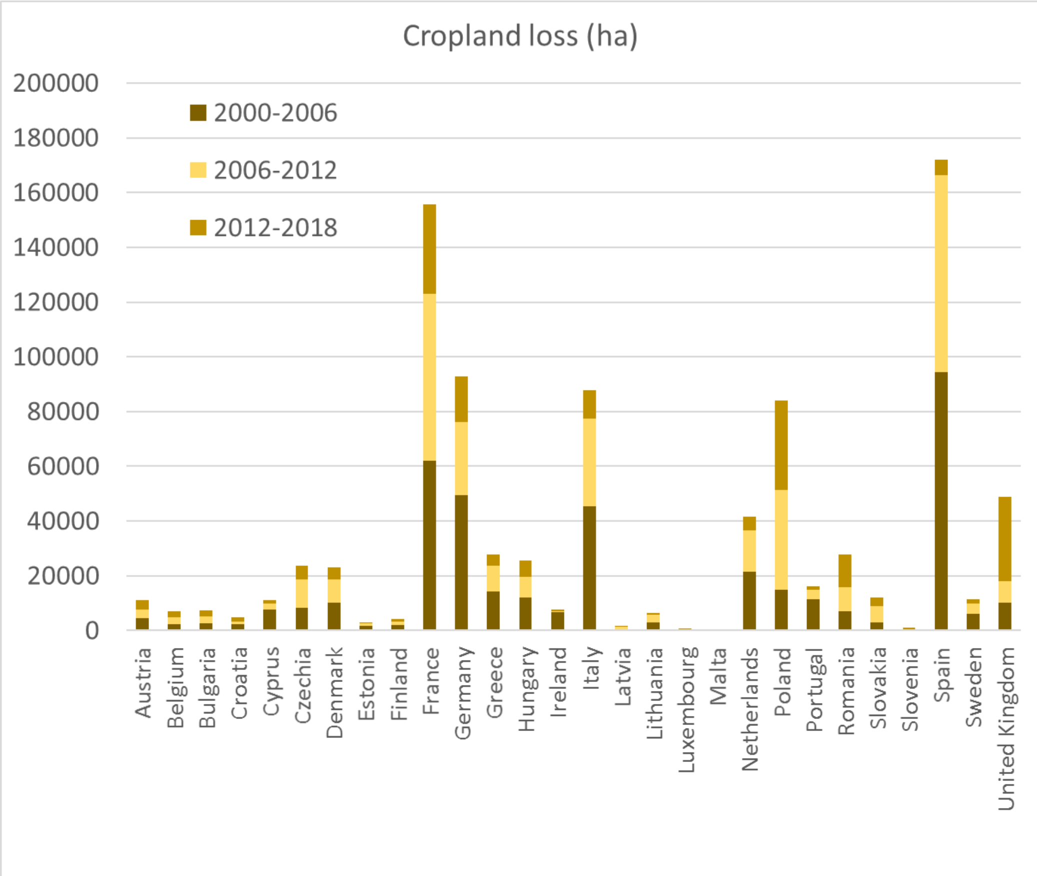


Figure 3 The amount of cropland (in hectares) taken in different periods

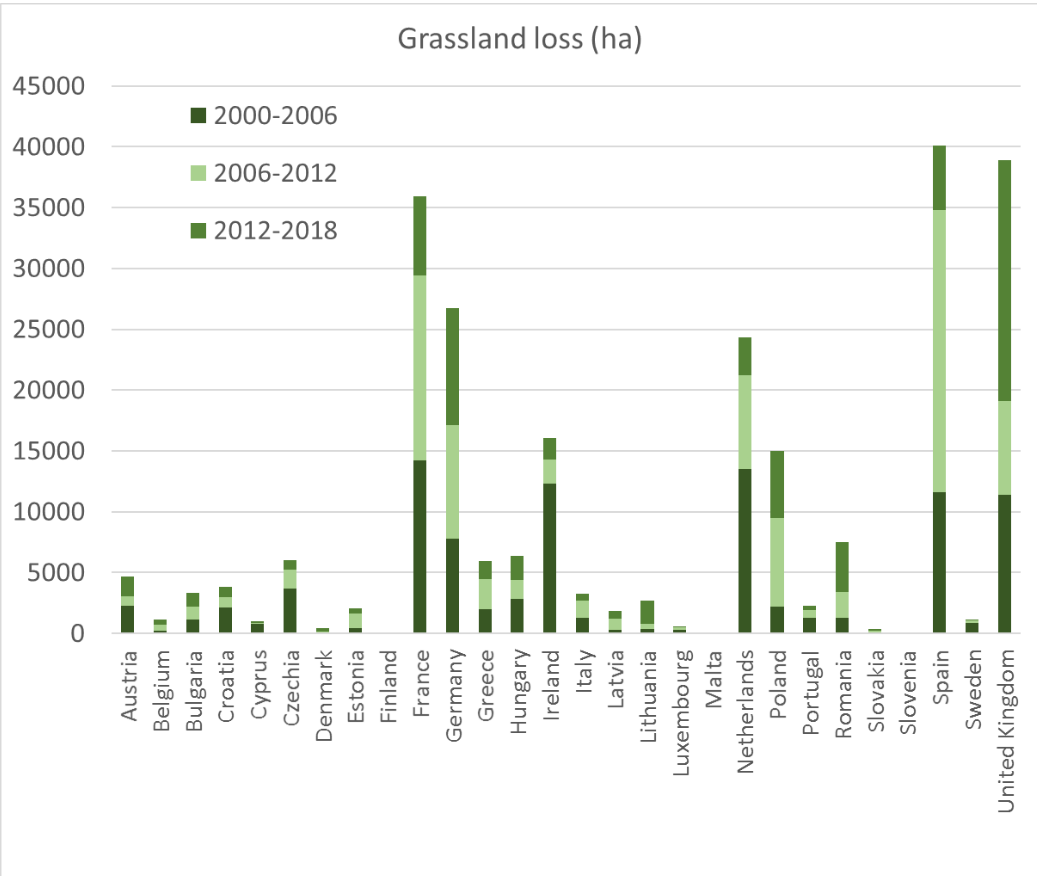


Figure 4 The amount of grassland (in hectares) taken in different periods

3.3 Statistical analysis of the trend

Change in land take was assessed comparing the amount of cropland and grassland taken in 2012-2018 (the last period with available data) and the periods of 2000-2006 and 2006-2012 corresponding to long-term and short-term change, respectively. The differences are expressed in percentage of the land taken in 2006-2012.

3.4. Key trend at EU level

There is a downward trend in land take both for croplands (Figure 1) and grasslands (Figure 2) at EU level, both in the long-term and in the short-term (Table 3).

Table 3 Land take at EU level in different periods and percentage changes.

Land take in the EU-28	2000-06	2006-12	2012-18	% change per 10 years (long-term)	% change per 10 years (short-term)
Cropland	404 100	327 185	185 598	-37.10	-36.06
Grassland	94 223	88 862	68 514	-16.073	-19.08
Grassland and cropland (ha)	498 323	416 047	254 112	-32.61	-32.44
Grassland and cropland (ha / year)	83 054	69 341	42 352		

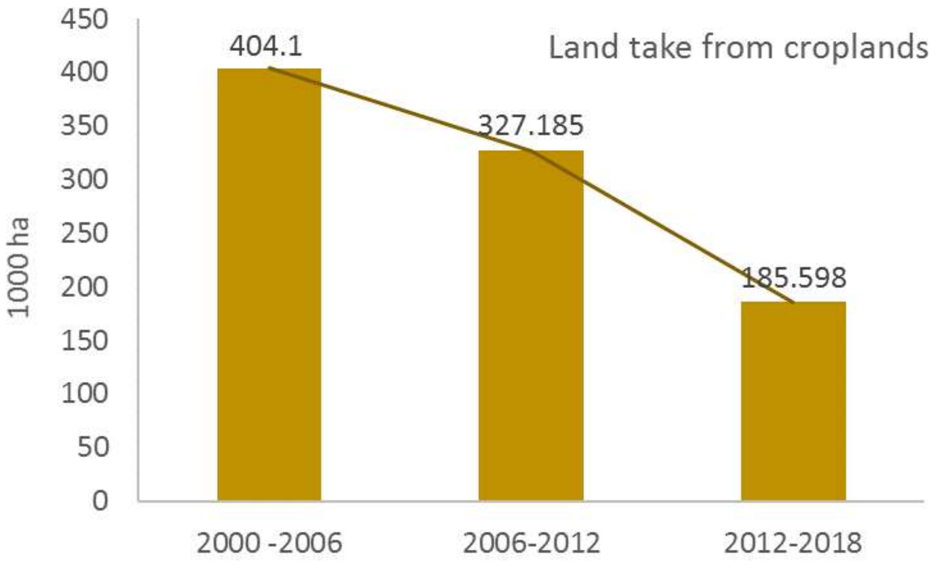


Figure 5 Land taken (in 1000 hectares in 6 years) from croplands by artificial land use.

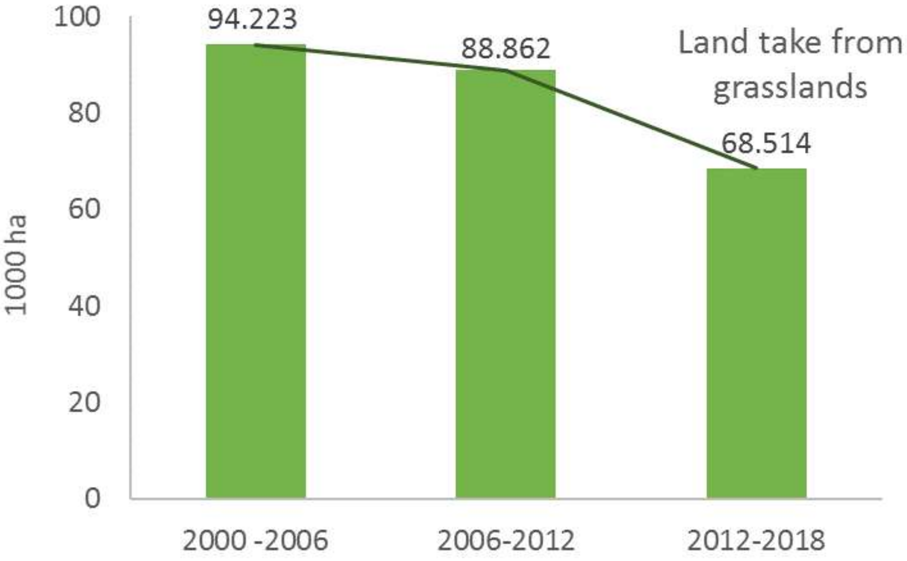


Figure 6 Land taken (in 1000 hectares in 6 years) from grasslands by artificial land use.

Fact sheet 3.2.102: Utilised agricultural area

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Pressures - Habitat conversion and degradation (Land conversion)
- Name of the indicator: Utilised agricultural area (UAA)
- Units: ha

2. Data sources

- Data holder: EUROSTAT
- Weblink: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpsh1&lang=en
- Year or time-series range: 2000 – 2016
- Access date: 10/04/2019
- Reference: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Utilised_agricultural_area_(UAA)

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Utilised agricultural area (UAA) is the total area taken up by arable land, permanent grassland, permanent crops and kitchen gardens used by the agricultural holdings, regardless of the type of tenure or of whether it is used as a part of common land.

3.2. Maps

The trend in utilized agricultural area is diverse among EU Member States. On the long-term (2000-2016) there is a downward trend in 19 Member States, upward trend in 7 Member States and no significant trend in two countries (Table 1). The UAA loss per decade in % of the 2010 baseline is highest in Italy, Austria and Poland (Figure 1, 13-16 %). The rate of the downward trend is higher than 100 000 ha per year in these countries (Figure 2). The UAA gain per decade is more than 10% in five countries (Baltic countries, Croatia, Greece). The rate of increase of UAA is the highest in Greece (Figure 2).

Figure 1 Decadal % change in utilized agricultural area compared to the 2010 baseline based on the trend in 2000-2016..

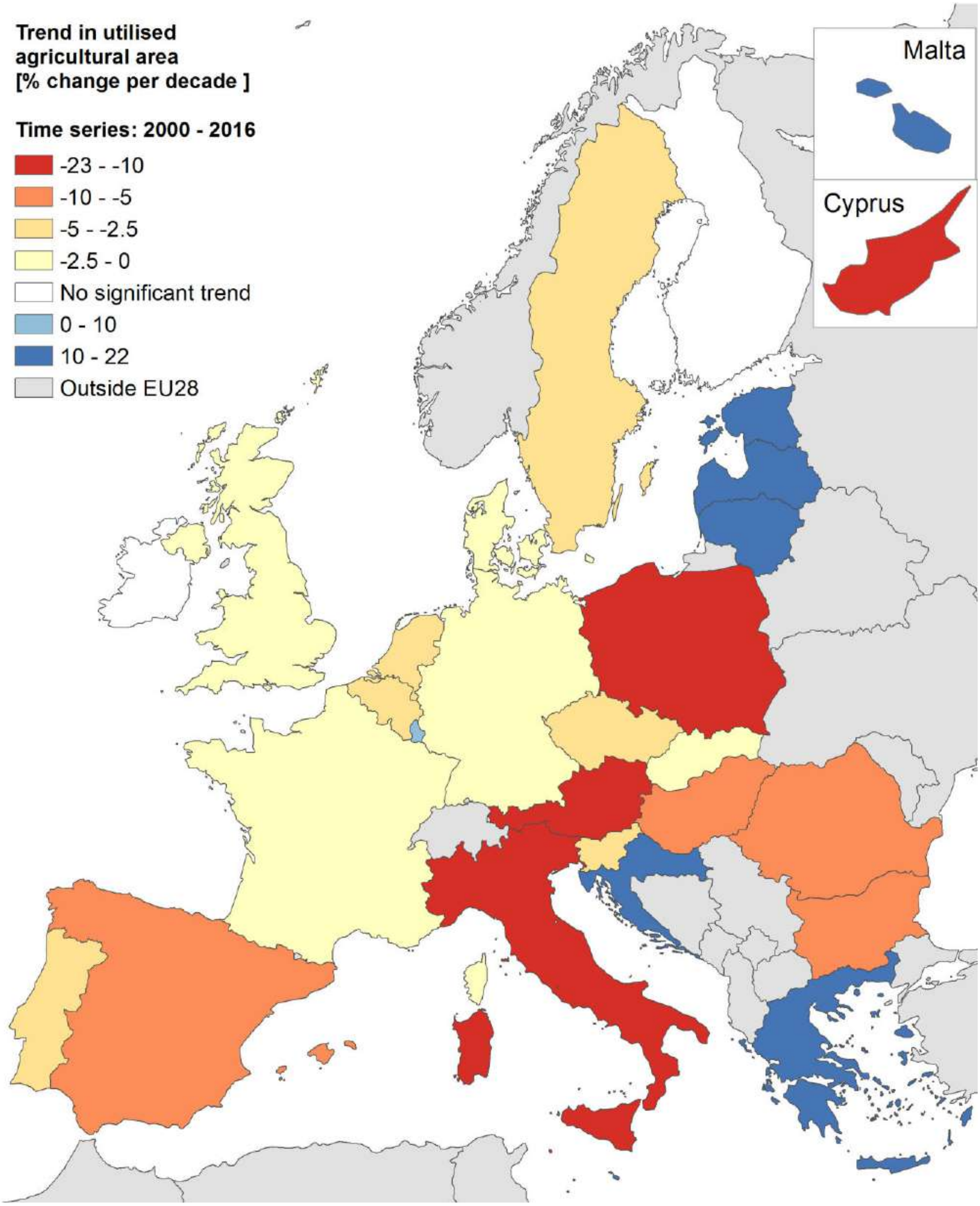


Figure 2 Slope of the long-term (2000-2016) trend in utilized agricultural area

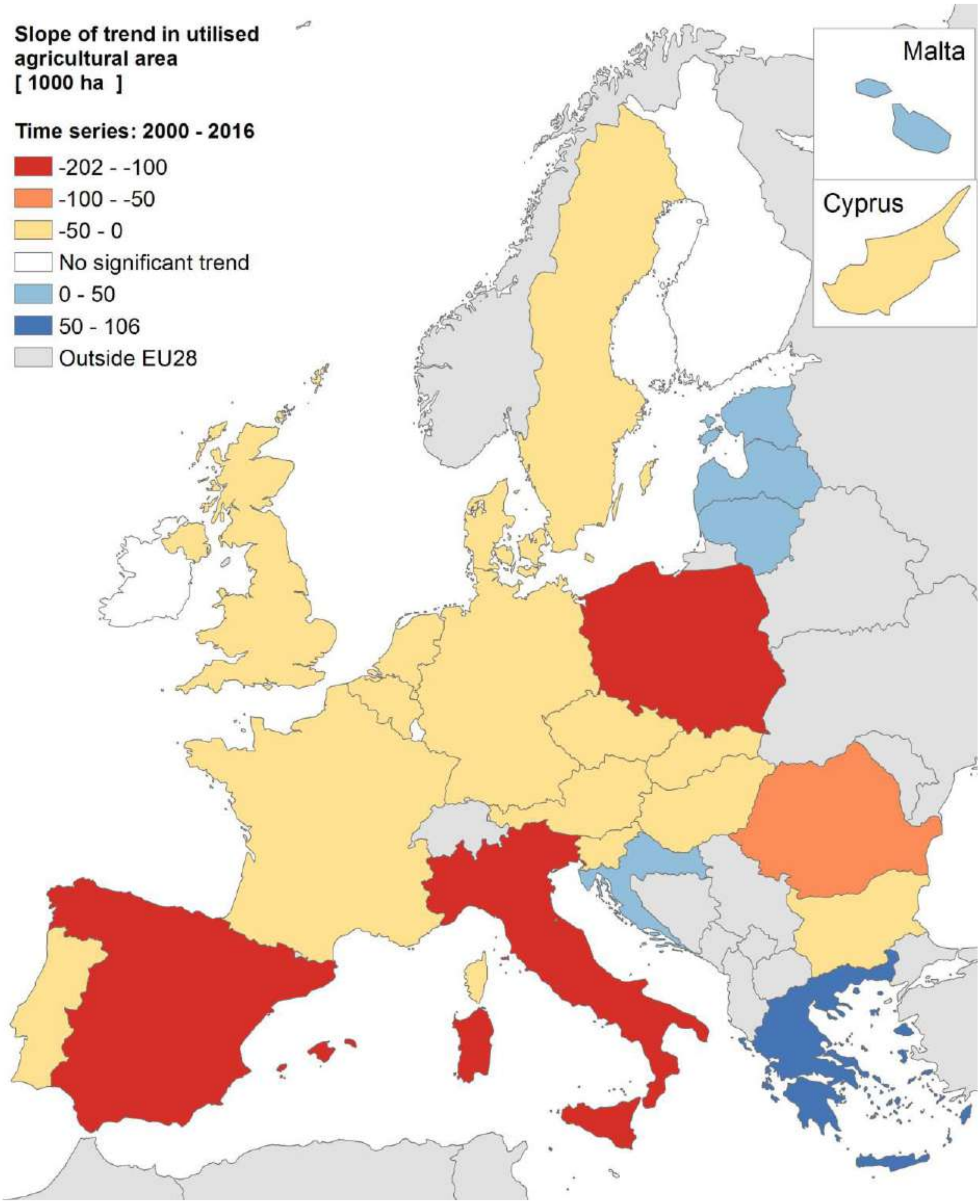


Table 1 Baseline values and trends in utilized agricultural area (UAA) at EU-28 level and in Member States.

Member State	Baseline UAA, 2010 [1000 ha]	Short-term slope [1000 ha / year]	% change per decade (based on the short-term trend, compared to the 2010 baseline)	Long-term slope [1000 ha / year]	% change per decade (based on the long-term trend, compared to the 2010 baseline)
EU-28	180136.81	-125.71	-0.96	-837.4	-4.64
BE	1358	-1.28	-2.61	-4.62*	-3.41
BG	5052	-13.31	-1.46	-30.87*	-6.11
CZ	3524	-5.17	-3.22	-14.03*	-3.95
DK	2676	-8.65*	0.07	-3.39*	-1.28
DE	16704	1.17	10.70	-26.67*	-1.59
EE	949	9.91*	-5.26	10.51*	11.23
IE	4569	-24.16*	-5.07	3.44	0.77
EL	5426	-27.65	1.33	105.71*	21.59
ES	23719	31.45	0.76	-133.39*	-5.53
FR	29311	22.01	6.41	-47.20*	-1.61
HR	1334	8.39	-0.18	15.17*	11.65
IT	12885	-2.33	-0.87	-201.92*	-15.67
CY	115	-0.10	9.90	-2.78*	-22.92
LV	1806	17.70*	15.71	21.74*	12.07
LT	2772	42.75*	-0.46	36.00*	12.94
LU	131	-0.06	0.28	0.22*	1.66
HU	5343	1.51*	2.28	-43.11*	-7.75
MT	11	0.03	-4.43	0.14*	12.40
NL	1872	-8.34*	-16.75	-8.95*	-4.78
AT	3166	-50.66*	-2.80	-46.64*	-15.54
PL	14603	-41.00*	1.48	-196.95*	-12.98
PT	3654	5.39	-5.23	-17.21*	-4.65
RO	14156	-74.22	-1.03	-70.67*	-5.03
SI	483	-0.50	-1.02	-2.29*	-4.70
SK	1922	-1.96	-1.37	-3.09*	-1.60
FI	2292	-3.15	-2.74	3.61	1.59
SE	3074	-8.44*	0.54	-8.39*	-2.73
UK	17231	9.33	-0.96	-38.53*	-2.22

***: significant trend at 0.05 level.**

3.3. Statistical analysis of the trend

The trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trends was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall 1975; Mann 1945).

3.4 Key trend at EU level

The UAA decreased by 6% between 2000 and 2016, it means a 4.6% decrease per 10 years, compared to the 2010 baseline value (Table 1 and Figure 1). The downward trend is statistically significant, the rate of decrease is -837.4 ha per year ($p<0.05$).

Based on the short-term trend (2010-2016) the relative change is 0.7 % decrease per 10 years. The trend is statistically not significant. So the downward trend has flattened in this decade compared to the long-term trend.

Table 2 Utilised agricultural area (UAA) in the EU-28 in 2000-2016. Data source: EUROSTAT.

Year	UAA (million ha)
2000	190.3
2001	190.0
2002	187.8
2003	186.5
2004	186.3
2005	NA
2006	185.8
2007	183.1
2008	182.8
2009	NA
2010	180.1
2011	179.4
2012	178.2
2013	178.1
2014	178.4
2015	179.0
2016	178.7

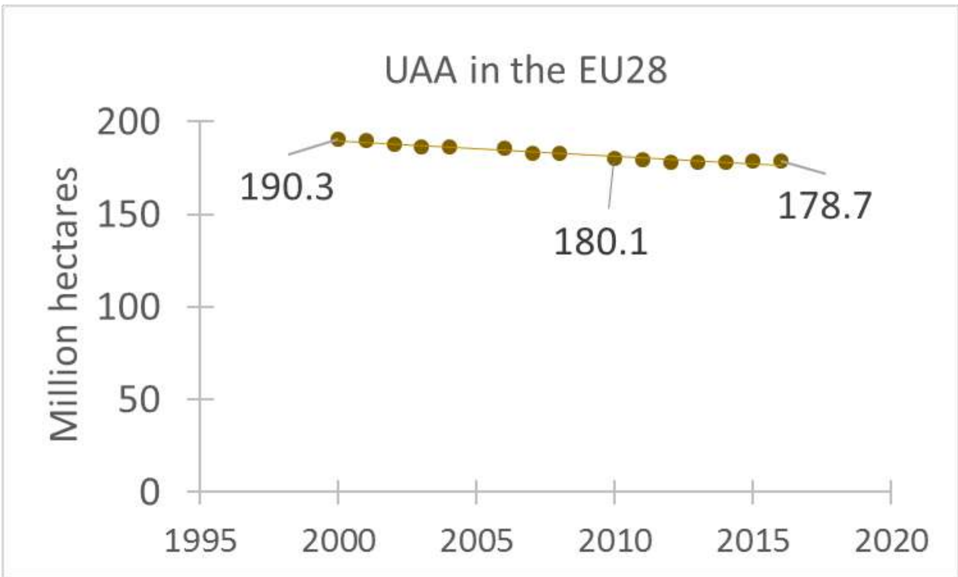


Figure 3 Utilised agricultural area (UAA) in the EU-28, 2000-2016. Data source: EUROSTAT.

Fact sheet 3.2.104: Ecosystem extent (cropland and grassland)

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class (See table 1): Habitat conversion and degradation
- Name of the indicator: Ecosystem extent
- Units: km^2

2. Data sources

- Data holder: EEA
- Weblink: https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics
- Years: 2000, 2006, 2012, 2018
- Access date: 30/09/2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The extent of croplands and grasslands was assessed based on the Corine Land Cover datasets.

3.2. Maps

The assessment was performed on data at EU level and Member State level. Maps were not produced.

The changes at Member State level were low. On the long term, all changes were below 1 % related to the 2010 baseline extent. The extent of cropland has increased by more than 1% but less than 5% in two countries (Latvia and Lithuania) on the short term. The extent of grassland has increased by more than 5% in Finland on the short term. All other short-term changes were below 1% (Table 1, Table 2 and Table 3).

Table 1 Extent of cropland (in 2000, 2006, 2012 and 2018) and its trends.

	Cropland 2000 [km^2]	Cropland 2006 [km^2]	Cropland 2012 [km^2]	Cropland 2018 [km^2]	Baseline 2010 [km^2]	Short-term trend (% change per decade)	Long-term trend (% change per decade)
Austria	19,831	19,789	19,758	19,725	19,768	-0.278	-0.003
Belgium	14,020	13,997	13,969	13,948	13,978	-0.250	-0.003
Bulgaria	53,270	53,254	53,258	53,407	53,257	0.466	0.001
Croatia	19,572	19,637	19,652	19,646	19,647	-0.051	0.002
Cyprus	4,468	4,422	4,401	4,386	4,408	-0.567	-0.010
Czechia	38,200	37,549	36,595	36,555	36,913	-0.181	-0.025
Denmark	31,568	31,456	31,380	31,312	31,405	-0.361	-0.005
Estonia	11,256	11,324	11,294	11,265	11,304	-0.428	0.000
Finland	27,447	27,892	27,854	27,983	27,867	0.772	0.011
France	239,840	239,282	238,804	238,551	238,963	-0.176	-0.003
Germany	140,586	140,294	140,334	140,186	140,321	-0.176	-0.002
Greece	50,120	49,944	49,853	49,810	49,883	-0.144	-0.003
Hungary	54,327	53,919	53,288	53,237	53,498	-0.159	-0.011
Ireland	9,173	9,036	8,841	8,759	8,906	-1.535	-0.026

Italy	152,805	152,376	152,100	152,015	152,192	-0.093	-0.003
Latvia	18,540	18,549	18,767	19,194	18,694	3.807	0.019
Lithuania	33,301	33,298	33,281	33,619	33,287	1.692	0.005
Luxembourg	963	964	962	958	963	-0.693	-0.003
Malta	164	164	164	163	164	-1.016	-0.003
Netherlands	14,419	14,159	13,959	13,870	14,026	-1.058	-0.022
Poland	156,676	156,376	155,822	155,394	156,007	-0.457	-0.005
Portugal	41,465	40,977	40,886	40,966	40,916	0.326	-0.007
Romania	109,117	109,092	108,966	109,107	109,008	0.216	0.000
Slovakia	20,543	20,506	20,440	20,402	20,462	-0.310	-0.004
Slovenia	5,885	5,881	5,880	5,873	5,880	-0.198	-0.001
Spain	231,339	230,888	230,229	230,425	230,449	0.142	-0.002
Sweden	37,242	37,168	37,124	37,117	37,139	-0.031	-0.002
United Kingdom	68,657	68,537	68,471	68,177	68,493	-0.715	-0.004

Table 2 Extent of grassland (in 2000, 2006, 2012 and 2018) and its trends.

	Grassland 2000 [km^2]	**Grassland 2006 [km^2]**	**Grassland 2012 [km^2]**	**Grassland 2018 [km^2]**	**Baseline 2010 km^{2}a]**	**Short-term trend (% change per decade)**	**Long-term trend (% change per decade)**
Austria	13,183	13,167	13,195	13,186	13,186	-0.114	0.000
Belgium	3,544	3,542	3,535	3,529	3,537	-0.283	-0.002
Bulgaria	8,239	8,219	8,173	7,974	8,188	-4.058	-0.018
Croatia	5,476	5,398	5,369	5,345	5,379	-0.745	-0.013
Cyprus	279	264	263	263	263	0.000	-0.032
Czechia	7,134	7,661	8,486	8,466	8,211	-0.393	0.104
Denmark	976	970	957	954	961	-0.522	-0.013
Estonia	3,518	3,413	3,382	3,383	3,392	0.049	-0.021
Finland	239	235	219	226	224	5.327	-0.030
France	97,775	97,553	97,298	97,187	97,383	-0.190	-0.003
Germany	66,790	66,560	66,161	66,102	66,294	-0.149	-0.006
Greece	11,160	11,177	11,138	11,156	11,151	0.269	0.000
Hungary	9,468	9,252	9,298	9,233	9,283	-1.165	-0.014
Ireland	39,151	38,898	38,937	38,856	38,924	-0.347	-0.004
Italy	11,854	11,802	11,771	11,747	11,781	-0.340	-0.005
Latvia	7,127	7,100	6,841	6,413	6,927	-10.427	-0.056
Lithuania	5,072	5,023	4,875	4,551	4,924	-11.077	-0.057
Luxembourg	412	407	406	406	406	0.000	-0.008
Malta	0	0	0	0	0	0.000	0.000
Netherlands	10,692	10,557	10,500	10,478	10,519	-0.349	-0.011
Poland	28,639	28,597	28,333	28,253	28,421	-0.471	-0.007
Portugal	3,661	3,607	3,596	3,536	3,600	-2.781	-0.019
Romania	32,285	32,228	32,183	31,972	32,198	-1.093	-0.005

Slovakia	3,006	2,976	2,963	2,955	2,967	-0.450	-0.009
Slovenia	1,266	1,265	1,265	1,266	1,265	0.132	0.000
Spain	46,203	46,109	45,937	45,896	45,994	-0.149	-0.004
Sweden	4,565	4,569	4,576	4,573	4,574	-0.109	0.001
United Kingdom	83,066	82,861	82,797	82,659	82,818	-0.278	-0.003

Table 3 2010 baseline and trends in extent of agroecosystems (cropland and grassland).

	Baseline 2010 (Cropland & Grassland) [km^2]	**Short-term trend (Cropland & Grassland) [km^2]**	**Long-term trend (Cropland & Grassland) [km^2]**
Austria	32,954	0.00	-0.17
Belgium	17,516	-0.07	-0.28
Bulgaria	61,445	-0.03	-0.12
Croatia	25,026	-0.02	-0.13
Cyprus	4,671	-0.17	-1.17
Czechia	45,124	-0.11	-0.39
Denmark	32,367	-0.10	-0.48
Estonia	14,696	-0.15	-0.48
Finland	28,091	-0.07	1.03
France	336,346	-0.08	-0.31
Germany	206,615	-0.06	-0.29
Greece	61,034	-0.08	-0.29
Hungary	62,781	-0.35	-1.17
Ireland	47,830	-0.12	-0.82
Italy	163,973	-0.07	-0.30
Latvia	25,622	-0.06	-0.13
Lithuania	38,211	-0.16	-0.30
Luxembourg	1,369	-0.08	-0.45
Malta	164	-1.02	0.00
Netherlands	24,545	-0.39	-1.73
Poland	184,428	-0.16	-0.50
Portugal	44,516	-0.08	-0.78
Romania	141,206	-0.04	-0.13
Slovakia	23,429	-0.12	-0.46
Slovenia	7,145	-0.01	-0.09
Spain	276,443	-0.11	-0.25
Sweden	41,712	-0.03	-0.16
United Kingdom	151,311	-0.03	-0.33

3.3. Statistical analysis of the trend

Percentage changes were calculated based on the first and last value of the dataset. The short term trend (expressed as % change per decade) is based on the data 2012 and 2018. The long term trend is based on the data series between 2000 and 2018.

3.4. Key trend at EU level

The change in the extent of croplands and grasslands, based on the Corine land cover data, was below 1% so less than 5 % both in the short term and in the long term (Table 4).

Table 4

	2000 [km^2]	**2006 [km^2]**	**2012 [km^2]**	**2018 [km^2]**	**Baseline 2010 [km^2]**	**short-term trend (% change per decade)**	**long-term trend (% change per decade)**
Cropland	1,604,793	1,600,732	1,596,331	1,596,051	1,597,798	-0.029	-0.003
Grassland	504,778	503,411	502,454	500,566	502,773	-0.626	-0.464
Cropland and Grassland	**2,109,571**	2,104,143	**2,098,785**	2,096,617	2,100,571	-0.094	-0.343

Fact sheet 3.2.105: Heat degree days

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Climate change
- Name of the indicator: heat degree days
- Units: degree days (cumulated heat above 30 °C)

2. Data sources

- **Data source: MARS database**
- Data holder: European commission, Joint Research Centre (JRC)
- Weblink: https://agri4cast.jrc.ec.europa.eu/DataPortal/
- Time-series range: 1985 – 2018
- Access date: 20/05/2019

The MARS meteorological database contains gridded meteorological data on maximum air temperature (°C), minimum air temperature (°C), mean air temperature (°C), mean daily wind speed at 10m (m/s), vapour pressure (hPa), sum of precipitation (mm/day), potential evaporation from a free water surface (mm/day), potential evapotranspiration from a crop canopy (mm/day), potential evaporation from a moist bare soil surface (mm/day), total global radiation (KJ/m2/day), snow depth. The parameters are interpolated from weather station data on a 25 x 25 km grid. The data is available on a daily basis from 1975 up to near real time, covering the EU Member States, neighbouring European countries and the Mediterranean countries. In the present assessment the MARS data series starting from 1985 is used to avoid potential inhomogeneities that can lead to uncertainties in the trend analysis.

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Heat degree days is the cumulated degrees/heat above 30 °C. It is an indicator of heat stress. The base temperature of 30°C is widely used in the agricultural domain, it is considered a threshold above which crops experience heat stress in Europe.

3.2. Statistical analysis of the trend

Temporal trends were calculated at EU level and at grid cell level covering the whole terrestrial domain of the EU. Trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trend was tested with

3.3. Maps

The indicator of heat degree days shows a general and clear upward trend in the territory of the EU. The rate of change ranges from -190 to 406 heat degree days. The increase is most pronounced in Central, Eastern, and South-Eastern Europe and in some areas of Northern and Southern Europe.

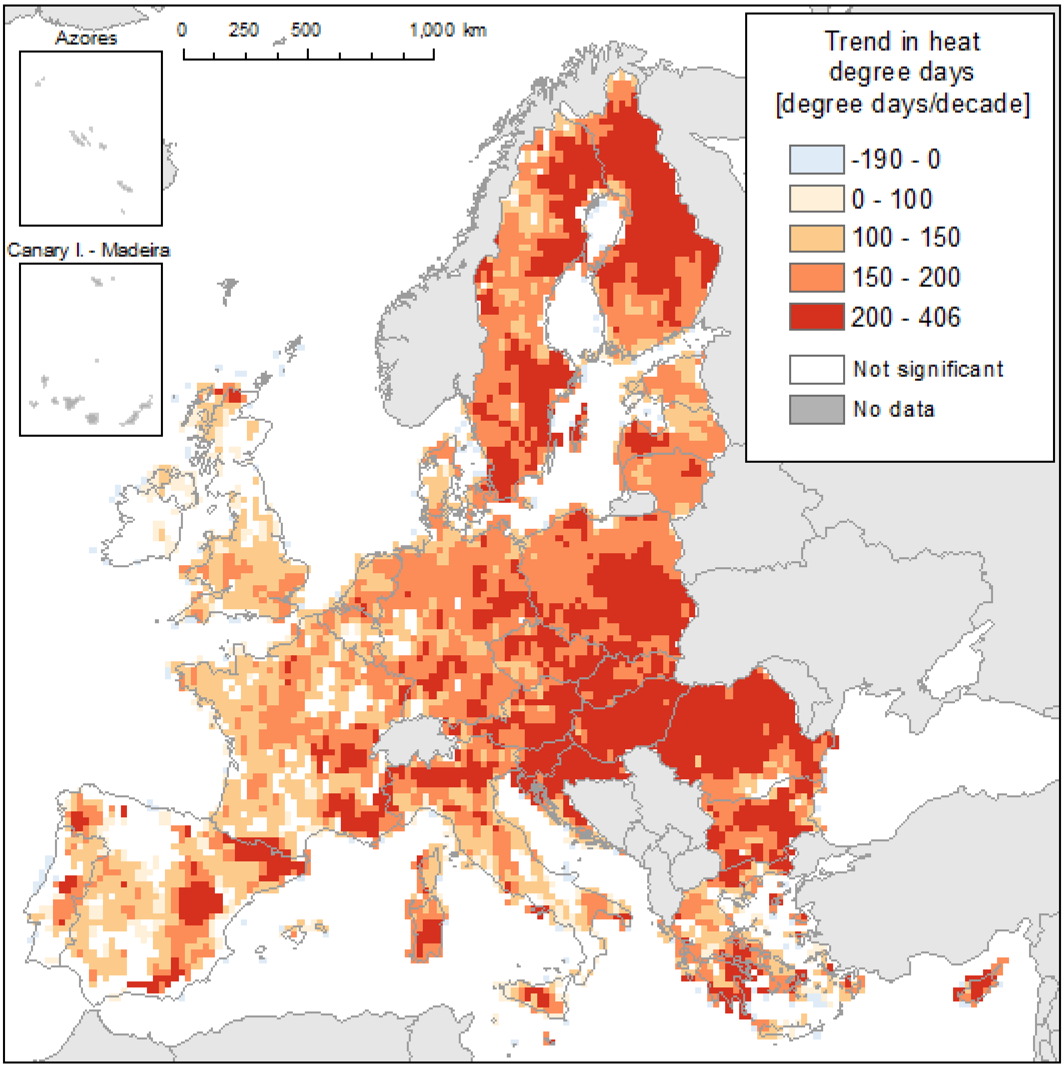


Figure 1 Trend in heat degree days in the period 1985-2018 in the EU.

3.4. Key trend at EU level

There was a significant upward trend in heat degree days in 1985-2018 (Figure 2, p-value = 4.868e-05). The rate of change is 17.70 degree days per year or 177.03 degree days per decade.

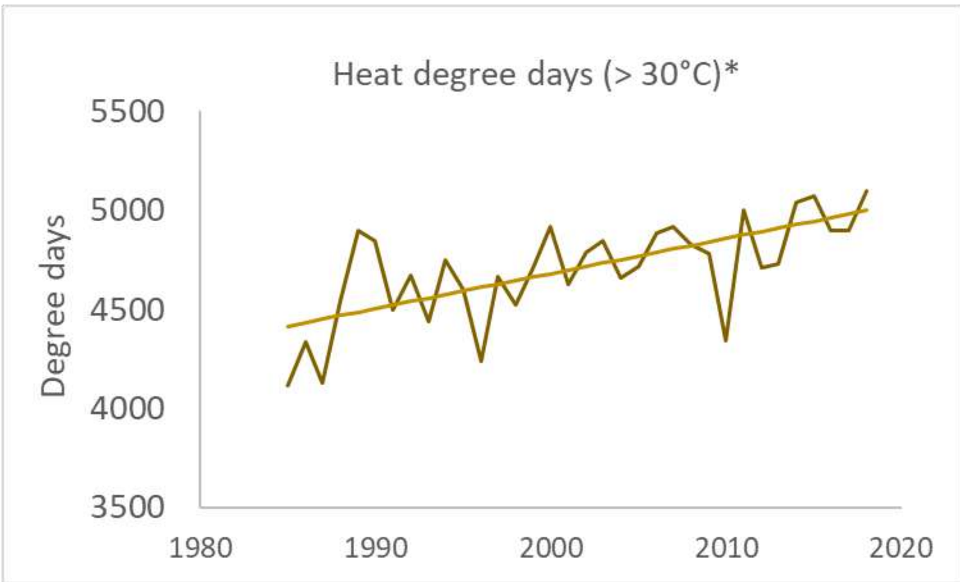


Figure 2 Time series and trend in heat degree days. Trend line computed using the Theil–Sen estimator. * Significant at 5% according to Mann-Kendall trend test.

Fact sheet 3.2.106: Frost-free days

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class (See table 1): Climate change
- Name of the indicator: Frost free days
- Units: number of days (with Tmin > 0°C)

2. Data sources

- Database: MARS
- Data holder: European commission, Joint Research Centre (JRC)
- Weblink: https://agri4cast.jrc.ec.europa.eu/DataPortal/
- Time-series range: 1985 – 2018
- Access date: 20/05/2019

The MARS meteorological database contains gridded meteorological data on maximum air temperature (°C), minimum air temperature (°C), mean air temperature (°C), mean daily wind speed at 10m (m/s), vapour pressure (hPa), sum of precipitation (mm/day), potential evaporation from a free water surface (mm/day), potential evapotranspiration from a crop canopy (mm/day), potential evaporation from a moist bare soil surface (mm/day), total global radiation (KJ/m2/day), snow depth. The parameters are interpolated from weather station data on a 25 x 25 km grid. The data is available on a daily basis from 1975 up to near real time, covering the EU Member States, neighbouring European countries and the Mediterranean countries. In the present assessment the MARS data series starting from 1985 is used to avoid potential inhomogeneities that can lead to uncertainties in the trend analysis.

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The duration of the frost free period is considered the most favourable period for plant growth. The increase in number of frost-free days indicates warming of the climate.

3.2. Statistical analysis of the trend

Temporal trends were calculated at EU level and at grid cell level covering the whole terrestrial domain of the EU. Trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trend was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall 1975; Mann 1945).

3.3. Maps

The number of frost-free days shows a general and clear upward trend in the territory of the EU, ranging between -16 and 33 days per 10 years. The negative changes may be resulted due to inconsistencies in the database. The increase in number of frost-free days is most pronounced in Central, Eastern and Northern Europe but also in some Southern European areas.

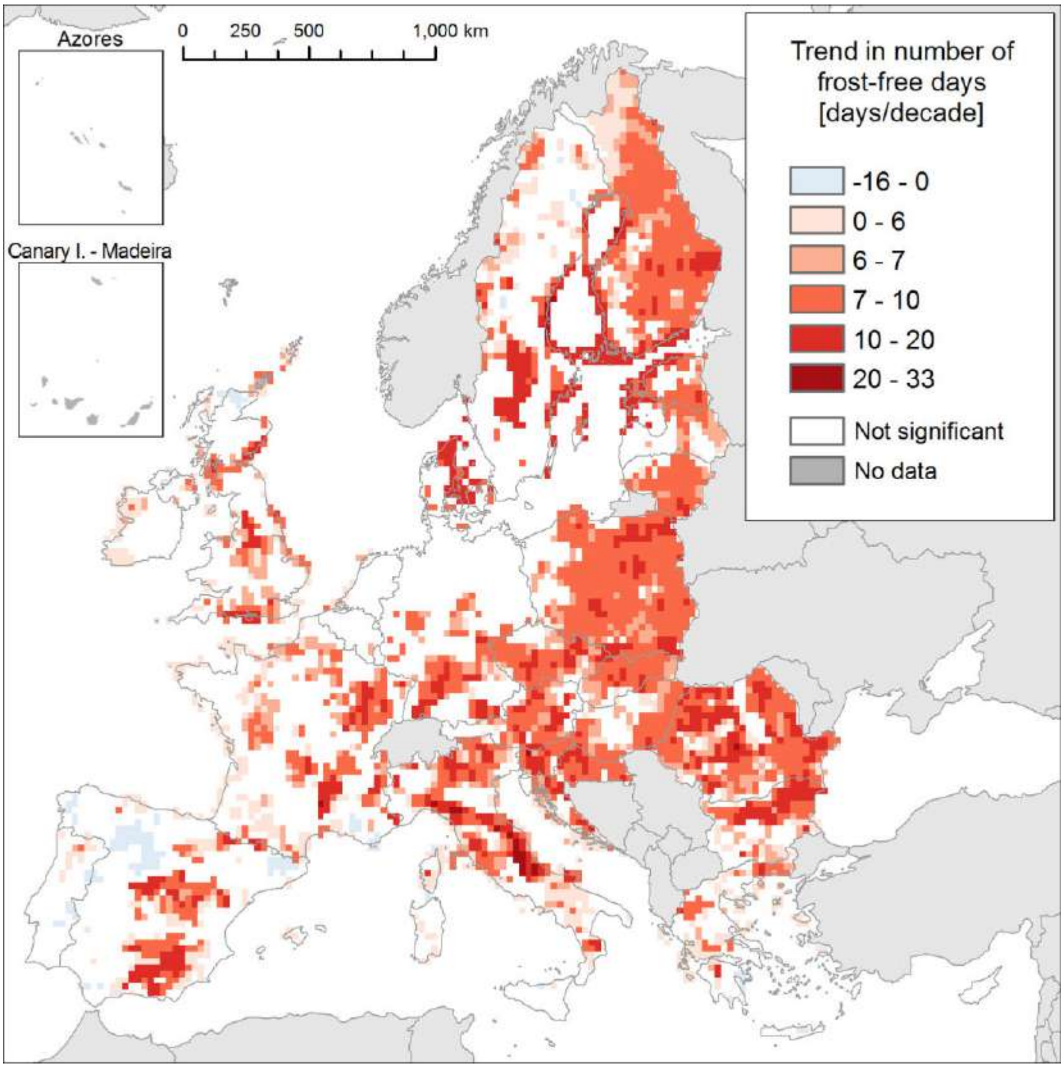


Figure 1 Trend in number of frost-free days in the period 1985-2018 in the EU.

3.4. Key trend at EU level

There was a statistically significant upward trend in frost-free days in 1985-2018. The rate of change is 0.54 days per year or 5.4 days per 10 years.

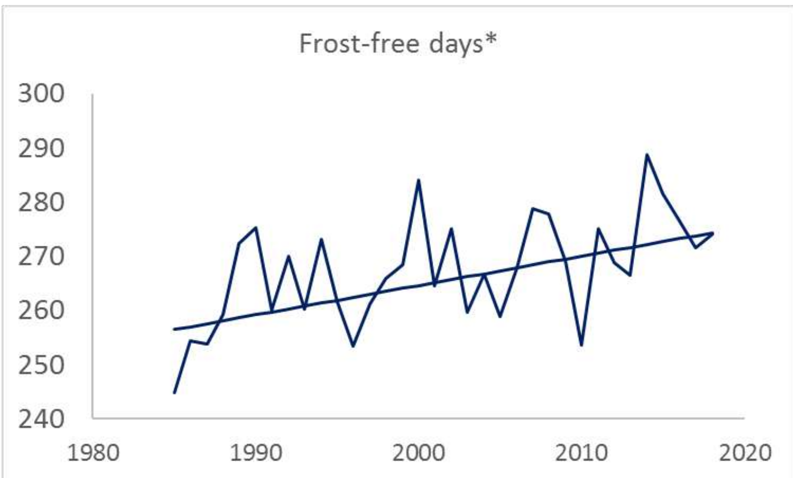


Figure 2 Time series and trend in number of frost-free days. Trend line computed using the Theil–Sen estimator. * Significant at 5% according to Mann-Kendall trend test.

Fact sheet 3.2.106: Spatial assessment of trends of exceedances of critical loads for acidification

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: pressure
- Name of the indicator: Exceedances of critical loads for acidification
- Units: equivalents ha^{-1} $year^{-1}$

2. Data sources

- Data holder: European Monitoring and Evaluation Programme
- data source:
- Year or time-series range: 2000-2005-2010-2016
- Access date--- 17/10/2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Pollutants causing acidification and eutrophication originate mainly from anthropogenic emissions of Sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3). SO_2 and NO_x are emitted into the atmosphere primarily as a result of combustion of fossil fuels, whilst agricultural and husbandry activities are the major source of NH_3 emissions, related to manure storage, spreading of fertilizer, and livestock deposition.

Once emitted, these pollutants may remain in the atmosphere for several days and transported over long distances by winds. Therefore, they can impact areas far from the emission source. Acidifying pollutants are removed from the atmosphere by wet deposition (commonly referred to as "acid rain") or dry deposition, i.e. direct uptake by vegetation and surfaces deposition. Acid deposition can damage terrestrial and water ecosystem by altering the pH and negatively affect soil and water biodiversity. They can also damage building by corrosion.

European critical loads for acidifying depositions have been established (Hettelingh et al., 2017) i.e. quantities of deposited compounds below which these phenomena are negligible. The indicator used here is the *exceedance* of the deposition compared to the established critical load on a 25x25 Km grid, on agroecosystems. Any value >0 is thus a net pressure on ecosystems.

3.2. Statistical analysis of the trend

The trend was analyzed by calculating the ten-year change (%) of exceedances over the long (2000-2016) and short term (2010-2016) trend per each 25 Km cell. Increases >5% and decreases < -5% were assessed respectively as “improvement” and “degradation”, whilst any change between -5% and 5% was assessed as “No change”.

3.3. Key trend at EU level

The trend at EU level is a marked decrease of the exceedances of critical loads causing acidification over the period 2000-2016 (Table 1). The average value dropped from 232.6 equivalent ha^{-1} $year^{-1}$ in 2000 to 70.6 in 2016.

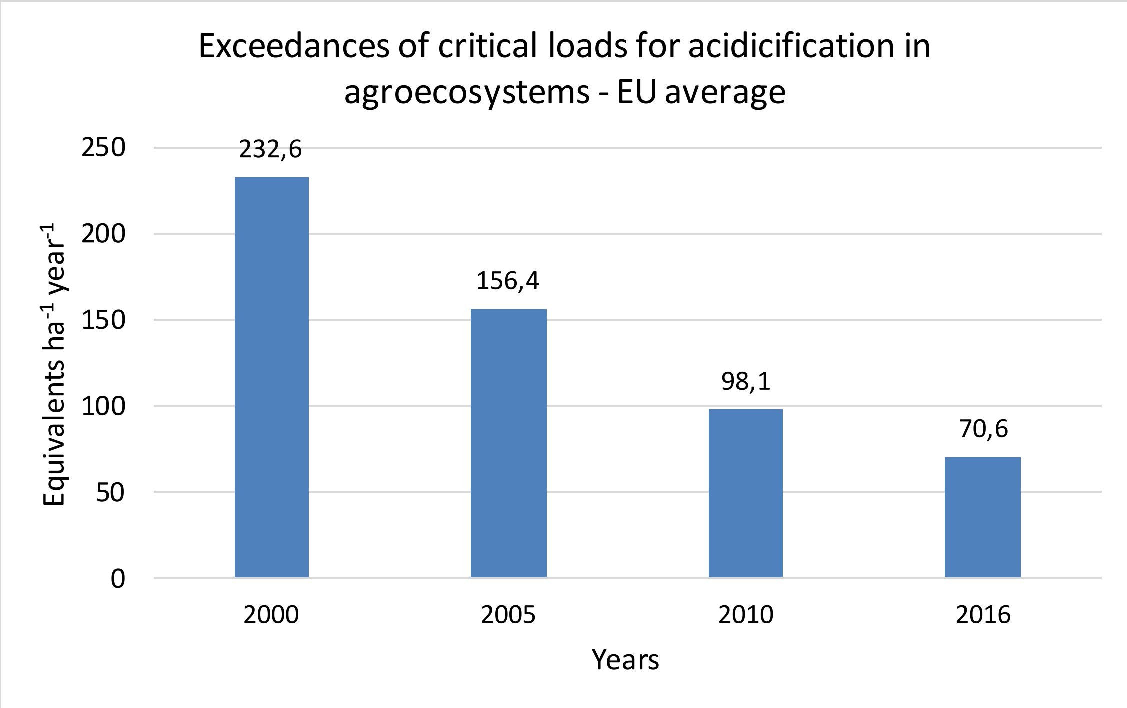


Figure 1: EU trend of the exceedances of critical load of Nitrogen deposition for acidification.

This represents a 10-years decrease of this pressure of about 77% in the long term and 47% in the short term with reference to the 2010 value. It is worth noting again, however, that the values reported in Figure 1 are not absolute values of pollutants deposition contributing to acidification, but represent already the exceedance above the critical loads defined for different ecosystems. Furthermore, the decrease is not uniform across Europe, as shown in the next subsection. Therefore, as the EMEP report points out, "Overall, the trends […] point in the 'right' direction, but a lot remains to be done in terms of emission reductions to achieve non-exceedance of critical loads everywhere." (EMEP 2018, pag. 36).

3.4. Maps

Figure 2 shows the value of exceedances in 2000, 2005, 2010 and 2016 in agroecosystems across Europe, mapped on 25x25 km grid. In 2000, virtually the entire territory of Denmark, Germany, Poland, Czech Republic, Benelux and England had very high exceedance, and many other areas in Europe were affected. In 2016, the situation has improved in all EU Member States (see also Figure 3), but critical loads are still largely exceeded in large areas in Germany, the Netherlands, Poland, Czech Republic, England.

Figure 3 shows the long and short-term trends, calculated as a 10-years percentage change with reference to the 2010 value. No degradation is recorded in the long term, but the trend is not always monotone and the short-term map shows that in some areas (mainly Northern Germany, Denmark and British islands), the pressure has increased.

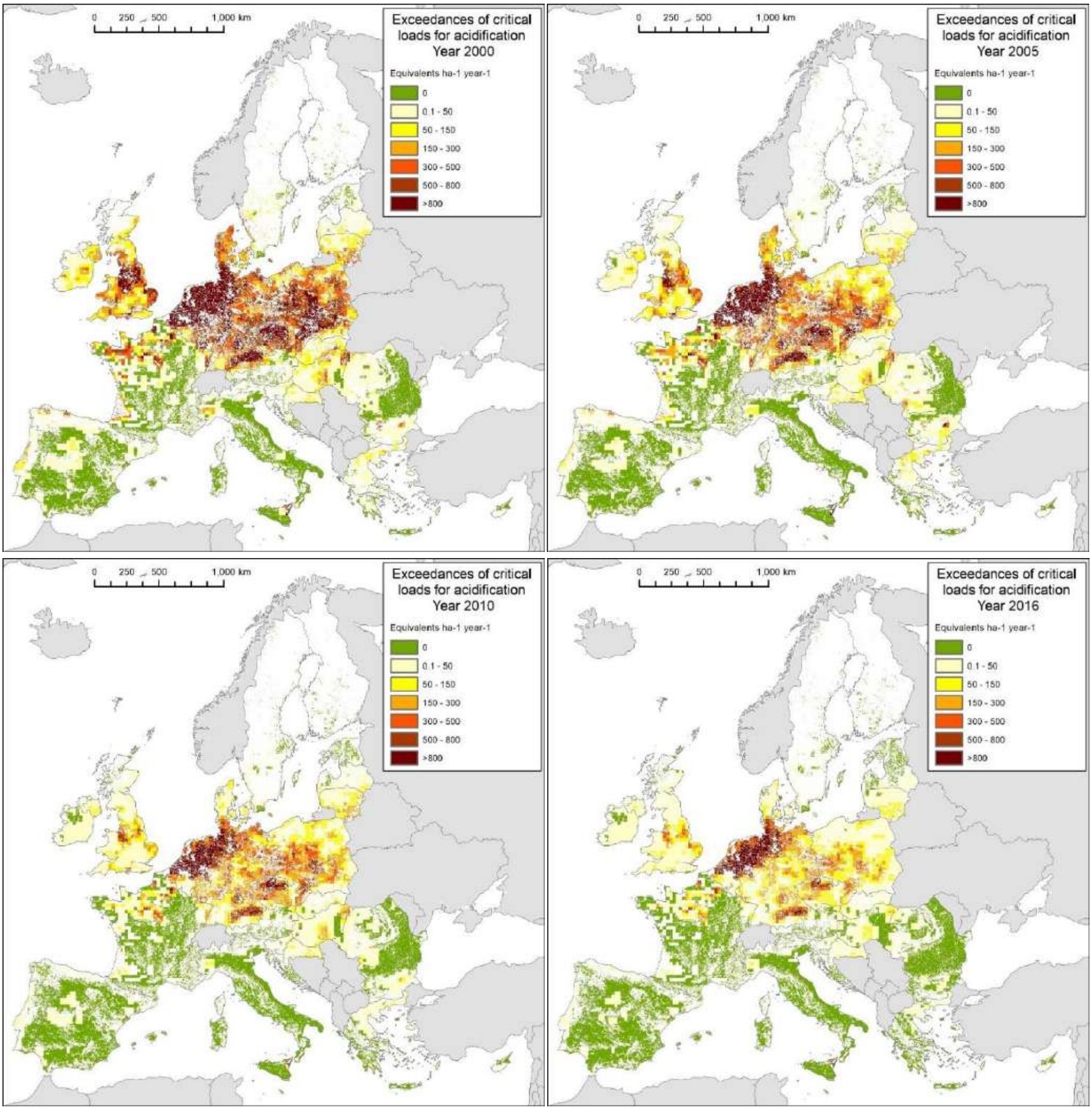


Figure 2 Exceedances of critical loads for eutrophication from N deposition in 2000, 2005, 2010 and 2016. Source: own elaboration based on EMEP, 2018

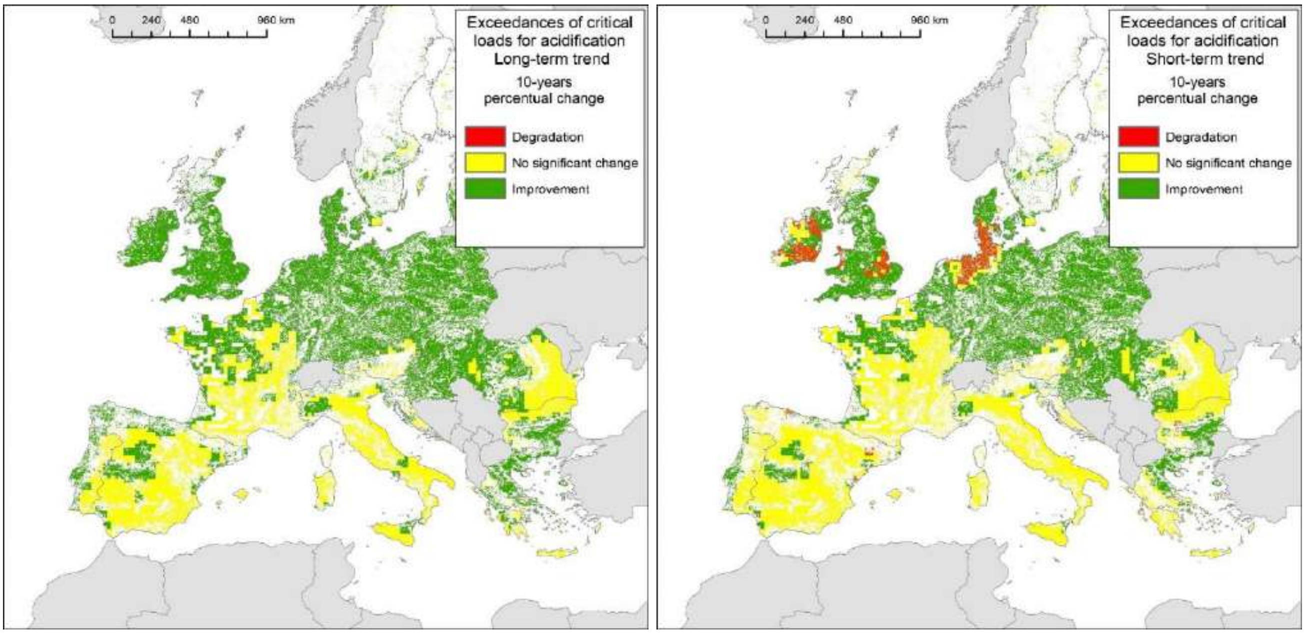


Figure 3 Trends of exceedances of critical loads for acidification (% change over 10 years): left: long-term trend; right: short-term trend

Fact sheet 3.2.108: Spatial assessment of trends of exceedances of critical loads for eutrophication

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: pressure
- Name of the indicator: Exceedances of critical loads of pollutants causing eutrophication
- Units: equivalents ha^{-1} year^{-1}

2. Data sources

- Data holder: European Monitoring and Evaluation Programme
- data source:
- Year or time-series range: 2000-2005-2010-2016
- Access date--- 17/10/2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Pollutants causing acidification and eutrophication originate mainly from anthropogenic emissions of Sulphur dioxide (SO_2), nitrogen oxides (NO_x) and ammonia (NH_3). SO_2 and NO_x are emitted into the atmosphere primarily as a result of combustion of fossil fuels, whilst agricultural and husbandry activities are the major source of NH_3 emissions, related to manure storage, spreading of fertilizer, and livestock deposition.

Once emitted, these pollutants may remain in the atmosphere for several days and transported over long distances by winds. Therefore, they can impact areas far from the emission source. Acidifying pollutants are removed from the atmosphere by wet deposition (commonly referred to as "acid rain") or dry deposition, i.e. direct uptake by vegetation and surfaces deposition. Deposition of compounds containing Nitrogen contribute to eutrophication, i.e. excessive nutrient enrichment that can degrade the ecosystems by favoring Nitrogen-tolerant species. Grasslands diversity and ecological value in particular can be severely affected by this.

European critical loads for eutrophying depositions have been established (Hettelingh et al., 2017) i.e. quantities of deposited compounds below which these phenomena are negligible. The indicator used here is the *exceedance* of the deposition compared to the established critical load on a 25x25 Km grid, on agroecosystems. Details on the methods used are provided in EMEP (2018)

3.2. Statistical analysis of the trend

The trend was analyzed at EU level (Figure 1) and subsequently in by calculating the ten-year change (%) of exceedances over the long and short term at grid level. Increases >5% and decreases < -5% were assessed respectively as “improvement” and “degradation”, whilst any change between -5% and 5% was assessed as “No change”.

3.3. Key trend at EU level

The analysis reported here concerns only depositions on agroecosystems[21]. At EU level, the general trend is a significant decrease of the pressure, as shown by Figure 1.

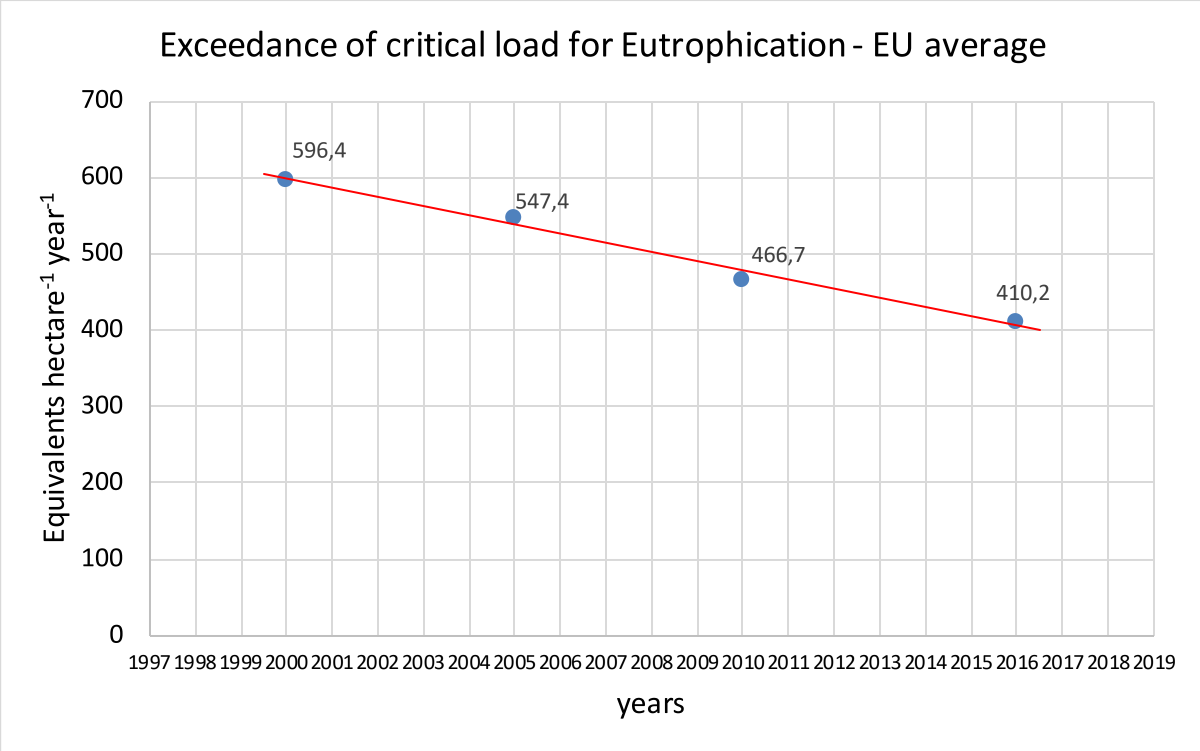


Figure 1 Long-term trend (2000-2018) of exceedances of critical loads of eutrophication, EU average on agroecosystems

Considering the value of 2010 as baseline, the long term trend is a 24% decrease over ten years and the short term trend is a 20% decrease over ten years.

Again, it should be stressed that the measured values already represent exceedances over critical loads, not absolute values of deposition: any value >0 is thus a net pressure on agroecosystems; furthermore, the situation is not homogeneous across Europe, as shown in the next subsection. Therefore, as the EMEP report states, "Overall, the trends […] point in the 'right' direction, but a lot remains to be done in terms of emission reductions to achieve non-exceedance of critical loads everywhere." (EMEP, 2018, pag. 36).

3.4. Maps

The following Figure 2 shows the value of exceedances in eutrophication and acidification in 2000 and 2016. Original data are modelled on a grid with spatial resolution of 0.1°x0.1° longitude-latitude (approximatively 11x5.5 Km at 60° North). All countries in the EU have exceedances in all years, the most affected areas being Northern France, Benelux, Northern Germany, Denmark, the Po Plain and the Ebro valley in Spain. Whilst the overall trend is a widespread decrease of exceedances (i.e. improvement) across Europe, decreases are not always monotone, with some years showing an increase compared to the previous one, reflecting spatial and temporal meteorological fluctuations (as critical loads are identical for all years).

[21] Therefore, numbers reported here may be different to those reported in the EMEP report, as all ecosystems are considered therein.

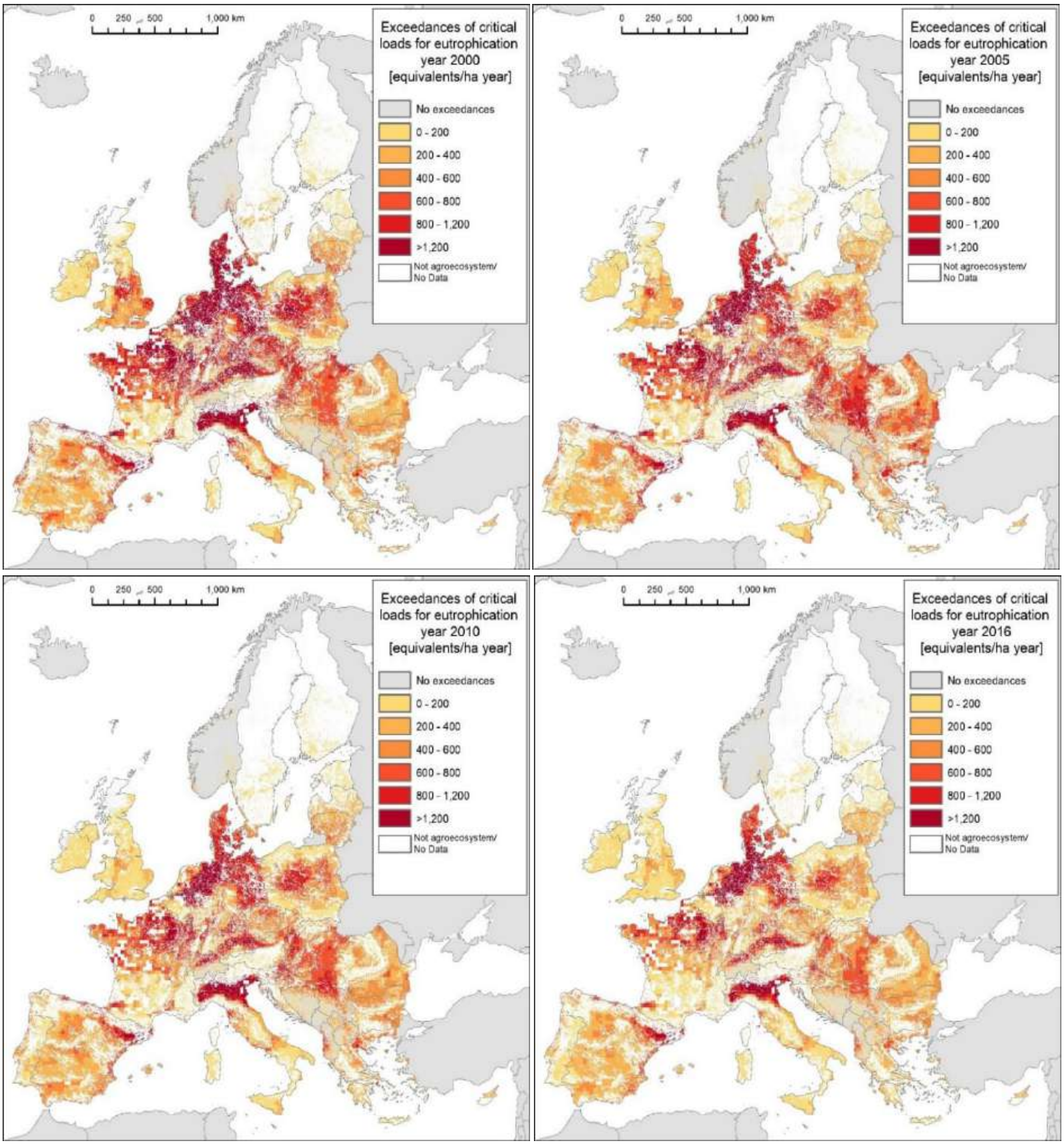


Figure 2: Exceedances of critical load for eutrophication in the EU in 2000, 2005, 2010 and 2016.

The following Figure 3 shows the changes in the pressure calculated on the long-term at grid level (25x25 km cells). The ten-year percentage change was computed for each cell through linear regression and classified as improvement/degradation if based on the slope of the regression line the change was greater/lass than 5% over 10 years. The spatial pattern is a widespread improvement, with only a few areas showing stable conditions in central/southern Spain and in the Danubian Plane. Degradation was recorded on some areas of Croatia, South western Romania and Bulgaria

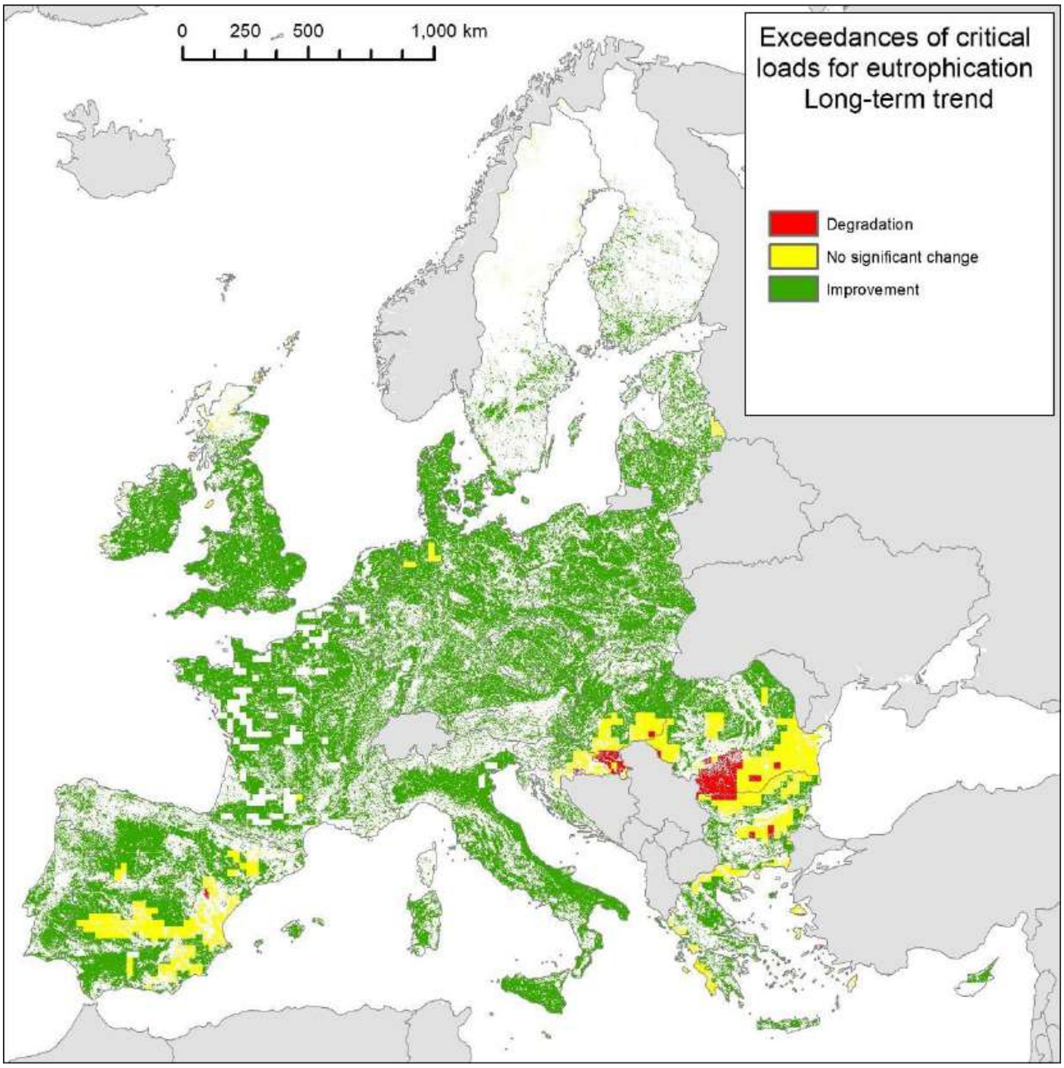


Figure 3 **Long-term trend of exceedance of critical load for eutrophication, based on percentage change over ten-years.**

References:

EMEP (2018) Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components. EMEP Status Report no. 1/2018. ISSN 1504-6192 (on-line)

Hettelingh, J.-P., Posch, M., and Slootweg, J.: European critical loads: database, biodiversity and ecosystems at risk., doi:10.21945/RIVM-2017-0155, CCE Final Report 2017. RIVM Report 2017-0155, 2017.

Fact sheet 3.2.109: Gross Nitrogen Balance (AEI15)

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Pressures - Pollution and nutrient enrichment
- Name of the indicator: Gross Nitrogen balance
- Unit: kgN/ha UAA/year

2. Data sources

- Data holder: EUROSTAT
- Weblink: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_pr_gnb&lang=en
- Years: 2004-2015
- Access date: 13/06/2019
- Reference: https://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rn310
- Spatial Resolution: Member State

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The gross nitrogen balance represents the total potential threat to the environment of nitrogen surplus or deficit in agricultural soils. A lack of nitrogen may cause degradation in soil fertility and erosion, while an excess may cause surface and groundwater (including drinking water) pollution and eutrophication. The data comes from multiple sources including the consumption of fertilisers, livestock population, crop production and areas of various types of crops. The land types included are arable land, permanent crops and permanent grassland.

3.2. Maps

According to EUROSTAT, the data on nitrogen balance are not comparable between countries due to differences in definitions, methodologies and data sources used by countries. Therefore, no map was produced showing annual values. The nitrogen balance was positive so there is a nitrogen surplus in all countries in all years of the time series, except some years in Romania (2010, 2011 and 2014). The gross nitrogen balance has declined significantly since 2010 in Denmark, Estonia and Lithuania (Figure 1). At the long-term, there has been a significant downward trend in Denmark, Greece, Croatia, Malta, the Netherlands and Sweden and upward trend in Cyprus and Latvia.

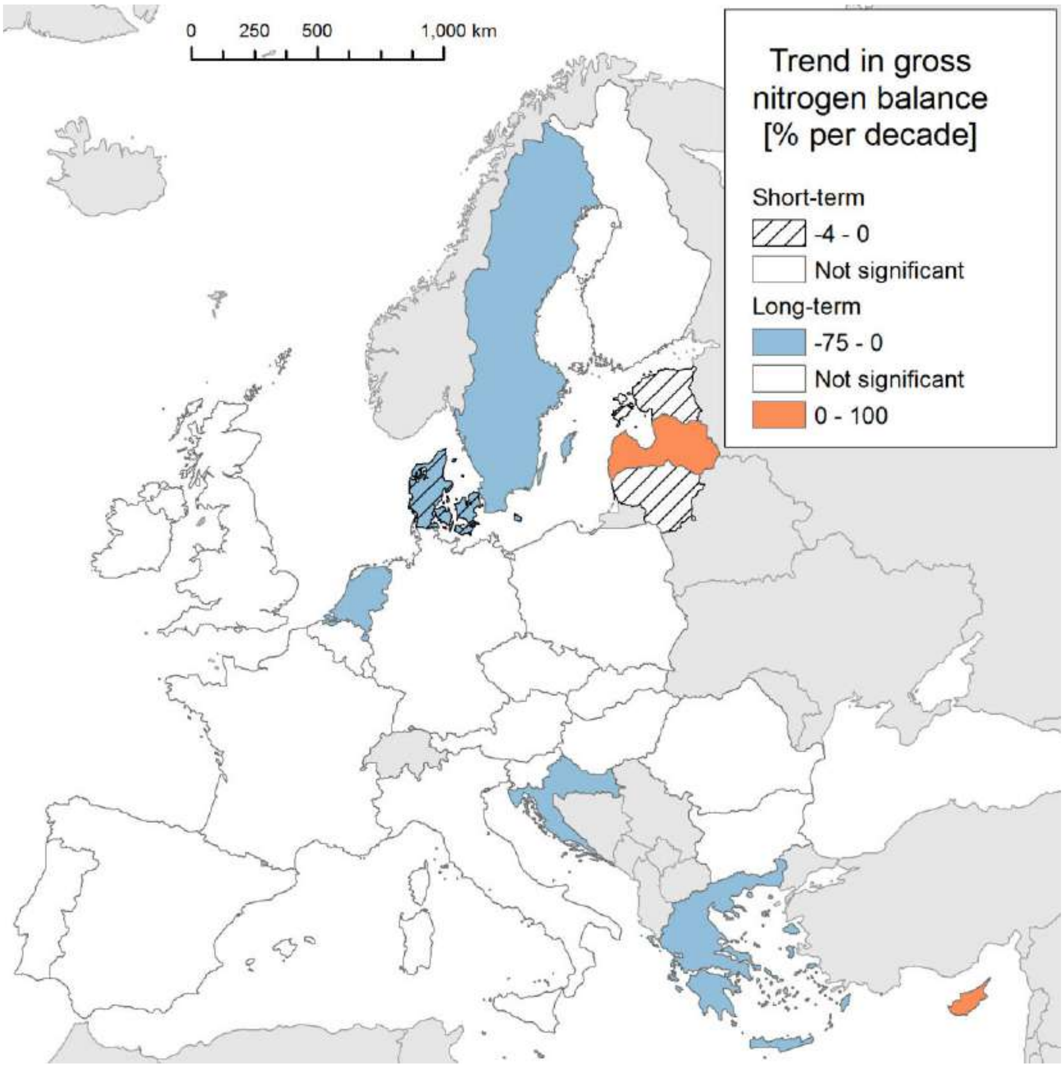


Figure 1 Trend in gross nitrogen balance at 0.05 significance level. Decadal trends are calculated from the 2010-2015 trend.

Table 1 Trends and decadal percentage changes in gross nitrogen balance at Member State level. *: significant trend at 0.05 level.

Member State	Baseline 2010	Long-term trend [kgN/ha UAA/year] 2004-2015	Short-term trend [kgN/ha UAA/year] 2010-2015	Decadal % change (calculated from long-term trend) [%/10 years)	Decadal % change (calculated from short-term trend) [%/10 years)	Decadal % change calculated from statistical values from 2004 and 2015	Decadal % change calculated from statistical values from 2010 and 2015
Belgium	142	-1.08	-2.5	-7.69	0.50	-8.72	-14
Bulgaria	14	0	2.8	0	0.26	43.06	200
Czech Republic	67	1.17	3.33	15.09	3.07	42.06	93
Denmark	90	-3.47*	-2*	-37.03	0.19	-30.80	-22
Germany	78	-1	-1.5	-12.66	-1.37	-2.16	10
Estonia	31	-0.75	-2.25*	-27.39	1.58	-35.35	-58
Ireland	34	-1.77	3.33	-39.90	0.30	-26.19	47
Greece	71	-2.33*	1.5	-35.94	-0.41	-23.01	-34
Spain	35	0	1	0	-1.05	7.58	23
France	40	-0.76	0	-16.17	0	-17.48	10
Croatia	81	-6.15*	-8.25	-74.82	0.50	-41.77	-52
Italy	59	0.17	1	2.67	0.05	2.84	24
Cyprus	191	3.35*	0	18.74	0	11.63	3
Latvia	29	1.2*	0	51.72	0	68.18	-7
Lithuania	44	-1.31	-4*	-41.08	0.50	-34.09	-86
Luxembourg	127	0	0.4	0	0.05	-10.03	3
Hungary	38	1.56	0	49.82	0	70.25	5
Malta	169	-11.81*	0	-63.35	0	-39.71	-26
Netherlands	173	-4.25*	-1.33	-23.66	0.53	-10.24	18
Austria	26	1.17	2	40.00	0.29	29.33	115
Poland	52	0	-1.25	0	0.19	20.98	-15
Portugal	41	0.25	0	6.23	0	4.66	0
Romania	-1	-0.56	2	-55.56	0.49		n.a.*
Slovenia	46	-0.27	-0.2	-5.25	0.05	-13.72	-4
Slovakia	46	0	-1.6	0	0.58	28.21	-35
Finland	57	-0.35	-1	-6.99	-0.80	-6.86	-28
Sweden	42	-1.5*	-2.33	-37.97	0.89	-24.79	-48
United Kingdom	90	-0.65	-1.25	-7.43	-0.56	-12.31	-16

The gross N balance changed from negative to positive value (from -1 to 9) from 2010 to 2015. Therefore the % change is not applicable.

3.3. Statistical analysis of the trend

The trends were analysed using the Theil-Sen estimator non-parametric statistical method. The significance was tested with Mann-Kendall test.

3.4. Key trend at EU level

EU-28 aggregate is directly provided by ESTAT (Table 1). In 2010 gross nitrogen balance amounted to 49 kg N/UUA ha/year. The trend is not significant neither on the long term nor short term (at 0.05 level) (Figure 3).

Table 2 EU-28 aggregates of gross Nitrogen balance in the period with available data (2004-2015).

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Gross N balance (kg/ha)	52	53	56	56	51	46	49	49	50	49	47	51

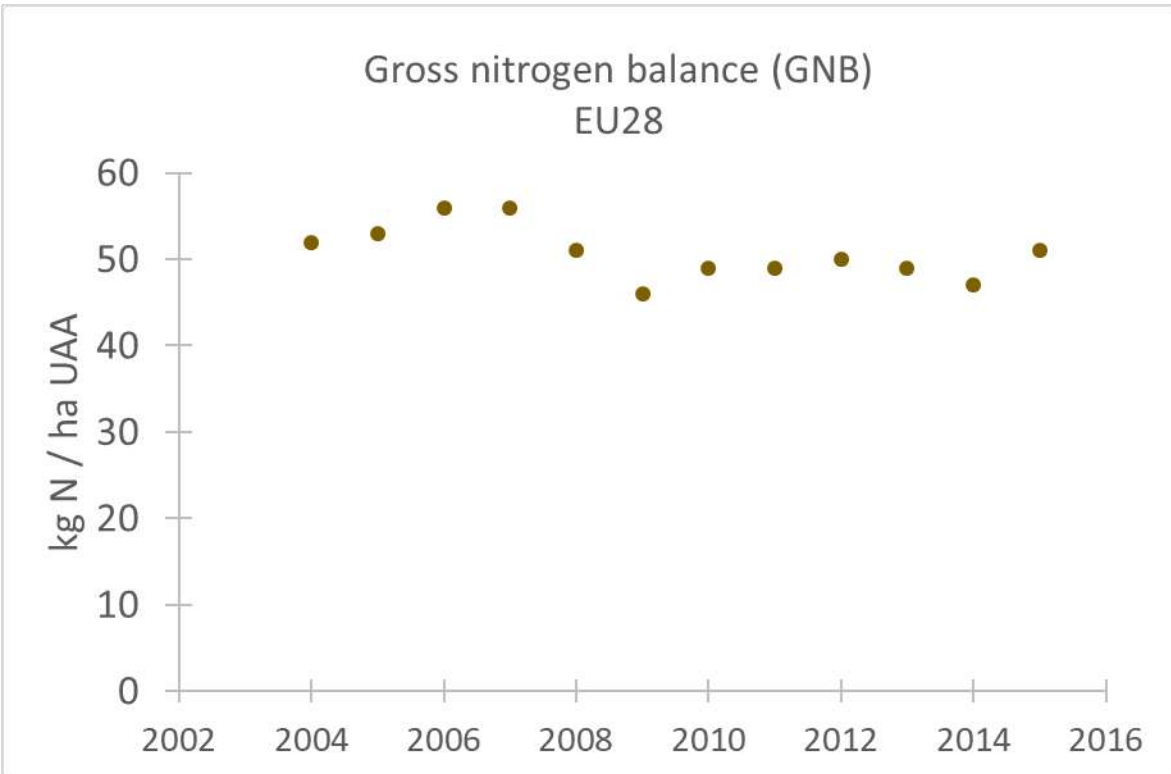


Figure 2 Gross Nitrogen balance in the EU-28 from 2004 to 2015.

Fact sheet 3.2.110: Gross phosphorus balance

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Pressures - Pollution and nutrient enrichment
- Name of the indicator: Gross phosphorus balance
- Units: kgP/ha UAA/year

2. Data sources

- Data holder: EUROSTAT
- Weblink: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_pr_gnb&lang=en
- Years: 2004-2015
- Access date: 13/06/2019
- Reference: https://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rn310
- Spatial Resolution: Member State

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The gross phosphorus balance provides an insight into the links between agricultural phosphorus (P) use, losses of P to the environment, and the sustainable use of soil P resources. The gross phosphorus balance indicates the total potential risk to the environment (water and soil). The actual risk depends on many factors including climate conditions, soil type and soil characteristics, soil P saturation, management practices such as drainage, tillage, irrigation etc. Additional information on the vulnerability of the soil to P leaching and run-off is necessary to assess the risk of P to water.

Data are available or have been estimated for the main inputs and outputs of the balance. These include consumption of inorganic fertilisers, manure production of total livestock, removal of nutrients by the harvest of crops, removal of nutrients by the harvest and grazing of fodder. Data are less available for consumption of organic fertilisers (excluding manure), manure withdrawals, manure stocks, manure imports, seeds and planting material and atmospheric deposition of phosphorus.

A positive phosphorus balance shows phosphorus surplus that can be leached to water bodies and cause pollution and euthrophication. A negative balance can mean risk for soil depletion but this has to be assessed in the context of the long-term trend. If previously decades of excess phosphorus applications have built up large reserves of phosphorus in the soil, maintaining a negative balance ("phosphorus mining") can be a sustainable management for years without reducing crop yield potential. According to EUROSTAT, this can be the case for example in Italy and the Netherlands. The opposite case occurs as well for example in Ireland. The phosphorus balance is positive, but there is a large deficit in soil phosphorus levels in certain soil types so there is a national campaign to increase phosphorus application.

3.2. Maps

The gross phosphorus balance cannot be compared across countries because the methodologies and data used in countries and quality and accuracy of the calculated balance vary. However, the trends can be compared.

There is significant downward trend between 2004 and 2015 in 13 countries where there has been phosphorus surplus (positive balance) in the studied period (Table 1 and Figure 1). The decrease in surplus is considered an improvement in the assessment. In one country, Bulgaria, there is significant downward trend in phosphorus deficit (negative balance), which is considered as degradation.

There has been no change in the short-term since 2010 in any country (Table 1 and Figure 1).

Table 1 Baseline values and trends in gross phosphorus balance in Member States of the EU-28. *: significant trend at 0.05 level. [1]: Surplus: the balance is mainly positive, Deficit: the balance is mainly negative in 2004-2015.

Member State	Baseline [kg P/ha UAA] (2010)	Main status in 2004-2015[1]	Slope of trend [kgP/ha UAA/year] 2004-2015	Slope of trend [kgP/ha UAA/year] 2010-2015	% change per decade compared to the baseline	Assessment
EU-28	2	Surplus	-0.25*	0	-117.6	Improvement
Belgium	5	Surplus	-0.56*	0	-76.65	Improvement
Bulgaria	-5	Deficit	-0.44*	-0.2	-102.27	Degradation
Czech Republic	-2	Deficit	-0.33	0	-182.32	No change
Denmark	8	Surplus	-0.50*	0	-57.14	Improvement
Germany	-1	Deficit	-0.23	-0.5	-209.57	No change
Estonia	-6	Deficit	-0.17	0.33	-28.06	No change
Ireland	2	Surplus	-0.28	1	-62.3	No change
Greece	2	Surplus	-0.38*	0	-208.58	Improvement
Spain	3	Surplus	-0.11	0.25	-27.81	No change
France	1	Surplus	-0.44*	-0.2	-184.54	Improvement
Croatia	7	Surplus	-0.87*	-0.5	-116.54	Improvement
Italy	-1	Deficit	-0.20	0.33	-200	No change
Cyprus	31	Surplus	0.25	0	8.16	No change
Latvia	2	Surplus	0.00	0	0	No change
Lithuania	6	Surplus	-0.87*	-1	-171.1	Improvement
Luxembourg	4	Surplus	-0.17*	0	-36.64	Improvement
Hungary	-2	Deficit	0.00	0.2	0	No change
Malta	33	Surplus	-2.51*	0	-68.27	Improvement
Netherlands	12	Surplus	-1.25*	-1.67	-161.29	Improvement
Austria	1	Surplus	0.17	0.25	143.31	No change
Poland	5	Surplus	-0.58*	-1	-120.95	Improvement
Portugal	6	Surplus	-0.54	0	-89.91	No change
Romania	-1	Deficit	-0.23	0	-420.09	No change
Slovenia	3	Surplus	-0.50*	-0.2	-117.65	Improvement
Slovakia	-3	Deficit	-0.27	-0.5	-67.25	No change
Finland	5	Surplus	-0.25*	0	-52.63	Improvement
Sweden	0	Surplus	-0.13	0	-246.45	No change
United Kingdom	6	Surplus	-0.35*	-0.2	-52.7	Improvement

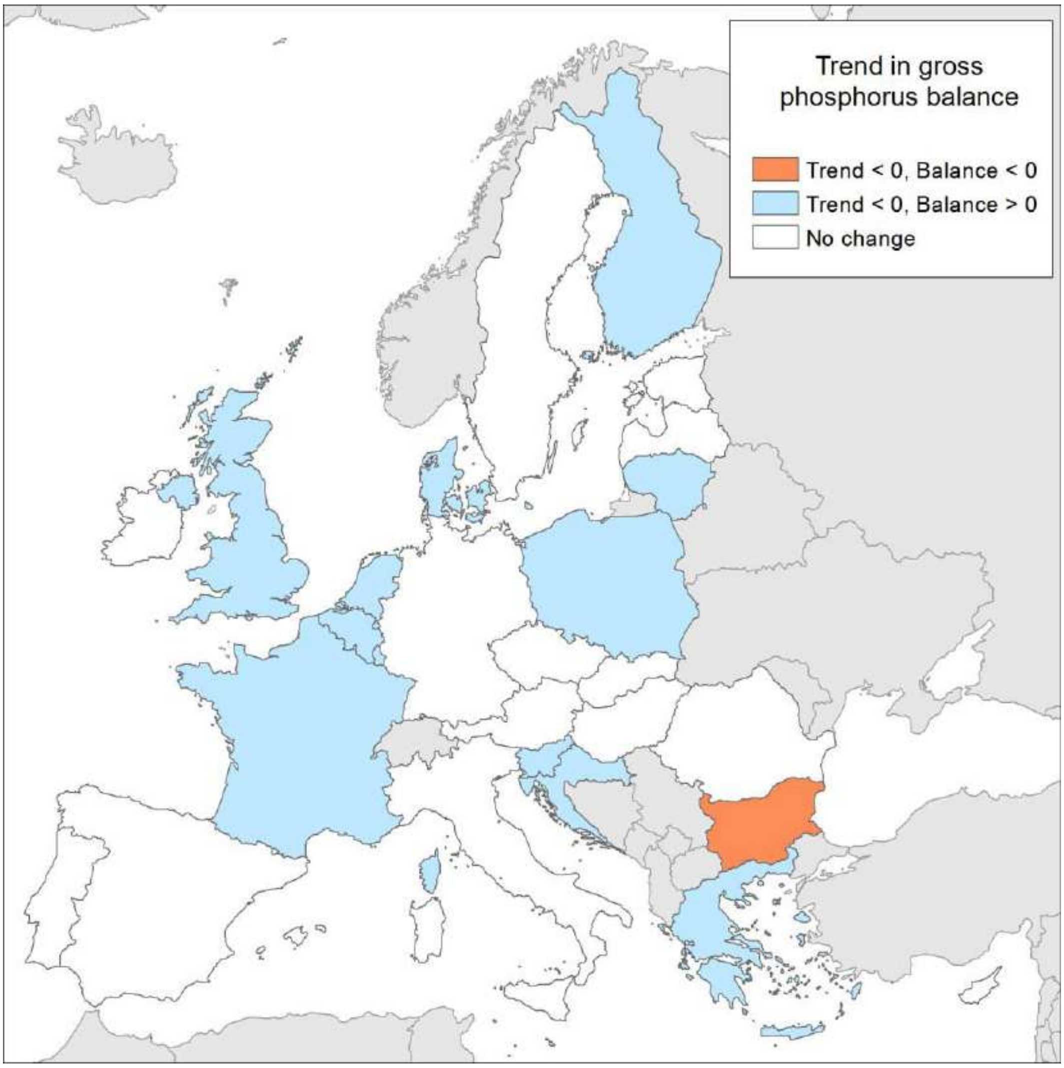


Figure 1 Long-term trend in gross phosphorus balance at country level in the EU-28 (at 0.05 significance level) from 2004 to 2015. Data source: ESTAT.

3.3. Statistical analysis of the trend

The trends were analysed using the non-parametric Theil-Sen estimator. The significance was tested with Mann-Kendall test.

3.4. Key trend at EU level

Phosphorous balance showed a significant downward trend of -0.25 kg P/UAA ha/y ($p = 0.027$) from 2004 to 2015 at EU-28 level, but since 2010 no significant change has occurred (Figure 4). The long-term trend corresponds 117.6 % decrease per decade compared to the baseline value of year 2010 (2 kg P / ha UAA).

Table 2 EU-28 aggregates of gross phosphorus balance in the period with available data (2004-2015).

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Gross P balance (kg P/ha)	4	4	4	2	0	2	1	2	2	1	1

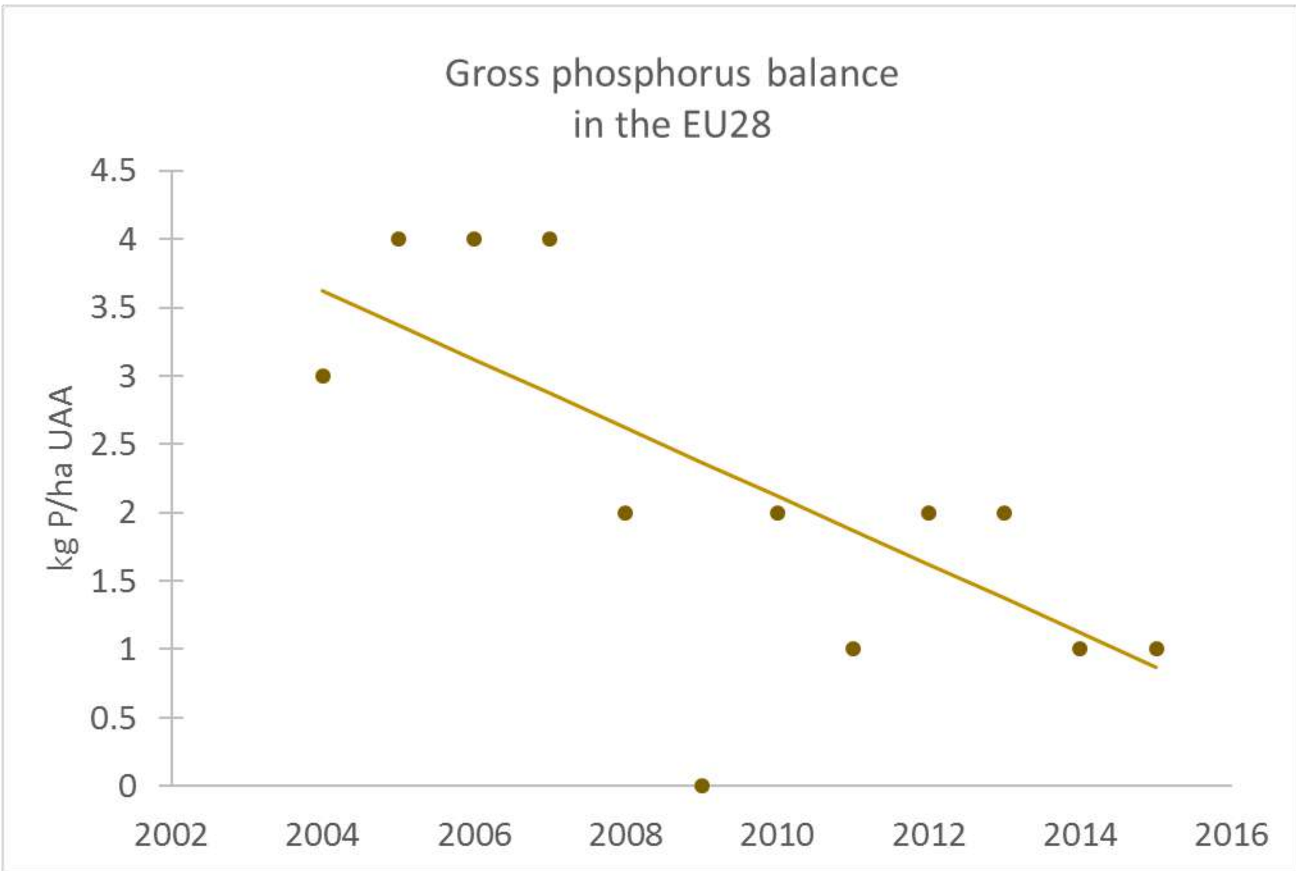


Figure 2 Gross phosphorus balance in the EU-28 between 2005 and 2015.

Fact sheet 3.2.111: Mineral fertilizer consumption

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Pressures - Pollution and nutrient enrichment
- Name of the indicator: Consumption of inorganic fertilisers (SEBI 019) (AEI5), nitrogen and phosphorus
- Units: tonnes of nitrogen/phosphorus

2. Data sources

- Data holder: EUROSTAT
- Data source, weblink: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_fm_usefert&lang=en
- Year or time-series range: 2010 - 2017
- Access date: 03/07/2019
- Reference: https://ec.europa.eu/eurostat/cache/metadata/en/aei_fm_usefert_esms.htm: Consumption of inorganic fertilisers (aei_fm_usefert), https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_mineral_fertiliser_consumption: Agri-environmental indicator - mineral fertiliser consumption

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

'Inorganic fertilizer' means a fertilizer in which the declared nutrients are in the form of minerals obtained by extraction or by physical and/or chemical industrial processes. Calcium cyanamide, urea and its condensation and association products, and fertilizers containing chelated or complex micro-nutrients may, by convention, be classed as inorganic fertilizers (Regulation (EC) No 2003/2003).
The EUROSTAT data refers to inorganic fertilisers *applied* to agricultural land.
The indicator is used to assess the pressure from fertilizer use in agriculture. Excessive use of fertilisers can lead to water, soil and air pollution.

3.2. Maps

A significant upward trend was found in Belgium, Bulgaria, Estonia, Latvia, Lithuania, Hungary, Austria and Sweden, whereas downward trend was shown in Italy (Figure 1). However, the percentage change per decade calculated from the 2017 and 2010 values is higher than 5% in most of the countries (Table 1). On the other hand, the percentage change is lower than 5% in two countries where the linear trend is significant.

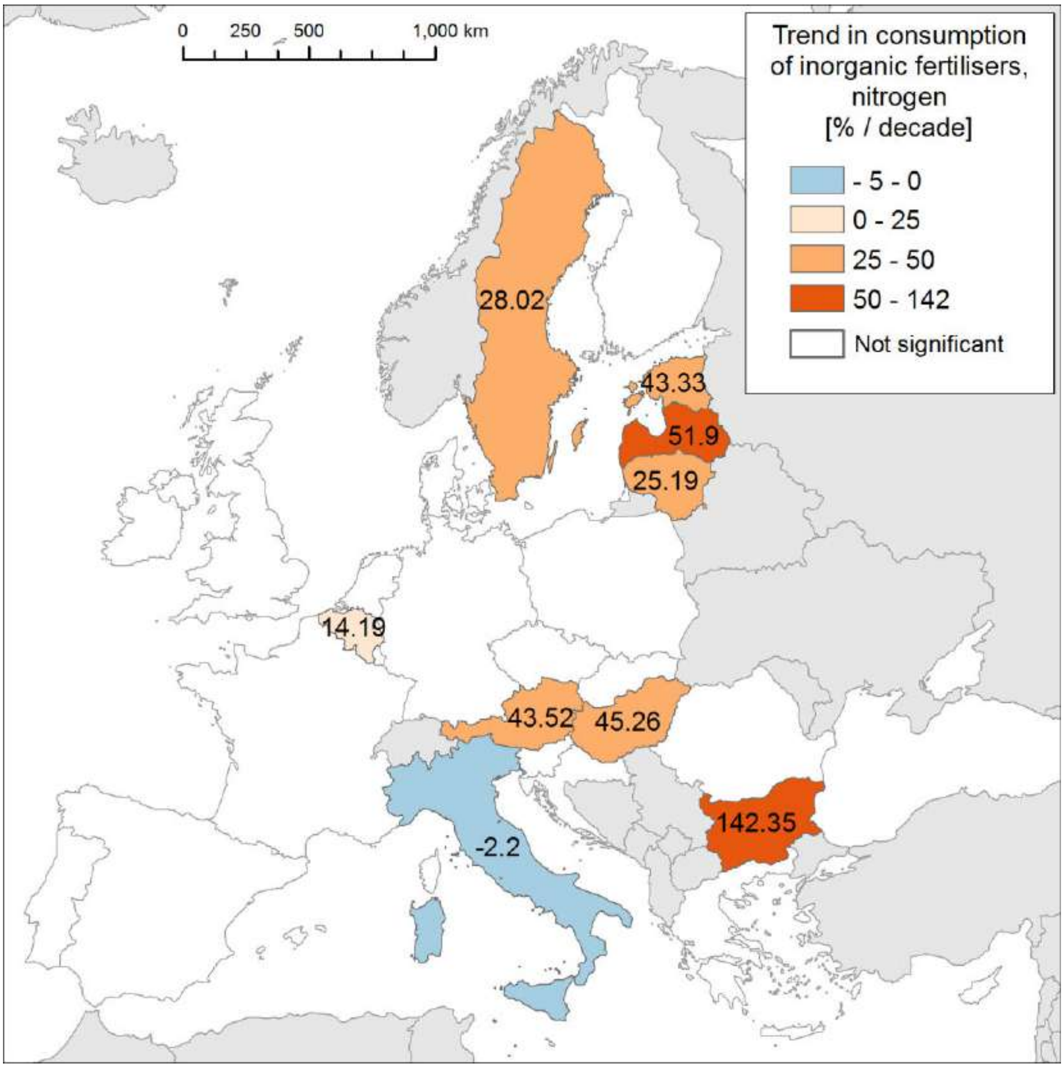


Figure 1 Percentage change in consumption of inorganic nitrogen fertilisers per 10 years where the linear trend is significant, calculated from the 2017 and 2010 data.

The consumption of inorganic phosphorus fertilisers has been increasing in 12 countries (Figure 2). The percentage change was high also in other countries but the linear trend is not significant due to inter-annual variability, e.g. in the Netherlands and in Malta.

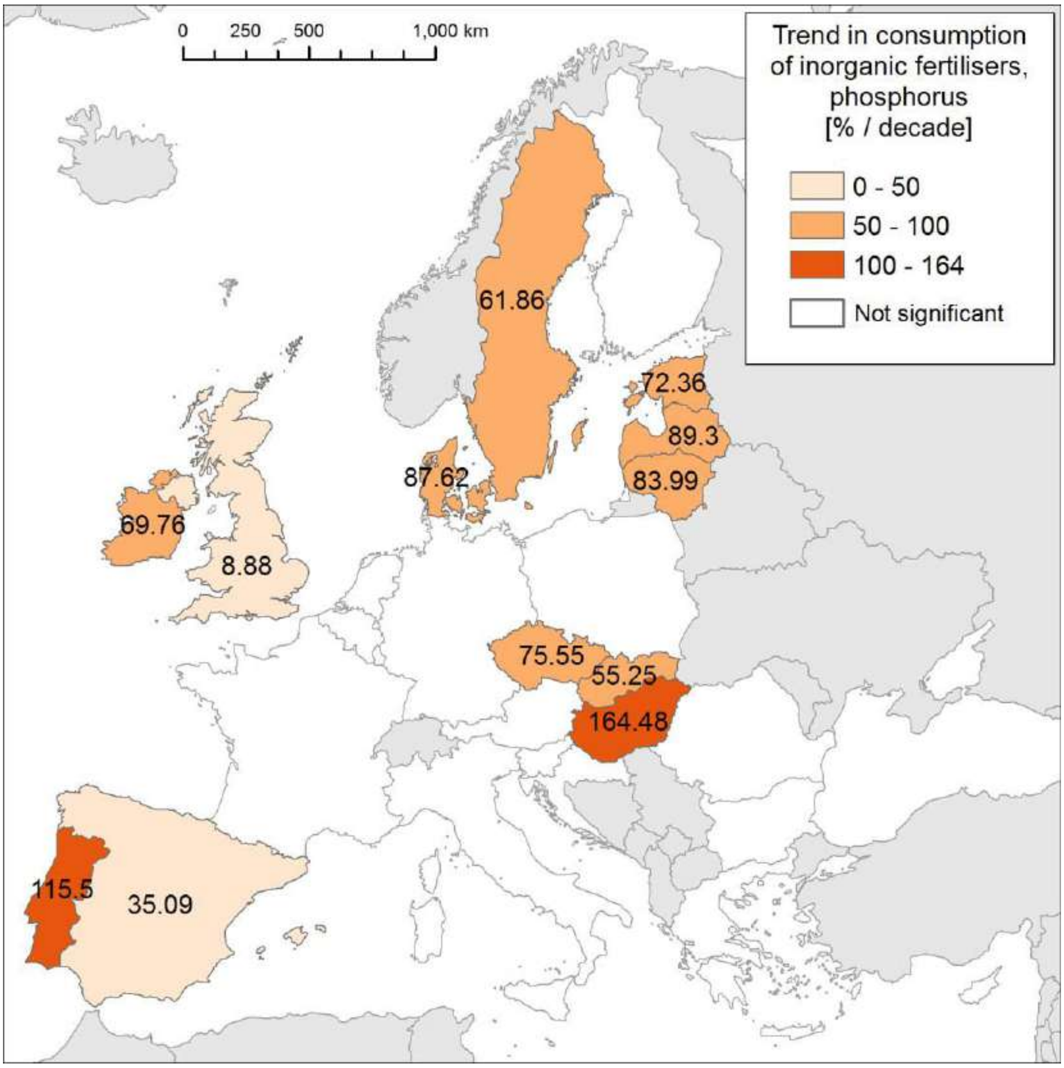


Figure 2 Percentage change in consumption of inorganic phosphorus fertilisers per 10 years where the linear trend is significant, calculated from the 2017 and 2010 data.

Table 1 Baseline and trend in consumption of inorganic fertilisers (nitrogen) by Member State. *: significant linear trend at 0.05 level

	Nitrogen			Phosphorus		
MS	Baseline (2010) [1000 tonnes N]	Slope [1000 tonnes N / year]	%change / decade	Baseline (2010) [1000 tonnes P]	Slope [1000 tonnes P / year]	%change / decade
BE	151.34	2.03*	4.43	5.6	0.06	14.09
BG	199.08	27.13*	109.10	17.043	2.78	190.75
CZ	270.26	14.20	67.31	13.654	1.16*	75.55
DK	190.07	2.80	47.22	10	0.86*	87.62
DE	1569.05	15.13	8.18	102.675	0.67	5.54
EE	28.63	1.25*	43.44	2.671	0.19*	72.36
IE	337.57	6.65	13.34	28.235	1.89*	69.76
EL	212.95	-2.29	-13.94	30.073	-0.42	-16.61
ES	940.98	27.37	19.91	147.495	5.35*	35.09
FR	2080.33	23.74	11.53	177.025	-0.74	-3.81
HR	109.35	-4.41	-14.28	15.763	-0.52	-33.97
IT	586.13	-1.29*	-2.17	229.716	-0.07	-0.28
CY	9.37	-0.05	-19.76	2.286	0.07	38.57
LV	59.46	3.10*	43.21	6.84	0.65*	89.30
LT	143.20	3.61*	23.89	15	1.21*	83.99
LU	13.77	-0.14	-1.98	0.515	0.00	-1.17
HU	281.43	12.90*	56.53	19.976	3.34*	164.48
MT	0.55	0.01	4.14	0.031	0.00	116.21
NL	205.21	3.42	12.32	12.513	-0.36	-53.76
AT	104.76	4.37*	9.71	12.527	0.35	29.01
PL	1027.43	3.10	17.13	154.183	-4.46	-26.22
PT	100.25	1.21	1.79	18.09	1.41*	115.50
RO	305.76	10.56	35.32	53.849	1.31	26.24
SI	27.49	-0.01	-2.09	4.323	0.00	1.07
SK	106.51	2.32	21.50	7.041	0.42*	55.25
FI	156.52	-1.94	-16.04	12.599	-0.08	-6.60
SE	168.00	4.61*	25.94	9.8	0.60*	61.86
UK	1016.42	4.52	3.31	80.314	0.73*	8.88

3.3. Statistical analysis of the trend

The short-term trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trends was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall 1975; Mann 1945).

3.4. Key trend at EU level

The consumption of inorganic nitrogen fertilisers has been significantly increasing between 2010 and 2017 at a rate of 164 542 tonnes nitrogen per year (Table 2, Figure 3). The trend in the consumption of inorganic phosphorus fertilisers is not significant, however the percentage change per 10 years is 16 % (Table 2, Figure 4).

Table 2 Statistical data on consumption of inorganic fertilisers in the EU-28. Data source: EUROSTAT. * : significant trend.

Year	2010	2011	2012	2013	2014	2015	2016	2017	Slope	% change per 10 years
Nitrogen [1000 tonnes]	10401.9	10885.7	10384.6	10914.9	11109	11372.7	11203.8	11566	164 542*	15.8
Phosphorus [1000 tonnes]	1189.8	1273.3	1226.9	1321.3	1312	1285.6	1308.7	1342.5	19 364	16.15

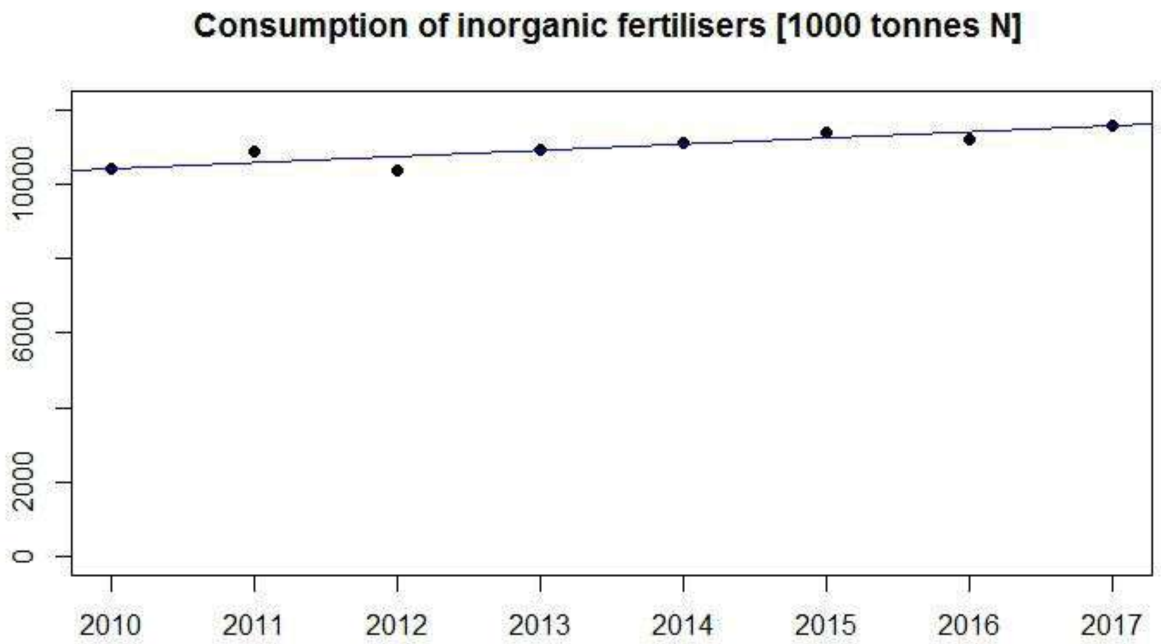


Figure 3 Consumption of inorganic nitrogen fertilisers in the EU-28.

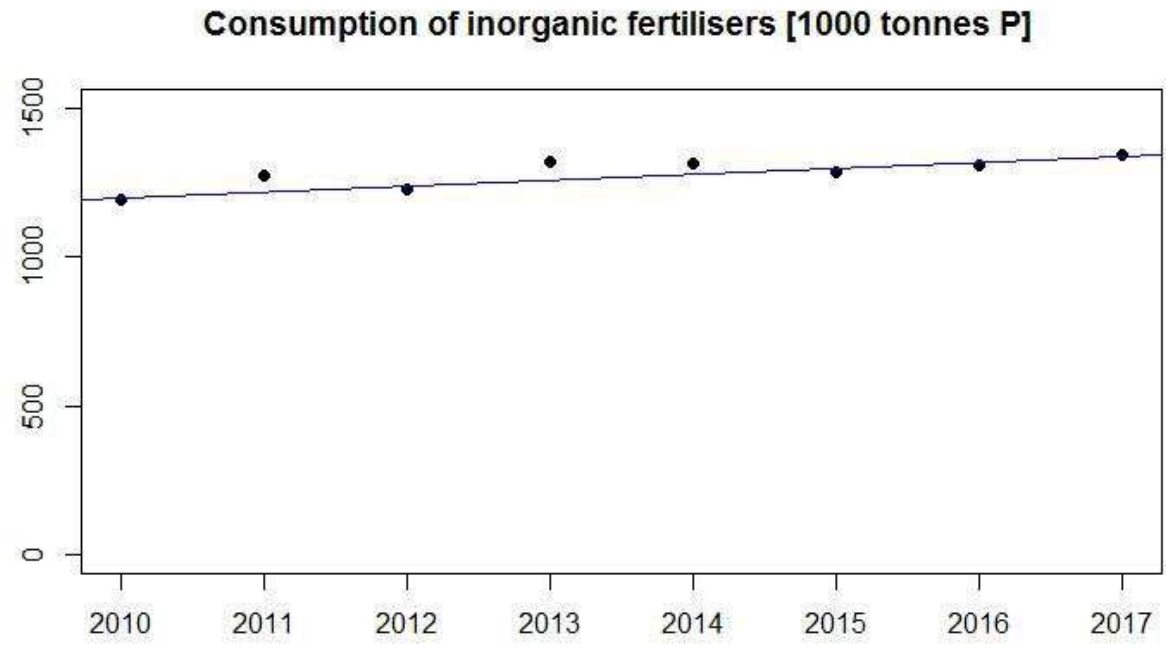


Figure 4 Consumption of inorganic nitrogen fertilisers in the EU-28.

Fact sheet 3.2.112: Pesticide sales

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Pressures - Pollution and nutrient enrichment
- Name of the indicator: Pesticide sales
- Units: kg active ingredient/year

2. Data sources

- Data holder, data source: EUROSTAT
- Weblink: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=aei_fm_salpest09&lang=en
- Year or time-series range: 2011- 2017
- Access date--- 09/04/2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

There are no EU statistics available on pesticides use in agriculture that could be an indicator of pressure by pollution. EUROSTAT published a research paper about the data collection on pesticides use between 2010 and 2014 that includes both volume of pesticide used and the area treated (EUROSTAT, 2019). However, data was collected by crops or crop groups and therefore it is not possible to calculate EU aggregates and trends. This gap is overcome by using as a proxy data on pesticides sales (in kg of active ingredients) that have some limitations. Pesticide sales are not always linked to use during the same year and pesticides are used outside of agriculture in large volumes. So pesticide sales is not a direct indicator of the pressure on agro-ecosystems. The EUROSTAT database starts from 2011 and contains missing data and confidential values. There is a break in the time series of the statistics in 2016, because the active substances included in the major groups were revised between 2011-2015 and 2016. Therefore, the trend in the different groups of pesticides could not be assessed but the total amount of pesticides is not affected by the changes. Furthermore, pesticide sales does not follow a linear trend but can show a high year-to-year variability depending on the weather, taxes, regulatory changes and other factors.

A complete time series is available only for 12 countries (Belgium, Denmark, Germany, Ireland, Spain, France, Italy, the Netherlands, Austria, Portugal, Romania and Slovenia). In order to include the remaining countries as much as possible, different rules were used to impute missing data and not available data due to confidentiality:

- data is missing in Croatia in 2011 and 2012 (not yet member of the EU) and in Luxembourg in 2017', the values were imputed taking the values from the closest years (from 2013 for Croatia and 2016 for Luxembourg);
- data gaps due to confidentiality were not filled only if values were 0 in all other years; in this case the affected quantity is estimated to be less than 3% of the total sold pesticides in the EU, so the trend analysis is not expected to be affected by these missing values. It led to missing values in one year in Greece, Hungary and Malta, and made trend analysis impossible for Estonia, Cyprus, Luxembourg and the UK for which countries' values are confidential in most or all years;

- for countries for which data is missing in more years due to confidentiality and the amounts are expected to be negligible compared to the totals, based on available data, the total sold pesticides exclude Molluscicides (for 5 countries) and other plant protection products (for 2 countries);
- other missing data were approximated by 0 assuming that in these cases no pesticide was authorized in that category.

Additionally, data on pesticide sales do not describe an important characteristic of pesticides: toxicity. The only available indication describing it is provided by the Harmonised Risk Indicator for pesticides in the EU (https://ec.europa.eu/food/plant/pesticides/sustainable_use_pesticides/harmonised-risk-indicators/trends-hri-eu_en), which shows a 20% reduction in the period 2011-2017.

3.2. Maps

At Member State level, the relative change in the amount of sold pesticides compared to 2011 was higher than 5 % almost in all countries except Romania (Figure 1, Table 1), increasing in 13 countries and decreasing in 10 countries.

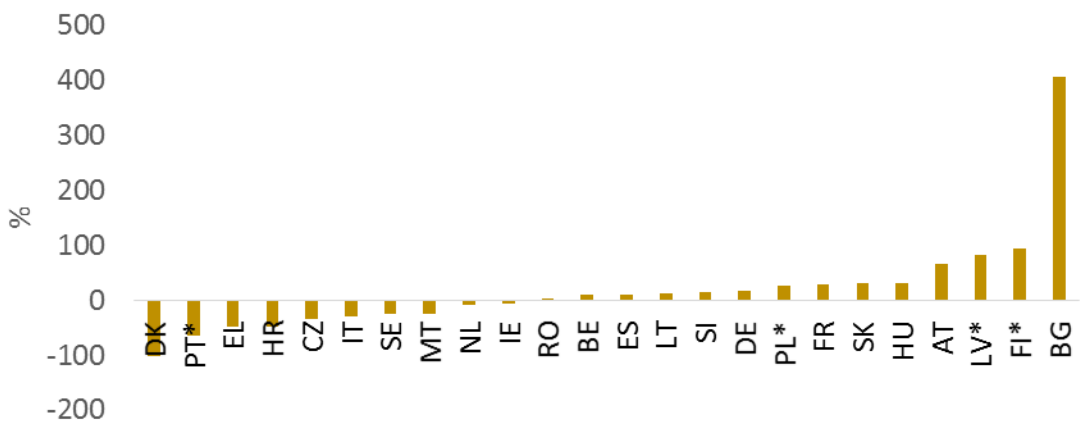


Figure 1 Decadal % change in EU Member States,calculated from Sen's slope and intercept. In LT, SI, DE, PL, FR: Other Plant Protection Products or Molluscicides (that are usually used in negligible amounts compared to the total) excluded in one or more years due to missing data. BG, CZ, EL, HR, HU, MT: there is one year data gap. Baseline year: 2011, in BG, CZ, EL: 2012, HR: 2013 due to missing data. *: significant trend according to the Mann-Kendall test. Data source: EUROSTAT.

From the countries with complete time series there is significant downward trend only in Portugal. Based on the statistical test, there was no significant trend in other Member States, which can mean that there is no monotonic trend in their data series or the time series were too short (< 8 points in time).

Table 1 The total amount of pesticides sold in 2011 and in 2017 and temporal changes in the Member States having complete time series. Slope of linear trend: slope determined with the Theil-Sen estimator. Relative change per 10 years: change in 10 years calculated from the slope of the trend and compared to the 2010 baseline value of the trendline.

Member State	Sold pesticides in 2011 [1000 tonnes of active ingredients]	Sold pesticides in 2017 [1000 tonnes of active ingredients]	Total sold pesticides [% of the EU-28 total] 2011	Total sold pesticides [% of the EU-28 total] 2017	Slope of linear trend [tonnes per year]	Relative change per 10 years
Belgium	6.15	6.49	1.61	1.72	55.96	9.00
Denmark	5.28	3.23	1.39	0.86	-539.15	-102.02
Germany	43.86	48.26	11.51	12.83	734.18	16.74
Ireland	3.72	2.86	0.98	0.76	-21.03	-6.90
Spain	73.11	71.99	19.19	19.13	765.67	10.47
France	61.34	70.56	16.10	18.75	1792.03	28.89
Italy	70.25	56.45	18.43	15.00	-2053.63	-29.24
Netherlands	10.95	10.57	2.87	2.81	-96.09	-8.77
Austria	3.45	4.62	0.90	1.23	213.57	64.84
Portugal	14.02	8.17	3.68	2.17	-854.63*	-63.68
Romania	11.43	11.55	3.00	3.07	14.38	1.26
Slovenia	1.12	1.09	0.29	0.29	14.22	14.19

From Member States with data gaps from one or two years, significant upward trend was found in Latvia, Poland and Finland (Table 2). In the particular case of Bulgaria the relative change was calculated comparing the change to the first available value (in year 2012) instead of the baseline of the linear trend because that was far from the statistical value due to non-linearity.

Table 2 The total amount of pesticides sold in 2011 and in 2017 and temporal changes in Member States for which time series are not complete. [1]: the annual totals were estimated in some years in these countries due to data availability issues. Data on other plant protection products in Lithuania and on Molluscicides in Lithuania, Slovakia, Finland and Sweden are not available in at least three years out of the seven but considered to be negligible so excluded. Molluscicides data is excluded from the annual total in Poland for 2014. *: significant trend, **: change compared to the 2012 statistical value. [2]: Data is available for 6 years. 3: Data is available in 5 years. n.a.: not available.

Member State	Sold pesticides in 2011 [1000 tonnes of active ingredients]	Sold pesticides in 2017 [1000 tonnes of active ingredients]	Total sold pesticides [% of the EU-28 total] 2011	Total sold pesticides [% of the EU-28 total] 2017	Slope of linear trend [tonnes per year]	Relative change per 10 years
BG[2]	n.a.	3.38	n.a.	0.90	539.90	405.6**
CZ[2]	n.a.	5.25	n.a.	1.39	-235.05	-35.06
EE	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
EL[2]	n.a.	4.52	n.a.	1.20	-312.15	-49.30
HR[3]	n.a.	1.58	n.a.	0.42	-118.09	-48.17
CY	n.a.	1.11	n.a.	0.30	n.a.	n.a.
LV	1.07	1.48	0.28	0.39	92.73*	81.40
LT[1]	2.56	2.99	0.67	0.80	32.47	12.85
LU	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
HU[2]	8.55	9.75	2.24	2.59	251.55	30.51
MT[2]	0.13	0.11	0.03	0.03	-3.54	-24.00
PL[1]	21.76	25.07	5.71	6.66	558.26*	25.71
SK[1]	1.81	2.21	0.47	0.59	56.90	30.22
FI[1]	3.02	4.36	0.79	1.16	272.77*	94.95
SE[1]	2.40	2.06	0.63	0.55	-60.06	-24.81
UK	24.43	n.a.	6.41	2017	n.a.	n.a.

3.3. Statistical analysis of the trend

The short-term trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trends was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall 1975; Mann 1945). The trend in total sold pesticides was calculated for the period 2011-2017.

3.3. Key trend at EU level

In order to assess the trend in pesticides sales, the Member State level data were aggregated. According to the statistical test, the trend is not significant (Figure 2, Table 2), meaning that changes at Member State level are balanced out.

Table 3 Statistics of total pesticide sales in the EU (in tonnes of active ingredients).

	2011	2012	2013	2014	2015	2016	2017	Sen's slope	% change per decade
Pesticide sales, EU-28	381072	362088	358299	396147	386635	386474	375708	1080	0

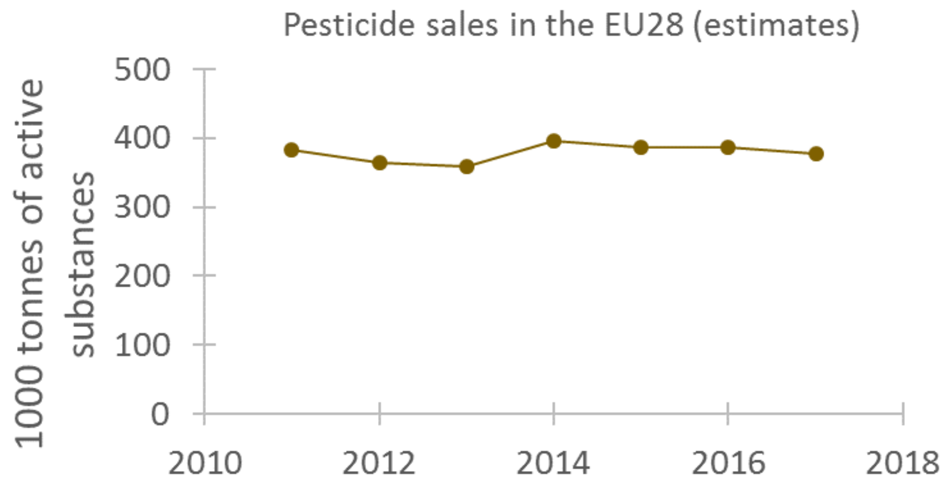


Figure 2 Estimates of pesticide sales in the EU-28 between 2011 and 2017 excluding confidential data representing < 3% of the total of sales over the entire time series.

References

EUROSTAT (2019) Statistics on agricultural use of pesticides in the European Union. Research paper. European Union.

Fact sheet 3.2.201: Nitrate concentration in groundwater

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Environmental quality (physical and chemical quality)
- Name of the indicator: Nitrate concentration in groundwater/ Share of monitoring points with nitrate concentration above 50 mg/l
- Units: mg nitrate per liter

2. Data sources

- Data holder: European Commission
- Weblink : https://ec.europa.eu/environment/water/water-nitrates/reports.html
- Year or time-series range: 2004-2007, 2008-2011, 2012-2015
- Access date: 25/09/2019
- Reference: https://ec.europa.eu/environment/water/water-nitrates/pdf/nitrates_directive_implementation_report.pdf

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Nitrate concentration is used to assess the chemical quality of groundwater and surface water. It is monitored in the frame of the EU Nitrates Directive. The comparability of data across the Member States is limited due to the differences in the monitoring networks and strategies. The Nitrates Directive sets general provisions but the details of the monitoring strategy such as location of stations, network density, frequency and timing of sampling, etc. is the responsibility of the Member States. The reported data show uneven monitoring efforts in the Member States and a high number of new stations with no trends across the EU. The intensity, i.e. both the density of monitoring networks and the frequency of sampling highly vary between Member States. Moreover, the sampling might not always be well adapted to the actual pressures.

3.2. Maps

There is no spatial information available, only data at Member State (with limited comparability) and EU-28 level.

3.3. Statistical analysis of the trend

The value of the 2008-2011 monitoring period that is based on the annual average nitrate concentration is considered the 2010 baseline. The short-term and long-term trends were calculated from the first and last year values of share of monitoring points with nitrate concentration > 50 mg/l.

3.4. Key trend at EU level

The share of sampling points with low nitrate concentration (< 25 mg/l) has been slightly increasing, the shares of sampling points with higher nitrate concentrations (25-40, 40-50 or > 50 mg/l) have been slightly decreasing, both in groundwater and surface water (Figure 1, Figure 2).

The short-term and long-term trends (Table 1) of changes in percentage of stations with high nitrate concentrations are below 5% considering percentage point changes but above 5% based on relative changes.

Table 1 Short-term and long-term trends in share of sampling points with high (> 50mg/l) nitrate concentration.

	% change per decade (absolute share of stations >50mg/l on total number of stations)	Relative change per decade (relative only to stations >50 mg/l)
Short-term change	-1.71	-11.90
Long-term change	-1.64	-10.91

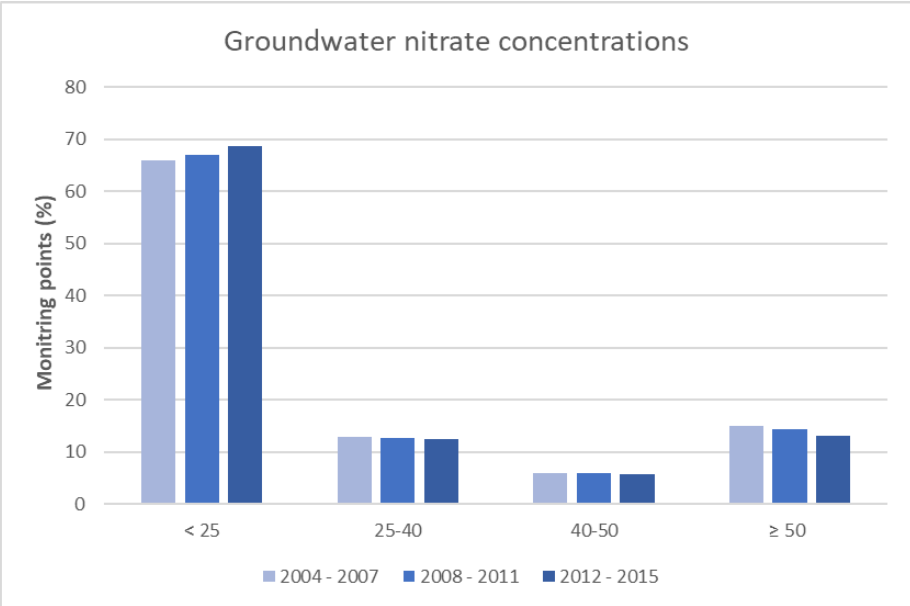


Figure 1 Groundwater nitrate concentrations in the three monitoring periods.

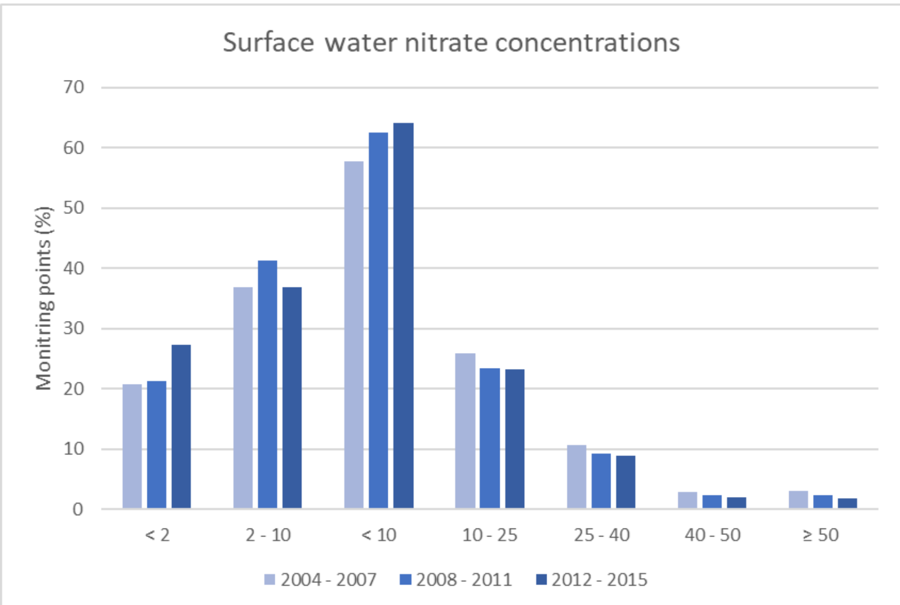


Figure 2 Surface water nitrate concentrations in the three monitoring periods.

Fact sheet 3.2.202: Spatial assessment of trend in arable crop diversity

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: condition
- Name of the indicator: Shannon crop diversity index in arable land
- Units: dimensionless index

2. Data sources

- Data holder: Joint Research Centre Directorate D - Sustainable resources / Unit 05 - Food security, Agri4Cast resource portal (https://agri4cast.jrc.ec.europa.eu/DataPortal/Index.aspx?o=d)
- data source: Elaboration of data from EUROSTAT and from different National Institutes of Statistics
- Year or time-series range: 2000-2017
- Access date--- 17/10/2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Crop diversity in agroecosystems is a measure of the variety of different crops in a given spatial unit. In general, higher crop diversity is considered to be beneficial for soil quality, to contrast the emergence of weeds and pests outbreaks and to support biodiversity, as diverse crops provide a more variegated and temporally distributed sources of food (e.g. for birds and bats).

JRC Unit D5 collects data on crop acreage in arable land, based on statistics provided by National Institutes of Statistics and to Eurostat. Based on this, yearly arable crop area is modeled on a 25 Km grid covering the EU-28. This data has been used to derive, for each grid, the Shannon Diversity Index (SDI) , a common measure of diversity used in ecology, for arable crops. To this end, data were preprocessed by merging some categories to avoid double counting. The final dataset contains the following 17 crops: soft wheat, durum wheat, sunflower, grain maize, fodder maize, spring barley, winter barley, rye, oats, rice, sugar beet , potatoes, triticale, field beans, soybean and turnip rapeseed. For each 25km cell, the SDI was calculated according to the following equation:

$$SDI_j = -\frac{\sum_{i=1}^{n} c_{ij} \ln c_{ij}}{\ln(n)}$$

Where SDI_j is the value of the Shannon Diversity Index in cell *j*; c_{ij} is the share (0-1) of the i^{th} crop in cell *j*, *n* is the number of crops considered (=17) and *ln* is the natural logarithm. The higher the value, the higher the level of crop diversity. The index is sensitive to both the total number of crops occurring in a cel l and their relative shares. When there is only one crop in a cell (minimum diversity), the index equals 0. The maximum possible value would be when all 17 crops are present in a cell with an equal share. In this case, the numerator of the equation = ln (17) ≈ 2.83. The numerator is divided by *ln* (17) to normalize the final value to [0-1].

3.2. Statistical analysis of the trend

The trend was analyzed by calculating the % change both for the long (2000-2017) and short term (2010-2017) trend per each 25 Km cell. Increases >5% and decreases < -5% were assessed respectively as "improvement" and "degradation", whilst any change between -5% and 5% was assessed as "No change".

The 10 years trend calculated on the short term (not shown) does not greatly differ from the long term trend, and identifiable spatial patterns of change are similar.

3.3. Maps

The following maps (figure 1) shows the value of the SDI in 2010 and in 2017 respectively. It is to be remarked that the index shows crop diversity in arable land only, not in agricultural areas in general, as permanent crops and grasslands are not included in the index calculation. The spatial patterns of crop diversity in 2017 is overall driven by climatic conditions, with higher diversity in the Continental and Atlantic region, medium to low values in the Mediterranean (lower in islands) and low values in the Boreal region.

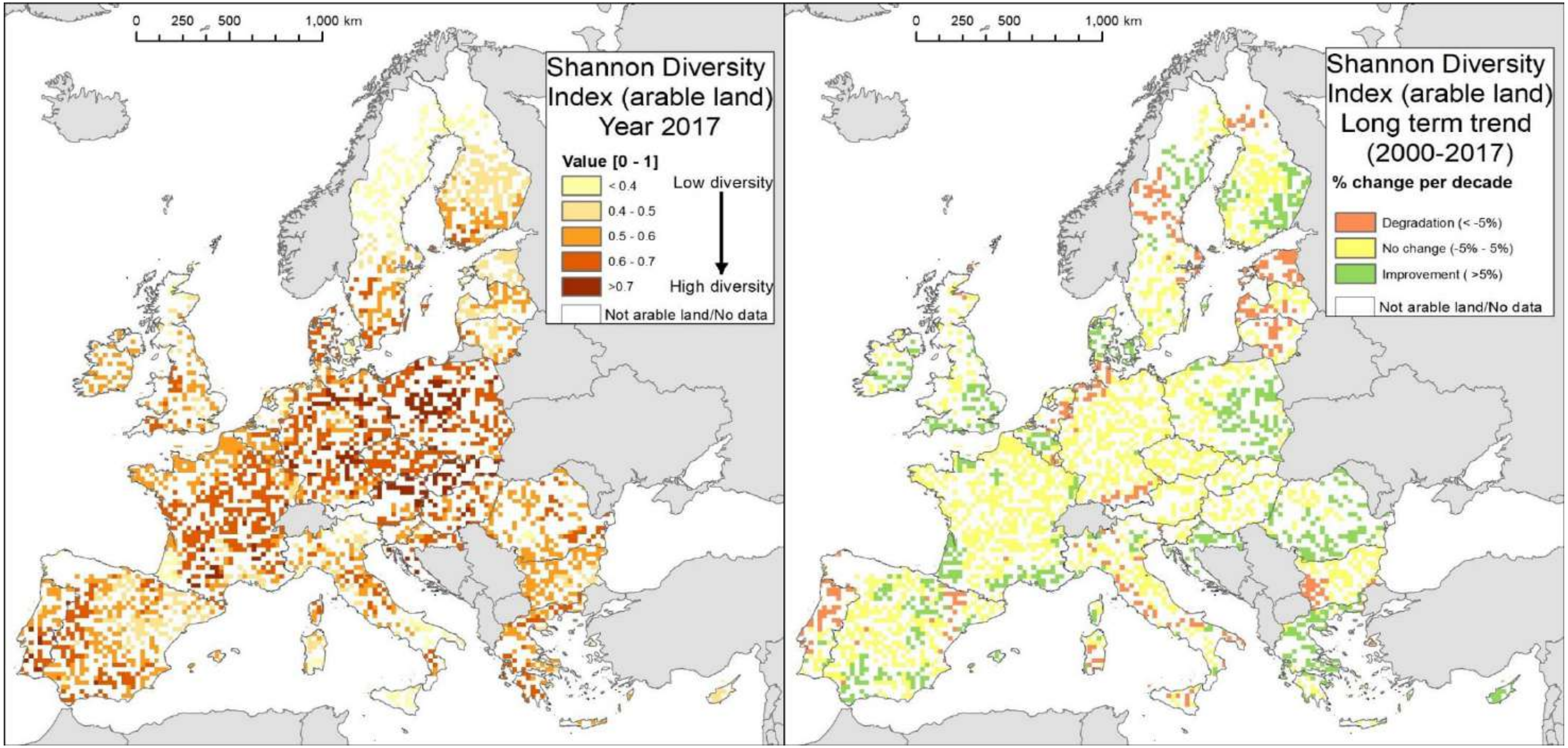


Figure 1 Left: Shannon Diversity index of arable crops in 2017; Right: Long term trend (2000-2017) as percentage change per decade

Trends (Figure 1 left) shows non-significant changes (increase/decrease <5%) over large areas of Europe, but spatial patterns are identifiable and statistically significant (i.e. likelihood clustered pattern could be the result of random chance is <0.01). Decrease in crop diversity (<-5% in a decade) occurred in Portugal, West Bulgaria, Baltic States, the southern part of Bayern (Germany), The Netherlands, Luxemburg, Central Sweden and Northern Finland. Significant (i.e. >5%) increases occurred in England and Ireland, Provence and Languedoc (Southern France), Landes (South Western France), The Paris Basin, Greece, Cyprus, Croatia, Romenia, Denmark, Central/Eastern Poland and Belgium. Large arable areas in Spain, France, Germany and the Pannonia Plain and Southern Sweden experienced no significant changes.

3.4. Key trend at EU level

The aggregated value of the SDI for the whole EU-28 is shown in the following table and diagram (. The value was calculated through a weighted average across all the cells, the weight being represented by the total area of arable crops in each cell (2009 was omitted because some crop data were missing/incomplete).

Year	SDI EU-28 [0-1]
2000	0.5734
2001	0.5787
2002	0.5760
2003	0.5826
2004	0.5785
2005	0.5786
2006	0.5823
2007	0.5842
2008	0.5786
2010	0.5859
2011	0.5708
2012	0.5756
2013	0.5902
2014	0.5757
2015	0.5916
2016	0.5545
2017	0.5948

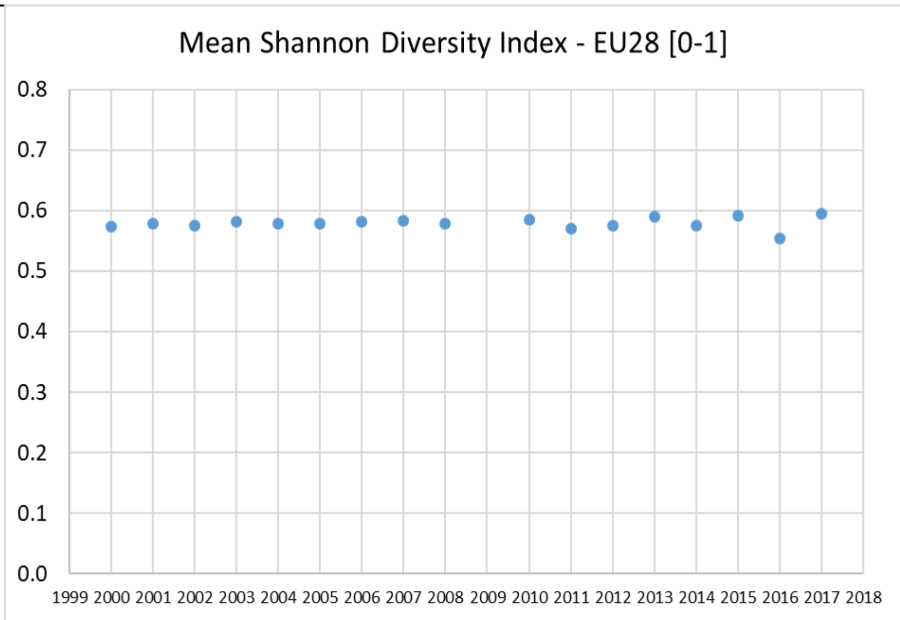


Figure 2: Table (left) and diagram (right) of the average Shannon Diversity Index (SDI) in the EU-28 from 2000 to 2017

At EU level, the decade percentage trend is an increase (improvement) of about 2.2% and 2.19% for the long and short term trend respectively, thus below the significance threshold of 5%. The slope of trend is not statistically different from 0 when assessed with the Mann-Kendall test. Overall, therefore, no significant change at EU level has been occurring since 2000 or since 2010.

Fact sheet 3.2.206: Share of fallow land in utilised agricultural area

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Condition - Structural ecosystem attributes (general)
- Name of the indicator: Share of fallow land in utilised agricultural area (UAA)
- Units: UAA %

2. Data sources

- Data holder: EUROSTAT
- Weblink: https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpsh1&lang=en
- Year or time-series range: 2000 – 2017 by country and NUTS2 regions, 2000 – 2016: EU aggregate is available
- Access date: 21/02/2019
- Reference: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Fallow_land

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Fallow land is all arable land included in the crop rotation system, whether worked or not, but with no intention to produce a harvest for the duration of the crop year.

Fallow land can be either:

- bare land bearing no crops at all;

- land with spontaneous natural growth which may be used as feed or ploughed in;

- land sown exclusively for the production of green manure (green fallow).

The common characteristic of all fallow lands that they are left to recover normally for the whole crop year, therefore they can be beneficiary for biodiversity and ecosystem services. However, their impact depends on the type of fallow land, on the management and other conditions.

The data is available at EU-28, Member State and NUTS2 region level. Data is missing in several NUTS2 regions in at least 3 years in the period since 2010 so trends were not calculated for those (e.g. in taly, Finland, Croatia).

3.2. Maps

No significant trend was found in most of the NUTS2 regions in the EU-28 in the short-term (Figure 1). There was a significant upward trend in a very small number of regions and downward trend is some regions, mostly in France, Poland, Romania and in Spain.

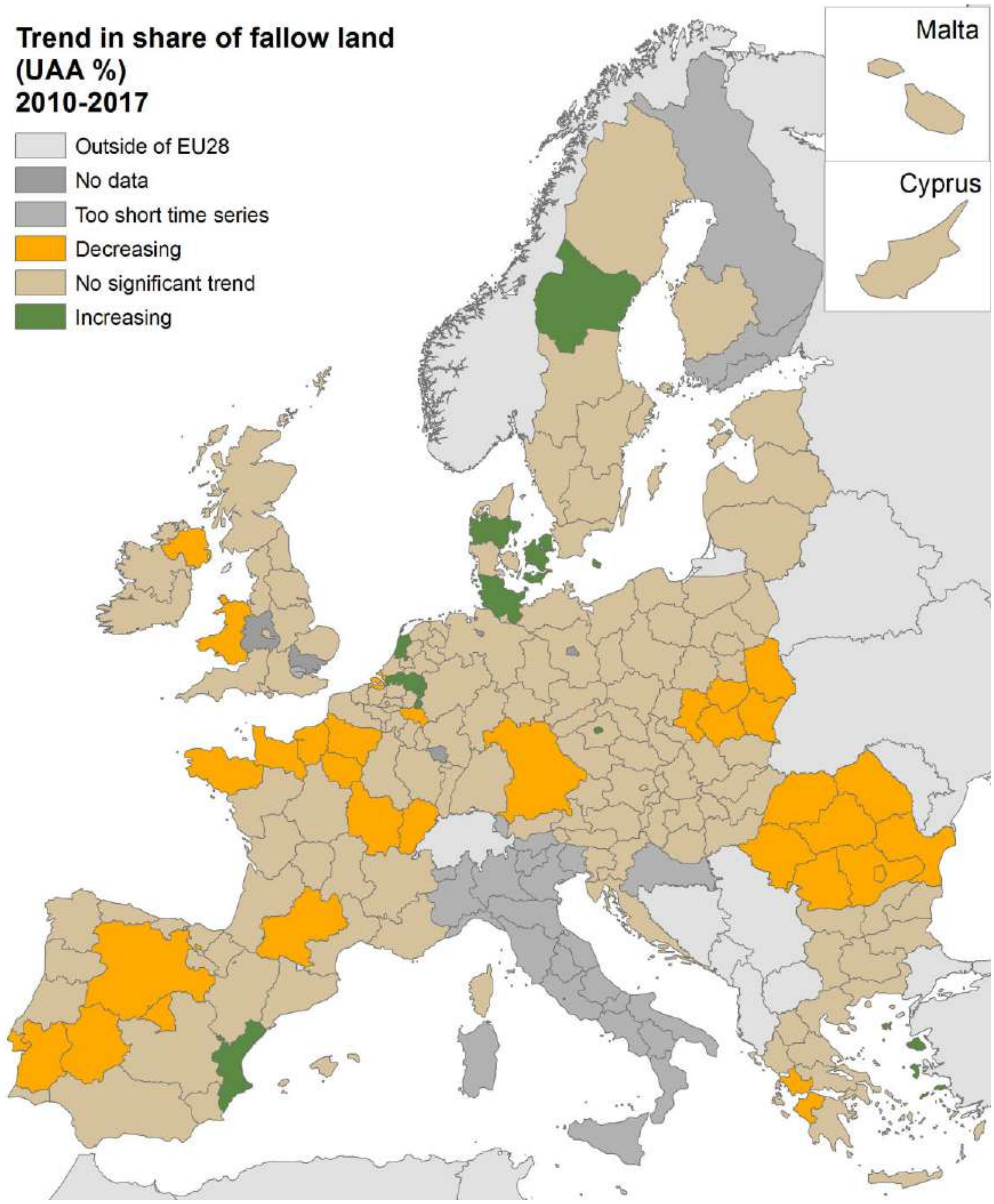


Figure 1 Short-term trend in share of fallow land at regional level (NUTS2) in the EU-28.

3.3. Statistical analysis of the trend

The long-term- and short-term trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trends was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall 1975; Mann 1945). The short-term and long-term relative changes were calculated from the slope of the trends and the baseline value (2010) of the trendline.

3.4. Key trend at EU level

The extent of fallow land decreased by 2 548 740 ha between 2010 (8 928 530 ha) and 2016 (6 379 790 ha) in the EU-28 (Figure 1, Table 1). The long-term downward trend (2000-2017) is significant, the corresponding relative decadal change is -37.8%. The relative change calculated from the short-term trend is 60.5%. Therefore, the share of fallow land shows degradation both on the short term and on the long term.

Table 1 Share of fallow land (UAA%) between 2010 and 2017 in the EU-28. NA: no data.

	2010	2011	2012	2013	2014	2015	2016	2017
Share of fallow land (UAA%) in the EU-28	4.96	NA	NA	3.87	3.69	3.85	3.57	NA

Table 2 Trends in share of fallow land. *: significant trend at 0.05 level.

	Slope of long-term linear trend [% / year]	Slope of short-term linear trend [% / year]	Percentage point change per 10 years (from short-term trend)	Relative change per 10 years (from long-term trend) (%)	Percentage point change per 10 years (from long-term trend)	Relative change per 10 years (from short-term trend) (%)
EU-28	-0.167*	-0.30	-3	-37.84	-1.67	-60.53

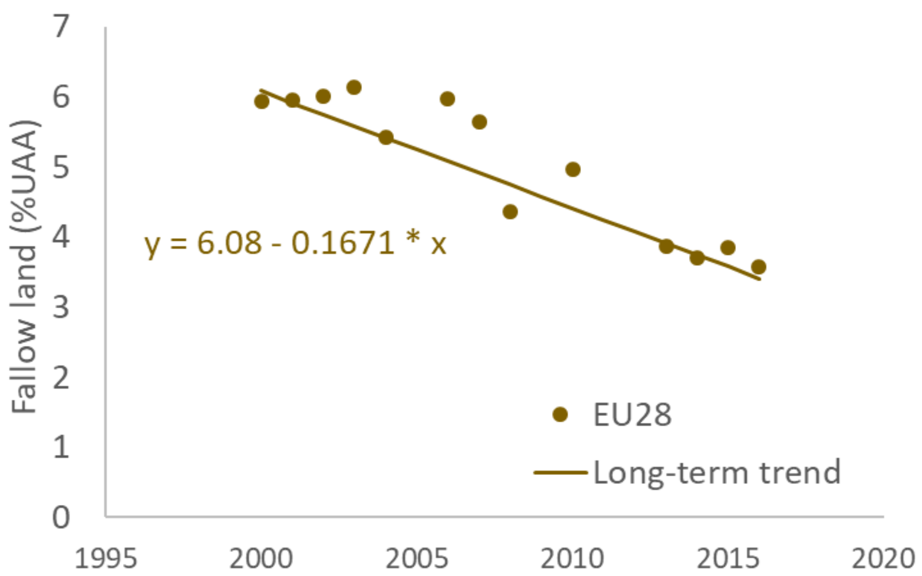


Figure 2 (Short-term and) long-term trend in fallow land (%) in the EU-28 based on linear regression and Sen's slope.

Fact sheet 3.2.207: High Nature value (HNV) farmland

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Condition - Structural ecosystem attributes (general)
- Name of the indicator: Share of HNV farmland in total agricultural area
- Units: %

2. Data sources

- Data holder: EEA
- Weblink: https://www.eea.europa.eu/data-and-maps/data/high-nature-value-farmland
- Year or time-series range: 2000, 2006, 2012, 2018
- Access date: 18/10/2019
- Version: the data is based on the Corine Land Cover accounting layers version v2018_20 (CLC2000ACC_V2018_20.tif, CLC2006ACC_V2018_20.tif, CLC2012ACC_V2018_20.tif and CLC2018ACC_V2018_20.tif)
- Reference: Report 1.7.7.2 – HNV farmland update 2000 – 2018 (2019), Paracchini, M. L.; Petersen, J.-E.; Hoogeveen, Y.; Bamps, C.; Burfield, I. and 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. JRC Scientific and Technical Reports. European Communities, Luxembourg

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The HNV farmland maps aim to provide information on the distribution and extent of farmland that potentially is of biodiversity value. They are based on Corine land cover and biodiversity related datasets (Paracchini et al., 2008).

3.2. Maps

The following map (Figure 1) shows the spatial distribution of HNV farmland in 2018

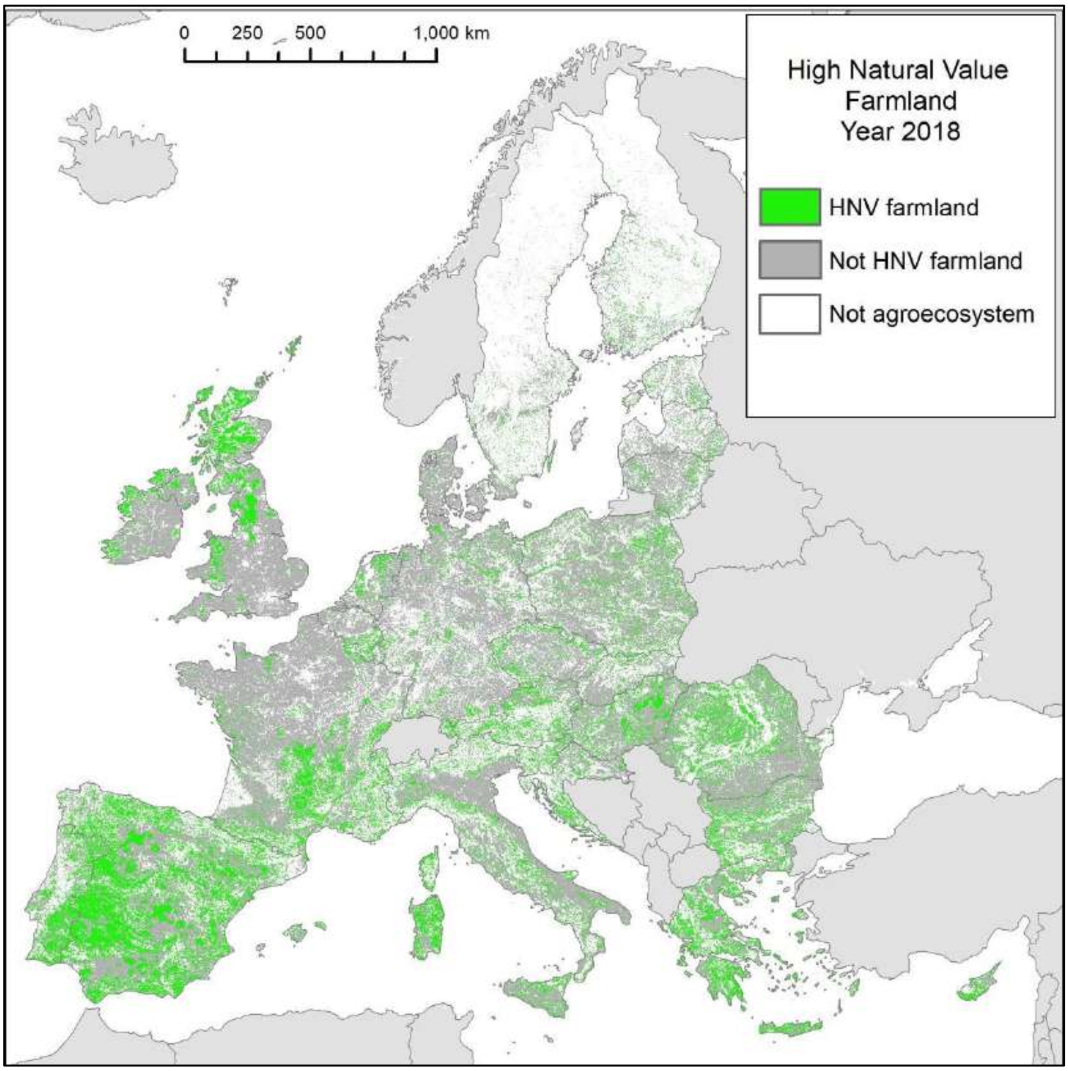


Figure 1 High Nature Value farmland in 2018 in the EU-28

3.3. Statistical analysis of the trend

The short-term and long-term trends were analysed with ordinary linear regression. The year 2012 was used as baseline as is the closest year to 2010.

3.4. Key trend at EU level

The indicator is very stable. In absolute terms (toal HNV area), there is a very slight decrease, whilst in percentage terms there is a very slight increase du to the concomitant decrease of total agricultural area. The 2012 baseline of share of HNV farmland on total agricultural area is 35.81%. In both cases, the slope of the trend line in the linear regression is not significantly different from 0, so the trend is 0 both on the short- and on the long term.

	2000	2006	2012	2018
HNV area EU-28 (ha)	75,231,217	75,144,969	75,167,308	75,082,135
% referring to 2000	100.00%	99.89%	99.92%	99.80%
Share of High Nature Value farmland in agricultural area (%)	35.66%	35.71%	35.81%	35.81%

Locally, some changes are visible in some member states (Figure 2), particularly in Hungary (reflecting changes in the presence of grasslands), Czech Republic and the western part of the Iberian peninsula, reflecting shrinkage of traditional agroforestry areas (*dehesas* and *montados*)

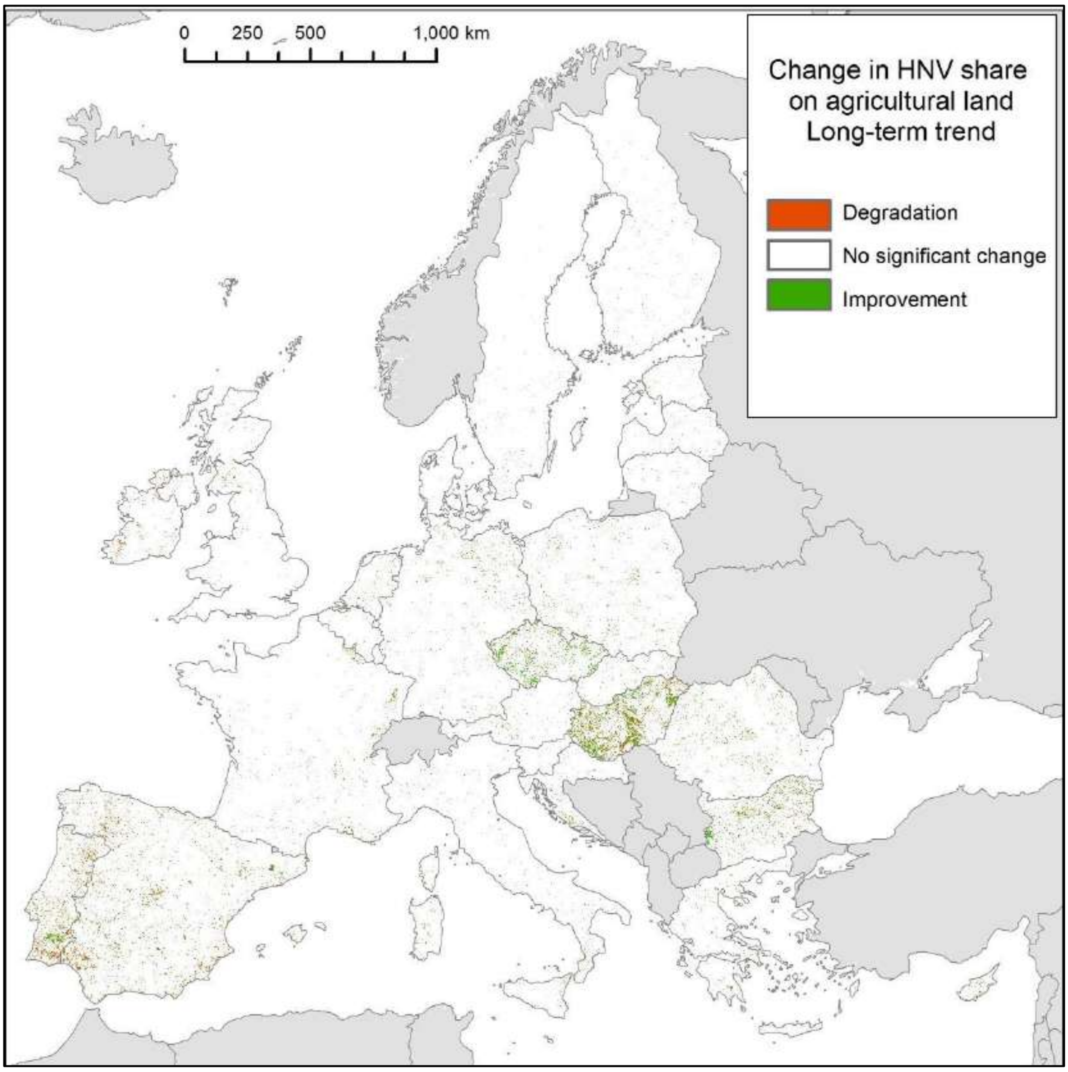


Figure 2 Long-term trend in share of HNV farmland on total agricultural area.

Fact sheet 3.2.208: Share of organic farming in Utilised Agricultural Area

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Condition - Structural ecosystem attributes (general)
- Name of the indicator: Share of organic farming in UAA
- Units: %

2. Data sources

- Data holder: EUROSTAT
- Weblink: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=sdg_02_40
  and UAA: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tag00025
- Year or time-series range: 2005 - 2017
- Access date: 22/01/2019 and 07/02/2019 for organic arable land and grasslands
- Reference: https://ec.europa.eu/eurostat/statistics-explained/index.php/Organic_farming_statistics

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The indicator is defined as the share of total utilised agricultural area (UAA) occupied by organic farming, including existing organically-farmed areas and areas in process of conversion. Organic production of crops and livestock is defined by the Council Regulation (EC) No 834/2007. The detailed rules for the implementation of this Regulation are laid down in Commission Regulation (EC) No 889/2008.

The indicator is used to assess the share of agroecosystems under management practices potentially supporting biodiversity, together with the indicator of share of High Nature Value farmland.

3.2. Statistical analysis of the trend

The long-term- and short-term trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trends was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall 1975; Mann 1945).

The trend in share of organic farming was analysed for the whole EU and for each Member States. The long-term trend was calculated for the whole period for which data is available (from 2005 for the EU, from 2000, 2003, 2004, 2005 or 2012 depending on the country until 2017). The short-term trend means the period 2010-2017, starting in 2012 for Croatia due to lack of data from previous years.

3.3. Maps

The share of organic farming has been significantly increasing between 2010 and 2017 in 19 Member States and decreasing in the United Kingdom. There was no significant trend in the remaining eight countries (EL, HU, MT, AT, PL, PT, RO, SK), where the actual share of organic farming (in 2017) is diverging from low to high compared to the EU average (Table 1).

The long-term trend is statistically significant for each country taking into account the whole period for which data is available. The share of organic farming has been increasing in all countries except the United Kingdom where it has been decreasing significantly and Malta where there was no change (Table 2).

Table 1 Share of organic farming in 2010-2017 and the trend in the Member States of the EU (in %). NA: not available. *: significant change at 0.05 level.

Member State	Baseline (2010)	2011	2012	2013	2014	2015	2016	2017	Slope (% / year)
BE	3.6	4.1	4.48	4.67	5	5.17	5.8	6.28	0.36*
BG	0.5	0.5	0.76	1.13	0.96	2.37	3.2	2.72	0.37*
CZ	12.4	13.1	13.29	13.47	13.44	13.68	14	14.09	0.18*
DK	6.1	6.1	7.31	6.44	6.25	6.33	7.81	8.6	0.21*
DE	5.9	6.1	5.76	6.04	6.18	6.34	6.82	6.82	0.15*
EE	12.8	14.1	14.86	15.65	15.96	15.68	18.02	19.6	0.79*
IE	1.1	1.1	1.16	1.2	1.16	1.65	1.72	1.66	0.09*
EL	8.4	5.2	9.01	7.36	6.72	7.7	6.5	7.96	-0.09
ES	6.7	7.5	7.49	6.85	7.26	8.24	8.48	8.73	0.25*
FR	2.9	3.4	3.55	3.66	3.87	4.54	5.29	5.99	0.42*
HR	NA	NA	2.4	3.13	4.03	4.94	6.05	6.46	0.85*
IT	8.6	8.4	9.3	10.6	10.91	11.79	13.99	14.86	0.90*
CY	2.8	2.9	3.38	4.03	3.63	3.72	4.94	4.57	0.27*
LV	9.2	10.1	10.63	9.89	10.86	12.29	13.42	13.92	0.67*
LT	5.2	5.4	5.51	5.74	5.57	7.11	7.5	7.98	0.41*
LU	2.8	2.8	3.14	3.39	3.43	3.21	3.47	4.15	0.16*
HU	2.4	2.3	2.45	2.45	2.34	2.43	3.48	3.73	0.12
MT	0.2	0.2	0.32	0.06	0.29	0.25	0.21	0.35	0.01
NL	2.5	2.5	2.61	2.65	2.67	2.67	2.91	3.14	0.07*
AT	19.5	19.6	18.62	18.4	19.35	20.3	21.25	23.37	0.56
PL	3.3	4.1	4.51	4.65	4.56	4.03	3.72	3.41	-0.08
PT	5.8	6.1	5.48	5.31	5.74	6.52	6.75	7.04	0.20
RO	1.3	1.6	2.1	2.06	2.09	1.77	1.67	1.93	0.04
SI	6.4	7	7.32	8.07	8.55	8.85	9.12	9.6	0.46*
SK	9.1	8.6	8.53	8.18	9.37	9.47	9.75	9.9	0.20
FI	7.4	8.2	8.65	9.07	9.29	9.91	10.47	11.38	0.51*
SE	14.3	15.7	15.76	16.5	16.53	17.14	18.3	19.16	0.62*
UK	4.1	3.7	3.41	3.24	3.02	2.89	2.82	2.87	-0.18*

Table 2 Slope of the long-term trend in the Member States of the EU (time series starts in 2000 or in 2003/2004/2005 depending on the country).

Member State	Long-term slope (% / year)
EU	0.28
BE	0.30
BG	0.18
CZ	0.60
DK	0.10
DE	0.20
EE	0.95
IE	0.05
EL	0.26
ES	0.45
FR	0.22
HR	NA
IT	0.36
CY	0.31
LV	0.56
LT	0.40
LU	0.11
HU	0.07
MT	0.01
NL	0.05
AT	0.47
PL	0.33
PT	0.28
RO	0.11
SI	0.39
SK	0.44
FI	0.26
SE	0.85
UK	-0.06

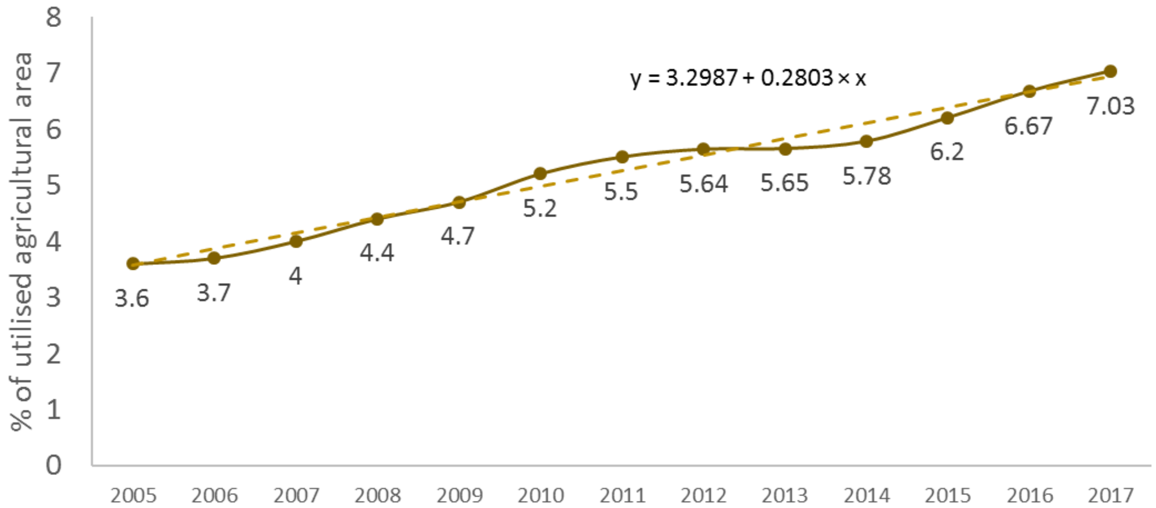
3.4. Key trend at EU level

The share of organic farming has been increasing in the EU (Table 3 and Figure 2), the linear trend is statistically significant at the 0.05 level, both for the period 2005-2017 and 2010-2017. The percentage changes are quite high but it has to be noted that they are not only high due to significant changes but also because the baseline values are rather low.

Table 3 Share of organic farming in utilized agricultural area in the EU (%UAA). 2005-2011: 27 countries, 2012-2017: 28 countries.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Organic farming (%) in the EU	3.6	3.7	4	4.4	4.7	5.2	5.5	5.64	5.65	5.78	6.2	6.67	7.03

	Baseline (2010) [UAA %]	**Share of organic farming in 2017 [UAA%]**	**Slope of long-term linear trend [% / year]**	**Slope of short-term linear trend [% / year]**	**Relative change per 10 years (from long-term trend) (%)**	**Relative change per 10 years (from short-term trend) (%)**
Organic farming	5.2	7.03	0.28	0.25	56.28	45.87



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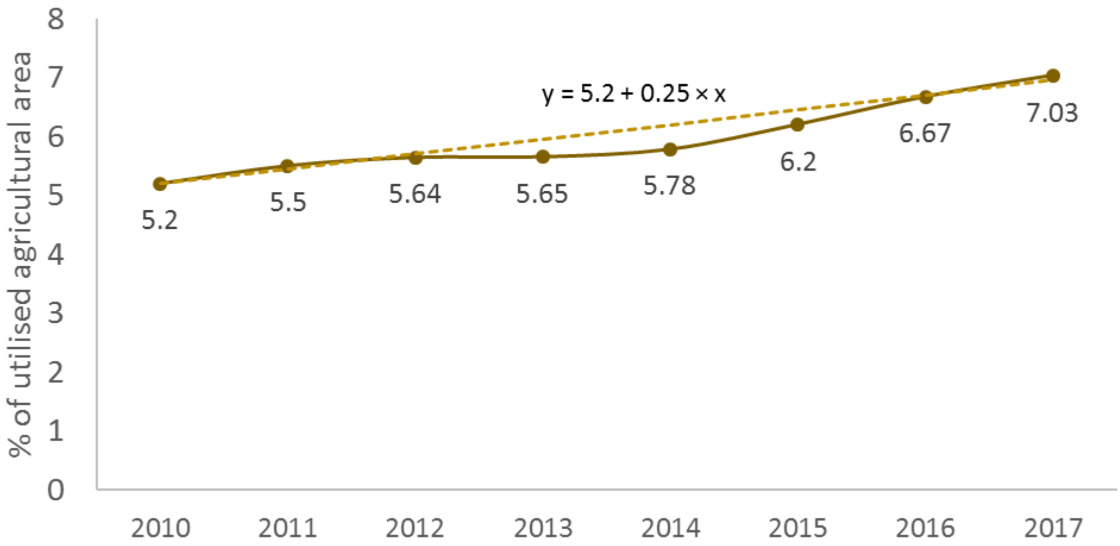


b.

Figure 1 Trend in share of organic farming in utilized agricultural area in the EU (%) for the periods (a) 2005-2017 and (b) 2010-2017 (2005-2011: 27 countries, 2012-2017: 28 countries).

Fact sheet 3.2.209: Livestock density

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Condition - Structural ecosystem attributes (general)
- Name of the indicator: Livestock density
- Units: Livestock units (LU)/ha

2. Data sources

- Data source: EUROSTAT
- Data holder: JRC
- Weblink:
- Livestock density: https://ec.europa.eu/eurostat/databrowser/view/tai09/default/table?lang=en
- Utilised agricultural area (UAA) : http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=apro_cpsh1&lang=en
- Years: 2005, 2007, 2010, 2013, 2016
- Access date: 29/11/2019
- https://ec.europa.eu/eurostat/web/products-datasets/-/tai09

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The livestock density index provides the number of livestock units (LSU) per hectare of utilised agricultural area. The LSU is a reference unit which facilitates the aggregation of livestock from various species and ages. The Eurofarm LSU coefficients, which are at the basis of this indicator, are established by convention (originally, they were related to the animals' feed requirements, the reference being a dairy cow with an annual yield of 3000 kg milk, without additional concentrated feedingstuffs). In the interpretation of the livestock density index, the limits of this theoretical unit are to be taken into account.
The livestock species aggregated in the LSU total, for the purpose of this indicator, are: equidae, cattle, sheep, goats, pigs, poultry and rabbits.

The condition of the agroecosystems is assumed to be better where the livestock density is lower.

The indicator is available at country level in 5 years, in every third year between 2005 and 2016. Data is missing for Croatia in 2005 so it was imputed taking the value from the next year available (2007). 2016 data was provisional for Ireland and Italy. The EU aggregates were calculated as weighted average using UAA values for weighting.

3.2. Maps

There is an upward short-term trend in 5 countries and downward short-term trend in 10 countries (Table 1). There was an upward long-term trend in 5 countries and downward long-term trend in 15 countries (Table 1). The upward trend was the highest in Ireland in the short term and in Austria in the short term. The downward trend was the highest in Croatia in the short term and in Bulgaria in the long te rm.

Table 1 Livestock density data between 2003 and 2016

Member State	2005	2007	2010	2013	2016	Short-term trend per 10years	Long-term trend for 10 years
Belgium	2.8	2.76	2.8	2.74	2.79	-0.60	-0.32
Bulgaria	0.49	0.41	0.26	0.22	0.24	-12.82	-87.41
Czechia	0.58	0.58	0.49	0.5	0.51	6.80	-12.99
Denmark	1.69	1.72	1.86	1.58	1.58	-25.09	-5.38
Germany	1.07	1.06	1.07	1.1	1.09	3.12	1.70
Estonia	0.38	0.35	0.33	0.32	0.28	-25.25	-27.55
Ireland	1.47	1.43	1.16	1.2	1.27	15.80	-15.67
Greece	0.62	0.64	0.46	0.44	0.46	0.00	-31.62
Spain	0.58	0.58	0.62	0.62	0.62	0.00	5.87
France	0.82	0.82	0.81	0.79	0.79	-4.12	-3.37
Croatia	0.9	0.9	0.78	0.55	0.48	-64.10	-48.95
Italy	0.75	0.78	0.77	0.77	0.75	-4.33	0.00
Cyprus	1.61	1.69	1.7	1.6	1.54	-15.69	-3.74
Latvia	0.27	0.28	0.26	0.26	0.26	0.00	-3.50
Lithuania	0.46	0.39	0.33	0.29	0.29	-20.20	-46.83
Luxembourg	1.22	1.23	1.28	1.26	1.33	6.51	7.81
Hungary	0.59	0.57	0.53	0.49	0.52	-3.14	-12.01
Malta	4.5	4.8	3.64	3.21	2.92	-32.97	-39.46
Netherlands	3.26	3.35	3.58	3.57	3.8	10.24	13.71
Austria	0.75	0.78	0.87	0.89	0.91	7.66	16.72
Poland	0.72	0.72	0.72	0.64	0.66	-13.89	-7.58
Portugal	0.56	0.58	0.6	0.56	0.61	2.78	7.58
Romania	0.47	0.44	0.41	0.38	0.39	-8.13	-17.74
Slovenia	1.08	1.13	1.07	1	1.05	-3.12	-2.55
Slovakia	0.42	0.39	0.35	0.34	0.33	-9.52	-23.38
Finland	0.51	0.5	0.49	0.51	0.48	-3.40	-5.57
Sweden	0.57	0.57	0.57	0.56	0.57	0.00	0.00
United Kingdom	0.9	0.86	0.79	0.76	0.79	0.00	-12.66

3.3. Statistical analysis of the trend

The relative short-term change was calculated from the last year and 2010 indicator values and the 5% rule was applied for the assessment of the trend. For the long-term trend, ordinary least squares regression was fitted on the observed data and the slope was used to calculate the relative change (%/ 10 years).

3.4 Key trend at EU level

The EU level weighted average of livestock density shows a slight but significant downward long-term trend at a rate of -0.0044 unit per decade on the long term (2005-2016), which corresponds to 6.51 % decrease per decade. The trend on the short term (2010-2016) was 2.96% decrease per decade, which is less than 5% so livestock density has been stable since 2010.

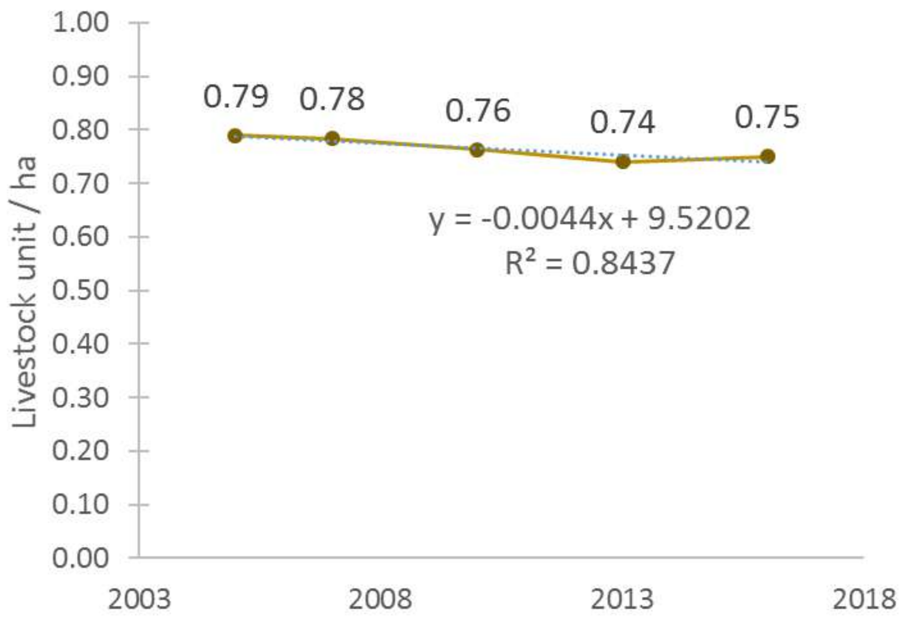


Figure 1 Livestock density at EU-28 level between 2005 and 2016.

Fact sheet 3.2.210: Changes in the abundance of common farmland birds

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Condition - Structural ecosystem attributes based on species diversity and abundance
- Name of the indicator: Farmland bird indicator
- Units: %, index of relative values with respect to a base year (1990)

2. Data sources

- Data holder: European Bird Census Council , EBCC
- Data source: EBCC/BirdLife/RSPB/CSO
- Weblink: http://www.pecbms.info/
- Year or time-series range: EU: 1990-2015, Regional indicators: 1980- / 1982- /1989 - 2016
- Access date: 08/04/2019
- Version: 2019
- Reference: Gregory R.D., Škorpilová J., Voříšek P., Butler S. 2019. An analysis of trends, uncertainty and species selection shows contrasting trends of widespread forest and farmland birds in Europe. Ecological Indicators 103: 676-687.

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The farmland bird indicator is used to assess biodiversity in agroecosystems. It shows trends in the abundance of common farmland birds across their European ranges over time. It is a composite index created from data of 39 bird species characteristic for farmland habitats in Europe. A value of 100 is set for the first year of the time series and the index values in the time series indicate the abundance relative to the base year. The base year of 1990 was chosen because the data and methodology are more consistent for the period since then.

3.2. Maps

The index and their trends are available for the EU and for four regions of Europe (West, North, East and South). Spatial data is not available.

The decadal relative decrease was more than 5% in each region for each period (first year-2016, 1990-2016, 2010-2016). The regional relative change between 2010 and 2015 was higher in each region than the EU level change (Table 2) but the trends were still not significant statistically (Table 1). The regional relative change between 1990 and 2015 was higher in each region except Southern Europe than the EU level change. The long-term downward trends were statistically significant in the four regions (Table 1 and Figure 1).

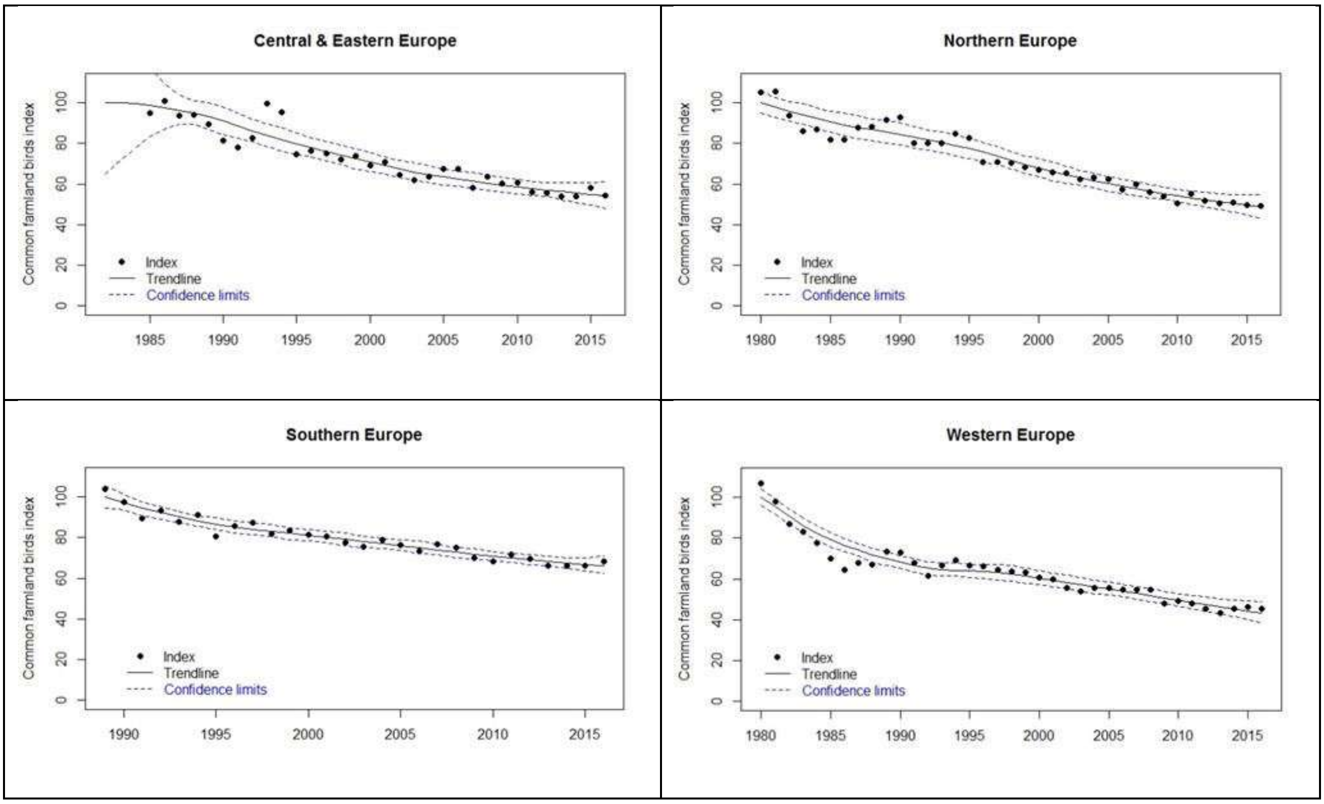


Figure 1 Regional farmland bird indices.

Table 1 Values and trends of the regional farmland bird indices, number of species included in the calculations, and number of species with different trends (increasing, declining, stable, uncertain). *: statistically significant trend at α = 0.05 level.

	Central & Eastern Europe	North Europe	South Europe	West Europe
Time period	1982-2016	1980-2016	1989-2016	1980-2016
Index value in 2010	58.63	54.19	70.86	49.62
Index value in the latest year (2016)	54.33	48.75	66.17	43.27
Decadal % change (long-term, 1990-2016)	-24.17	25.30	-16.82	-19.29
Decadal % change (long-term, first year-2016)	-22.91	-27.82	-17.68	--31.76
Decadal % change (short-term, 2010-2016)	-10.46	-14.27	-11.03	-17.84
Slope of the long-term trend, 1990-2016 (unit/year)	-1.17*	-1.376*	-1.08*	-1.08*
Decadal % change from the long-term linear trend (1990-2016)	-19.78	-25.32	-15.31	-21.55
Slope of the short-term trend 2010-2016 (unit/year)	-0.508	-0.555	-0.388	-0.4725
Decadal % change from the short-term linear trend	-8.94	-10.53	-5.69	-9.76
Total number of species included	23	14	37	22
Increasing	2	1	6	4
Declining	13	10	19	17
Stable	6	3	11	1
Uncertain	2	0	1	0

Data source: EBCC/BirdLife/RSPB/CSO. The countries included in the regional indicators:
Central & Eastern Europe: Czech Republic, Estonia, former East Germany, Hungary, Latvia, Lithuania, Poland, Slovakia. **North Europe**: Finland, Norway, Sweden. **South Europe**: France, Italy, Portugal, Spain. **West Europe**: Austria, Belgium, Denmark, former West Germany, Luxembourg, Netherlands, Republic of Ireland, Switzerland, United Kingdom.

3.3. Statistical analysis of the trend

The smoothed trend provided by EBCC and the 5% rule was used for the assessment.

The regional trends (relative changes) were calculated for the long-term (first year-2016, 1990-2016) and short-term (2010-2016).

Both the long-term- (1990-2016) and short – term (2010-2016) trends were estimated using also the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012) for the indicator values (not smoothed). The significance of monotonic trends was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall 1975; Mann 1945).

3.4 Key trend at EU level

The percentage changes of the indicator calculated from the smoothed trend line values are shown in Table 1. The relative decrease per 10 years was more than 5% on both the long-term and short-term (Table 1).

The common farmland bird indicator has been decreasing statistically significantly at EU level on the long-term at a rate of 1.23 per year ($p < 0.05$) (Figure 1). The decreasing trend seems to be flattened between 2010 and 2015. The linear trend for this period is not significant statistically (Figure 2).

Table 2 Percentage changes of the smoothed farmland bird index for the EU-28 (without Croatia and Malta due to missing data). *: statistically significant trend at α = 0.05 level.

	First year	Last year	Baseline (2010)	% change occurred in the studied period (from smoothed values)	Decadal % change (from smoothed values)	Slope of linear trend (index/year)	Decadal % change (from the linear trend)
Long-term trend (1990-2015)	100	68.2	72.15	-44.07%	-17.63%	-1.33*	-13.47*
Short-term trend (2010-2015)	72.15	68.2	72.15	-5.47	-10.95	-0.53	-7.38

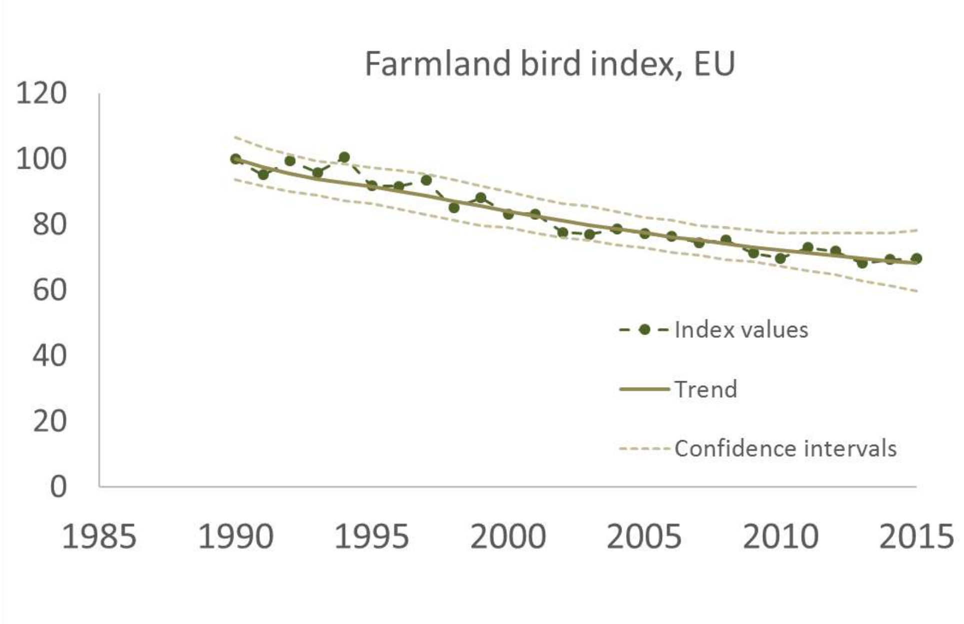


Figure 1 Trend in common farmland bird index in the EU between 1990 and 2015. The dashed lines represent the confidence limits. Source: EBCC/BirdLife/RSPB/CSO.

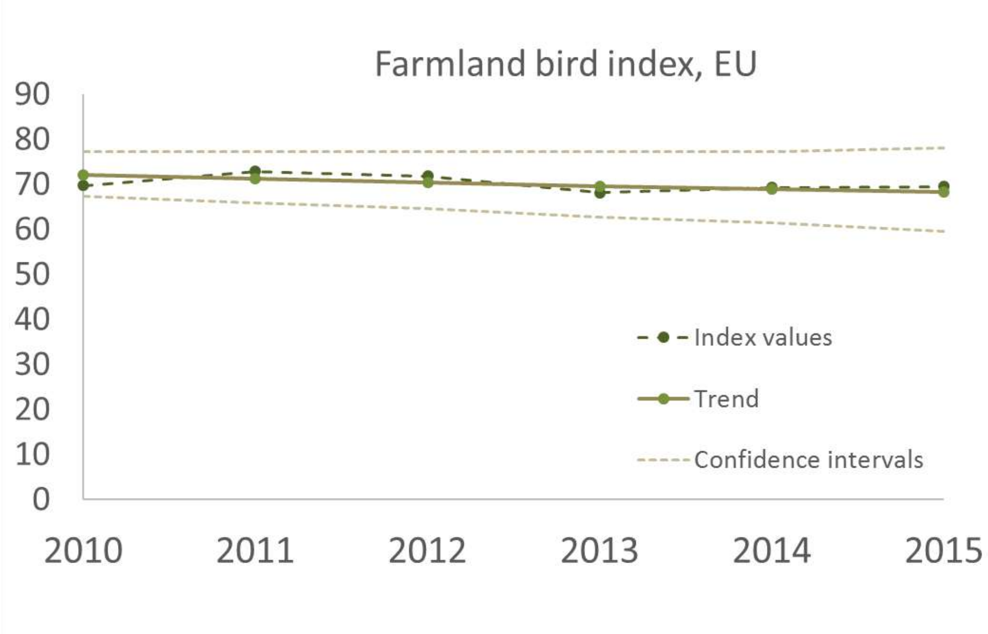


Figure 2 Farmland bird indicator of the EU in 2010-2015.

Technical details about the indicator

The index

The index is a is a composite, Multi-Species Indicator (MSI) calculated using Monte Carlo simulations as described in Soldaat et al. (2017) and an R-script developed by Statistics Netherlands (2017).

The index and their trends for the EU and for regions of Europe (West, North, East and South) were calculated from different data, from EU and regional individual species indices, respectively. The number of common farmland bird species included in the EU index is 39.

In this assessment, the index calculated based on the single European species habitat classification was used.

The trendline

The trendlines (smoothed indicators) and their lower and upper confidence limits for the time periods from 1990-onwards were downloaded from the EBCC website. In case of the regional indicators, the baseline year was different in the different regions. It was 1982 for Central and East Europe, 1989 for Southern Europe and 1980 for Western Europe and North Europe. More information about the computation of the indices and the trend can be found on the web link provided.

Fact sheet 3.2.211: EU grassland butterfly indicator

1. General information

- Thematic ecosystem assessment: Grassland
- Indicator class: Condition - Structural ecosystem attributes based on species diversity and abundance
- Name of the indicator: EU grassland butterfly indicator (SEBI 001)
- Units: index without unit

2. Data sources

- Data holder: EEA, Butterfly Conservation Europe, European Butterfly Monitoring Scheme partnership, Assessing Butterflies in Europe (ABLE) project
- Data source: eBMS: www.butterfly-monitoring.net
- Weblink: https://www.eea.europa.eu/data-and-maps/daviz/european-grassland-butterfly-indicator-3#tab-chart_6
- Year or time-series range: 1990-2017
- Country coverage: Belgium, Estonia, Finland, France, Germany, Ireland, Lithuania, Luxembourg, the Netherlands, Portugal, Romania, Slovenia, Spain, Sweden, United Kingdom
- Access date: 08/07/2019
- Reference: Van Swaay, C.A.M., Dennis, E.B., Schmucki, R., Sevilleja, C.G., Balalaikins, M., Botham, M., Bourn, N., Brereton, T., Cancela, J.P., Carlisle, B., Chambers, P., Collins, S., Dopagne, C., Escobés, R., Feldmann, R., Fernández-García, J. M., Fontaine, B., Gracianteparaluceta, A., Harrower, C., Harpke, A., Heliölä, J., Komac, B., Kühn, E., Lang, A., Maes, D., Mestdagh, X., Middlebrook, I., Monasterio, Y., Munguira, M.L., Murray, T.E., Musche, M., Õunap, E., Paramo, F., Pettersson, L.B,, Piqueray, J., Settele, J., Stefanescu, C., Švitra, G., Tiitsaar, A., Verovnik, R., Warren, M.S., Wynhoff, I. & Roy, D.B. (2019). The EU Butterfly Indicator for Grassland species: 1990-2017: Technical Report. Butterfly Conservation Europe & ABLE/eBMS (www.butterfly-monitoring.net). https://butterfly-monitoring.net/sites/default/files/Publications/Technical%20report%20EU%20Grassland%20indicator%201990-2017%20June%202019%20v4%20(3).pdf

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The European Grassland Butterfly Indicator is one of the status indicators on biodiversity in Europe. It is based on the population trends of 17 butterfly species in 19 countries. Out of the 17 species, 8 species showed decline, 2 species stable, 1 species moderate increase and the trend in 6 species is uncertain.

For the interpretation it has to be kept in mind that a large decline of butterflies in north-western Europe happened before 1990. Large year-to-year fluctuations or a low number of transects can lead to high uncertainty at EU level. Data is not available from 9 Member States but the coverage can be reasonably representative. The coverage of the species' populations may be lower at the beginning of the data series as countries have been joining in during the years.

3.2. Statistical analysis of the trend

Linear trends were calculated from the unsmoothed indicator. The long-term- and short-term trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trends was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall

1975; Mann 1945). The short-term and long-term relative changes were calculated from the slope of the trends and the baseline value (2010) of the trendline.

3.3. Key trend at EU level

The grassland butterfly indicator has been significantly decreasing in the long-term (1990-2017). The relative change per 10 years calculated from the long-term trend (and compared to the 2010 baseline value of the trend) is 21.6% (Table 1 and Figure 1). The relative change per 10 years calculated from the short-term trend (and compared to the 2010 baseline value of the trend) is more than 5%. However the trend is not significant and based on visual inspection of the temporal pattern the values are fluctuating so the short-term trend is considered unresolved.

Table 1 Changes in grassland butterfly index between 1990 and 2017. *: significant change at 0.05 level.

	Baseline (2010)	Decadal % change (calculated from long-term trend 1990-2017) [%/10 years]	Decadal % change (calculated from short-term trend 2010-2017) [%/10 years]
Grassland butterfly indicator	62.15	-21.63	-9.36

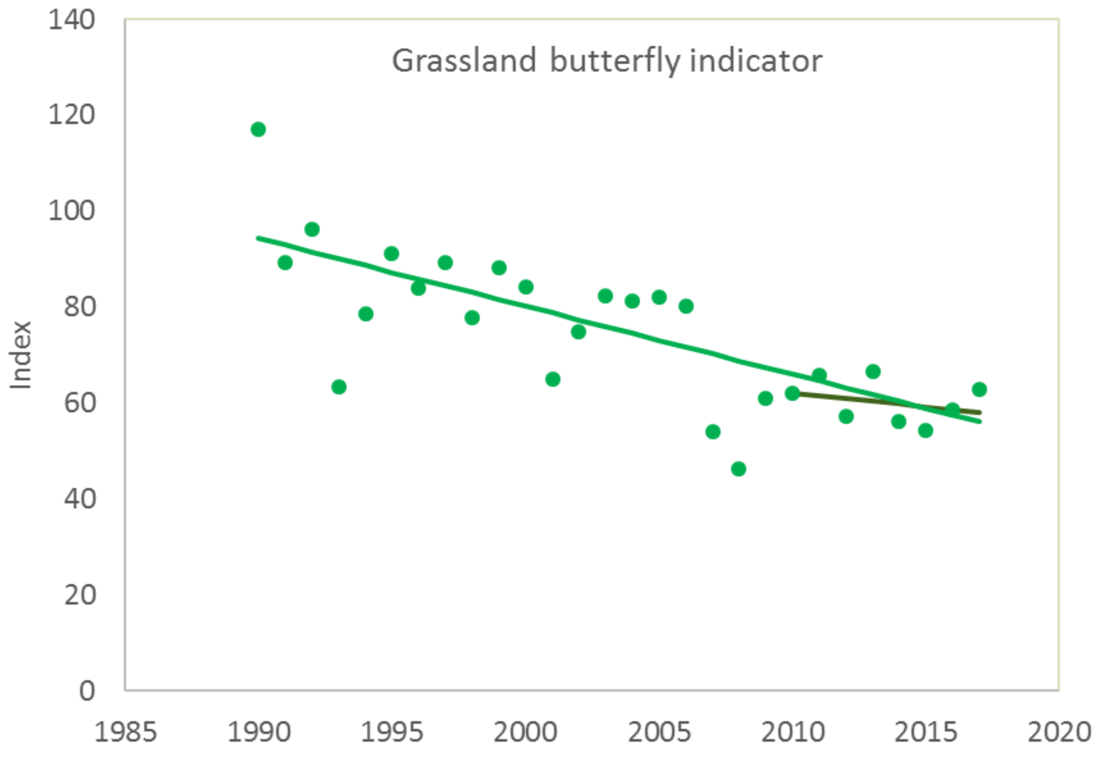


Figure 1 Grassland butterfly index. Annual values, long-term and short-term trend. The long-term trend is significant, short-term trend is not.

Fact sheet 3.2.213: Percentage of cropland and grassland covered by Natura 2000 (%)

1. General information

- Thematic ecosystem assessment: cropland and grassland
- Indicator class: Condition. Structural ecosystem attributes monitored under the EU nature directives
- Name of the indicator: Percentage of cropland and grassland covered by Natura 2000 (%)
- Indicator description: The indicator measures the percentage of cropland and grassland protected by Natura 2000 sites from 2000 to 2018 and the trends.
- Units: percentage (%)

2. Data sources

- Data holder: EEA
- Weblinks:
    - Corine Land Cover https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data
    - Natura 2000 data - the European network of protected sites https://www.eea.europa.eu/data-and-maps/data/natura-10
- Year or time-series range 2000 / 2006 / 2012 / 2018
- Versions
    - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
    - Natura 2000 End 2018 – Shapefile
    - Natura 2000 End 2013 rev1 - Shapefile

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

At the EU level, the Nature Directives (Birds and Habitats) are the centerpiece of its nature legislation and biodiversity policy. The Natura 2000 sites are one of the Nature Directive's main tools that contribute to ensuring the conservation of many species and habitats of EU interest. Its purpose is primarily to ensure the conservation of targeted species and habitats of European interest. The Natura 2000 network is largely complete as far as the terrestrial environment is concerned and connectivity — spatial and functional — of Natura 2000 sites across national borders is relatively good.

Every country has designated Natura 2000 sites to help conserve the rare habitats and species present in their territory. Progress in designating sites was slow at first but currently the protected area is over 18 % of the EU's land area being the largest network of protected areas in the world (EEA, 2012).

This indicator aims to evaluate how the percentage of cropland and grassland protected by Natura 2000 site has been changed. The changes could be due to changes of ecosystem extent, for example due to agricultural abandonment, or also be associated with changes in the protection zones, either by the designation of new areas or by the modification of the limits of those already existing. Both cases are included in this assessment since the indicator values are obtained by overlapping the spatial information, by means of spatial analysis tools, of CLC 2000, 2006, 2012 and 2018 with Natura 2000 network informed by MS end of 2013 (previous versions of spatial data of Natura 2000 present gaps and geometric inconsistences), and from CLC 2018 with Natura 2000 version provided by 2018.

3.2. Maps

Maps as pixel based were not available. This indicator was provided as tabular information, aggregated at country, biogeographical region and EU-28 level. Figure 1 shows the indicator values in biogeographical regions in 2018.

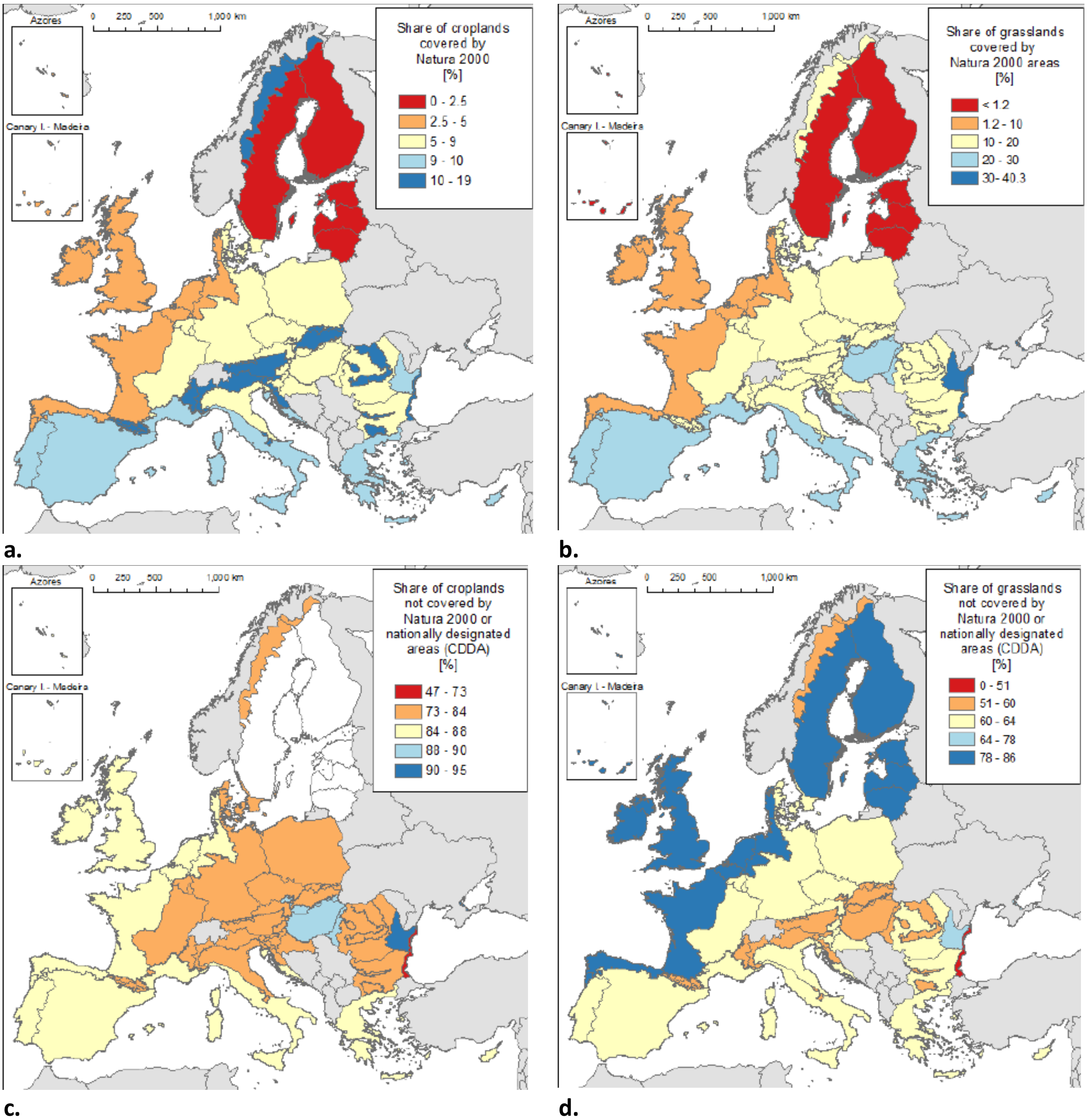


Figure 1 Share of (a) croplands and (b) grasslands covered by nationally designated areas (CDDA), (c) croplands and (d) grasslands not covered by CDDA or Natura 2000 in 2018.

3.3. Statistical analysis of the trend

Statistical tests were not used for trend analysis of this indicator because there are only four data points in time. Short-term change was calculated based on change between the most recent year (2018) and the closest year of Corine mapping to 2010 (2012). Long-term change was calculated based on the difference between 2018 and 2000. The 2010 baseline value was calculated by linear interpolation.

3.4. Key trend at EU level

The share of cropland and grassland covered by Natura 2000 has not changed in the studied period (Figure 2). The short-term and long-term percentage change per 10 years is 0% both for croplands and grasslands (Table 1).

Table 1 Percentage of croplands and grasslands covered by Natura 2000 in the period 2000-2018. % change / 10 years is calculated from the changes between 2012 and 2018 (short-term) and between 2000 and 2018 (long-term).

	2000	2006	2012	2018	2010 baseline	% change/10 years (2012-2018)	% change/10 years (2000-2018)
Cropland	5.77	5.78	5.78	5.79	5.78	0.0	0.0
Grassland	10.01	10.03	10.03	10.04	10.03	0.0	0.0

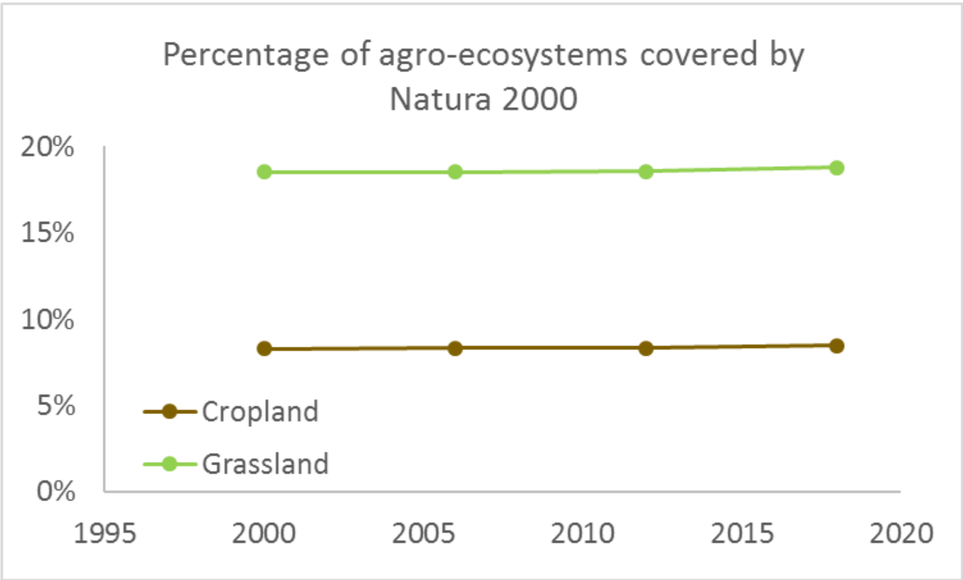


Figure 2 Percentage of croplands and grasslands covered by Natura 2000 in the period 2000-2018.

References

EEA, 2012. *Protected areas in Europe - an overview. European Environment Agency. EEA Report / No 5/2012,* s.l.: s.n.

Fact sheet 3.2.214: Percentage of cropland and grassland covered by Nationally designated areas –CDDA

1. General information

- Thematic ecosystem assessment: cropland and grassland
- Indicator class: Condition. Structural ecosystem attributes monitored under the EU nature directives
- Name of the indicator: Percentage of cropland and grassland covered by CDDA (%)
- Indicator description: The indicator measures the percentage of cropland and grassland protected by nationally designated areas from 2000 to 2018 and the trends.
- Units: percentage (%)

2. Data sources

- Data holder: EEA
- Weblinks:
    - Corine Land Cover https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/b90803ac-57db-4653-b393-3e04445a7035
    - CDDA data - Nationally designated areashttps://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-13
- Year or time-series range 2000 / 2006 / 2012 / 2018
- Versions
    - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
    - CDDA 2018 – Shapefile
- Reference https://www.eea.europa.eu/data-and-maps/indicators/nationally-designated-protected-areas-10

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The nationally designated areas -CDDA- is the official source of protected area information from the 39 European countries members of EEA to the World Database of Protected Areas (WDPA). A 'nationally designated protected area' is an area designated by a national designation instrument, based on national legislation.

This indicator aims to evaluate how the percentage of cropland and grassland protected by the nationally designated areas has being changed against time. The changes could be due to changes of ecosystem extent, for example due to agricultural abandonment, or also be associated with changes in the protection zones, either by the designation of new areas or by the modification of the limits of those already existing. This indicator focuses only on the trend in the percentage of protected cropland and grassland due to the change in the ecosystem extent. The CDDA digital maps are being reported by the countries from 2002, however this voluntary provision could trigger restrictions on the fully publication of the datasets. Consequently, the CDDA spatial information is not consistent over time. In fact, the last available dataset, CDDA v2018 , shows partially the spatial information of Estonia, Finland, Ireland and Turkey, since EEA does not have permission to distribute some or all sites reported by them.

The values of the indicator are the result of the overlapping, by means of spatial analysis tools, of CORINE LC 2000, 2006, 2012 and 2018 with and the nationally designated areas -CDDA- informed by MS in 2018.

3.2. Maps

Maps as pixel based were not available. This indicator was provided as tabular information, aggregated at country, biogeographical region or EU-28 level. Figure 1 shows the indicator values in biogeographical regions in 2018.

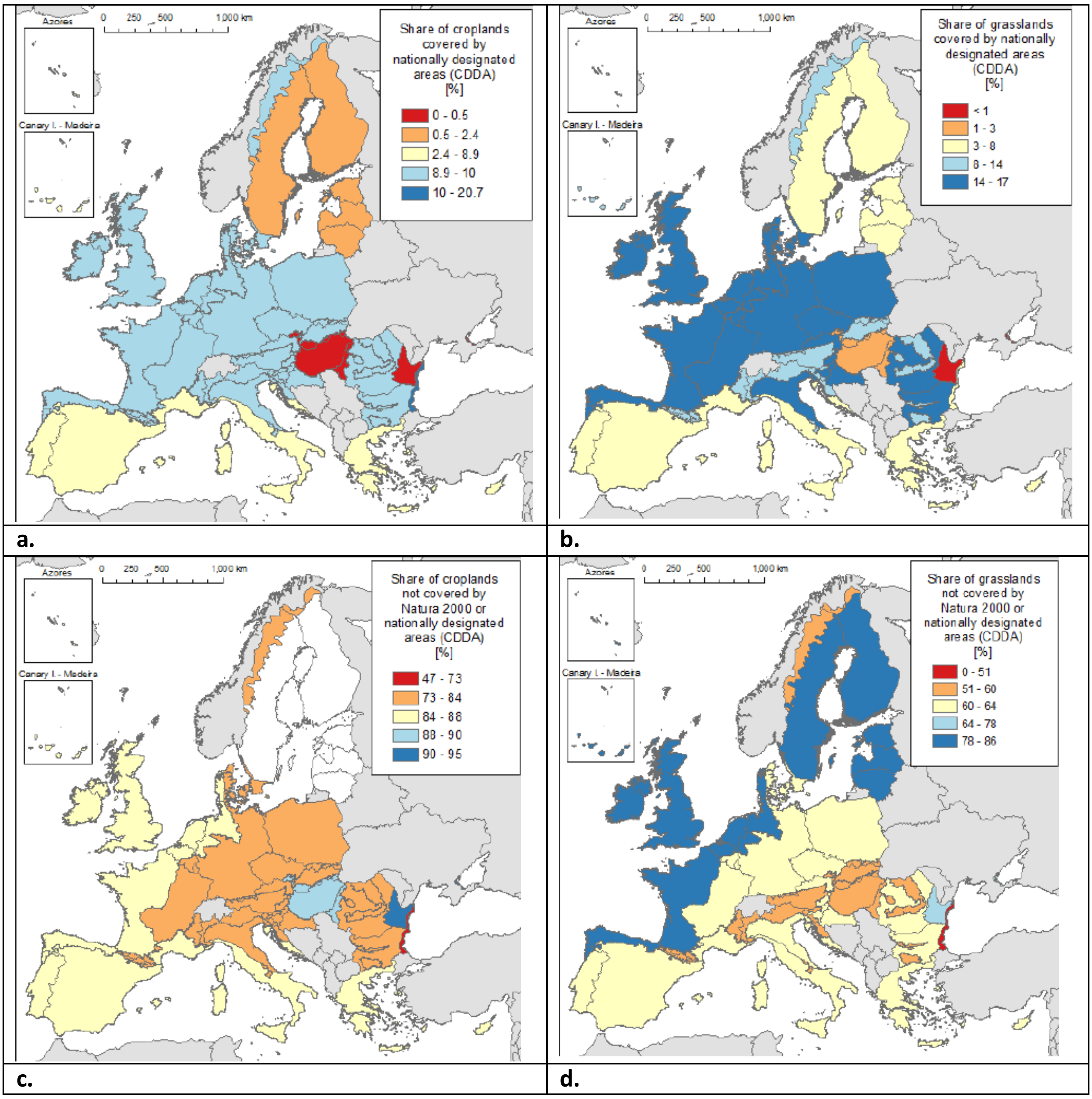


Figure 1 Share of grasslands covered by nationally designated areas (CDDA) in 2018.

3.3. Statistical analysis of the trend

Statistical tests were not used for trend analysis of this indicator because there are only four data points in time. The 2010 baseline value was calculated from the 2006 and 2012 values by linear interpolation. Short-term change was calculated based on change between the most recent year (2018) and the closest year of Corine mapping to 2010 (2012). Long-term change was calculated based on the difference between 2018 and 2000. The assessment of the indicator was done using the 5% rule.

3.4. Key trend at EU level

The share of cropland and grassland covered by CDDA is around 6 and 13%, respectively (Figure 2). These shares have not changed in the studied period. The short-term and long-term percentage change per 10 years are both below 5% both for croplands and grasslands (Table 1).

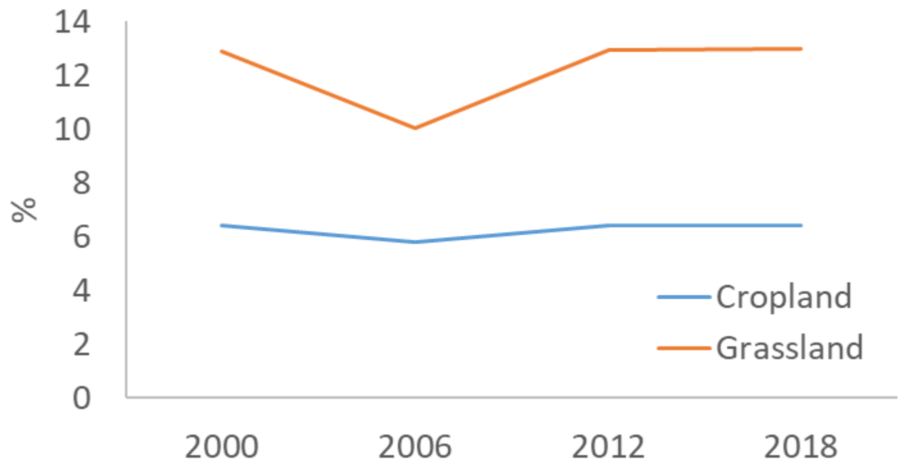


Figure 2 Share of croplands and grasslands covered by CDDA in the period 2000-2018.

Table 1 Percentage of croplands and grasslands covered by CDDA in the period 2000-2018. % change / 10 years is calculated from the changes between 2012 and 2018 (short-term) and between 2000 and 2018 (long-term).

	2000	2006	2012	2018	2010 baseline	% change/10 years (2012-2018)	% change/10 years (2000-2018)
Cropland	6.40	6.41	6.41	6.41	6.407	-0.0438	0.0226
Grassland	12.90	12.93	12.94	12.97	12.935	0.442	0.326

Fact sheet 3.2.216: Spatial assessment of trend in topsoil organic carbon content

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: condition
- Name of the indicator: topsoil organic carbon content
- Units: Tons of Carbon/ha

2. Data sources

- Data holder, data source: JRC
- Year or time-series range: 1980, 1990, 2000, 2010, 2008, 2010, 2015, 2020 (extrapolated)
- Access date--- 17/10/2019
- **References**: Lugato, E., Bampa, F., Panagos, P., Montanarella, L., & Jones, A. (2014). Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices. *Global Change Biology*, 20(11), 3557-3567. doi:10.1111/gcb.12551
- Lugato, E., Panagos, P., Bampa, F., Jones, A., & Montanarella, L. (2014). A new baseline of organic carbon stock in European agricultural soils using a modelling approach. *Global Change Biology*, 20(1), 313-326. doi:10.1111/gcb.12292

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Soil organic matter is a key component of the soil ecosystem as it affects soil's structure, stability, nutrient availability water retention and resilience. These properties regulates soils contribution to ecosystem dynamics and soils capacity to provide key ecosystem services like food/feed/fiber production and the prevention of land degradation. On average, 58% of soil organic matter colonists of soil organic carbon (SOC), which is therefore often used as a measure of organic matter. SOC is the largest stock of Carbon (C) in most terrestrial ecosystems and is also the second largest stock of the biosphere after oceans. SOC therefore plays a key role in the reduction and absorption of greenhouse gas emissions. SOC decline is one of the eight main threats to soil preservation identified by the EU Soil thematic strategy (COM(2006) 231 final) and retaining and enhancing SOC is an identified objective in EU policy, particularly the Common Agricultural Policy.

The indicator represents the SOC content in the topsoil (0-30 cm layer), expressed as Tons C/ha. It is calculated through modelling based on approximately 20,000 topsoil surveys conducted in the frame of the LUCAS 2009 survey (Lugato et al., 2014). The is available for the years 1980, 1990, 2000, 2010, 2015 and 2030 as model projection; from these data, the value at 2020 was calculated by interpolating the values at 2015 and 2030.

3.2. Maps

Figure 1 below shows the value of SOC in the topsoil for the baseline year 2010 (resolution: 1 km^2). Changes in the values of this indicator occur over long periods, therefore the main spatial patterns identifiable through the figure are the same in 2020. Overall, SOC is higher in grasslands and pastures compared to arable and lowest in permanent crops; however, SOC content is influenced by a combination of other different factors, including agroeconomic and pedoclimatic conditions, latitude and agricultural management. SOC lowest in the Mediterranean bioregion and is below 40 t C/ha across large areas. In

Eastern Europe the interactions between agroeconomic and pedoclimatic conditions produces more complex SOC distribution patterns, whilst SOC content tends to increase with latitude, although even at latitudes >50° N low and medium-low values are modelled over large areas of eastern Germany, Poland and Denmark, characterized by coarse parent material deposited during the last glacial period. Conversely, SOC is higher across Hungary and Romania, where the soils are rich in clay. Very high values in the British island are due to the presence of peatlands.

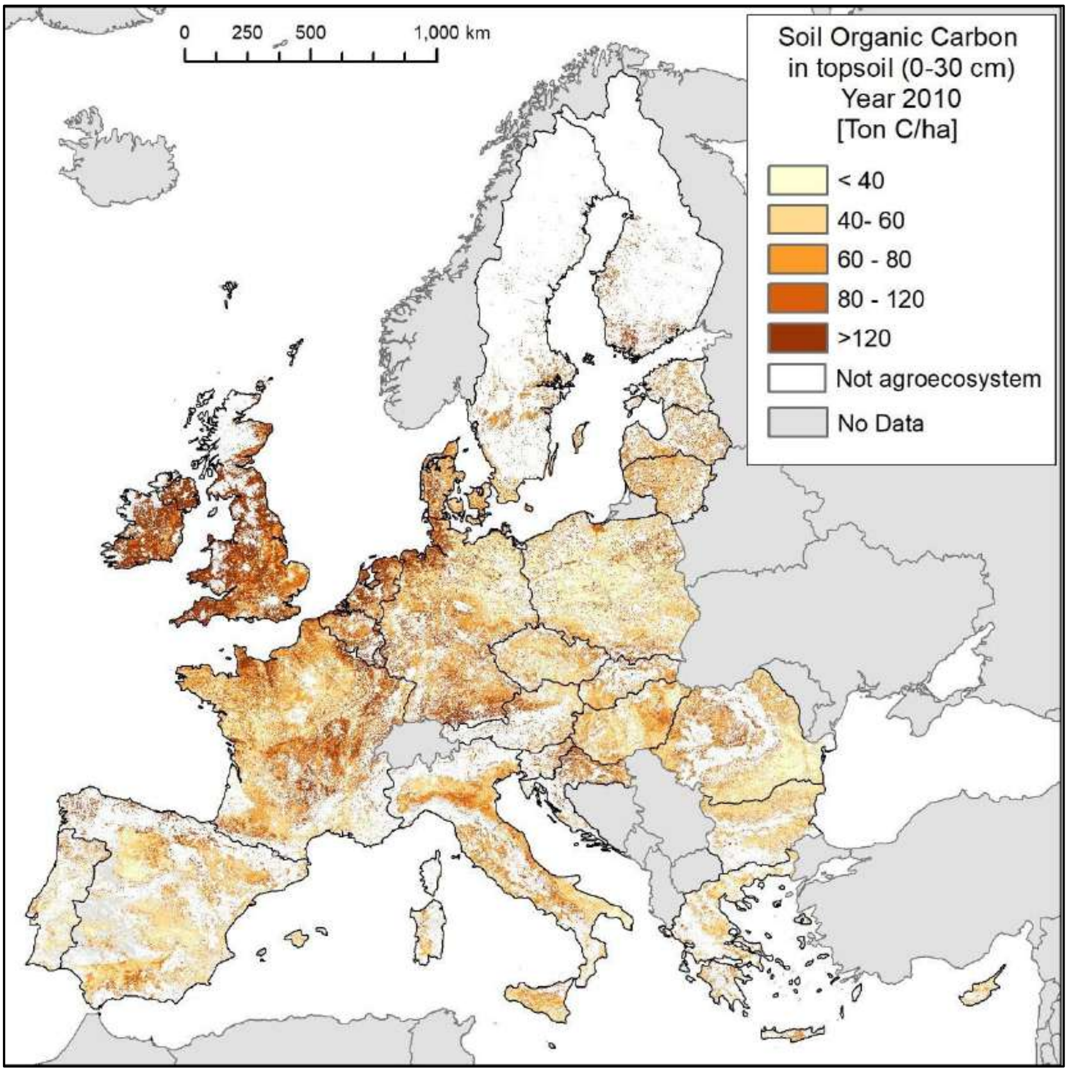


Figure 1 Soil Organic Carbon content in the topsoil in agroecosystems. Source: own elaboration base on Lugato et al., 2014

The following Figure 2 shows the absolute (left) and percentage (right) difference in SOC values between 2010 and 2020. Decreases are spread across the Mediterranean region and in eastern and Baltic countries. Hotspots of decrease are also modelled to occur in the British islands. When calculated as percentage of 2010 values, however, only in very few cases these correspond to decreases greater than 5%. Increases are projected to occur mainly in the Atlantic bioregion, (Brittany in NW France, Belgium, England) and in continental region in Germany and some areas in France. Again, very rarely such increase are greater than 5% in relative terms.

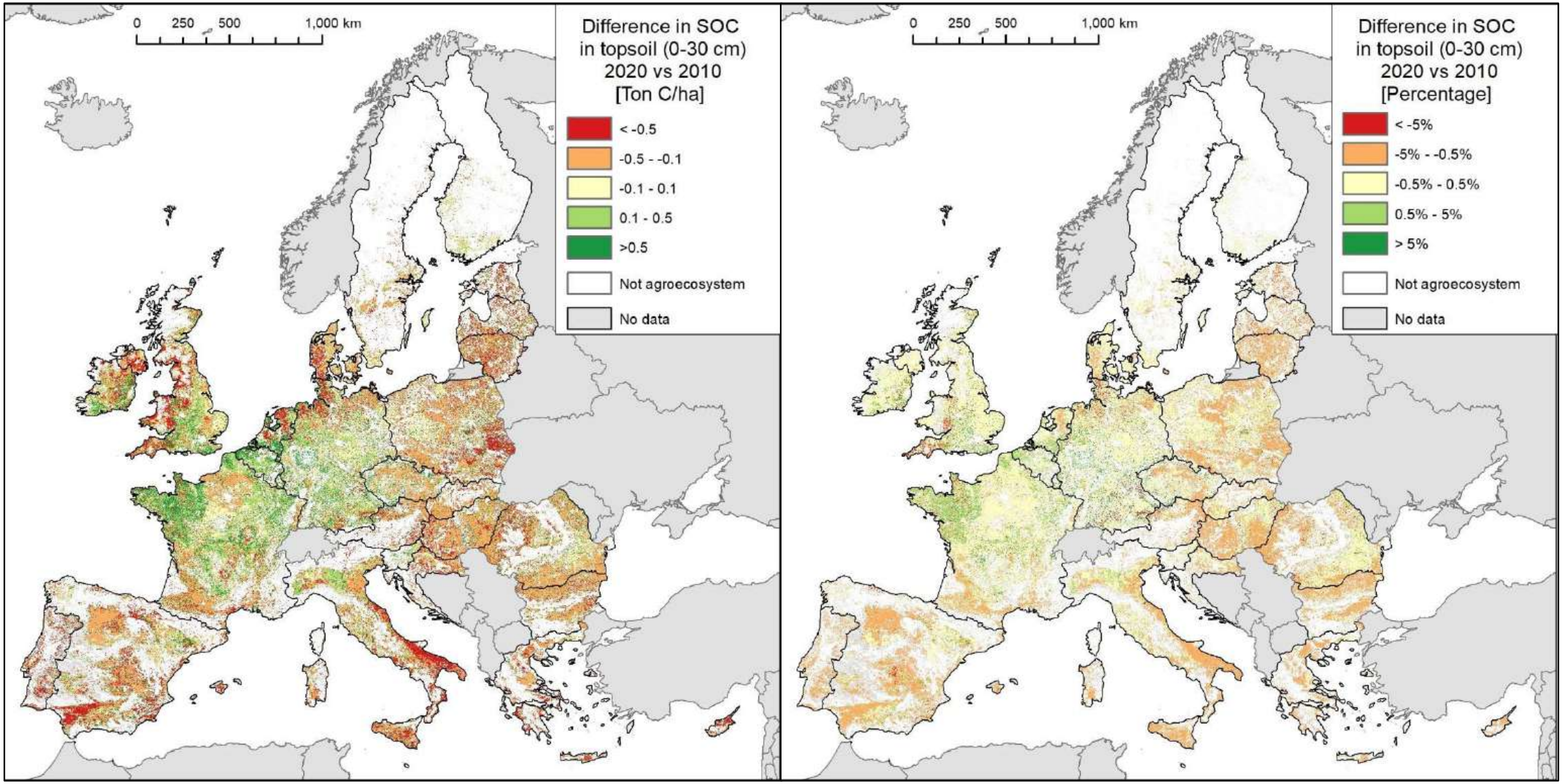


Figure 2 Left: differences in SOC values between 2010 and 2020; left: absolute values; right: percentage change

3.3. Statistical analysis of the trend

The long term trends at EU level were calculated through a standard linear regression using the 6 available data the values at 2020 (extrapolated from the values at 2015 and 2030) (Figure 3).

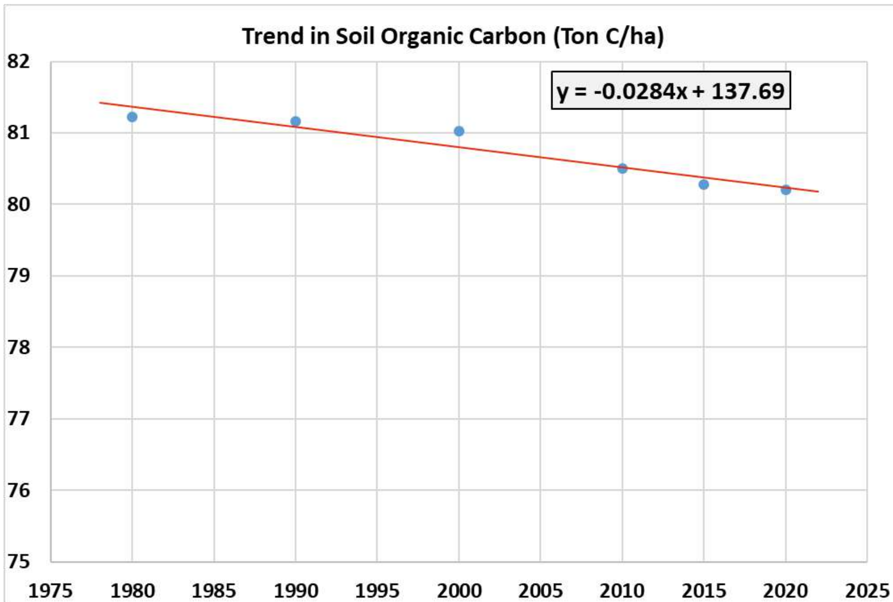


Figure 3 Statistical Analysis of the long term SOC trend at EU level, 1980-2020

The result of the regression are reported in the following Table 1.

Table 1 Result of the linear regression of average SOC at EU level (1980-2020)

	Coefficients	*Standard Error*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	137.6870	8.7483	0.0001	113.40	161.98
Slope	-0.0284	0.0044	0.0029	-0.0406	-0.0163

The analysis thus shows a slight, but statistically significant ($p < 0.01$), decrease of SOC over the years.

3.4. Key trend at EU level

The following Table 2 reports the value of the indicators at 1980, 1990, 2000, 2010, 2015 and 2020.

Table 2 Average SOC values at EU level from 1980 to 2020 and corresponding fitted values from the linear regression

Year	Average EU SOC (ton/ha)	Fitted value linear regression
1980	81.22	81.37
1990	81.16	81.09
2000	81.03	80.80
2010	80.50	80.52
2015	80.28	80.38
2020	80.20	80.23

The percentage change at 2020 with the baseline year (2010) is -0.373%; the percentage change calculated using the fitted values of the linear regression for the same year is very similar: -0.353%. The short term trend is -0.36%. Therefore, at aggregate EU level, in both cases the decrease is very limited. The following bar diagram (Figure 4) shows the indicators values (second column in Table 2).

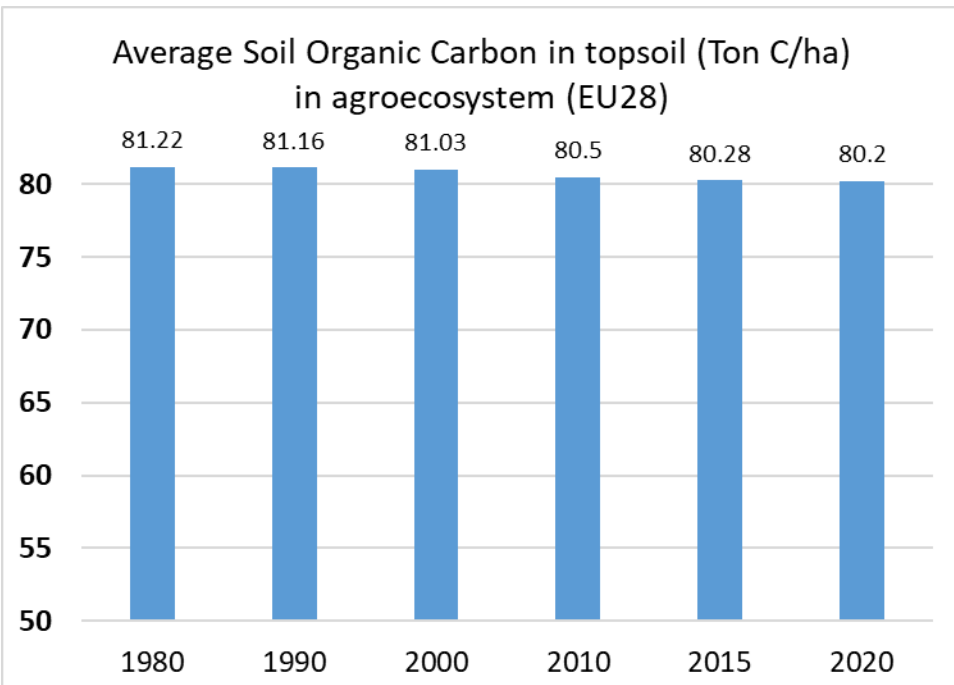


Figure 4 Average SOC in topsoil in agroecosystem (EU-28)

Fact sheet 3.2.217: Gross primary production

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Condition - Functional ecosystem attributes
- Name of the indicator: Gross primary production (GPP)
- Units: Kg C m-2 per year

2. Data sources

- Data holder: JRC
- Weblink: https://modis.gsfc.nasa.gov/data/dataprod/mod17.php
- Year or time-series range: 2001-2018
- Access date: 29/05/2019
- Reference: https://www.ntsg.umt.edu/files/modis/MOD17UsersGuide2015_v3.pdf

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The annual cumulative GPP values were computed from MODIS product MOD17A2H by the JRC, D5.

3.2. Maps

There are mostly positive trends with values up to + 0.76 kgC/m^2 per 10 years (Figure 1). There are a few pixels with downward trend scattered, not well visible on the map. The mean annual GPP over the area ranges from 0.7 to 1 kg C/m^2 per year.

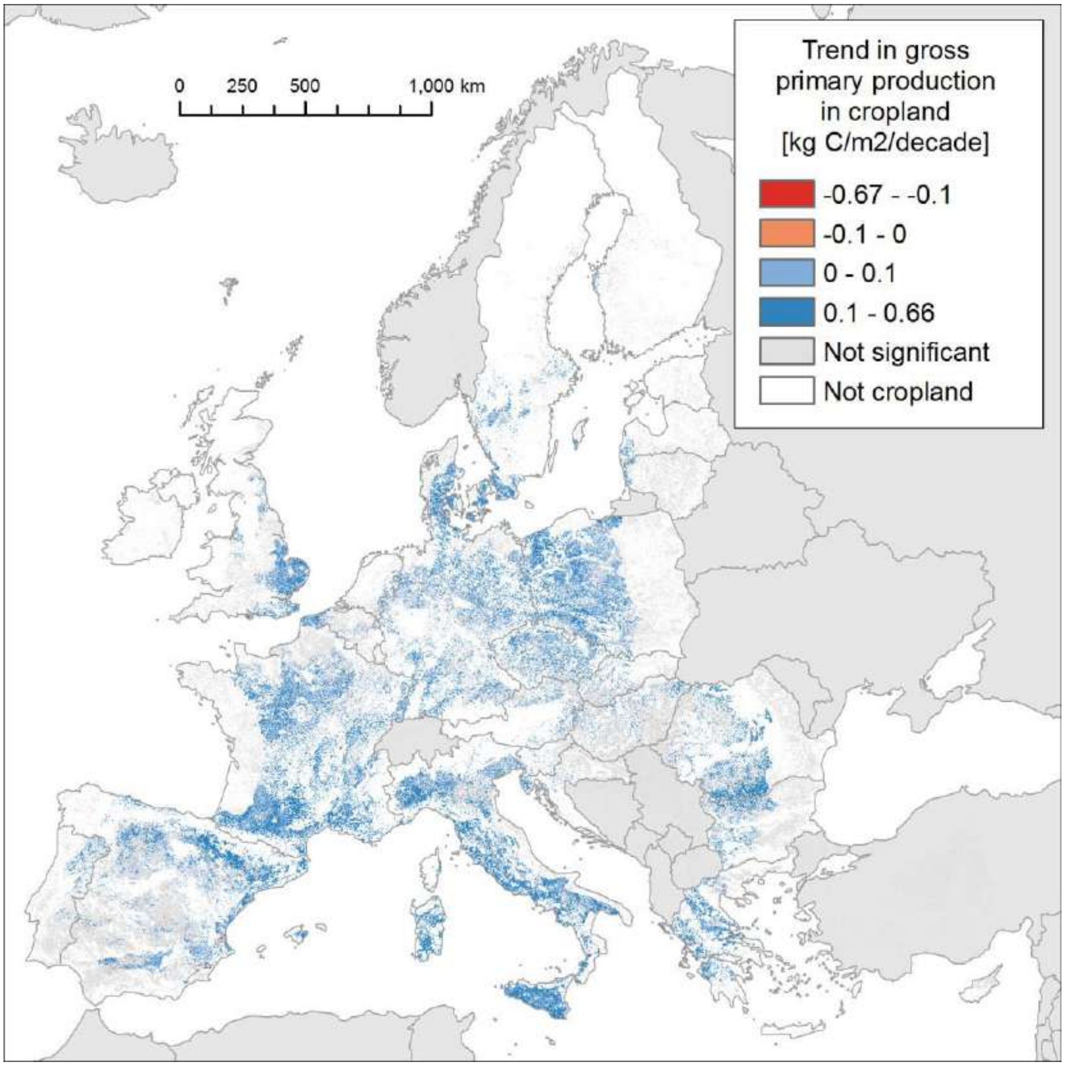


Figure 1 Trend in gross primary production (GPP) in croplands (significant at the 5% level according to the Mann-Kendall test)

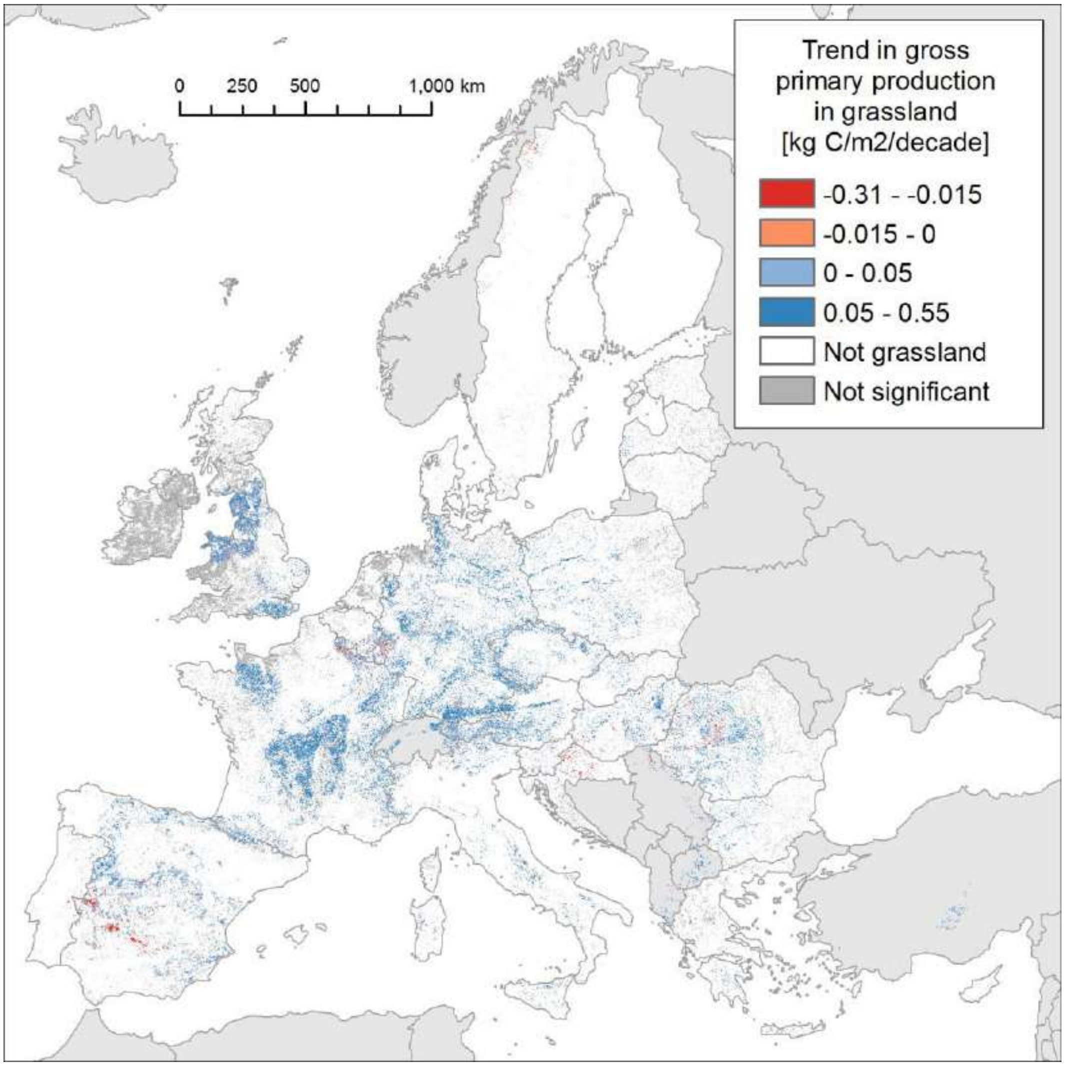


Figure 2 Trend in gross primary production (GPP) in grasslands (significant at the 5% level according to the Mann-Kendall test).

Figure 3 Distribution of areas showing significant decrease, increase and no change in gross primary production.

3.3. Statistical analysis of the trend

The long-term- and short-term trends were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012). The significance of monotonic trends was tested with the two-sided Mann-Kendall non-parametric test (Gilbert 1987; Kendall 1975; Mann 1945). The short-term and long-term relative changes were calculated from the slope of the trends and the baseline value (2010) of the trendline.

3.4. Key trend at EU level

Gross primary production has been increasing significantly at EU level on the long-term (Figure 1). The short-term slopes of the trends are steeper than the long-term slopes but not significant. The decadal percentage change calculated from the long-term trends and the calculated 2010 baseline value are 6.72% for croplands and 6.15% for grasslands.

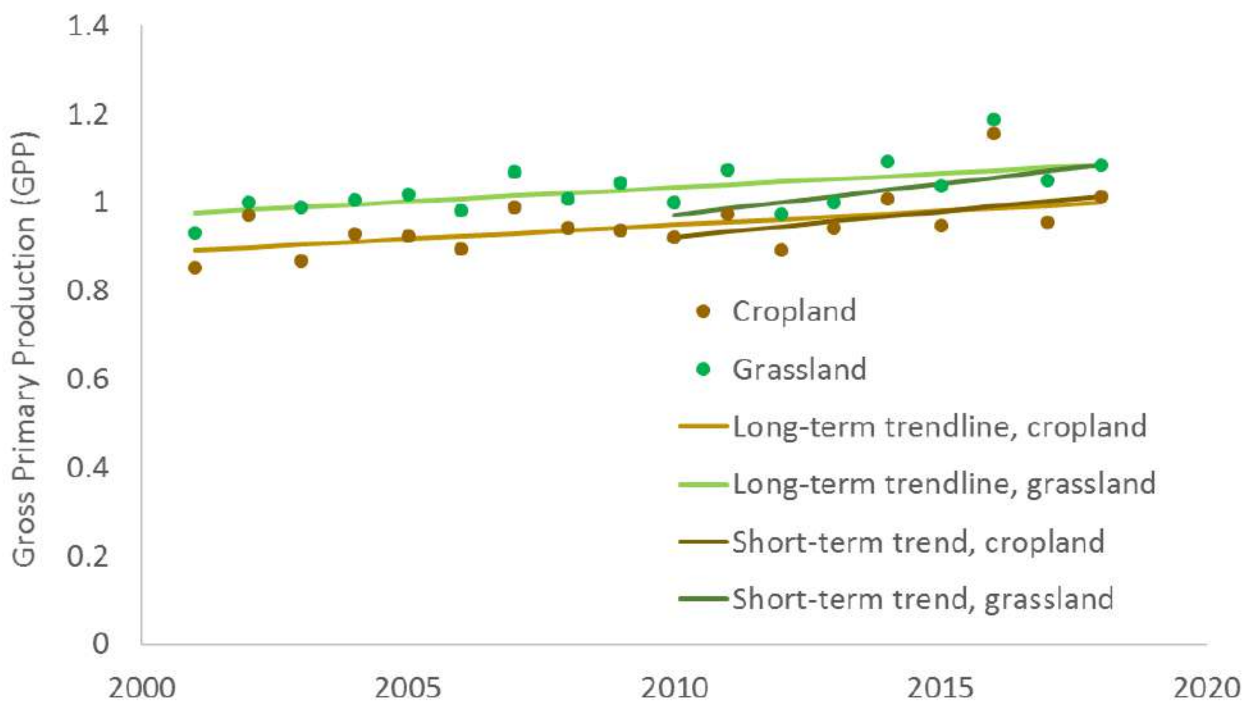


Figure 4 Trends in gross primary production based on Theil-Sen trend estimator and Mann-Kendall test.

Table 1 Slopes of the trends [ΔGPP/year] estimated with the Theil-Sen estimator

	Baseline GPP (2010)	GPP in 2017	Slope of long-term linear trend [% / year]	Slope of short-term linear trend [% / year]	Relative change per 10 years (from long-term trend) (%)	Relative change per 10 years (from short-term trend) (%)
Cropland	0.9213	0.9537	0.006363	0.011501	6.72	12.50
Grassland	0.9983	1.0494	0.006359	0.014109	6.15	14.50

Limitations

The MODIS GPP is calculated from the absorbed photosynthetically active radiation (APAR) using a set of biome specific radiation use efficiency parameters. MODIS uses a global land cover product for the definition of land cover at 1km pixel level. There can be inconsistencies between the global dataset and the map of MA ES grasslands and croplands, which can lead to misclassification and inclusion of other land covers in the calculations.

Fact sheet 3.3.101: Forest cover change

1. General information

- Thematic ecosystem assessment: Forest
- Indicator class: Pressure. Habitat conversion and degradation (Land conversion)
- Name of the indicator: Forest cover change
- Units: ha/km^2 in 6 years

2. Data sources

The indicator is based on existing data:

Maps: Corine Land Cover Change (LCC) accounting layer 2000; 2006; 2012 and 2018
Tabular information: Land ecosystem accounting LEAC. LEAC Cube

- Data holder: EEA
- Weblinks:
  - https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data
  - https://tableau.discomap.eea.europa.eu/t/Landonline/views/LEACCube2018/LEAC2018 Table
- Year or time-series range: 2000, 2006, 2012 and 2018
- Versions
  - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019

- Reference https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers

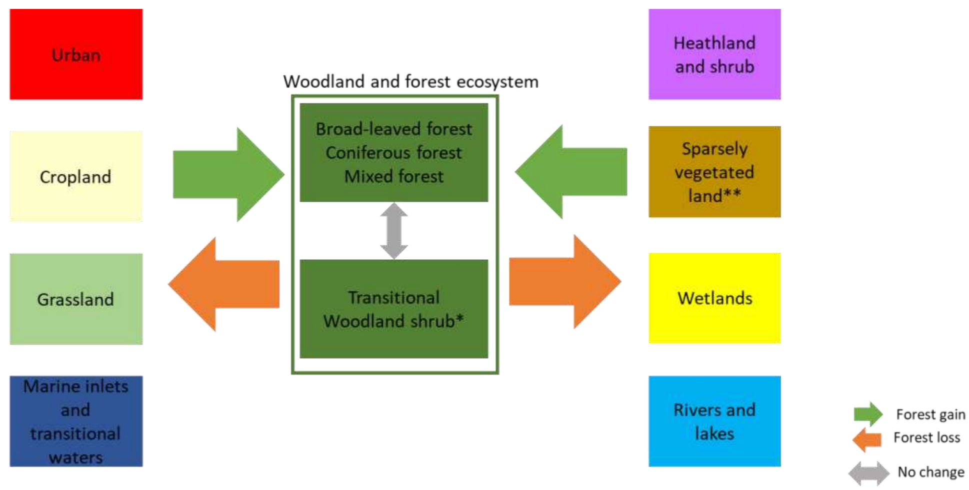
3. Assessment of the indicator

3.1. Short description of the scope of the indicator

This indicator aims to evaluate the trends of forest cover change (gain/loss) from 2000 to 2018 based on the spatial explicit information provided by Corine Land Cover. According to Annex 2 of 1st MAES report (Maes et al., 2013) the correspondence to woodland and forest ecosystems in Corine land cover are the classes 3.1 (Forest) and 3.2.4 (Transitional woodland shrub).

The change area, by land cover (LC) changes, has been calculated for the following periods: 2000-2006, 2006-2012, 2012-2018 and 2000-2018. The indicator has two components. (1) Forest loss (the conversion from forest cover classes to other LC) that includes loss of forest cover resulting from forest operations, natural disturbances (fires, storms), deforestation and conversion to other non-forest land cover. (2) Forest gain that includes the conversion from non-forest LC to forest LC, including reforestation after forest operations, natural expansion and succession and afforestation. The internal changes between different forest types and between forest classes (i.e. 3.1.X CLC classes) and transitional forest (i.e. 3.2.4 CLC class) were not considered as change (Figure 1).

The indicator focuses on forest dynamics and is complementary to tree cover loss and forest area indicators (assessed in other fact sheets). The net change is the result of the difference between forest cover loss and forest cover gain. The final values of the indicator are the average value of net change, expressed in hectares per square kilometre of forest area.



* 3.2.4 Corine class: Transitional bushy and herbaceous vegetation with occasional scattered trees. Can represent woodland degradation, forest regeneration / recolonization or natural succession.
** Sparsely vegetated land ecosystem type includes the Corine class 3.3.4: burnt areas

Figure 1 Methodological sketch about the changes of the ecosystem types accounted for computing the indicator.

3.2. Maps

The following figures present the forest cover change indicator, by each category and period. Note that the original resulting maps at 1 km grid size were upscaled to 10 km grid size for better readability in the figures. Maps for each period at 1 km grid size are not presented in this document. However., the datasets are available in the MAES server.

Regarding the forest cover loss maps (figures 2-5) Portugal, Western Spain, South of France, Croatia, the Polish-German border show most of the hotspot areas, whereas the hotspots about forest gain (figures 6-9) are in Portugal, Ireland, Poland and Hungary.
The overlap of grid cells with forest LC loss and gain is a proxy to identify areas with forest dynamics.

Overall analysis of the maps shows a decline in the rate of change from non-forest LC classes to forest classes (forest gain) while maintaining the loss of forest. This is observed when comparing the three maps (figure 10-13) that reveal that the grid cells with negative net change (interpreted as more loss than gain, in purple colours) remain constant (in relative quantity and intensity) between the maps of the series, while the grid cells with positive change (more gain than loss of forest cover, in green colours) are less and less intense, only Portugal and partially Ireland maintain the pattern shown throughout the series. The long-term trend spatially explicit for the net change of forest is shown in figure 14, that shows most of forest area with no trends with some hot-spots in Finland and the Western of the Iberian Peninsula.

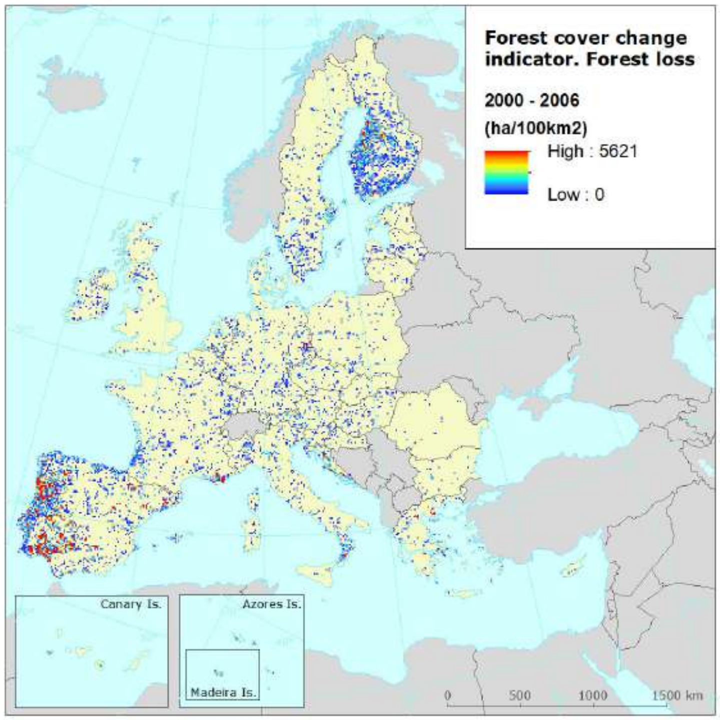


Figure 2 Forest pressure indicator: Forest cover change. Forest cover loss from 2000 to 2006 in hectares per 100 km^2.

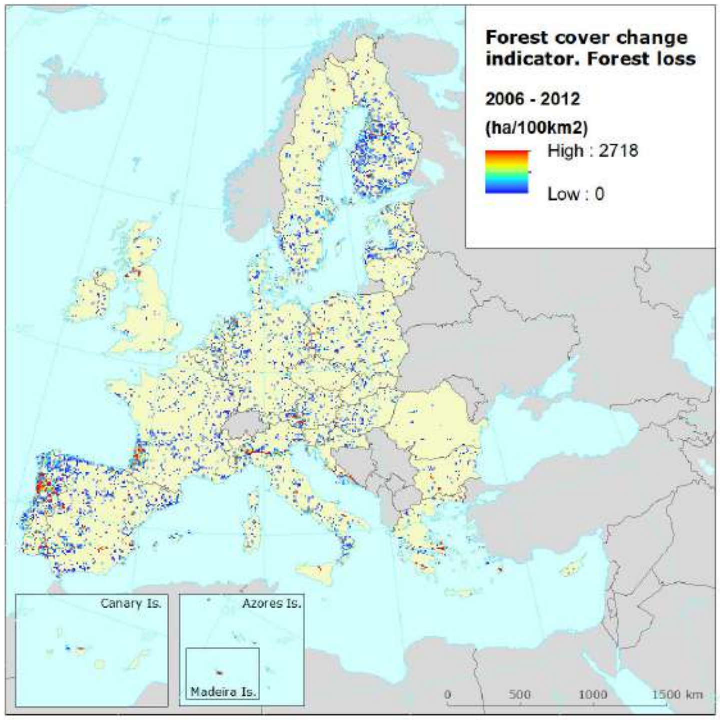


Figure 3 Forest pressure indicator: Forest cover change. Forest cover loss from 2006 to 2012 in hectares per 100 km^2.

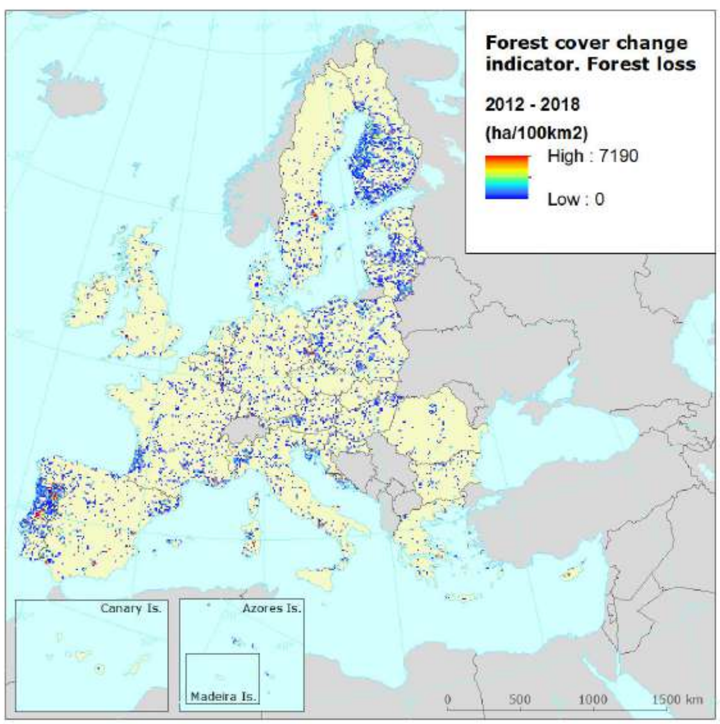


Figure 4 Forest pressure indicator: Forest cover change. Forest cover loss from 2012 to 2018 in hectares per 100 km^2.

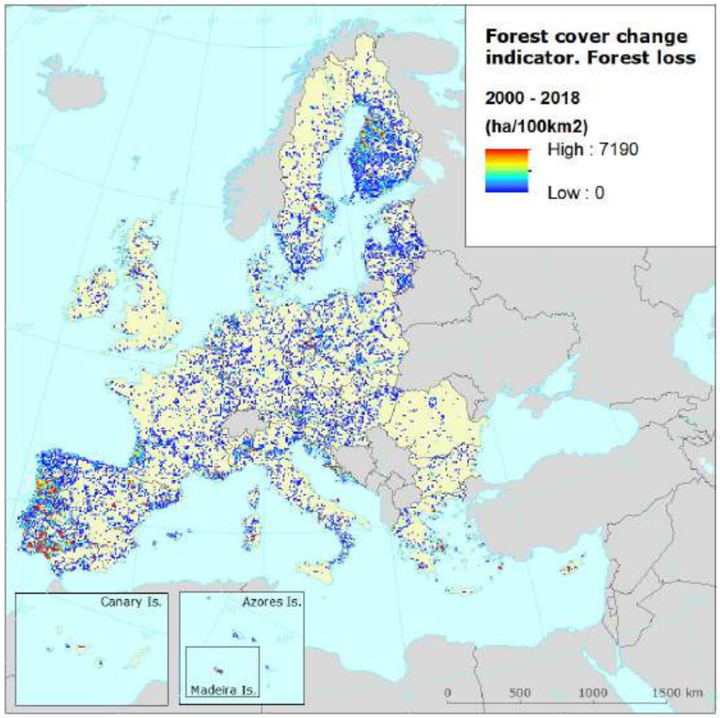


Figure 5 Forest pressure indicator: Forest cover change. Forest loss from 2000 to 2018 in hectares per 100 km^2.

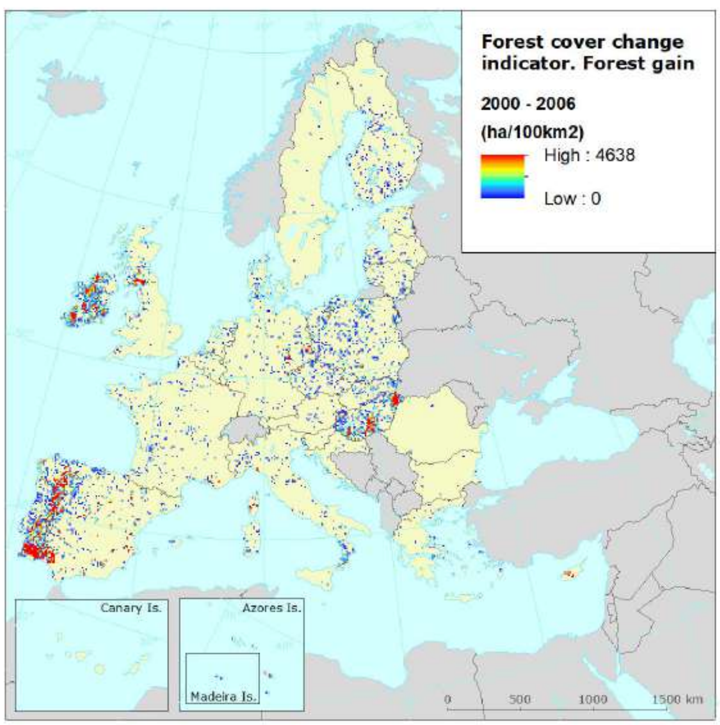


Figure 6 Forest pressure indicator: Forest cover change. Forest cover gain from 2000 to 2006 in hectares per 100 km^2.

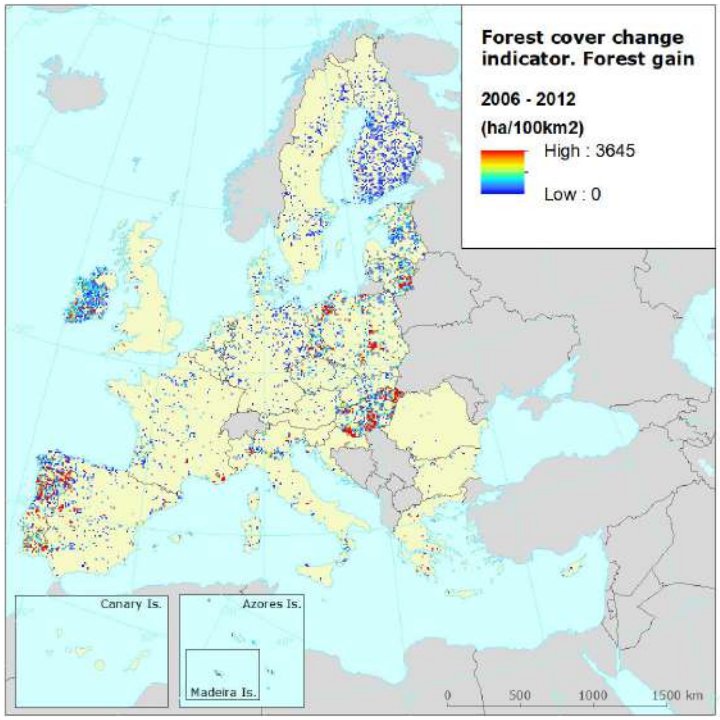


Figure 7 Forest pressure indicator: Forest cover change. Forest gain from 2006 to 2012 in hectares per 100 km^2.

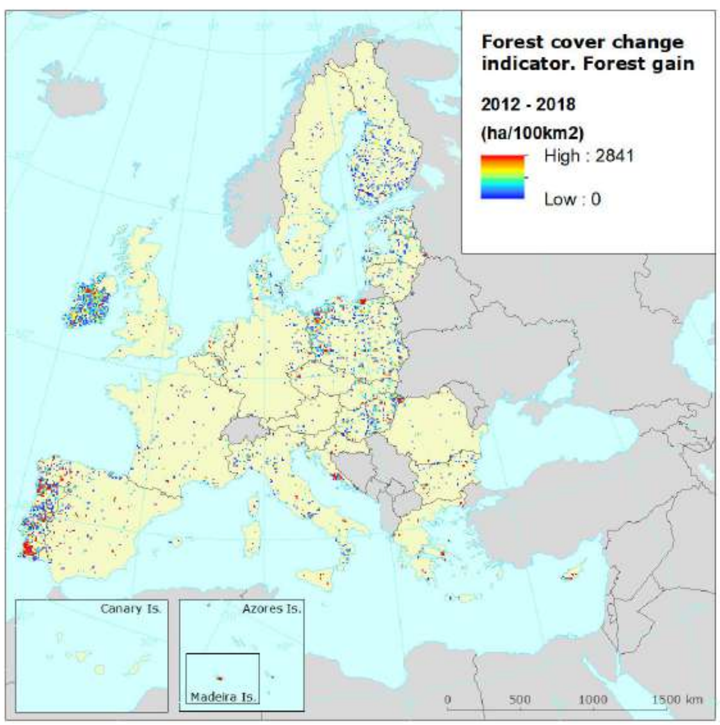


Figure 8 Forest pressure indicator: Forest cover change. Forest cover gain from 2012 to 2018 in hectares per 100 km^2.

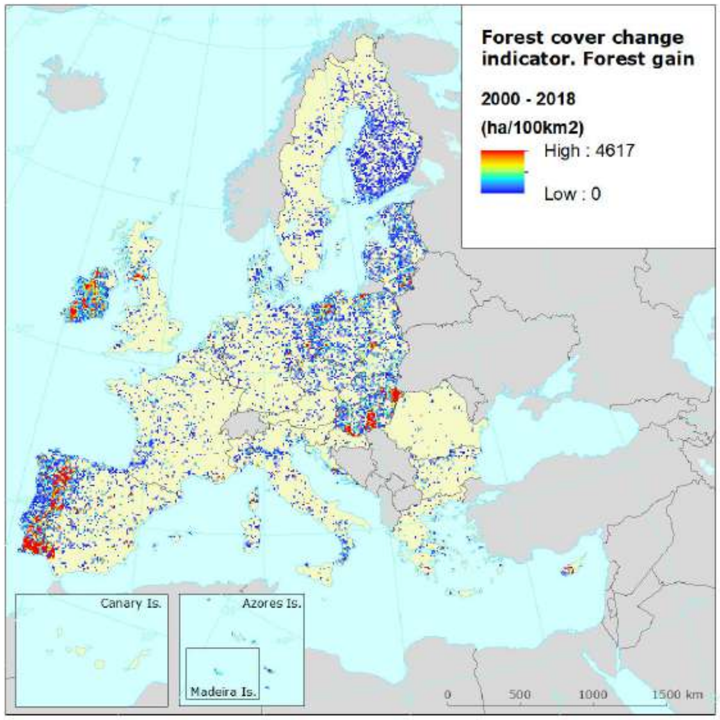


Figure 9 Forest pressure indicator: Forest cover change. Forest cover gain from 2000 to 2018 in hectares per 100 km^2.

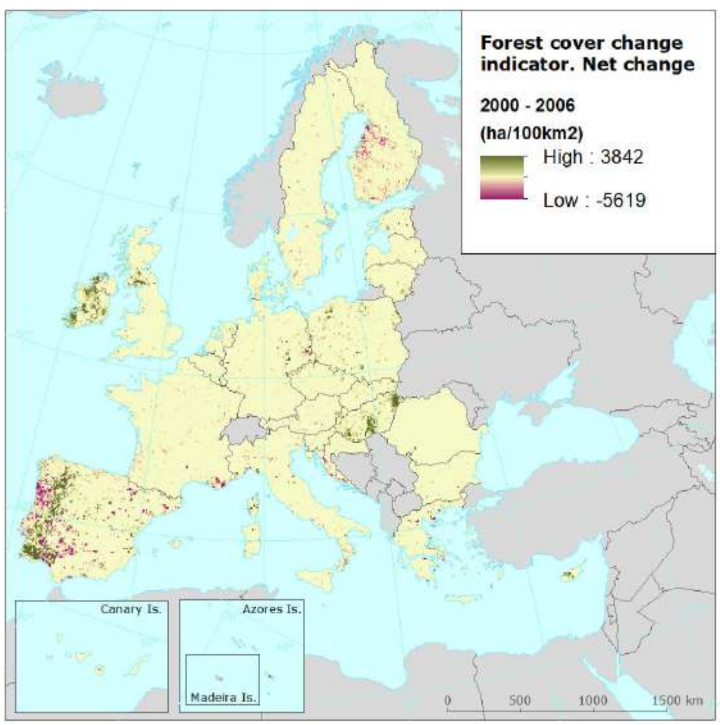


Figure 10 Forest pressure indicator: Forest cover change. Net forest change area from 2000 to 2006 in hectares per 100 km^2. Result of subtracting the forest cover loss from the area gain. Negative values mean that the forest cover loss is higher than the forest cover gain while positive values are the opposite.

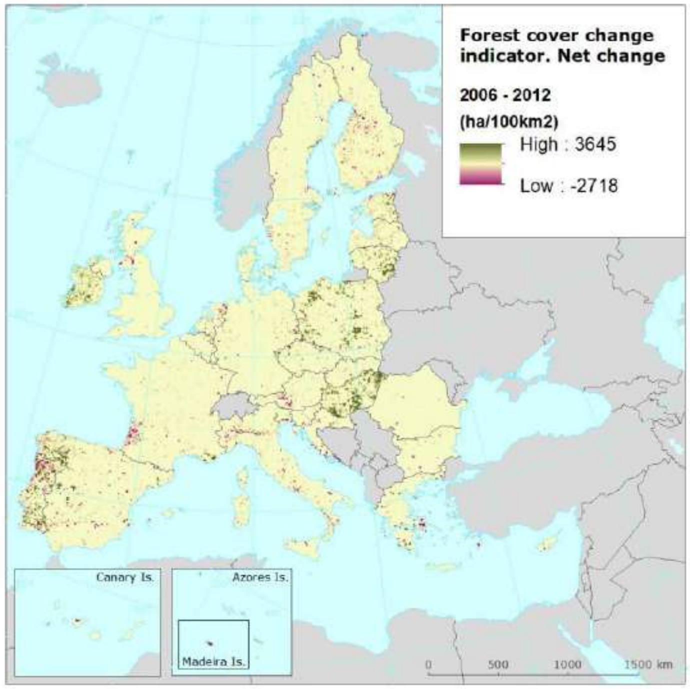


Figure 11 Forest pressure indicator: Forest cover change. Net forest change area from 2006 to 2012 in hectares per 100 km^2. Result of subtracting the forest cover loss from the area gain. Negative values mean that the forest cover loss is higher than the forest cover gain while positive values are the opposite.

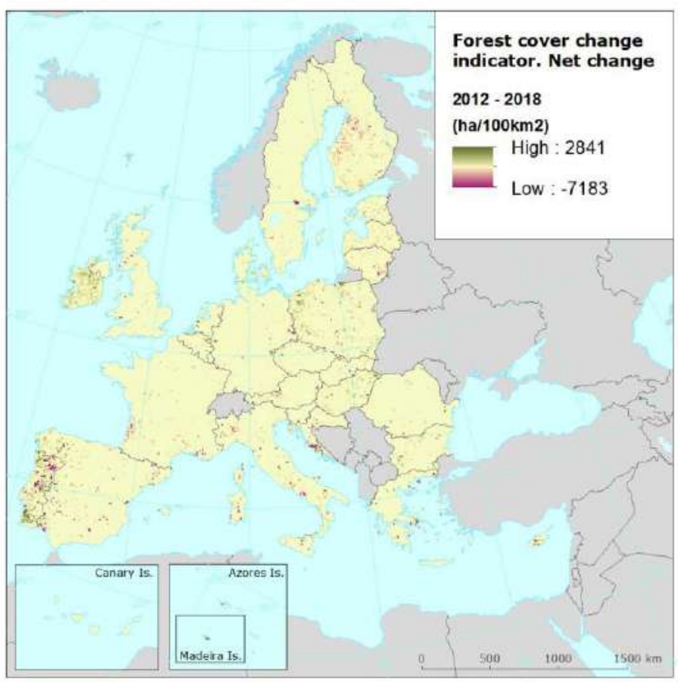


Figure 12 Forest pressure indicator: Forest cover change. Net forest change area from 2012 to 2018 in hectares per 100 km^2. Result of subtracting the forest cover loss from the area gain. Negative values mean that the forest cover loss is higher than the forest cover gain while positive values are the opposite.

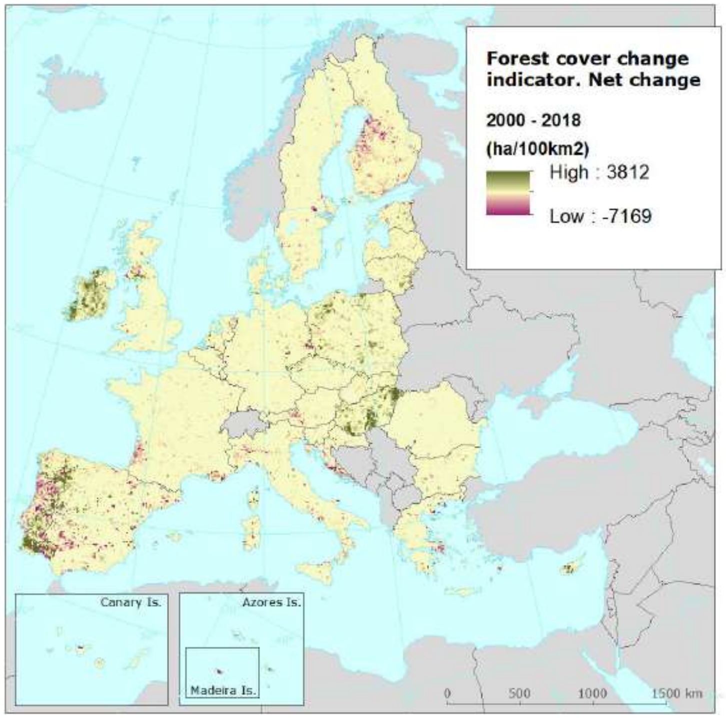


Figure 13 Forest pressure indicator: Forest cover change. Net forest change area from 2000 to 2018 in hectares per 100 km^2. Result of subtracting the forest cover loss from the area gain. Negative values mean that the forest cover loss is higher than the forest cover gain while positive values are the opposite.

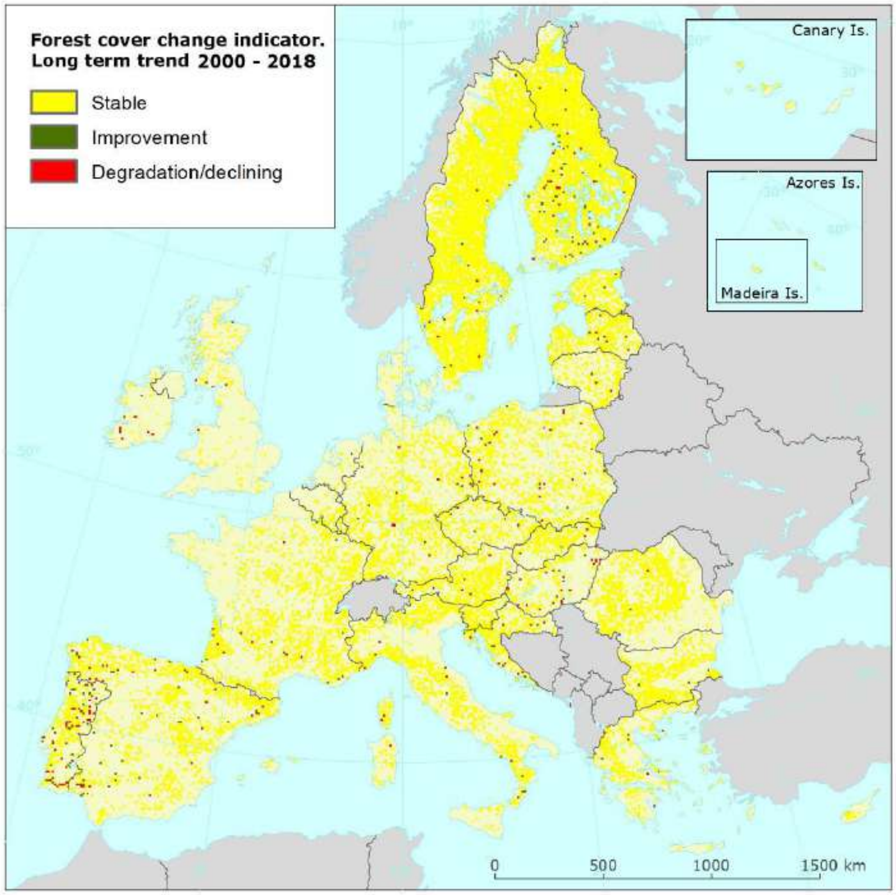


Figure 14 Forest pressure indicator: Forest cover change. Long term trend of net forest change area between 2000-2006 and 2012-2018.

3.3. Statistical analysis of the trend

Temporal trends of the forest cover change indicator are shown in Table 2. These statistics cover all four CORINE assessment years, this means three time slots 2000-2006, 2006-2012 and 2012-2018, including decadal changes for short and long-term changes. The significant assessment and the qualification of the indicator was done using the 5% rule due to the low number of observations; therefore, a statistical test cannot be performed.

The trend assessment for net change values of this indicator requires specific interpretation of the meaning of the change since it contains positive (when the forest gain is higher than the loss) and negative (when the forest gains is lower than the forest loss) values. The rational interpretation of the trends is indicated in table 1 (and show in figure 14).

Table 1 Short and long-term trend analysis and interpretation for forest cover change indicator.

	Net change value		Decadal change rate (%)	5% rule	Trend
	2000-2006	2012-2018			
1	(+)	(+)	< -5%	Significant	Degradation / declining if 2012-2018<2000-2006
2	(+)	(+)	> 5%	Significant	Improvement --> both positive but 2012-2018 > 2000-2006
2	(+)	(-)	< -5%	Significant	Degradation / declining
3	(-)	(-)	< -5%	Significant	Improvement --> both negative but 2012-2018>2000-2006
4	(-)	(+)	< -5%	Significant	Improvement
5	0	(+)	N/A	N/A	Improvement
6	-	-	-5%> <5%	Non-significant	Stable
7	0	(+)	N/A	N/A	Improvement
8	0	(-)	N/A	N/A	Degradation / declining

3.4. Key trend at EU level

The indicator was computed as the average of hectares of forests changed per square kilometre across the EU forest ecosystem extent. The time series is based on the CLC accounting layers available for the years 2000, 2006, 2012 and 2018. This indicator is a proxy of forest dynamics because it describes gain and loss changes in forest LC classes (see section 3.1).

Table 2 shows the aggregated values at EU-28 level, the average of hectares changed by square kilometre of forest. The forest cover change indicator shows, for the whole period analysed, average values of less than 1 ha/km^2 at EU level indicating non-change. Then, the decadal change rate is considered 0% (no change) because the average values of Net change in forest ecosystems are less than 1 ha/km^2 (<1%) and therefore negligible.

Although the trend at EU level is stable, there are dynamic areas as show the figures 11, 12 and 13, affected in some cases by unbalanced forest gain and loss. At biogeographical region scale the negative net change forest area concerns specially the Macaronesian biogeographical region (table 3) where the deforestation pressure, especially of laurel forests, is important due to agricultural pressures (EC, 2009 a). On the other hand, there is a positive balance in the Pannonian region (Figure 3) where the area of forest in the hills has, in fact, increased over the years due to the abandonment of grazing which helped to keep the tall grasses and the commercial plantation of the invasive false acacia *Robinia pseudoacacia* (EC, 2009 b).

Table 2 Forest pressure indicator: Forest cover change. Average forest change (ha/km^2) in EU-28 based on Corine Land Cover 2000, 2006, 2012 and 2018.

	Average forest change area (ha/km^2)				
	2000-2006	2006 – 2012*	2012 - 2018	2000-2018	Change rate (% per decade)***
Forest gain. New forest LC from non-forest LC	0.173	0.115	0.059	0.304	≈ 0% No change
Forest loss. From forest LC to non-forest LC	0.139	0.088	0.132	0.317	≈ 0% -No change
Net change**	**0.034**	**0.027**	**-0.073**	**-0.013**	≈ **0%** No change

* Values set as baseline
** Net change value is the result of subtracting the forest cover loss from the area gain
** The decadal change rate is considered ≈0% (no change) because the average values of net change are less than 1 ha/km2 (<1%) and therefore negligible

Table 3 Forest pressure indicator: Forest cover change. Average forest change area (ha/km^2) in EU-28 by biogeographical region based on Corine Land Cover 2000, 2006, 2012 and 2018.

Average forest change area (ha/km2)		Bio-geographical Region								
		Alpine	Atlantic	BlackSea	Boreal	Continental	Macaronesia	Mediterranean	Pannonian	Steppic
Forest Gain	2000-2006	0.04	0.56	0.06	0.06	0.21	0.47	0.88	2.33	0.09
	2006-2012	0.01	0.16	0.02	0.04	0.09	0.23	0.27	1.10	0.00
	2012-2018	0.01	0.11	0.05	0.02	0.05	0.46	0.18	0.15	0.09
	2000-2018	0.04	0.56	0.06	0.06	0.21	0.47	0.88	2.33	0.09
Forest Loss	2000-2006	0.02	0.15	0.01	0.07	0.04	0.26	0.57	0.04	0.00
	2006-2012	0.03	0.16	0.01	0.04	0.05	1.62	0.26	0.05	0.02
	2012-2018	0.03	0.11	0.01	0.08	0.06	0.24	0.48	0.05	0.00
	2000-2018	0.08	0.33	0.02	0.19	0.14	1.68	1.10	0.12	0.02
Net change	2000-2006	0.00	0.23	-0.01	-0.06	0.04	-0.07	0.06	1.04	0.00
	2006-2012	-0.02	0.00	0.01	0.00	0.04	-1.39	0.02	1.05	-0.02
	2012-2018	-0.02	0.00	0.04	-0.06	-0.01	0.22	-0.30	0.10	0.09
	2000-2018	-0.04	0.23	0.04	-0.12	0.07	-1.22	-0.22	2.21	0.07

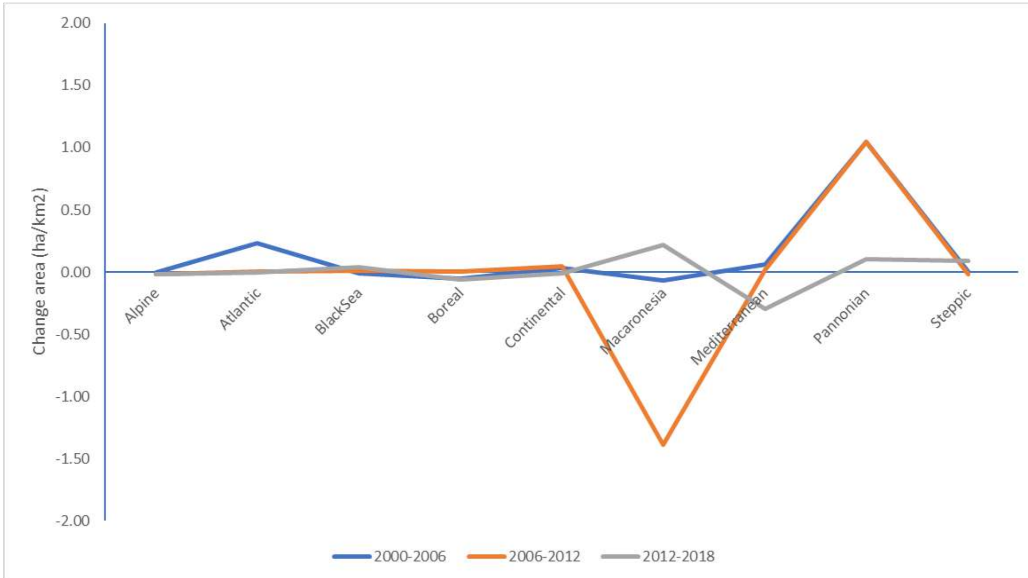


Figure 15 Forest pressure indicator: Forest cover change. Average net change area in ha/km^2 per biogeographical regions in EU-28. Table3.

4. References

EC, (2009) a. Natura 2000 in the Macaronesian Region. European Commission, Environment Directorate General. Office for Official Publications of the European Communities. https://ec.europa.eu/environment/nature/info/pubs/docs/biogeos/Macaronesian.pdf.

EC, (2009) b. Natura 2000 in the Pannonian Region, European Commission, Environment Directorate General. Office for Official Publications of the European Communities, Luxembourg. https://ec.europa.eu/environment/nature/info/pubs/docs/biogeos/pannonian.pdf.

Maes J, Teller A, Erhard M, et al. (2013). Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg. https://catalogue.biodiversity.europa.eu/uploads/document/file/1673/5th_MAES_report.pdf

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Fact sheet 3.3.102: Tree cover loss

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class (See table 1): Pressures - Habitat conversion and degradation
- Name of the indicator: Tree cover loss
- Units: Ha

2. Data sources:

The indicator is based on processed remote sensing data.

- Data holder: University of Maryland, Department of Geographical Sciences
- Weblink: https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.0.html
- Year or time-series range: 2001-2012 (v.1) and 2001–2018 (v1.6)
- Version: v.1 and v.1.6
- Access date: 07/01/2019 and 05/05/2020
- Reference: Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., et al. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. Science, 342(6160), 850-853, doi:10.1126/science.1244693.

3. Assessment of the indicator

Changes in tree cover affect the supply of ecosystem services, including habitat for biodiversity, climate regulation, erosion protection, carbon storage and water supply (Foley et al. 2005). Fires, windstorms and forestry are examples of drivers changing tree cover. These drivers affect the condition of forest ecosystems and therefore its services. The **aim** of this indicator is to assess the spatial distribution and trends of tree cover loss in the EU-28 using observational data acquired by remotely sensed imagery sourced from Hansen et al. (2013).

3.1 Data and methods

Trends in tree cover loss were assessed using the Global Forest Change dataset v.1 for the period 2000-2012 and v1.6 for the period 2011-2018 (Hansen et al. 2013). The reason of using two versions covering different periods is that, as acknowledged by the data provider[22], in v1.6 the data was reprocessed from 2011 onward. The reprocessing lead to a different and improved detection of tree cover loss from 2011. Therefore, users might find inconsistencies from 2011 in v1.6. In consequence, the "integrated use of version 1.0 (2001-2012 data) and updated version 1.6 (2011–2018 data) should be performed with caution". Nevertheless, recent evidence suggests that these inconsistencies are minor in the data sets covering the European region (Ceccherini et al., 2020). In addition, we acknowledge that tree cover loss data for the period 2001-2003 might present some gaps.

This dataset provides data on **tree cover loss** and **tree density (tree canopy cover)** available at 30 m grid size. We used version 1 of this data set for assessing the long-term trend, and version 1.6 for the short term trend.

[22] https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.6.html

Tree cover loss is defined as a stand-replacement disturbance, or a change from a forest (tree) to a non-forest (non-tree) state. This data is encoded as either 1 (loss) or 0 (no loss) for the years 2001 to 2018. The dataset represents the effects of logging, forest fires, windstorms and other disturbances leading to a change in the tree cover.

Tree canopy cover is referred to year 2000 and is defined as canopy closure for all vegetation taller than 5m in height. It is estimated as a percentage per grid cell in the range 0–100.

Trends were assessed by computing tree cover loss per year on each European biogeographical region (EEA 2002, 2019) within the EU-28 countries. Before computing the tree cover loss, we excluded grid cells falling outside forest areas. For doing so, first, we used the 20% tree canopy cover threshold, similarly to Potapov et al. (2008) and Heino et al. (2015), to define whether the 30 m grid cells are classified as forest or non-forest. Second, we used a forest map created using Corine Land Cover (CLC) 2012 (v. 18.5) according to the MAES (2013) classification of ecosystems for excluding grid cells falling outside forest areas.

3.2 Statistical assessment of the trend

Trends were computed using robust regression. Regression slopes were estimated using the non-parametric **Theil-Sen estimator** (Sen 1968; Wilcox 2012) because it accommodates non-normal distributions and is a robust trend slope estimator resistant to the effects of outliers. Additionally, a two-sided **Mann-Kendall** (Gilbert 1987; Kendall 1975; Mann 1945) non-parametric trend test was used to assess the significance of monotonic trends.

3.3 Key trend at EU level – Results

Results of this assessment indicate upward trends of tree cover loss across biogeographical regions in both periods in the EU-28, with the exception of the Back Sea and the Macaronesian regions that show downward trends (Table 1). This might suggests tree cover loss intensification across the EU-28 in both the short and long term. Nevertheless, statistically significant upward trends were found only in two regions on each period. It should be noted that the short time range of the series makes challenging assessing trends.

In the EU-28 domain, not statistically significant upward trends were estimated at around 25,000 ha of tree cover loss per year in the first period, and at 55,000 ha per year in the second period (Figure 1). The amount of tree cover loss in 2017, the maximum of the series, is around 1.5 million ha. This is equivalent to half the size of Belgium and represents around 0.9% of the extent of forest in the EU-28 (161 million ha according to FOREST EUROPE (2015)). Table 2 shows the decadal trend calculated according to the MAES method.

Table 1. Trends of tree cover loss in European biogeographical regions (EEA 2002, 2019) within the EU-28 countries. Note that the areas were computed using a 1 km grid size map. Bold: significant at the 5% level according to the Mann-Kendall test. Trends should be considered with caution due the limitations mentioned above.

Biogeographical region	Total area (Km^2)	Tree cover loss trend 2001-2012 (data set v1.0) (ha/y)	Tree cover loss trend 2009-2018 (data set v1.6) (ha/y)
Alpine	379,142	1988	1814
Atlantic	802,912	**6561**	1150
Black Sea	11,942	-25	-1
Boreal	858,430	8428	23 351
Continental	1,292,677	7549	8999
Macaronesian	12,001	7	-7
Mediterranean	923,170	2652	**13 547**
Pannonian	126,158	268	429
Steppic	37,112	**34**	**76**
Total EU-28	4,443,544	25 048	54 799

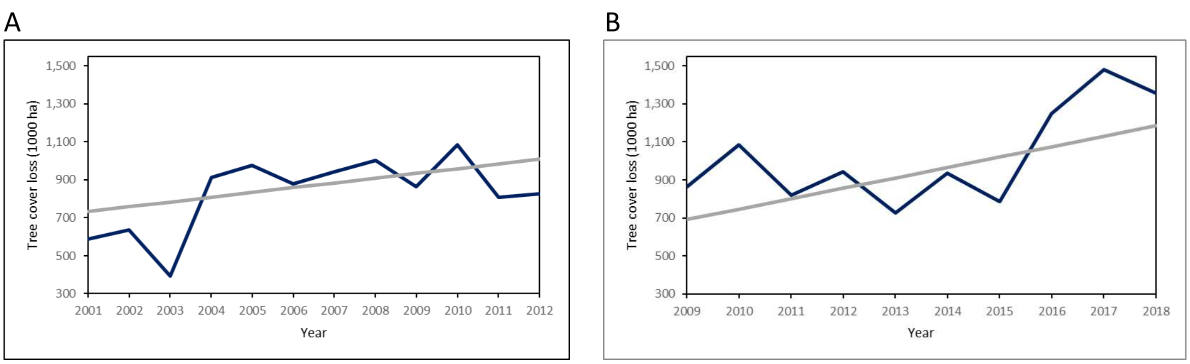

Figure 1. Trend of annual tree cover loss in the EU-28. (A) 2001-2012 (data set v1.0); (B) 2009-2018 (data set v1.6). Trend lines computed using the Theil–Sen non-parametric estimator. Upward trends (A: 25 048 ha/y and B: 54 799 ha/y) not significant at 5% according to Mann-Kendall trend test. Trends should be considered with caution due the limitations mentioned above. Note that some differences in the years 2011 and 2012 between A and B are likely due to the reprocessing of the data provided in v1.6.

Table 2. Long-term trend and short-term trend of annual tree cover loss in the EU-28. N.S.: not significant at 5% according to Mann-Kendall trend test. Note: According to the methodology adopted in this assessment a change is always considered significant in case the percentage change per decade is higher than or equal to +5 % or lower than or equal to -5 %. This is valid for both short and long-term trends and regardless statistical testing. A change outside this interval is thus always considered as policy-relevant to report. Trends should be considered with caution due the limitations mentioned above.

	Long-term trend	**Short-term trend**
% per decade	26.1 (N.S.)	73.5 (N.S.)
Time range	2001-2012 (data set v1.0)	2009-2018 (data set v1.6)
Method	Mann-Kendall	Mann-Kendall

The assessment of the series 2001-2018 using the data set v1.6 indicates that according to the Mann-Kendall trend test there is a statistically significant upward trend ($p=0.023$) of 33,044 ha/y. This is equivalent to a decadal increase of 35.1%.

3.4 Mapping tree cover loss

A map of average tree cover loss in the 12-year period 2001-2012 (v.1) were computed in grid cells of 10 x 10 km. Using large grid cells provides a more readable map if compared with the maps at the high resolution of the original data. We summed the annual tree cover loss in the 10 x 10 km grid cells to produce a measure of tree cover loss from 2001 to 2012 and averaged this over the 12-y (Figure 2). Despite an overall increase of forest area in the EU-28 (FOREST EUROPE 2015), the map shows regions where the more intense tree cover loss occurred, for example, Portugal, west France, Sweden, Finland, Slovakia, Czech Republic, some areas of Estonia and Latvia, as well as other zones such as the Carpathians, parts of Germany and south Belgium. Changes in tree cover affect many ecosystem services such as erosion protection or habitat for biodiversity.

Despite that a significant trend was not fond at EU-28 level, Figure 3 shows areas where significant trends of tree cover loss were found at the grid cell level. The map shows areas where intensification of tree cover loss was occurring, i.e. upward trends. These areas represent around 400,000 km^2, which is equivalent to 25% of the EU-28 forest area. In these zones an increasing amount of tree cover is lost every year.

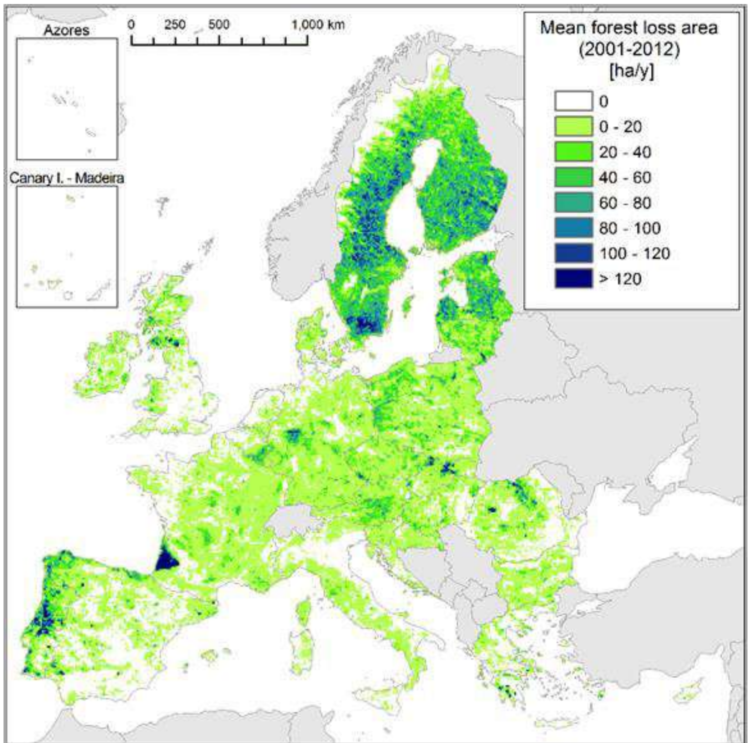

Figure 2. Mean tree cover loss area in 10 x 10 km grid cells in the period 2001-2012 in the EU-28. Data source: v.1 Hansen et al. (2013).

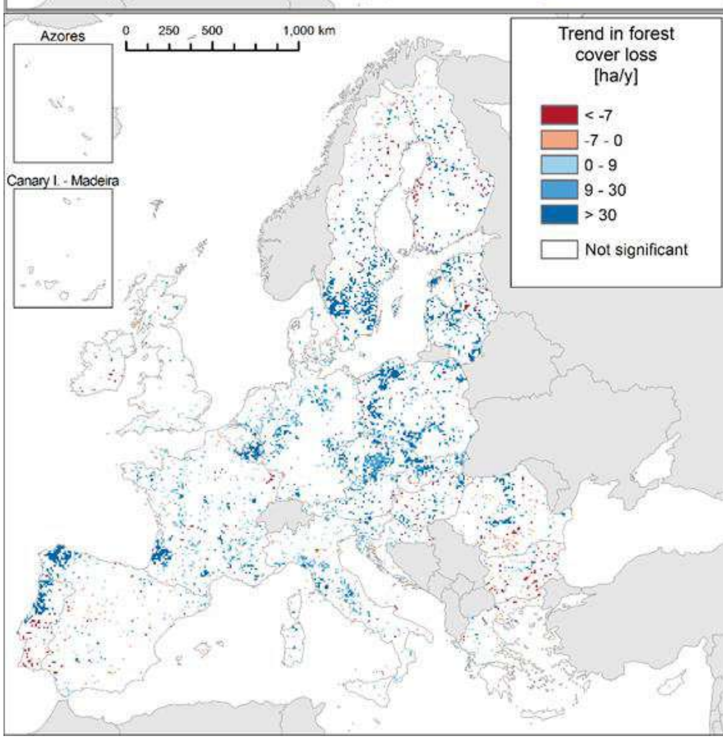

Figure 3. Trends in tree cover loss in 10 x 10 km grid cells in the period 2001-2012 in the EU-28. Significant at the 5% level according to the Mann-Kendall test. Light grey: outside area of interest. Data source: v.1 Hansen et al. (2013). Trends should be considered with caution due the limitations mentioned above.

References

Ceccherini G., G. Duveiller, G. Grassi, G. Lemoine, V. Avitabile, A. Cescatti. (2020). Abrupt increase in harvested forest area over Europe after 2015, Nature, Vol 583.

EEA (2002). Europe's biodiversity – biogeographical regions and seas. Luxembourg: European Environment Agency.

EEA (2019). Biogeographical regions. https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3#tab-figures-produced2019.

Foley, J. A., DeFries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., et al. (2005). Global Consequences of Land Use. *Science, 309*(5734), 570-574, doi:10.1126/science.1111772.

FOREST EUROPE (2015). State of Europe's Forests 2015. (pp. 312): Ministerial Conference on the Protection of Forests in Europe.

Gilbert, R. O. (1987). *Statistical Methods for Environmental Pollution Monitoring*. NY, USA: Wiley.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., et al. (2013). High-Resolution Global Maps of 21st-Century Forest Cover Change. *Science, 342*(6160), 850-853, doi:10.1126/science.1244693.

Heino, M., Kummu, M., Makkonen, M., Mulligan, M., Verburg, P. H., Jalava, M., et al. (2015). Forest Loss in Protected Areas and Intact Forest Landscapes: A Global Analysis. *PLoS ONE, 10*(10), e0138918, doi:10.1371/journal.pone.0138918.

Kendall, M. G. (1975). *Rank Correlation Methods (4th edition)*. London: Charles Griffin.

MAES (2013). Mapping and Assessment of Ecosystems and their Services - An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. (pp. 57). Luxembourg.

Mann, H. B. (1945). Nonparametric Tests Against Trend. *Econometrica, 13*(3), 245-259, doi:10.2307/1907187.

Potapov, P., Hansen, M. C., Stehman, S. V., Loveland, T. R., & Pittman, K. (2008). Combining MODIS and Landsat imagery to estimate and map boreal forest cover loss. *Remote Sensing of Environment, 112*(9), 3708-3719, doi:10.1016/j.rse.2008.05.006.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. *Journal of the American Statistical Association, 63*(324), 1379-1389, doi:10.2307/2285891.

Wilcox, R. R. (2012). *Introduction to Robust Estimation and Hypothesis Testing*. San Diego, California, USA: Academic Press.

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Fact sheet 3.3.103: Fragmentation by forest cover loss

1. General information

- Thematic ecosystem assessment: Forest
- Indicator class: Pressures, Habitat conversion and degradation
- Name of the indicator: Fragmentation by forest cover loss
- Units: percent; six fragmentation classes: Rare, Patchy, Transitional, Dominant, Interior, Intact

2. Data sources

The indicator is derived from CORINE (v20) land cover data:

- Data holder: JRC; MAES collection. Contact: Peter Vogt
- Weblink: EIONET
- Year or time-series range: 2000, 2006, 2012, 2018
- Reference: summary in Vogt 2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Forest fragmentation is a key aspect in biodiversity, ecosystem services and the ever-increasing pressure from anthropogenic land use. Forest fragmentation may lead to the isolation and loss of species and gene pools, degraded habitat quality, and a reduction in the forest's ability to sustain the natural processes necessary to maintain ecosystem health.

The goal of the indicator is to provide intuitive classes of various degree of forest fragmentation. Measuring the spatial integrity of forest land cover the indicator accounts for key fragmentation aspects, such as isolation of small fragments and perforations within compact forest patches.

The indicator measures forest area density in a local neighbourhood, which is then classified into six degrees of fragmentation classes. The result is a map product showing the degree of forest fragmentation at pixel-level accompanied by a statistical summary table. A conceptually similar approach (Riitters et al. 2002, 2012; Wickham 2008) is used for official reporting on forest fragmentation by the US-Forest Service (2003, 2010), the Montréal Process, FAO (indicator 1.5, Vogt et al. 2019a), and Forest Europe (indicator 4.7, Vogt et al. 2019b) enabling common usage of the same information across disciplines and locations, and permitting rigorous evaluations of the trade-offs or synergies involved in land-cover pattern management.

Implementation summary:

The CORINE (CLC) land cover maps (https://land.copernicus.eu/pan-european/corine-land-cover) identify 44 land cover classes at a spatial resolution of 1 hectare per pixel (100 m x 100 m) for a series of assessment years over Europe. The CLC land cover classes 23, 24, 25, 29 are combined into a binary forest/nonforest map. Forest area density (FAD) is defined as the proportion of all forest pixels within a fixed-area neighbourhood area. FAD measurements are conducted via a moving window algorithm to create a new map of forest area density: the given neighbourhood (here, a square window of size 23x23 pixels = 529 hectares) is centred over a given pixel, the forest area density within that neighbourhood is measured and assigned in a new map at the location of the subject pixel. This process is repeated for all pixels resulting in a new map of the same dimensions but showing forest area density values for the analysed neighbourhood over each forest pixel; The area density map may be post-stratified or aggregated in different ways to answer different assessment questions. Within MAES, the area density values (in [0, 100] %) are converted to an ordered categorical variable (one of six forest area density classes – Intact (FAD=100%), Interior (FAD=90-99%), Dominant (FAD=60-89%), Transitional (FAD=4059%), Patchy (FAD=10-39%), and Rare (FAD<10%) indicative for various degrees of forest fragmentation (see Figure 1). This processing scheme (FAD 6-class) is implemented in the free software GuidosToolbox (Vogt & Riitters 2017) and further detailed in Vogt 2019.

Statistics of forest fragmentation at EU-28-scale are summarized with the following parameters:

1. Proportion of fragmentation in: Intact, Interior, Dominant, Transitional, Patchy and Rare [%].
2. Total forest area [hectares]
3. Total number of forest patches
4. APS [hectares]: Average forest patch size = total forest area / total number of forest patches
5. FAD_av [%]: Average forest area density for all forest pixels

Aggregation: Aggregated maps with a pixel resolution of 1 km^2 and 10 km^2 are derived by building the mean value of all FAD values in the original FAD maps at 100 m resolution for the respective new pixel area. The purpose of spatially aggregated maps is to provide a comparative reference layer for other MAES indicators, which are derived at a spatial resolution of 1 km^2 or 10 km^2.

Change analysis:

Tabular statistics can only provide a simple summary but they cannot capture geographical variability. Instead, the map product provides crucial information on any spatially explicit question, such as where is the forest, where are fragmentation hotspots, where did forest cover change and in which way? A quantitative and spatially explicit index is obligatory to evaluate progress in policy programs, for example landscape dynamics inside versus outside protected areas, or guidance in landscape planning and monitoring in risk assessment studies. As a consequence, an informative change analysis should communicate key messages inherent in the statistical summary table as well as the geospatial variability coming from the map product only. Temporal trends of forest fragmentation are derived for the time frame 2000-2012, 2012-2018, and 2000-2018 and the following two categories (see also Section 3.3):

a) **Statistical summary:** Trends in each of the 6 forest fragmentation classes, total forest area, total number of patches, APS and FAD_av.

b) **Spatial maps:** Trend maps showing geographic locations where forest fragmentation has changed. Changes in forest fragmentation are constrained to areas where forest was present at both times. In addition, the fragmentation change map also includes information on areas where forest cover is present but a fragmentation analysis is not meaningful, such as areas of forest loss/gain and smallscale spurious changes. With the focus on essential change areas we ensure to provide a clear message and facilitate interpretation.

All status and trend maps and related statistics are available on EIONET for each assessment year 2000, 2006, 2012, 2018.

3.2. Maps

Figure 1 shows the processing chain starting from the CORINE land cover data to the final forest fragmentation map, providing spatial detail in six degrees of forest fragmentation.

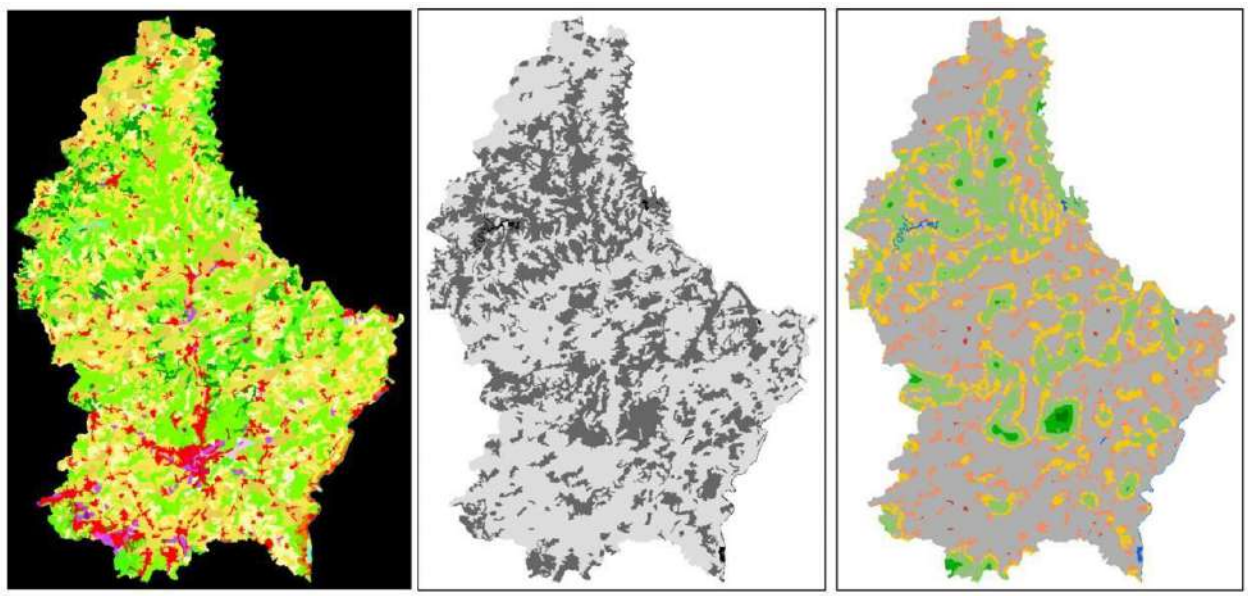

Figure 1. Processing steps to derive forest fragmentation exemplified for Luxembourg: CORINE 2012 land cover data (left), forest map (centre), forest fragmentation (legend see Figure 2).

Figure 2 shows forest fragmentation at 100-meter spatial resolution for the year 2018. Unsurprisingly, the most intact forest areas can be found in areas with a high forest coverage, for example Scandinavia, the alpine regions in Europe, the Pyrenees and northern Balkan countries. Areas of high fragmentation coincide with either a low amount of forest cover (Ireland, United Kingdom) or areas with high population density (the Netherlands), where agriculture and urban land cover is dominant and the remaining forest area is highly fragmented into isolated small fragments.

Status maps for other assessment years are not shown here because they do not exhibit significant visual differences compared to Figure 2 when viewed at European scale.

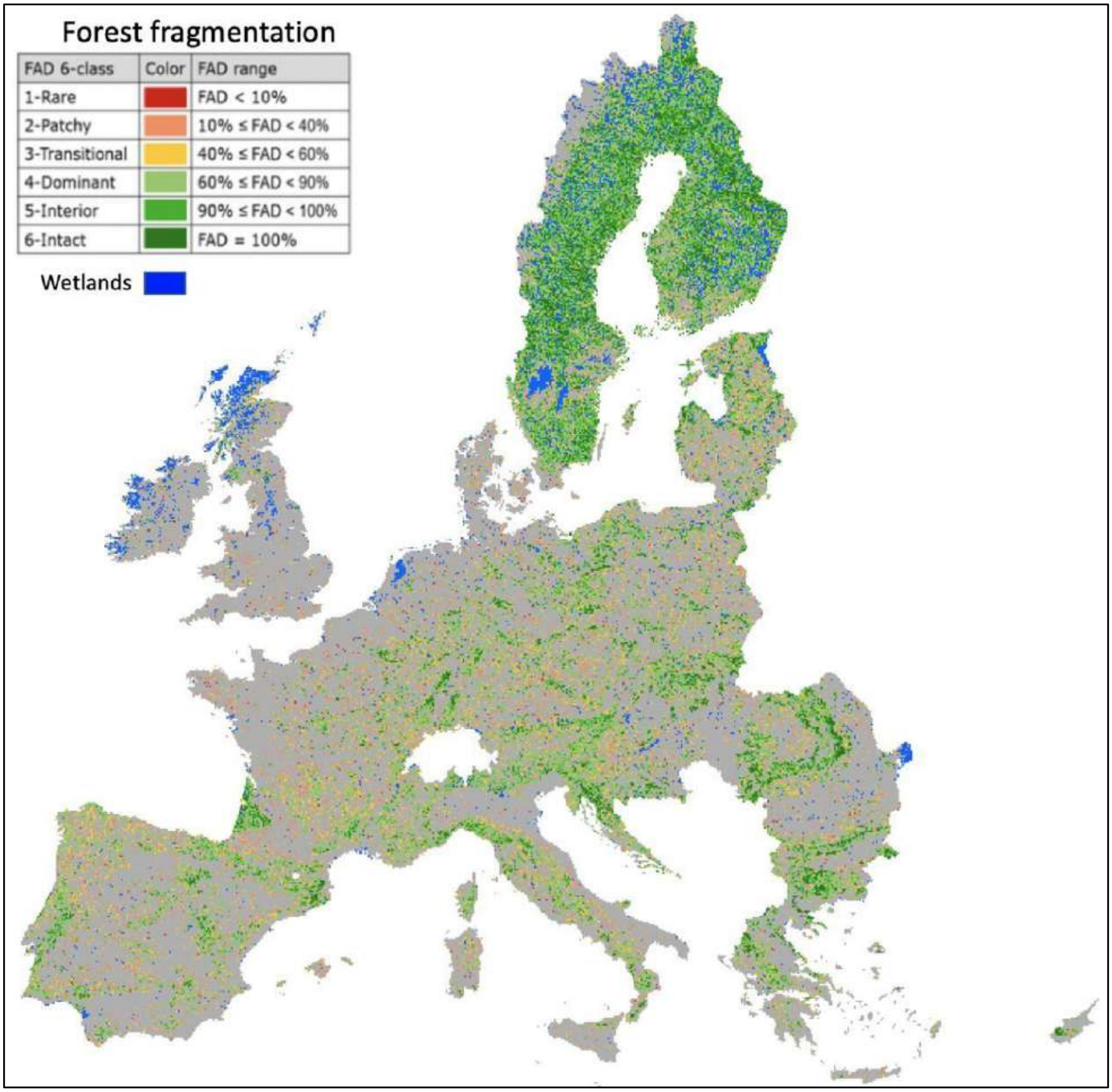

Figure 2. Forest fragmentation for the EU-28 countries at 100 m^2 spatial resolution for the year 2018. Fragmentation is calculated for a local neighbourhood of 500 hectares and categorized into 6 classes with varying degree of forest fragmentation.

3.3. Statistical analysis of the trend

The statistical method used to evaluate the short-term and long-term trend is the 5% rule according to the MAES approach. Table 1 summarises decadal trends in average forest area density (AV-FAD). Further details can be found in Table 2.

Table 1. Long-term trend and short-term trend of average forest area density (AV-FAD) in forests in the EU-28.

	Long-term trend	**Short-term trend**
% per decade	-0.15 (No change)	0.05 (No change)
Time range	2000 - 2020	2010 - 2020
Method	5% rule	5% rule

3.4. Key trend at EU level

Table 2 provides a statistical summary of forest fragmentation parameters and their changes for the four CORINE assessment years and decadal changes with respect to the baseline year 2010.

Table 2. Statistical summary and decadal changes of proportions in the six fragmentation classes, total forest area, number of forest patches, average forest patch size (APS) and average forest area density (AV-FAD).

			Baseline			**Short-term trend**	**Short-term trend**	**Long-term trend**
Forest fragmentation class:	2000	2006	**2010**	2012	2018	**2000-2010**	**2010-2020**	**2000-2020**
Rare [%]	0.53	0.58	**0.59**	0.59	0.60	0.06	0.01	0.03
Patchy [%]	11.45	11.68	**11.71**	11.72	11.72	0.26	0.01	0.15
Transitional [%]	16.31	16.43	**16.44**	16.45	16.42	0.14	-0.03	0.06
Dominant [%]	40.34	40.31	**40.29**	40.28	40.14	-0.05	-0.19	-0.11
Interior [%]	20.11	20.02	**20.02**	20.02	20.03	-0.09	0.02	-0.04
Intact [%]	11.27	10.97	**10.95**	10.93	11.10	-0.32	0.20	-0.09
Area [ha]	158413985	158897958	**159271995**	159459014	159448147	858010	220190	574534
Number of patches	198511	229473	**229218**	229090	228133	30707	-1356	16457
APS [ha]	798.01	692.45	**694.85**	696.05	698.93	-103.16	5.09	-55.05
AV-FAD [%]	72.29	72.01	**71.98**	71.96	72.02	-0.32	0.05	-0.15

Table 3. Statistical summary of change classes for the short and long-term periods shown in Figure 4 and 5.

Map change class:	Colour	2000- 2012	2012- 2018	2000-2018
Forest loss [ha]		5263817	216381	5437631
Forest gain [ha]		5091464	116181	5154965
Spurious change [ha]		8044156	358437	8106730
Forest at both times [ha]		148915252	159015144	148758135
Fragmentation increase [ha]		4692344	169037	4753580
Fragmentation stable [ha]		139016418	158736283	138619858
Fragmentation decrease [ha]		5206490	109824	5384697
Fragmentation increase [%]		3.15	0.11	3.20
Fragmentation stable [%]		93.35	99.82	93.18
Fragmentation decrease [%]		3.50	0.07	3.62

From a statistical perspective, the overall state of forest fragmentation of the EU-28 countries in the time range 2000 to 2018 is stable. This key message is underpinned by the approximately constant value of average forest area density (AV-FAD) and total forest area. However, trends in the contributions of the individual fragmentation classes indicate that larger compact forest patches are converted into smaller patches. This tendency is confirmed by the increasing number of forest patches and the decreasing number of APS. Yet, this tendency is mostly valid for the first decade 2000-2010, while the current decade 2010-2020 shows a more stable situation.

It should be noted that a decreasing APS is not necessarily indicative for increased fragmentation. The increasing number of forest patches combined with the slight growth in total forest area suggests that more small forest patches appear in the vicinity of larger patches. This process might be linked to demographic developments of land abandonment and increased urbanization as is found in the past decades. Despite the fact that more fragments were found (and APS decreased), this process should not be classified as strongly negative because we also found a small increase in total forest area. This fact is well represented by the virtual constant value of AV-FAD.

While the statistics suggest an overall stable situation across the EU-28 countries, it is obvious that local conditions may show significant variations. Geospatial variability of forest fragmentation and their changes can be captured in spatial maps only. Because forest fragmentation can only be measured where forest is present, a forest fragmentation change map must start from a forest cover change map. Moreover, it is not meaningful to calculate forest fragmentation changes on areas that are covered by forest only at one time (forest loss or gain) or where very small, local cover changes occur. The latter would provide local, spurious changes, which are less reliable and dilute the key message focusing on the essential change areas. However, the information on these excluded areas is added to the change map to provide a full picture of where forest was present at both times used for the change analysis. The conceptual approach for deriving essential change areas (Morphological Change Detection) is described in Seebach et al. (2013) and implemented in the free software GuidosToolbox (Vogt & Riitters 2017). The forest cover change map delineates areas where forest is present at both times. This mask is then applied to both forest fragmentation status maps and searched for pixels where forest area density (FAD) has changed by at least 10%. A positive (negative) difference in FAD of 10% is indicative for fragmentation decrease (increase). The final forest fragmentation change map provides a rich set of information extracted from the two time points of the individual state maps: where forest fragmentation is stable, has increased or decreased, where forest cover was lost or gained, and smallscale forest cover changes occur. Figure 3 shows the forest fragmentation change in full resolution to illustrate local details over a sample area in the south of Lisbon, Portugal. The trend map shows areas where forest cover was lost (red), gained (green), the degree of forest fragmentation is stable (darkgrey) or has increased by more than 10% (yellow) or decreased by more than 10% (orange). Blue pixels are assigned to water or wetland present at either time of the change period.

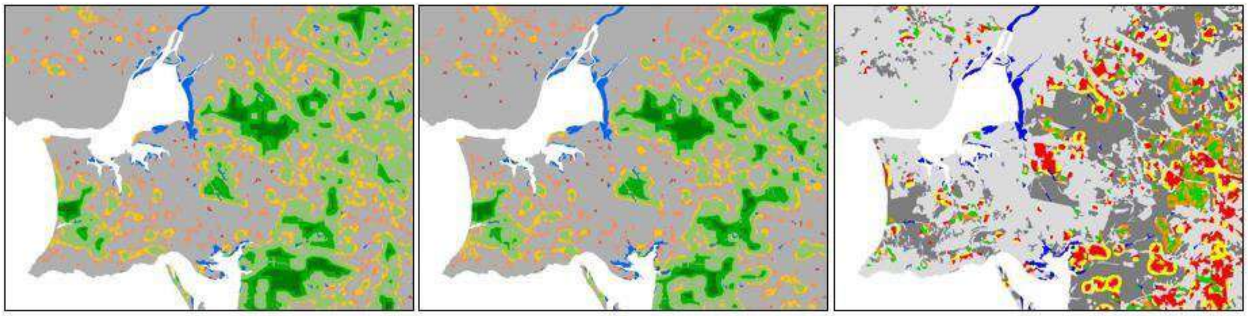

Figure 3. Forest fragmentation, change, forest cover gain and loss south of Lisbon, Portugal in the time frame 2000-2012. Fragmentation 2000 (left), fragmentation 2012 (centre) and fragmentation change map (right), see the legend in Figure 4.

Figure 4 shows the forest fragmentation change for the EU-28 countries in the time frame 2012-2018. As indicated by the statistical summary, the overall situation is very stable. However, the trend map reveals local variability, with increased forest fragmentation in Portugal, southern France, Corsica, southern Greece and the eastern Carpathians mountains. When looking in more detail, an increase in forest fragmentation is often accompanied by a loss of forest (see also Figure 3), which in the case of the Mediterranean region may be linked to occurrence of forest fires (i.e. Coimbra fire, 6/2017, Portugal, visible in Figure 4). On the contrary, a decrease in forest fragmentation is correlated with forest area increase and closing up of perforations within forests. Change map statistics (Table 3) list 99.8% of the common forest area of the two years to be stable (within +/- 10% variability). The relatively small changes in forest cover and fragmentation in Figure 4 could be caused by the very short time-frame of 6 years only.

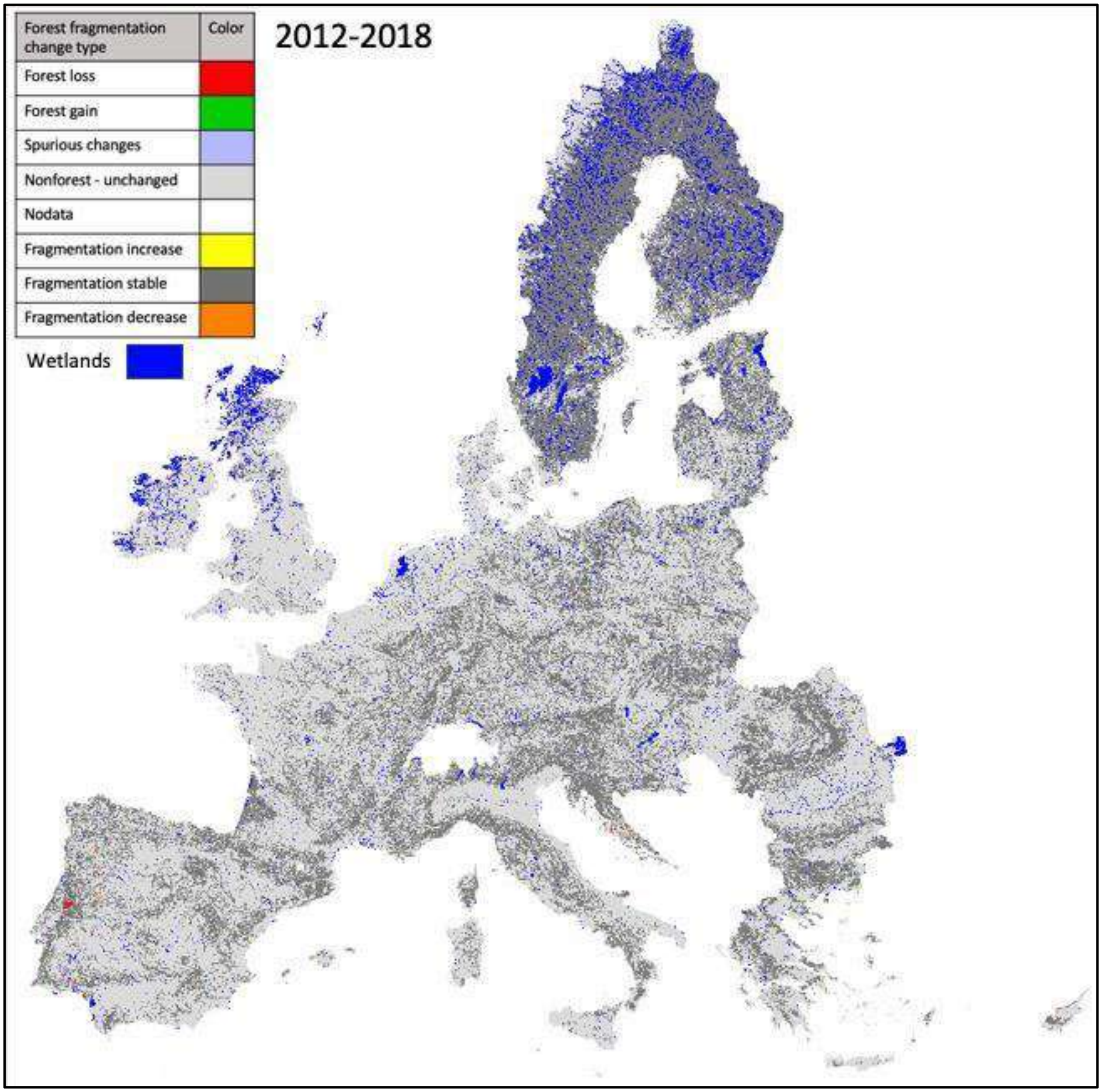

Figure 4. Forest fragmentation change for the EU-28 countries in the time frame 2012-2018.

Changes in forest cover and fragmentation may become more pronounced when the observed time sequence is extended. Figure 5 shows the same assessment but for the long-term time frame from 2000 to 2018. Statistics for this longer observation time frame (Table 3) now list only 93.2% of the common forest area as stable and changes are now more visible: the major change areas are found in the Iberian Peninsula, the northern part of Finland and the Alpine regions. The quite different spatial pattern of forest fragmentation changes for the two periods (Figure 4 and 5) may be related to different length of time, occurrence of natural disasters or perhaps a better implementation of a successful sustainable forest policy in Europe in the past years.

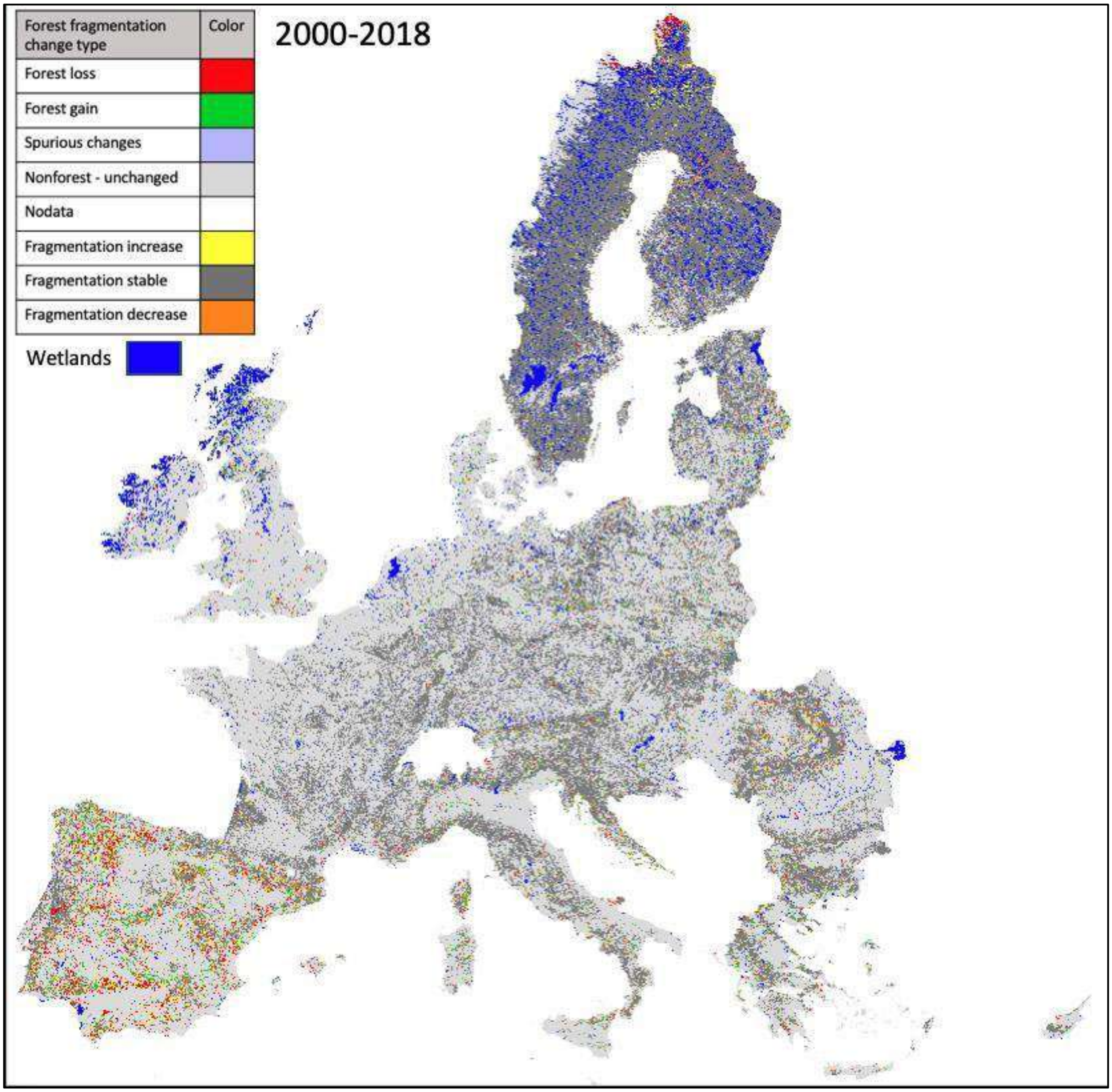

Figure 5. Forest fragmentation change for the EU-28 countries in the time frame 2000-2018.

References

Montréal Process Working Group:

https://www.montrealprocess.org/documents/publications/techreports/MontrealProcessSeptember2015.pdf

Riitters, K.H., Wickham, J.D., O'Neill, R.V., Jones, K.B., Smith, E.R., Coulston, J.W., Wade, T.G. & Smith, J.H. 2002. Fragmentation of continental United States forests. *Ecosystems* 5:815-822.

Riitters, K.H., Wickham, J.D. 2012. Decline of forest interior conditions in the conterminous United States. Scientific Reports 2, Article number: 653. DOI: 10.1038/srep00653

Seebach, L., Strobl, P., Vogt, P., Mehl, W., San-Miguel-Ayanz, J. 2013. Enhancing post-classification change detection through morphological post-processing – a sensitivity analysis. International Journal of Remote Sensing 34:20, 7145-7162, DOI: 10.1080/01431161.2013.815382

Vogt P., Riitters, K. 2017. GuidosToolbox: universal digital image object analysis. *European Journal of Remote Sensing* 50:1, 352-361, DOI: 10.1080/22797254.2017.1330650.

Vogt, P. 2019. Measuring Forest Area Density to quantify Forest Fragmentation. https://ies-ows.jrc.ec.europa.eu/gtb/GTB/psheets/GTB-Fragmentation-FADFOS.pdf

Vogt, P., Riitters, K.H., Caudullo, G., Eckhardt, B., 2019a. FAO – State of the World's Forests: Forest Fragmentation, EUR 29972 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-13036-9, DOI: 10.2760/145325, JRC118594

Vogt, P., Riitters, K.H., Caudullo, G., Eckhardt, B. and Raši, R., 2019b. An approach for pan-European monitoring of forest fragmentation, EUR 29944 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-10374-5, DOI: 10.2760/991401, JRC118541

Wickham, J.D., Riitters, K.H., Wade, T.G., Homer, C. 2008. Temporal change in fragmentation of continental US forests. *Landscape Ecology* 23:891-898. DOI: 10.1007/s10980-008-9258-z

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Fact sheet 3.3.104: Land take (forests)

1. General information

- Thematic ecosystem assessment: Forest
- Indicator class: Pressure. Habitat conversion and degradation (Land conversion)
- Name of the indicator: Land take
- Units: (ha/6 year)

2. Data sources

The indicator based on readily available data: Land take indicator. EEA CSI 014

- Data holder: EEA
- Weblink https://tableau.discomap.eea.europa.eu/t/Landonline/views/Landtakeindicator/Landtakeandnetlandtakeindicator.
- Time-series range: 2000 - 2018
- Version: EEA Land Take viewer version end June 2019 (based on CLC v20)
- Access date 01/07/2019
- Reference: https://www.eea.europa.eu/data-and-maps/indicators/land-take-2/assessment-1

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The main objective of this indicator is to measure the pressure from the development of urban and other artificial land use on natural and managed landscapes that are necessary 'to protect and restore the functioning of natural systems and halt the loss of biodiversity' (Sixth Environment Action Programme (6th EAP, COM(2001)31)).

Land use in Europe is driven by a number of factors such as the increasing demand for living space per person, the link between economic activity, increased mobility and the growth of transport infrastructure, which usually result in urban expansion.

The impact of urbanisation depends on the area of land taken and on the intensity of land use, for example, the degree of soil sealing and the population density. Land take by urban areas and infrastructure is generally irreversible and results in soil sealing, i.e. the loss of soil resources due to the covering of land for housing, roads or other construction work. Converted areas become highly specialised in terms of land use and support few functions related to socio-economic activities and housing. Urban land take consumes mostly agricultural land, but also reduces space for habitats and ecosystems that provide important services such as the regulation of the water balance and protection against floods, particularly if soil is highly sealed. Land occupied by man-made surfaces and dense infrastructure connects human settlements and fragments landscapes. It is also a significant source of water, soil and air pollution.

This indicator looks at the change in the amount (in ha per 6 years) of forest land taken by urban and other artificial land development. It includes areas sealed by construction and urban infrastructure, as well as urban green areas, and sport and leisure facilities. The main drivers of land take are grouped in processes resulting in the extension of:

- housing, services and recreation;
- industrial and commercial sites;
- transport networks and infrastructures;
- mines, quarries and waste dumpsites;
- construction sites.

3.2. Maps

Maps as pixel based were not available. This indicator was provided as tabular information, aggregated at EU-28 level.

3.3. Statistical analysis of the trend

Temporal trends of the Land take indicator are shown in Table 1. These statistics cover all CORINE assessment years, including decadal changes for short and long-term trends. The assessment of the indicator was done using the 5% rules due to the low number of observations; therefore, a statistical test of significance was not done.

3.4. Key trend at EU level

At the European level the land take indicator shows a significant downward trend with a negative decadal change rate of -37% in the short term and -31% in the long term (Table 1 and figure 2). The land take pressure decreased, in terms of area taken for, from 80,331 ha in 2000-2006 to 54,070 in 2012-2018. The downward trend is maintained throughout the time series with a gradual decline of the pressure in the three periods (see figure 2).

Table 1. Forest area taken by urban and other artificial land development in the EU-28 (hectares) in three periods.

	2000-2006	**2010***	**2006-2012**	**2012-2018**	**Short-term trend (% per decade)****	**Long-term trend (% per decade)****
EU-28	80,331	76,428	74,477	54,070	**-37%**	**-31%**
* Baseline (interpolated)						
** Decadal change estimated using the forest area taken between 2010 vs 2012- 2018 values (short term trend); and 2000-2006 vs 2012-2018 (long term trend using 2010 as baseline).						

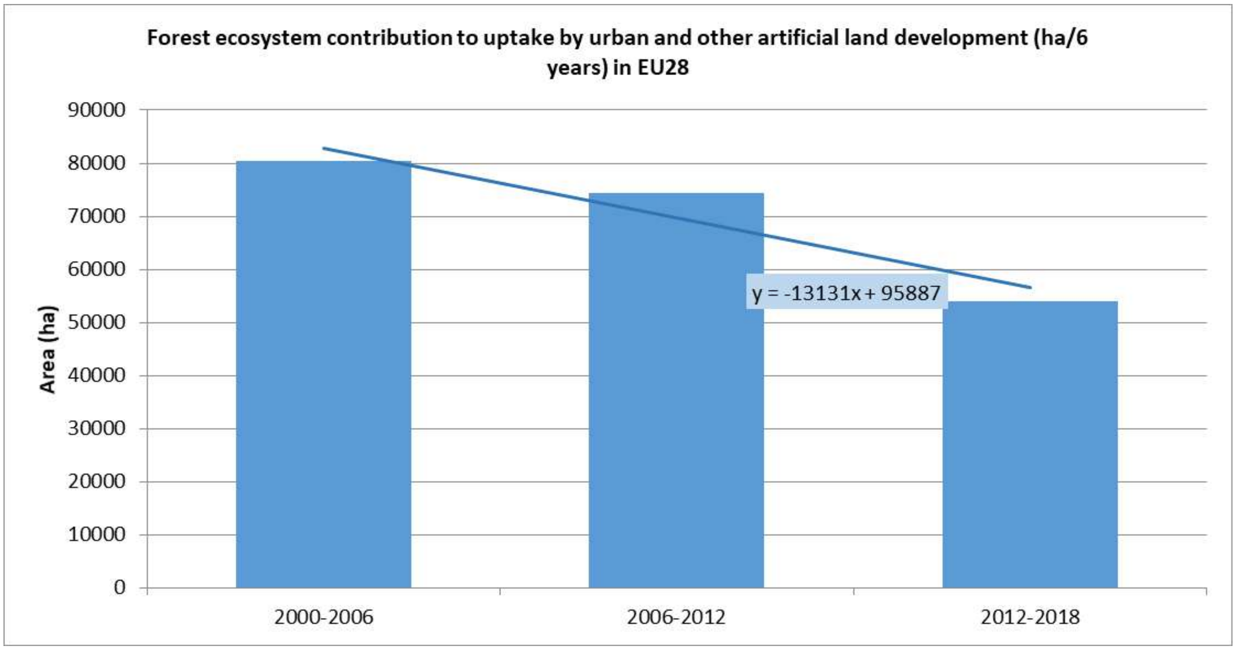

Figure 2 Trend of forest area taken by urban and other artificial land development in the EU-28 in three periods. Values from EEA Land take indicator based on CLC 2000, 2006, 2012 and 2018. See values in Table 1.

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Fact sheet 3.3.105: Wildfires – Burnt area and number of fires

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class (See table 1): Pressures - Climate change
- Name of the indicator: Burnt area and number of fires
- Units: Ha and number of fires

2. Data sources:

The indicator is based on 1) country level statistics, and 2) processed remote sensing data, both provided by the European Forest Fire Information System (EFFIS).

- Data holder: EFFIS - JRC
- Weblink: http://effis.jrc.ec.europa.eu/
- Year or time-series range: 1980-2017
- Version: 2018
- Access date: 07/01/2019
- Reference: San-Miguel-Ayanz, J., Durrant, T., Boca, R., Libertá, G., Branco, A., de Rigo, D., et al. (2017). Forest Fires in Europe, Middle East and North Africa. (pp. 139): European Commission - Joint Research Centre.

3. Assessment of the indicator

Fire is a natural component of ecosystems and they have been occurring for long time before the human era. Changes in fire occurrence can result in ecosystem degradation if plants are not adapted to the new regime. Currently, wildfires are complex phenomena resulting from the interaction between human and biophysical systems. Climate and weather conditions are key determinants of fire activity, they may facilitate fire ignition and spread. However, human actions such as land management and fire prevention reduce rates of fire occurrence. In contrast, other human causal factors, such as arson or negligence, may also contribute to increased occurrence.

Analyses of wildfires occurring in Europe in the last 30 years indicate an increase in the length of the fire season (EFFIS 2018). However, improved management and fire prevention actions contributed to mitigate fire occurrence, specifically in Sothern European countries that are the most fire-affected in the EU. The aim of this report is to assess areas of high occurrence and trends in wildfires that may suggest a decreasing condition of ecosystems in Europe.

Data and methods

EFFIS data

We accessed two types of time-series of burnt area and number of fires from EFFIS (2018). First, country level statistics as provided by countries of the EFFIS network. These data cover the period 1980-2017 for Southern EU countries, with the exception of Croatia and Cyprus that cover 1992-2017 and 2000-2017, respectively.

Second, spatially explicit data covering the period 2000-2017 (18 y) from the Rapid Damage Assessment[23] module of EFFIS. This time series is composed of annual layers at a spatial resolution of 250 m obtained from MODIS daily images representing fires of about 30 ha or larger. The series shows some limitations for this study, among which small burnt areas below the spatial resolution of the MODIS imagery are not mapped. These may include small unburned islands inside the burnt area perimeter. Therefore, the time series maps only a fraction, of around 75% to 80%, of the total area burnt by fires in the EU. Other limitation regards some changes in the remote sensing sensors used by EFFIS in the creation of the time series. This could affect the amount of burnt area and number of fires in the first years of the time series. Finally, the time series represents fires in natural and semi-natural areas and excludes fires occurring in agricultural land.

3.1 Country level data - Trend assessment

To identify trends in the country level data of burnt areas and number of fires, we used robust regression to mitigate the effect of anomalous fire years that might bias the ordinary least squares regression (Dennison et al. 2014; Giglio et al. 2013). Regression slopes were estimated using the non-parametric **Theil-Sen estimator** (Sen 1968; Wilcox 2012) because it accommodates non-normal distributions and is a robust trend slope estimator, meaning that is resistant to the effects of outliers. Additionally, a two-sided **Mann-Kendall** (Gilbert 1987; Kendall 1975; Mann 1945) non-parametric trend test was used to assess the significance of monotonic trends in annual burnt area and number of fires (Dennison et al. 2014; Jolly et al. 2015; Rodrigues et al. 2013).

3.2 Maps - Spatially explicit data

Maps of average burnt area and average number of fires in the 18-year period 2000-2017 were computed in grid cells of 25 km x 25 km. Using large grid cells provides a more comprehensive assessment due to the stochastic character of fire occurrence. Computing averages of fire parameters in short time series is problematic (Archibald et al. 2013), however, longer time series than those provided by EFFIS are not available. For example, the Global Fire Emissions Database (Giglio et al. 2013) provides time series comparable to EFFIS.

We summed the annual EFFIS burnt area data in the 25 km x 25 km grid cells to produce a measure of burnt area from 2000 to 2017 and averaged this over the 18 years. Additionally, we computed the average number of fires occurring in the grid cells. This was done by summing the annual number of fires per grid cell to produce a measure of number of fires from 2000 to 2017 and averaged this over the 18 years. Therefore, one time series was created per grid cell. The time series are highly skewed and often contains a large number of no fire occurrence (zero). This, in addition to the short time range of the series makes challenging assessing trends. Additionally, in short series the effect of outliers is increased, an aspect that may characterise the series in many grid cells. Therefore, the spatial wildfire indicator for the aggregated condition index was produced by selecting those grid cells having at least one fire over the 2000-2017 period with 1 km grid cells following Cherlet et al. (2018).

[23] http://effis.jrc.ec.europa.eu/about-effis/technical-background/rapid-damage-assessment/

3.3 Results

Trend assessment

Results at country level indicate that there is a statistically significant downward trend of annual burnt area in Spain, France, Italy, Greece and Cyprus (Table 1). In Portugal and Croatia no significant trends were found regarding burnt area (Figure 1). However, a strongly significant ($P = 0.008$) upward trend in the number of fires was found in Portugal. In the other countries, either downward trends, in France, Italy and Cyprus, or not significant trends, in Spain, Greece and Croatia, were found (Figure 2).

Table 1. Trends in burnt area and number of fires in six southern EU countries 1980-2017 (Croatia: 1992-2017 and Cyprus 2000-2017). Data source: EFFIS (2018).

Country	Trend in burnt area (ha/y)	Trend in number of fires (n/y)	Period
Portugal	NS	450***	1980-2017
Spain	-3501***	NS	1980-2017
France	-565***	-39**	1980-2017
Italy	-2806***	-217***	1980-2017
Greece	-628*	NS	1980-2017
Croatia	NS	NS	1992-2017
Cyprus	-119*	-13***	2000-2017

NS, not significant.
Results of non-parametric tests examining temporal trends in burnt area and number of fires (***$P<0.01$, **$P<0.05$, *$P<0.1$). Slopes (trends) were estimated using the Theil–Sen non-parametric trend slope estimator and significance tests were performed using the Mann–Kendall trend test.

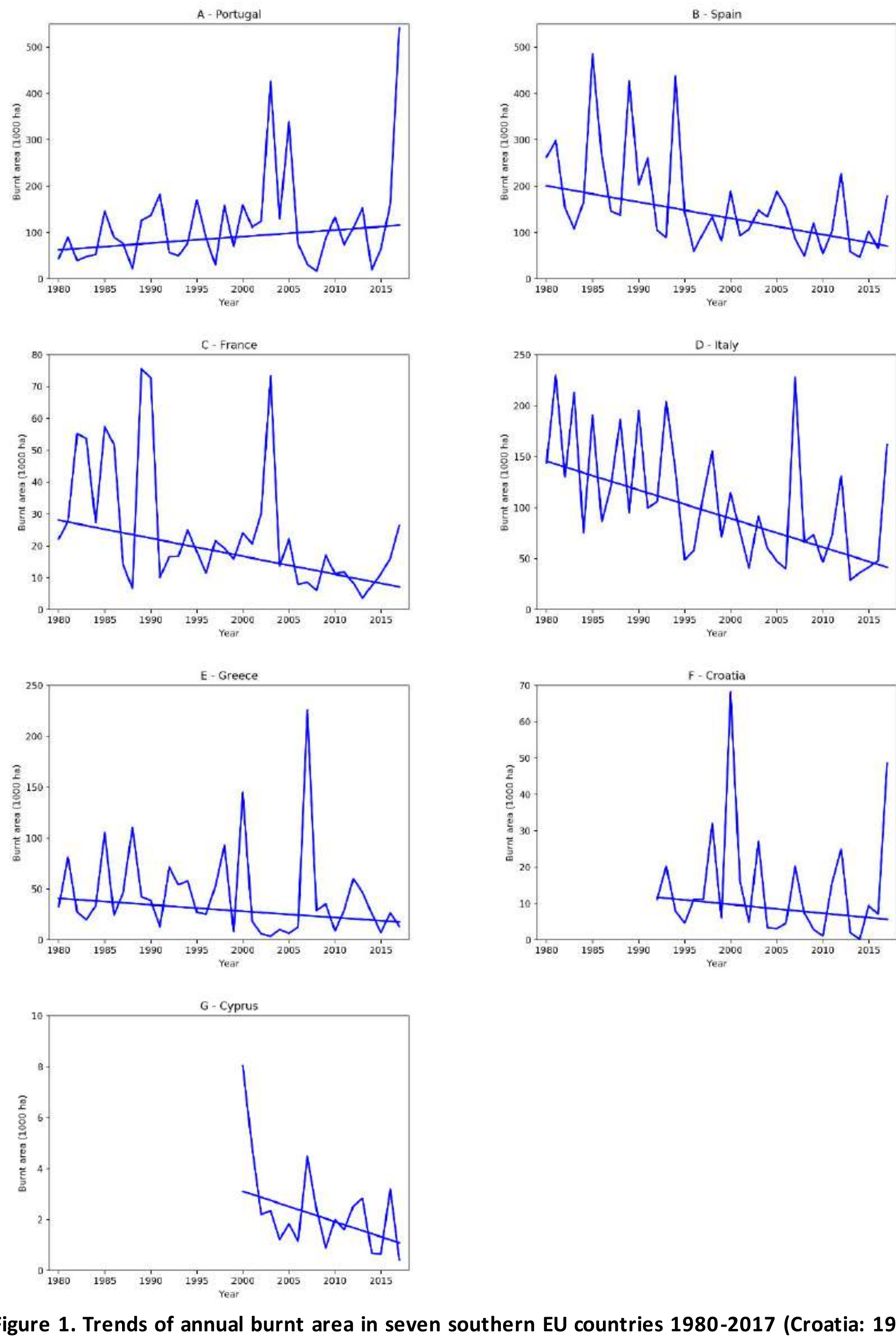


Figure 1. Trends of annual burnt area in seven southern EU countries 1980-2017 (Croatia: 1992-2017 and Cyprus: 2000-2017). Trend line computed using the Theil–Sen non-parametric estimator. Data source: EFFIS (2018).

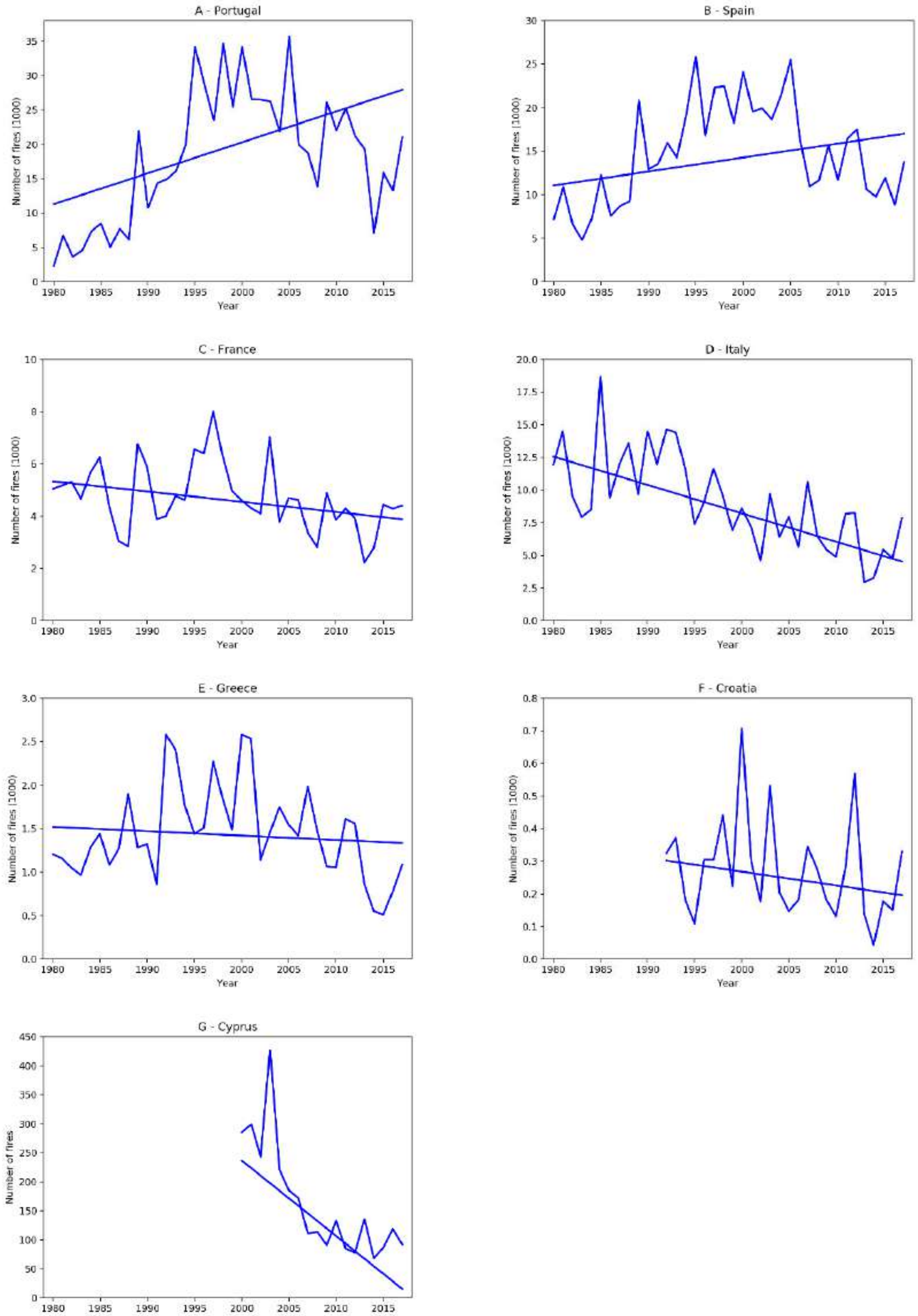


Figure 2. Trends of annual number of fires in seven southern EU countries 1980-2017 (Croatia: 1992-2017 and Cyprus 2000-2017). Trend line computed using the Theil–Sen non-parametric estimator. Data source: EFFIS (2018).

An assessment of the domain covered by Southern countries having long time series (1980-2017), i.e. Portugal, Spain, France, Italy and Greece, indicates a statistically significant ($P = 0.009$) downward trend in burnt area (Figure 3) and a not significant ($P = 0.303$) upward trend in number of fires (Figure 4). Table 2 shows the decadal trend of burnt area and number of fires calculated according to the MAES method.

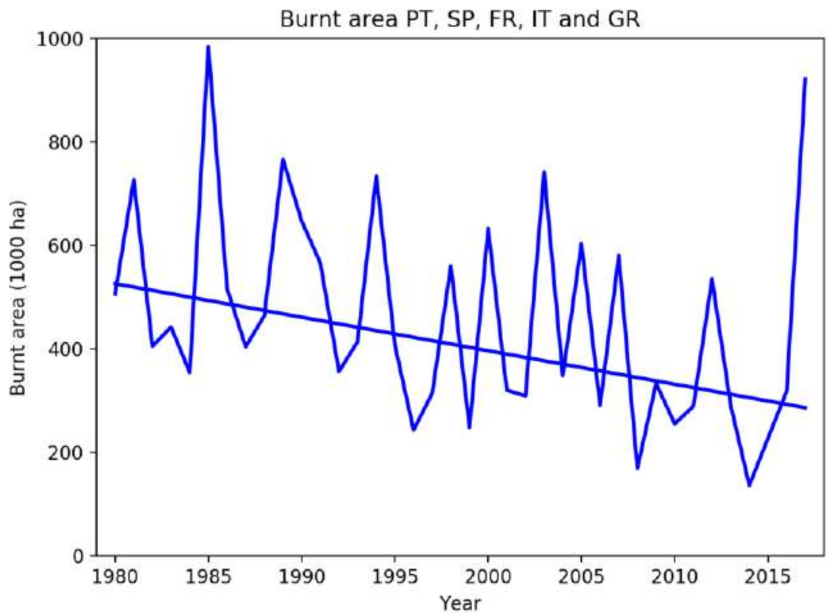


Figure 3. Trend of annual burnt area in Southern EU countries (Portugal, Spain, France, Italy and Greece) 1980-2017. Trend line computed using the Theil–Sen non-parametric estimator. Downward trend (-6478 ha/y) significant at 5% according to Mann-Kendall trend test. Data source: EFFIS (2018).

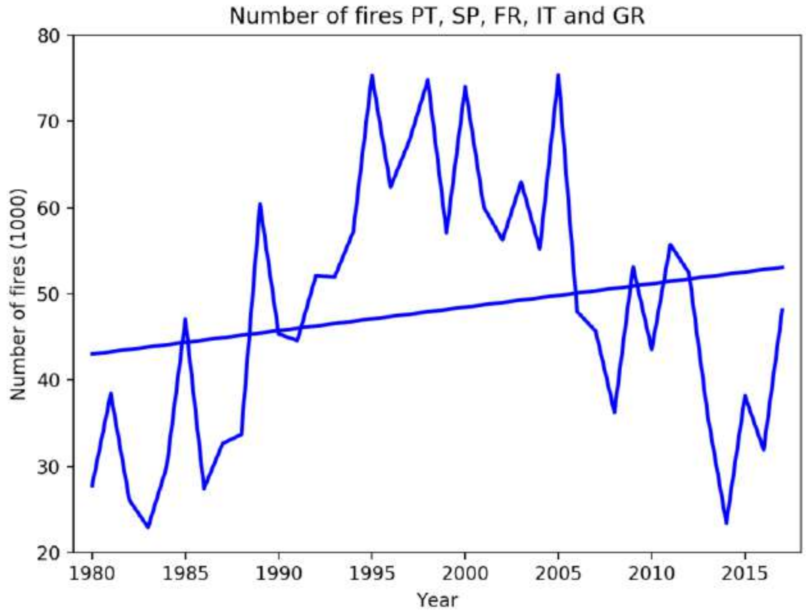


Figure 4. Trend of annual number of fires in Southern EU countries (Portugal, Spain, France, Italy and Greece) 1980-2017. Trend line computed using the Theil–Sen non-parametric estimator. Not significant upward trend (272 fires/y) according to Mann-Kendall trend test. Data source: EFFIS (2018).

A trend is not evident regarding the number or large fires (>50 ha), indeed the number of large fires exhibits a relative decrease from the 1980s until now as shown in Figure 5. The same applies to the number of very large fires (>500 ha). They show fluctuations from year to year, however a trend is not evident. These findings are consistent with the trend assessed Figure 4 including fires of all sizes, where a significant trend was not found.

Table 2. Long-term trend and short-term trend of burnt area and number of fires in Southern EU countries (Portugal, Spain, France, Italy and Greece). N.S.: not significant at 5% according to Mann-Kendall trend test. * Significant at 5% according to Mann-Kendall trend test. Note: Change is always considered as significant in case the percentage change per decade is higher than or equal to +5 % or lower than or equal to -5 %. This is valid for both short and long-term trends and regardless statistical testing. A change outside this interval is thus always considered as policy-relevant to report.

	Long-term trend	Short-term trend
Burnt area		
% per decade	-19.5*	46.2 (N.S.)
Time range	1980-2017	2008-2017
Method	Mann-Kendall	Mann-Kendall
Number of fires		
% per decade	5.3 (N.S.)	-24.7 (N.S.)
Time range	1980-2017	2008-2017
Method	Mann-Kendall	Mann-Kendall

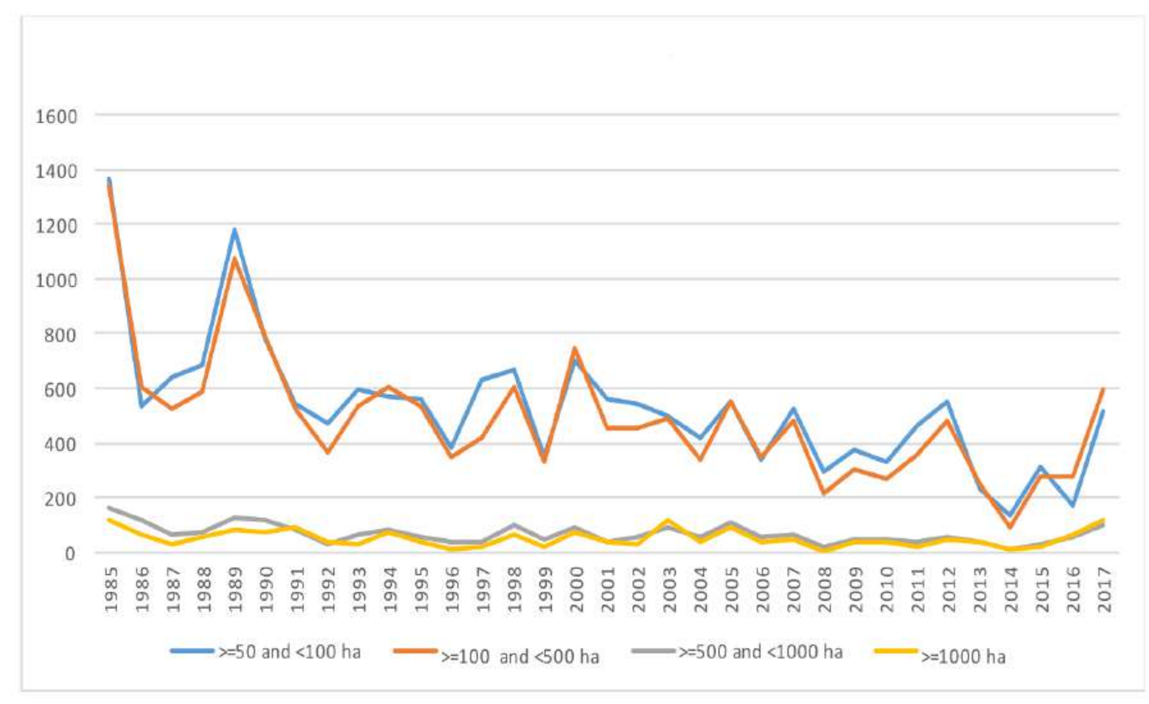


Figure 5. Annual number of large fires (>50 ha) in Southern EU countries (Portugal, Spain, France, Italy and Greece) per fire size, 1985-2017. Data source: EFFIS (2018).

<u>Mapping burn area and number of fires</u>

Maps of mean burnt area (Figure 6) and mean number of fires (Figure 7) show the incidence of these two indicators in the 2000-2017 period. As expected, the areas most affected by fires are in Southern Europe. Specifically, higher levels of mean burnt area and mean number of fires are present in zones of the Iberian Peninsula, South of Italy and Sicily, South of France and Corse, Croatia, Greece and Cyprus

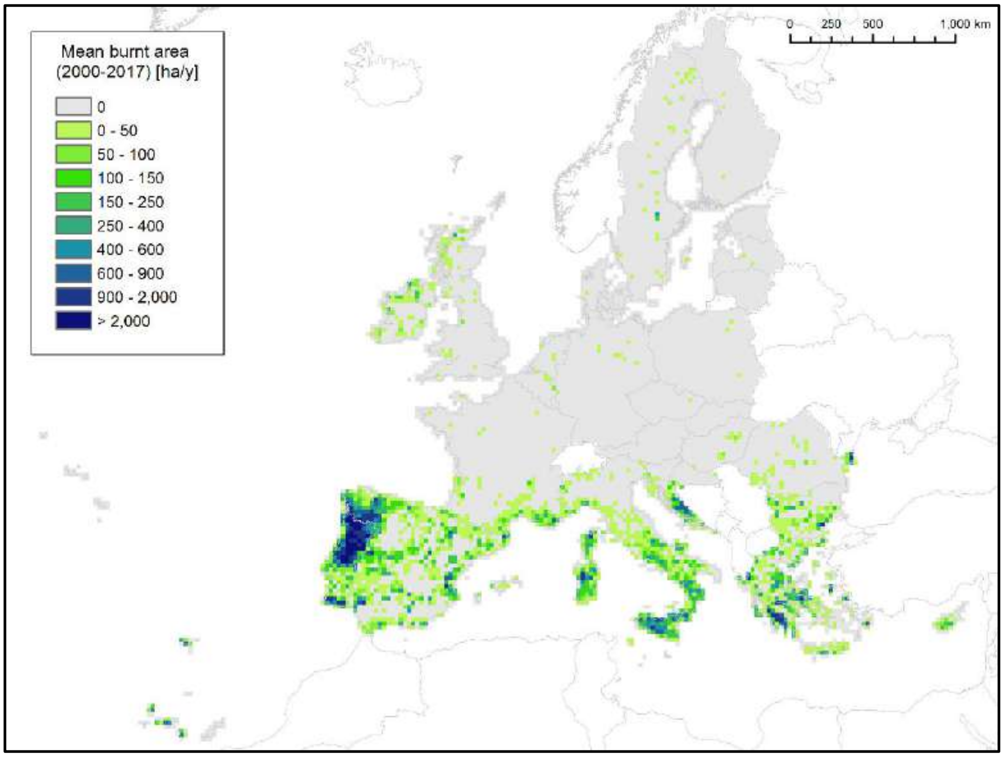
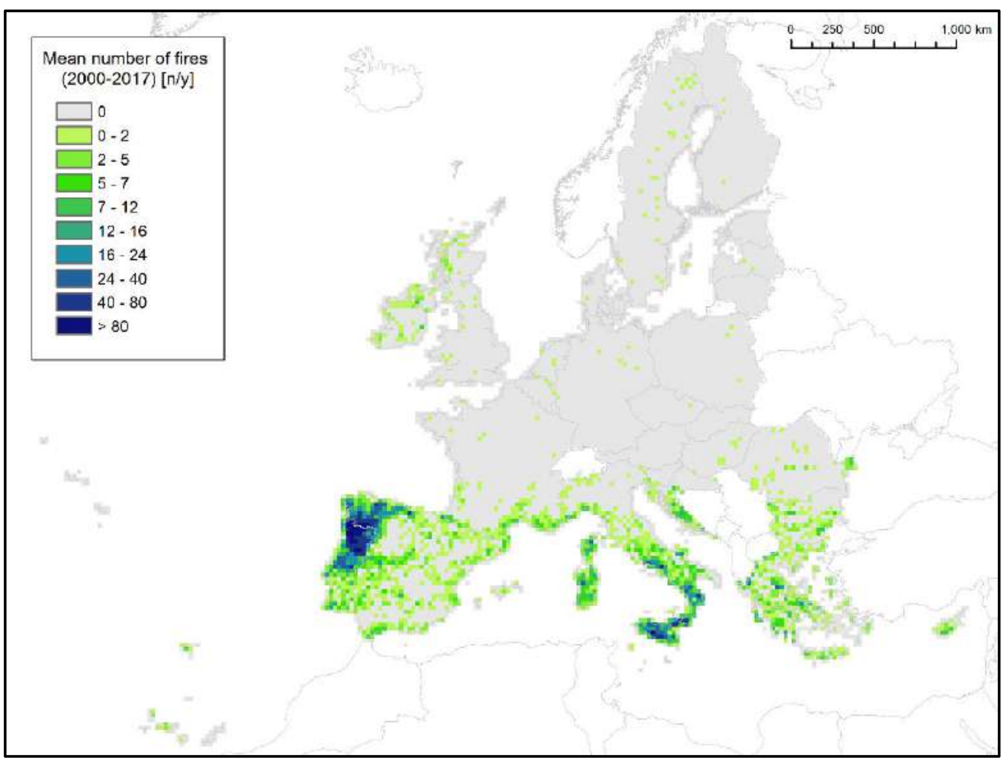


Figure 6. Mean burnt area in 25 x 25 km grid cells in the period 2000-2017 in the EU-28. Data source: EFFIS (2018).

Figure 7. Mean number of fires in 25 x 25 km grid cells in the period 2000-2017 in the EU-28. Data source: EFFIS (2018).



Discussion

Results of this assessment are in line with Giglio et al. (2013) that found a downward trend in burnt area in Europe in the period 1996-2013 and with EFFIS that found no upward trends in the five large Mediterranean countries i.e. Portugal, Spain, France, Italy and Greece, in the period 1980-2017 (San-Miguel-Ayanz et al. 2017). Nevertheless, our results using the spatially-explicit time-series covering 2000-2017 illustrate some hotspot areas regarding mean burnt area and mean number of fires in southern EU (Figure 6 and Figure 7). Evidence indicates that frequently burned areas experience a significant decline in surface soil carbon and nitrogen over time that, in turn, affect ecosystem productivity, among other effects (Pellegrini et al. 2017). Therefore, fire mitigation measures and restoration in these areas should be considered.

Despite hotspot areas are concentrated in a few zones in the EU-28 and that in most of the continent critical areas are not evident, future scenarios projects a worsening situation. Turco et al. (2018) assessed future trends in bunt area in the Mediterranean region. Their results indicate that a warmer and drier climate can affect fire activity not only leading to more favourable conditions, but also changing the structure of the fuel i.e. more available fire-prone biomass in time and space. Therefore, the relation climate fire may change over time facilitating fire ignition and spread. Results of the study of Turco et al. (2018) projects an increase of burnt area over the extended summer months (JJAS) under three warming levels, i.e. at 1.5 °C, 2 °C, and 3 °C of mean global warming. In the 1.5 °C warming burnt area is projected to increase between 40 to 54% with respect to the reference period 1971–2000. Then, in the 2 °C and 3 °C warming the increase is projected at 62-87% and 96-187%, respectively. There is consensus in the scientific literature projecting a worsening of fire activity in Europe under scenarios of climate change (Amatulli et al. 2013; Migliavacca et al. 2013; Sousa et al. 2015; Turco et al. 2014; Wu et al. 2015). Additionally, spatial shifts of the Mediterranean climate domain suggest increased fire activity in areas not traditionally associated with fires (Barredo et al. 2016; Barredo et al. 2018).

The scenarios pointing towards an increased fire activity call for a coordinate action at EU level. In addition to the measures in place, there is a need for further preventing fires through an ecosystem-based approach. For instance, relying more on the natural capacity of forest of limiting fire spread and severity (Bradley et al., 2016; Odion et al., 2004, de Rigo et al., 2017). This is a characteristic of multi-species and multi-age forest stands.

References

Amatulli, G., Camia, A., & San-Miguel-Ayanz, J. (2013). Estimating future burned areas under changing climate in the EU-Mediterranean countries. Science of The Total Environment, 450-451, 209-222, doi:10.1016/j.scitotenv.2013.02.014.

Archibald, S., Lehmann, C. E. R., Gómez-Dans, J. L., & Bradstock, R. A. (2013). Defining pyromes and global syndromes of fire regimes. Proceedings of the National Academy of Sciences, 110(16), 6442-6447, doi:10.1073/pnas.1211466110.

Barredo, J. I., Caudullo, G., & Dosio, A. (2016). Mediterranean habitat loss under future climate conditions: Assessing impacts on the Natura 2000 protected area network. Applied Geography, 75, 83-92, doi:10.1016/j.apgeog.2016.08.003.

Barredo, J. I., Mauri, A., Caudullo, G., & Dosio, A. (2018). Assessing Shifts of Mediterranean and Arid Climates Under RCP4.5 and RCP8.5 Climate Projections in Europe. Pure and Applied Geophysics, 1-17, doi:10.1007/s00024-018-1853-6.

Bradley, C. M., Hanson, C. T., DellaSala, D. A., 2016. Does increased forest protection correspond to higher fire severity in frequent-fire forests of the western United States? Ecosphere 7 (10), e01492+. https://doi.org/10.1002/ecs2.1492.

Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S., & von Maltitz, G. (Eds.). (2018). World Atlas of Desertification. Luxembourg: Publication Office of the European Union.

de Rigo, D., Libertà, G., Houston Durrant, T., Artés Vivancos, T., San-Miguel-Ayanz, J., Forest fire danger extremes in Europe under climate change: variability and uncertainty, EUR 28926 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN: 978-92-79-77046-3, doi:10.2760/13180, JRC108974.

Dennison, P. E., Brewer, S. C., Arnold, J. D., & Moritz, M. A. (2014). Large wildfire trends in the western United States, 1984–2011. Geophysical Research Letters, 41(8), 2928-2933, doi:doi:10.1002/2014GL059576.

EFFIS (2018). European Forest Fire Information System. http://effis.jrc.ec.europa.eu/. Accessed 10th October 2018.

Giglio, L., Randerson, J. T., & Werf, G. R. (2013). Analysis of daily, monthly, and annual burned area using the fourth-generation global fire emissions database (GFED4). Journal of Geophysical Research: Biogeosciences, 118(1), 317-328, doi:doi:10.1002/jgrg.20042.

Gilbert, R. O. (1987). Statistical Methods for Environmental Pollution Monitoring. NY, USA: Wiley.

Jolly, W. M., Cochrane, M. A., Freeborn, P. H., Holden, Z. A., Brown, T. J., Williamson, G. J., et al. (2015). Climate-induced variations in global wildfire danger from 1979 to 2013. [Article]. Nature Communications, 6, 7537, doi:10.1038/ncomms8537.

Kendall, M. G. (1975). Rank Correlation Methods (4th edition). London: Charles Griffin.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3), 245-259, doi:10.2307/1907187.

Migliavacca, M., Dosio, A., Camia, A., Hobourg, R., Houston-Durrant, T., Kaiser, J. W., et al. (2013). Modeling biomass burning and related carbon emissions during the 21st century in Europe. Journal of Geophysical Research: Biogeosciences, 118(4), 1732-1747, doi:doi:10.1002/2013JG002444.

Odion, D. C., Frost, E. J., Strittholt, J. R., Jiang, H., Dellasala, D. A., Moritz, M. A., 2004. Patterns of fire severity and forest conditions in the western Klamath Mountains, California. Conservation Biology 18 (4), 927-936. https://doi.org/10.1111/j.1523-1739.2004.00493.x

Pellegrini, A. F. A., Ahlström, A., Hobbie, S. E., Reich, P. B., Nieradzik, L. P., Staver, A. C., et al. (2017). Fire frequency drives decadal changes in soil carbon and nitrogen and ecosystem productivity. Nature, 553, 194, doi:10.1038/nature24668.

Rodrigues, M., San Miguel, J., Oliveira, S., Moreira, F., & Camia, A. (2013). An insight into spatial-temporal trends of fire ignitions and burned areas in the European Mediterranean countries. Earth Science and Engineering, 3, 497–505.

San-Miguel-Ayanz, J., Durrant, T., Boca, R., Libertá, G., Branco, A., de Rigo, D., et al. (2017). Forest Fires in Europe, Middle East and North Africa. (pp. 139): European Commission - Joint Research Centre.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324), 1379-1389, doi:10.2307/2285891.

Sousa, P. M., Trigo, R. M., Pereira, M. G., Bedia, J., & Gutiérrez, J. M. (2015). Different approaches to model future burnt area in the Iberian Peninsula. Agricultural and Forest Meteorology, 202, 11-25, doi:10.1016/j.agrformet.2014.11.018.

Turco, M., Llasat, M.-C., von Hardenberg, J., & Provenzale, A. (2014). Climate change impacts on wildfires in a Mediterranean environment. [journal article]. Climatic Change, 125(3), 369-380, doi:10.1007/s10584-014-1183-3.

Turco, M., Rosa-Cánovas, J. J., Bedia, J., Jerez, S., Montávez, J. P., Llasat, M. C., et al. (2018). Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nature Communications, 9(1), 3821, doi:10.1038/s41467-018-06358-z.

Wilcox, R. R. (2012). Introduction to Robust Estimation and Hypothesis Testing. San Diego, California, USA: Academic Press.

Wu, M., Knorr, W., Thonicke, K., Schurgers, G., Camia, A., & Arneth, A. (2015). Sensitivity of burned area in Europe to climate change, atmospheric CO2 levels, and demography: A comparison of two fire-vegetation models. Journal of Geophysical Research: Biogeosciences, 120(11), 2256-2272, doi:doi:10.1002/2015JG003036.

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Fact sheet 3.3.106: Heat and drought-induced tree mortality

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Pressures, Climate change
- Name of the indicator: Tree mortality
- Unit: Unit less

2. Data sources

The indicator is based on literature collected by JRC.

- Data holder: JRC D1
- Weblink: not available
- Year or time-series range: 1970-2017
- Access date: November 2018
- References: Caudullo and Barredo (2019).

3. Assessment of the indicator

The indicator shows tree mortality occurrences in Europe reported in the peer-reviewed literature and caused directly or indirectly by drought or heat. All collected sources reported (1) the impacted tree species, (2) the detailed localization of the occurrence, and (3) the years (start and end) of the drought and of the tree mortality.

Methods

The dataset on tree mortality in Europe was created by Caudullo and Barredo (2019). Their study departs from the work of Allen, et al. (2010) that cover the period since 1970 until 2009. In addition, Caudullo and Barredo (2019) collected data from Allen, et al. (2015) for extending the period of the original dataset with post-2009 occurrences according to Settele, et al. (2014). Finally, they did a bibliographic survey for complementing and updating the information on tree mortality within the period 1970-2017 in Europe. For every documented tree mortality occurrence, a point was included in a GIS layer with the help of coordinates, maps or toponyms reported in the reference source. The survey provided 69 peer-reviewed references containing useful information for creating the data set. Thus, the data set contains 293 tree mortality occurrences (Figure 1). The map in figure 1 shows the resulting data set of documented mortality occurrences.
In the data set, each drought/heat event reported in the attribute table is represented by one or more records (points) where mortality occurred. Therefore, the user can query and retrieve the locations where mortality occurred as consequence of specific drought/heat events. Additionally, the source reference of the information of each record is also provided. Thus, each point is associated with its source reference. The attribute table of the tree mortality layer provides, for every mortality occurrence, detailed information of the sources, tree species affected, localisation and years of the drought and the mortality event (Table 1).

Table 1. Information provided in the attribute table of tree mortality layer for every point.

FIELD	DESCRIPTION
REFERENCE	Reference of the source reporting the tree mortality
SOURCE_REF	The source where the reference was found. "Survey" if sourced from the survey done in Caudullo and Barredo (2019)
HEAT_START	Starting year of the drought period
HEAT_END	Ending year of the drought period
MORT_START	Starting year of tree mortality
MORT_END	Ending year of tree mortality
CNTR	Country of the mortality occurrence
ZONE	Zone or region name of the mortality occurrence
SPECIES	Tree species affected
LON	Longitude in decimal degrees of the mortality occurrence (WGS84)
LAT	Latitude in decimal degrees of the mortality occurrence (WGS84)
GEO_SOURCE	Type of source used to localise the point: coordinates, map, toponym

3.1 Short description of the scope of the indicator

Environmental and climatic changes alter the composition, structure and function forest ecosystems. A particular concern requiring further information and data for assessment is tree mortality associated with climate induced physiological stress and interactions with other related pressures such as insect outbreaks and wildfires. This indicator is an attempt to mitigate the lack of information and data on tree mortality in Europe. The indicator builds on previous knowledge and provides a systematic assessment of documented tree mortality occurred in Europe. The spatial domain of the data set covers the EU, Switzerland, Norway and the Balkan countries.

3.2. Maps

The map in figure 1 shows documented tree mortality occurrences induced by drought in the period 1970-2017.

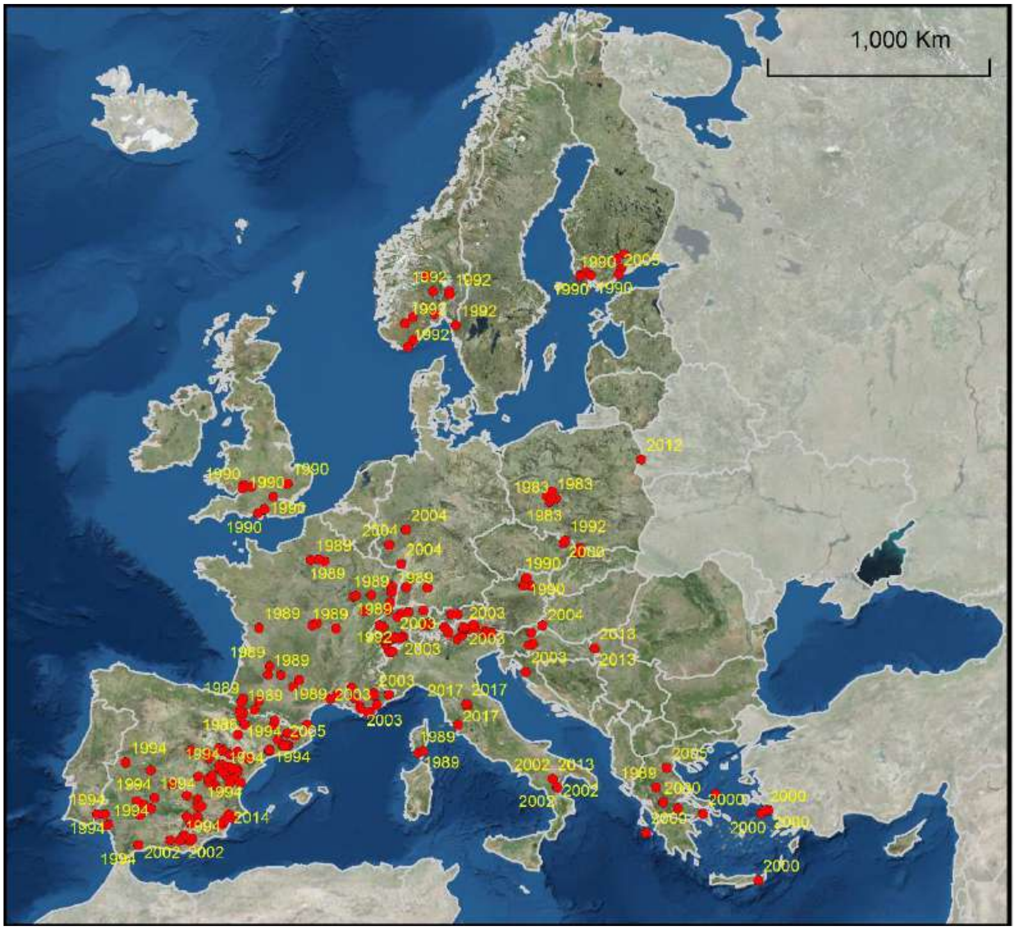

Figure 1. Documented tree mortality occurrences (orange dots) induced by drought 1970—2017. Numbers indicate the starting year of mortality for a sample of records and refer to one or more dots. Information on tree mortality occurrences in the EU-28 outside the map extent was not found. Satellite map of Europe sourced from: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, Swisstopo, and GIS User Community.

3.3. Key trend at EU level

No trend is computed for this indicator because the source data is not the result of a systematic monitoring schema. Therefore, this might limit computing trends. The data set was created from available peer reviewed literature. Therefore, some gaps might be present regarding mortality occurrences not reported in the scientific literature. Despite it, the data set is a valuable reference providing an overview of the extent of documented occurrences that contribute to forest degradation at local level in Europe.

References

Allen, C. D., Breshears, D. D., & McDowell, N. G. (2015). On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. *Ecosphere, 6* (8), art129.

Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D. D., Hogg, E. H., Gonzalez, P., Fensham, R., Zhang, Z., Castro, J., Demidova, N., Lim, J.-H., Allard, G., Running, S. W., Semerci, A., & Cobb, N. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management, 259* (4), 660-684.

Caudullo, G., & Barredo, J. I. (2019). A georeferenced data set of drought and heat-induced tree mortality in Europe. *One ecosystem, (submitted)*.

Settele, J., Scholes, R., Betts, R., Bunn, S., Leadley, P., Nepstad, D., Overpeck, J., & Taboada, M. A. (2014). Terrestrial and inland water systems. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea & L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation and Vulnerability* (pp. 271– 359). Cambridge University Press, Cambridge, UK.

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Fact sheet 3.3.107: Effect of drought on forest productivity.

This fact-sheet is missing.

See: Ivits et al. (2016) Assessing European ecosystem stability to drought in the vegetation growing season. https://doi.org/10.1111/geb.12472

Fact sheet 3.3.108: Tropospheric ozone (AOT40)

4. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class (See table 1): Pressures, Pollution and nutrient enrichment
- Name of the indicator: Tropospheric ozone (AOT40)
- Units: ppb.hours (1 part per billion by volume per hours)[24]

5. Data sources:

The indicator is based on existing reference data:

- Data holder:
- Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP)
- Weblink: https://www.emep.int/
- Year or time-series range: 2000-2017
- Version: v1
- Access date: 19/08/2019

6. Scope of the indicator

Ground level ozone is one of the most prominent air pollution issues in Europe, mainly due to its effects on human health, crops and natural ecosystems (EEA 2018, Karlsson et al. 2019). Relatively to the preindustrial level, the concentration of ground level ozone has more than double in the past century in Europe (Karlsson et al. 2017). High ground level ozone concentrations may cause serious damages to forests particularly during the growing season. These include a reduction of photosynthesis, therefore decreasing forest growth and increasing plant's risks to disease and pest attacks. From an ecosystem perspective this might lead to a loss of biodiversity, decreased habitat quality and changes in water and nutrient cycles.

Over the European continent periods with high concentration of ground level ozone are observed during the summer half of the year, particularly when stable weathers with dry and sunny days occur.

The EU legislation (EU directive 2008/50/EC) as well as the Long-Range Transboundary Air Pollution (LRTAP) convention have adopted as environmentally quality standard (EQS) for the protection of vegetation the AOT40 metric, which stands for Accumulated exposure Over the Threshold value of 40 ppb over daylight hours (8:00–20:00). For forests, the AOT40 is estimated at forest-top over the growing season from April to September. A critical level of 5,000 ppb.hours of AOT40 has been suggested for forests (LRTAP 2009).

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[24] AOT40 is the accumulated amount of ozone over the threshold value of 40 ppb, i.e.:
$AOT40 = \int \max(O_3 - 40\ \text{ppb}, 0.0)\ dt$
where the max function ensures that only ozone values exceeding 40 ppb are included. The integral is taken over time, namely the relevant growing season for the vegetation concerned, and for daytime only. The corresponding unit are ppb·hours. See: https://www.emep.int/mscw/definitions.pdf

The aim of this assessment is to provide a general overview of AOT40 changes in forests within the EU-28 for the period 2000-2017. Average maps over the whole period as well as trends are provided at EU and biogeographical level.

7. Assessment of the indicator and statistical analysis of the trend

AOT40 yearly layers presented in this report were obtained from the EMEP hosted by the EEA (EEA 2018). The original data was produced by the European Monitoring and Evaluation Programme (EMEP) dispersion model (Fagerli et al. 2018), driven by hourly measurements from sparse rural background stations, elevation (GTOPO30) and surface solar radiation (MARS). The year 2017 was modeled using emissions data from 2016. Only data series with more than 75% of valid data were considered and only stations located below 500 m above see level (asl) were used to avoid uncertainties related to the extraction of model data in regions with complex topography (EMEP 2014). These layers were projected a posteriori by the EEA from geographic coordinates to LAEA with a spatial resolution of approximately 7 km x 9 km.

Starting from the AOT40 layers, we implemented a gap-filling procedure to fill-in the missing data present in some grid cells of the time-series. This is a necessary step for the calculation of temporal trends. Following previous literature studies, we gap-filled the data vertically (among different time steps of a target cell). This action was performed when less than or equal to 25% of values on each grid cell was missing, while the data were excluded from the analysis when more than 25% of the values in each grid cell was missing (Jong et al. 2013).

From these maps, we created two products: first, an average map of AOT40 over the whole period, and second, a map showing the trends in AOT40. The latter map was computed estimating regression slopes on each grid cell using the non-parametric Theil–Sen (TS) estimator (Sen 1968, Wilcox 2012). The Theil–Sen (TS) procedure is a rank-based test that calculates the slope and intercept of the time-series by determining the median of all estimates of the slopes derived from all pairs of observations (Hoaglin et al. 2000). The TS procedure is commonly used in estimating vegetation indices trends, such as NDVI trends (Alcaraz-Segura et al 2009) because it is resistant to outliers and is robust in case of skewed data (Eastman et al. 2009). The significance of the TS slope, was tested using the non-parametric Mann-Kendall test (Kendall 1975, Mann 1945).

The same analysis as done at grid cell level was conducted at biogeographical level (EEA, 2018) and over the whole EU. For each biogeographical region/EU level we calculated zonal mean annual values from the AOT40 layers and then calculated the trends using the TS slope estimator and its significance using the Mann-Kendall test.

It is important to mention that all the results obtained have been masked with the 'woodland and forest' ecosystem type. This was derived from the Corine Land Cover (CLC) 2012 v. 18.5 at 100 m and 250 m spatial resolution following MAES (2013).

4.1 Maps and trends

EU level

Figure 1 shows mean values of AOT40 in forests, computed at the grid cell level (~ 8 km), ranging between nearly 500 ppb.hours to 68,000 ppb.hours. The lowest values of ATO40 are in Northern Europe and exhibit an increasing gradient from north (e.g. Lapland) to Central Europe (e.g. Denmark and Germany). The highest AOT40 values are reported in the Southern Alps, however high values are also shown in the Apennines and forested zones of Austria, Slovenia, the Istrian peninsula and the Provence in France.

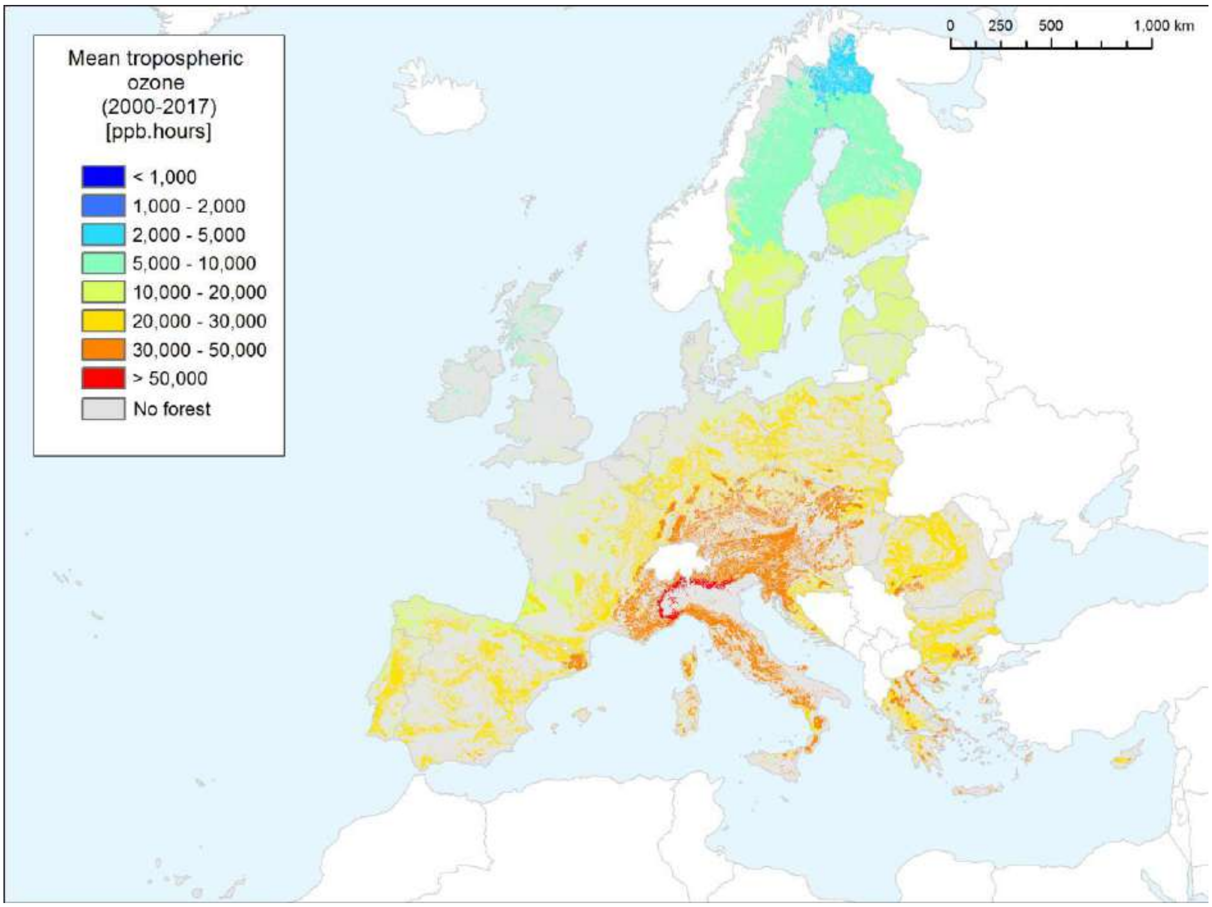

Figure 1. Mean tropospheric ozone (AOT40) in forests for the period 2000-2017 within the EU-28 countries.

Figure 2 shows significant trends of AOT40 in forests over the period 2000 to 2017 with values ranging between nearly -1500 ppb.hours/y to 700 ppb.hours/y. The greatest part of Europe is characterised by downward trends of AOT40, which is also shown in Figure 3, where the trend of AOT40 in forests is presented over the whole EU-28 domain. Grid cells exhibiting upward trends of AOT40 are very few and sparsely distributed (e.g. Luxemburg and Catalonia in Spain). Table 1 shows the decadal trend calculated according to the MAES approach.

Table 1. Long-term trend and short-term trend of tropospheric ozone (AOT40) in forests in the EU. * Significant at 5% according to Mann-Kendall trend test.

	Long-term trend	Short-term trend
% per decade	-27.87*	-31.0*
Time range	2000-2017	2000-2017
Method	Mann-Kendall	Mann-Kendall

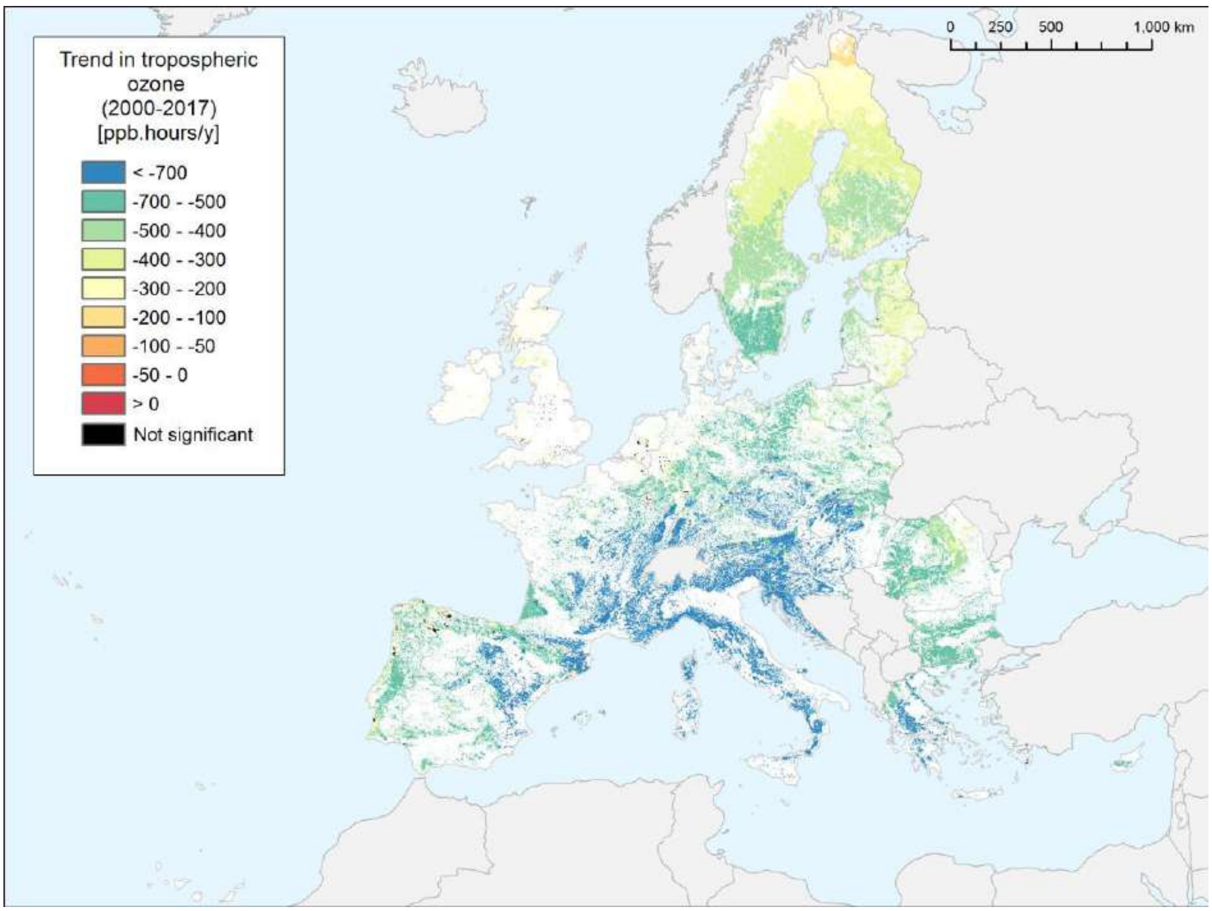

Figure 2. Trend in tropospheric ozone (AOT40) in forests in the EU-28 countries at a spatial resolution of 7 km x 9 km (significant at the 5% level according to the Mann-Kendall test).

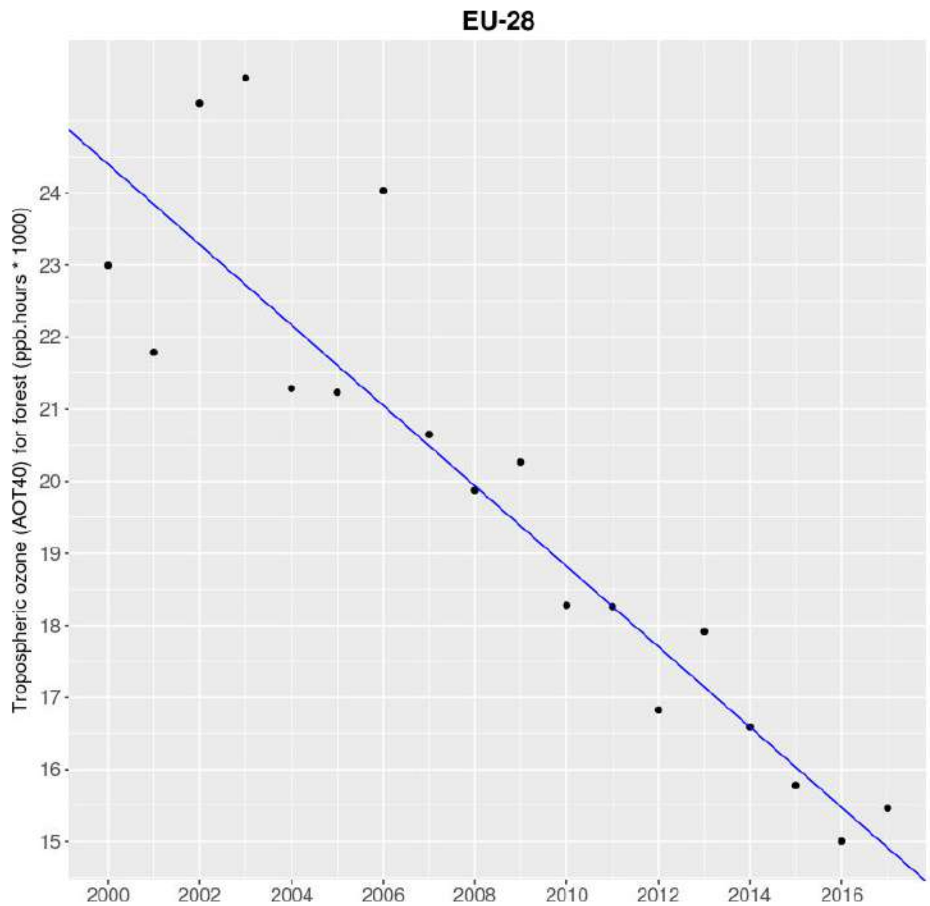

Figure 3. Trend of tropospheric ozone (AOT40) in forests in the EU-28. Trend significant at the 5% level according to the Mann-Kendall test.

Biogeographical level

The analysis done at biogeographical level show different values of mean AOT40 in forests among the regions (Figure 4). The highest mean AOT40 is present in the Pannonian and the Alpine region both reaching AOT40 values over 30,000 ppb.hours. Follow the Mediterranean, Black Sea, Continental and Steppic regions with values ranging from 27,400 ppb.hours to 25,000 ppb hours.

The lowest values are shown in the Atlantic, Boreal and Macaronesia regions with values of 15,600, 9,700 and ~6,700 ppb.hours, respectively. It is important to mention that the Black Sea, the Alpine and Steppic regions do not fall entirely in the EU-28, therefore their values refer to the EU-28 part. In fact, the Alpine domain does not include Switzerland and Norway, the Steppic region is only represented by a very small region North-west of the Black Sea, and the Black Sea region is only represented by a narrow band on the West coast of the Black Sea.

Concerning the trends, the general downward trend observed over the whole Europe in Figure 3 is confirmed at biogeographical region level (Figure. 5). For all the biogeographical regions, the downward trend is statistically significant at 5% level according to the Mann-Kendal test (Table 2).

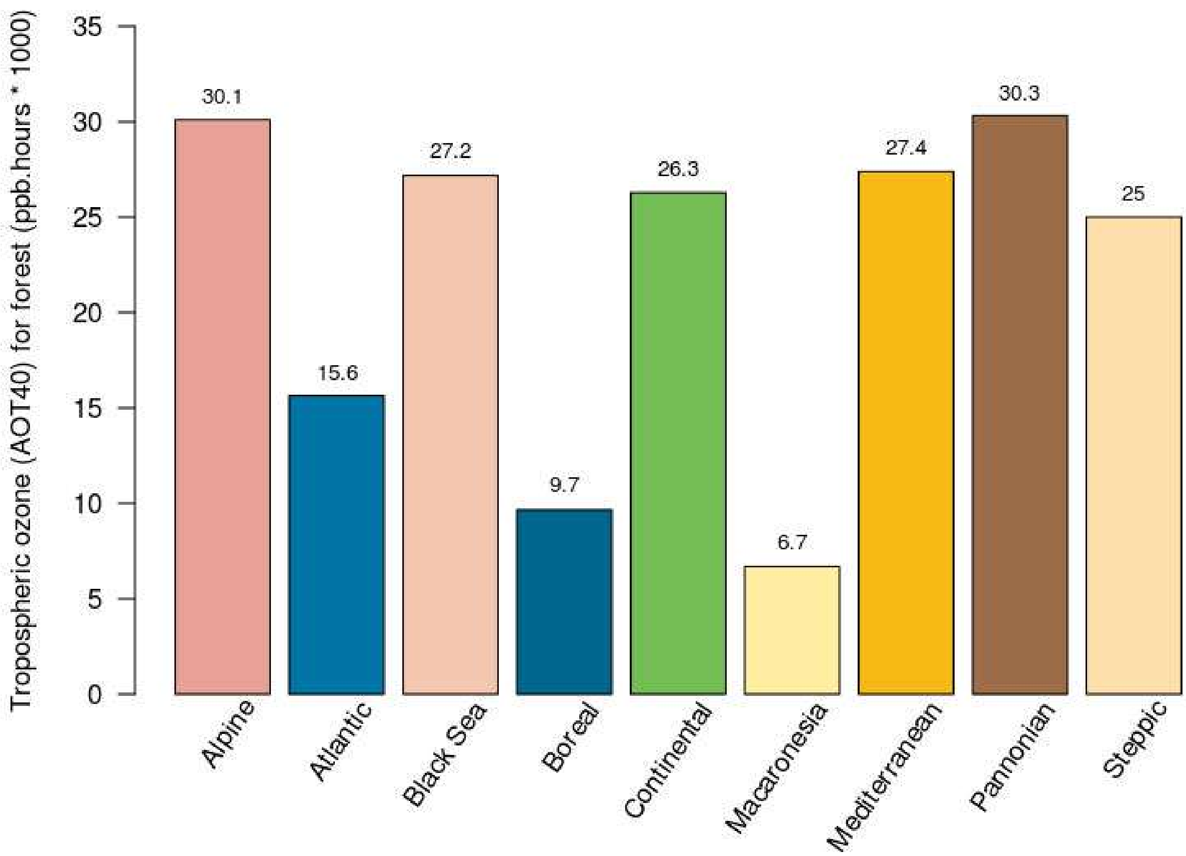

Figure 4. Area-averaged tropospheric ozone (AOT40) in forests for the period 2000-2017 computed for each biogeographical region within the EU-28 countries.

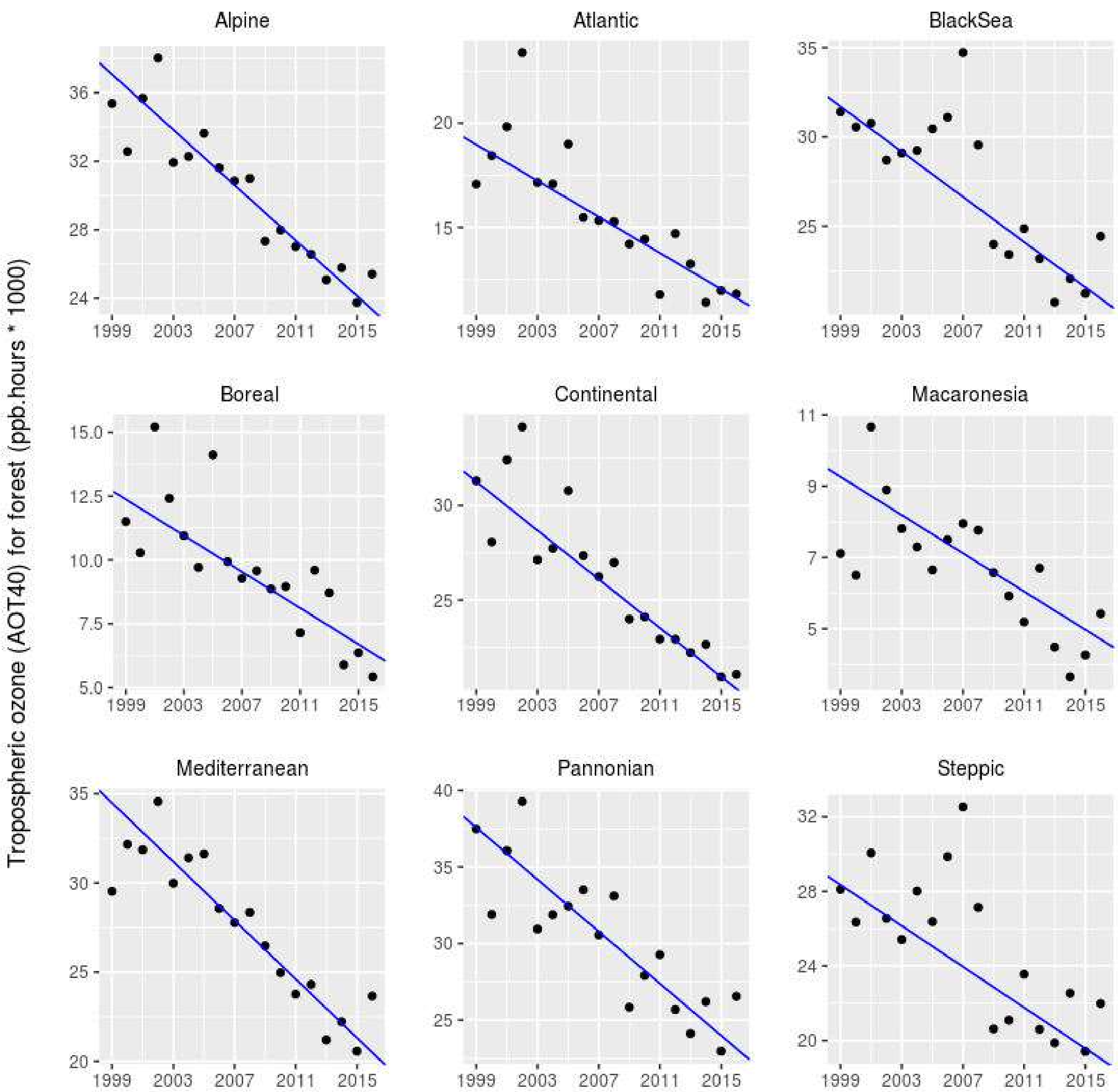

Figure 5. Trends of tropospheric ozone (AOT40) in forests per biogeographical region. All trends are significant at the 5% level according to the Mann-Kendall test.

Table 2. Trends of tropospheric ozone (AOT40) in forests per biogeographical region. All trends are statistically significant at the 5% level according to the Mann-Kendall test.

Biogeographical region	**AOT40 trend (ppb.hours/y)**
Alpine	-807.6
Atlantic	-432.4
Black Sea	-632.9
Boreal	-354.7
Continental	-644.9
Macaronesia	-267.9
Mediterranean	-822.9
Pannonian	-849.3
Steppic	-548.5

Summary and discussion

Average values of AOT40 in forest over the period 2000-2017 reveal an increasing gradient from North to South. The lowest values are recorded in the British Islands, Sweden, Finland as well as Estonia and Latvia. In contrast, the highest values are shown in the Southern Alps, Apennines and forested zones of Austria, Slovenia, the Istrian peninsula and the Provence. Concerning trends, an overall downwards trend of AOT40 in forests is shown in Europe and in all the biogeographical regions. This trend is in line with findings of other studies although for a slight different period such as 2001-2014 in Anav et al. (2019). A limited part of the study domain showed significant upward trends of AOT40, e.g. Luxemburg and parts of Catalonia in Spain.

Mean values of AOT40 for the period 2000-2017 exceed in much of of the EU-28 domain the critical level of 5,000 ppb.hours suggested for forests (LRTAP 2009). Only in Northern Lapland, in the northern part of Sweden and Finland, AOT40 values are lower than 5,000 ppb.hours.

Additionally, despite a considerable reduction of mean AOT40 levels in the EU (Figure 3), e.g. in all Northern Fennoscandia as shown in the EMEP report (Fagerli et al. 2018, Figure 2.5 therein), in 2017 around 72% of the EU forest area was exposed to AOT levels above the critical value of 5,000 ppb.hours. However, it should be noted the many uncertainties derived from the modelling implemented for producing the AOT40 dataset. Indeed, it is indicated that "it seems premature to compare the modelled AOT40 values with critical levels" (Fagerli et al. 2018: 24). It is important to mention that other studies have found that modeled AOT40 tends to overestimate the observed values in many regions of Europe (EMEP, 2018) and conclude that the comparison between modelled AOT40 values and critical levels is discouraged (EMEP, 2018). One of the reason for the mismatch might be related to the fact that a major limitation of AOT40 is that it considers only the ozone concentration at forest-top, while ozone damages the leaves of trees by entering the tree system and reaching the leaves through the stomata (Anav et al. 2019).

References

Anav, A., et al. (2019). "Growing season extension affects ozone uptake by European forests." Science of the Total Environment **669**: 1043-1052.

EEA (2018). Exposure of ecosystems to acidification, eutrophication and ozone, European Environment Agency.

Eastman, J. R., et al. (2009). "Seasonal trend analysis of image time series." International Journal of Remote Sensing **30**(10): 2721-2726.

Fagerli, H., et al. (2014). Transboundary particulate matter , photo-oxidants, acidifying and eutrophying components. EMEP Report 1/2014, EMEP.

Fagerli, H., et al. (2018). Transboundary particulate matter , photo-oxidants, acidifying and eutrophying components. EMEP Report 1/2018, EMEP.

de Jong, R., et al. (2013). "Shifts in Global Vegetation Activity Trends." Remote Sensing **5**(3): 1117-1133.

Karlsson, P. E., et al. (2017). "Past, present and future concentrations of ground-level ozone and potential impacts on ecosystems and human health in northern Europe." Science of the Total Environment **576**: 22-35

LRTAP (2009). Mapping critical levels for vegetation. Manual on Methodologies and Criteria for Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends. G. Mills.

MAES (2013). Mapping and Assessment of Ecosystems and their Services - An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. (pp. 57). Luxembourg.

Mann, H. B. (1945). "Nonparametric Tests against Trend." Econometrica **13**(3): 245-259.

Wilcox, R. (2012). "Introduction to Robust Estimation and Hypothesis Testing, 3rd Edition." Introduction to Robust Estimation and Hypothesis Testing, 3rd Edition: 1

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Fact sheet 3.3.109: Exceedances of critical loads for acidification and eutrophication in forest ecosystems

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Pressures, pollution and nutrient enrichment
- Name of the indicator: Exceedances of critical loads for acidification and eutrophication in forest ecosystems
- Units: (eq/ha yr) and forest ecosystem area exceeded (%)

2. Data sources

- Data holder: Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP)
- Web link: https://www.emep.int/
- Year of time-series range: 2000, 2005, 2010 and 2016
- Version: 2018 (EMEP Status Report 1/2018)
- Access date: 01/07/2019
- References:
    - Hettelingh, J.P. Posch, M. Slootweg, J. (eds.), 2017. European critical loads: database, biodiversity and ecosystems at risk: CCE Final Report 2017. RIVM Report 2017-0155, Coordination Centre for Effects, Bilthoven, Netherlands, 204 pp; ISBN 978-90-6960-288-2, DOI: 10.21945/RIVM-2017-0155.
    - Tsyro, S. Aas, W. Solberg, S. Benedictow, A. Fagerli, H. Posch, M., 2018. Chapter 2: Status of transboundary air pollution in 2016. In: Fagerli, H., et al. (Eds.): Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components. EMEP Status Report 1/2018, Norwegian Meteorological Institute, Oslo, Norway, pp. 15-40; ISSN 1504-6109.

3. Assessment of the indicator

3.1 Short description of the scope of the indicator

Nitrogen and sulphur emissions and depositions can lead to eutrophication and acidification of ecosystems. When this pollution exceeds certain levels, i.e. "critical load", it affects ecosystems and biodiversity[25]. The exceedances of critical loads were computed for the total nitrogen and sulphur depositions modelled on 0.1 x 0.1 degree grid cells across Europe by Hettelingh et al. (2017) and Tsyro et al. (2018). Spatial data (maps) of exceedances of critical loads for eutrophication and acidification were provided by EMEP for the years 2000, 2005, 2010 and 2016. The exceedance shown in the maps is the so-called "average accumulated exceedance" (AAE). AAE is computed on each grid cell as the area weighted average of the exceedance of critical loads of all ecosystems (Tsyro et al. 2018).

[25] https://www.eea.europa.eu/data-and-maps/indicators/critical-load-exceedance-for-nitrogen/critical-load-exceedance-for-nitrogen and https://www.eea.europa.eu/data-and-maps/indicators/exposure-of-ecosystems-to-acidification-14/assessment-1

In this assessment we created maps of exceedances of critical loads for eutrophication and acidification in EU-28 forests by masking the EMEP maps with a forest ecosystem map produced from CORINE land cover 2012 data (version 18.5) (EEA 1993, 2000) according to MAES (2013) at the spatial resolution of the EMEP maps.

3.2 Maps

Maps of change in exceedances of critical loads for acidification and eutrophication in EU-28 forests are shown in Figure 1 and Figure 2, respectively. The maps show the change in the long term, 2000-2016, and short-term, 2010-2016. A decrease of critical loads for acidification and eutrophication across EU-28 forests in both the long and short term is evidenced in the maps. However, despite these reductions, critical loads for acidification in 2016 were exceeded in 30% of the EU-28 forest area, and the mean exceedance is about 28 eq/ha yr in this ecosystem. The situation regarding critical loads for eutrophication is more severe because critical loads in the same year were exceeded in 74% of the EU-28 forest area, exhibiting a mean exceedance of about 205 eq/ha yr in forests (Table 1 and Figure 3: C and D). Additionally, in the short term trend maps of Figure 2-B, increasing levels of exceedances of critical loads for eutrophication are evident in the Carpathians, Pyrenees and some other forested areas across the EU-28.

A B

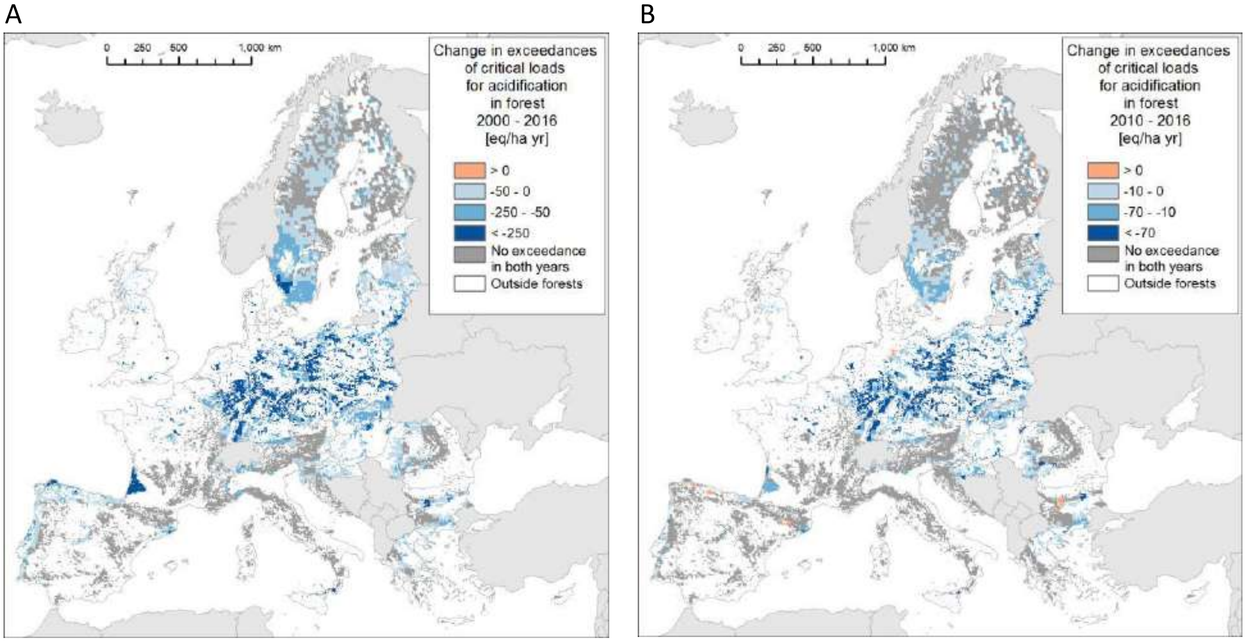

Figure 1. Change in exceedances of critical loads for acidification between A) 2000 and 2016 (long term) and B) 2010 and 2016 (short term) in EU-28 forests. Change maps created from the EMEP 2000, 2010 and 2016 maps of exceedances of critical loads for acidification simulated with the EMEP MSC-W model (Hettelingh et al. 2017; Tsyro et al. 2018). Source of data: EMEP.

A B

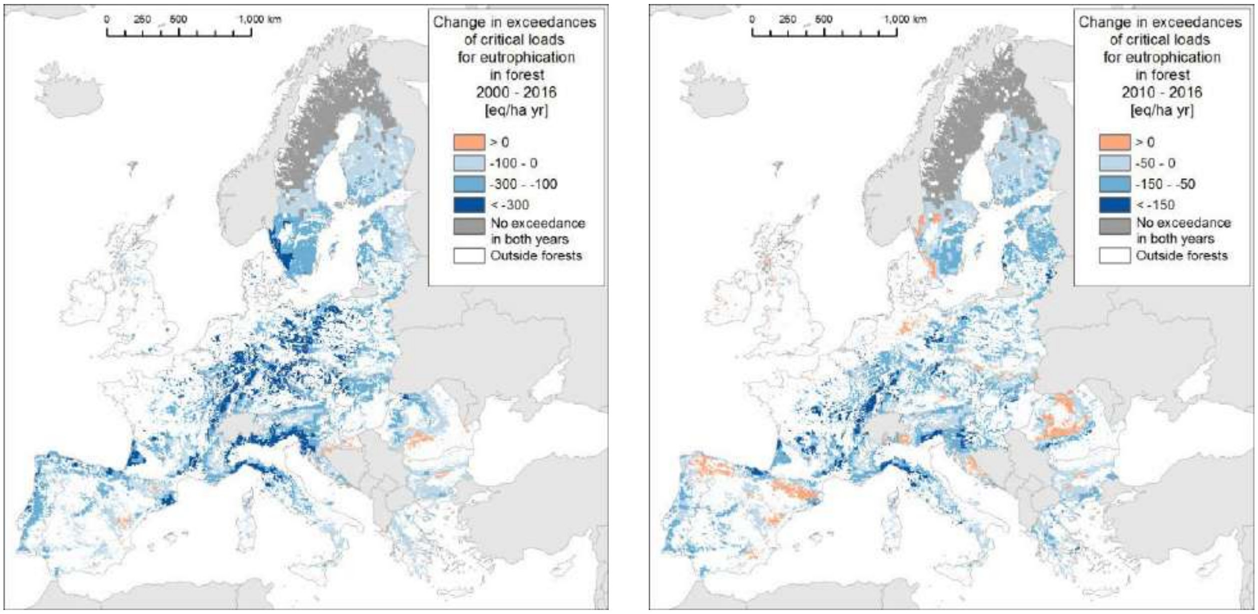

Figure 2. Change in exceedances of critical loads for eutrophication between A) 2000 and 2016 (long term) and B) 2010 and 2016 (short term) in EU-28 forests. Change maps created from the EMEP 2000, 2010 and 2016 maps of exceedances of critical loads for eutrophication simulated with the EMEP MSC-W model (Hettelingh et al. 2017; Tsyro et al. 2018). Source of data: EMEP.

3.3 Key trend at EU level

Trends of critical loads exceedance and the area exceeded for acidification and eutrophication in EU-28 forests indicate a decrease from 2000 onwards (Figure 3). Mean critical loads exceedance for acidification in forests have decreased constantly from 124 eq/ha yr in 2000 to 28 eq/ha yr in 2016, resulting in a downward long term trend of -93% per decade (Table 1)[26]. Similarly but less pronounced, critical loads exceedance for eutrophication exhibits a long term downward trend of -34% per decade. Passing from 344 eq/ha yr in 2000 to 205 eq/ha yr in 2016. As shown in Figure 3 (A and B) and Table 1, a downward trend for critical loads exceedance for acidification and eutrophication in EU-28 forests is evidenced in both the long and short term periods.

Results of the assessment of the area exceeded for acidification and eutrophication in EU-28 forests indicate a downward trend in both the long and short term period (Figure 3: C and D and Table 1). The downward trends of forest area exceeded for acidification are more pronounced that those of eutrophication in both the short and long term periods. That means that the area affected by acidification has been reduced more rapidly than that affected by eutrophication.

The trends shown in Figure 3 point in the right direction, but more efforts are needed in terms of emissions reductions to reach non-exceedance of critical loads in European forests and other ecosystems (Tsyro et al. 2018).

[26] 5% rule according to the MAES approach.

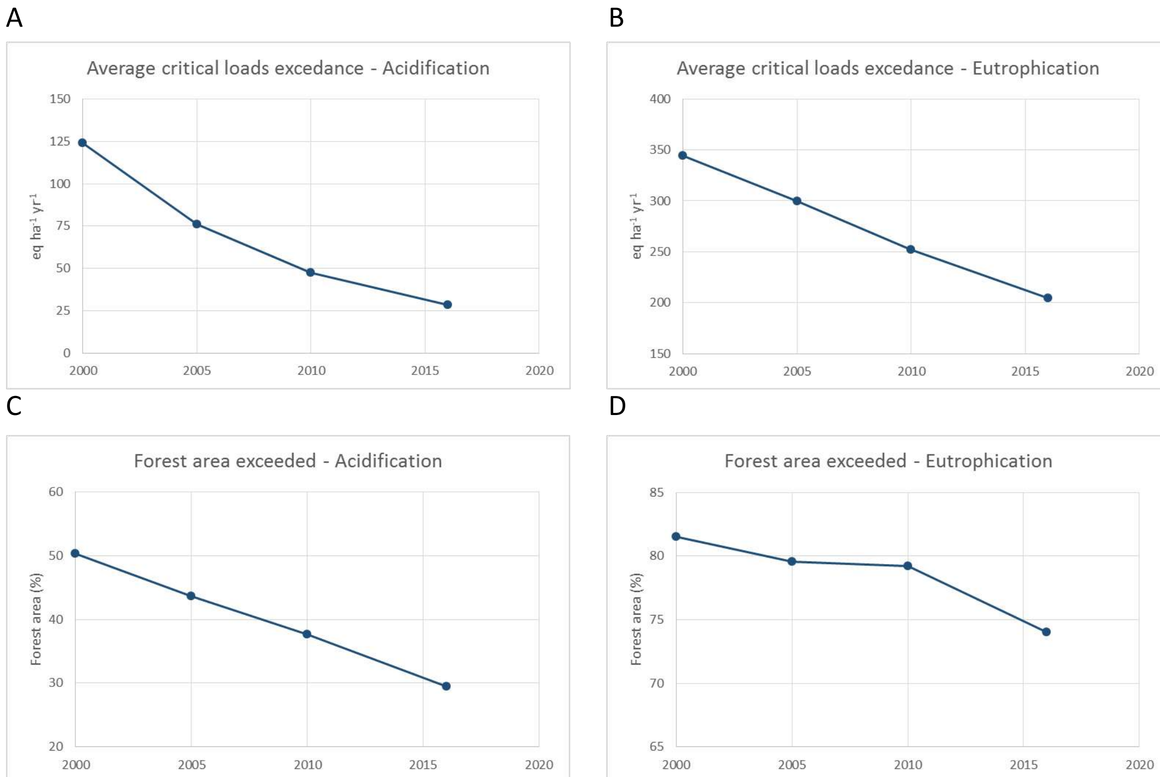

Figure 3. Temporal trends of the mean critical loads exceedance in EU-28 forests (A and B) and the forest area exceeded in percent of total forest area in the EU-28 (C and D), both for acidification and eutrophication. Source of data: EMEP.

Table 1. Mean exceedances of critical loads and area exceeded for acidification and eutrophication in EU-28 forests in four years. Long term trend: 2000 vs 2016, short term trend: 2010 vs 2016, according to the 5% rule of the MAES approach. Source of data: EMEP.

	2000	**2005**	**2010**	**2016**	**Long term trend (% per decade)**	**Short term trend (% per decade)**
Mean exceedances of critical loads for acidification in forests (eq/ha yr)	124	76	48	28	-93 (Improvement)	-68 (Improvement)
Forest area exceeded for acidification (000 Km^2)	888	770	665	520	-35 (Improvement)	-36 (Improvement)
Mean exceedances of critical loads for eutrophication in forests (eq/ha yr)	344	300	252	205	-34 (Improvement)	-31 (Improvement)
Forest area exceeded for eutrophication (000 Km^2)	1,436	1,402	1,396	1,305	-6 (Improvement)	-11 (Improvement)

References

EEA (1993). CORINE Land Cover - Technical Guide. Luxembourg: European Environment Agency.

EEA (2000). CORINE land cover technical guide – Addendum 2000. (pp. 105). Copenhagen: European Environment Agency.
Hettelingh, J. P., Posch, M., & Slootweg, J. (2017). European critical loads: database, biodiversity and ecosystems at risk: CCE Final Report 2017. (pp. 204). Bilthoven, Netherlands: RIVM, Coordination Centre for Effects.
MAES (2013). Mapping and Assessment of Ecosystems and their Services - An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. (pp. 57). Luxembourg.
Tsyro, S., Aas, W., Solberg, S., Benedictow, A., Fagerli, H., & Posch, M. (2018). Chapter 2: Status of transboundary air pollution in 2016. In H. Fagerli, et al. (Ed.), *Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components. EMEP Status Report 1/2018* (pp. 15-40). Oslo, Norway: Norwegian Meteorological Institute.

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Fact sheet 3.3.110: Ratio of annual fellings to annual increment

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Pressures, Over-harvesting
- Name of the indicator: Ratio of annual fellings to net annual increment
- Units: %

2. Data sources

- Data holder: Forest Europe, State of Europe's forests 2015
- Web link: https://foresteurope.org/state-europes-forests-2015-report/
- Year of time-series range: 1990, 2000, 2005, 2010
- Version: State of Europe's forests 2015
- Access date: 01/05/2019
- Reference: FOREST EUROPE (2015). State of Europe's Forests 2015. (pp. 113): Ministerial Conference on the Protection of Forests in Europe.

3. Assessment of the indicator

Increment and fellings data on forests available for wood supply is available for four years: 1990, 2000, 2005 and 2010. Data for 2015 was not available at the moment of drafting this report. The indicator shows the ratio of annual fellings to net annual increment in forests (felling rates). Therefore, data of both, fellings and increment, is necessary for computing the ratio per Member State (MS) per year. In some cases data gaps are present in a few MS. Therefore, we excluded MS for which data is missing in two or more years, resulting in that data on increment and fellings was available only for 20 MS.

From these data we have calculated the ratio of annual fellings to annual increment, which represent the proportion of increment that is used by fellings. We computed the indicator using data from 17 MS that have records of both increment and fellings for the all the four years. However, we also computed the indicator using data from 20 MS where some data gaps are present in specific years in Germany, Latvia and Portugal (Table 1). Other countries, such as Sweden or Poland were excluded because two or more years were missing data in either increment or fellings (Table 2).

Table 1 shows the ratios for two groups of MS. The ratio for EU-17 includes MS for which data is available in the four dates (i.e. excluding Germany, Latvia and Portugal). In contrast, the ratio for EU-20 includes data of the 20 Members States listed in the table. The group of 20 MS represents 62% of the EU-28 forest area. As shown in Table 1, felling rates vary significantly among countries. For instance, Austria, Denmark, Finland, Germany and Hungary have felling rates mostly above 70%, whilst Bulgaria, Italy, Slovenia and the United Kingdom have felling rates below 50%. Denmark exhibits felling rates above 100% in 1990, 2000, and 2005 but in 2010 felling rates have decrease to 62.7%. Table 2 shows the indicator for MS with incomplete data.

Table 1. Ratio of annual fellings to net annual increment (%) for 20 Member States of the EU. The ratio for EU-17 includes only Member States where the data is available in the four dates (i.e. excluding Germany, Latvia and Portugal). The ratio for EU-20 includes data of the 20 Members States listed in the table. Source of data: FOREST EUROPE (2015).

Country	Forest [1,000 ha]	Ratio of annual fellings to net annual increment (%)			
	2010	1990	2000	2005	2010
Austria	3,860	75.3	60.5	93.5	93.5
Belgium	681	89.2	76.9	93.3	84.3
Bulgaria	3,737	34.9	27.7	49.3	48.5
Croatia	1,920	59.3	52.9	59.1	67.0
Cyprus	173	110.8	57.6	26.0	19.8
Czech Republic	2,657	68.0	75.6	84.4	85.2
Denmark	587	100.3	100.5	101.0	62.7
Estonia	2,234	35.8	105.5	58.6	63.7
Finland	22,218	72.4	85.9	77.1	73.0
Germany	11,409	-	76.8	79.1	80.3
Hungary	2,046	72.6	83.8	71.4	76.2
Italy	9,028	48.0	47.5	42.4	39.2
Latvia	3,354	32.1	87.8	-	65.2
Netherlands	374	58.0	60.8	48.0	47.3
Portugal	3,239	74.6	66.4	75.4	-
Romania	6,515	54.0	49.3	57.4	60.2
Slovakia	1,939	53.7	56.9	70.8	77.4
Slovenia	1,247	34.8	34.7	39.2	37.1
Spain	18,247	61.8	52.6	51.4	55.5
United Kingdom	3,059	40.9	45.9	48.0	50.5
EU-17		60.9	64.7	65.9	65.1
EU-20		60.3	68.7	69.6	68.9

Table 2. Ratio of annual fellings to net annual increment (%). EU Member States with incomplete data. Source of data: FOREST EUROPE (2015).

Country	Forest [1,000 ha]	Ratio of annual fellings to net annual increment (%)			
	2010	1990	2000	2005	2010
France	16,424				47.3
Greece	3,903	81.5			
Ireland	725.6				52.5
Lithuania	2,170			87.4	
Poland	9,329				74.8
Sweden	28,073			118.3	101.8
Malta	0.3				
Luxembourg	86.8				

3.1 Short description of the scope of the indicator

The indicator represents the balance between net annual increment and annual fellings in forest. Net annual increment (NAI) is defined as the total increase of growing stock over the given reference period minus that of natural losses of all trees with a minimum diameter of 0 cm at breast height. Fellings is the average annual standing volume of all trees measured overbark to a minimum diameter of 0 cm d.b.h. that are felled during the given reference period, including the volume of trees or parts of trees that are not removed from the forest, other wooded land or other felling site.

The ratio of fellings to increment measures the balance between increment and fellings. If fellings are lower than increment, the growing stock increases and vice versa (FOREST EUROPE 2015). This indicator is considered one of the criteria used for assessing the sustainability of forest. Nevertheless, according to the EU Forest Strategy (European Commission, 2013) sustainable forest management means using forests and forest land in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems. For the purpose of MAES the notion of over-exploitation comprises all forest management practices with adverse effects on these objectives, and which can be assessed by an array of indicators embracing relevant aspects of forest condition and forestry practices. Therefore, the present indicator should be measured as long-term average (ideally taking into consideration information on annual fellings and net annual increment for the whole rotation period or more) and it should be interpreted carefully, taking into account complementary information and other indicators. For instance, large areas of older stands may have large potential for harvesting and relatively small mean net annual increments. Another example is the use of fast-growing non-native species or fertilisation which may contribute to an increase in growing stock, but may be detrimental to biodiversity (MAES, 2018).

The ratio fellings to increment is one indicator included in the Streamlined European Biodiversity Indicators (SEBI[27]), where more information regarding the importance of this indicator for forest ecosystems is available.

3.2 Maps

Available information on increment and fellings is rather coarse, usually at MS level, therefore maps were not produced for this indicator in the context of this assessment. Nevertheless, a map produced and provided by Levers et al (2014) is presented in Figure 1. The map of Levers et al. was created by collecting and merging sub-national forest harvesting statistics, NAI and forest area. Then, the dataset was harmonised to correct for differences in national harvesting definitions. Therefore, a straight comparison with the MS level data in Table 1 and 2 is challenging. Nevertheless, the map shows the spatial distribution of the indicator at sub-national scale averaging the period 2000-2010.

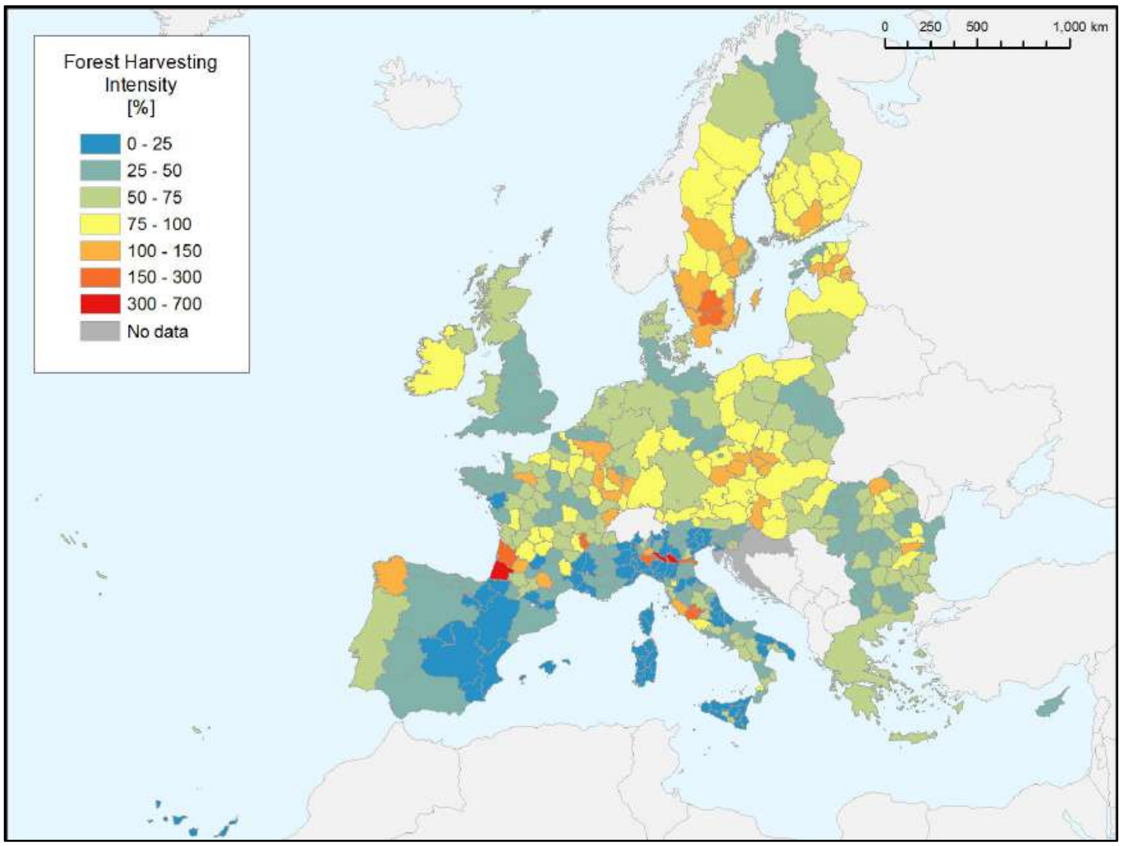

Figure 1. Average ratio of annual fellings to net annual increment (%) or forest harvesting intensity in European administrative units (NUTS 0-3) for 2000–2010. Source: Levers et al. (2014).

[27] https://biodiversity.europa.eu/topics/sebi-indicators

Statistical analysis of the trend

For assessing whether there is a significant change between 1990 and 2010 (long term trend) we used the non-parametric Wilcoxon signed-rank test (Wilcoxon, 1945; Siegel, 1956). We tested for a significant change in the mean value of the indicator in 1990 versus 2010 (17 MSs as described in Table 1).

Key trend at EU level

Figure 2 shows felling rates for the EU-17 and EU-20 groups of MS. The total figures of both groups indicate that felling rates remain below the recommended long term sustainable threshold of around 70%. In both cases, felling rates after a continuous increase until 2005 have undergone a slightly decrease in 2010. Nevertheless, the assessment of felling rates highlights major differences between MS. In some cases, as in Sweden, the ratio exceeds 100% in the available records, while in other do not exceed the 70% threshold.

In summary, at the EU-17 level after two periods of sustained increment, i.e. 1990—2000 and 2000—2005, the ratio of forest fellings to increment exhibited a minor decrease in the last period with available data, i.e. 2000—2010. Nevertheless, there are pronounced differences among MS, for instance, 9 out of 23 MS having available data in 2010 exhibits a felling ratio greater than 70% (Table 1 and 2). A consequence of the relatively stable ratio observed at EU-17 level in the four periods, between 60.9 and 65.9%, is that the forest stock to continue to increase. An aspect that is considered beneficial for biodiversity and forest services. The Wilcoxon test indicates that there is a not significant decadal increase of 2.1% between the mean felling rate in 1990 and 2010 (Table 3).

Regarding future scenarios, the ratio of fellings to increment is projected to increase during the coming years. One of the reasons is an expected increase in the demands for woody biomass as a renewable energy source. JRC's modelling results indicate that under a business and usual scenario forest harvest is projected to increase by 7% by 2030, and 55% under a high mobilisation scenario in the same period (Jonsson et al., 2018).

Table 3. Long-term trend and short-term trend of the ratio of annual fellings to net annual increment (%) for 17 Member States of the EU. N.S.: not significant at 5% according to the Wilcoxon test. N/A: not available.

	Long-term trend	**Short-term trend**
% per decade	2.1 (N.S.)	N/A
Time range	1990-2010	N/A
Method	Wilcoxon	N/A

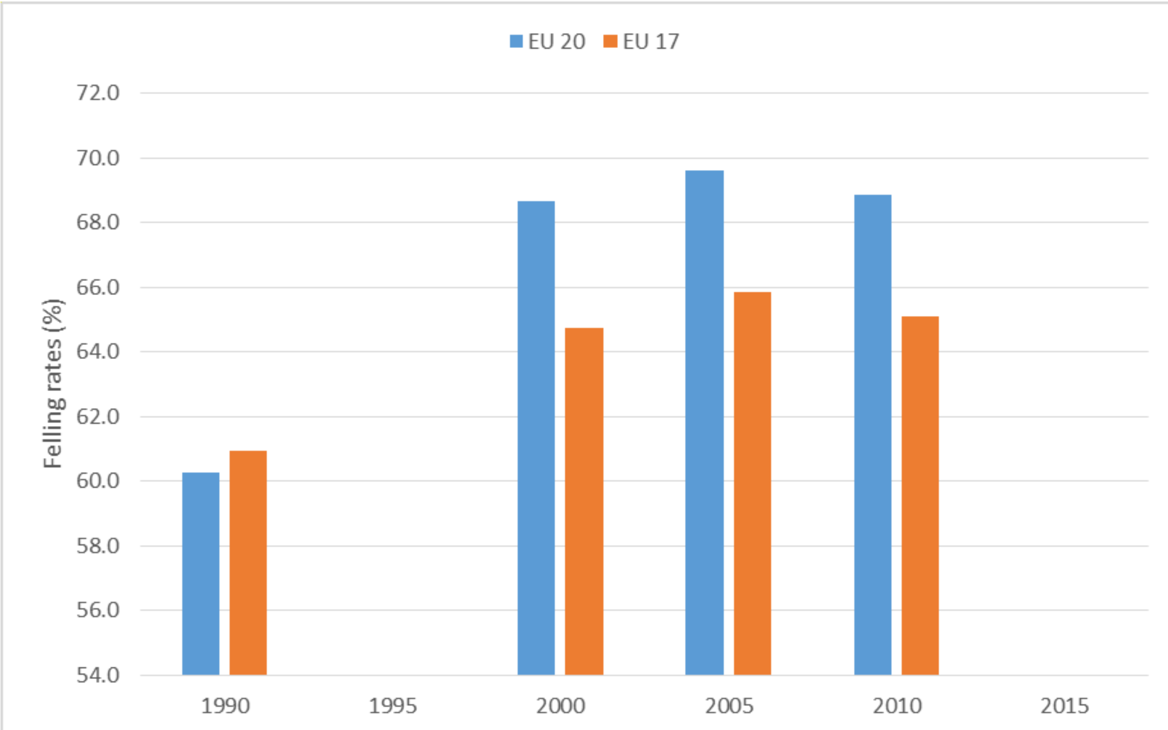

Figure 2. Ratio of annual fellings to net annual increment (%) for 17 and 20 Member States of the EU. For details regarding the list of the Member States used to create the graph, refer to Table 1. Source of data: FOREST EUROPE (2015).

References

EEA (2017). "Forest: growing stock, increment and fellings." from https://www.eea.europa.eu/data-and-maps/indicators/forest-growing-stock-increment-and-fellings-3/assessment#tab-related-briefings.

European Commission (2013). COM(2013) 659 final: A new EU Forest Strategy: for forests and the forest-based sector. (pp. 17). Brussels: European Commission.

FOREST EUROPE (2015). State of Europe's Forests 2015. (pp. 113): Ministerial Conference on the Protection of Forests in Europe.

Jonsson, R., Blujdea, V. N., Fiorese, G., Pilli, R., Rinaldi, F., Baranzelli, C., et al. (2018). Outlook of the European forest-based sector: forest growth, harvest demand, wood-product markets, and forest carbon dynamics implications. iForest, 11, 315-328, doi:10.3832/ifor2636-011.

Levers, C., Verkerk, P. J., Müller, D., Verburg, P. H., Butsic, V., Leitão, P. J., et al. (2014). Drivers of forest harvesting intensity patterns in Europe. Forest Ecology and Management, 315, 160-172, doi:10.1016/j.foreco.2013.12.030.

MAES (2018). Mapping and Assessment of Ecosystems and their Services - An analytical framework for mapping and assessment of ecosystem condition in EU. European Commission, DG-Environment, Technical Report - 2018 – 001, Luxembourg. pp. 75.

Siegel, S. (1956). Non-parametric statistics for the behavioral sciences. New York: McGraw-Hill. pp. 75–83.

Wilcoxon, F. (1945). Individual Comparisons by Ranking Methods. Biometrics Bulletin, Vol. 1, pp. 80-83. doi:10.2307/3001968.

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Fact sheet 3.3.111: Effective rainfall (precipitation – potential evapotranspiration)

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class (See table 1): Pressures, climate change
- Name of the indicator: Effective rainfall
- Units: mm

2. Data sources:

The indicator is based on existing reference data:

- Data holder:
  - PET: University of East Anglia Climatic Research Unit (CRU) Time-Series (TS) (1901–2016) version 4.01 gridded monthly data at 0.5 degree (~43 km at 40° N) spatial resolution (Harris et al. 2014).
  - Precipitation: Full Data Monthly Product Version 2018 provided by the Global Precipitation Climatology Centre (GPCC) of the Deutscher Wetterdienst (DWD) (Schneider et al. 2018; Schneider et al. 2017)
- Weblink:
  - PET: https://crudata.uea.ac.uk/cru/data/hrg/
  - Precipitation: https://www.dwd.de/EN/ourservices/gpcc/gpcc.html
- Year or time-series range: 1960–2016
- Version: See above
- Access date: 22/02/2019
- Reference:
  - Harris, I., Jones, P. D., Osborn, T. J., & Lister, D. H. (2014). Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset. International Journal of Climatology, 34(3), 623-642, doi:doi:10.1002/joc.3711.
  - Schneider, U., Becker, A., Finger, P., Meyer-Christoffer, A., & Ziese, M. (2018). GPCC Full Data Monthly Product Version 2018 at 0.5°: Monthly Land-Surface Precipitation from Rain-Gauges built on GTS-based and Historical Data.

3. Assessment of the indicator

Introduction

The focus of the present assessment is to examine significant changes in **effective rainfall (ER)** in Europe. **ER** is the difference between mean annual precipitation (MAP) and mean annual **potential evapotranspiration (PET)** (Archibald et al. 2013; Santhi et al. 2008; Wolock et al. 2004). It is considered an index of plant productivity, where values below zero indicate that evaporative demands exceeds precipitation and values above zero that precipitation exceeds evaporative demands. Therefore, ER is a quantitative indicator of the degree of water deficiency at a given location. The productivity of land biological systems is related to available moisture, which in turn is related to rainfall and the evaporative demand of the system (Archibald et al. 2013). In forest ecosystems the amount of biomass is largely controlled by the productivity of the system.

PET is an important climatic parameter that describes the amount of water needed for plant growth and development. **PET** represents the potential flux of water from a surface having enough soil moisture so that the amount of water is not limited. Thus, **PET** is defined as the amount of water that would be evaporated and transpired by a specific crop, or ecosystem, if there is sufficient water available. The FAO Penman–Monteith method defines PET as the potential evapotranspiration from a clipped grass-surface having 0.12 m height and bulk surface resistance equal to 70 s m^{-1}, an assumed surface albedo of 0.23 (Allen et al. 1994; Ekström et al. 2007), and no moisture stress. This definition was used by Harris et al. (2014) for computing the PET dataset used in this assessment. The Penman–Monteith algorithm includes the effects of surface air temperature, humidity, solar radiation and wind. An upward trend of PET indicates plant water shortage when PET becomes greater than precipitation, consequently decreasing ER. Therefore, a sustained downward trend of ER suggests loss of ecosystem productivity and ultimately degradation. When the water demand as consequence of increased PET is not met, dry soil moisture conditions prevail resulting in a trend toward drought and aridity (Feng and Fu 2013). Natural ecosystems have adapted to temporal water shortages, however, regime shifts in water supply represent a serious threat.

Data and methods

We computed annual effective rainfall (**ER**) as the difference between annual precipitation and annual PET, which gives a value ranging from around –1200 mm to 2100 mm. Negative values indicate areas in which evaporative demands exceeds incoming precipitation and vice versa. Thus, one layer of ER was created for each year of the time series between 1960 and 2016 using data from two sources. First, we used a PET dataset from the University of East Anglia Climatic Research Unit (CRU) Time-Series (TS) (1901–2016) version 4.01 gridded monthly data at 0.5 degree (~43 km at 40° N) spatial resolution (Harris et al. 2014). The CRU TS v4.01 data are monthly gridded fields based on monthly observational data calculated from daily or sub-daily data by National Meteorological Services and other external agents. Second, gridded monthly data of precipitation at 0.5 degree (1891-2016) was sourced from the Full Data Monthly Product Version 2018 provided by the Global Precipitation Climatology Centre (GPCC) of the Deutscher Wetterdienst (DWD) (Schneider et al. 2018; Schneider et al. 2017). Version 2018 was created by merging in situ time-series of raingauge data based on more than 53,000 stations globally. Both datasets have been widely used in many applications and are accepted as reliable data.

The annual layers of ER were used for detecting spatial trends on each grid cell. We used robust regression to mitigate the effect of anomalous years. Regression slopes were estimated using the non-parametric **Theil-Sen estimator** (Sen 1968; Wilcox 2012) because it accommodates non-normal distributions and is a robust trend slope estimator resistant to the effects of outliers. Additionally, a two-sided **Mann-Kendall** (Gilbert 1987; Kendall 1975; Mann 1945) non-parametric trend test was used to assess the significance of monotonic trends in ER.

3.1 Trends and maps

Results

The map of Figure 1 shows areas where significant changes in ER have occurred in the study period. Changes below 0 mm/decade indicate a drying climate and changes above 0 mm/decade a wetter climate. Within the Mediterranean domain large areas of the Iberian Peninsula, France, Italy, major Mediterranean islands and the Balkans, exhibit a downward trend of ER.

Among the European biogeographical regions, after the Black Sea (63%), the Mediterranean shows the larger proportion of area (61%) having significant decreases of ER (Table 1). Additionally, other regions beyond the Mediterranean such as zones of Belgium, Germany, Poland, Czech Republic, Hungary, Bulgaria and Romania also exhibited downward significant trends. In these zones, an increasing climatic water deficit indicates evaporative demands not met by precipitation. Therefore, suggesting increasing aridity. Other biogeographical regions showing a large proportion of area affected by significant decreases of ER are the Continental, Atlantic, Pannonian and Steppic, all exhibiting decreases in at least 20% of their extent (Table 1).

In contrast, some zones of northern Europe show a significant increase of ER, for instance, parts of Sweden, Finland, north Britain, but also some zones of the western part of the Island of Sicily. In these areas, an upward wetter trend prevails. Specifically, the Alpine and Boreal biogeographical regions exhibit increases in 12% and 13%, of their extent, respectively.

Table 1. Percentage area of significant changes in effective rainfall (ER) in European biogeographical regions (EEA 2002, 2019) within the EU-28 countries (1960–2016). Note that the areas were computed using a 1 km grid size map.

Biogeographical region	Total area (Km^2)	ER significant decrease (%)	ER significant increase (%)
Alpine	379,142	14	12
Atlantic	802,912	21	3
Black Sea	11,942	63	0
Boreal	858,430	0	13
Continental	1,292,677	22	0
Macaronesia	12,001	18	0
Mediterranean	923,170	61	1
Pannonian	126,158	20	0
Steppic	37,112	20	0
Total	**4,443,544**	**25**	**4**

Decreases of ER as result of climate change has a direct consequence on land degradation in arid, semiarid and subhumid areas (Feng and Fu 2013), being mostly located in Europe within the Mediterranean biogeographical region. In forest ecosystems, a downward trend in ER suggests higher mortality of trees, increased bark-beetles outbreaks, more favourable conditions for wildfires and a reduction of forest productivity. Nevertheless, the effects can vary from site to site depending of local conditions. Despite climate models uncertainty, there is consensus in that future impacts of climate change indicate a projected increase of aridity in the European continent (Barredo et al. 2016; Barredo et al. 2018; Cherlet et al. 2018; Feng and Fu 2013; Lin et al. 2018; Spinoni et al. 2015), specifically in southern Europe and in the Mediterranean biogeographical region.

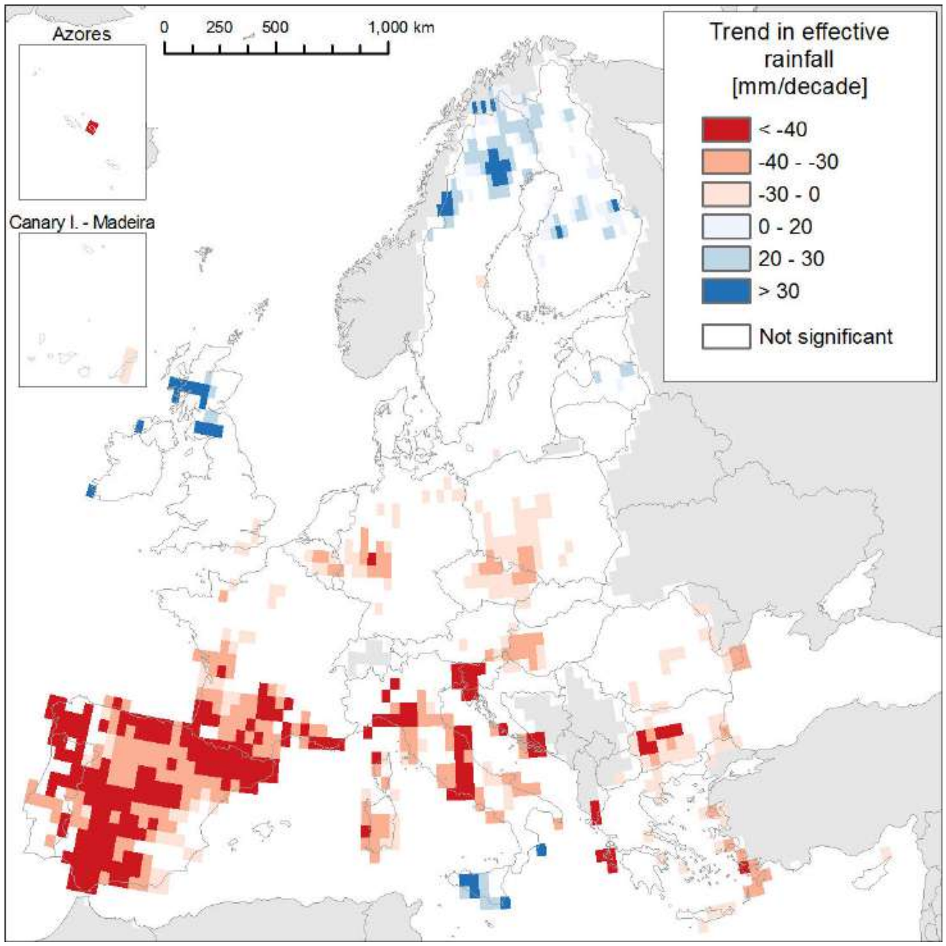

Figure 1. Trends in annual effective rainfall 1960–2016 in the EU-28 (significant at the 5% level according to the Mann-Kendall test). Light grey: outside area of interest.

The assessment of annual ER computed in the domain covered by the EU-28 indicates a significant ($p = 0.031$) downward trend of -1.2 mm/y (Figure 2). Therefore, the decadal long term trend is -38% (statistically significant at the 5% level) and the decadal short-term trend -57% (but not statistically significant at the 5% level). However, note that change is always considered as significant in case the percentage change per decade is higher than or equal to +5 % or lower than or equal to -5 %. This is valid for both short and long-term trends and regardless statistical testing. A change outside this interval is thus always considered as policy-relevant to report.

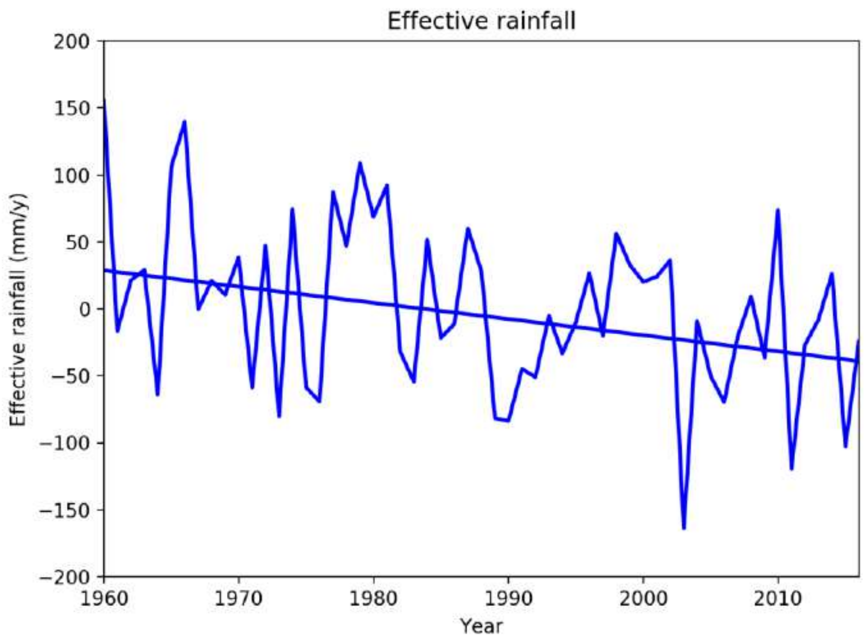

Figure 2. Trend of annual effective rainfall 1960–2016 in the EU-28. Trend line computed using the Theil–Sen non-parametric estimator. Downward trend (-1.2 mm/y) significant at 5% according to Mann-Kendall trend test.

References

Allen, R. G., Smith, M., Pereira, L. S., & Perrier, A. (1994). An update for the calculation of reference evapotranspiration. ICID Bulletin, 43, 35-92.

Archibald, S., Lehmann, C. E. R., Gómez-Dans, J. L., & Bradstock, R. A. (2013). Defining pyromes and global syndromes of fire regimes. Proceedings of the National Academy of Sciences, 110(16), 6442-6447, doi:10.1073/pnas.1211466110.

Barredo, J. I., Caudullo, G., & Dosio, A. (2016). Mediterranean habitat loss under future climate conditions: Assessing impacts on the Natura 2000 protected area network. Applied Geography, 75, 83-92, doi:10.1016/j.apgeog.2016.08.003.

Barredo, J. I., Mauri, A., Caudullo, G., & Dosio, A. (2018). Assessing Shifts of Mediterranean and Arid Climates Under RCP4.5 and RCP8.5 Climate Projections in Europe. Pure and Applied Geophysics, 1-17, doi:10.1007/s00024-018-1853-6.

Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S., & von Maltitz, G. (Eds.). (2018). World Atlas of Desertification. Luxembourg: Publication Office of the European Union.

EEA (2002). Europe's biodiversity – biogeographical regions and seas. Luxembourg: European Environment Agency.

EEA (2019). Biogeographical regions. https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3#tab-figures-produced2019.

Ekström, M., Jones, P. D., Fowler, H. J., Lenderink, G., Buishand, T. A., & Conway, D. (2007). Regional climate model data used within the SWURVE project – 1: projected changes in seasonal patterns and estimation of PET. Hydrology and Earth System Sciences, 11(3), 1069-1083, doi:10.5194/hess-11-1069-2007.

Feng, S., & Fu, Q. (2013). Expansion of global drylands under a warming climate. Atmospheric Chemistry and Physics, 13(19), 10081-10094, doi:10.5194/acp-13-10081-2013.

Gilbert, R. O. (1987). Statistical Methods for Environmental Pollution Monitoring. NY, USA: Wiley.

Harris, I., Jones, P. D., Osborn, T. J., & Lister, D. H. (2014). Updated high-resolution grids of monthly climatic observations – the CRU TS3.10 Dataset. International Journal of Climatology, 34(3), 623-642, doi:doi:10.1002/joc.3711.

Kendall, M. G. (1975). Rank Correlation Methods (4th edition). London: Charles Griffin.

Lin, L., Gettelman, A., Fu, Q., & Xu, Y. (2018). Simulated differences in 21st century aridity due to different scenarios of greenhouse gases and aerosols. [journal article]. Climatic Change, 146(3), 407-422, doi:10.1007/s10584-016-1615-3.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3), 245-259, doi:10.2307/1907187.

Santhi, C., Allen, P. M., Muttiah, R. S., Arnold, J. G., & Tuppad, P. (2008). Regional estimation of base flow for the conterminous United States by hydrologic landscape regions. Journal of Hydrology, 351(1), 139-153, doi:https://doi.org/10.1016/j.jhydrol.2007.12.018.

Schneider, U., Becker, A., Finger, P., Meyer-Christoffer, A., & Ziese, M. (2018). GPCC Full Data Monthly Product Version 2018 at 0.5°: Monthly Land-Surface Precipitation from Rain-Gauges built on GTS-based and Historical Data.

Schneider, U., Finger, P., Meyer-Christoffer, A., Rustemeier, E., Ziese, M., & Becker, A. (2017). Evaluating the Hydrological Cycle over Land Using the Newly-Corrected Precipitation Climatology from the Global Precipitation Climatology Centre (GPCC). Atmosphere, 8(3), 52.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324), 1379-1389, doi:10.2307/2285891.

Spinoni, J., Vogt, J., Naumann, G., Carrao, H., & Barbosa, P. (2015). Towards identifying areas at climatological risk of desertification using the Köppen–Geiger classification and FAO aridity index. International Journal of Climatology, 35(9), 2210-2222, doi:doi:10.1002/joc.4124.

Wilcox, R. R. (2012). Introduction to Robust Estimation and Hypothesis Testing. San Diego, California, USA: Academic Press.

Wolock, D. M., Winter, T. C., & McMahon, G. (2004). Delineation and Evaluation of Hydrologic-Landscape Regions in the United States Using Geographic Information System Tools and Multivariate Statistical Analyses. [journal article]. Environmental Management, 34(1), S71-S88, doi:10.1007/s00267-003-5077-9.

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Fact sheet 3.3.201: Dead wood

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Ecosystem condition, Structural ecosystem attributes (general)
- Name of the indicator: Dead wood
- Units: Tonnes/ha

2. Data sources

- Data holder: FAO, Global Forest Resource Assessment (FRA)(FAO 2015)
- Web link: http://www.fao.org/forest-resources-assessment/en/
- Year of time-series range: 1990, 2000, 2005, 2010, 2015
- Version: FRA 2015
- Access date: 01/02/2019
- Reference: FAO (2015). Global Forest Resources Assessment 2015. Rome: Food and Agriculture Organization of the United Nations.

According to FAO (2015) dead wood is defined as "all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country".

Available data: Data on dead wood is available for a group of 15 MS of the EU for 1990, 2000, 2005, 2010 and 2015. The MS are: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Hungary, Italy, Latvia, Lithuania, Netherlands, Slovakia, Slovenia, Sweden and United Kingdom.

Additionally, Germany has data only for four dates, i.e.: 2000, 2005, 2010 and 2015.

The amount of dead wood per unit area was computed by dividing the total amount of dead wood by forest area on each year (i.e. 1990, 2000, 2005, 2010 and 2015) for the group of 15 MS. Data on forest area was provided from the same source as dead wood, i.e. FAO FRA (FAO 2015). The same computation was done for a group of 16 MS (15 MS + Germany) but only for 2000, 2005, 2010 and 2015.

3. Assessment of the indicator

3.1 Short description of the scope of the indicator

Dead wood is an important trait of forest ecosystems representing the substrate for a large number of animal and plant species, including vertebrates, invertebrates, vascular plants, algae, bryophytes, fungi, slime moulds and lichens (FOREST EUROPE 2015). Additionally, dead wood contributes to several forest features and functions such as structural stability of soils, microhabitats, carbon sequestration, nutrient supply and water retention (Lachat et al. 2013). Dead wood is one indicator included in the Streamlined European Biodiversity

Indicators (SEBI[28]), where more information regarding the importance of dead wood for forest ecosystems is available.

3.2 Maps

Available information on dead wood is rather coarse, usually at country level, therefore maps were not produced for this indicator.

3.3 Statistical analysis of the trend

For assessing whether there is a significant change between 2000 and 2015 (long term trend), and between 2010 and 2015 (short term trend) we used the non-parametric Wilcoxon signed-rank test (Siegel 1956; Wilcoxon 1945). We tested for a significant change in the mean value of the indicator in the long term (2000 versus 2015) and short term (2010 versus 2015).

3.4 Key trend at EU level

The data available suggests an increase of dead wood over time from 1990 to 2015 (Figure 1). There are noticeable differences in the evolution of dead wood at country level (not shown). However, at EU scale the increase is evident. Amounts of dead wood can vary due to several factors ranging from the effect of disturbances such as windstorms, forest fires or insect outbreaks, or due to sustainable forest management practices oriented to conserve more dead wood in place after fellings. These drivers affects dead wood at local level and can change significantly in space and time, thus making it difficult to attribute the reasons of the increase at EU level.

The Wilcoxon test indicates that there is a significant long (2000 vs 2015) and short (2010 vs 2015) term decadal increase of 18% and 10%, respectively, in the mean deadwood (tonnes/ha) of the group of 16 Members Sates (Table 1).

Table 1. Long and short term trend of mean deadwood (tonnes/ha) for 16 Member States of the EU. * Significant at 5% according to the Wilcoxon test.

	Long-term trend	Short-term trend
% per decade	18*	10*
Time range	2000-2015	2010-2015
Method	Wilcoxon	Wilcoxon

[28] https://biodiversity.europa.eu/topics/sebi-indicators

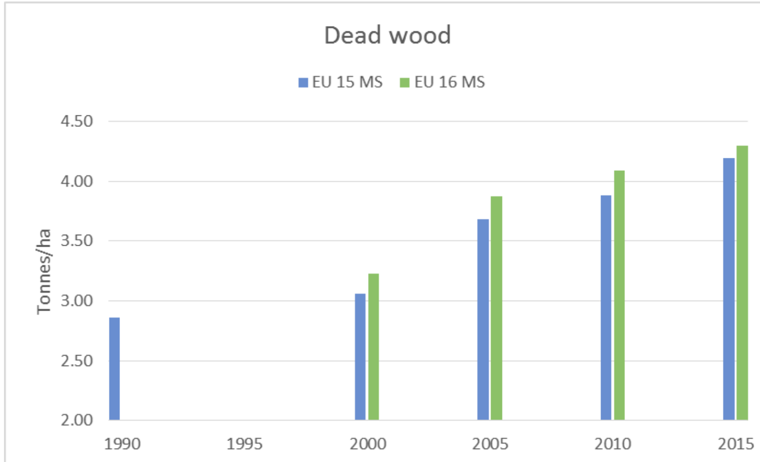

Figure 1. Dead wood in 15 and 16 Members States of the EU in 1990, 2000, 2005, 2010 and 2015; and 2000, 2005, 2010 and 2015 respectively. Source: FAO (2015). EU-15 MS: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, Hungary, Italy, Latvia, Lithuania, Netherlands, Slovakia, Slovenia, Sweden and United Kingdom. EU-16 MS: the same as in 15 MS plus Germany.

References

FAO (2015). Global Forest Resources Assessment 2015. Rome: Food and Agriculture Organization of the United Nations.

FOREST EUROPE (2015). State of Europe's Forests 2015. (pp. 312): Ministerial Conference on the Protection of Forests in Europe.

Lachat, T., Bouget, C., Bütler, R., & Müller, J. (2013). 2.2 Deadwood: quantitative and qualitative requirements for the conservation of saproxylic biodiversity. In D. Kraus, & F. Krumm (Eds.), Integrative approaches as an opportunity for the conservation of forest biodiversity (pp. 284): European Forest Institute.

Siegel, S. (1956). Non-parametric statistics for the behavioral sciences. New York: McGraw-Hill.

Wilcoxon, F. (1945). Individual Comparisons by Ranking Methods. Biometrics Bulletin, 1, 80-83, doi:10.2307/3001968.

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Fact sheet 3.3.202: Biomass (growing stock)

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Ecosystem condition, Structural ecosystem attributes (general)
- Name of the indicator: Biomass (growing stock)
- Units: m^3/ha

2. Data sources

- Data holder: Forest Europe, State of Europe's forests 2015
- Web link: https://foresteurope.org/state-europes-forests-2015-report/
- Year of time-series range: 1990, 2000, 2005, 2010, 2015
- Version: State of Europe's forests 2015
- Access date: 01/05/2019
- Reference: FOREST EUROPE/UNECE/FAO enquiry on pan-European quantitative indicators. FOREST EUROPE (2015). State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe. pp. 312.

3. Assessment of the indicator

Growing stock data on forest is available from almost all the EU-28 countries for the years 1990, 2000, 2005, 2010 and 2015. Exception is made for Ireland, where figures of growing stock are missing for the years 1990 and 2000, and in Portugal 2015. The total growing stock of forests in the EU-28 amounts to 26.3 billion m^3 in 2015 (not including Portugal). This figure produces an average growing stock density of 210 m^3/ha, however pronounced differences exists among countries. The highest growing stock density is for Slovenia with 346 m^3/ha, followed by Germany, Luxembourg , Austria and Czech Republic with values above 297 m^3/ha. The countries with lowest value are Greece with 47 m^3/ha followed by Cyprus and Spain with 64 and 66 m^3/ha, respectively (Table 1). Environmental and climatic conditions, and human actions such as forest protectio n and management practices, explain differences in growing stock density. The figures provided in table 1 are averages at country level, however, considerable differences may exist at sub-national and local level.

Table 1. Growing stock density in forests. EU-28 is the average of the 28 countries in the table. EU-26 is the average excluding data for Ireland and Portugal that present data gaps. Data source: FOREST EUROPE/UNECE/FAO (FOREST EUROPE 2015).

Country	Forest growing stock [m³/ha] - years				
	1990	2000	2005	2010	2015
Austria	245.5	278	286.2	292.5	298.5
Belgium	189	235.9	251.1	262	274.7
Bulgaria	121.7	155.9	161.9	172.6	182.8
Croatia	167.8	191	202.3	211.6	215.9
Cyprus	46	46.2	48.5	57.4	64.4
Czech Republic	237.5	264.9	277.7	284	296.6
Denmark	123.8	160.2	205	201	204.5
Estonia	178.3	204.4	202	210.5	213.4
Finland	85.9	92.8	98.4	104.4	104.4
France	143.9	147.4	158.4	161.3	168.3
Germany	249.1	297.8	307.6	317	320.8
Greece	47.3	47.2	47.2	47.4	47.4
Hungary	159.9	170.5	172.1	175.4	182.2
Ireland	-	-	99.8	124	154.9
Italy	112.6	127.6	134	141.7	148.9
Latvia	139.3	165.7	168.9	183.1	198.2
Lithuania	212.3	222.5	219	225.7	236.2
Luxembourg	237.5	299.1	299.1	299.1	299.1
Malta	230.5	230.5	230.5	230.5	230.5
Netherlands	151.9	169.7	191.8	203.5	215.2
Poland	167.2	191.6	207.5	254.3	269.2
Portugal	59.1	59.2	56.1	57.4	-
Romania	211.5	211.5	211.5	211.5	281.4
Slovakia	209	241.1	256.1	265.2	274.3
Slovenia	230.1	269.9	301	325.7	345.8
Spain	48.1	53.4	59.4	61.4	65.8
Sweden	89.1	96	103	105	106.5
United Kingdom	131.7	162.5	177.8	194.5	207.4
EU-28	157	178	183	192	208
EU-26	160	182	191	200	210

3.1 Short description of the scope of the indicator

Growing stock represents the living tree component of the standing volume. It refers to the volume of standing tress and includes all tress with a diameter over 0 cm at breast height (d.b.h.). Standing volume includes tops of stems and large branches, and excludes small branches, twigs and foliage. Growing stock is a fundamental indicator of forest inventories and is considered a proxy for biodiversity (FOREST EUROPE 2015, EEA 2017). Growing stock can be used to compute above and below ground forest biomass. In addition, data on growing stock, increment and fellings is fundamental for the calculation of carbon budgets in forests. Growing stock is commonly reported as volume in cubic meters (m^3). However, for correcting the effects of forest area and ease comparability, growing stock is also measured as density in cubic meters per unit area (m^3/ha).

An increase of growing stock relative to forest area is an indication of a maturing forest. This indicator, together with the ratio of fellings to increment, provides useful information of the potential of forest for biodiversity, health, recreation and other forest features and services (EEA, 2019).

3.2 Maps

Available information on growing stock is rather coarse, usually at country level, therefore maps were not produced for this indicator.

3.3. Statistical analysis of the trend

For assessing whether there is a significant change between 1990 and 2015 (long term trend), and between 2010 and 2015 (short term trend) we used the non-parametric Wilcoxon signed-rank test (Siegel 1956; Wilcoxon 1945). We tested for a significant change in the mean value of the indicator in the long term (1990 versus 2015) and short term (2010 versus 2015).

3.4. Key trend at EU level

Over the last 25 years, growing stock in EU forests increased by 7.3 billion m^3, from 18.9 to 26.2 billion m^3 between 1990 and 2015 (Figure 1). Thus, the growing stock increased each year by an average of 292 million m^3 over this period. An amount equivalent to an annual rate of 4%. One of the drivers behind the increase of growing stock is the increment of forest area. However, growing stock density that corrects for the effect of changes in forest area is also increasing as evidenced in Figure 2. In this case, the average increase per year is 1.25% over the same period.

The overall increase in growing stock in the EU is consistent with the growing stock figures reported at country level, that show increases in all cases with the exception of Portugal. In this country growing stock has decreased between 1990 and 2005, although in 2010 a slightly increase was reported (Table 1). The information of Figure 2 indicates that the increase in growing stock in forest was higher than the increase of forest area during the assessed period. The reasons behind the observed increase are complex and manifold, and in many cases related with sub-national level factors.

The Wilcoxon test indicates that there is a significant long (1990 vs 2015) and short (2010 vs 2015) term decadal increase of 10% in both cases in the mean growing stock (m^3/ha) of the group of 26 Members Sates (Table 2).

Table 2. Long and short term trend of mean growing stock (m^3/ha) for 26 Member States of the EU. *Significant at 5% according to the Wilcoxon test.

	Long-term trend	**Short-term trend**
% per decade	10*	10*
Time range	1990-2015	2000-2015
Method	Wilcoxon	Wilcoxon

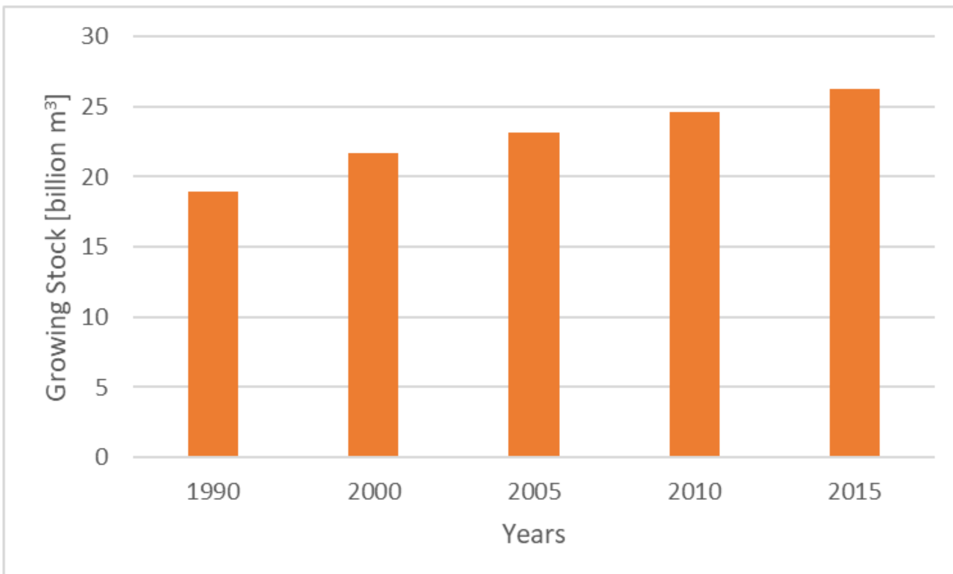

Figure 1. Growing stock in 26 Member States of the EU. Note that data for 1990 and 2000 was not available for Ireland and 2015 for Portugal; therefore these countries were excluded for creating the figure. Source: FOREST EUROPE/UNECE/FAO (FOREST EUROPE, 2015).

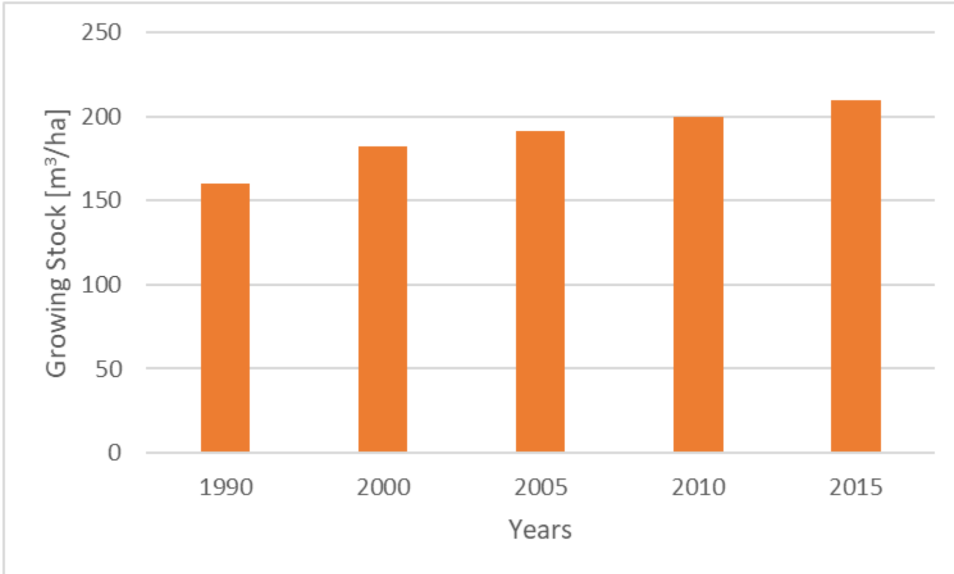

Figure 2. As for Figure 1 but for unit area. Source: FOREST EUROPE/UNECE/FAO (FOREST EUROPE, 2015).

References

EEA (2019). Forest: growing stock, increment and fellings. Available at: https://www.eea.europa.eu/data-and-maps/indicators/forest-growing-stock-increment-and-fellings-3/

FOREST EUROPE (2015). State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe. pp. 312.

Siegel, S. (1956). Non-parametric statistics for the behavioral sciences. New York: McGraw-Hill. pp. 75–83.

Wilcoxon, F. (1945). Individual Comparisons by Ranking Methods. Biometrics Bulletin, Vol. 1, pp. 80-83. doi:10.2307/3001968.

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Fact sheet 3.3.203: Forest area

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Ecosystem condition, Structural ecosystem attributes (general)
- Name of the indicator: Forest area
- Units: hectares (ha)

2. Data sources

- Data holder: Forest Europe, State of Europe's forests 2015
- Web link: https://foresteurope.org/state-europes-forests-2015-report/
- Year of time-series range: 1990, 2000, 2005, 2010, 2015
- Version: State of Europe's forests 2015
- Access date: 01/05/2019
- Reference: FOREST EUROPE/UNECE/FAO enquiry on pan-European quantitative indicators. FOREST EUROPE (2015). State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe. pp. 312.

3. Assessment of the indicator

Estimates of forest area are available for all EU-28 countries for the years 1990, 2000, 2005, 2010 and 2015. In 2015, the countries with the highest forest area were Sweden followed by Finland, Spain and France with 28,000, 22,000, 18,000 and 17,000 million hectares, respectively (Table 1). Six countries (Malta, Luxembourg, Cyprus, Netherlands, Denmark, Belgium and Ireland, in increasing order) have a forest area below 1,000 million ha with Malta having only 300 ha of forest area. Large forest areas are found in Northern Europe. In Finland, almost three quarters of the total land area is covered by forests. At 68%, Sweden is the country with the second largest forest area. Slovenia is the only country in the South Europe region with more than 60% forest cover.

Table 1. Forest area for the years 1990, 2000, 2005, 2010 and 2015 and proportion of land area (2015). Data source: FOREST EUROPE/UNECE/FAO (FOREST EUROPE 2015).

Country	Proportion of land area (%) (2015)	Area [Million ha]				
		1990	2000	2005	2010	2015
Austria	46.9	3.8	3.8	3.9	3.9	3.9
Belgium	22.6	0.7	0.7	0.7	0.7	0.7
Bulgaria	35.2	3.3	3.4	3.7	3.7	3.8
Croatia	34.3	1.9	1.9	1.9	1.9	1.9
Cyprus	18.7	0.2	0.2	0.2	0.2	0.2
Czech Republic	34.5	2.6	2.6	2.6	2.7	2.7
Denmark	14.4	0.5	0.6	0.6	0.6	0.6
Estonia	49.4	2.2	2.2	2.3	2.2	2.2
Finland	73.1	21.9	22.5	22.2	22.2	22.2
France	31.0	14.4	15.3	15.9	16.4	17.0
Germany	32.8	11.3	11.4	11.4	11.4	11.4
Greece	30.3	3.3	3.6	3.8	3.9	3.9
Hungary	22.2	1.8	1.9	2.0	2.0	2.1
Ireland	10.9	0.5	0.6	0.7	0.7	0.8
Italy	31.6	7.6	8.4	8.8	9.0	9.3
Latvia	54.0	3.2	3.2	3.3	3.4	3.4
Lithuania	34.8	1.9	2.0	2.1	2.2	2.2
Luxembourg	33.5	0.1	0.1	0.1	0.1	0.1
Malta	0.9	0.0	0.0	0.0	0.0	0.0
Netherlands	11.1	0.3	0.4	0.4	0.4	0.4
Poland	30.8	8.9	9.1	9.2	9.3	9.4
Portugal	35.3	3.4	3.3	3.3	3.2	3.2
Romania	29.8	6.4	6.4	6.4	6.5	6.9
Slovakia	40.3	1.9	1.9	1.9	1.9	1.9
Slovenia	62.0	1.2	1.2	1.2	1.2	1.2
Spain	36.9	13.8	17.0	17.3	18.2	18.4
Sweden	68.4	28.1	28.2	28.2	28.1	28.1
United Kingdom	13.0	2.8	3.0	3.0	3.1	3.1

Short description of the scope of the indicator

Forest area is a key indicator to assess the overall status of afforestation, reforestation and deforestation actions. It is at the basis of forest-related policies, for instance, changes of forest area over time are fundamental for assessing the sustainability of land-use management (FOREST EUROPE 2015). In 2015, forest covered around 38% of the EU-28 extent, totalling 161 million hectares. Of this extent, 84% falls within forest available for wood supply (FAWS), i.e. forest where any legal, economic, or specific environmental restrictions do not have a significant impact on the supply of wood. FAWS include areas where, although there are no such restrictions, harvesting is not taking place, for example areas included in long-term utilization plans or intentions (UNECE, 2019).

3.2 Maps

Available information on forest area is rather coarse, usually at country level, therefore maps were not produced for this indicator.

3.3 Statistical analysis of the trend

For assessing whether there is a significant change between 1990 and 2015 (long term trend), and between 2010 and 2015 (short term trend) we used the non-parametric Wilcoxon signed-rank test (Siegel 1956; Wilcoxon 1945). We tested for a significant change in the mean value of the indicator in the long term (1990 versus 2015) and short term (2010 versus 2015).

3.4 Key trend at EU level

The forest area in the EU-28 expanded by nearly 13 million hectares over the last 25 years, an area equivalent to the size of Greece, from 148 to 161 million hectares (Figure 1). The forest expansion is the net balance of afforestation, natural forest expansion, regeneration and deforestation (FOREST EUROPE 2015). This is equivalent to an increase of 520,000 ha (0.35%) per year. The rate of increase in forest area was higher in the first decade (1990-2000) than in the 2000-2015 period, around 680,000 ha/y versus 410,000 ha/y. This indicates that forest area continues to increase but at a lower rate than in the first sub-period.

Net forest expansion in the period 1990-2015 was highest in Spain (184,000 ha/y) and France (104,000 ha/y), whereas in relative terms the highest increase per year was in Ireland with around 2%. Most Member States reported stable or increasing in forest area, however Portugal reported a net decrease in forest area in the 1990-2015 period of 254,000 ha and Sweden a decrease in the period 2005-2015 of 145,000 ha.

The Wilcoxon test indicates that there is a significant long (1990 vs 2015) and short (2010 vs 2015) term decadal increase of 3.27% and 2.13%, respectively, in forest area in the EU (Table 2).

Table 2. Long and short term trend of forest area in the EU. *Significant at 5% according to the Wilcoxon test.

	Long-term trend	**Short-term trend**
% per decade	3.27*	2.13*
Time range	1990-2015	2010-2015
Method	Wilcoxon	Wilcoxon

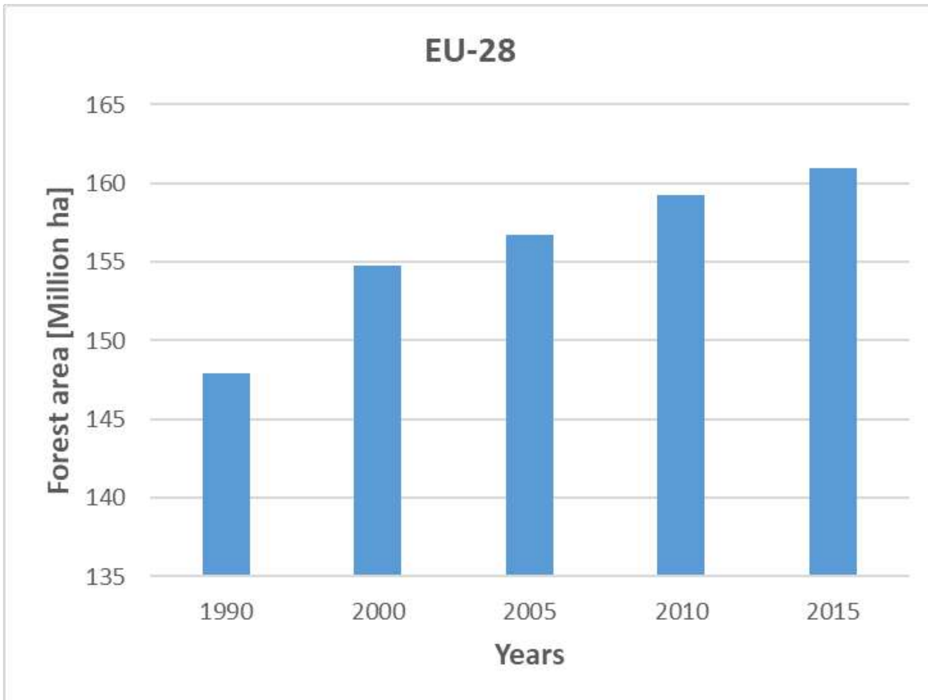

Figure 1. Forest area in the EU-28. Data source: FOREST EUROPE/UNECE/FAO (FOREST EUROPE 2015).

References

FOREST EUROPE (2015). State of Europe's Forests 2015. Ministerial Conference on the Protection of Forests in Europe. pp. 312.

UNECE (2019). Terms and definitions applied in the UN-ECE/FAO Temperate and Boreal Forest Resources Assessment 2000. Available at: http://www.unece.org/forests/fra/definit/

Siegel, S. (1956). Non-parametric statistics for the behavioral sciences. New York: McGraw-Hill. pp. 75–83.

Wilcoxon, F. (1945). Individual Comparisons by Ranking Methods. Biometrics Bulletin, Vol. 1, pp. 80-83. doi:10.2307/3001968.

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Fact sheet 3.3.204: Tree defoliation

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Ecosystem condition, Structural ecosystem attributes (general)
- Name of the indicator: Tree defoliation
- Units: percentage of leaf or needle loss

2. Data sources

- Data holder: ICP Forests (Michel A 2018); FOREST EUROPE (2015)
- Web link: http://icp-forests.net/
- Year of time-series range: 1998—2017 (20-year)
- Version: 2018 (Michel A 2018)
- Access date: 16/10/2019
- Reference:
    - Michel A, S. W., Prescher A-K, (Ed.). (2018). Forest Condition in Europe: 2018 Technical Report of ICP Forests. Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Vienna: BFW-Dokumentation 25/2018. BFW Austrian Research Centre for Forests.
    - FOREST EUROPE (2015). State of Europe's Forests 2015. (pp. 312): Ministerial Conference on the Protection of Forests in Europe.

Crown defoliation of trees is an important indicator of forest health. In fact, defoliation is one of the indicators collected periodically by the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) (Michel A 2018) and reported in Forest Europe under Criterion 2 “forest Ecosystem Health and Vitality” (FOREST EUROPE 2015). Defoliation is a parameter of tree vitality, which can be affected by a number of human and natural factors (abiotic and biotic). Therefore, defoliation is a natural bioindicator useful as warning sing in the fate of forest pressures. Defoliation can occurs, for example, when trees are exposed to insect’s infestations, fungi, deposition, abiotic factors such as heat and drought, frost, wind, snow/ice, or the action of man. For a more comprehensive description of the indicator see Michel A (2018) and FOREST EUROPE (2015).

3. Assessment of the indicator

3.1 Short description of the scope of the indicator

Defoliation describes a loss of needles or leaves in tree crown compared to a fully foliated reference tree. Defoliation is measured in percentage from 0% (no defoliation) to 100% (dead tree). Tress with defoliation above 25% are considered damaged (25%-60% moderate, 60%-<100% severe, and 100% dead).

The defoliation survey from ICP in 2017 assessed 5496 plots in 26 European countries, in total 101,779 trees (Michel A 2018). Of the 26 countries assessed, 20[29] are MS of the EU, the other six countries are: Moldova,

[29] The eight MS of the EU not included in the 2017’s defoliation data are Malta, Portugal, Austria, Cyprus, Finland, Ireland, Netherlands and UK.

Montenegro, Norway, Serbia, Switzerland and Turkey. The reporting from ICP indicates that 25.1% of all assessed trees had needle of leaf loss exceeding 25%, thus classified as either damaged or dead. Thought, there were only 595 (0.6%) dead trees in the damage assessment 2017.

The mean defoliation of all tress was 21.7%, indicating a 0.3% increase in relation to 2016. Broadleaved trees had a higher mean defoliation, 22.7%, than coniferous trees with 20.7%. Around 71% of all the plots assessed had a mean defoliation up to 25%, therefore some 29% of plots had a mean defoliation above 25% i.e. the damage threshold.

3.2 Maps

Available information on tree defoliation is provided a plot level, therefore maps were not produced for this indicator.

3.3 Statistical analysis of the trend

The ICP report (Michel A 2018), main source of this fact sheet, used the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012) for calculating regression slopes, and Mann-Kendall (Gilbert 1987; Kendall 1975; Mann 1945) non-parametric trend test to assess the significance of monotonic trends in annual mean plot defoliation.

3.4 Key trend at EU level

The overall trend of mean plot defoliation from 1998 to 2017 per group of tree species is shown in Table 1. All the 10 groups of tree species exhibited upward trends of defoliation, of which seven significant. The groups exhibiting significant upward trends represent around 70% of all the trees of the survey.

For computing the long term trend of defoliation at European level, first, we selected the upper and lower slope from the seven groups of tree species showing a significant upward trend in Table 1. Second, we calculated the decadal long-term trend for the two groups (lower and upper bound). Results indicate a decadal increase between 3.4% (lower bound) and 16.5% (upper bound) in the groups with significant trends in mean annual plot defoliation (Table 2).

Figures showing the annual data and trends of defoliation of tree species groups can be accessed in pages 44 and 45 of the ICP-forests report (Michel A 2018)[30].

[30] https://www.icp-forests.org/pdf/TR2018.pdf

Table 1. Trend of mean annual plot defoliation (percentage) in the most abundant tree species groups across Level I plots (5057 plots) from 1998-2017 in 26 European countries. A positive trend (slope) indicates increasing defoliation. (*) Significant at 5% according to the Mann-Kendall test. Source: Michel A (2018).

Tree species/groups [abundance of the species on Level I plots]	Trend 1998-2017 (slope)	Significance (*p*-value)
Scots pine (*Pinus sylvestris*) [16.5%]	0.064	0.381
Norway spruce (*Picea abies*) [12%]	0.070	0.035*
Austrian pine (*Pinus nigra*) [5.1%]	0.230	0.010*
Mediterranean lowland pines (*Pinus brutia, P. halepensis, P. pinaster, P. pinea*) [>7.3%]	0.371	< 0.001*
Other conifers	0.081	< 0.001*
Common beech (*Fagus sylvatica*) [11.7%]	0.118	< 0.012*
Deciduous temperate oaks (*Quercus petraea and Q. robur*) [8.5%]	0.065	0.347
Deciduous sub-Mediterranean oaks (*Quercus cerris, Q. frainetto, Q. pubescens, Q. pyrenaica*) [>5.4%]	0.003	0.871
Evergreen oaks (*Quercus coccifera, Q. ilex, Q. rotundifolia, Q. suber*) [>3.7%]	0.329	< 0.001*
Other broadleaves	0.283	< 0.001*

Table 2. Long term trend and short term trend of mean annual plot defoliation (percentage) in two groups of tree species in European countries. Lower/upper bound corresponds to groups of tree species with lower/higher significant slope (trend) in Table 1. (*) Significant at 5% according to the Mann-Kendall test.

	Long-term trend	Short-term trend
Lower bound: Norway spruce (*Picea abies*)		
% per decade	3.4*	N/A
Time range	1998-2017	N/A
Method	Mann-Kendall	N/A
Upper bound: Mediterranean lowland pines (*Pinus brutia, P. halepensis, P. pinaster, P. pinea*)		
% per decade	16.5*	N/A
Time range	1998-2017	N/A
Method	Mann-Kendall	N/A

Key messages

- One out of four (25.1%) of all assessed trees showed defoliation levels suggesting damage or dead.
- The mean defoliation of all assessed tress in 2017 was 21.7%, this represents a 0.3% increase in relation to 2016. Note that trees having defoliation above 25% are considered damaged or dead.
- Broadleaved trees had a higher mean defoliation, 22.7%, than coniferous trees with 20.7%.
- Around 29% of all the 5496 plots assessed had a mean defoliation above 25% i.e. the damage threshold.
- All the 10 groups of the most abundant tree species exhibited upward trends of defoliation between 1998 and 2017 (of which seven groups significant trends).
- The groups exhibiting significant upward trends represent around 70% of all the assessed trees.

References

FOREST EUROPE (2015). State of Europe's Forests 2015. (pp. 312): Ministerial Conference on the Protection of Forests in Europe.

Gilbert, R. O. (1987). Statistical Methods for Environmental Pollution Monitoring. NY, USA: Wiley.

Kendall, M. G. (1975). Rank Correlation Methods (4th edition). London: Charles Griffin.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3), 245-259, doi:10.2307/1907187.

Michel A, S. W., Prescher A-K, (Ed.). (2018). Forest Condition in Europe: 2018 Technical Report of ICP Forests. Report under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention). Vienna: BFW-Dokumentation 25/2018. BFW Austrian Research Centre for Forests.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324), 1379-1389, doi:10.2307/2285891.

Wilcox, R. R. (2012). Introduction to Robust Estimation and Hypothesis Testing. San Diego, California, USA: Academic Press.

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Fact sheet 3.3.205: Changes in the abundance of common forest birds (index) (SEBI 001)

1. General information

- Thematic ecosystem assessment **Forest**
- Indicator class **Structural ecosystem attributes based on species diversity and abundance**
- Name of the indicator: **Changes in the abundance of common forest birds**
- Units **index of relative values with respect to a base year**

2. Data sources

Based on existing (reference) data:

- Data holder: **European Bird Census Council (EBCC)**
- Weblink:
  http://www.pecbms.info/
  https://www.eea.europa.eu/data-and-maps/indicators/abundance-and-distribution-of-selected-species-7/assessment
- Year or time-series range: **1990-2016, see different ranges for regional indicators**
- Version: **2019**
- Access date: **06.06.2019**
- Reference: Gregory R.D., Škorpilová J., Voříšek P., Butler S. 2019. An analysis of trends, uncertainty and species selection shows contrasting trends of widespread forest and farmland birds in Europe. Ecological Indicators, 103: 676-687.

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

This indicator shows trends in the abundance of common forest birds across their European ranges over time. It is a composite index created from data of bird species characteristic for forest habitats in Europe. A value of 100 is set for each species in the first year of the time series.

3.2. Maps

No maps are available for this indicator.

3.3. Statistical analysis of the trend

Trends were computed using robust regression. Regression slopes were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012) because it accommodates non-normal distributions and is a robust trend slope estimator resistant to the effects of outliers. Additionally, a two-sided Mann-Kendall (Gilbert 1987; Kendall 1975; Mann 1945) non-parametric trend test was used to assess the significance of monotonic trends.

3.3. Key trend at EU level

Between 1990 and 2016, the common forest bird index decreased by 3%[31] in the 26 EU Member States that have bird population monitoring schemes (Figure 1). Meanwhile, around 2005 the index stays in stable situation and improves in the most recent years. In contrasts, the common farmland bird index continues to show a steep decline of 16% between 2000 and 2016. While the forest bird indicator uses 1990 as the baseline of the time series, it should be considered that a decrease of 4% had already occurred since 1980[32].

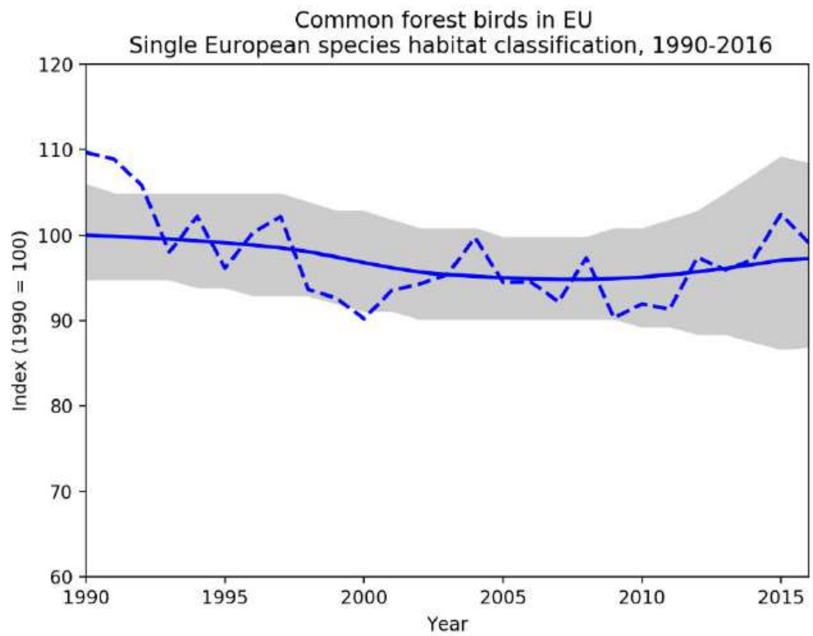

Figure 1. EU common forest bird indicator, single European species habitat classification, 34 species, 1990-2016. Blue line: smoothed index; blue broken line: unsmoothed index; grey area: upper and lower confidence limits. The indicator was created using data from EU countries with the exception of Croatia and Malta. Data source: European Bird Census Council (EBCC), BirdLife International, Royal Society for the Protection of Birds (RSPB) and Czech Society for Ornithology (CSO).

Table 1 shows the decadal trend calculated according to the MAES approach.

[31] Change in percentage (trend) in the index value between the first and last year of the time series. Trend according to Pan-European Common Bird Monitoring Scheme (PECBMS): https://pecbms.info/trends-and-indicators/indicators/

[32] See: https://pecbms.info/trends-and-indicators/indicators/indicators/EU1_Fo/confidential/yes/

Table 1. Long-term trend and short-term trend of the common forest bird indicator, single European species habitat classification, 34 species. N.S.: not significant at 5% according to Mann-Kendall trend test. Note: Change is always considered as significant in case the percentage change per decade is higher than or equal to +5 % or lower than or equal to -5 %. This is valid for both short and long-term trends and regardless statistical testing. A change outside this interval is thus always considered as policy-relevant to report.

	Long-term trend	**Short-term trend**
% per decade	-2.98 (N.S.)	11.20 (N.S.)
Time range	1990-2016	2007-2016
Method	Mann-Kendall	Mann-Kendall

3.4. Trends at regional level

A regional overview of the indicator of forest birds is shown in Figure 2. The change in percentage (trend) in the index, calculated between the first year of the time series (here 1980) and 2016, indicates a decrease in North and South Europe of 12% (statistically significant) and 14%, respectively. In contrast, in Central and East Europe, and West Europe, there is an increase of 7% and 1%, respectively. Note the different base years and geographical coverage (EU + Norway and Switzerland) in the regional indicators of Figure 2.

3.5. Summary

According to EBCC[33] there are some likely drivers of the changes in the forest bird index. The decline suggested in the EU, and specifically in North and South Europe, could be the result of changes in forest area, forest composition, forest age and structure. These factors influence bird community composition and species trends, both positively and negatively depending on the species. There is evidence that some forest specialists, particularly birds associated with old-growth stands, have declined and are threatened by intensive forest management practices. A large body of literatures has focused on birds of boreal forest, however our knowledge regarding other forest regions and their associated bird populations is more limited. There is an ongoing effort within the PECBMS to improve the indicators further, particularly to improve the procedure of selection of species for the indicators and to fill in the gaps in spatial coverage.

[33] http://www.ebcc.info/art-435/

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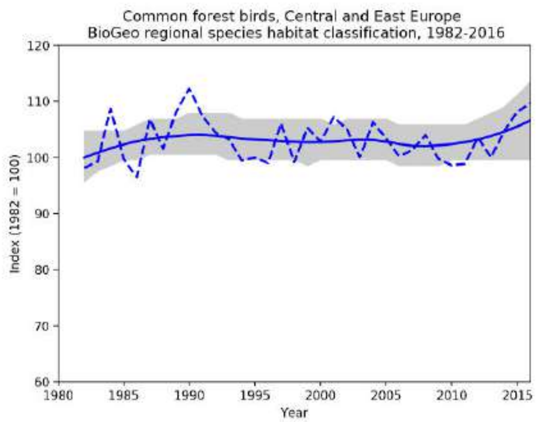

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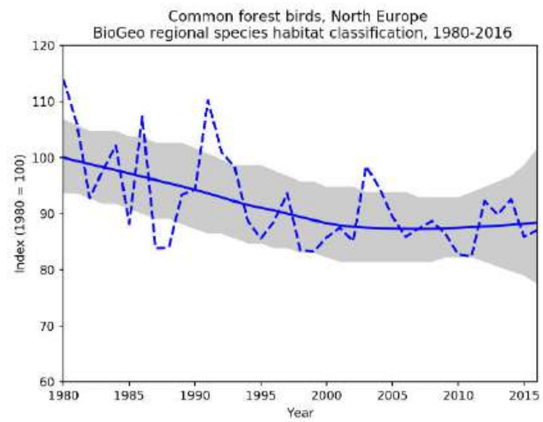

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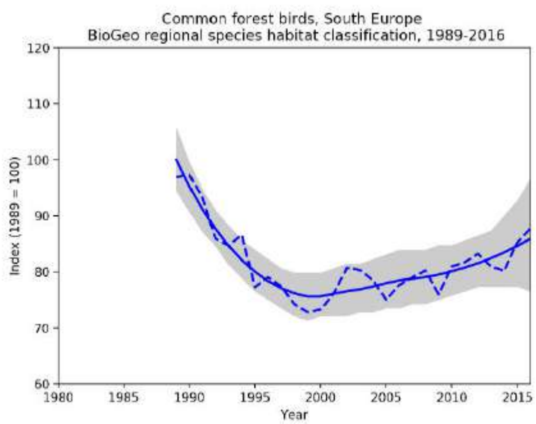

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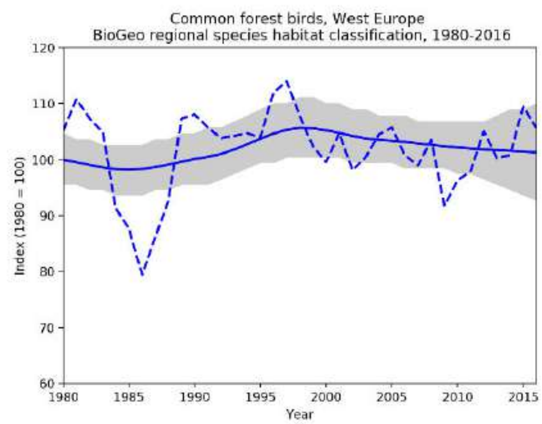

Figure 2. Common forest bird indicator in four European regions according to the BioGeo regional species habitat classification of EBCC. A) Central and East Europe (34 species): Czech Republic, Estonia, former East Germany, Hungary, Latvia, Lithuania, Poland and Slovakia; B) North Europe (18 species): Finland, Norway and Sweden; C) South Europe (32 species): France, Italy, Portugal and Spain; D) West Europe (32 species): Austria, Belgium, Denmark, former West Germany, Luxembourg, Netherlands, Ireland, Switzerland and United Kingdom. Blue line: smoothed index; blue broken line: unsmoothed index; grey area: upper and lower confidence limits. Data source: European Bird Census Council (EBCC), BirdLife International, Royal Society for the Protection of Birds (RSPB) and Czech Society for Ornithology (CSO).

References

Gilbert, R. O. (1987). Statistical Methods for Environmental Pollution Monitoring. NY, USA: Wiley.

Kendall, M. G. (1975). Rank Correlation Methods (4th edition). London: Charles Griffin.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3), 245-259, doi:10.2307/1907187.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324), 1379-1389, doi:10.2307/2285891.

Wilcox, R. R. (2012). Introduction to Robust Estimation and Hypothesis Testing. San Diego, California, USA: Academic Press.

Annex 1. Reference data table.

Indicator	BaseYear	Year	Index (unsmoothed)	Smoothed indicator	Lower CL smoothed	Upper CL smoothed
EU_Fo	1990	2000	90.88	97.14	92.35	102.06
EU_Fo	1990	2006	95.22	95.08	90.52	100.04
EU_Fo	1990	2010	92.14	95.1	90.52	100.04
EU_Fo	1990	2012	97.16	95.57	89.62	102.06
EU_Fo	1990	2016	99.1	97.26	86.97	108.37
EU_Fo	2000	2000	93.55	100	94.95	104.94
EU_Fo	2000	2006	97.92	97.89	94.01	101.84
EU_Fo	2000	2010	94.79	97.93	93.07	102.86
EU_Fo	2000	2012	100.17	98.41	93.07	103.89
EU_Fo	2000	2016	102.08	100.16	90.32	110.32
EU_Fo	2016	2000	93.06	99.8	94.42	105.4
EU_Fo	2016	2006	97.67	97.69	93.48	102.29
EU_Fo	2016	2010	94.31	97.74	93.48	102.29
EU_Fo	2016	2012	100.01	98.22	93.48	103.31
EU_Fo	2016	2016	101.79	100	92.55	107.53

Values of common bird indicators for Europe and EU, time period 1990–2016
Baseyear = baseyear used for calculation of the indicator (1990, 2000 and 2016)
Year = year in time series
Indicator (unsmoothed) = the unsmoothed values of the indicator
Smoothed indicator = smoothed values of the common bird indicator (multi-species index) calculated using the indicator tool (https://www.cbs.nl/en-gb/society/nature-and-environment/indices-and-trends--trim--/msi-tool, the method is described in Soldaat et al 2017: A Monte Carlo method to account for sampling error in multi-species indicators. Ecological Indicators 81 (2017) 340–347.)
Lower CL smoothed = lower confidence limit of the smoothed indicator
Upper CL smoothed = upper confidence limit of the smoothed indicator
Indicator name (abbreviation) = Indicator full name, incl. region and species habitat classification:
EU_Fo = Common forest birds, EU, single European species habitat classification

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Fact sheet 3.3.206: Percentage of forest covered by Natura 2000 (%)

1. General information

- Thematic ecosystem assessment: Forest
- Indicator class: Condition. Structural ecosystem attributes monitored under the EU nature directives
- Name of the indicator: Percentage of forest covered by Natura 2000 (%)
- Indicator description: The indicator measures the percentage of forest protected by Natura 2000 sites from 2000 to 2018 and the trends.
- Units: percentage (%)

2. Data sources

- Data holder: EEA
- Weblinks:
    - Corine Land Cover https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data
    - Natura 2000 data - the European network of protected sites https://www.eea.europa.eu/data-and-maps/data/natura-10
- Year or time-series range 2000 / 2006 / 2012 / 2018
- Versions
    - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
    - Natura 2000 End 2018 – Shapefile
    - Natura 2000 End 2013 rev1 - Shapefile

3. Assessment of the indicator

3.1 Short description of the scope of the indicator

At the EU level, the Nature Directives (Birds and Habitats) are the centerpiece of its nature legislation and biodiversity policy. The Natura 2000 sites are one of the Nature Directive's main tools that contribute to ensuring the conservation of many species and habitats of EU interest. Its purpose is primarily to ensure the conservation of targeted species and habitats of European interest. The Natura 2000 network is largely complete as far as the terrestrial environment is concerned and connectivity — spatial and functional — of Natura 2000 sites across national borders is relatively good.

Every country has designated Natura 2000 sites to help conserve the rare habitats and species present in their territory. Progress in designating sites was slow at first but currently the protected area is over 18 % of the EU’s land area being the largest network of protected areas in the world (EEA, 2012).

This indicator aims to evaluate how the percentage of forest protected by Natura 2000 site has being changed against time. The changes could be due to changes of ecosystem extent, for example due to agricultural abandonment, or also be associated with changes in the protection zones, either by the designation of new areas or by the modification of the limits of those already existing. Both cases are included in this assessment since the indicator values are from overlap the spatial information, by means of spatial analysis tools, of CLC 2000, 2006 and 2012 with Natura 2000 network informed by MS end of 2013 (previous versions of spatial data of Natura 2000 present gaps and geometric inconsistences), and from CLC 2018 with Natura 2000 version provided by 2018.

3.2 Maps

Maps as pixel based were not available. This indicator was provided as tabular information, aggregated at biogeographical regions and at EU-28 level.

The next maps show the decadal change rate (in percentage) across the biogeographical regions (Figure 1). From the biogeographical (BGR) perspective (Figure 2 and Table 2), in most of BGR there are no significant changes, the decadal change rates range between -1% and +1%. Only in Boreal BGR the indicator shows a negative decadal change rate of -11.42%, being the strongest downward trend.

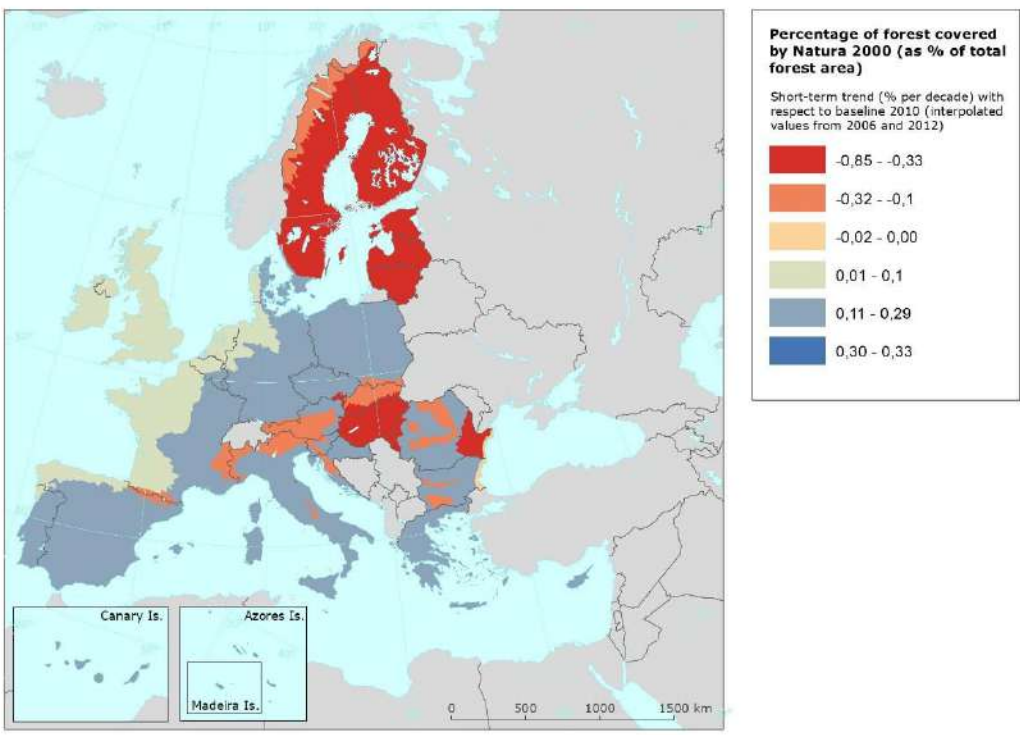

Figure 1 Forest condition indicator: Percentage of forest covered by Natura 2000 sites by Biogeographical regions. Short-term trend (in %) with respect to baseline. Red colors mean downwards trends in the percentage of forest area covered by Natura 2000, while blue colors mean an upward trend. The baseline is 2010 which values were interpolated based on the values for 2006 and 2012.

3.3 Statistical analysis of the trend

Temporal trends of the percentage of forest covered by Natura 2000 are shown in Table 1. These statistics cover all four CORINE assessment years, including decadal changes for short and long-term trends. The assessment of the indicator was done using the 5% rules due to the low number of observations, therefore a statistical test of significance was not done.

3.4 Key trend at EU level

At the European level (Figure 2, Table 1) the percentage of forest ecosystem within Natura 2000 is almost stable from 2000 to 2018. The indicator shows a slightly decrease in both the short-term trend (2010-2018) and the long-term trend (2000-2018) by –0.27% and –0.12%, respectively.

Table 1 Structural condition indicator. Percentage of forest protected by Natura 2000 sites at EU-28. Values got from overlap the spatial information of CLC 2000, 2006 and 2012 with Natura 2000 network informed by MS end of 2013, and from CLC 2018 with Natura 2000 version provided by 2017. (*) values for the baseline 2010 (interpolated between 2006 and 2012.

	Percentage of forest covered by Natura 2000 sites						
	2000	**2006**	**2010***	**2012**	**2018**	**Short-term trend (% per decade)**	**Long-term trend (% per decade)**
EU-28	**22.84**	**22.85**	**22.84**	**22.84**	**22.63**	- 0.27% No-change	-0.12% No-change
Time range						2010 vs 2018	2000 vs 2018
Method						5% rule	5% rule

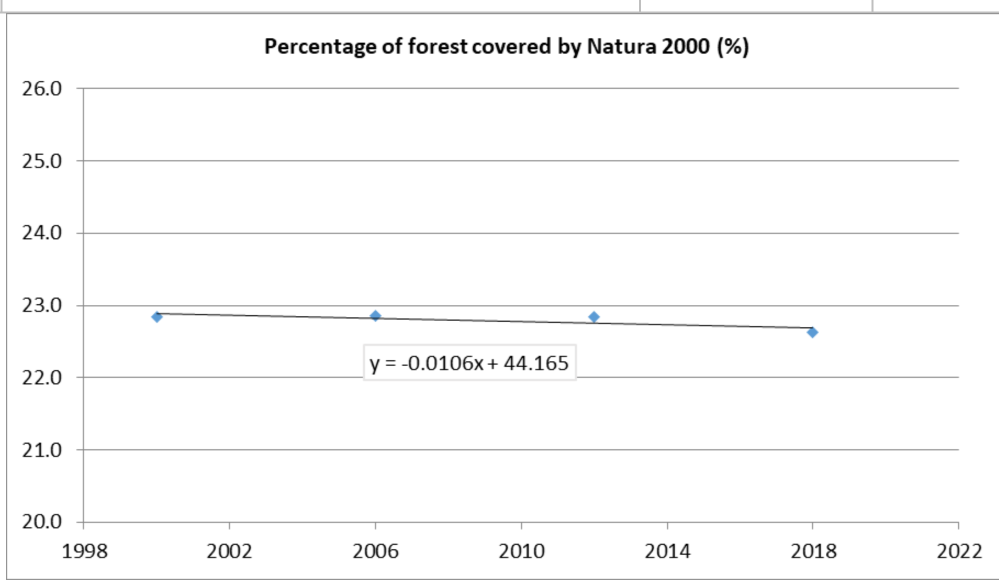

Figure 2 Trend of percentage of forest covered by Natura 2000 site from 2000 to 2018. Values got from overlap the spatial information of CLC 2000, 2006 and 2012 with Natura 2000 network informed by MS end of 2013, and from CLC 2018 with Natura 2000 version provided by 2017.

For none of the biogeographic region, a change in the percentage of protected forest ecosystem can be detected, Table 2. Also, at this spatial level, for both short- and long-term trends, the condition of this ecosystem measured by the indicator is *stable*. The BGR with higher rate of change per decade, within stable range value, is in Boreal BGR (-0.85, Stable). However, this rate is affected by the redefinition of the polygon for FI1301912 site, submitted by Finland in the version of spatial information for Natura 2000 in 2018.

The values per biogeographical region used for Figure 2 are reported in Table 2.

Table 2 Structural condition indicator. Percentage of forest protected by Natura 2000 sites by biogeographical region. Values got from overlap the spatial information of CLC 2000, 2006 and 2012 with Natura 2000 network informed by MS end of 2013, and from CLC 2018 with Natura 2000 version provided by 2017. (*) values for the baseline 2010 (interpolated between 2006 and 2012. The change per decade is computed based on the interpolated value for the baseline year 2010, using as time rage for long term trend 2000 – 2018 and for short-term trend 2010-2018

	PERCENTAGE OF FOREST COVERED BY NATURA 2000 (%)						
BIOGEOGRAPHICAL REGION	**2000**	**2006**	**2010***	**2012**	**2018**	**Long-term trend (% per decade)**	**Short-term trend (% per decade)**
ALPINE	39.74	39.75	39.76	39.76	39.58	-0.09% No-change	-0.22% No-change
ATLANTIC	16.07	16.12	16.12	16.12	16.16	0.05% No-change	0.05% No-change
BLACK SEA	76.15	76.15	76.15	76.15	76.10	-0.03% No-change	-0.06% No-change
BOREAL	7.41	7.42	7.42	7.42	6.74	-0.37% No-change	-0.85% No-change
CONTINENTAL	28.04	28.03	28.03	28.03	28.11	0.04% No-change	0.10% No-change
MACARONESIAN	59.45	59.46	59.58	59.63	59.65	0.11% No-change	0.10% No-change
MEDITERRANEAN	36.59	36.60	36.59	36.58	36.82	0.13% No-change	0.29% No-change
PANNONIAN	40.20	39.65	39.26	39.07	38.91	-0.44% No-change	-0.72% No-change
STEPPIC	71.84	71.84	71.84	71.83	71.44	-0.22% No-change	-0.49% No-change
EU-28	**22.84**	**22.85**	**22.84**	**22.84**	**22.63**	**-0.12% No-change**	**-0.27% No-change**

References

EEA, 2012. *Protected areas in Europe - an overview.European Environment Agency. EEA Report / No 5/2012,* s.l.: s.n.

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Fact sheet 3.3.207: Percentage of forest covered by Nationally designated areas -CDDA

1. General information

- Thematic ecosystem assessment: Forest
- Indicator class: Condition. Structural ecosystem attributes monitored under the EU nature directives
- Name of the indicator: Percentage of forest covered by CDDA (%)
- Indicator description: The indicator measures the percentage of forest protected by nationally designated areas from 2000 to 2018 and the trends.
- Units: percentage (%)

2. Data sources

- Data holder: EEA
- Weblinks:
  - Corine Land Cover https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data
  - CDDA data - Nationally designated areashttps://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-13
- Year or time-series range 2000 / 2006 / 2012 / 2018
- Versions
  - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
  - Natura 2000 End 2018 – Shapefile
  - CDDA 2018 – Shapefile
- Reference https://www.eea.europa.eu/data-and-maps/indicators/nationally-designated-protected-areas-10

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The nationally designated areas -CDDA- is the official source of protected area information from the 39 European countries members of EEA to the World Database of Protected Areas (WDPA). A 'nationally designated protected area' is an area designated by a national designation instrument, based on national legislation.

This indicator aims to evaluate how the percentage of forest protected by the nationally designated areas has being changed against time. The changes could be due to changes of ecosystem extent, for example due to agricultural abandonment, or also be associated with changes in the protection zones, either by the designation of new areas or by the modification of the limits of those already existing. This i ndicator focuses only on the trend in the percentage of protected forest due to the change in the ecosystem extent. The CDDA digital maps are being reported by the countries from 2002, however this voluntary provision could trigger restrictions on the fully publication of the datasets. Consequently, the CDDA spatial information is not consistent over time. In fact, the last available dataset, CDDA v2018 , shows partially the spatial information of Estonia, Finland, Ireland and Turkey, since EEA does not have permission to distribute some or all sites reported by them.

The values of the indicator are the result of the overlapping, by means of spatial analysis tools, of CORINE LC 2000, 2006, 2012 and 2018 with and the nationally designated areas -CDDA- informed by MS in 2018.

3.2 Maps

Maps as pixel based were not available. This indicator was provided as tabular information, aggregated at country, biogeographical region or EU-28 level.

The next maps show the short-term trend (in percentage per decade) across the European biogeographical regions (Figure 2). This indicator is almost stable across Europe. Although the changes are not significant (Table 2), all the major decadal change rates indicate downward trends (-0.20% in Pannonian and -0.33% in Macaronesian biogeographical regions).

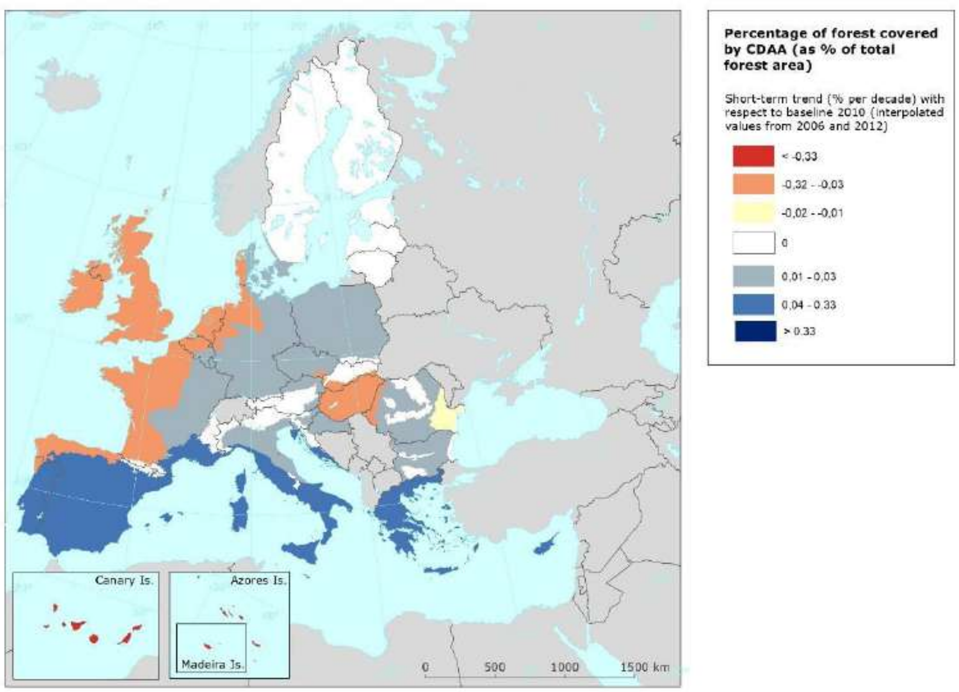

Figure 2 Forest condition indicator: Percentage of forest covered by CDDA from 2000 to 2018 per Biogeographical regions. Short-term trend (in %) with respect to baseline. Red colors mean downwards trends in the percentage of forest area covered by CDDA, while blue colors mean an upward trend. The baseline is 2010 which values were interpolated based on the values for 2006 and 2012.

3.3 Statistical analysis of the trend

Temporal trends of the percentage of forest covered by CDDA indicator are shown in Table 1. These statistics cover all four CORINE assessment years, including the interpolated baseline and decadal changes for short and long-term changes. The significant assessment and the qualification of the indicator was done using the 5% rule due to the low number of observations, then a statistical test cannot be performed.

3.4 Key trend at EU level

At the European level, the percentage of woodland and forest ecosystem protected by CDAA is around 21%. This percentage is stable from 2000 to 2018, with a decadal change rate of +0.01% in the short-term and 0 in the long-term. The indicator at EU-28 level reveals no significant changes, therefore the condition is no-change (Table 1 and Figure 3).

Table 1 Structural condition indicator. Percentage of forest protected by CDDA sites. Long-term trend and short-term trends. Values obtained by overlapping the spatial information of CLC 2000, 2006, 2012 and 2018 with the CDDA network provided by MS in 2018. The baseline 2010 was interpolated between 2006 and 2012.

	Percentage of forest covered by nationally designated areas - CDDA						
	2000	**2006**	**2010***	**2012**	**2018**	**Short-term trend (% per decade)**	**Long-term trend (% per decade)**
EU-28	21.22 %	21.22%	21.21%	21.21%	21.22 %	0.01% No-change	≈0.00% No-change
Time range						2010 vs 2018	2000 vs 2018
Method						5% rule	5% rule

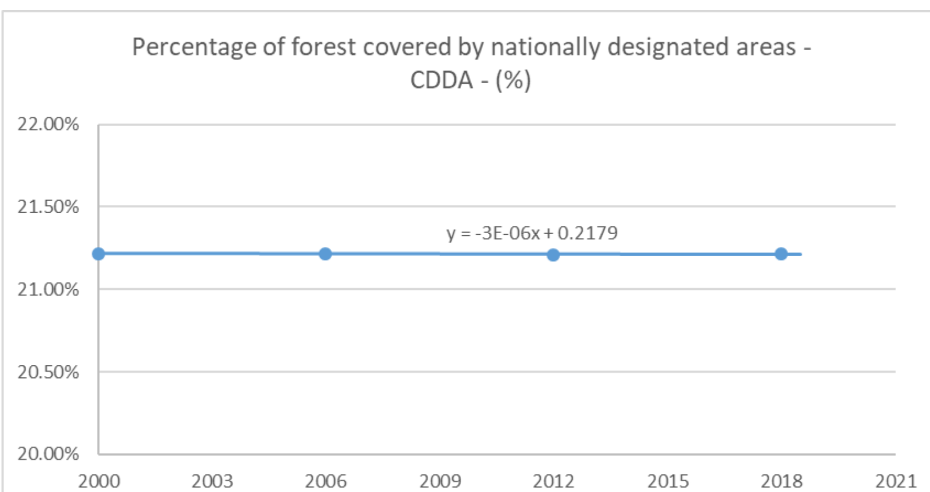

Figure 3 Trend of percentage of European forests (EU-28) covered by CDDA from 2000 to 2018. Values got from overlap the spatial information of CLC 2000, 2006, 2012 and 2018 with CDDA network informed by MS in 2018. See values in Table 1.

The values per biogeographical regions which were used for Figure 2 are reported in Table 2. The percentage of forest protected by CDDA differs considerably depending on the biogeographical zone, being almost 65% in the Macaronesian region and in contrast less than 8% in the Boreal region. As mentioned above, the indicator remains stable exhibiting decadal changes of less than 1%. The indicator at BGR level reveals that no significant changes occurred in the assessed period. Therefore, the indicator suggests no change.

Table 2 Structural condition indicator. Percentage of forest protected by CDDA sites per biogeographical region. Values obtained by overlapping the spatial information of CLC 2000, 2006, 2012 and 2018 with CDDA network provided by MS in 2018. *Baseline 2010 interpolated between 2006 and 2012).

PERCENTAGE OF FOREST COVERED BY NATIONALLY DESIGNATED AREAS

	2000	2006	2010 *	2012	2018	Long-term trend (% per decade)	Short-term trend (% per decade)
ALPINE	31.09	31.10	31.10	31.10	31.10	0.00% No-change	0.00% No-change
ATLANTIC	23.87	23.80	23.78	23.77	23.74	-0.07% No-change	-0.05% No-change
BLACK SEA	53.14	53.15	53.15	53.15	53.15	0.01% No-change	0.00% No-change
BOREAL	7.33	7.34	7.34	7.34	7.34	0.01% No-change	0.00% No-change
CONTINENTAL	33.41	33.41	33.42	33.43	33.43	0.01% No-change	0.01% No-change
MACARONESIAN	64.92	64.84	64.58	64.45	64.32	-0.33% No-change	-0.33% No-change
MEDITERRANEAN	23.55	23.55	23.53	23.52	23.56	0.01% No-change	-0.04% No-change
PANNONIAN	20.81	20.49	20.25	20.13	20.09	-0.40% No-change	-0.20% No-change
STEPPIC	10.66	10.66	10.66	10.66	10.65	-0.01% No-change	-0.01% No-change

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Fact sheet 3.3.208: Dry Matter Productivity

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Ecosystem condition, Functional ecosystem attributes
- Name of the indicator: Dry Matter Productivity
- Units: Kg/ha/year

2. Data sources

The indicator is based on processed remote sensing data:

- Data holder: Copernicus Global Land Service
- Weblink data source: https://land.copernicus.eu/global/products/dmp
- Year or time-series range: 1999-2018
- Version: Dry Matter Productivity at 1 km Version 2.0.1
- Access date: 31.12.2018
- Reference: Swinnen, E., Van Hoolst, R., Eerens, H. (2018). Algorithm theoretical basis document, Dry matter productivity (DMP) version 2. Copernicus, VITO, ssueI2.10, pp. 53.

3. Assessment of the indicator

3.1 Scope of the indicator

Ecosystem productivity is a crucial ecological variable considered to be at the core of numerous ecological processes including decomposition, biomass production, nutrient cycling, and fluxes of nutrients and energy (Gower et al. 2001). A fundamental measure of ecosystem productivity is net primary productivity (NPP). NPP is the difference between the total amount of carbon fixed by autotroph organisms through the process of photosynthesis, also called Gross Primary Production (GPP), and plant autotrophic respiration. Hereafter, we will focus on Dry Matter Productivity (DMP), which is a customized version of NPP for agricultural purposes.

Monitoring DMP through time is of fundamental importance, because changes in DMP have important implications on ecosystem services. These include carbon sequestration and storage, biodiversity, water supply, erosion control, recreation but also provisioning services on which a number of sectors are dependent upon such as biomass for bioenergy, fiber and timber supply and many other bio-based products (Neumann et al. 2016).

DMP is a long-term gauge of ecosystem condition (Polis 1999) and is listed as a key indicator of functional diversity in forest ecosystems (Lausch et al. 2016). Reductions of DMP could indicate an early signal of potential plant-pest outbreak or could be the results of increasing deforestation or fires. Increase DMP instead could be the result of warming, natural regeneration, reforestation and afforestation practices.

Accurate estimates of DMP in time will be increasingly important in the future in order to monitor the condition of the forest. This is particularly so in European Union, where forests and their ecosystem services will be at the core of the bio-based economy (EC 2018). Additionally, spatially explicit estimates of DMP will enable to identify those areas where carbon sequestration is potentially decreasing, favoring the identi fication of areas where sustainable management practices would be required to mitigate climate change (Browers et al. 2016).

The aim of this assessment is to settle an indicator of DMP over the EU-28 and for a period of 20 years ranging from 1999 to 2018. This indicator will be updated from time to time providing researchers and public authorities with a fundamental tool to monitor the condition of forest ecosystems in Europe. Furthermore, we provide an assessment of DMP changes at the biogeographical region level, being able to monitor forest condition for regions that are climatically and ecologically diverse such as for instance the Mediterranean region, the Pannonian region or the Alpine region. DMP will become part of a collection of indicators specifically designed to monitor ecosystem condition at European level, being able support policy-makers in decision-making.

Methods

Data download from Copernicus

Data on DMP was downloaded from Copernicus Global Land Service (Copernicus 2018), delivered in compressed Network Common Data Form (NetCDF) files having a global coverage. DMP layers are derived from SPOT-VGT (until December 2013) and PROBA-V (from January 2014) satellite imagery and are combined with (modelled) meteorological data from the European Center Medium Weather Forecast (ECMWF). The spatial resolution of the layers is of 0.083 arcsec (~1km). Each NetCDF file represents the DMP average for a ca. 10-days period, where the starting position is always set to the 01st, 11th and 21st day of the month. DMP is expressed in kgDM/ha/day. The period covered by the images ranges 20 years from 1999 until 2018.

Analysis and trends

From the three monthly decadal averages we derived a single average value for each month and multiplied it by the number of days in the month to obtain cumulative monthly values of DMP (kgDM/ha/month). The latter were summed up over the whole year to acquire a total year sum of DMP (kgDM/ha/year).

As one of our objectives is to track changes in DMP over time we created yearly maps of DMP from 1999 to 2018. As a preprocess step we implemented a gap-filling procedure to fill-in the missing data present in some grid cells of the time-series that could arise from cloud cover, missing meteorological data or other sources. Following previous literature studies, we gap-filled our data by interpolating values horizontally (between neighboring cells of the same layer), and vertically (among different time steps of a target cell). The first was made on a 3 x 3 grid cell basis obtaining the average value over the 9 neighboring grid cells pixels around the targeted-grid cell as suggested by Ivits et al. (2013). The latter was performed when less than equal to 25% of values in each grid cell was missing, while the data were excluded from the analysis when more than 25% of the values in each grid cell was missing (Jong et al. 2013).

As a first product, we obtained 20 yearly sum maps of DMP with a spatial resolution of 0.083 arc sec (~1 km). From these maps, we created two products: first, an average map of yearly sums of DMP over the whole period, and second, a map showing the trends in DMP. The latter map was computed estimating regression slopes on each grid cell using the non-parametric Theil–Sen (TS) estimator (Sen 1968, Wilcox 2012). The Theil–Sen (TS) procedure is a rank-based test that calculates the slope and intercept of the time-series by determining the median of all estimates of the slopes derived from all pairs of observations (Hoaglin et al. 2000). The TS procedure is commonly used in estimating vegetation indices trends, such as NDVI trends (Alcaraz-Segura et al 2009) because it is resistant to outliers and is robust in case of skewed data (Eastman et al. 2009). The significance of the TS slope, was tested using the non-parametric Mann-Kendall test (Kendall 1975, Mann 1945).

The same analysis as done at grid cell level was conducted at biogeographical level (EEA, 2018) and over the whole Europe. For each biogeographical region/EU level we calculated yearly area averaged values from the 1-km yearly DMP total sums and then we calculated trends using the TS slope estimator and its significance using the Mann-Kendall test.

It is important to mention that all the results obtained have been masked with the 'woodland and forest' ecosystem type. This was derived from the Corine Land Cover (CLC) 2012 v. 18.5 at 100m and 250m spatial resolution.

Results

3.2 Maps and trends

EU level

Figure 1 shows mean values of DMP, computed at the grid cell level (~ 1 km), ranging between nearly 1000 kg/ha/year to 24,000 kg/ha/year. The lowest values of DMP are recorded in the Alps, Scotland, a substantial part of the Iberian Peninsula, and in general Fennoscandia although southern Sweden and Finland report relatively higher DMP rates. The highest DMP values are reported for North and Western Iberia, Italy, France and the Balkans countries. Our results are in agreement with previous satellite-based NPP estimates for the European region (Newmann et al. 2016) although for a slightly different period (2000-2012). Results are also in-line with a global assessment of GPP for a very similar period (2000-2016) (Zhang et al 2017).

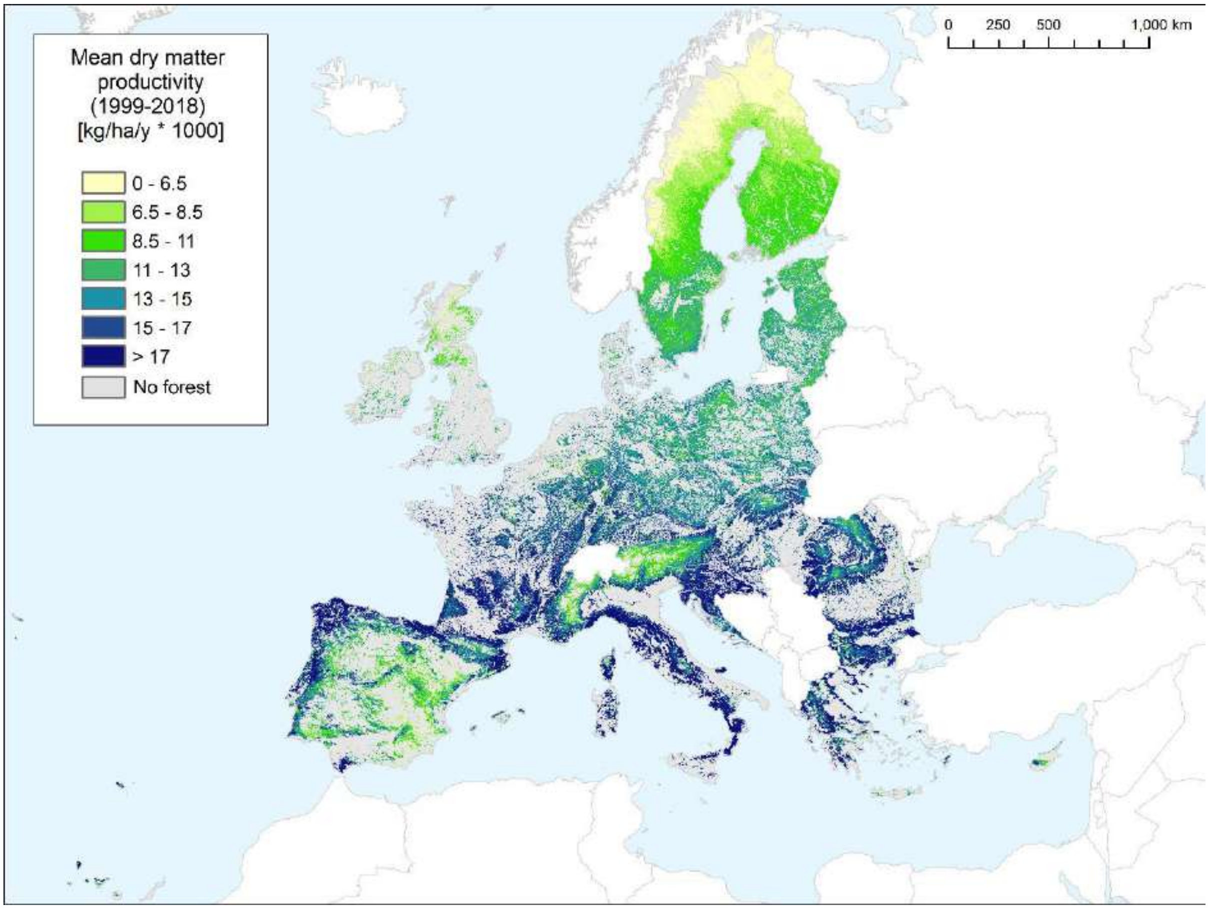

Figure 1. Mean dry matter productivity (DMP) for the period 1999-2018 within the EU-28 countries. DMP is shown only for forest and woodland.

Figure 2 shows significant trends of DMP over the period 1999 to 2018. Most of Europe is characterised by upward trends of DMP, with an increasing gradient from West to East. Nevertheless, a downward trend of DMP is evidenced in Scotland, Ireland, the Po Valley in Italy, North Western Iberia, and in the Landes of Gascony in France. It is remarkable that some of the areas that exhibit a downward trend of DMP are agricultural land or represent managed grasslands such as the Po Valley or Ireland as evidenced in Figure 3, where the DMP trends are shown only for forest and woodland. The upward trend in DMP is confirmed in Figure 4, where the trend in forest and woodland over the whole EU-28 domain is presented. As explained above this was computed from yearly area-average values of DMP. Table 1 shows the decadal trend calculated according to the MAES method.

Table 1. Long-term trend and short-term trend of dry matter productivity in the EU. * Statistically significant at 5% according to Mann-Kendall trend test. N.S.: not statistically significant at 5% according to Mann-Kendall trend test. Note: Change is always considered as significant in case the percentage change per decade is higher than or equal to +5 % or lower than or equal to -5 %. This is valid for both short and long-term trends and

regardless statistical testing. A change outside this interval is thus always considered as policy-relevant to report.

	Long-term trend	Short-term trend
% per decade	8.3*	11.1 (N.S.)
Time range	1999-2018	2009-2018
Method	Mann-Kendall	Mann-Kendall

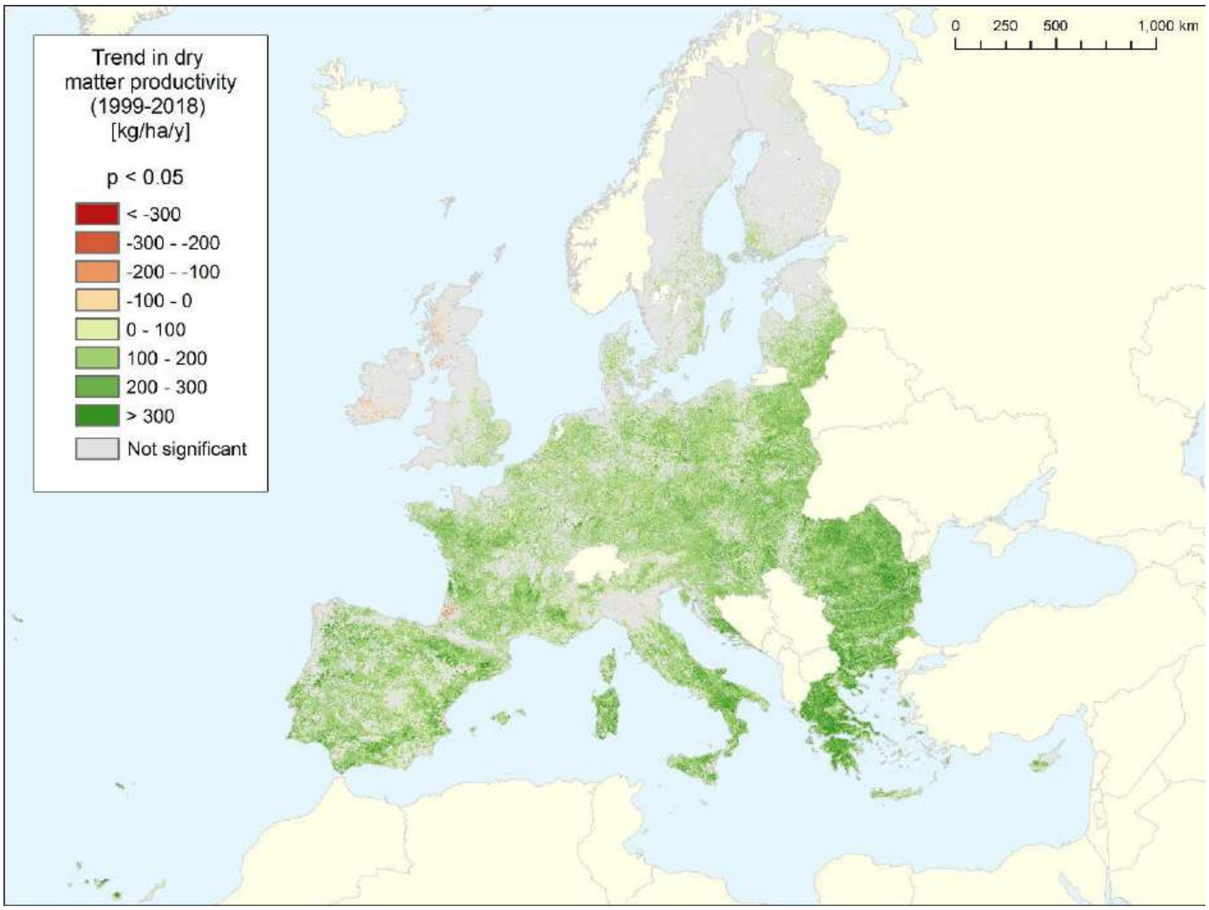

Figure 2. Dry matter productivity (DMP) trends in Kg/ha/year within the EU-28 countries at 0.083 (~1 km) spatial resolution (significant at the 5% level according to the Mann-Kendall test).

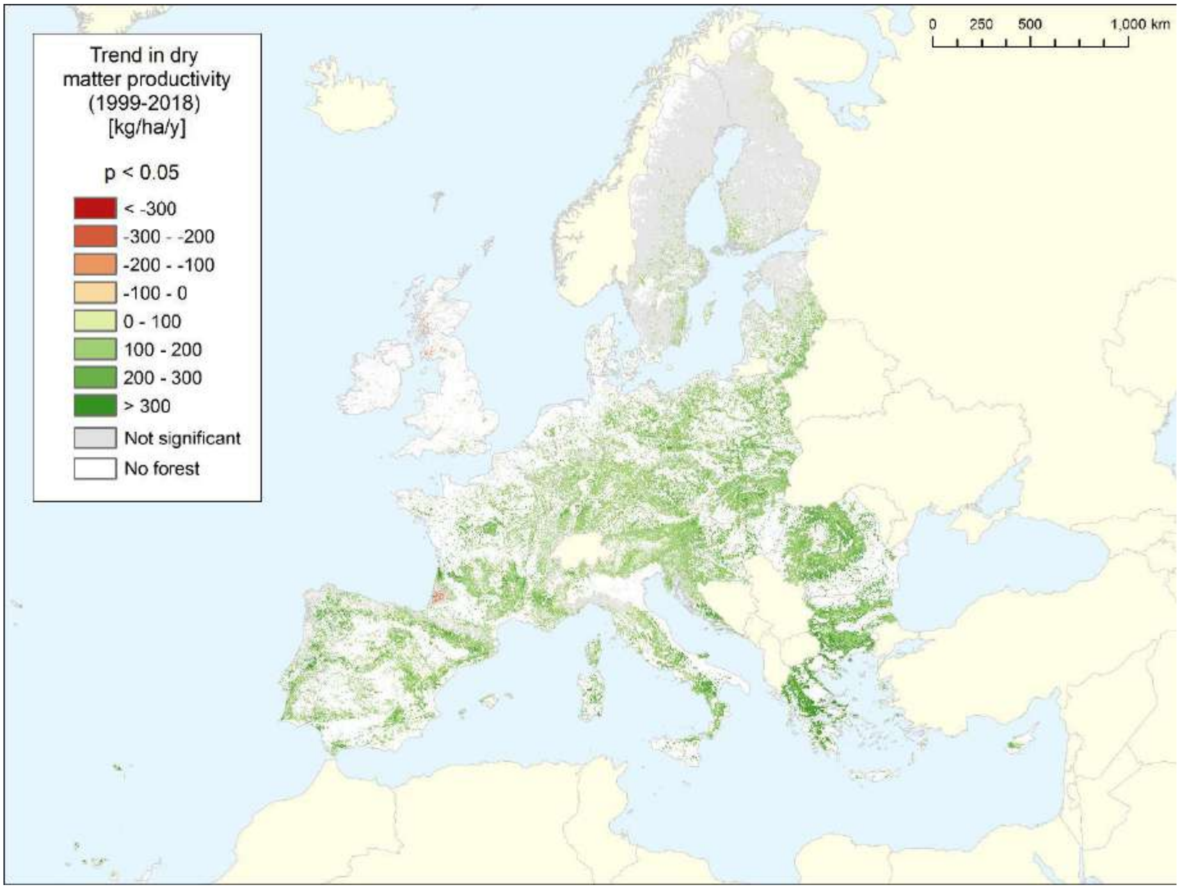

Figure 3. As figure 2 but only for forest and woodland.

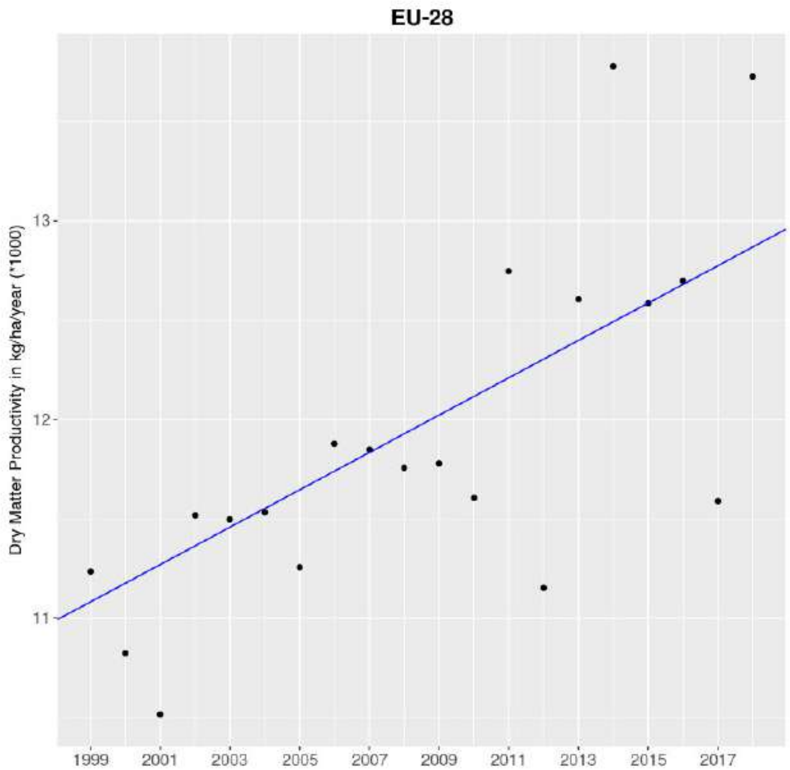

Figure 4. Trends of dry matter productivity (DMP) over forest and woodland for the EU-28 region. The trend is significant at the 5% level according to the Mann-Kendall test.

Biogeographical level

The analysis made at biogeographical level show different values of mean DMP among the biogeographical regions (Figure 5). The highest mean DMP is present in the Macaronesia region reaching DMP values over 20,000 Kg/ha/year, followed by the Black Sea region with DMP just below 18,000 Ka/ha/year. The lowest values are present in the Boreal and Alpine regions with values of 8,700 and ~11,100 Kg/ha/year respectively. The remaining regions present similar values ranging from 14.500 Kg/ha/year in the Steppic region to 16.100 kg/ha/year in the Pannonian region. It is important to mention that the Black Sea, the Alpine and Steppic regions do not fall entirely in the EU-28, therefore their values refer to the EU-28 part. In fact, the Alpine domain does not include Switzerland and Norway, the Steppic region is only represented by a very small region North-West of the Black Sea, and the Black sea region is only represented by a narrow band on the West coast of the Black Sea.

Concerning the trends, the general upward trend observed over the whole Europe (Fig 3) is confirmed at biogeographical region level (Fig. 6). For all the biogeographical regions, the upward trend is statistically significant at 0.05 level according to the Mann Kendal test, except for the Boreal region as shown in Table 2.

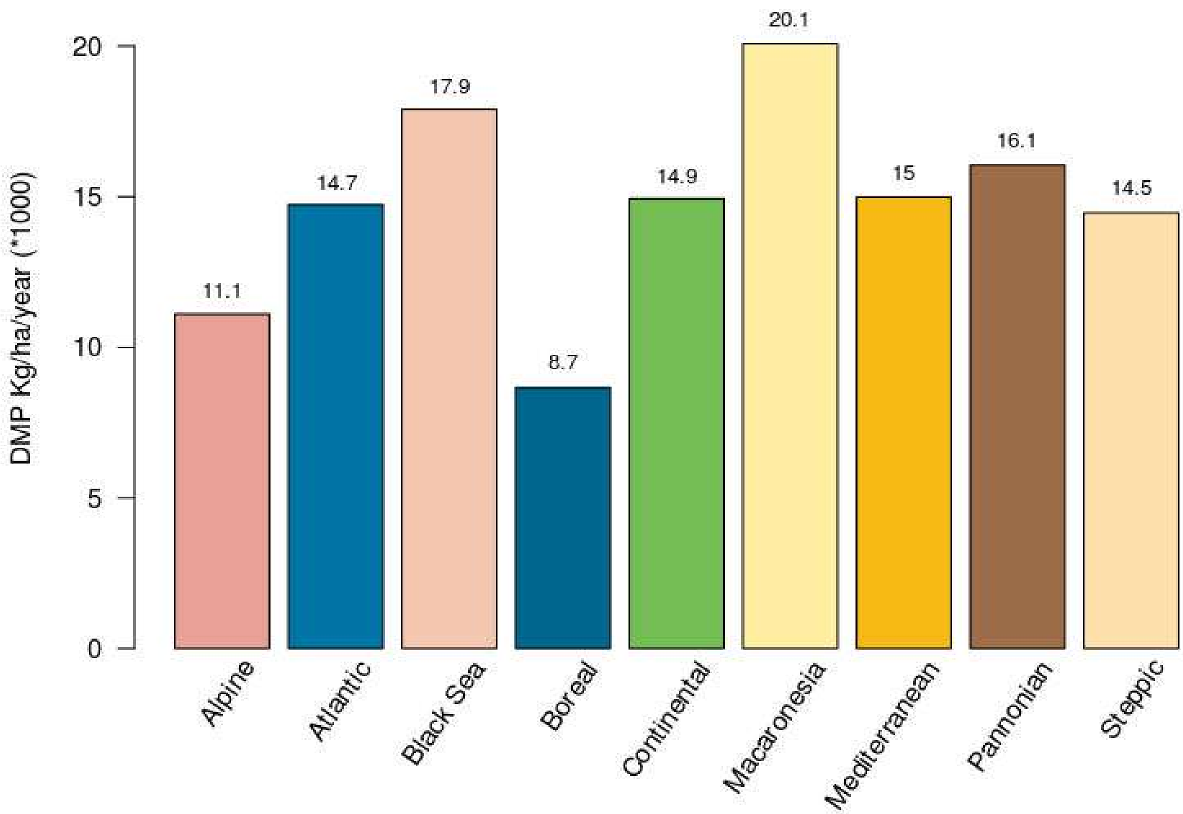

Figure 5. Area-averaged DMP for the period 1999-2018 computed for each biogeographical region within the EU-28 countries.

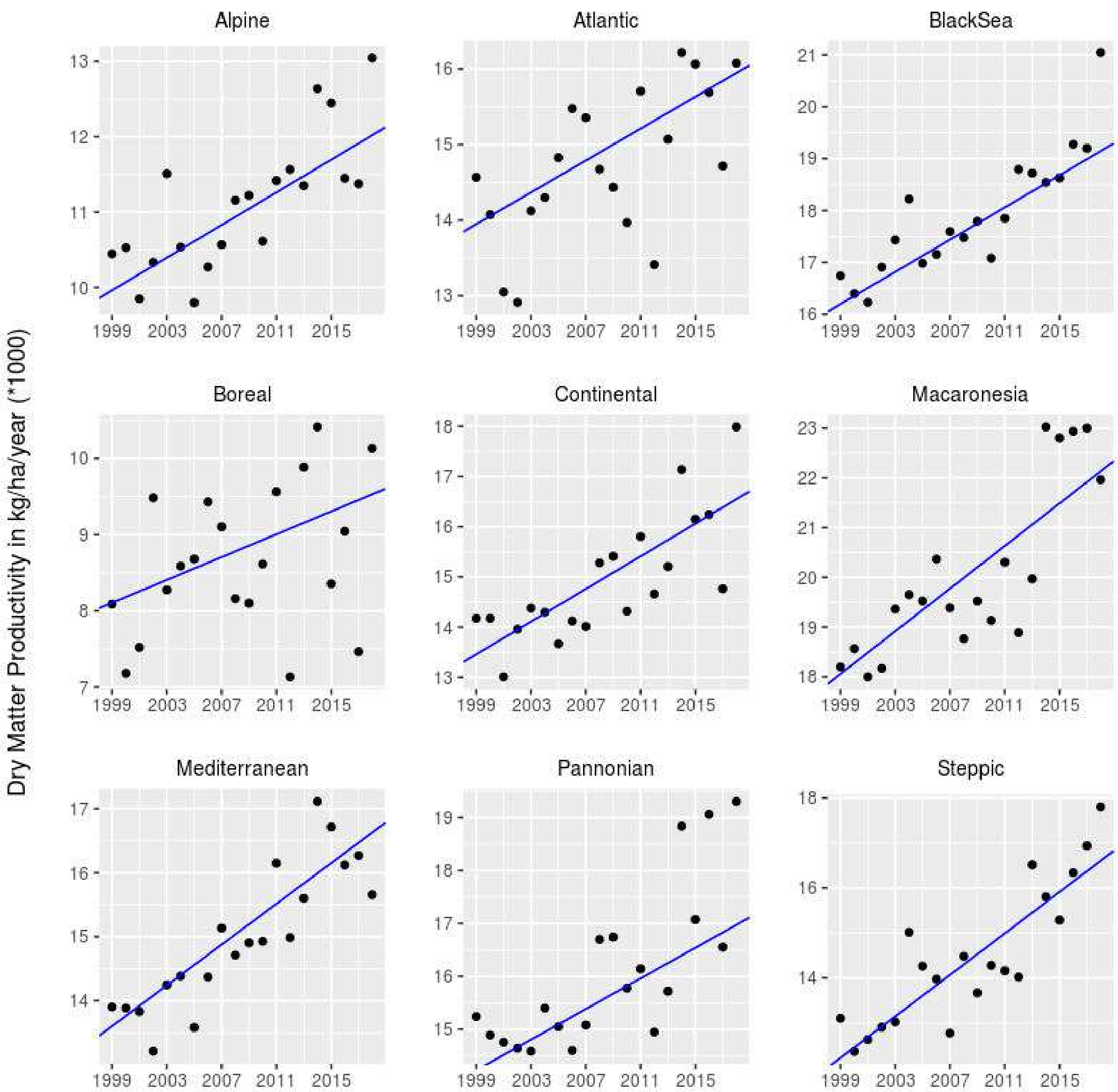

Figure 6. Trends of dry matter productivity (DMP) per biogeographical region. All trends are significant at the 5% level according to the Mann-Kendall test, except in the Boreal region

Table 2. Trends of dry matter productivity (DMP) in biogeographical regions. In bold significant at the 5% level according to the Mann-Kendall test.

Biogeographical region	DMP trend (kg/ha/year)
Alpine	**104.6**
Atlantic	**99.7**
Black Sea	**164.8**
Boreal	72.1
Continental	**147.7**
Macaronesia	**235.7**
Mediterranean	**146.3**
Pannonian	**151.2**
Steppic	**244.0**

Summary

Our analysis reveal an overall upwards trend of DMP in Europe and for all the biogeographical regions. This confirms the continuation of a greening trend observed over Europe in a precedent period (1982-2012) using remote sensing imagery (Rafique et al. 2016, Jong et al. 2011) and ecosystem-based models (Liu et al. 2015). Our findings are in agreement with previous evidence, e.g. with Zhang et al. (2017) that found increasing trends in GPP in a similar period (2000-2016) in Europe, although using data at a coarser spatial resolution of 0.5 degree.

A limited part of the study domain showed significant downward trends of DMP. The downward trend over the Po Valley that occurs in agricultural areas might be related to a shortening of the growing season length observed over this area although for a previous period (1982-2011) (Garonna et al. 2014). However, it is important to note that in this region very few grid cells show a significant decreasing trend. The decreasing trend in DMP in the Landes of Gascony might be related to the loss in forest cover observed over the period from 2000 to 2012 in Hansen et al. (2013).

The significant downward trend over Scotland and Ireland is partly shown in the land productivity maps available in Cherlet et al. (2018). However our maps show a greater extension of the downward trend for this area. For the Iberian Peninsula, our results are in line with the indicator of vegetation response to climate variability shown in the Atlas of desertification (Cherlet et al. 2018: 122). Although, focusing on a slight shorter period, this indicator does not exhibit a significant downward trend of vegetation photosynthetic activity (fAPAR), despite a period with prolonged drought condition. The second lowest values in DMP shown for the Mediterranean region in 2005 (Fig. 6) is concomitant with a drought event occurred in the same year, also confirmed by Ivits et al. (2016). The droughts occurred in the Mediterranean in 2007, 2008 and 2009 haven't resulted in a decreasing DMP because most of the droughts occurred outside of the growing season (Ivits et al. 2016).

The assessment presented in this report provides a first overview of the trends of DMP in the EU. With new data becoming available in the next coming years by the Copernicus Programme, these trends could be extended to longer time-series. Integrated assessments using a suite of indicators, such as changes in biomass, NDVI, soil-moisture indexes or wild fires occurrence are deemed relevant for a comprehensive overview of the condition of ecosystems.

References

Alcaraz-Segura, D.; Chuvieco, E.; Epstein, H.E.; Kasischke, E.S.; Trishchenko, A. Debating the greening vs. browning of the North American boreal forest: Differences between satellite datasets. Global Change Biol. 2009, 16, 760–770.

Browers et al. 2016. Decreasing Net Primary Production in forest and shrub vegetation across southwest Australia

Cherlet, M., Hutchinson, C., Reynolds, J., Hill, J., Sommer, S., von Maltitz, G. (Eds.), World Atlas of Desertification, Publication Office of the European Union, Luxembourg, 2018.

Copernicus (2018) Dry Matter Productivity. https://land.copernicus.eu/global/products/dmp

distribution of biomass. Oikos 1999, 86, 3–15.

Eastman, J. R.; Sangermano, F.; Ghimire, B.; Honglei, Z.; Hao, C.; Neeti, N.; Yongming, C.;

EC 2018, Bioeconomy: The European way to use our natural resources : action plan 2018

EEA (2019). "Biogeographical regions. https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3#tab-figures-produced2019.".

Garonna et al. 2014. Strong contribution of autumn phenology to changes in satellite-derived growing season length estimates across Europe (1982–2011)

Gower, S. T., et al. 2001. "Net primary production and carbon allocation patterns of boreal forest ecosystems." Ecological Applications 11(5): 1395-1411.

Hoaglin, D.C.; Mosteller, F.; Tukey, J.W. Understanding Robust and Exploratory Data Analysis; Wiley: New York, NY, USA, 2000; Volume 3.

Ivits et al. 2013. Addressing the complexity in non-linear evolution of vegetation phenological change with time-series of remote sensing images

Jong et al. 2011. Trend changes in global greening and browning: contribution of short-term trends to longer-term change

Jong et al. 2013. Shifts in Global Vegetation Activity Trends

Kendall, M. G. (1975). Rank Correlation Methods (4th edition). London: Charles Griffin.

Lausch, A., Erasmi, S., King, D., Magdon, P., & Heurich, M. (2016). Understanding Forest Health with Remote Sensing -Part I—A Review of Spectral Traits, Processes and Remote-Sensing Characteristics. Remote Sensing, 8 (12), 1029+

Liu et al. 2015. Spatial and Temporal Patterns of Global NDVI Trends: Correlations with Climate and Human Factors

Machado, E.A.; Crema, S.C. Seasonal trend analysis of image time series. Int. J. Remote Sens. 2009, 115, 692–702.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3), 245-259, doi:10.2307/1907187.

Neumann et al. 2016. Creating a Regional MODIS Satellite-Driven Net Primary Production Dataset for European Forests

Polis, G.A. Why are parts of the world green? Multiple factors control productivity and the

Pope & Traitz 2013. Leaf Area Index (LAI) Estimation in Boreal Mixedwood Forest of Ontario, Canada Using Light Detection and Ranging (LiDAR) and WorldView-2 Imagery

Rafique et al. 2016. Global and Regional Variability and Change in Terrestrial Ecosystems Net Primary Production and NDVI: A Model-Data Comparison

Sen 1968. Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324), 1379-1389, doi:10.2307/2285891.

Wilcox, R. R. (2012). Introduction to Robust Estimation and Hypothesis Testing. San Diego, California, USA: Academic Press.

Zhang et al 2017. A global moderate resolution dataset of gross primary production of vegetation for 2000–2016.

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Fact sheet 3.3.209: Evapotranspiration

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class (See table 1): Ecosystem condition, Functional ecosystem attributes
- Name of the indicator: Evapotranspiration
- Units: mm

2. Data sources:

The indicator is based on existing reference data:

- Data holder: GLEAM dataset (Global Land Evaporation Amsterdam Model), Vrije Universiteit Amsterdam, Ghent University, ESA.
- Weblink: https://www.gleam.eu/
- Year or time-series range: 1980-2017
- Version: v3.2a
- Access date: 22/01/2019
- Reference: Martens, B., Miralles, D. G., Lievens, H., van der Schalie, R., de Jeu, R. A. M., Fernández-Prieto, D., et al. (2017). GLEAM v3: satellite-based land evaporation and root-zone soil moisture. Geoscientific Model Development, 10(5), 1903-1925, doi:10.5194/gmd-10-1903-2017.

3. Assessment of the indicator

Definition

The focus of this assessment is to examine significant changes in Evapotranspiration (ET) in Europe. ET is the process by which liquid water pass to water vapour driven energetically by incoming solar radiation (Zhang et al. 2016). It is considered to be one of the most significant processes of the hydrological cycle as it returns about 60% of global land surface precipitation and consumes more than half of absorbed solar radiation (Trenberth et al. 2009). Therefore, terrestrial ET is a fundamental component of the energy and water cycles with important implications for ecosystem services such as fresh water availability and micro and regional climate regulation (Goulden and Bales 2014; Pan et al. 2015; Seneviratne et al. 2006).

Changes in terrestrial ET are expected to impact land surface temperature, having implications on regional and global warming (Wang and Dickinson 2012). Additionally, ET is a driver of air humidity, cloud formation and precipitation (Miralles et al. 2012; Seneviratne et al. 2010; Taylor et al. 2012). Plants take up water from ground and transpire it back to the atmosphere, therefore affecting ground water supply and influencing regional precipitation (Jung et al. 2010). Empirical evidence indicates that around 74% of the terrestrial ET comes from plant transpiration. Bare soil evaporation contributes with 15% and plant rainfall interception loss 11% (Martens et al. 2017) (not considering ET from inland waters).

Climate change is expected to intensify the hydrological water cycle (Huntington 2006), and hence to alter ET with implications for ecosystem condition and services and complex feedbacks to regional and global climate.

Drivers of ET

Climate, atmospheric CO_2 concentration, and functional, structural and compositional traits of vegetation affect terrestrial ET. Climate factors that drive ET include wind speed, temperature, precipitation and solar radiation. Elevated atmospheric CO_2 is another factor influencing ET (Allen 1991). Evidence in literature suggests that elevated atmospheric CO_2 concentrations stimulates plant growth, thus increasing the area of transpiring leaves, which enhances ET. Nevertheless, a consensus is yet to be reached concerning this point (Pan et al. 2015).

Land surface properties, specifically vegetation cover in natural, semi-natural and agricultural ecosystems, influence the partitioning of radiative energy (Taylor et al. 2012) affecting ET rates. For instance, forest density or forest species composition are factors affecting ET. Plantation forest and the extensive use of exotic forest species can affects evapotranspiration regimes, with negative implications on water availability (Trabucco et al. 2008). The effects of changes in land cover, such as grasslands to forest or vice versa, are considerable in ET rates (Martens et al. 2017; Sterling et al. 2012).

Data and methods

We computed layers of annual ET (mm/y). Thus, one layer was created for each year of the time series between 1980 and 2017 using daily (mm/day) data from GLEAM v3.2a (Martens et al. 2017; Miralles et al. 2011). The GLEAM model uses a set of algorithms driven by remote-sensing observations for estimating all the components of ET at 0.25° spatial resolution globally. The Priestley and Taylor equation used in GLEAM calculates ET based on satellite-observed soil moisture, vegetation optical depth and snow-water equivalent, reanalysis air temperature and radiation, a multi-source precipitation product, and land cover and soil properties. The ET dataset is validated against measurements from 91 eddy-covariance towers and 2325 soil moisture sensors across a broad range of ecosystems (Martens et al. 2017).

3.1 Statistical analysis of the trend

The layers of annual ET were used for detecting spatial trends on each grid cell. We used robust regression to mitigate the effect of anomalous years. Regression slopes were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012) because it accommodates non-normal distributions and is a robust trend slope estimator resistant to the effects of outliers. Additionally, a two-sided Mann-Kendall (Gilbert 1987; Kendall 1975; Mann 1945) non-parametric trend test was used to assess the significance of monotonic trends in ET. The same test was conducted for computing the EU level trend.

3.2 Trends and maps

The assessment of annual ET computed in the domain covered by the EU-28 indicates a significant ($P < 0.01$) upward trend of 0.8 mm/y (Figure 1). Table 1 shows the decadal trend calculated according to the MAES method. However, a more detailed view is shown in the map of Figure 2, where areas with significant upward and downward trends are exhibited, in addition to areas with no significant trends.

Upward trends are present in around 1.9 million square kilometres. Most of the areas exhibiting increased ET are in the range 0 to 20 mm/decade, followed by areas with increases between 20 to 60 mm/decade, and some marginal areas exhibiting an increase greater than 60 mm/decade. Downward trends are less prominent and cover an area of around 9,500 km^2. These results are coherent with previous studies (e.g. Zhang et al. 2019; Zhang et al. 2016) where increases of similar magnitude were reported in Europe.

Table 1. Long-term trend and short-term trend of evapotranspiration in the EU. * Significant at 5% according to Mann-Kendall trend test. N.S.: not significant at 5% according to Mann-Kendall trend test.

	Long-term trend	**Short-term trend**
% per decade	1.69 *	-2.04 (N.S.)
Time range	1980-2017	2008-2017
Method	Mann-Kendall	Mann-Kendall

A significant positive trend of ET is evident in 42% of the EU domain (Table 2). Five biogeographical regions exhibit an upward trend in 40% or more of their extent, these are the Steppic (86%), Black Sea (73%), Continental (58%), Alpine (51%) and Atlantic (40%) regions. It is also remarkable an upward trend in 29% of the Mediterranean region, a region where water deficit is common during the warmest months. The proportion of area with significant downward trends of ET is limited, 0.2% of the EU, and is concentrated in four regions, i.e. Alpine, Atlantic, Continental and Mediterranean.

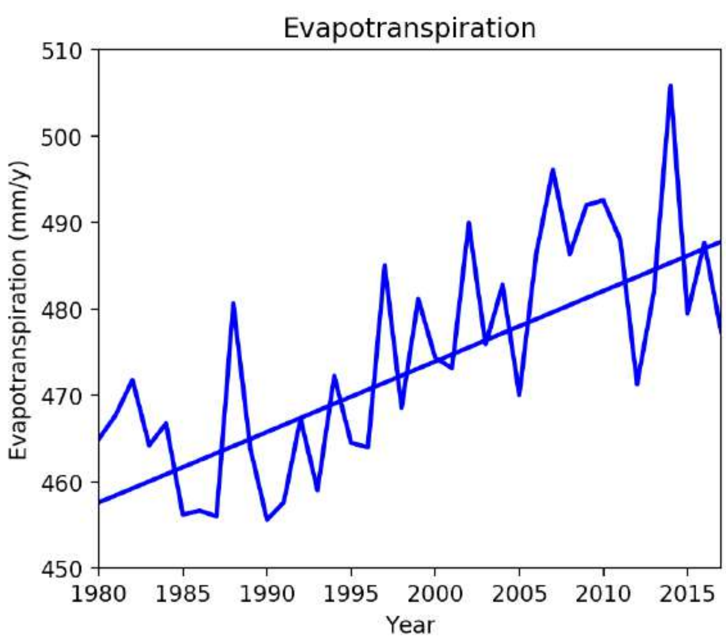

Figure 1. Trend of annual evapotranspiration 1980-2017 in the EU-28. Trend line computed using the Theil–Sen non-parametric estimator. Increasing trend (0.8 mm/y) significant at 5% according to Mann-Kendall trend test.

Table 2. Percentage area of significant changes in evapotranspiration (ET) in European biogeographical regions (EEA 2002, 2019) within the EU-28 countries. Note that the areas were computed using a 1-km grid size map.

Biogeographical region	Total area (Km^2)	Area of significant downward trend in ET (%)	Area of significant upward trend in ET (%)
Alpine	379,142	< 1	51
Atlantic	802,912	< 1	40
Black Sea	11,942	-	73
Boreal	858,430	-	36
Continental	1,292,677	1	58
Macaronesia	12,001	-	27
Mediterranean	923,170	< 1	25
Pannonian	126,158	-	26
Steppic	37,112	-	86
Total	**4,443,544**	**0.2**	**42**

Attributing the drivers behind the upward or downward trend in ET are beyond the scope of this assessment. However, positive trends in ET are consistent with an accelerated hydrological cycle (Huntington 2006) caused by an increased evaporative demand associated with rising radiate forcing and temperature (Jung et al. 2010). Significant increases in mean annual temperature in the period 1960-2017 are widespread in Europe. In fact, the mean annual temperature for the last decade (2008-2017) in Europe was around 1.7 °C above preindustrial levels (EEA 2018). Nevertheless, ET is also sensible to other environmental drivers. Long-term significant increases of ET have been attributed to vegetation change, specifically increases in leaf area index (LAI). Which in turn are associated to CO_2 fertilisation, global warming, increased cropland productivity, afforestation and reforestation (Goulden and Bales 2014; Trabucco et al. 2008; Zhang et al. 2016).

The upward ET trends shown in Figure 2 mostly affecting zones within the temperate humid climate is consistent with a lengthening of the growing season (Huntington 2006). In these zones, the period for active transpiration is longer and warmer provided moisture is not limited.

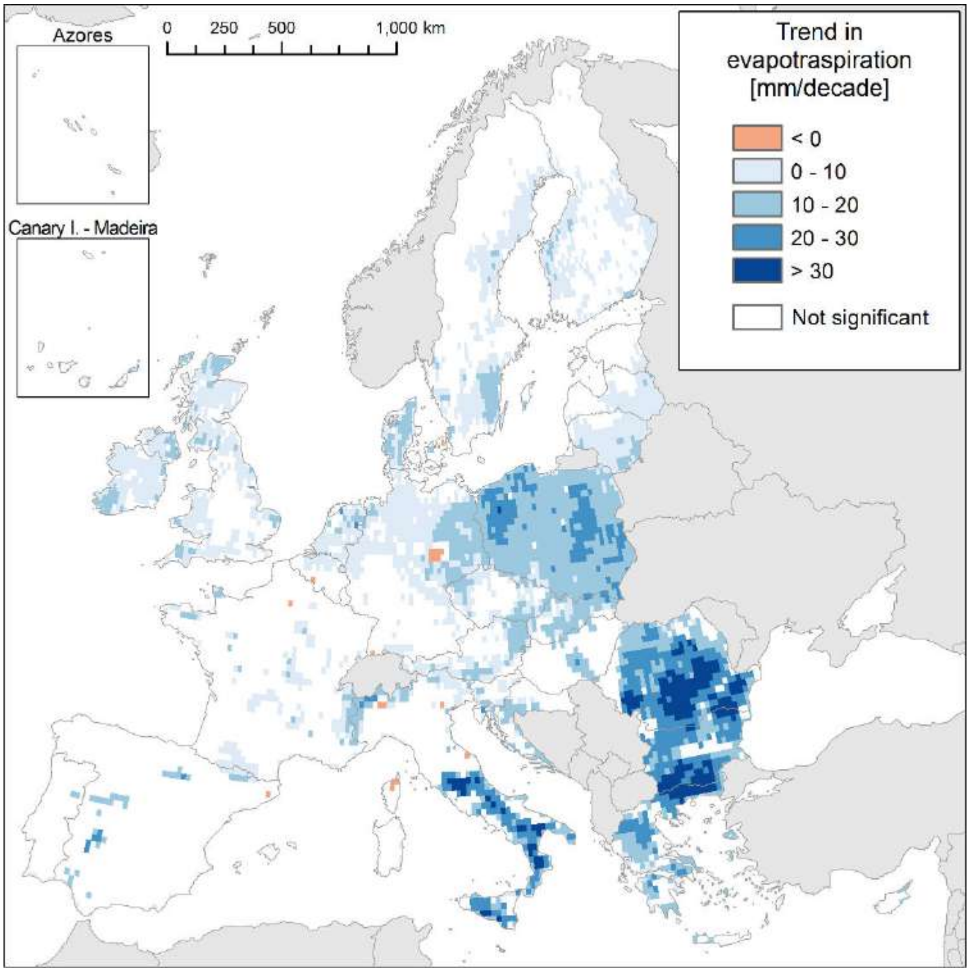

Figure 2. Trends in annual evapotranspiration 1980-2017 (significant at the 5% level according to the Mann-Kendall test). Light grey: outside area of interest.

Discussion – Implications of changes in ET

River flow is a function of precipitation minus ET, therefore an increase of ET as result of e.g. increased temperature or changes in vegetation traits, is consistent with reduced river flow (Goulden and Bales 2014). The relation precipitation minus ET is generally positive or close to zero because ET cannot exceed precipitation over long periods averaged at basin level (Byrne and O'Gorman 2015). Likewise, changes in land cover resulting from afforestation and/or reforestation can result in an in-site increase of ET and a decreased off-site (downstream) water availability. However, whether this is positive or negative for water resources, soil and land conservation and/or biodiversity is highly site specific, and dependent upon local environmental traits (Trabucco et al. 2008).

Downward trends in ET could be associated with several drivers that may act individually or concomitantly. For instance, deforestation, land cover change, changes in plant phenology or vegetation degradation affects ET rates (Sterling et al. 2012; Zhang et al. 2016). Similarly, climatic drivers could also reduce ET rates in the long term, for instance in case of reduced moisture supply.

Although the drivers of the significant changes in ET in Europe have yet to be elucidated, ET is a sensitive bioindicator of ecosystem function and services due to the consistent relationship between ecosystem change (temperature, plant traits, land cover), ET and water supply (Goulden and Bales 2014).

In summary, at the level of whole ecosystems ET is limited by moisture input (Jung et al. 2010), when moisture deficit (more output that input) is continued over long periods, changes in vegetation due to moisture stress would have subsequent effects in ecosystem functions and services, including water supply.

References

Allen, L. (1991). Effects of increasing carbon dioxide levels and climate change on plant growth, evapotranspiration, and water resources. In National Research Council (Ed.), Managing Water Resources in the West Under Conditions of Climate Uncertainty (pp. 101–147). Washington, DC: The National Academies Press.

Byrne, M. P., & O'Gorman, P. A. (2015). The Response of Precipitation Minus Evapotranspiration to Climate Warming: Why the "Wet-Get-Wetter, Dry-Get-Drier" Scaling Does Not Hold over Land. Journal of Climate, 28(20), 8078-8092, doi:10.1175/jcli-d-15-0369.1.

EEA (2002). Europe's biodiversity – biogeographical regions and seas. Luxembourg: European Environment Agency.

EEA (2018). Global and European temperature. Accessed 12 Febrary 2019.

EEA (2019). Biogeographical regions. https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3#tab-figures-produced2019.

Gilbert, R. O. (1987). Statistical Methods for Environmental Pollution Monitoring. NY, USA: Wiley.

Goulden, M. L., & Bales, R. C. (2014). Mountain runoff vulnerability to increased evapotranspiration with vegetation expansion. Proceedings of the National Academy of Sciences of the United States of America, 111(39), 14071-14075, doi:10.1073/pnas.1319316111.

Huntington, T. G. (2006). Evidence for intensification of the global water cycle: Review and synthesis. Journal of Hydrology, 319(1), 83-95, doi:doi.org/10.1016/j.jhydrol.2005.07.003.

Jung, M., Reichstein, M., Ciais, P., Seneviratne, S. I., Sheffield, J., Goulden, M. L., et al. (2010). Recent decline in the global land evapotranspiration trend due to limited moisture supply. Nature, 467, 951, doi:10.1038/nature09396.

Kendall, M. G. (1975). Rank Correlation Methods (4th edition). London: Charles Griffin.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3), 245-259, doi:10.2307/1907187.

Martens, B., Miralles, D. G., Lievens, H., van der Schalie, R., de Jeu, R. A. M., Fernández-Prieto, D., et al. (2017). GLEAM v3: satellite-based land evaporation and root-zone soil moisture. Geoscientific Model Development, 10(5), 1903-1925, doi:10.5194/gmd-10-1903-2017.

Miralles, D. G., Holmes, T. R. H., De Jeu, R. A. M., Gash, J. H., Meesters, A. G. C. A., & Dolman, A. J. (2011). Global land-surface evaporation estimated from satellite-based observations. Hydrology and Earth System Sciences, 15(2), 453-469, doi:10.5194/hess-15-453-2011.

Miralles, D. G., van den Berg, M. J., Teuling, A. J., & de Jeu, R. A. M. (2012). Soil moisture-temperature coupling: A multiscale observational analysis. Geophysical Research Letters, 39(21), doi:doi:10.1029/2012GL053703.

Pan, S., Tian, H., Dangal, S. R. S., Yang, Q., Yang, J., Lu, C., et al. (2015). Responses of global terrestrial evapotranspiration to climate change and increasing atmospheric CO2 in the 21st century. Earth's Future, 3(1), 15-35, doi:10.1002/2014EF000263.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324), 1379-1389, doi:10.2307/2285891.

Seneviratne, S. I., Corti, T., Davin, E. L., Hirschi, M., Jaeger, E. B., Lehner, I., et al. (2010). Investigating soil moisture–climate interactions in a changing climate: A review. Earth-Science Reviews, 99(3), 125-161, doi:10.1016/j.earscirev.2010.02.004.

Seneviratne, S. I., Lüthi, D., Litschi, M., & Schär, C. (2006). Land–atmosphere coupling and climate change in Europe. Nature, 443, 205, doi:10.1038/nature05095.

Sterling, S. M., Ducharne, A., & Polcher, J. (2012). The impact of global land-cover change on the terrestrial water cycle. Nature Climate Change, 3, 385, doi:10.1038/nclimate1690.

Taylor, C. M., de Jeu, R. A. M., Guichard, F., Harris, P. P., & Dorigo, W. A. (2012). Afternoon rain more likely over drier soils. Nature, 489, 423, doi:10.1038/nature11377.

Trabucco, A., Zomer, R. J., Bossio, D. A., van Straaten, O., & Verchot, L. V. (2008). Climate change mitigation through afforestation/reforestation: A global analysis of hydrologic impacts with four case studies. Agriculture, Ecosystems & Environment, 126(1), 81-97, doi:10.1016/j.agee.2008.01.015.

Trenberth, K. E., Fasullo, J. T., & Kiehl, J. (2009). Earth's Global Energy Budget. Bulletin of the American Meteorological Society, 90(3), 311-324, doi:10.1175/2008bams2634.1.

Wang, K., & Dickinson, R. E. (2012). A review of global terrestrial evapotranspiration: Observation, modeling, climatology, and climatic variability. Reviews of Geophysics, 50(2), doi:doi:10.1029/2011RG000373.

Wilcox, R. R. (2012). Introduction to Robust Estimation and Hypothesis Testing. San Diego, California, USA: Academic Press.

Zhang, Y., Kong, D., Gan, R., Chiew, F. H. S., McVicar, T. R., Zhang, Q., et al. (2019). Coupled estimation of 500 m and 8-day resolution global evapotranspiration and gross primary production in 2002–2017. Remote Sensing of Environment, 222, 165-182, doi:10.1016/j.rse.2018.12.031.

Zhang, Y., Peña-Arancibia, J. L., McVicar, T. R., Chiew, F. H. S., Vaze, J., Liu, C., et al. (2016). Multi-decadal trends in global terrestrial evapotranspiration and its components. [Article]. Scientific Reports, 6, 19124, doi:10.1038/srep19124.

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Fact sheet 3.3.210: Land Productivity Dynamics – Normalized Difference Vegetation Index (NDVI)

1. General information

- Thematic ecosystem assessment: Forest condition
- Indicator class: Ecosystem condition, Functional ecosystem attributes
- Name of the indicator: Land Productivity Dynamics – Normalized Difference Vegetation Index (NDVI)
- Units: unite less (index)

2. Data sources

The indicator is based on existing data:

- Data holder: JRC World Atlas Of Desertification, Third edition (WAD-3)
- Year or time-series range: 1999-2013
- Reference: Cherlet, M. et al. (2018). World Atlas of Desertification. Luxembourg, Publication Office of the European Union. Ivits, E. and Cherlet, M. (2013). Land-Productivity Dynamics Towards integrated assessment of land degradation at global scales, EUR 26052, Luxembourg: Publications Office of the European Union.

Land productivity dynamics (LPD) changes for the period 1999-2013 were computed from phenological metrics, such as growing season productivity, derived from time series of the Copernicus Global Land SPOT VGT products of normalised difference vegetation index (Copernicus-NDVI 2018), composited in 10-day intervals at a spatial resolution of 1 km. An exhaustive description of the methodology is found in Ivits and Cherlet (2013) and Cherlet et al. (2018).

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The LPD indicator aims at providing the status of Earth's vegetative cover and its development over time. In general terms it refers to the amount of carbon fixed by plants through the process of photosynthesis.

The global monitoring of land productivity typically relies on the multi-temporal and thematic evaluation of long-term time series of remotely-sensed vegetation indices such as NDVI of fAPAR, computed from continuous spectral measurements of photosynthetic activity. These data are highly correlated with photosynthetic capacity and primary production, which in turn are related to processes of land degradation and recovery (Sommer et al., 2017).

LPD also reflects the overall capacity of land to support biodiversity and provide ecosystem services. A persistent decline in land productivity points to the long-term alteration in the health and productive capacity of the land, the basis for economic growth and sustainable livelihoods (Sommer et al. 2017).

The LPD is one of the key-indicators used to assess land degradation. It has been used in the World Atlas of Desertification (WAD-3, Cherlet et al., 2018), in the United Nations Convention to Combat Desertification

(Sommer et al., 2017) and it is proposed as a global indicator to monitor progress towards achieving Sustainable Development Goal (SDG) (UNCCD, 2015).

3.2. Maps

Maps for single years were not available for this indicator. Therefore, trends and statistical tests were not implemented.

3.3. Key trend at EU level

Changes in LPD were assessed for the period 1999-2013 by integrating information on the direction, intensity and persistence of trends and changes in NDVI. In total 5 qualitative classes of persistent land productivity trajectories where estimated (declining, moderate decline, stressed, stable, increasing). Figure 1 shows upward trends in LPD for most of the EU-28 region. Downward trends are evident in a few marginal zones of Southern Iberia, the Po Valley, Apulia, Western Sicily, Southern Greece including Crete, Hungary, South-East Romania and parts of Scotland. However, it is worth noticing that most of the downward trend is confined to agricultural land or managed grasslands as evidenced in Figure 2, where the LPD trends are presented only for forest and woodland. In forest and woodland, the downward trend is mainly located in a few scattered zones of Southern Iberia, the Landes of Gascony, Scotland and the Southern tip of Sweden.

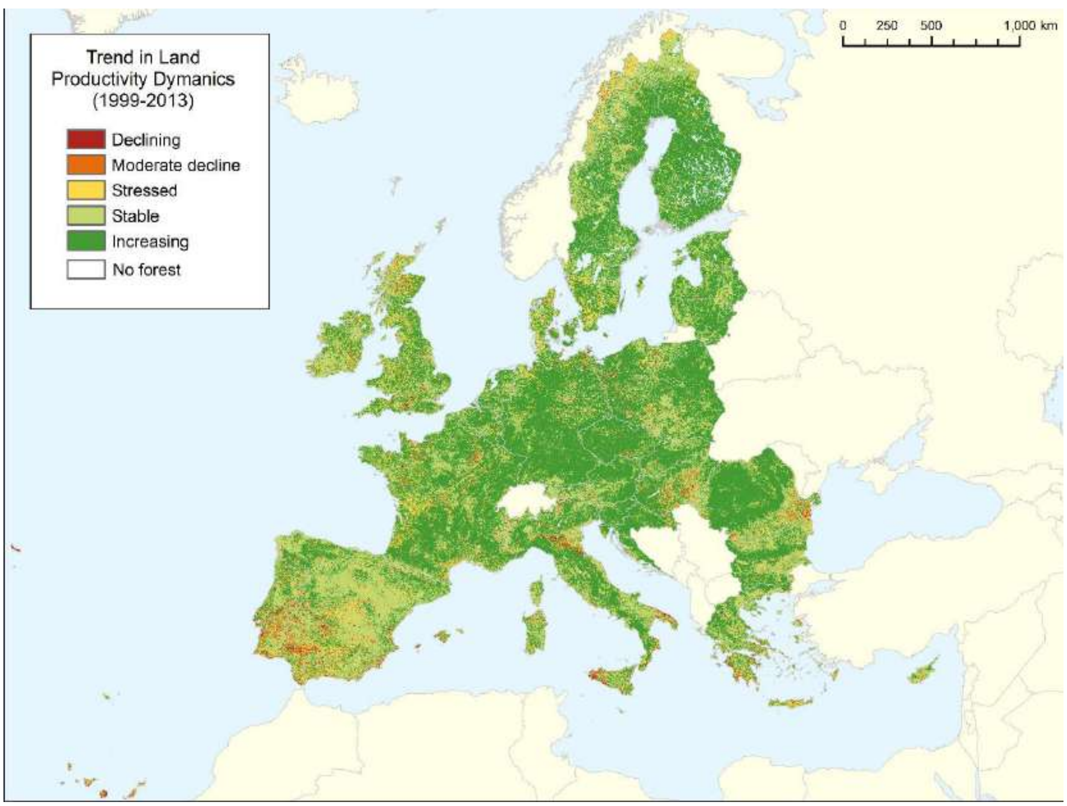

Figure 1. Changes in land productivity dynamics (LPD) for the period 1999-2013 within the EU-28 domain.

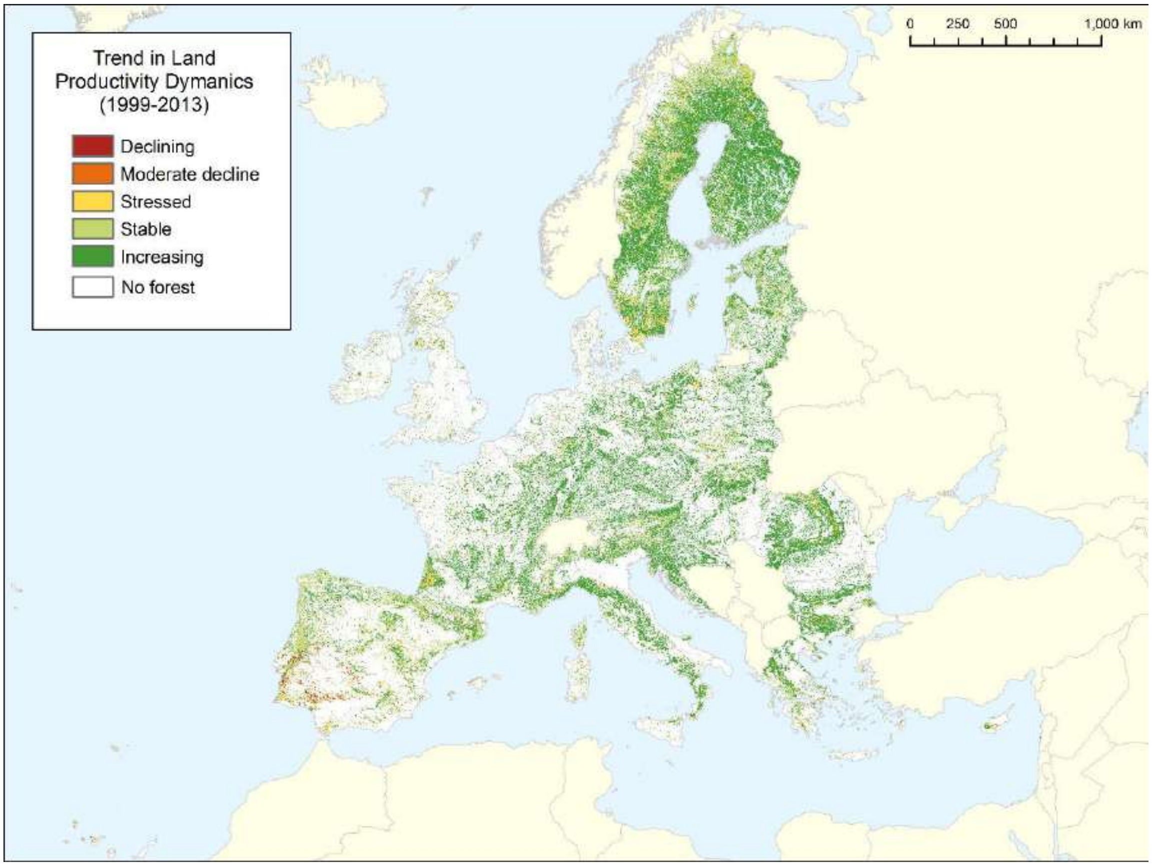

Figure 2. As Figure 1 but only for forest and woodland.

In most of the EU domain an upward or stable trend of LPD is observed (Figure 3). In the whole EU domain only around 2% of the area shows a downward trend. In the forest and woodland domain LPD show an upward trend or is stable in 68% and 28% of the area respectively. Only less than 5% of the domain falls within the categories stressed or declining. In summary, in both the whole EU-28 domain and in the forest and woodland domain there is a clear upward trend of LPD in the period 1999-2013.

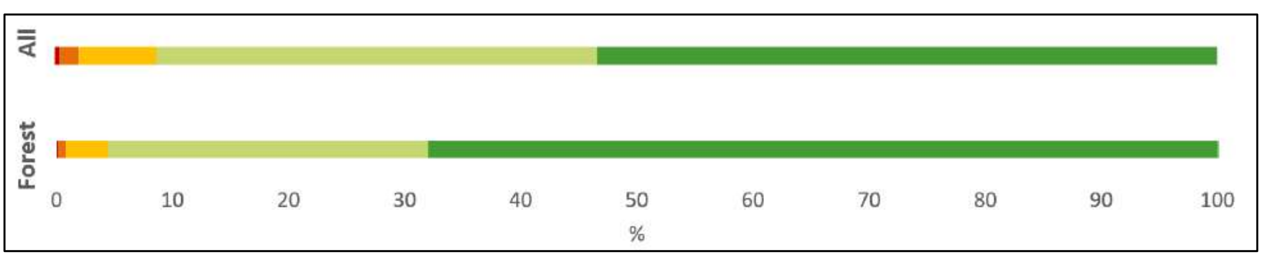

Figure 3. Percentage area changes in land productivity dynamics (LPD) for the period 1999-2013. Upper panel: the changes in the whole EU-28 domain, lower panel: changes in forest and woodland. The colour code is the same as in Figure 1 and Figure 2.

References

Cherlet, M. et al. (2018). World Atlas of Desertification. Luxembourg, Publication Office of the European Union.

Copernicus-NDVI (2018). Normalized Difference Vegetation Index. https://land.copernicus.eu/global/products/ndvi

Sommer S. et al. (2017). Mapping Land Productivity Dynamics: detecting critical trajectories of global land transformations. United Nations Convention to Combat Desertification. The Global Land Outlook, first edition. Bonn. 321–333.

UNCCD (2015). Report of the Conference of the Parties on its twelfth session, held in Ankara from 12 to 23 October 2015.

Ivits, E. and Cherlet, M. (2013). Land-Productivity Dynamics Towards integrated assessment of land degradation at global scales, EUR 26052, Luxembourg: Publications Office of the European Union.

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Fact sheet 3.4.101: Change of area due conversion (wetlands)

1. General information

- Thematic ecosystem assessment: Inland marshes and peatbogs
- Indicator class: Habitat conversion and degradation (Land conversion)
- Name of the indicator: Change of area due to conversion
- Units: %/6 years

2. Data sources

The indicator based on readily available data.

- Data holder: EEA
- Weblink: https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics
- Year or time-series range: 2000-2018
- Version: Corine Land Cover version 20 accounting layers
- 19/09/2019
- Reference: https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

"Land accounts describe, in a consistent and systematic way, the amount of land stock and its changes over time"[34]: This indicator assessed for different years aims to help monitoring the trends of inland marshes and peatbogs habitat conversion in time.

Wetlands, although constituting only 2% of the EU-28 land area, are considered an ecosystem of key-importance due to its unique ecological and hydrological features.

Europe has historically suffered the greatest losses in mires having suffered great declines since 1900. Approximately two thirds of European wetlands were lost before the 1990s[35] and peat formation has stopped in about 60% of the original mire area and possibly 10-20% is not even peatland anymore (Joosten, 1997). Transformational changes in their use and cover has transformed these areas from wetlands to wastelands, reverting in many cases their condition from carbon sink to carbon emitter.

3.2. Maps

No map is available for this indicator.

3.3. Statistical analysis of the trend

Both short-term and long-term trends are computed for this indicator.

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[34] https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

[35] https://www.eea.europa.eu/data-and-maps/indicators/ecosystem-coverage-3/assessment

The significance of the trends is assessed based on the 5% change per decade rule.

3.4. Key trend at EU level

The ecosystem extent (km^2) for the years covered by the CLC product are shown in Table 1. From these time-series, the indicator values are derived and shown in Table 2.

Table 1: Inland marshes and peatbogs ecosystem extent for the period 2000-2018

MAES ecosystem types area (km^2)	*2000*	*2006*	*2012*	*2018*
Inland wetlands	98,452	97,999	98,106	98,003

Table 2: Change of area due to conversion (%/6 years) for the three time periods for which CLC data are available

Indicator	*2000-2006*	*2006-2012*	*2012-2018*
%/6 years	-0.46	0.11	-0.11

As visible from Figure 1, there is a negative change (loss of habitat) in the first and, to a lesser extent, in the last time frames while a positive change (habitat gain) appears in the central part of the series. All of these changes are anyways very small being less than ±0.5%/6 years.

It is interesting to note how the change in extent from 2000 to 2018 (resulting in a loss of 0.46% of inland marshes and peatbogs) could also be put in relationship to the conservation and restoration efforts going on across Europe: the loss of habitat is mainly happening in the first reporting period (2000-2006) while it seems to have levelled off for the first time between 2006 and 2012 and, for the following years, almost no change is reported.

The short-term trend (2006-2012 to 2012-2018) of the indicator for EU-28 is computed as the percentage change per decade and equals to -0,36 %; based on the 5% change per decade rule, the ecosystem condition as described by this indicator can be considered as *stable*.

The *long-term* trend of the indicator for EU-28 is computed between the time periods 2000-2006 and 2012-2018. The percentage change per decade is positive in this case (0.3) but, based on the 5% change per decade rule, the ecosystem condition is also considered as *stable*.

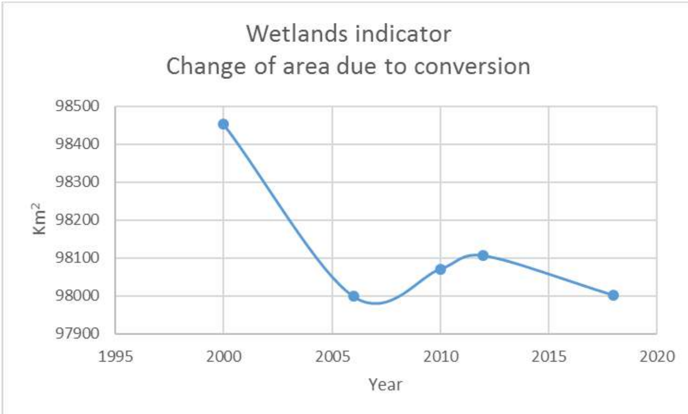

Figure 1: Inland marshes and peatbogs ecosystem extent change over time

The change of areas reported in the period 2000-2018 is, for more than 70% of the area, due to conversion of wetland areas to agricultural and forest and semi-natural areas (Figure 2).

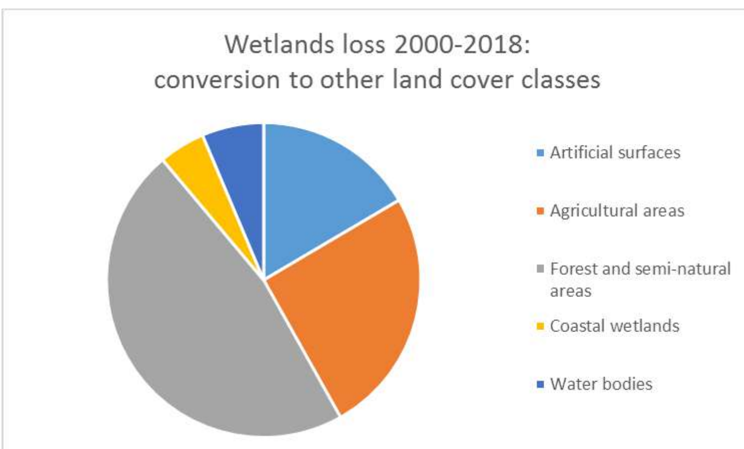

Figure 2: Conversion of inland marshes and peatbogs to other land cover classes between 2000 and 2018

The MAES wetland class is made up of peat bogs and inland marshes: the extension of peat bogs covers about 89% of the entire class (Table 2).

Table 3: Habitat extent of inland marshes and peat bogs for the period 2000-2018

Wetland class	*2000*	*2006*	*2012*	*2018*
Inland marshes	10,593	10,611	10,704	10,641
Peatbogs	87,859	87,388	87,403	87,362

Figure 3 shows that the change produced between 2000 and 2018 has opposite directions for the two components. While Inland marshes have increased their extent by ~0.5%, peat bogs extent has decreased of the same percentage. Nevertheless, the overall balance is still a loss due to the bigger extent of the peatbogs component.

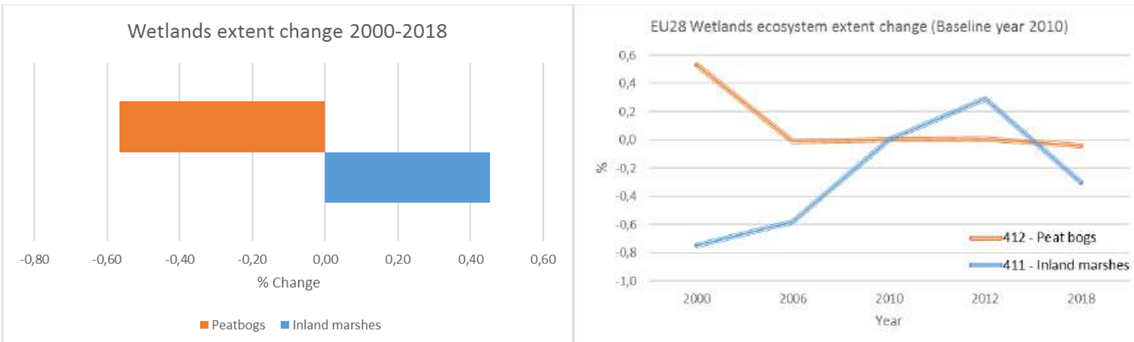

Figure 3: Percentage extent change of the two wetland classes between 2000 and 2018

3.5 Key trends observed at regional level

The change in extent from 2000 to 2018 has also been analyzed at the level of European biogeographical regions. The only region for which an increase in terms of extent has been reported is the Continental one while the regions with the highest decreases in this period are the Black Sea and the Mediterranean ones.

In the case of the Mediterranean, the trend is also depicted in the Mediterranean Wetlands Outlook 2 report (MWO2 report, 2018), that indicates a decrease of natural-wetlands area and a continuing conversion of inland-wetlands to other land-uses.

The short-term trend (table 3) can be however considered as *stable* in all the regions except for the Steppic one where the trend shows *degradation* (-16,4% decadal change): the trend of change in extent is significantly negative.

Table 4: Habitat conversion indicator values at biogeographical region level for the period 2000-2018.

Biogeographical region	Km^2				%/6 years			Trend	
	2000	***2006***	***2012***	***2018***	***2000-2006***	***2006-2012***	***2012-2018***	***Short-term***	***Long-term***
Alpine	11.106	11.106	11.105	11.105	0,0	0,0	0,0	0,0	0,0
Atlantic	34.805	34.506	34.493	34.421	-0,9	0,0	-0,2	-0,3	1,1
Black Sea	1.230	1.230	1.230	1.205	0,0	0,0	-2,0	-3,4	-3,4
Boreal	44.591	44.442	44.501	44.563	-0,3	0,1	0,1	0,0	0,8
Continental	3.189	3.194	3.197	3.205	0,2	0,1	0,3	0,3	0,2
Macaronesian	48	48	48	48	0,0	0,0	0,0	0,0	0,0
Mediterranean	685	677	684	675	-1,2	1,0	-1,3	-3,9	-0,2
Pannonian	981	981	979	981	0,0	-0,2	0,2	0,7	0,3
Steppic	1.233	1.233	1.287	1.217	0,0	4,4	-5,4	***-16,4***	-4,5

The long-term trend shows *stable* conditions of the ecosystem in all the biogeographical regions.

References

Joosten, H 1997. Mires in Europe: a preliminary status report. International Mire Conservation Group Members Newsletter, 3

Mediterranean Wetlands Outlook 2: Solutions for sustainable Mediterranean Wetlands, 2018, Tour du Valat, France.

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Fact sheet 3.4.102: Exposure to eutrophication indicator (mol nitrogen eq/ha/y)

1. General information

- Thematic ecosystem assessment. Inland marshes and peatbogs
- Indicator class: Atmospheric Pollution and nutrition enrichment
- Name of the indicator: Exposure to eutrophication
- Units: mol nitrogen eq/ha/y

2. Data sources

- Data holder: EMEP
- Weblink: https://emep.int/publ/reports/2018/EMEP_Status_Report_1_2018.pdf
- Year or time-series range: 2000, 2005, 2010, 2016
- Version: 2018
- Access date: 19/07/2019
- Reference: EMEP Status Report 1/2018, "Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components", Joint MSC-W & CCC & CEIP Report

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The indicator shows the exposure of inland wetland ecosystems to eutrophication reporting for each grid cell the so-called 'average accumulated exceedance' (AAE), computed as the area-weighted mean of the exceedances of the critical loads for eutrophication by nitrogen in that grid cell (EMEP, 2018).

Eutrophication of wetlands leads to drastic changes with major effects on their structure and functions (Vaithiyanathan and Richardson 1999, Álvarez-Cobelas et al. 2001). Eutrophication amplifies the negative effects on Climate Change by increasing the net emissions of greenhouse gases to the atmosphere (Verhoven et al., 2006).

Nutrient enrichment within a wetland results in the great increase of primary productivity in what are often low nutrients/production systems. The consequent ecological and biodiversity changes (e.g. species abundance, displacement, biodiversity loss and changes in structure and composition) haven´t been sufficiently studied in wetlands yet (Sanchez-Carrillo et al., 2010), a clear gap that need to be highlighted.

3.2. Maps

Figure 1 shows, for the available years, the indicator on the pressure from critical loads on inland marshes and peatbogs. The results show that throughout the years assessed, and beside northern Scandinavia, the loads are exceeded everywhere in Europe with hotspots in Denmark, Northern Germany, Netherlands and Northern Italy.

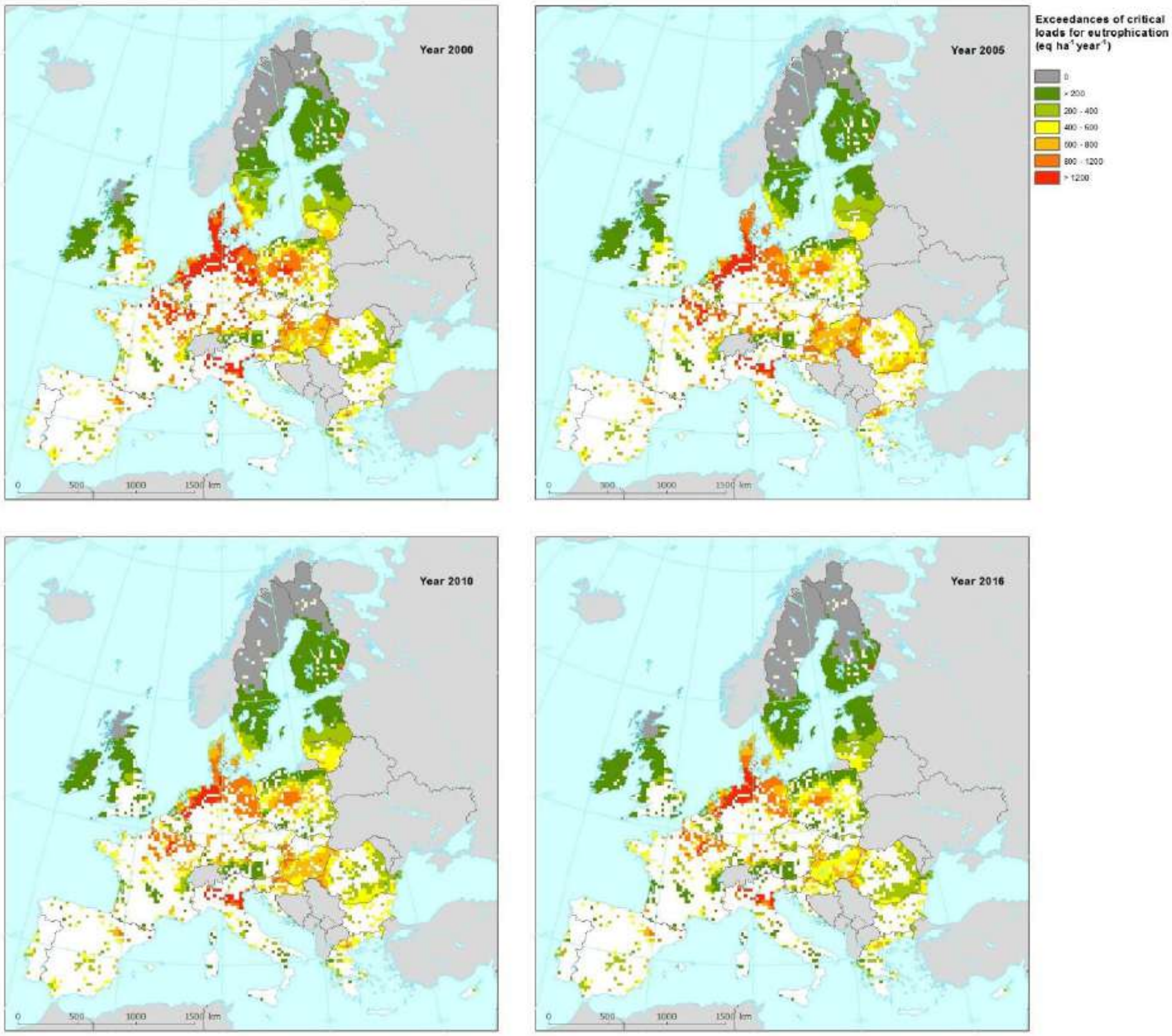

Figure 1: Exceedances of critical loads for eutrophication in wetlands computed with the 2000, 2005, 2010 and 2016 nitrogen depositions

Figure 2 shows the percentage change per decade of critical loads for eutrophication between the latest available year (2016) and the baseline one (2010).

For most of the wetlands across Europe, the indicator shows a reduction in load values, although the critical threshold is still exceeded. Most of critical load reduction is visible in the Baltic sea basin and in Italy, Southern France and along the Danube in Romania. Negative changes (increase in eutrophication over time) are affecting Ireland, the United Kingdom and Denmark.

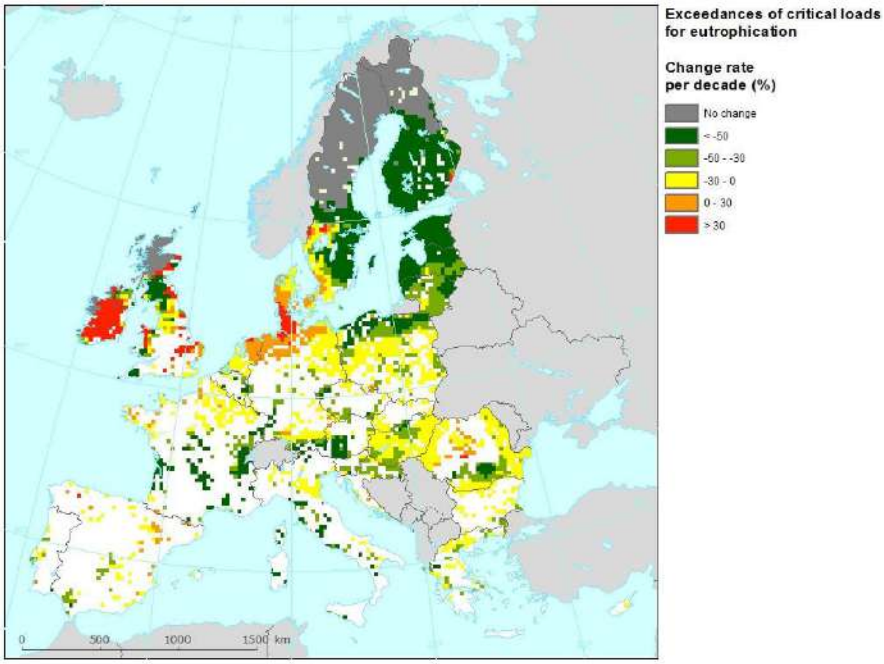

Figure 2: Change in exceedance of critical loads for eutrophication in wetlands between years 2010 and 2016 expressed as a percentage of change per decade

3.3. Statistical analysis of the trend

Both short-term (2010-2016) and long-term (2000-2016) trends are computed for this indicator; in both cases, the statistical significance is assessed based on the 5% rule.

3.4. Key trend at EU level

The indicator values per year are given in Table 1 and Figure 3.

The indicator has a significant downward short-term trend (percentage change per decade): this decrease of pressure translates into an *improvement* of the ecosystem condition.

Table 1: Indicator values per year and short-term trend of the exposure to eutrophication

Pressure	*2000*	*2005*	*2010*	2016	Short-term trend (% per decade)
Pollution and nutrient enrichment *Exposure to eutrophication* (eq ha^{-1} yr^{-1})	94.6	79.1	65.4	57.3	-20.7%

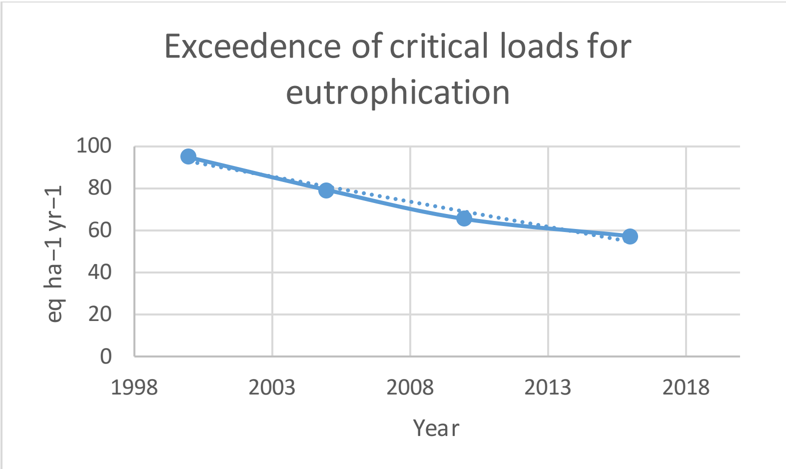

Figure 3: Pressure on wetlands from exposure to eutrophication: temporal trend of the exceedance of critical loads at EU-28 level

The long-term trend of the indicator for EU-28 is computed for the time range 2000-2016. The pressure from eutrophication is decreasing also in this case on European inland marshes and peatbogs (percentage change per decade is -34,21%).

References

Alvarez-Cobelas M, Cirujano S, Sanchez-Carrillo S et al (2001) Hydrological and botanical man-made changes in the Spanish wetland of Las Tablas de Daimiel. Biol Conserv 97:89–98

EMEP, 2018. Status Report 1/2018, "Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components", Joint MSC-W & CCC & CEIP Report

Sánchez-Carrillo, S., Angeler, D. G., Álvarez-Cobelas, M., & Sánchez-Andrés, R. (2010). Freshwater wetland eutrophication. In Eutrophication: causes, consequences and control (pp. 195-210). Springer, Dordrecht.

Vaithiyanathan P, Richardson CJ (1999) Macrophyte species changes in the Everglades: examination along a eutrophication gradient. J Environ Qual 28:1347–1358

Verhoeven JTA, Arheimer B, Yin C, Hefting MM et al (2006) Regional and global concerns over wetlands and water quality. Trend Ecol Evol 21:96–103

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Fact sheet 3.4.103: Agriculture intensity pressure on inland marshes and peatbogs

1. General information

- Thematic ecosystem assessment: Inland marshes and peatbogs
- Indicator class: Over-exploitation
- Name of the indicator: Agriculture intensity pressure on inland marshes and peatbogs
    - Sub-indicator *i*: Non-atmospheric nitrogen input from agriculture to soil
    - Sub-indicator *ii*: Extent of agricultural area around inland marshes and peatbogs
- Units
    - Sub-indicator *i* Kg/ha/year
    - Sub-indicator *ii* %

2. Data sources

The indicator is made-up of two sub-indicators.

i) Non-atmospheric nitrogen inputs to soils from manure application and mineral fertiliser

Derived through GIS analysis of the input dataset "Nitrogen flows relevant for HSU database" combined with the MAES Wetland Ecosystem types mask derived from the Corine Land Cover 2012.

- Data holder: JRC
- Year or time-series range: 2000, 2002, 2004, 2006, 2008, 2010, 2012
- Reference:
    - o Leip A. Koeble R. 2018 The CAPRI disaggregation. Report in preparation
    - o Leip A. Koeble R. Reuter H.I. Lamboni M. Homogeneous Spatial Units (HSU) - a Pan-European geographical basis for environmental and socio-economic modelling. PANGAEA. https://doi.org/10.1594/PANGAEA.860284 Unpublished data archive
    - o Lamboni M. Koeble R. Leip A. 2016. Multi-scale land-use disaggregation modelling: Concept and application to EU countries. Environ. Model. Softw. 82 183-217. https://doi.org/10.1016/j.envsoft.2016.04.028
    - o Leip A. Marchi G. Koeble R. Kempen M. Britz W. Li C. 2008. Linking an economic model for European agriculture with a mechanistic model to estimate nitrogen and carbon losses from arable soils in Europe. Biogeosciences 5 73-94. https://doi.org/10.5194/bg-5-73-2008

ii) Extent of agricultural area around inland marshes and peatbogs

The indicator is derived through GIS analysis of the input Corine Land Cover status layers

- Corine Land Cover 2000 (raster 100m) version 18.5 status layer, Mar. 2017
- Corine Land Cover 2006 (raster 100m) version 18.5 status layer, Mar. 2017
- Corine Land Cover 2012 (raster 100m) version 18.5 status layer, Mar. 2017
- Corine Land Cover 2018 (raster 100m) version 20.b2 status layer, Apr. 2018

- Data holder: JRC
- Year or time-series range: 2000, 2006, 2012, 2018
- Reference: This fact sheet

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

This indicator aims to evaluate spatial and temporal trends of pressure on inland marshes and peatbogs from agriculture intensification.

The intensification of agricultural activities has a significant negative impact on ecosystems, both in quantitative (decreases in flow) and qualitative terms (loads of pollutants, including nutrients and other chemicals used to maximize production on cropland) (Davies et al., 2008).

This pressure occurs frequently within and in the surroundings of the wetland bodies. For the indicator purposes, the area around inland marshes and peatbogs considered to have a potential impact on its ecosystems has been defined through a buffer area of 10km radius around each wetland body. This area approximates a statistical measurement (IQR) of the distribution of the European river catchments extent, which are important geographical units to consider for the management of inland marshes and peatbogs and water resources.

Pressure is assessed by means of two sub-indicators. The sub-indicator *i* quantifies the amount of nitrogen inputs to soil from manure application and mineral fertilizer, while the sub-indicator *ii* defines the percentage of area around inland marshes and peatbogs which is used for agricultural purposes.

Nutrient balance (nitrogen in this case) can be considered a proxy for agricultural intensification since, in many inland marshes and peatbogs, natural fluxes of nutrient availability is altered by agricultural practices, increasing nutrient loading and altering the physical and chemical conditions (Sánchez-Carrillo et al., 2010) and the ecosystem structure and functions.

3.2. Maps

Sub-indicator *i*

The sub-indicator *i* is computed for EU-27 (no nitrogen input data are available for Croatia) and for each available year. It represents the average nitrogen input rate (kg/ha) in the proximity area of each wetland body. In Figure 1, the sub-indicator *i* is shown as average input rate (kg/ha) at 25*25 km^2 resolution. This resolution has been selected for informative purposes; the indicator is available as a vector file with yearly values for each wetland body.

Differences between years are barely visible and the general spatial pattern of the indicator is very similar along the considered timeframe. Pressure on inland marshes and peatbogs is higher in central Europe with a wide hot-spot in the Netherlands and high values also in Germany, South of Denmark and West of France. Values also peak in the southern half of Ireland. Inland marshes and peatbogs in southern and Eastern Europe generally experience a lower pressure, but hotspots are visible in the Po valley in Italy, central Greece and eastern Hungary, with peaks in Danube delta.

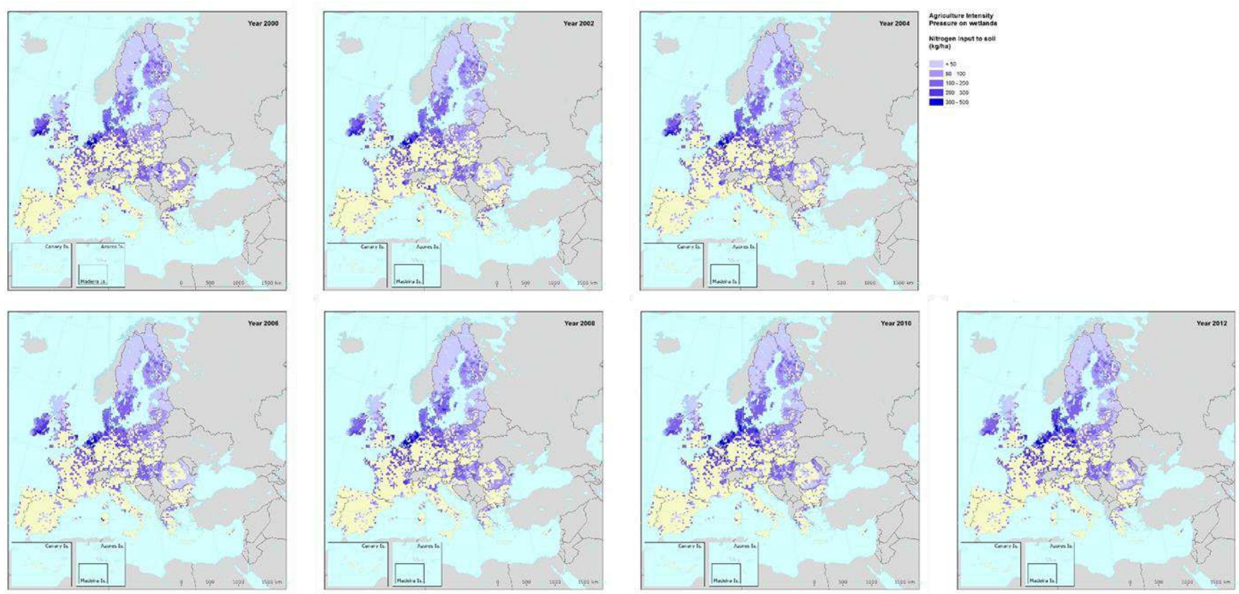

Figure 1 Pressure on Inland marshes and peatbogs from Nitrogen input to soil for years 2000, 2002, 2004, 2006, 2008, 2010 and 2012

For each wetland body, a multi-temporal regression (Ordinary Least Square) has been computed and the regression values used to derive the change rate per decade (long-term trend) and identify the areas affected by a change in time (upward or downward trend) or areas where there is no change detected. The significance of the trend is evaluated based on the 5% change rule.

The long-term trend of the indicator is expressed as percentage change per decade and shown in Figure 2.

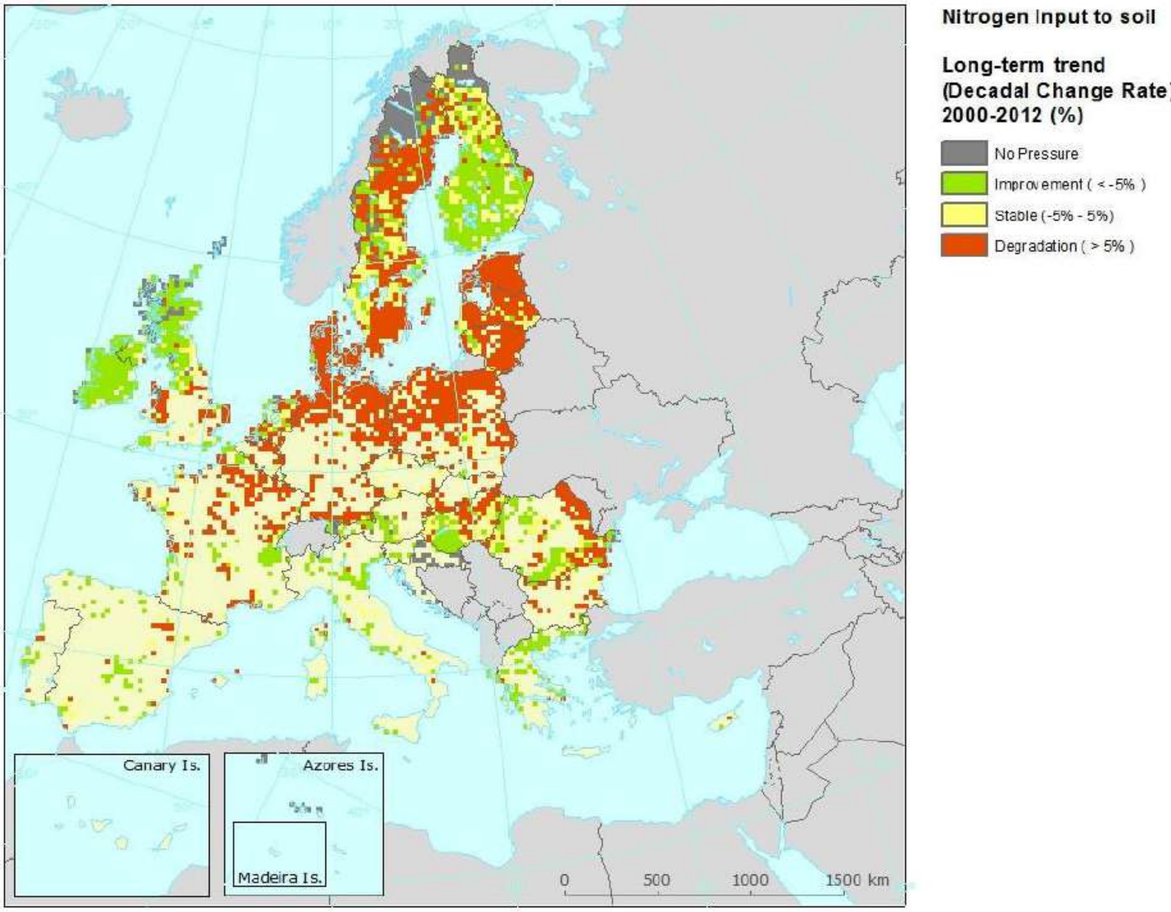

Figure 2. Nitrogen input to agricultural soils in the surrounding of inland marshes and peatbogs in EU-27: trend of the change between years 2000 and 2012. The trend is considered as positive or negative only when significant (lower than -5% or higher than 5%)

Opposite trends are visible between the north-east and the south-west of Europe. With the exception of southern Finland, the rate of nitrogen input is increasing in the entire Baltic basin which translates into a negative trend: the increasing use of fertilizer in the catchment is happening since the enlargement of the EU in the Baltic region[36]. The trend is negative also in Germany and partially in Hungary, Bulgaria and Romania. The indicator shows a positive trend in Ireland, northern Great Britain and the Mediterranean countries.

Statistical analysis of the trend

For this indicator, the only long-term trend between 2000 and 2012 could be computed due to the lack of recent data.

It is assessed based on an ordinary least square regression applying the 5% rule.

[36] http://www.helcom.fi/action-areas/agriculture/basic-facts

Sub-indicator *ii*

The sub-indicator *ii* is computed for the EU-28 extent defining the percentage of area in the proximity of each wetland body which has an agricultural land use (Cropland Ecosystem type). In Figure 3, the sub-indicator *ii* is shown at 25*25 km^2 resolution.

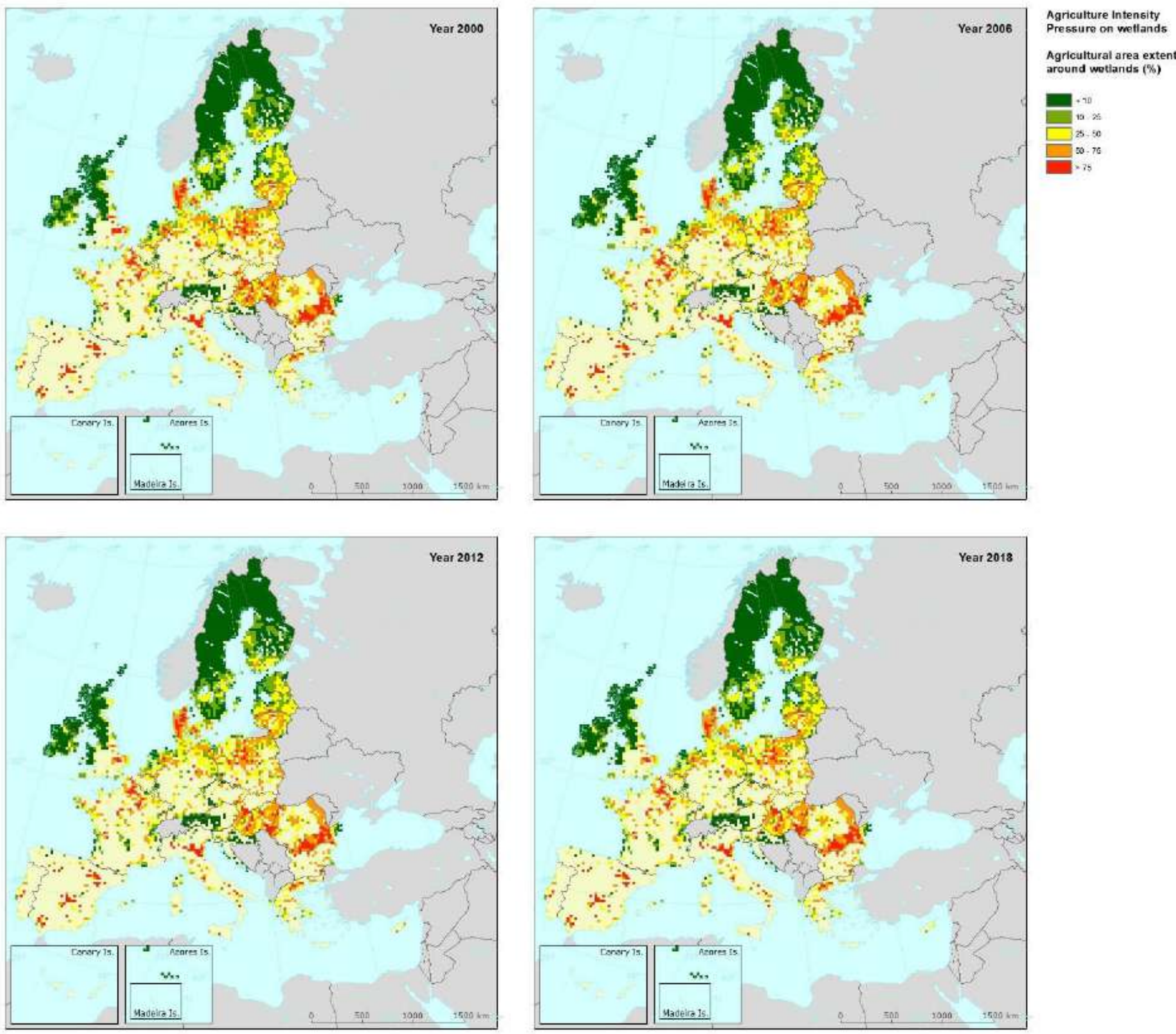

Figure 3: Pressure on wetlands from the agricultural intensification: percentage of agricultural land use in the proximity of inland marshes and peatbogs for years 2000, 2006, 2012, and 2018

With the exception of mountain regions in central Europe and Denmark, there is a clear gradient of intensification from North to South and the general spatial pattern is not coincident with the pattern of nutrient input pressure.

In particular, the percentage of surrounding area used for agriculture is very high in Romania and Spain while the pressure from nutrient load is lower. The opposite trend can be seen, for instance, in Ireland.

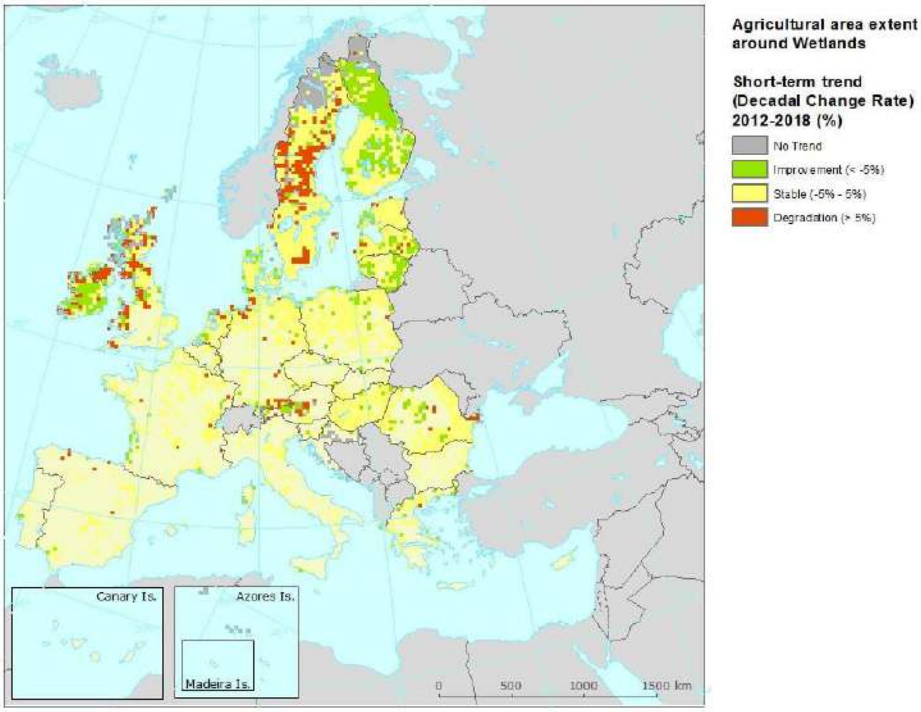

Figure 4. Agricultural land use in the surrounding of inland marshes and peatbogs in EU-28: trend of the change between years 2012 and 2018.

The indicator doesn´t show meaningful changes in most of Central and Southern Europe while this pressure is decreasing in Germany, Baltic countries, Finland and Ireland. Pressure is increasing in Sweden, UK, central Austria and at the delta of Danube.

Statistical analysis of the trend

Both short-term (2012-2018) and long-term (2000-2018) trends are computed for this indicator and assessed based on the 5% rule.

3.3. Key trends at EU level

The aggregated sub-indicators at EU level are computed as the average of the sub-indicators values for each of the wetland polygons.

Sub-indicator *i*

For the sub-indicator *i*, the time series is based on the nutrient input database, hence it covers years 2000, 2002, 2004, 2006, 2008, 2010 and 2012. The value for the baseline year 2010 is in bold.

The trend for EU-27 is shown in Table 1 and Figure 5. Based on the 5% rule, the multi-temporal correlation is not statistically significant, hence the indicator at EU-27 level reveals that no significant change is occurring in time: the pressure is *stable*. Nevertheless, regional fluctuations are obvious.

Table 1: Nitrogen input to inland marshes and peatbogs indicator values aggregated at EU-28 level for the period 2000-2012.

Pressure	*2000*	*2002*	*2004*	*2006*	*2008*	2010	*2012*	Change (% per decade)
Agriculture intensity pressure on wetlands *Sub-indicator (i)* Nitrogen Input to wetlands (kg/ha)	31.1	29.2	29.2	29.1	29.0	**31.3**	30.9	2.1%

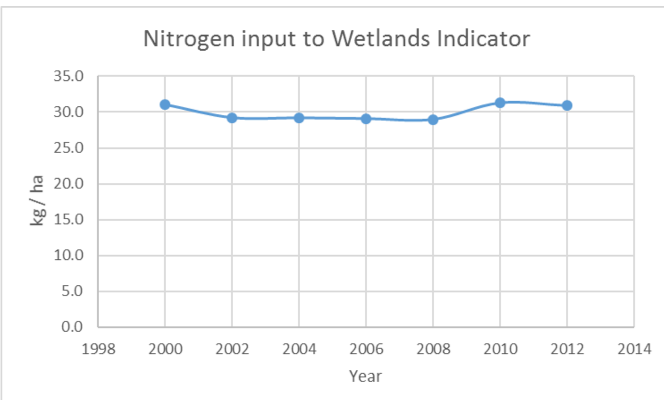

Figure 5: Trends of the nitrogen input to inland marshes and peatbogs indicator at EU-28 level

Sub-indicator *ii*

For the sub-indicator *ii*, the indicator values per year are given in Table 3 and Figure 6. Both short- and long-term trends, computed respectively for the period 2012-2018 and 2000-2018, according to the 5% rule, show a stable condition of the ecosystem.

Table 3. Short-term trend of the pressure on inland marshes and peatbogs from agricultural intensification: percentage of agricultural land use in the proximity of inland marshes and peatbogs for years 2000, 2006, 2012, and 2018 at EU-28 level

Pressure	*2000*	*2006*	*2010*	2012	*2018*	Short-term trend (% per decade)
Agriculture intensity pressure on wetlands *Sub-indicator (ii)* Agricultural area extent around wetlands (%)	8,2	8,1	**8,0**	8,0	7,9	-0,1

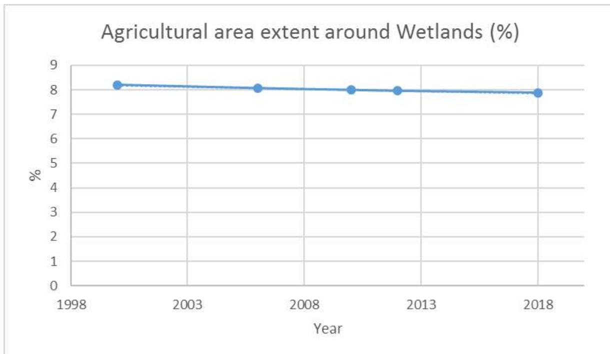

Figure 6. Pressure on inland marshes and peatbogs from agricultural intensification: temporal trend of the percentage of agricultural land use in the proximity of inland marshes and peatbogs at EU-28 level

References

Davies, B. R., Biggs, J., Williams, P. J., Lee, J. T., & Thompson, S. (2007). A comparison of the catchment sizes of rivers, streams, ponds, ditches and lakes: implications for protecting aquatic biodiversity in an agricultural landscape. In Pond Conservation in Europe (pp. 7-17). Springer, Dordrecht.

Sánchez-Carrillo, S., Angeler, D. G., Álvarez-Cobelas, M., & Sánchez-Andrés, R. (2010). Freshwater wetland eutrophication. In Eutrophication: causes, consequences and control (pp. 195-210). Springer, Dordrecht.

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Fact sheet 3.4.104: Soil sealing in wetlands

1. General information

- Thematic ecosystem assessment: Inland marshes and peatbogs
- Indicator class: Other pressures
- Name of the indicator: Soil sealing
- Units: km^2/year

2. Data sources

The indicator is based on existing data.

- Data holder: EEA
- Weblink: https://www.eea.europa.eu/data-and-maps/dashboards/imperviousness-in-europe
- Year or time-series range: 2006, 2009, 2012, 2015
- Version: 2018
- Access date: 15/09/2019
- Reference: https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/status-maps

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Soil sealing, expressed as "the substitution of the original (semi-) natural land cover or water surface with an artificial, often impervious cover"[37], can be considered a quantifiable land-use indicator closely correlating with impacts on water resources (Arnold et al., 1996).

Wetland condition degradation occurs at relatively low levels of imperviousness: Hicks (1995) could define a direct relationship between wetlands habitat quality and impervious surface area, with wetlands being impacted once the imperviousness of the local drainage basin exceeded 10%. It would then be important to extend the assessment of this indicator to the areas surrounding wetland bodies.

3.2. Maps

No maps are available for this indicator.

3.3. Statistical analysis of the trend

Both short- and long-term trends have been computed for this indicator; the significance of the trend is assessed based on the 5% rule.

[37] https://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/status-maps/2006?tab=metadata

3.4. Key trend at EU level

The aggregated indicator values at EU-28 level are shown in Table 1 and Figure 1.

Table 1: Soil sealing indicator values aggregated at EU-28 level for the period 2006-2015. Baseline value for year 2010 is shown in bold. The change per decade is computed based on the regression coefficient values

Pressure	*2006*	*2009*	*2010*	*2012*	*2015*
Soil sealing (km^2)	27,5	27,9	**28,2**	28,8	29,1

The *short-term* trend of the indicator for EU-28 is computed for the time range 2010-2015 while the *long-term* trend is computed for the time range 2006-2015, based on the regression coefficients for slope and intercept.

Based on the 5% rule, both short- and long-term trends are significant and the condition of inland marshes and peatbogs as measured by this indicator is *degrading*. The extent of inland marshes and peatbogs soils being sealed is increasing with a rate per decade of 6,5% and 6,8% for short- and long-term respectively.

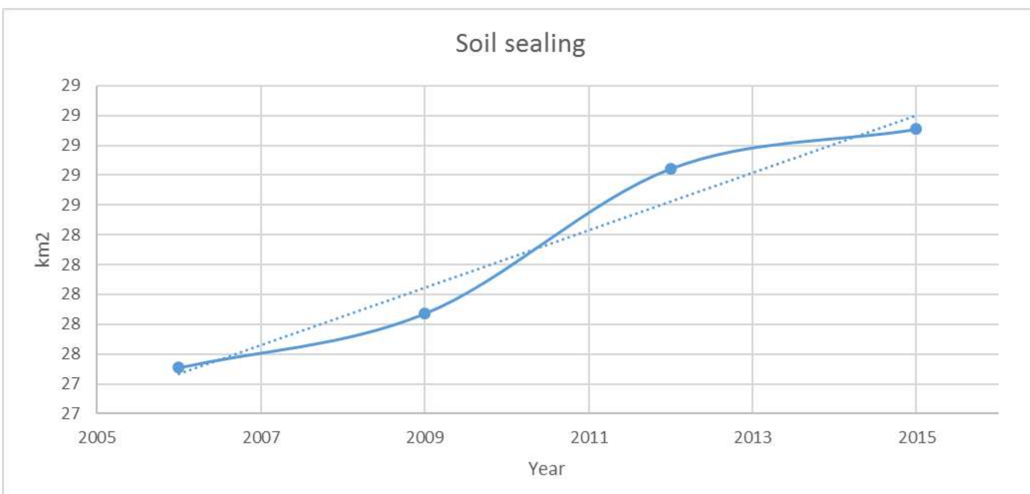

Figure 1: The short-term trend of the indicator for EU-28 is computed for the time range 2006-2015. The percentage change per decade is 6,8% and it can be considered significantly negative ($p<0.05$): the indicator shows degradation of the ecosystem

References

Arnold Jr, C. L., & Gibbons, C. J. (1996). Impervious surface coverage: the emergence of a key environmental indicator. Journal of the American planning Association, 62(2), 243-258.

Hicks, A, 1995. Impervious surface area and benthic macroinvertebrate response as index of impact from urbanization on freshwater wetlands. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/R-95/074.

WORK DONE BY MARCO TROMBETTI, DANIA ABDUL MALAK AND ANA MARIN (ETC/ULS – UMA)
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Fact sheet 3.4.201: Wetland connectivity

1. General information

- Thematic ecosystem assessment: Inland marshes and peatbogs
- Indicator class: Ecosystem condition – Structural ecosystem attributes (general)
- Name of the indicator: Wetland connectivity
- Units: km

2. Data sources

The indicator is derived through GIS analysis of the input Corine Land Cover accounting layers:

  - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019

- Dataholder: ETC/UMA
- Year or time-series range: 2000, 2006, 2012, 2018
- Reference: Abdul Malak et al., 2018. European Wetland Connectivity Indicator 2012: Synthesis of ETC/ULS work for supporting to MAES, Deliverable 30, ETC/ULS

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Wetland connectivity is broadly used as a proxy to assess the pressure from management activities on this ecosystem. Indicators on wetland connectivity should be species and habitat specific and involve other ecosystems connected to inland marshes and peatbogs, namely rivers, estuaries, and mud flats, among others (Kingsford & Norman, 2002).

A well-connected network of wetland habitats is crucial for the ecological functioning of this ecosystem since its deterioration can have a significant impact, for instance, on waterbird populations (Merken et al., 2015). The spatial distribution of wetlands is a key aspect in determining their connectivity (Amezaga et al., 2002) as well as addressing management and planning efforts to restore and maintain connectivity patterns (UN Environment, 2017).

Wetland connectivity can then be assessed through the simplest measure of structural connectivity which is calculated as the distance from one wetland to its nearest neighboring wetland (Calabrese and Fagan 2004). This index, although simple, reflects different scales and/or probabilities of movement for waterbirds (5 km, 10 km, 50 km and 100 km; Morris, et al., 2012) and Amphibians (0.5-1-10km; Sinsch, 2006), as well as the dispersal range of plants and invertebrate propagules.

3.2. Maps

In Figure 1, the connectivity indicator is shown as the average distance (km) between inland marshes and peatbogs during the years for which the indicators is available. The indicator is produced with a spatial resolution of 100m pixel size but the results are shown here after aggregation at 25km pixel size resolution for visualization purposes.

Although differences between years are visible, the general spatial pattern of the indicator is similar along the considered timeframe. A decreasing gradient of connectivity (increasing distance) from north to south is evident, related to higher density of inland marshes and peatbogs in the northern European countries. It can also be seen how, to a lesser extent, the connectivity decreases east to west, with greater distances between inland marshes/peatbogs (so less connectivity) in France, Italy and Spain.

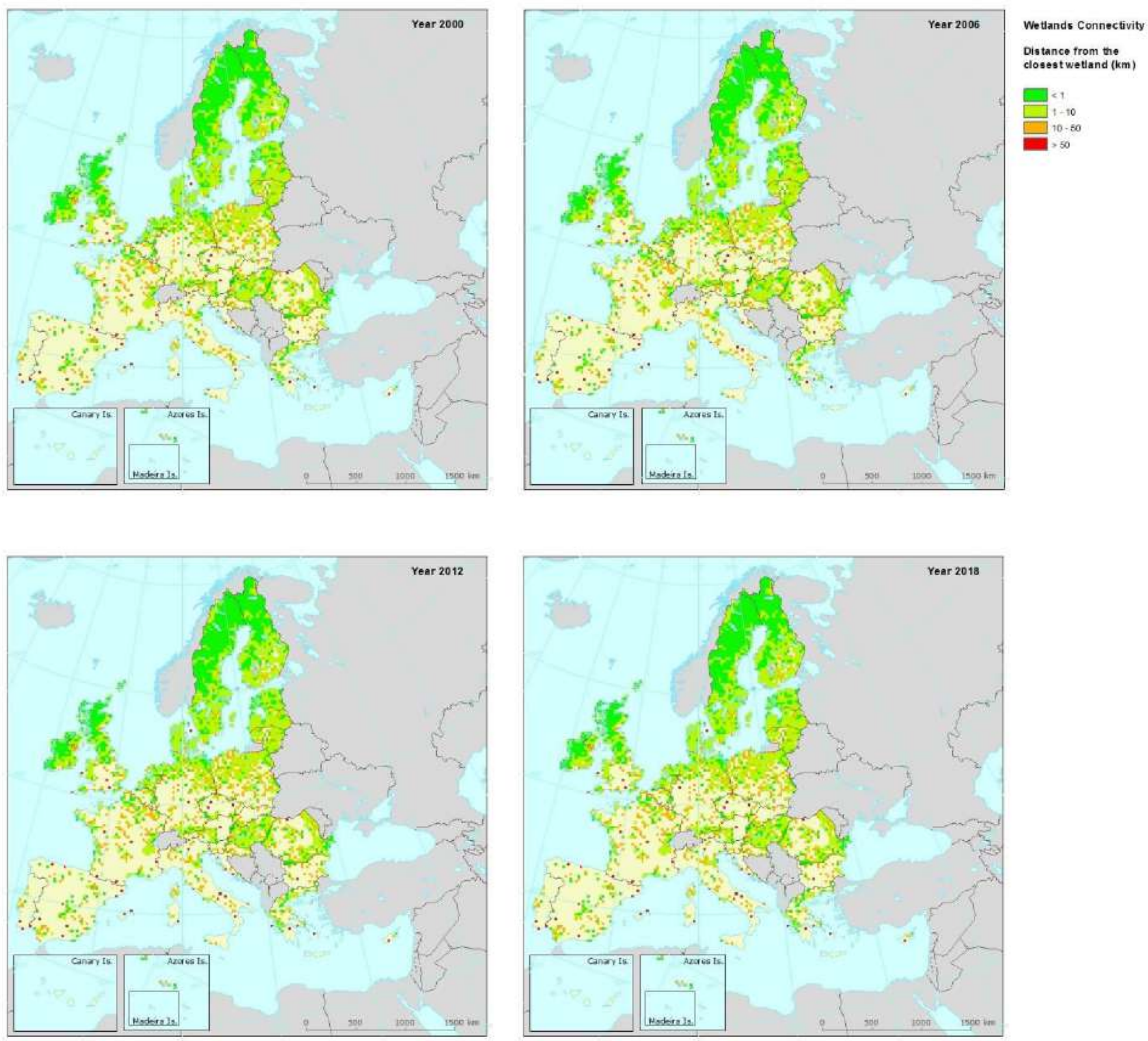

Figure 1 Inland marshes and peatbogs connectivity for years 2000, 2006, 2012 and 2018

Figure 2 shows the change in inland marshes and peatbogs connectivity between the most recent available year (2018) and the one closest to the baseline (2012). While most of the Inland marshes and peatbogs areas across Europe experience no change in connectivity, major hot-spots of negative change appear in the south of Finland and in Ireland. Positive changes showing better connectivity are evident in the Netherlands and in Belgium.

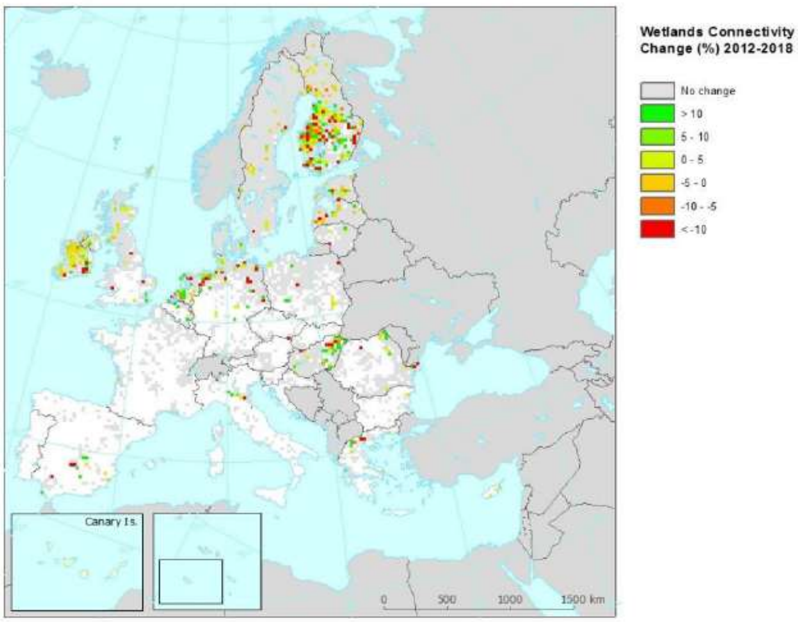

Figure 2: Change in connectivity between years 2012 and 2018 expressed as a percentage.

3.3. Statistical analysis of the trend

Both short-term and long-term trends are computed for this indicator and their significance is assessed based on the 5% change per decade rule in the first case and on the significance of the Ordinary Least Square regression in the second one.

3.4. Key trend at EU level

The aggregated indicator values at EU-28 level are computed as the average of the indicator values for each polygon (Table 1). The value for the baseline year 2010 is based on the interpolation between the closest years (2006 and 2012).

Table 1: Connectivity indicator values aggregated at EU-28 level for the period 2000-2018. The change per decade is computed based on the interpolated value for the baseline year 2010

Structural ecosystem attribute	*2000*	*2006*	*2010*	*2012*	*2018*
Connectivity (km)	1.272,9	1.282,8	1.294,0	1.299,6	1.306,7

The *short-term trend (2012 to 2018)* of the indicator for EU-28 is computed as the percentage change per decade and equals to 0,91%; based on the 5% change per decade rule, it can be considered as *stable*.

The *long-term* trend of the indicator for EU-28 is computed in for the time range 2000-2018. The percentage change per decade is 1,52% and it can be considered significantly negative ($p<0.05$): the indicator in this case shows *degradation* (Figure 3) meaning a significant decrease in connectivity between inland marshes and peatbogs in Europe.

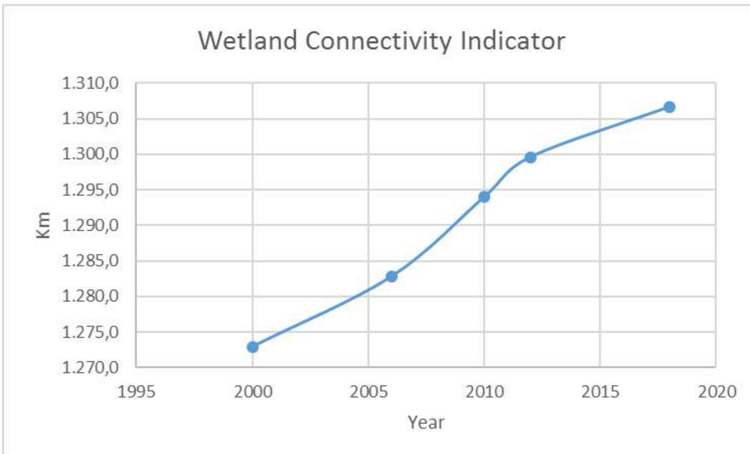

Figure 3: Long-term trend of the connectivity indicator

3.5 Key trends observed at regional level

The trend of the indicator has also been analyzed at the level of biogeographical regions.

The lowest values of connectivity (highest values of average distance) are observed in the Mediterranean and the Macaronesia regions. The regions with the best connectivity are the Alpine and the Boreal one, both with an average value of distance below 1km (table 2).

For all of the regions, the short-term trend can be considered *stable*, since in none of the cases the observed percentage change is significant. The only exception is the Steppic region, where the short-term trend shows a decrease of average distance between inland marshes and peatbogs (increase of connectivity).

Table 2: Connectivity indicator values at biogeographical region level for the period 2000-2018. The short-term trend (change per decade) is computed based on the interpolated value for the baseline year 2010

Bio-Geographical Region	*2000*	*2006*	*2010*	*2012*	*2018*	*Short-term trend*
Alpine	762,5	762,3	763,8	764,5	764,5	0,00%
Atlantic	1569,9	1621,8	1629,5	1633,3	1649,0	1,60%
Black Sea	1346,1	1346,1	1346,1	1346,1	1367,4	2,64%
Boreal	829,8	830,8	838,3	842,1	849,2	1,40%
Continental	4222,4	4261,5	4302,0	4322,2	4331,2	0,35%
Macaronesia	8028,4	8028,4	8028,4	8028,4	8028,4	0,00%
Mediterranean	9600,3	9751,2	9735,6	9727,7	9637,7	-1,54%
Pannonian	2320,5	2286,7	2280,7	2277,7	2266,0	-0,86%
Steppic	2442,8	2442,8	2461,3	2470,6	2380,8	-6,06%

The long-term trends show significant changes only for the Boreal and Pannonian regions ($p<0.05$). While in the boreal region the indicator shows *degradation* (percentage change per decade of 1,37%), in the case of the Pannonian region, the average distance between inland marshes and peatbogs decreases revealing an *improvement* (percentage change per decade -1.25%).

References

Amezaga, J. M., Santamaría, L., & Green, A. J. (2002). Biotic wetland connectivity—supporting a new approach for wetland policy. Acta oecologica, 23(3), 213-222.

Calabrese, J. M., & Fagan, W. F. (2004). A comparison-shopper's guide to connectivity metrics. Frontiers in Ecology and the Environment, 2(10), 529-536.

Merken, R., Deboelpaep, E., Teunen, J., Saura, S., & Koedam, N. (2015). Wetland suitability and connectivity for trans-Saharan migratory waterbirds. PloS one, 10(8), e0135445.

Morris, K. (2012). Wetland connectivity: understanding the dispersal of organisms that occur in Victoria's wetlands. Heidelberg: Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment.

Kingsford, R. T., & Norman, F. I. (2002). Australian waterbirds—products of the continent's ecology. Emu, 102(1), 47-69.

Sinsch, U. (2006). Orientation and navigation in Amphibia. Marine and Freshwater Behaviour and Physiology, 39(1), 65-71.

UN Environment, 2017. Convention on migratory species. Improving ways of addressing connectivity in the conservation of migratory species. UNEP/CSM/Resolution 12.26.
https://www.cms.int/sites/default/files/document/cms_cop12_res.12.26_connectivity_e.pdf

Fact sheet 3.4.202: Percentage of wetlands covered by Natura 2000

1. General information

- Thematic ecosystem assessment: Wetlands (Inland marshes and peatbogs)
- Indicator class: Condition. Structural ecosystem attributes monitored under the EU Nature Directive
- Name of the indicator: Percentage of inland marshes and peatbogs covered by Natura 2000 (%)
- Units: percentage (%)

2. Data sources

- Data holder: EEA
- Weblinks:
  - Corine Land Cover https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data
  - Natura 2000 data - the European network of protected sites https://www.eea.europa.eu/data-and-maps/data/natura-9#tab-gis-data
- Year or time-series range 2000 / 2006 / 2012 / 2018
- Versions
  - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
  - Natura 2000 End 2018 – Shapefile
  - Natura 2000 End 2013 rev1 - Shapefile

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

At the EU level, the Nature Directive (Birds and Habitats) is the centerpiece of nature legislation and biodiversity policy. The Natura 2000 sites are one of the Nature Directive's main tools that contribute to ensuring the conservation of many species and habitats of EU interest. Its purpose is primarily to ensure the conservation of targeted species and habitats of European interest.

Every country has designated Natura 2000 sites to help conserve the rare habitats and species present in their territory. Progress in designating sites was slow at first but currently the protected area is over 18% of the EU's land area, constituting the largest network of protected areas in the world (EEA, 2012).

This indicator aims to evaluate how the percentage of inland marshes and peatbogs protected by Natura 2000 site has changed against time. The changes could be due to changes of ecosystem extent (e.g. related to agricultural abandonment or urban expansion) or also be associated with changes in the protection zones, either by the designation of new areas or by the modification of the limits of those already existing. Both cases are included in this assessment since the indicator values are derived overlapping the spatial information of

CLC 2000, 2006 and 2012 with Natura 2000 network informed by MS at the end of 2013 (previous versions of spatial data of Natura 2000 present gaps and geometric inconsistences), and from CLC 2018 with Natura 2000 version provided in 2018.

3.2. Maps

This indicator is provided as tabular information, aggregated at country or EU-28 level, hence maps at grid level are not available.

In Figure 1, the percentage of protected area across biogeographical regions is shown for the year 2018. The maps for the other years are not shown since the values are very similar (see next section). For the same reason, since changes are not significant, no change map is shown.

The spatial trend in percentage of inland marshes and peatbogs listed under Natura2000 shows a clear increasing gradient from north, where the extent of this ecosystem is very high, to south. In the east (Steppic and Black sea regions), more than 90% of this ecosystem is protected by Natura2000.

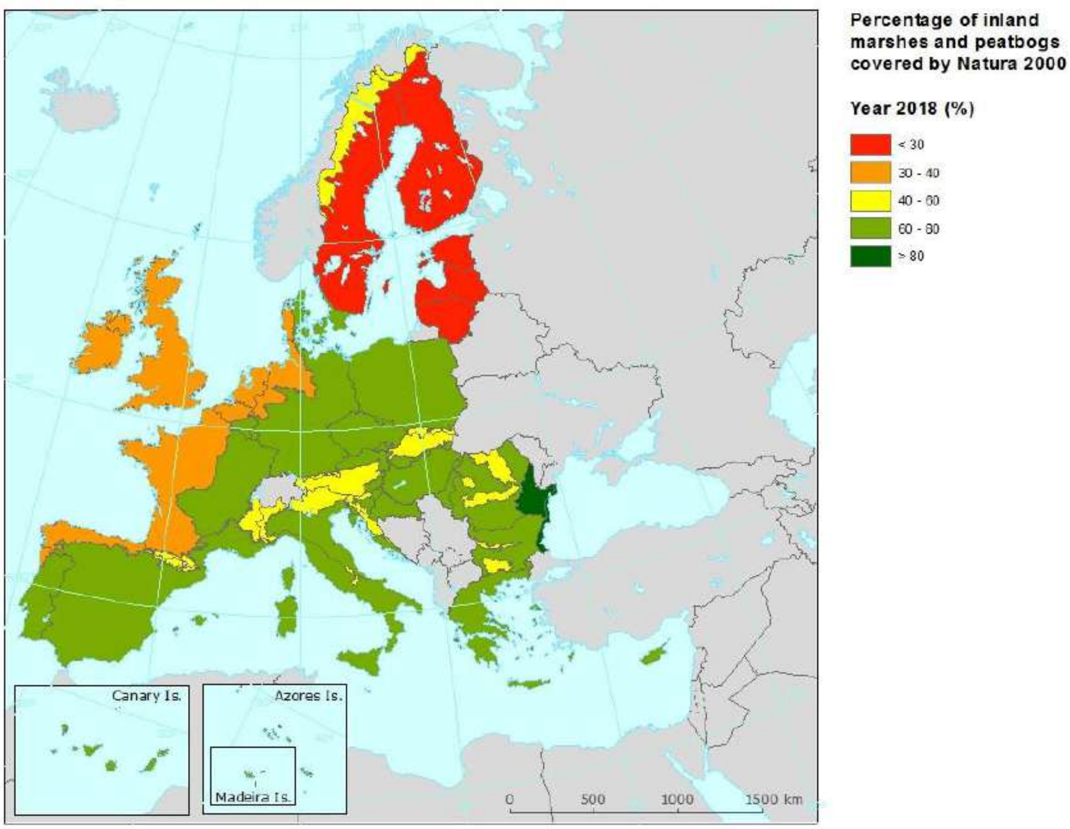

Figure 1 Percentage of inland marshes and peatbogs covered by Natura 2000 sites by bio-geographical region in the year 2018

3.3. Statistical analysis of the trend

Both short-term and long-term trends are computed for this indicator and assessed based on the 5% change per decade rule. The long-term trend is computed based on an ordinary least square regression.

3.4. Key trend at EU level

In the current decade, the percentage of inland marshes and peatbogs listed under Natura2000 hasn´t changed at the EU-28 level. The short-term trend, computed for the period 2012-2018 as percentage change per decade shows a *stable* condition of the ecosystem, being the decreasing rate (-2.05% per decade) not less than -5% (Figure 2 and Table 1).

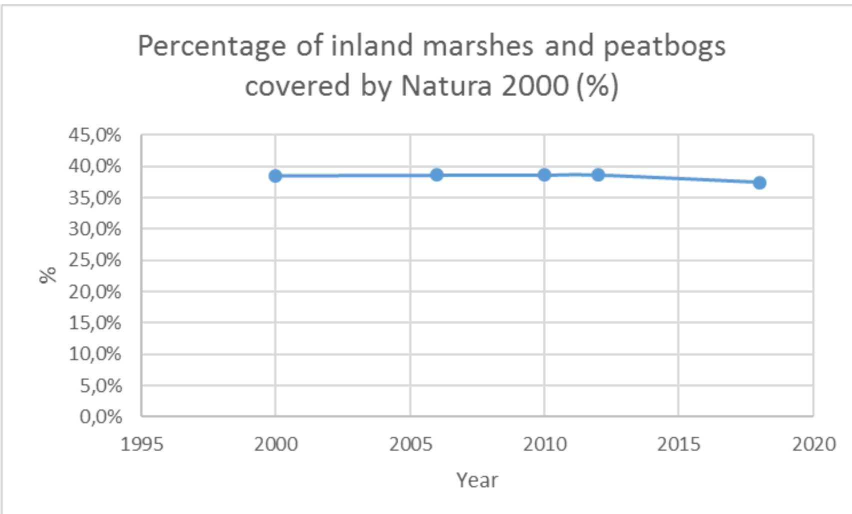

Figure 2 Trend of percentage of wetland area listed under Natura 2000 site from 2000 to 2018. Values are derived overlapping the spatial information of CLC 2000, 2006 and 2012 with Natura 2000 network informed by MS end of 2013, and CLC 2018 with Natura 2000 version provided by 2017.See values in table 1

Table 1 Percentage of inland marshes and peatbogs area listed under Natura 2000 site from 2000 to 2018 at EU-28 level. The interpolated value for the baseline year 2010 is shown in bold.

Structural ecosystem attribute	*2000*	*2006*	***2010***	*2012*	*2018*
Percentage of wetlands covered by Natura 2000 (%)	38,5%	38,6%	**38,6%**	38,6%	37,4%

No change is detected when we look at the previous decade neither (long-term trend). The percentage of inland marshes and peatbogs listed under Natura2000 hasn´t changed at the EU-28 level between 2000 and 2018. The trend is not significant (negative change being more than -5%) and the ecosystem condition can be considered *stable*.

The values per country which were used for Figure 1 are reported in Table 2. More than 70% of the extent of inland marshes and peatbogs are listed under Natura2000 in most of the biogeographical regions while lower values are reported for the Atlantic, Boreal and Alpine region.

For none of the biogeographic region, a change in the percentage of protected inland marshes and peatbogs can be detected. Also at this spatial level, for both short- and long-term trends, the condition of this ecosystem measured by the indicator is *stable*.

Table 2: Percentage of inland marshes and peatbogs area listed under Natura 2000 site from 2000 to 2018 at EU-28 bio-geographical region level. The interpolated value for the baseline year 2010 is shown in bold

Bio-geographical region	2000	2006	2010	2012	2018
Alpine	62,0%	62,0%	*62,0%*	62,0%	58,3%
Atlantic	37,0%	37,1%	*37,1%*	37,1%	36,9%
Black Sea	99,4%	99,4%	*99,4%*	99,4%	99,3%
Boreal	26,9%	27,0%	*26,9%*	26,9%	25,6%
Continental	71,2%	71,4%	*71,4%*	71,4%	71,3%
Macaronesian	74,6%	74,6%	*74,6%*	74,6%	74,2%
Mediterranean	79,6%	79,8%	*79,6%*	79,5%	79,0%
Pannonian	69,7%	70,0%	*70,1%*	70,2%	69,1%
Steppic	94,2%	94,2%	*94,4%*	94,5%	93,9%

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Fact sheet 3.4.203: Percentage of inland marshes and peatbogs covered by Natura 2000

1. General information

- Thematic ecosystem assessment: Inland marshes and peatbogs
- Indicator class: Condition. Structural ecosystem attributes monitored under the EU Nature Directive
- Name of the indicator: Percentage of inland marshes and peatbogs covered by Natura 2000 (%)
- Units: percentage (%)

2. Data sources

- Data holder: EEA
- Weblinks:
    - Corine Land Cover https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data
    - CDDA data - Nationally designated areas https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-13
- Year or time-series range 2000 / 2006 / 2012 / 2018
- Versions
    - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
    - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
    - CDDA 2018 – Shapefile

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The CDDA database - nationally designated areas - is the official source of protected area information from the 39 European countries members of EEA to the World Database of Protected Areas (WDPA). A 'nationally designated protected area' is an area designated by a national designation instrument, based on national legislation.

This indicator aims to evaluate how the percentage of inland marshes and peatbogs protected by the nationally designated areas has changed over time. The changes could be due to changes of ecosystem extent, for example due to agricultural abandonment, or also be associated with changes in the protection zones, either by the designation of new areas or by the modification of the limits of those already existing. This indicator focuses only on the trend in the percentage of protected area due to the change in the ecosystem extent. The CDDA digital maps are being reported by the countries from 2002, however this voluntary provision could trigger restrictions on the fully publication of the datasets. Consequently, the CDDA spatial information is not consistent over time.

The values of the indicator are the result of the overlapping, by means of spatial analysis tools, of CORINE LC 2000, 2006, 2012 and 2018 with the nationally designated areas -CDDA- as provided by MS in 2018.

3.2. Maps

This indicator is provided as tabular information, aggregated at country, biogeographical region or EU-28 level, hence maps at grid level are not available.

In Figure 1, the percentage of protected areas across biogeographical regions is shown for the year 2018. The maps for the other years are not shown since the values are very similar (see next section). For the same reason, since changes are not significant, no change map is shown.

The spatial trend in percentage of inland marshes and peatbogs listed under CDDA shows higher percentages of protected area in the centre of Europe. The Mediterranean, Steppic and Black sea regions, which are extensively protected under Natura2000, have instead a very low degree of protection under the national designations. It is to note that these figures indicate the declaration of protected areas by countries, but it can´t be used to assess whether there are management plans of these protected wetland areas in place or not.

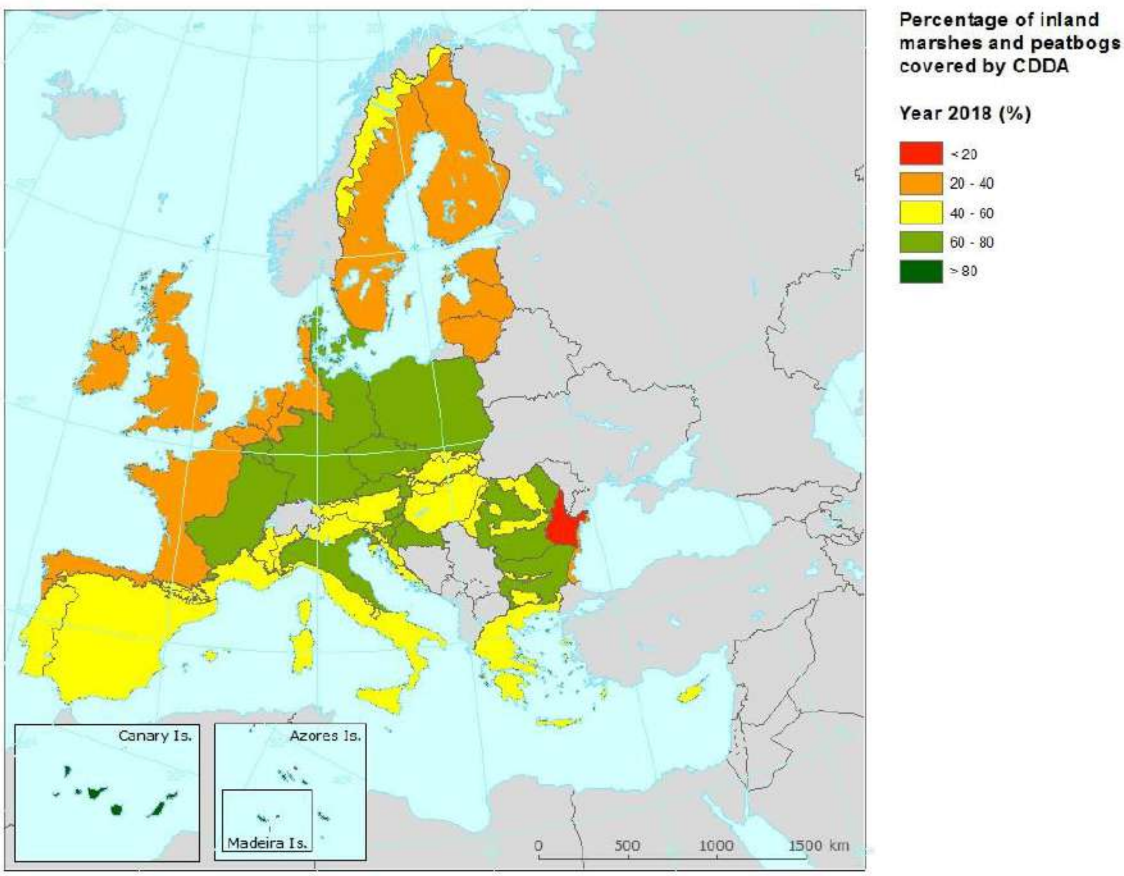


Figure 1 Percentage of inland marshes and peatbogs covered by Natura 2000 sites by biogeographical region in the year 2018

3.3. Statistical analysis of the trend

Both short-term and long-term trends are computed for this indicator and assessed based on the 5% change per decade rule.

3.4. Key trend at EU level

At the European level (Figure 2 and Table 1) both the short-term trend, computed for the period 2012-2018, and the long-term trend, computed for the period 2010-2018 as percentage change per decade show a *stable* condition, the positive changes being less than 5%: there hasn´t been a significant change in the percentage of inland marshes and peatbogs covered at the national level in the last 18 years.

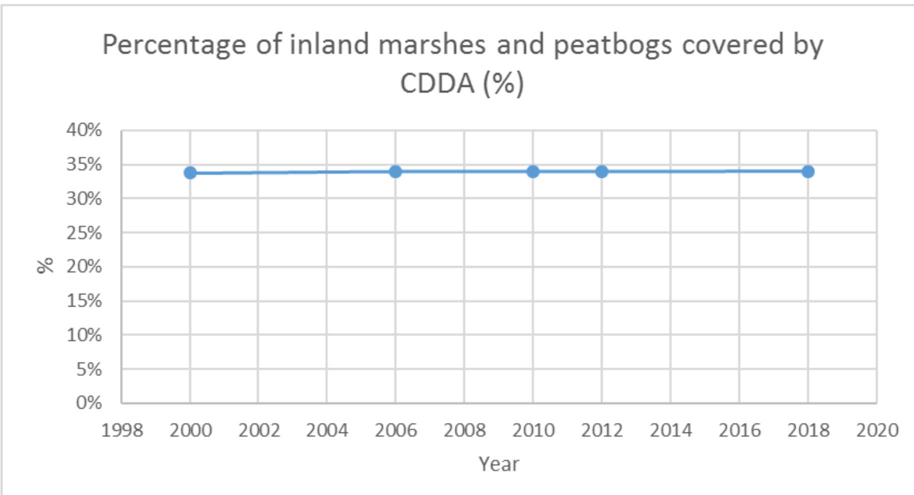


Figure 2 Trend of percentage of wetland area listed under CDDA from 2000 to 2018. The change per decade is computed based on the interpolated value for the baseline year 2010. See values in table 1

Table 1 Percentage of inland marshes and peatbogs area listed under Natura 2000 site from 2000 to 2018 at EU-28 level. The interpolated value for the baseline year 2010 is shown in bold.

Structural ecosystem attribute	*2000*	*2006*	***2010***	*2012*	*2018*
Percentage of wetlands covered by CDDA (%)	33,75%	33,91%	**33,91%**	33,91%	33,96%

The values per biogeographical region which were used for Figure 1 are reported in Table 2.

Also at this spatial level of aggregation, both short- and long-term trends indicate *stable* conditions for all the regions (all changes are within the -5% - 5% range).

Table 2: Percentage of inland marshes and peatbogs area listed under Natura 2000 site from 2000 to 2018 at EU-28 biogeographical region level. The interpolated value for the baseline year 2010 is shown in bold

Bio-geographical regior	2000	2006	2010	2012	2018
Alpine	55,5%	55,5%	***55,6%***	55,6%	55,6%
Atlantic	36,5%	36,8%	***36,9%***	36,9%	37,0%
Black Sea	20,1%	20,1%	***20,1%***	20,1%	20,5%
Boreal	24,2%	24,3%	***24,3%***	24,3%	24,2%
Continental	64,6%	64,7%	***64,7%***	64,7%	64,8%
Macaronesian	86,2%	86,2%	***86,2%***	86,2%	86,2%
Mediterranean	55,5%	55,9%	***55,8%***	55,8%	55,1%
Pannonian	45,6%	46,1%	***46,2%***	46,2%	45,8%
Steppic	15,4%	15,4%	***15,0%***	14,8%	15,6%

WORK DONE BY MARCO TROMBETTI, DANIA ABDUL MALAK AND ANA MARIN (ETC/ULS – UMA)
Version December 2019

Fact sheet 3.5.101: Land take (Heathlands and Shrub / Sparsely Vegetated Land)

1. General information

- Thematic ecosystem assessment: **Heathlands and Shrub / Sparsely Vegetated Land**
- Indicator class: Pressure. Habitat conversion and degradation (Land conversion)
- Name of the indicator: **Land take**
- Units: (km2/6 year)
- The extent of heathlands and shrubs as reported in Corine Land Cover as Moors and heathlands (322) and Sclerophyllous vegetation (323) and sparsely vegetated lands as Beaches, dunes, sands (331), Bare rocks (332), Sparsely vegetated areas (333), Burnt areas (334), Glaciers and perpetual snow (335) (MAES, 2013)

2. Data sources

The indicator based on readily available data: Land take indicator. EEA CSI 014

- Data holder: EEA
- Weblink https://www.eea.europa.eu/data-and-maps/dashboards/land-take-statistics
- Time-series range: 2000 - 2018
- Version: EEA Land Take viewer version end June 2019 (based on CLC v20)
- Access date 04/2020
- Reference:

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The main objective of this indicator is to measure the pressure from the development of urban and other artificial land use on natural and managed landscapes that are necessary 'to protect and restore the functioning of natural systems and halt the loss of biodiversity' (Sixth Environment Action Programme (6th EAP, COM(2001)31)).

Land use in Europe is driven by several factors such as the increasing demand for living space per person, the link between economic activity, increased mobility and the growth of transport infrastructure, which usually result in urban expansion.

The impact of urbanisation depends on the area of land taken and on the intensity of land use, for example, the degree of soil sealing and the population density. Land take by urban areas and infrastructure is generally irreversible and results in soil sealing, i.e. the loss of soil resources due to the covering of land for housing, roads or other construction work. Converted areas become highly specialised in terms of land use and support few functions related to socio-economic activities and housing. Urban land take consumes mostly agricultural land, but also reduces space for habitats and ecosystems that provide important services such as the regulation of the water balance and protection against floods, particularly if soil is highly sealed. Land occupied by man-made surfaces and dense infrastructure connects human settlements and fragments landscapes. It is also a significant source of water, soil and air pollution.

This indicator looks at the change in the amount (in km2 per 6 years) of heathlands and shrubs, and sparsely vegetated lands land taken by urban and other artificial land development. It includes areas sealed by construction and urban infrastructure, as well as urban green areas, and sport and leisure facilities. The main drivers of land take are grouped in processes resulting in the extension of:

- housing, services and recreation;
- industrial and commercial sites;
- transport networks and infrastructures;
- mines, quarries and waste dumpsites;
- construction sites.

3.2. Maps

Maps as pixel based were not available. This indicator is based on tabular information, aggregated at EU-28 level.

3.3. Key trend at EU level

Heathlands and shrubs[38]**:** At EU-28 level the land take indicator shows a significant downward long-term trend with a negative change rate of -35.82% (Table 1). The land take pressure decreased, in term of area taken for, from 243 km^2during 2000-2006 to 86 km^2 during the last 6 years assessed.
Looking at table 2, the importance of land take for the two periods 2000-2006 and 2006-2012 is mainly due to Spain with respective land take of 151 km^2 (62% of the total EU-28 land take) and then 88 km^2 (53% of the total EU-28 land take). For the period 2012-2018, the land take for Spain is only 15% of the total EU-28. Compared to the period 2006-2018, Belgium, Croatia, Cyprus, France and Portugal had also a more important land take for the period 2000-2006 due to construction.

On heathlands, the reduction of pressures related to land take since 2000 can give a positive signal but we should remind that only between 5 and 10 % of heathlands areas still exist in Western Europe compared to 1800 (Glemarec et al., et al., 2015).

Sparsely vegetated lands[39]**:** At EU-28 level the land take indicator shows a significant downward long-term trend with a negative change rate of -45.62% (Table 1). The land take pressure decreased, in term of area taken for, from 57 km^2 during 2000-2006 to 10 during the last 6 years assessed.
Looking at table 3, still Spain has an important contribution to the land take due to construction with 65% of the total EU-28 for the period 2000-2006. Germany has a stable land take across the three periods and is the most impacted by loss of sparsely vegetated lands with 31% for the period 2006-2012 and 26% for the period 2012-2018, compared to the total EU land take. Construction in Spain and sprawl of mines and quarrying areas are the most important reasons of loss of extent.

[38] Equals to CLC 322 and 323
[39] Equals to CLC 331-335

Table 1 Pressure; Habitat conversion and degradation indicator. Land take. Ecosystems contribution to uptake by urban and other artificial land development in EU-28 (km2)

	2000-2006	2006- 2012	2012-2018	Baseline value (2010)	ST Change (% per decade)	LT Change (% per decade)
Heathlands & shrubs	243	165	86	**191**	**-68,53%**	**-35.82%**
Sparsely vegetated lands	576	16	10	**30**	**-82,43%**	**-45.62%**

Table 2 Pressure; Habitat conversion and degradation indicator. Land take. Ecosystems contribution to uptake by urban and other artificial land development in EU-28 Member states (km2)

Heathland and shrub			
Area in km2	2000-2006	2006-2012	2012-2018
Austria	0,78	0,88	0,52
Belgium	7,47	3,05	3,61
Bulgaria	0,70		
Croatia	6,12	2,31	0,51
Cyprus	16,93	5,97	6,07
Czechia			
Denmark			
Estonia		0,27	
Finland			
France	16,30	8,92	7,71
Germany	0,30	2,81	1,87
Greece	22,31	26,64	14,09
Hungary			
Ireland	0,18		
Italy	5,28	4,64	1,51
Latvia			
Lithuania			
Luxembourg			
Malta	0,08	0,19	0,05
Netherlands	0,81		0,30
Poland			
Portugal	12,48	6,88	5,79
Romania			
Slovakia			
Slovenia			
Spain	150,89	88 ,34	13,14
Sweden	0,04	0,11	1,54
United Kingdom	2,33	14,18	29,63
Grand Total	**243,00**	**165,19**	**86,34**

Table 3 Pressure; Habitat conversion and degradation indicator. Land take. Ecosystems contribution to uptake by urban and other artificial land development in EU-28 Member states (km2)

Sparsely vegetated land			
Area in km2	2000-2006	2006-2012	2012-2018
Austria		0,47	0,22
Belgium			
Bulgaria	0,24		
Croatia	1,38	0,32	0,69
Cyprus	0,44	0,66	0,11
Czechia			
Denmark	0,95		0,32
Estonia	0,17	0,30	
Finland	0,07	0,30	
France	0,65	0,73	1,19
Germany	5,17	5,14	2,73
Greece	1,60	0,54	0,85
Hungary			
Ireland			
Italy	1,06	0,19	0,57
Latvia			0,34
Lithuania			
Luxembourg			
Malta			
Netherlands			0,01
Poland			
Portugal	6,22	1,89	0,43
Romania	0,66	0,25	0,50
Slovakia			
Slovenia			
Spain	38,34	4,41	2,35
Sweden	0,47	0,31	
United Kingdom	0,21	1,09	
Grand Total	**57,63**	**16,60**	**10,31**

References

Glemarec, E., et al., 2015, Les landes du Massif armoricain ? Approche phytosociologique et conservatoire. Les cahiers scientifiques et techniques du CBN Brest.

Fact sheet 3.5.102: Land cover change due to fire (Heathlands and Shrub)

1. General information

- Thematic ecosystem assessment: **Heathlands and Shrub**
- Indicator class: Pressure. Habitat conversion and degradation (Land conversion)
- Name of the indicator: **Land cover change due to fire**
- Units: (km2/6 year)
- The extent of heathlands and shrubs as reported in Corine Land Cover as Moors and heathlands (322) and Sclerophyllous vegetation (323) (MAES, 2013)

2. Data sources

The indicator based on readily available data: LEAC - Land and Ecosystem Accounting

- Data holder: EEA
- Weblink https://tableau.discomap.eea.europa.eu/t/Landonline/views/LEACCube2018Advanced/LEAC2018
- Time-series range: 2000 - 2018
- Version: EEA under development
- Access date 04/2020
- Reference:

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Heathlands are a peculiar habitat of Western Europe, and have markedly declined over the last decades. Most of the remaining fragments are now protected, but are still threatened by the encroachment of pioneer trees such as birches and poplars. Controlled burning and mechanical cutting are commonly used to control pioneer trees in northern countries, but there is little understanding of their effects towards the southern edge of the range of European heathlands. Even if fire can be prescribed for management, there is a need of combination with mowing and grazing (Borghesio, 2014).
Often shrublands suffer from lack of management, polluting aerial deposition, overgrazing, excessive wildfires, or size reduction or fragmentation due to different land uses. Climate change may add to these threats and make these ecosystems even more vulnerable. In the Mediterranean shrubland both warming and drought led to a shift in the species composition, which might lead to a reduction in biodiversity and an increased threat of wildfires (Wessel et al, 2004).

3.2. Maps

Maps as pixel based were not available. This indicator is based on tabular information, aggregated at EU-28 level.

3.3. Key trend at EU level

Along the period 2000-2018, there is an increase of burnt heathlands with more than 40% of areas affected by fire. Looking at the details, this happens mainly in Mediterranean region. The distinction between controlled fires and wild fires cannot be done.

Table 1 Pressure; Land cover conversion and degradation indicator due to Forests and shrubs fires in EU-28 (km2)

	2000-2006	2006- 2012	2012-2018	Baseline value (2010)	ST Change (% per decade)	LT Change (% per decade)
322 Moors & Heathland	*58*	*119*	*150*			
323 Sclerophyllous vegetation	*215*	*161*	*338*			
Heathlands and Shrubs	**273**	**280**	**488**	**418**	**20.75%**	**43.81%**

Based on LCF92 Forests and shrubs fires

References

Borghesio, L., 2014, 'Can fire avoid massive and rapid habitat change in Italian heathlands?', *Journal for Nature Conservation*, Volume 22, Issue 1, 2014, pp. 68-74, https://doi.org/10.1016/j.jnc.2013.09.002. (http://www.sciencedirect.com/science/article/pii/S1617138113000952)

Wessel W.W., et al, 2004, 'A Qualitative Ecosystem Assessment for Different Shrublands in Western Europe under Impact of Climate Change', *Ecosystems*, 7, 662–671. https://link.springer.com/article/10.1007/s10021-004-0219-3

Fact sheet 3.5.103: Exposure to eutrophication indicator

1. General information

- Thematic ecosystem assessment: **Heathlands and Shrub / Sparsely Vegetated Land**
- Indicator class: Pollution and nutrition enrichment
- Name of the indicator: **Exposure to eutrophication**
- Units: mol nitrogen eq/ha/y

2. Data sources

- Data holder: EMEP
- Weblink: https://projects.eionet.europa.eu/eea-ecosystem-assessments/library/restricted/air-pollution/emep-data-deposition-and-air-pollution
- Year or time-series range: 2000, 2005, 2010, 2016
- Version: 2018
- Access date: 19/07/2019
- Reference: EMEP Status Report 1/2018, "Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components", Joint MSC-W & CCC & CEIP Report

3. Assessment of the indicator

3.1.Short description of the scope of the indicator

The indicator reports for each grid cell the so-called 'average accumulated exceedance' (AAE), computed as the area-weighted mean of the exceedances of the critical loads for eutrophication in that grid cell (EMEP, 2018).

Elevated atmospheric nitrogen (N) deposition is a major driver of change, altering the structure/functioning of nutrient-poor heathlands over Europe. These effects may vary across the ecosystem's distribution, especially at the range limits, as heathlands are highly vulnerable to land-use changes combined with present climate change (Taboeda, 2018).

3.2. Maps

This indicator is based on tabular information, aggregated at EU-28 level.

3.3. Statistical analysis of the trend

Both short-term (2010-2016) and long-term (2000-2016) trends are computed for this indicator.

The short-term trend is assessed based on the non-parametric Wilcoxon test[40] with bootstrapping, used in this case to compare the EU aggregated value based on two spatial datasets.

[40] The Wilcoxon test is a non-parametric statistical hypothesis test used to compare two related samples (paired difference test) to assess whether their population mean ranks differ. It is used in this case to compare EU-28 aggregated values based on two spatial datasets

The long-term trend is assessed based on an ordinary least square regression: the number of observations is 4, hence a non-parametric test is not applied being 10 the recommended minimum number of observations.

3.4. Key trend at EU level

The indicator values per year are given in Table 1 and Figure 2.

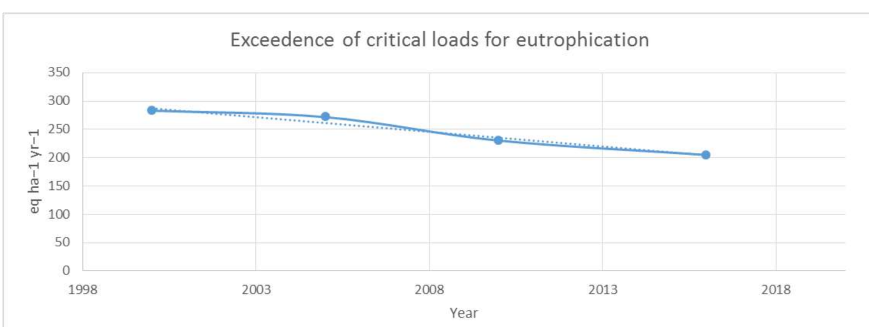
The indicator has a downward short-term trend (percentage change per decade), significant at 95% level ($p<0.05$): this decrease of pressure translates into an *improvement* of the ecosystem condition.

For **Heathlands and shrubs**, the exposure in 2016 is nearly 205 mole/ha/year meaning 3 kg N/ha/year which is below the critical N loads for this ecosystem (10-20 kg N/ha/year). But some ecosystem function might negatively respond to low but chronic inputs of N equivalent to <10kgN/ha/yr (Bähring et al., 2017).

The long-term trend of the indicator for EU-28 is computed for the time range 2000-2016. The pressure from eutrophication is decreasing in this case of **Heathlands and shrubs** (percentage change per decade is -22,1% , $p<0.05$) and **Sparsely Vegetated Lands** (percentage change per decade is -41,4% , $p<0.05$).

Table 1: Indicator values per year and short-term trend of the exposure to eutrophication

Exposure to eutrophication (eq ha^{-1} yr^{-1})	2000	2005	2010	2016	Short-term trend (% per decade)	Long-term trend (% per decade)
Heathlands and shrubs	283,1	271,7	230,3	204,9	**-18,4%**	**-22,1%**
Sparsely vegetated lands	204,0	174,0	134,5	112,0	**-27,9%**	**-41,4%**



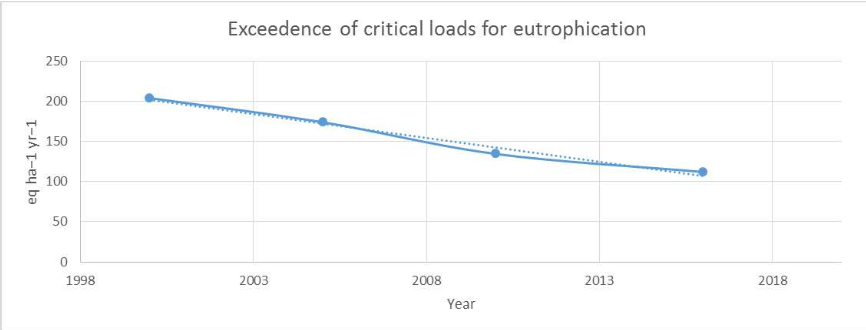


Figure 2: Pressure on Heathlands and shrubs (top) / Sparsely vegetated lands (bottom) from exposure to eutrophication: temporal trend of the exceedance of critical loads at EU-28 level

References

Bähring, A., et al., 2017, 'Ecosystem functions as indicators for heathland responses to nitrogen fertilisation', *Ecological Indicators* Volume 72, 2017, pp. 185-193 https://doi.org/10.1016/j.ecolind.2016.08.013. (http://www.sciencedirect.com/science/article/pii/S1470160X16304745)

EMEP, 2018. Status Report 1/2018, 'Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components', Joint MSC-W & CCC & CEIP Report

Taboada, A., et al., 2018, 'Plant and vegetation functional responses to cumulative high nitrogen deposition in rear-edge heathlands', *Science of The Total Environment*, Volumes 637–638, 2018, pp. 980-990

Fact sheet 3.5.201: Percentage of Heathlands and shrubs / Sparsely vegetated lands covered by Natura 2000 sites and/or Nationally designated areas - CDDA

1. General information

- Thematic ecosystem assessment: **Heathlands and Shrub / Sparsely Vegetated Land**
- Indicator class: Condition. Structural ecosystem attributes monitored under the EU nature directives and national legislations
- Name of the indicator: Percentage of **heathlands and shrubs / sparsely vegetated lands** covered by Natura 2000 sites and/or Nationally designated areas -CDDA- (%)
- Units: percentage (%)
- The extent of heathlands and shrubs as reported in Corine Land Cover as Moors and heathlands (322) and Sclerophyllous vegetation (323) and sparsely vegetated lands as Beaches, dunes, sands (331), Bare rocks (332), Sparsely vegetated areas (333), Burnt areas (334), Glaciers and perpetual snow (335) (MAES, 2013)

2. Data sources

- Data holder: EEA
- Weblinks:
  - Corine Land Cover https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/b90803ac-57db-4653-b393-3e04445a7035
  - CDDA data - Nationally designated areashttps://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-13
- Year or time-series range 2000 / 2006 / 2012 / 2018
- Versions
  - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
  - CDDA 2018 – Shapefile
  - Natura 2000 End 2018 - Shapefile

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The 'nationally designated protected area' is an area designated by a national designation instrument, based on national legislation. If a country has included sites designated under international agreements such as the EU Birds and Habitats Directives, or the Bern or Ramsar Convention in its legislation, those figures overlap spatially. The degree of overlap between Natura 2000 sites and nationally designated sites illustrates the extent to which countries have made use of their nationally designated areas to underpin Natura 2000 and to what extent Natura 2000 sites extend beyond national systems.

The overlap of Natura 2000 boundaries with the boundaries of nationally designated sites shows very different patterns across the EU. But it should be stressed that while the Natura 2000 digital maps fully reflect the actual extension of the network, the CDDA digital maps only reflects what countries have reported on a voluntary basis to the European Environment Agency.

This indicator aims to evaluate how the percentage of **Heathlands and Shrub / Sparsely Vegetated Land** covered by both networks has being changed against time. As based on the situation of Natura2000 network and nationally designated areas network in 2018, this indicator focuses only on the trend due to the change in the ecosystem extent. The values of the indicator are the result of the overlapping, by means of spatial analysis tools, of CORINE LC 2000, 2006, 2012 and 2018 with Natura 2000 network informed by MS end of 2018 and the nationally designated areas -CDDA- informed by MS in 2018.

3.2. Maps

Maps as pixel based were not available. This indicator is based on tabular information aggregated at country and EU-28 level.

3.3. Key trend at EU level

As detailed in table 1, around 40% of **heathlands and shrubs** are covered by N2000 network and around 32% are under national designations.

Around 53% of **sparsely vegetated lands** are covered by N2000 network and around 44% are under national designations.

Table 1 – Share of Heathlands covered by Natura 2000 and by national designations

	2000	2006	2012	2018
% Heathlands in N2K (*)	40.50%	40.55%	40.60%	40.66%
% Heathlands in CDDA (**)	31.95%	32.05%	32.11%	32.20%
	2000	**2006**	**2012**	**2018**
% SVL in N2K (*)	52.99%	53.11%	53.17%	52.61%
% SVL in CDDA (**)	43.90%	43.89%	44.04%	43.39%

(*) designated only by N2K and by the overlapping of both (N2K and CDDA)
(**)designated only by nationally designated areas and by the overlapping of both (N2K and CDDA)

3.4. Key status at biogeographic level

The share of ecosystems under EU or national legislations is also stable at biogeographic level since 2000. In 2018, the share of heathlands and shrub under Natura 2000 designation are above 74% in the Pannonian and Boreal regions. Between 45 and 55% in Alpine, Continental and Macaronesian regions (figure 1). The share under national designations is about 75% in the Boreal region and between 45 and 56% in the Macaronesian, Continental, Alpine and Atlantic regions. In the Macaronesian region, bushy sclerophyllous shrubs are predominant.

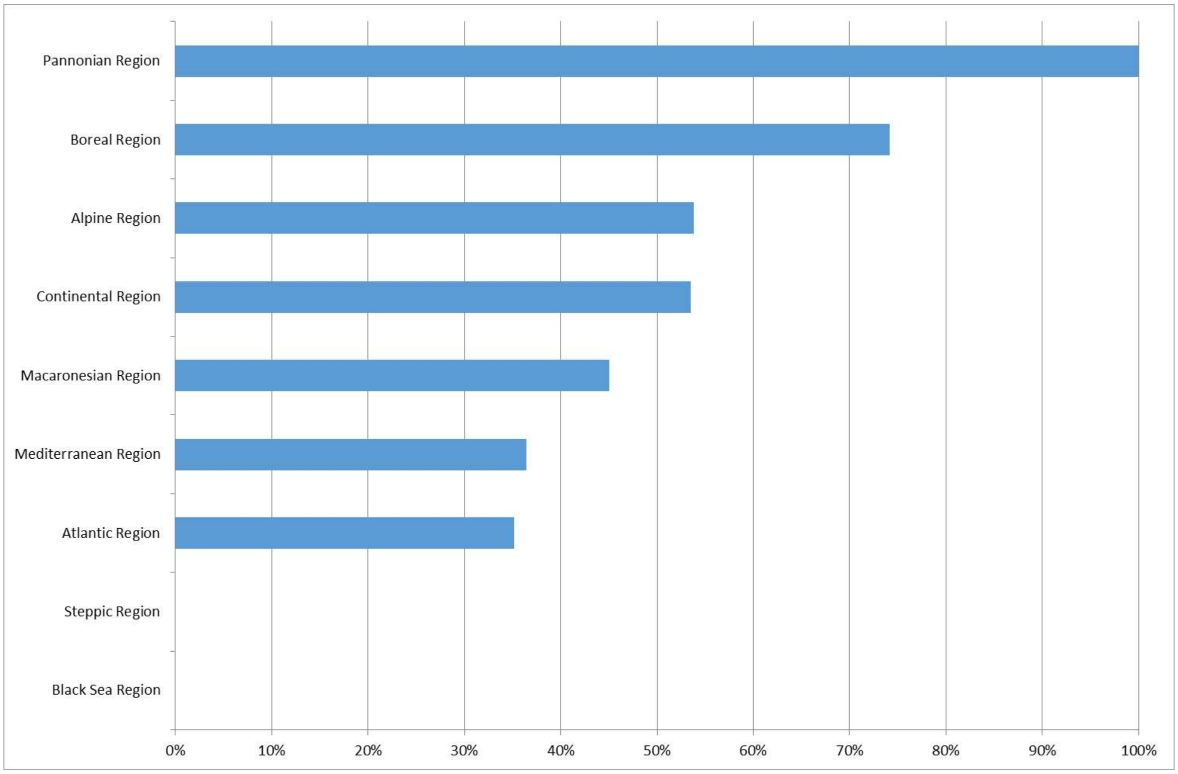


Figure 1 – Share of Heathlands and shrubs covered by Natura2000 per biogeographic region - 2018

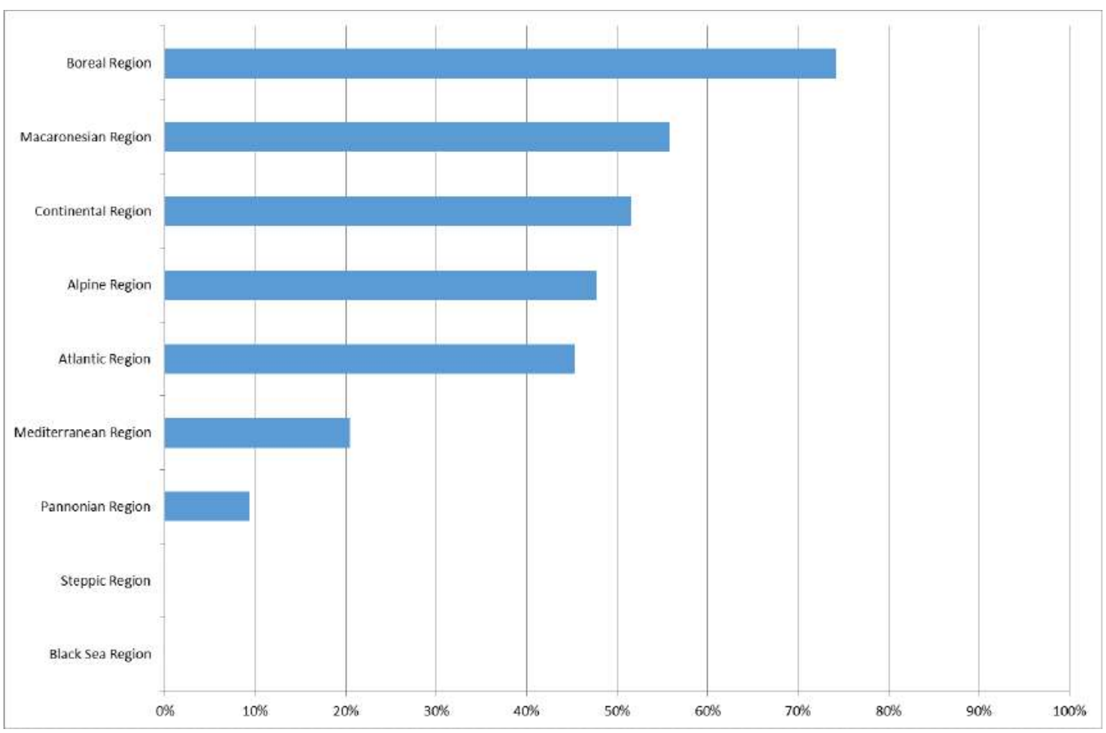


Figure 2 – Share of Heathlands and shrubs covered by National designations (CDDA) per biogeographic region

The share of **sparsely vegetated lands** under Natura 2000 designation are around and more of 90% in the Pannonian, Steppic and Black Sea regions. Between 48 and 60% for the other regions (figure 3).

The share under national designations is between 50 and 70% in the Pannonian, Atlantic and Boreal regions. Between 28 and 48% for the other regions.

These proportions are not due to the ecosystem extent in each region. Indeed, the, Alpine, Mediterranean and Atlantic regions share the most important part of the total extend of sparsely vegetated lands

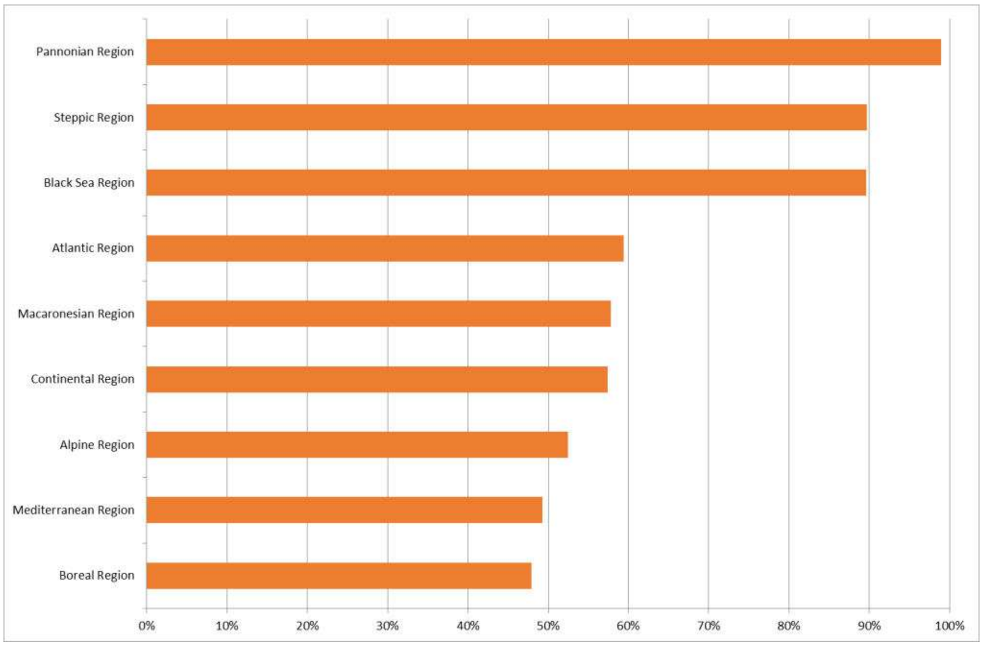


Figure 3 – Share of sparsely vegetated lands covered by Natura2000 per biogeographic region

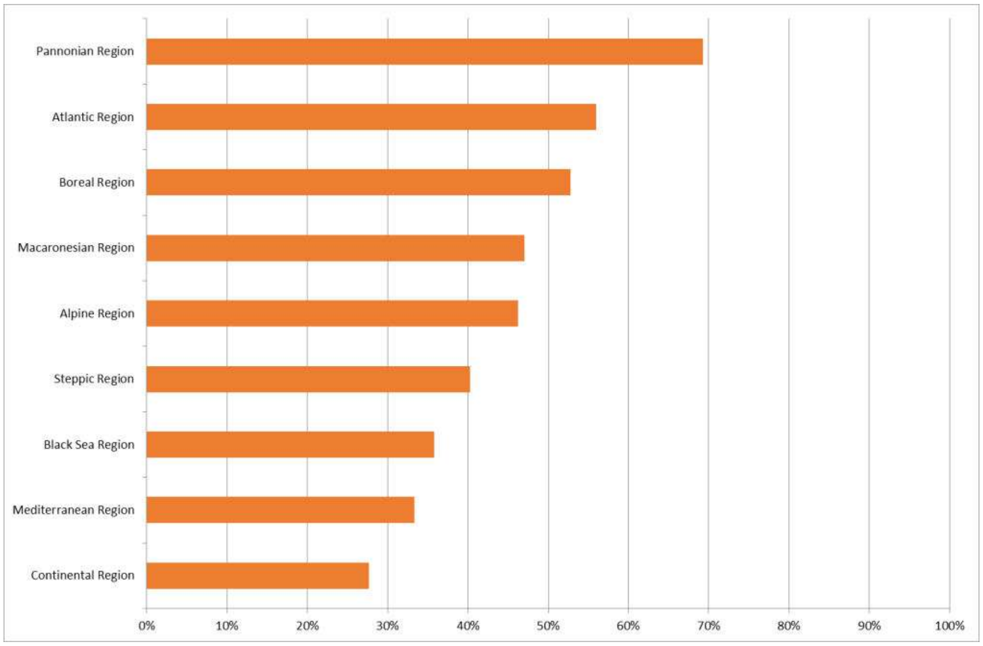


Figure 4 – Share of sparsely vegetated lands covered by National designations (CDDA) per biogeographic region

Fact sheet 3.5.203: Article 17 habitat conservation status

1. General information

- Thematic ecosystem assessment: **all**
- Indicator class: **Conservation status and Structural ecosystem attributes monitored under the EU nature directives**
- Name of the indicator: **Conservation status and trends per habitat group**
- Units: **%**

2. Data sources

- Data holder: EEA
- Weblink: not online yet
- Year or time-series range: 2013-2018
- Version 17/04/2020
- Access date:
- Reference (paper, report, …): State of Nature in the EU. Results from reporting under the Nature Directives 2013-2018 Version: 6.0

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The EU Habitats Directive aims to achieve a favourable conservation status for 233 different habitats. Listed in the Annex I of the directive, these habitats are grouped along 9 groups (Coastal habitats, Dunes habitats, Freshwater habitats, Heath & scrub, Sclerophyllous scrubs, Grasslands, Bogs, mires & fens, Rocky habitats, Forests).

As described in the table below, these groups fit not exactly to the MAES ecosystems typology. Therefore to be consistent with 2020 publications using the results of the Article 17 reporting, it has been decided to use the same grouping and results as published in the State of Nature report 2020.

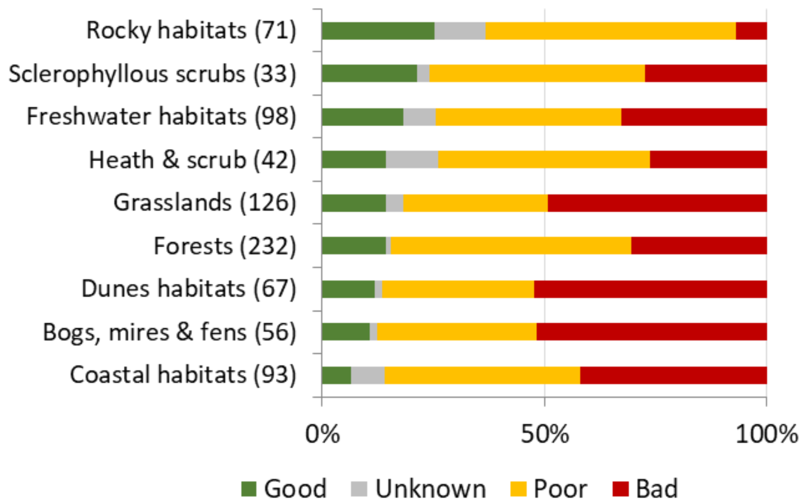
The EU Member States report every six years on the conservation status and trends of these habitats under Art.17 of the directive. The conservation status of each habitat is derived by individually assessing four parameters: natural range, area, structure and functions and future prospects.
Then the EU regional assessments are based on the conservation status and trends reported by MSs.

Conservation status and trends per habitat group are expressed as percentage of total number of assessments.

For the MAES chapter dedicated to Wetlands, three approaches similar to the Ramsar Convention definition, are presented: *Inland Wetlands* (equivalent to Bogs, mires and fens of Annex I Habitat grouping), *Coastal Wetlands* and *Extended Wetlands* as described below.

For the MAES chapter dedicated to Marine ecosystems, as there is no specific marine habitat grouping, information based on conservation status and trends per habitat reported for the five marine regions have been used.

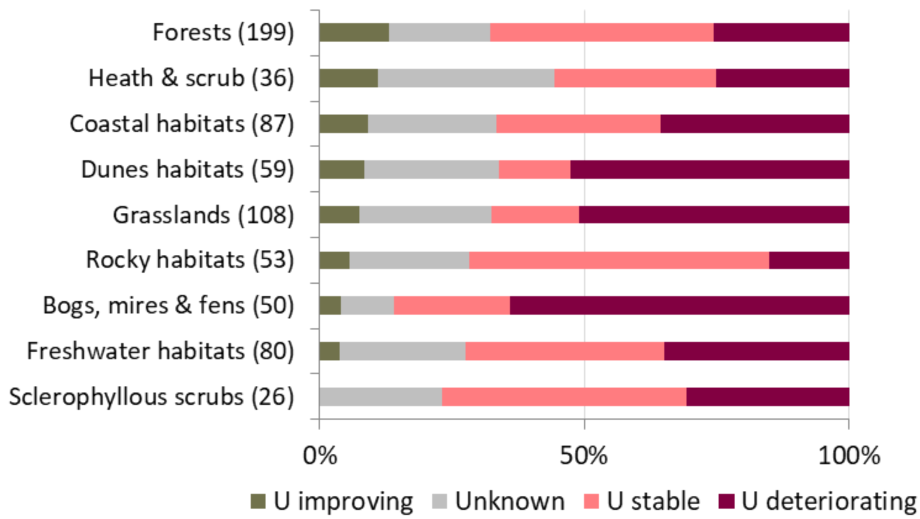
Figure Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**-5 Conservation status per habitat group at the EU level**



Note: Conservation status is based on habitat assessments. The number of assessments is indicated in parentheses. The total number of assessments is 818.

Source: EEA, 2020, Article 17 reports and assessments

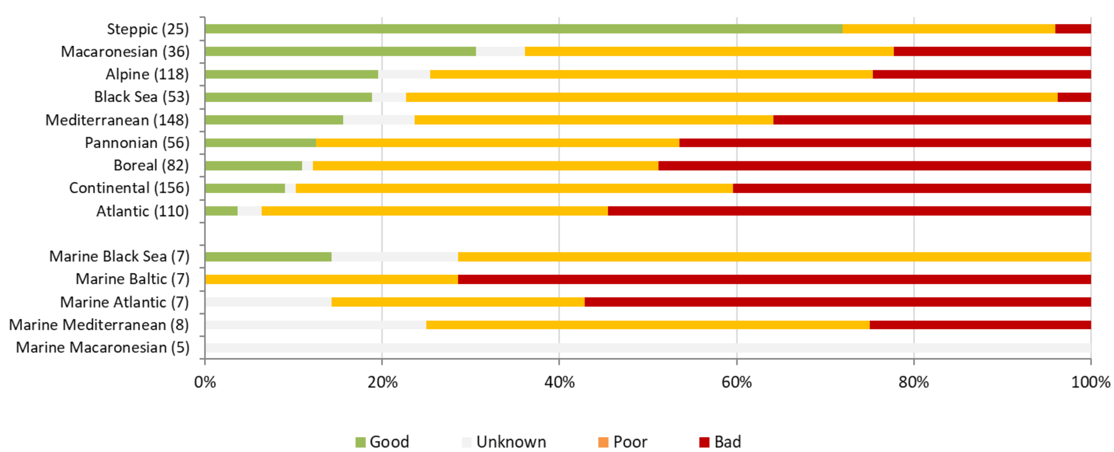
Figure Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**-15 Conservation status trends per habitat group at EU level**



Note: Conservation status trends are based on habitat assessments. The number of assessments is indicated in parentheses. The total number of assessments is 698

Source: EEA, 2020, Article 17 reports and assessments

Figure Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**-7 Conservation status of habitat group for each biogeographic and marine region at EU level**



Note: Conservation status trends are based on habitat assessments. The number of assessments is indicated in parentheses. The total number of assessments is 698
Source: EEA, 2020, Article 17 reports and assessments

Habitat conservation status (nb assessments)	Good	Unknown	Poor	Bad
Coastal habitats (93)	6	7	41	39
Bogs, mires & fens (56)	6	1	20	29
Dunes habitats (67)	8	1	23	35
Forests (232)	33	3	125	71
Grasslands (126)	18	5	41	62
Heath & scrub (42)	6	5	20	11
Freshwater habitats (98)	18	7	41	32
Sclerophyllous scrubs (33)	7	1	16	9
Rocky habitats (71)	18	8	40	5
Total (818)	120	38	367	293
Habitat conservation status (%)	**Good**	**Unknown**	**Poor**	**Bad**
Coastal habitats (93)	6.5%	7.5%	44.1%	41.9%
Bogs, mires & fens (56)	10.7%	1.8%	35.7%	51.8%
Dunes habitats (67)	11.9%	1.5%	34.3%	52.2%
Forests (232)	14.2%	1.3%	53.9%	30.6%
Grasslands (126)	14.3%	4.0%	32.5%	49.2%
Heath & scrub (42)	14.3%	11.9%	47.6%	26.2%
Freshwater habitats (98)	18.4%	7.1%	41.8%	32.7%
Sclerophyllous scrubs (33)	21.2%	3.0%	48.5%	27.3%
Rocky habitats (71)	25.4%	11.3%	56.3%	7.0%
Habitat conservation status trends (nb assessments)	**U improving**	**Unknown**	**U stable**	**U deteriorating**
Sclerophyllous scrubs (26)	0	6	12	8
Freshwater habitats (80)	3	19	30	28
Bogs, mires & fens (50)	2	5	11	32
Rocky habitats (53)	3	12	30	8
Grasslands (108)	8	27	18	55
Dunes habitats (59)	5	15	8	31
Coastal habitats (87)	8	21	27	31
Heath & scrub (36)	4	12	11	9
Forests (199)	26	38	84	51
Total (698)	59	155	231	253
Habitat conservation status trends (%)	**U improving**	**Unknown**	**U stable**	**U deteriorating**
Sclerophyllous scrubs (26)	0.0%	23.1%	46.2%	30.8%
Freshwater habitats (80)	3.8%	23.8%	37.5%	35.0%

Bogs, mires & fens (50)	4.0%	10.0%	22.0%	64.0%
Rocky habitats (53)	5.7%	22.6%	56.6%	15.1%
Grasslands (108)	7.4%	25.0%	16.7%	50.9%
Dunes habitats (59)	8.5%	25.4%	13.6%	52.5%
Coastal habitats (87)	9.2%	24.1%	31.0%	35.6%
Heath & scrub (36)	11.1%	33.3%	30.6%	25.0%
Forests (199)	13.1%	19.1%	42.2%	25.6%

Coastal Wetlands

The Annex I habitats groups don't make distinction with "Coastal Wetlands" as defined in the MAES chapter dedicated to Wetlands.
In the MAES framework, *Coastal wetland* habitats are defined as "Marine" (level 1) and "Marine inlets and transitional waters" ecosystem types (level 2). The Marine inlets and transitional waters ecosystem types are defined in the first MAES report, page 24 (Maes et al, 2013), as "ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5 ‰" which, beside coastal wetlands, also include "lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments".
The Annex I habitats defined as characteristic of "Coastal wetlands" are a subset of the Annex I Coastal Habitats, and the table below lists them with information on Conservation Status and Trends.

	Coastal Wetlands Conservation Status	**Good**	**Poor**	**Bad**	**Unknown**
1130	Estuaries		2	2	
1140	Mudflats and sandflats not covered by seawater at low tide		2	2	1
1150	Coastal lagoons		1	5	
1160	Large shallow inlets and bays		1	3	1
1310	Salicornia and other annuals colonizing mud and sand	1	4	1	
1320	Spartina swards (Spartinion maritimae)		1	3	
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)		1	3	
1650	Boreal Baltic narrow inlets			1	
	Total number of EU assessments	**1**	**12**	**20**	**2**
	Percentage	**2.9%**	**34.3%**	**57.1%**	**5.7%**
	Coastal Wetlands Conservation Status Trends for Unfavourable	**Deteriorating**	**Improving**	**Stable**	**Unknown**
1130	Estuaries			2	2
1140	Mudflats and sandflats not covered by seawater at low tide	1		2	1
1150	Coastal lagoons		3	3	
1160	Large shallow inlets and bays		1		3
1310	Salicornia and other annuals colonizing mud and sand	3	1		1
1320	Spartina swards (Spartinion maritimae)	1		2	1
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)	3		1	
1650	Boreal Baltic narrow inlets			1	
	Total number of EU assessments	**8**	**5**	**11**	**8**
	Percentage	**24.2%**	**15.2%**	**33.3%**	**24.2%**

Extended Wetlands

The Annex I habitats groups don't make distinction with "Extended wetland ecosystem" as defined in the MAES chapter dedicated to Wetlands.

The extended wetland ecosystem is defined according to the Ramsar Convention, signed by all EU-28 parties, which states that wetlands are "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water the depth of which at low tide does not exceed six meters". Furthermore, wetlands "may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six meters at low tide lying within the wetlands".

The Annex I habitats defined as characteristic of "Extended wetland ecosystem" are a selection of the Annex I habitats from different habitat groups. The table below lists them with information on Conservation Status and Trends.

	Extended Wetlands Conservation Status	Good	Poor	Bad	Unknown	
1110	Sandbanks which are slightly covered by sea water all the time		2	2	1	5
1120	Posidonia beds (Posidonion oceanicae)		1			1
1130	Estuaries		2	2		4
1140	Mudflats and sandflats not covered by seawater at low tide		2	2	1	5
1150	Coastal lagoons		1	5		6
1160	Large shallow inlets and bays		1	3	1	5
1170	Reefs		2	1	1	4
1310	Salicornia and other annuals colonizing mud and sand		3	1		4
1320	Spartina swards (Spartinion maritimae)		1	3		4
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)		1	3		4
1340	Inland salt meadows		1	3		4
1410	Mediterranean salt meadows (Juncetalia maritimi)		3	2		5
1510	Mediterranean salt steppes (Limonietalia)			1		1
1530	Pannonic salt steppes and salt marshes	1	3			4
1630	Boreal Baltic coastal meadows			2		2
1650	Boreal Baltic narrow inlets			1		1
2170	Dunes with Salix repens ssp. argentea (Salicion arenariae)			1		1
2190	Humid dune slacks		2	3		5
3110	Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae)	1	3	1		5
3120	Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with Isoetes spp.			2		2
3130	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea	2	3	4		9
3140	Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.	2	3	3		8
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation	1	3	4	1	9
3160	Natural dystrophic lakes and ponds	3	3	2		8
3170	Mediterranean temporary ponds		1	3	1	5
3180	Turloughs	1	3			4
3190	Lakes of gypsum karst	1		1	1	3
31A0	Transylvanian hot-spring lotus beds			1		1
3210	Fennoscandian natural rivers	1	2			3
3220	Alpine rivers and the herbaceous vegetation along their banks	2	2		2	6
3230	Alpine rivers and their ligneous vegetation with Myricaria germanica		1	2		3
3240	Alpine rivers and their ligneous vegetation with Salix elaeagnos		2	2		4
3250	Constantly flowing Mediterranean rivers with Glaucium flavum			2	1	3
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation	1	5	2		8
3270	Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation	3	4	1		8
3280	Constantly flowing Mediterranean rivers with Paspalo-Agrostidion species and hanging curtains of Salix and Populus alba		2	1		3
3290	Intermittently flowing Mediterranean rivers of the Paspalo-Agrostidion		1			1
4010	Northern Atlantic wet heaths with Erica tetralix		1	3		4
4020	Temperate Atlantic wet heaths with Erica ciliaris and Erica tetralix		2	2		4
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)	2	1	5		8
6420	Mediterranean tall humid grasslands of the Molinio-Holoschoenion		4	2		6
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	1	5	2		8
6440	Alluvial meadows of river valleys of the Cnidion dubii	3		3		6
6450	Northern boreal alluvial meadows			2		2
6460	Peat grasslands of Troodos	1				1
7110	Active raised bogs		1	6		7
7120	Degraded raised bogs still capable of natural regeneration	1		4		5
7130	Blanket bogs (* if active bog)	1		2		3
7140	Transition mires and quaking bogs		4	3		7
7150	Depressions on peat substrates of the Rhynchosporion		3	2		5
7160	Fennoscandian mineral-rich springs and springfens	1		2		3
7210	Calcareous fens with Cladium mariscus and species of the Caricion davallianae	2	2	2		6
7220	Petrifying springs with tufa formation (Cratoneurion)		6	1		7
7230	Alkaline fens		2	4		6
7240	Alpine pioneer formations of Caricion bicoloris-atrofuscae		1	1	2	4
7310	Aapa mires	1	1			2
7320	Palsa mires			2		2
91D0	Bog woodland	1	3	2		6
91E0	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)		1	6		7
91F0	Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris)		3	5		8
92B0	Riparian formations on intermittent Mediterranean water courses with Rhododendron ponticum, Salix and others		1			1
	Total number of EU assessments	**33**	**104**	**127**	**12**	276
	Percentage	**12.0%**	**37.7%**	**46.0%**	**4.3%**	100.0%

	Extended Wetlands Conservation Status Trends for Unfavourable	Deteriorating	Improving	Stable	Unknown	
1110	Sandbanks which are slightly covered by sea water all the time	2	1	1	1	5
1120	Posidonia beds (Posidonion oceanicae)				1	1
1130	Estuaries			2	2	4
1140	Mudflats and sandflats not covered by seawater at low tide	1		2	1	4
1150	Coastal lagoons		3	3		6
1160	Large shallow inlets and bays		1		3	4
1170	Reefs	1			3	4
1310	Salicornia and other annuals colonizing mud and sand	3			1	4
1320	Spartina swards (Spartinion maritimae)	1		2	1	4
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)	3		1		4
1340	Inland salt meadows	3		1		4
1410	Mediterranean salt meadows (Juncetalia maritimi)	4		1		5
1510	Mediterranean salt steppes (Limonietalia)				1	1
1530	Pannonic salt steppes and salt marshes			3		3
1630	Boreal Baltic coastal meadows		1	1		2
1650	Boreal Baltic narrow inlets			1		1
2170	Dunes with Salix repens ssp. argentea (Salicion arenariae)	1				1
2190	Humid dune slacks	3			2	5
3110	Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae)	2		2		4
3120	Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with Isoetes spp.	1		1		2
3130	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea	4		3		7
3140	Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.	4		2		6
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation	1		6	1	8
3160	Natural dystrophic lakes and ponds	1		4		5
3170	Mediterranean temporary ponds	2		1	2	5
3180	Turloughs		1	2		3
3190	Lakes of gypsum karst	1			1	2
31A0	Transylvanian hot-spring lotus beds	1				1
3210	Fennoscandian natural rivers	1		1		2
3220	Alpine rivers and the herbaceous vegetation along their banks	2			2	4
3230	Alpine rivers and their ligneous vegetation with Myricaria germanica	1	1		1	3
3240	Alpine rivers and their ligneous vegetation with Salix elaeagnos	3		1		4
3250	Constantly flowing Mediterranean rivers with Glaucium flavum	1		1	1	3
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation	2	1	3	1	7
3270	Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation	1		1	3	5
3280	Constantly flowing Mediterranean rivers with Paspalo-Agrostidion species and hanging curtains of Salix and Populus alba				3	3
3290	Intermittently flowing Mediterranean rivers of the Paspalo-Agrostidion				1	1
4010	Northern Atlantic wet heaths with Erica tetralix	3	1			4
4020	Temperate Atlantic wet heaths with Erica ciliaris and Erica tetralix			2	2	4
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)	6				6
6420	Mediterranean tall humid grasslands of the Molinio-Holoschoenion	3	1	1	1	6
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	3	2		2	7
6440	Alluvial meadows of river valleys of the Cnidion dubii	1		2		3
6450	Northern boreal alluvial meadows	1			1	2
7110	Active raised bogs	6		1		7
7120	Degraded raised bogs still capable of natural regeneration			2	2	4
7130	Blanket bogs (* if active bog)	2				2
7140	Transition mires and quaking bogs	5		2		7
7150	Depressions on peat substrates of the Rhynchosporion	3		1	1	5
7160	Fennoscandian mineral-rich springs and springfens	2				2
7210	Calcareous fens with Cladium mariscus and species of the Caricion davallianae	3		1		4
7220	Petrifying springs with tufa formation (Cratoneurion)	2	1	3	1	7
7230	Alkaline fens	6				6
7240	Alpine pioneer formations of Caricion bicoloris-atrofuscae	1	1	1		3
7310	Aapa mires	1				1
7320	Palsa mires	2				2
91D0	Bog woodland	4		1		5
91E0	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)	5	1		1	7
91F0	Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris)	3	1	3	1	8
92B0	Riparian formations on intermittent Mediterranean water courses with Rhododendron ponticum, Salix and others				1	1
	Total number of EU assessments	**112**	**17**	**66**	**45**	240

Lists of Annex I Habitats grouping

Coastal habitats

habitatcode	HDname
1110	Sandbanks which are slightly covered by sea water all the time
1120	Posidonia beds (Posidonion oceanicae)
1130	Estuaries
1140	Mudflats and sandflats not covered by seawater at low tide
1150	Coastal lagoons
1160	Large shallow inlets and bays
1170	Reefs
1180	Submarine structures made by leaking gases
1210	Annual vegetation of drift lines
1220	Perennial vegetation of stony banks
1230	Vegetated sea cliffs of the Atlantic and Baltic Coasts
1240	Vegetated sea cliffs of the Mediterranean coasts with endemic Limonium spp.
1250	Vegetated sea cliffs with endemic flora of the Macaronesian coasts
1310	Salicornia and other annuals colonizing mud and sand
1320	Spartina swards (Spartinion maritimae)
1330	Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
1340	Inland salt meadows
1410	Mediterranean salt meadows (Juncetalia maritimi)
1420	Mediterranean and thermo-Atlantic halophilous scrubs (Sarcocornetea fruticosi)
1430	Halo-nitrophilous scrubs (Pegano-Salsoletea)
1510	Mediterranean salt steppes (Limonietalia)
1520	Iberian gypsum vegetation (Gypsophiletalia)
1530	Pannonic salt steppes and salt marshes
1610	Baltic esker islands with sandy, rocky and shingle beach vegetation and sublittoral vegetation
1620	Boreal Baltic islets and small islands
1630	Boreal Baltic coastal meadows
1640	Boreal Baltic sandy beaches with perennial vegetation
1650	Boreal Baltic narrow inlets

Dunes habitats

habitatcode	HDname
2110	Embryonic shifting dunes
2120	Shifting dunes along the shoreline with Ammophila arenaria (‘white dunes’)
2130	Fixed coastal dunes with herbaceous vegetation (“grey dunes’)
2140	Decalcified fixed dunes with Empetrum nigrum
2150	Atlantic decalcified fixed dunes (Calluno-Ulicetea)
2160	Dunes with Hippophae rhamnoides
2170	Dunes with Salix repens ssp. argentea (Salicion arenariae)
2180	Wooded dunes of the Atlantic, Continental and Boreal region
2190	Humid dune slacks
21A0	Machairs (* in Ireland)
2210	Crucianellion maritimae fixed beach dunes
2220	Dunes with Euphorbia terracina
2230	Malcolmietalia dune grasslands
2240	Brachypodietalia dune grasslands with annuals
2250	Coastal dunes with Juniperus spp.
2260	Cisto-Lavenduletalia dune sclerophyllous scrubs
2270	Wooded dunes with Pinus pinea and/or Pinus pinaster
2310	Dry sand heaths with Calluna and Genista
2320	Dry sand heaths with Calluna and Empetrum nigrum
2330	Inland dunes with open Corynephorus and Agrostis grasslands
2340	Pannonic inland dunes

Freshwater habitats

habitatcode	HDname
3110	Oligotrophic waters containing very few minerals of sandy plains (Littorelletalia uniflorae)
3120	Oligotrophic waters containing very few minerals generally on sandy soils of the West Mediterranean, with Isoetes spp.
3130	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea
3140	Hard oligo-mesotrophic waters with benthic vegetation of Chara spp.
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition — type vegetation
3160	Natural dystrophic lakes and ponds
3170	Mediterranean temporary ponds
3180	Turloughs
3190	Lakes of gypsum karst
31A0	Transylvanian hot-spring lotus beds
3210	Fennoscandian natural rivers
3220	Alpine rivers and the herbaceous vegetation along their banks
3230	Alpine rivers and their ligneous vegetation with Myricaria germanica
3240	Alpine rivers and their ligneous vegetation with Salix elaeagnos
3250	Constantly flowing Mediterranean rivers with Glaucium flavum
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
3270	Rivers with muddy banks with Chenopodion rubri p.p. and Bidention p.p. vegetation
3280	Constantly flowing Mediterranean rivers with Paspalo-Agrostidion species and hanging curtains of Salix and Populus alba
3290	Intermittently flowing Mediterranean rivers of the Paspalo-Agrostidion
32A0	Tufa cascades of karstic rivers in the Dinaric Alps

Heaths and Scrub

habitatcode	HDname
4010	Northern Atlantic wet heaths with Erica tetralix
4020	Temperate Atlantic wet heaths with Erica ciliaris and Erica tetralix
4030	European dry heaths
4040	Dry Atlantic coastal heaths with Erica vagans
4050	Endemic macaronesian heaths
4060	Alpine and Boreal heaths
4070	Bushes with Pinus mugo and Rhododendron hirsutum (Mugo-Rhododendretum hirsuti)
4080	Sub-Arctic Salix spp. scrub
4090	Endemic oro-Mediterranean heaths with gorse
40A0	Subcontinental peri-Pannonic scrub
40B0	Rhodope Potentilla fruticosa thickets
40C0	Ponto-Sarmatic deciduous thickets

Sclerophyllous scrubs

habitatcode	HDname
5110	Stable xerothermophilous formations with Buxus sempervirens on rock slopes (Berberidion p.p.)
5120	Mountain Cytisus purgans formations
5130	Juniperus communis formations on heaths or calcareous grasslands
5140	Cistus palhinhae formations on maritime wet heaths
5210	Arborescent matorral with Juniperus spp.
5220	Arborescent matorral with Zyziphus
5230	Arborescent matorral with Laurus nobilis
5310	Laurus nobilis thickets
5320	Low formations of Euphorbia close to cliffs
5330	Thermo-Mediterranean and pre-desert scrub
5410	West Mediterranean clifftop phryganas (Astragalo-Plantaginetum subulatae)
5420	Sarcopoterium spinosum phryganas
5430	Endemic phryganas of the Euphorbio-Verbascion

Grasslands

habitatcode	HDname
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)
6220	Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea
6230	Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)
6240	Sub-Pannonic steppic grasslands
6250	Pannonic loess steppic grasslands
6260	Pannonic sand steppes
6270	Fennoscandian lowland species-rich dry to mesic grasslands
6280	Nordic alvar and precambrian calcareous flatrocks
62A0	Eastern sub-Mediterranean dry grasslands (Scorzoneratalia villosae)
6110	Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi
6120	Xeric sand calcareous grasslands
6130	Calaminarian grasslands of the Violetalia calaminariae
6140	Siliceous Pyrenean Festuca eskia grasslands
6150	Siliceous alpine and boreal grasslands
6160	Oro-Iberian Festuca indigesta grasslands
6170	Alpine and subalpine calcareous grasslands
6180	Macaronesian mesophile grasslands
6190	Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis)
62B0	Serpentinophilous grassland of Cyprus
62C0	Ponto-Sarmatic steppes
62D0	Oro-Moesian acidophilous grasslands
6310	Dehesas with evergreen Quercus spp.
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (Molinion caeruleae)
6420	Mediterranean tall humid grasslands of the Molinio-Holoschoenion
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6440	Alluvial meadows of river valleys of the Cnidion dubii
6450	Northern boreal alluvial meadows
6460	Peat grasslands of Troodos
6510	Lowland hay meadows (Alopecurus pratensis, Sanguisorba officinalis)
6520	Mountain hay meadows
6530	Fennoscandian wooded meadows
6540	Sub-Mediterranean grasslands of the Molinio-Hordeion secalini

Bogs, mires & fens

habitatcode	HDname
7110	Active raised bogs
7120	Degraded raised bogs still capable of natural regeneration
7130	Blanket bogs (* if active bog)
7140	Transition mires and quaking bogs
7150	Depressions on peat substrates of the Rhynchosporion
7160	Fennoscandian mineral-rich springs and springfens
7210	Calcareous fens with Cladium mariscus and species of the Caricion davallianae
7220	Petrifying springs with tufa formation (Cratoneurion)
7230	Alkaline fens
7240	Alpine pioneer formations of the Caricion bicoloris-atrofuscae
7310	Aapa mires
7320	Palsa mires

Rocky habitats

habitatcode	HDname
8110	Siliceous scree of the montane to snow levels (Androsacetalia alpinae and Galeopsietalia ladani)
8120	Calcareous and calcshist screes of the montane to alpine levels (Thlaspietea rotundifolii)
8130	Western Mediterranean and thermophilous scree
8140	Eastern Mediterranean screes
8150	Medio-European upland siliceous screes
8160	Medio-European calcareous scree of hill and montane levels
8210	Calcareous rocky slopes with chasmophytic vegetation
8220	Siliceous rocky slopes with chasmophytic vegetation
8230	Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo albi-Veronicion dillenii
8240	Limestone pavements
8310	Caves not open to the public
8320	Fields of lava and natural excavations
8330	Submerged or partially submerged sea caves
8340	Permanent glaciers

Forests

habitatcode	HDname
9010	Western Taïga
9020	Fennoscandian hemiboreal natural old broad-leaved deciduous forests (Quercus, Tilia, Acer, Fraxinus or Ulmus) rich in epiphytes
9030	Natural forests of primary succession stages of landupheaval coast
9040	Nordic subalpine/subarctic forests with Betula pubescens ssp. czerepanovii
9050	Fennoscandian herb-rich forests with Picea abies
9060	Coniferous forests on, or connected to, glaciofluvial eskers
9070	Fennoscandian wooded pastures
9080	Fennoscandian deciduous swamp woods
9110	Luzulo-Fagetum beech forests
9120	Atlantic acidophilous beech forests with Ilex and sometimes also Taxus in the shrublayer (Quercion robori-petraeae or Ilici-Fagenion)
9130	Asperulo-Fagetum beech forests
9140	Medio-European subalpine beech woods with Acer and Rumex arifolius
9150	Medio-European limestone beech forests of the Cephalanthero-Fagion
9160	Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli
9170	Galio-Carpinetum oak-hornbeam forests
9180	Tilio-Acerion forests of slopes, screes and ravines
9190	Old acidophilous oak woods with Quercus robur on sandy plains
91A0	Old sessile oak woods with Ilex and Blechnum in the British Isles
91AA	Eastern white oak woods
91B0	Thermophilous Fraxinus angustifolia woods
91BA	Moesian silver fir forests
91C0	Caledonian forest
91CA	Rhodopide and Balkan Range Scots pine forests
91D0	Bog woodland
91E0	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)
91F0	Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris)
91G0	Pannonic woods with Quercus petraea and Carpinus betulus
91H0	Pannonian woods with Quercus pubescens
91I0	Euro-Siberian steppic woods with Quercus spp.
91J0	Taxus baccata woods of the British Isles
91K0	Illyrian Fagus sylvatica forests (Aremonio-Fagion)
91L0	Illyrian oak-hornbeam forests (Erythronio-Carpinion)
91M0	Pannonian-Balkanic turkey oak –sessile oak forests
91N0	Pannonic inland sand dune thicket (Junipero-Populetum albae)
91P0	Holy Cross fir forest (Abietetum polonicum)
91Q0	Western Carpathian calcicolous Pinus sylvestris forests

91R0	Dinaric dolomite Scots pine forests (Genisto januensis-Pinetum)
91S0	Western Pontic beech forests
91T0	Central European lichen Scots pine forests
91U0	Sarmatic steppe pine forest
91V0	Dacian Beech forests (Symphyto-Fagion)
91W0	Moesian beech forests
91X0	Dobrogean beech forests
91Y0	Dacian oak & hornbeam forests
91Z0	Moesian silver lime woods
9210	Apeninne beech forests with Taxus and Ilex
9220	Apennine beech forests with Abies alba and beech forests with Abies nebrodensis
9230	Galicio-Portuguese oak woods with Quercus robur and Quercus pyrenaica
9240	Quercus faginea and Quercus canariensis Iberian woods
9250	Quercus trojana woods
9260	Castanea sativa woods
9270	Hellenic beech forests with Abies borisii-regis
9280	Quercus frainetto woods
9290	Cupressus forests (Acero-Cupression)
92A0	Salix alba and Populus alba galleries
92B0	Riparian formations on intermittent Mediterranean water courses with Rhododendron ponticum, Salix and others
92C0	Platanus orientalis and Liquidambar orientalis woods (Platanion orientalis)
92D0	Southern riparian galleries and thickets (Nerio-Tamaricetea and Securinegion tinctoriae)
9310	Aegean Quercus brachyphylla woods
9320	Olea and Ceratonia forests
9330	Quercus suber forests
9340	Quercus ilex and Quercus rotundifolia forests
9350	Quercus macrolepis forests
9360	Macaronesian laurel forests (Laurus, Ocotea)
9370	Palm groves of Phoenix
9380	Forests of Ilex aquifolium
9390	Scrub and low forest vegetation with Quercus alnifolia
93A0	Woodlands with Quercus infectoria (Anagyro foetidae-Quercetum infectoriae)
9410	Acidophilous Picea forests of the montane to alpine levels (Vaccinio-Piceetea)
9420	Alpine Larix decidua and/or Pinus cembra forests
9430	Subalpine and montane Pinus uncinata forests (* if on gypsum or limestone)
9510	Southern Apennine Abies alba forests
9520	Abies pinsapo forests
9530	(Sub-) Mediterranean pine forests with endemic black pines
9540	Mediterranean pine forests with endemic Mesogean pines
9550	Canarian endemic pine forests
9560	Endemic forests with Juniperus spp.
9570	Tetraclinis articulata forests
9580	Mediterranean Taxus baccata woods
9590	Cedrus brevifolia forests (Cedrosetum brevifoliae)
95A0	High oro-Mediterranean pine forests

Fact sheet 3.6.101: Land take in freshwaters

1. General information

- Freshwaters
- Pressure: Habitat conversion and degradation (Land conversion)
- Land take
- km^2/18 year

2. Data sources

The indicator based on readily available data: Land take indicator. EEA CSI 014

- Data holder: EEA
- Weblinks
  - Rivers and Lakes https://tableau.discomap.eea.europa.eu/t/Landonline/views/Landtakeindicator/Landtakeandnetlandtakeindicator.
  - Potentially flooded land https://tableau.discomap.eea.europa.eu/#/site/Landonline/views/RiparianZonesanalysis2019-DRAFT/RiparianZoneanalysiswithinpotentialfloodproneareas?:iid=1
- Time-series range: 2000 - 2018
- Version: EEA Land Take viewer version end June 2019 (based on CLC v20)
- Access date 14/10/2019
- Reference: https://www.eea.europa.eu/data-and-maps/indicators/land-take-2/assessment-1

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The main objective of this indicator is to measure the pressure from the development of urban and other artificial land use on natural and managed landscapes that are necessary 'to protect and restore the functioning of natural systems and halt the loss of biodiversity' (Sixth Environment Action Programme; 6th EAP, COM(2001)31).

Land use in Europe is driven by a number of factors such as the increasing demand for living space per person, the link between economic activity, increased mobility and the growth of transport infrastructure, which usually result in urban expansion. The impact of urbanisation depends on the area of land taken and on the intensity of land use, for example, the degree of soil sealing and the population density. Land take by urban areas and infrastructure is generally irreversible and results in soil sealing, i.e. the loss of soil resources due to the covering of land for housing, roads or other construction work. Converted areas become highly specialised in terms of land use and support few functions related to socio-economic activities and housing. Urban land take consumes mostly agricultural land, but also reduces space for habitats and ecosystems that provide important services such as the regulation of the water balance and protection against floods, particularly if soil is highly sealed. Land occupied by man-made surfaces and dense infrastructure connects human settlements and fragments landscapes. It is also a significant source of water, soil and air pollution.

This indicator looks at the change in the amount (in ha per 6 years) of land taken by urban and other artificial land development. It includes areas sealed by construction and urban infrastructure, as well as urban green areas, and sport and leisure facilities. The main drivers of land take are grouped in processes resulting in the extension of:

- housing, services and recreation;
- industrial and commercial sites;
- transport networks and infrastructures;
- mines, quarries and waste dumpsites;
- construction sites.

For freshwater ecosystems two indicators of land takes were evaluated:

(i) Land take of Rivers and Lakes – in this case, land take was measured for Corine CLC classes of Rivers and Lakes, and

(ii) Land take in potential flood prone areas. In this case, areas that may be subject to flooding by events with a return time of 100 years (see Fact sheet on Freshwater extent) was considered. This second indicator include riparian and floodplain areas where several freshwater ecosystem services take place, and is thus appropriate to assess their rate of conversion into artificial land. Land take in potential flood prone areas was assessed in 2000 to 2018 for long term trends and 2012-2018 for the short term trend.

3.2. Tables

Land take indicators were provided as tabular information aggregated at country and EU-28 level (Table 1). Land take of Rivers and Lakes in EU-28 was 23 km^2 from 2000 to 2018, with largest land take in the Netherlands and Germany. Land take was mostly due to conversion of land into mines, dumpsites and construction sites. In 2012-2018 land take of rivers and lakes amounted to 7.24 km^2 in EU-28 (Table 2), 41% of which due to conversion to mines, followed by a 26% of construction sites.

Land take in potential flood-prone areas in 2000-2018 amounted to 1325 km^2, equal to 0.4% of the land considered (Table 1). The largest land take was recorded in the Netherlands and France. Mostly, land take occurred at the expenses of agricultural land. Transition from cropland or grassland into artificial areas accounted for 93% of land take, whereas 5% was from conversion of woodlands. Land take in the most recent time (2012-2018) amounted to 318 km^2 and spatial and temporal trends did not differed from the long term 2000-2018 observations.

3.3. Statistical analysis of the trend

- No statistical test could be performed on the data. The 5%/decade change rule was applied to assess weather changes were significant from an ecological point of view.

3.4. Key trend at EU level

Decadal change of land take in rivers and lakes was estimated at 0.01% per decade in both the long and the short term periods; land take in potential floodplain areas was estimated at 0.15%-0.2%. Conditions were thus considered stable both in the short and long term.

Table 1. Land take in 2000-2018 of River and Lakes and potential flood-prone areas per country and at EU-28 scale.

	Rivers and Lakes	Potential flood-prone areas	
	km^2	km^2	% of area
Austria	0.12	33.63	0.6%
Belgium	2.32	18.02	0.9%
Bulgaria	0.78	7.31	0.1%
Croatia	0.02	25.25	0.4%
Cyprus	0	1.08	1.8%
Czechia	0.09	24.14	0.6%
Denmark	0	0.47	0.1%
Estonia	0	3.7	0.1%
Finland	1.02	4.64	0.0%
France	1.53	192.53	0.6%
Germany	4.49	114.05	0.4%
Greece	0.01		0.0%
Hungary	0.87	62.81	0.3%
Ireland	0.07	0.77	0.0%
Italy	0.4	143.32	0.5%
Latvia	0.49	8.82	0.2%
Lithuania	0.01		0.0%
Luxembourg	0	0.41	0.5%
Malta	0		
Netherlands	3.83	200.85	2.3%
Poland	1.02	102.85	0.4%
Portugal	1.83	8.21	0.2%
Romania	0.08	67.99	0.2%
Slovakia	0	32.65	0.5%
Slovenia	0.05	2.92	0.2%
Spain	2	198.95	0.7%
Sweden	0.98	16.03	0.0%
United Kingdom	0.96	53.4	0.4%
EU-28	*22.97*	*1324.8*	*0.4%*

Table 2. Land take in 2012-2018 of River and Lakes and potential flood-prone areas per country and at EU-28 scale.

	Rivers and Lakes	Potential flood-prone areas	
	km^2	km^2	% of area
Austria	0.12	9.25	0.2%
Belgium	0.73	7.38	0.4%
Bulgaria	0.3	2.54	0.0%
Croatia	0	9.91	0.1%
Cyprus	0	0.35	0.6%
Czechia	0	4.18	0.1%
Denmark	0	0.2	0.0%
Estonia	0	0.98	0.0%
Finland	0.12	1.24	0.0%
France	1.31	36.23	0.1%
Germany	1.74	33.37	0.1%
Greece	0.05	0	0.0%
Hungary	0.54	19.38	0.1%
Ireland	0	0	0.0%
Italy	0.56	17.71	0.1%
Latvia	0.16	1.97	0.1%
Lithuania	0	0	0.0%
Luxembourg	0	0.08	0.1%
Malta	0	0	
Netherlands	0.48	35.99	0.4%
Poland	0.77	38.33	0.2%
Portugal	0	1.01	0.0%
Romania	0.08	41.3	0.2%
Slovakia	0	11.25	0.2%
Slovenia	0.05	1.75	0.1%
Spain	0.06	13.4	0.0%
Sweden	0	2.52	0.0%
United Kingdom	0.17	28.17	0.2%
EU-28	*7.24*	*318.49*	*0.1%*

Fact sheet 3.6.102: Atmospheric Deposition of Nitrogen

1. General information

- Freshwater ecosystems
- Pressure: Pollution and nutrient enrichment
- Atmospheric deposition (Nitrogen)
- kg/ha/y

2. Data sources

- Data holder: EMEP
- Weblink: https://emep.int/mscw/mscw_moddata.html with files from http://thredds.met.no/thredds/catalog/data/EMEP/2018_Reporting/catalog.html
- Years: 2000-2016
- Access date: 19/07/2019
- References:
  - https://emep.int/publ/reports/2018/EMEP_Status_Report_1_2018.pdf
  - https://www.atmos-chem-phys.net/12/7825/2012/acp-12-7825-2012.html
- Spatial Resolution: Nuts2

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Air pollution of nitrogen gases emitted by agricultural and industrial activities is harmful to human and ecosystem health, contributing to acidification and eutrophication of rivers and lakes. Nitrogen emitted in the air in form of gases returns on land and surface waters through wet and dry deposition. Part of the nitrogen deposited on land may reach waters through surface or subsurface pathways, whereas deposition on waters enters the water cycle directly, enriching nutrient content of river and lake waters. In Europe, air pollution impacts peaked in the 1980s (for acidification) through 1990s (for euthrophication). International legislation, particularly the EU National Emission Directive (EC, 2001; 2016), prompted pollution reduction investments that triggered a general improvement of environmental conditions.

Air pollution and nitrogen deposition are significantly affected by both emissions and weather conditions. Annual nitrogen deposition at the European continent scale is modelled by European Modelling and Evaluation Programme (EMEP). Nitrogen deposition (NDEP, kg/ha) is the sum of four annual components, i.e. oxidized (OX) or reduced (RD) nitrogen components, each with wet (W) or dry (D) deposition:

NDEP = (DDEP_OXN_m2Grid + DDEP_RDN_m2Grid) + (WDEP_OXN + WDEP_RDN)

For this assessment, annual nitrogen deposition for 2000-2016 was averaged at Nuts2 scale, providing important information of this nutrient source in time. No differentiation was made on where deposition occurred, i.e. on land or water, thus basin attenuation of nitrogen deposited on land before entering the stream network was not accounted for. Also, ecosystem response to nitrogen deposition is non-linear, as harmful effects appears when deposition exceeds ecosystem thresholds (critical load concept). The nitrogen deposition indicator does not consider critical load exceedance, thus is not a measure of direct impact on the freshwater ecosystem.

3.2. Maps

Figure 1 shows nitrogen deposition (in kg/ha) in 2005, 2010, 2015, showing that the central part of Europe from North to South is the most exposed to nitrogen deposition.

The rate of change, assessed through ordinary least square regression from 2010 (reference year) to 2016 (latest available year) for each spatial unit and reported only where it is significant at probability level of 5%, indicates that conditions since 2010 are generally static except in the Baltic region where nitrogen deposition is declining. In one NUTS2 region (in Germany) N deposition was reported to be increasing in 2010-2016, however the longer term time series (2000-2016) indicated a decline.

3.3. Statistical analysis of the trend

- Rates of change were assessed by Ordinary Least Square regression for the long (2000-2016) and the short (2010-2016) period, both at EU-28 and at Nuts2 scale (Figure 1). Change was reported only if significant at 5% probability level.

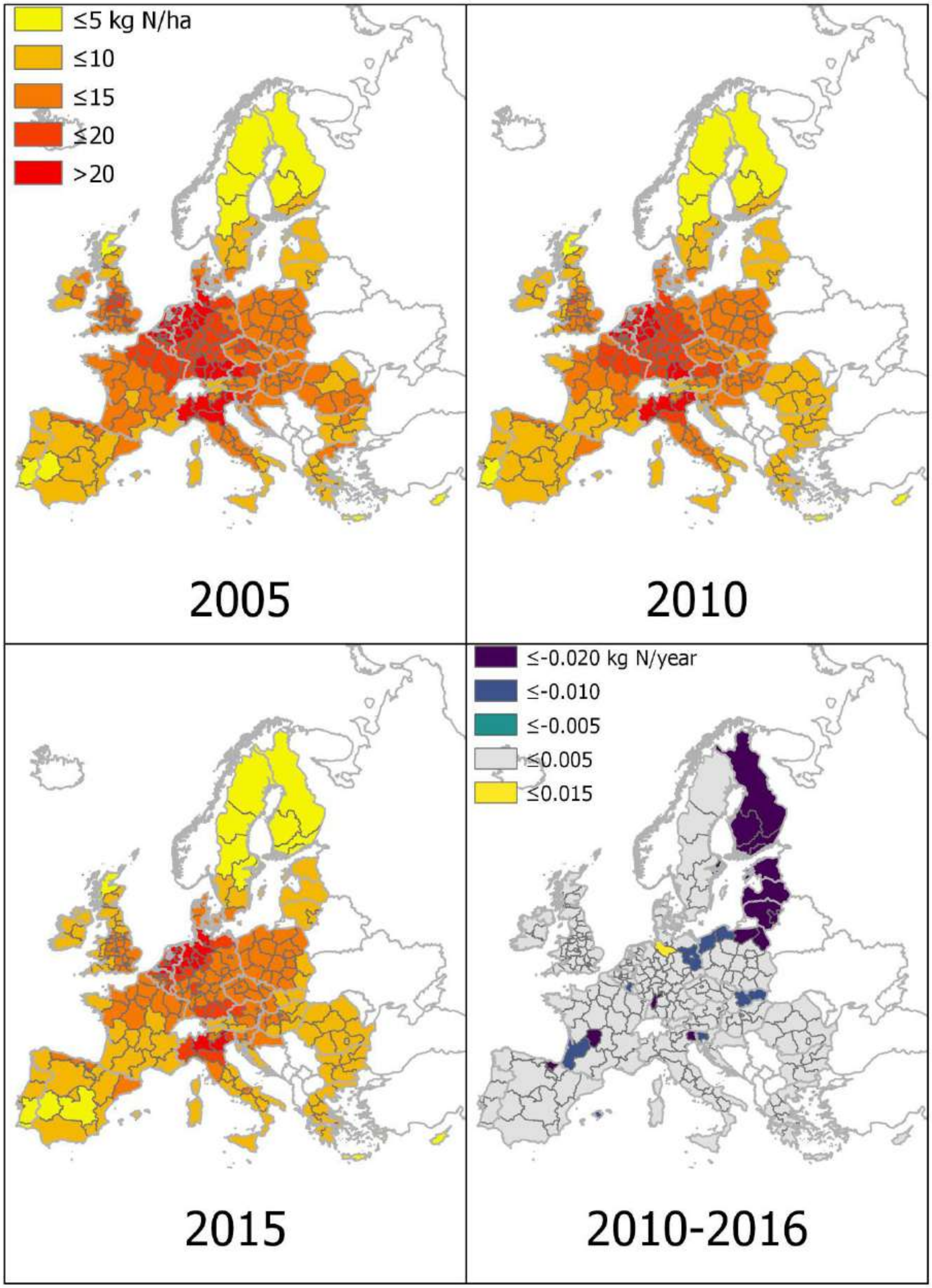


Figure 1. Mean annual atmospheric deposition of nitrogen (kg/ha) in Europe in 2005, 2010, 2015, and annual rate of change (kg N/year) for the 2010-2016 (latest year) period. Data source: EMEP

3.4. Key trend at EU level

In 2010, nitrogen deposition on the EU-28 territory was estimated at 9.59 kg/ha. During the 17 years of available data (2000-2016), nitrogen deposition has reduced steadily (Figure 2) at a rate of change for the whole period (estimated through ordinary least square regression) of -0.17 kg/ha (-18%) over a decade. Large reductions of deposition have been attained in the most polluted areas of Europe, such as Benelux, Germany, France, the United Kingdom, and Italy (Figure 1), indicating a reduction of pollution pressure for freshwater ecosystems.

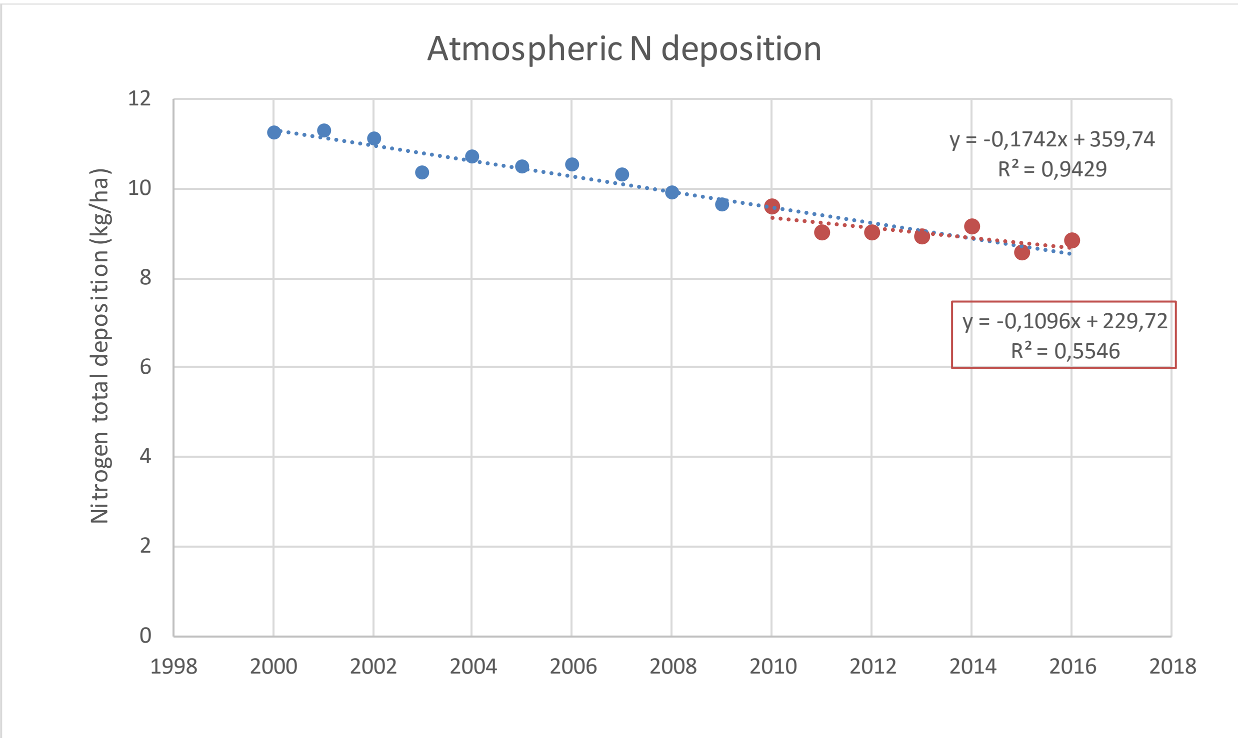


Figure 2. Long and short term trend of atmospheric nitrogen deposition in the EU-28 territory from 2000 to 2016.

The rate of change appears to have slowed for 2010-2016, and was estimated at -0.12 kg N/decade, but this change was significant only at $p < 10\%$, thus at EU-28 scale the short term trend was considered stable. Significant ($p < 5\%$) reductions since 2010 are reported only in some areas, particularly in the Baltic (figure 1). In one case nitrogen deposition increased in 2010-2016, but this short-term trend is in contrast with the entire 2000-2016 period of the same area.

Fact sheet 3.6.103a: Domestic waste emissions to the environment trend

1. General information

- Freshwater ecosystems
- Pressure: Pollution and nutrient enrichment
- Domestic emissions trends
- % of population whose waste is treated at least at secondary level

2. Data sources

- Data holder: EUROSTAT
- Weblink: https://ec.europa.eu/eurostat/en/web/products-datasets/-/ENV_WW_CON ; https://ec.europa.eu/eurostat/en/web/products-datasets/-/MIGR_POP3CTB
- Years: 2007-2015
- Access date: 20/6/2019
- Spatial Resolution: MS and EU-27 (no data for Slovakia)

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Pollutant emissions from domestic sources impact freshwaters altering nutrient balance. Domestic waste comprises emissions from point sources, i.e. direct discharges to river network form wastewater treatment plans and sewerage systems without treatment, and from diffuse sources, i.e. disconnected dwellings and independent appropriate systems. Wastewater treatment may reduce emissions to the environment to large extent when treatment level increases to at least secondary. Higher population rates connected to at least secondary treatment, therefore, indicate a reduction in domestic waste emissions.

Trends of domestic waste emissions were estimated from EUROSTAT data of population and the share of population that is connected to at least secondary level to calculate the amount of people whose waste was treated in at least secondary treatment level. However, no calculation of pollution load change was performed as this depends on amount of emitted pollution load/PE and treatment efficiency, both of which vary with the pollutant agent (e.g. see fact sheet 3.6.103b). The period of assessment is 2007-2015, for which shares of population connected to at least secondary level was available. Some reporting gaps in data series for each member state were noted; for years where figures were not reported, these were interpolated between the two closest information, or taking the first or last available year. Slovakia did not report this information so it was excluded from the analysis. This indicator is supplementary to maps of domestic waste emissions shown in 'Domestic waster emissions to the environment' that refer to years 2014-2015 (fact sheet 3.6.103b).

3.2. Maps

Population (Millions if inhabitants) and rate of change of population connected to at least secondary treatment level are shown in Figure 1.

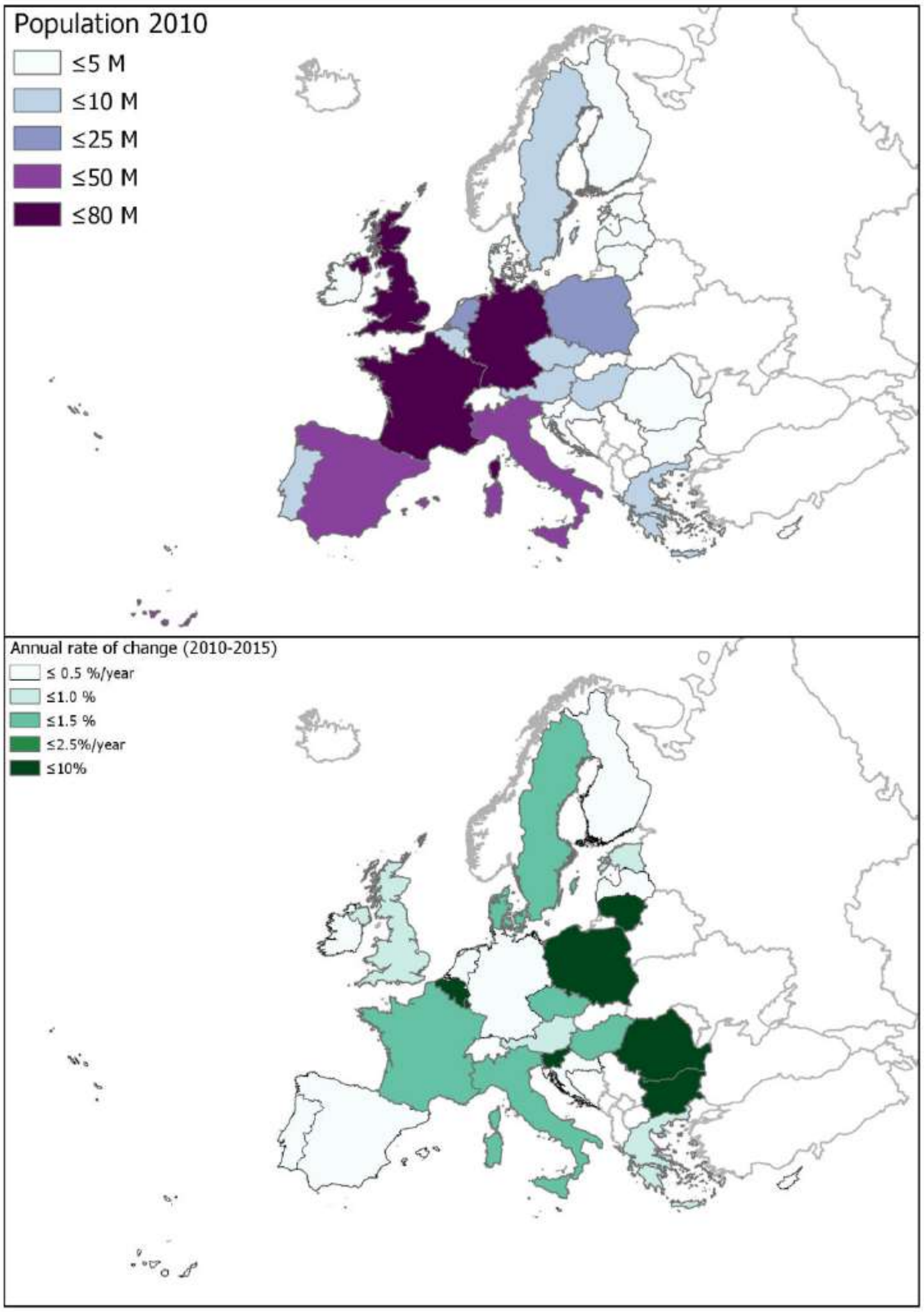


Figure 1. Amount (M inhabitants in 2010) and rate of change (2010-2015) of population treated at least at secondary level in Europe. Data source: EUROSTAT

3.3. Statistical analysis of the trend

- Rates of change were assessed by Ordinary Least Square regression for the long (2007-2015) and the short (2010-2015) period, both at EU-27 and at Nuts0 scale (Figure 1). Change was reported only if significant at 5% probability level.

3.4. Key trend at EU level

The EU-27 (excluding Slovakia, for which no statistics on population share treated at least at secondary level was available) trend of the indicator is shown in Figure 2. In 2007 about 373 M people accessed at least secondary treatment, up to almost 412 M in 2015, indicating that domestic emissions of pollutants are declining in Europe. In 2010 the EU-27 population access to at least secondary treatment was 78.7% (392 M inhabitants).

From 2007 to 2015 a steady increase in accessing secondary treatment was observed in Europe, at a pace of about 1% increase of population per year (from 76 to 82%), although the rate of change slightly slowed down after 2010. The rate of change was estimated at 10.6%/decade using the whole time series, and at 7.5%/decade for the shorter period 2010-2015. Pressure condition was thus judged as improving conditions in both temporal timeframes. Access to secondary or higher treatment in 2010-2015 has been larger in several Eastern European countries (Figure 1).

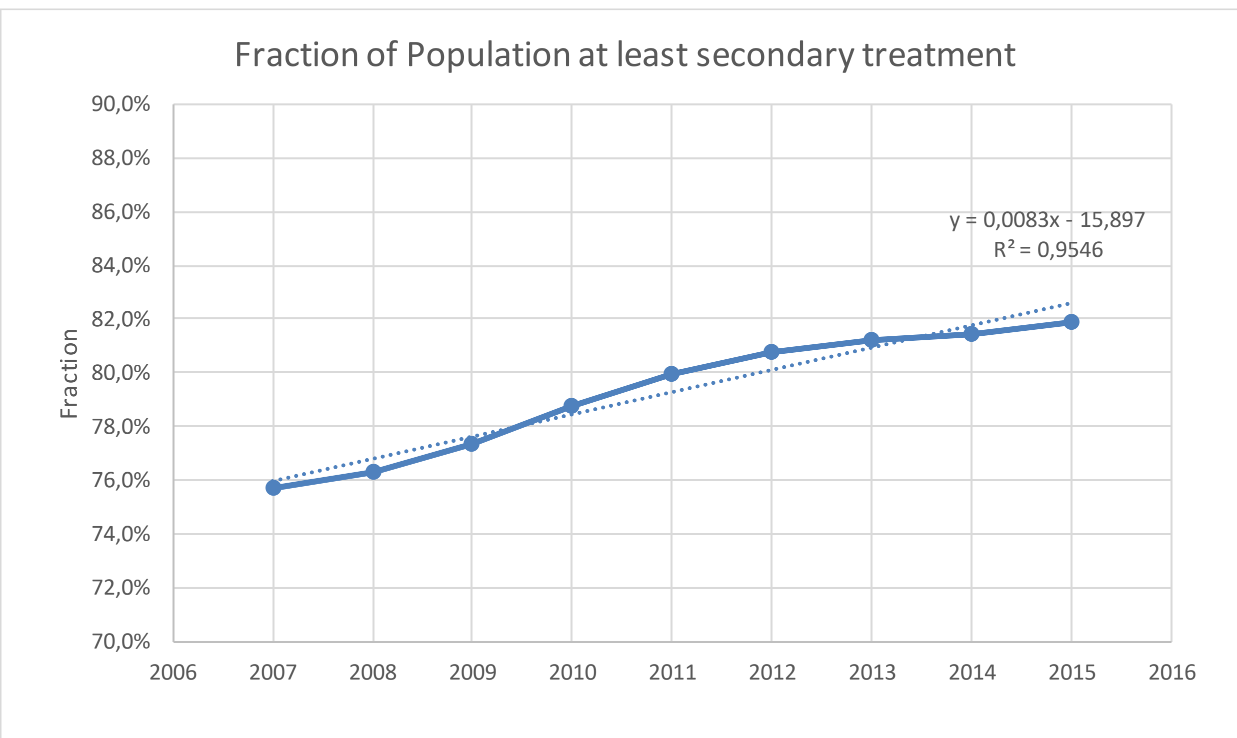


Figure 2. Population fraction whose domestic waste that access at least secondary treatment. Data source: EUROSTAT.

Fact sheet 3.6.103b: Domestic waste emissions to the environment

1. General information

- Freshwater ecosystems
- Pressure: Pollution and nutrient enrichment
- Domestic emissions (Biochemical Oxygen Demand, Nitrogen and Phosphorous)
- t/y

2. Data sources

- Data holder: JRC
- Weblink: http://data.europa.eu/89h/0ae64ac2-64da-4c5e-8bab-ce928897c1fb
- Years: 2014
- Access date: 28/08/2019
- Reference: http://publications.jrc.ec.europa.eu/repository/handle/JRC113729
- Spatial Resolution: Nuts2

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Pollutant emissions from domestic sources impact freshwaters altering balance between nutrients. Domestic waste comprise emissions from point sources, i.e. direct discharges to river network form wastewater treatment plans and sewerage systems without treatment, and from diffuse sources, i.e. disconnected dwellings and independent appropriate systems. Emissions of domestic waste are reported in terms of Population Equivalent (PE) by Member States in the Urban Waste Water Directive database (v5 with reference year 2014) but the database was revised for data gap filling (e.g. dwellings smaller than 2000 PEs). From PEs, 5-days biochemical oxygen demand (BOD), nitrogen and phosphorous loads (t/y) were estimated considering mean national protein consumption. Literature based removal efficiencies for septic tanks, primary, secondary, or more advanced treatment were applied before releases to the environment. It should be noted that emissions from disconnected sources would be further attenuated before reaching the river network; however, this attenuation has not been considered for these reported domestic emission indicators.

3.2. Maps

Figure 1 shows the domestic emissions of nitrogen (N), phosphorous (P), and 5-days biochemical oxygen demand (BOD) loads per km^2 ($t/y/km^2$).

3.3. Key trend at EU level

No trend could be calculated as data refer only to 2014-2015.

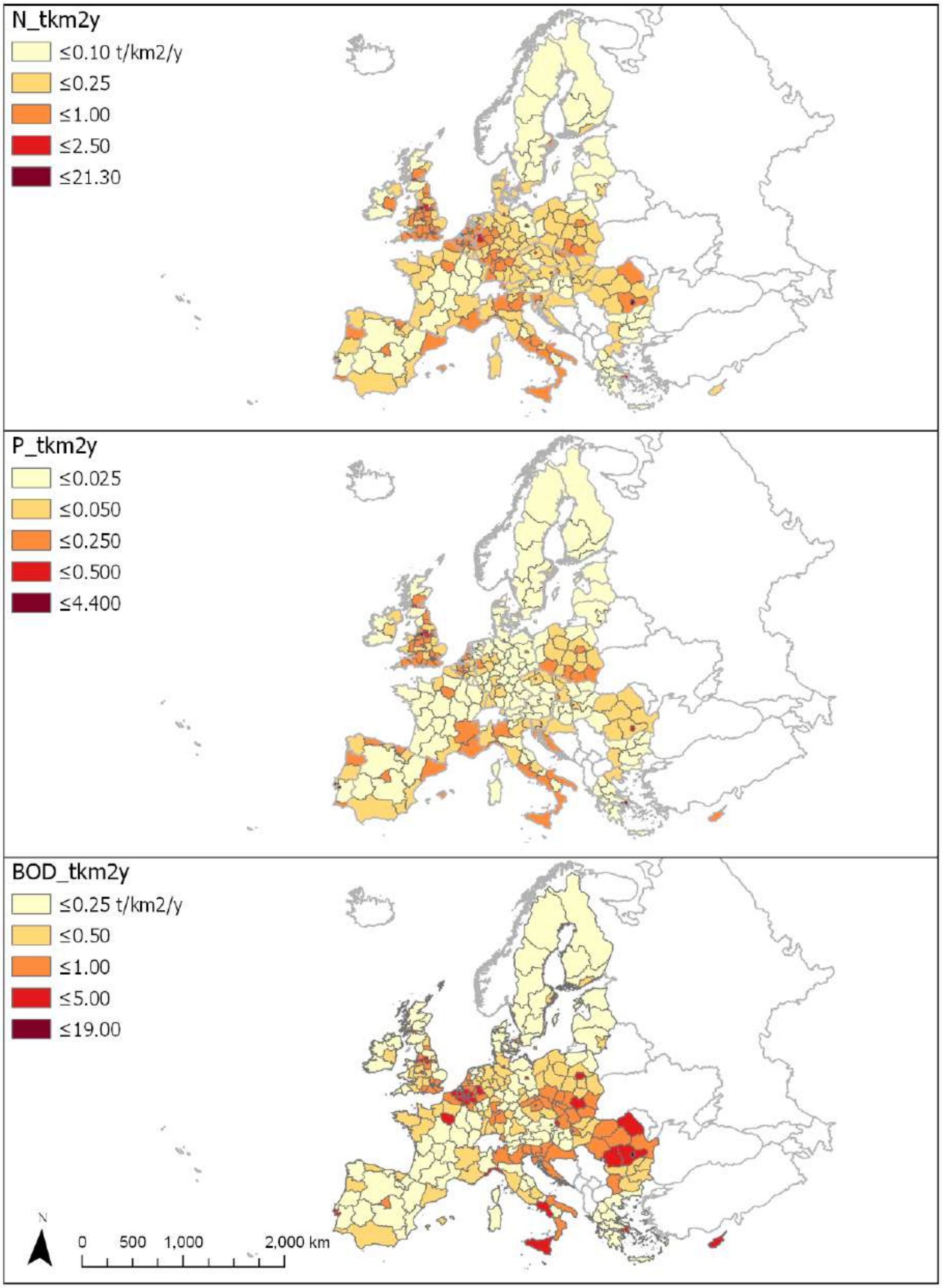


Figure 1. Domestic emissions of Nitrogen, Phosphorous and Biochemical Oxygen Demand (BOD, all in t/y/km^2) in 2014. Data source: JRC.

Fact sheet 3.6.104: Gross Water Abstraction

1. General information

- Freshwater ecosystems
- Pressure: over-exploitation
- Gross Water Abstraction (total and by sectors)
- Million m^3/y

2. Data sources

- Data holder: EEA
- Weblink: https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-2/assessment-3
- Years: Average 2000-2015
- Access date: 19/9/2019
- Reference: EEA. Use of freshwater resources. 2018. https://www.eea.europa.eu/data-and-maps/indicators/use-of-freshwater-resources-2/assessment-3
- Spatial Resolution: Nuts0

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Water abstractions pose heavy pressure on freshwater ecosystems, especially where water availability is limited. Water abstraction serves demands from the energy (cooling), agriculture, manufacturing and mining, and public water supply sectors.

Water is abstracted for generating electricity through hydro or thermal power, i.e. for cooling. While hydropower generation involves storing water behind a dam or reservoir in order to use its hydraulic energy to move turbines, the generation of thermal power involves the use of water to cool hot steam used to move turbines. In general, water for hydropower is abstracted in-stream and regarded as non-consumptive. However, it is not impact free. Hydropower generation leads to changes in natural water cycles in rivers and lakes, deteriorates erosion and sedimentation patterns in river beds and causes substantial changes in riparian ecosystems. Cooling installations return water back to the environment at increased temperature (resulting in heat emissions) that may favor invasive species and act as barrier to native species moving upstream.

Water plays a crucial role in agriculture. The major cause of water consumption in the agricultural sector is crop irrigation, especially in the southern basins where precipitation and soil moisture are not sufficient to satisfy crop water needs. In general, vegetables and other crops that generate high gross value added are also very water demanding. Around 7-8 % of total agricultural areas are irrigated in Europe with this value reaching 15 % in southern Europe.

Various industrial sectors, such as the pulp and paper, iron and steel, textiles, food and beverages, and chemicals sectors, use water in production processes. Some industries, such as the food industry, also incorporate water into products. The mining industry undertakes activities to prepare materials for market, e.g. crushing, grinding, cleaning, drying, sorting, concentrating ores, liquefaction of natural gas and agglomeration of solid fuels. The mining industry uses water in production processes, e.g. dust depression and rock crushing, as well as in dewatering processes for removing water from mines. Therefore, the mining industry carries out off-stream water abstraction but also water discharge at the same time as the dewatering process, resulting in substantial levels of water-borne emissions and pollutants. Water abstraction for mining usually lowers the groundwater table and deteriorates water quality because of the high levels of emissions released from the dust depression and dewatering processes. Available data on water abstraction and water use for mining are very limited. This means that there is a high degree of uncertainty in relation to water abstraction for the mining industry.

The public water supply industry uses relatively large amounts of water of a certain quality (i.e. drinking water quality) from the environment to provide sufficient water to meet societal needs. Water is supplied by utilities companies to households for domestic needs and to other industries, e.g. business and production services, food and beverage, and accommodation sectors. Water collection, treatment and supply relate to water supplies for both households and the services sector. Around 64 % of the total public water supply, on average, goes to households, while the remainder is allocated to other connected services.

3.2 Data sources

For each sector, primarily data from the Waterbase — Water Quantity database have been used. Eurostat, OECD and Aquastat (FAO) databases have also been used to fill the gaps in the data sets. Furthermore, the statistical office websites of all European countries have each been visited several times to get the most up-to-date data from these national open sources. Despite this, some gaps still needed to be filled by applying certain statistical or geospatial methodologies. A substantial amount of gap filling has been performed in the data on water abstraction for irrigation. First, a mean factor between utilised agricultural areas and irrigated areas has been used to fill the gaps in the data on irrigated areas. Then, a multiannual mean factor of water density (m^3/ha) in irrigated areas per country has been used to fill the gaps in the data on water abstraction for irrigation. The gaps in the data on water abstraction for manufacturing and construction have been filled by using Eurostat data on production in industry and the E-PRTR database with the methodologies to convert the production level into the volume of water.

3.3. Graph

Figure 1 shows gross water abstractions in EU-28 zone. In 2010 around 204 490 million m^3 of water (roughly equivalent to 46.8 mm) was abstracted in the EU-28 zone as off-stream to meet sectorial demands. In 2015, about 211 585 million m^3 (48.4 mm) of water was abstracted, 39% of which was used and 61% of which was returned back to the environment with a certain level of physical or chemical deterioration. In 2010 the highest share of gross abstraction was from cooling sector (42%), followed by Agriculture (26%), Manufacturing and mining (16%) and Public water supply (16%). Net abstractions however indicate different use shares. Around 40

% of total water use is accounted for by agriculture, followed by 28 % for cooling and 18 % for manufacturing and mining, while public water supplies account for 14 %.

At the regional level, overall, water use for cooling in electricity generation is the main pressure in western and eastern Europe, whereas agriculture is the most water-demanding sector in southern Europe. The manufacturing industry is most water-demanding in northern Europe.

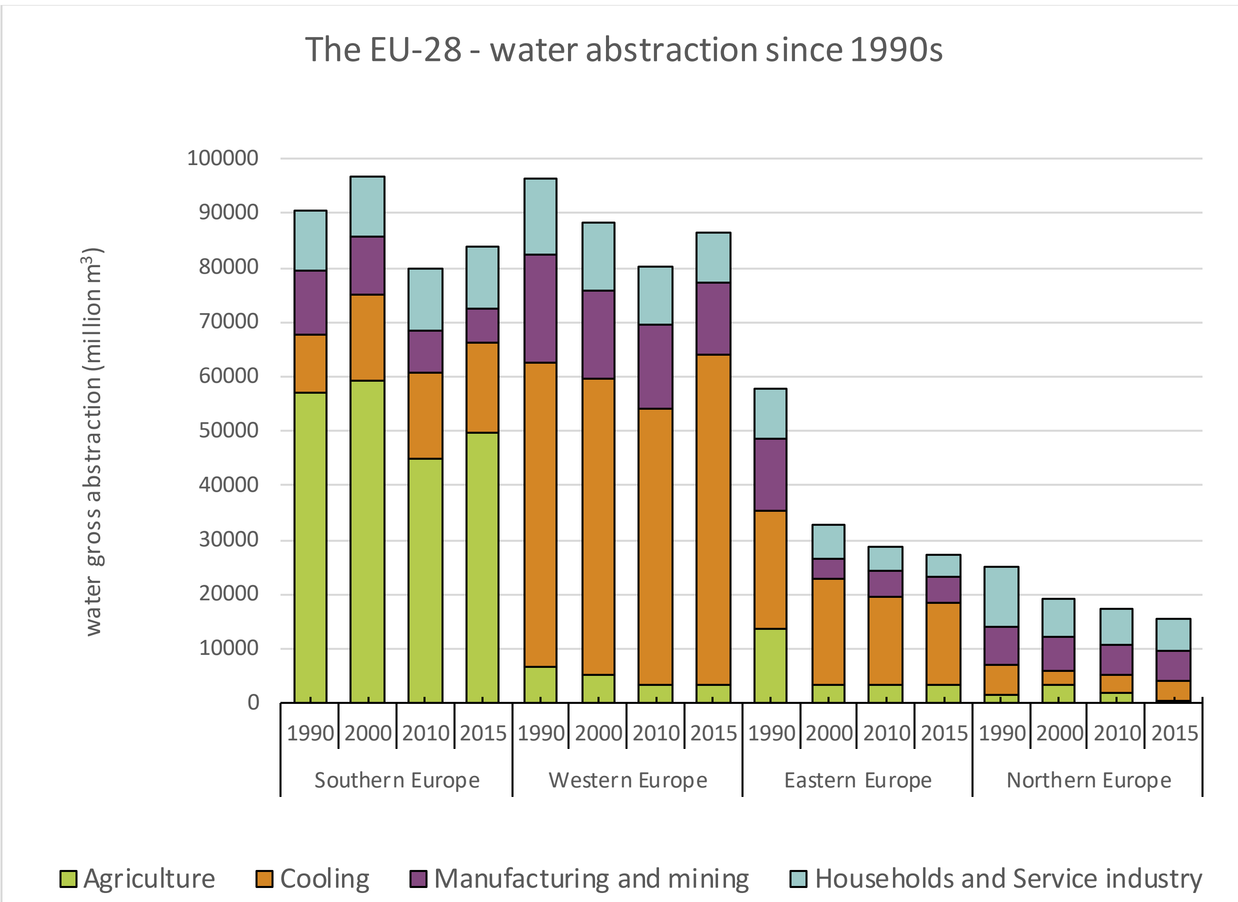


Figure 1. Gross water abstraction (million m^3) in Europe from 1990 to 2015 by sector. Source: EEA. Regions are defined according to European M49 regions (https://unstats.un.org/unsd/methodology/m49/) but limited to EU-28 zone.

Figure 2 shows gross water abstractions at MS scale, showing a general decline in abstractions. In the short term however the situation is stable.

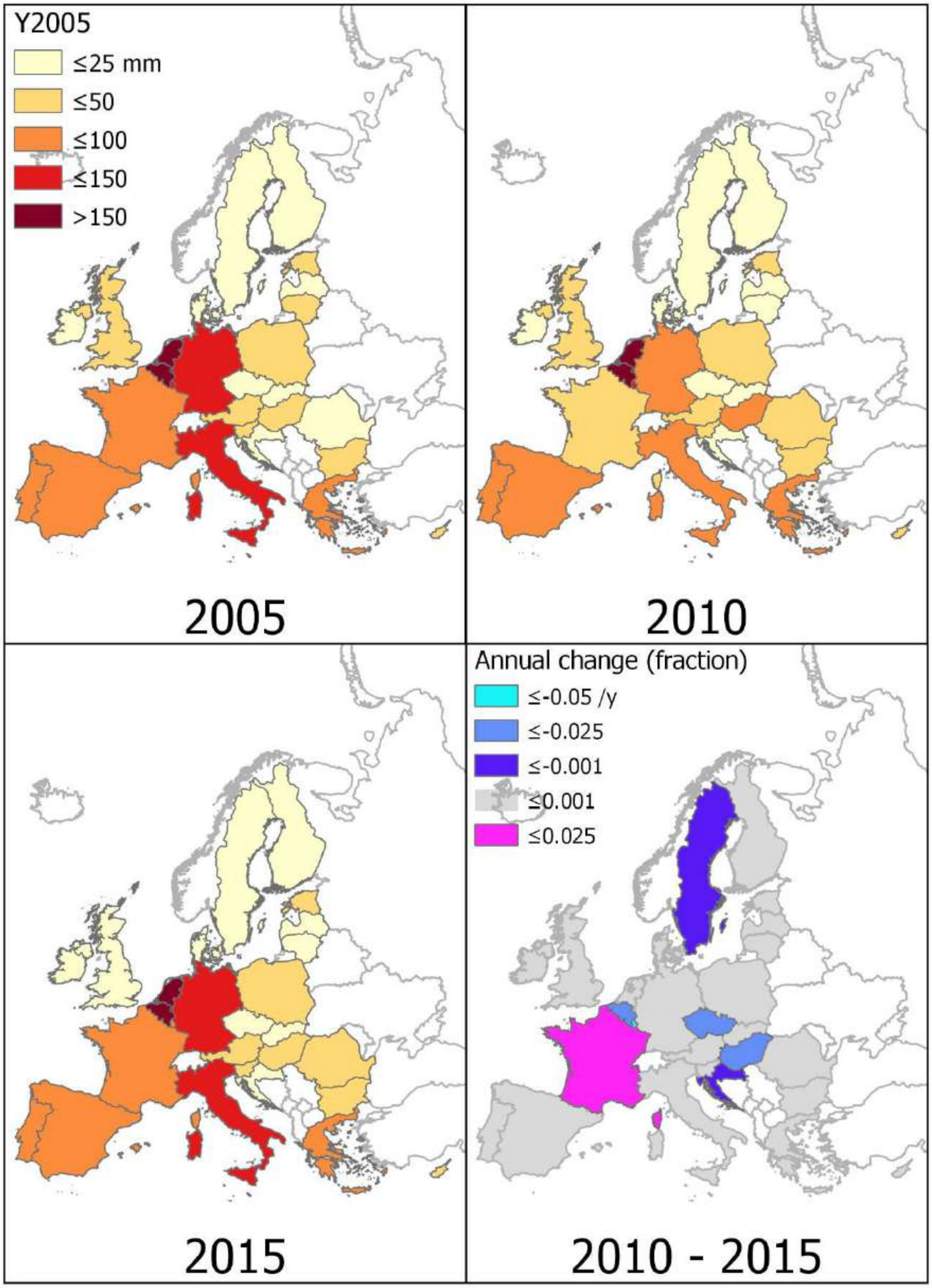


Figure 2. Gross water abstraction (mm) in EU-28 in 2005, 2010, 2015, and annual rate of change from 2010 to 2015. Source: EEA

3.4. Statistical analysis of the trend

- Data was available from 1990 to 2015, however data gaps especially in the agricultural sector were important in the 1990s. Analysis was conducted with Ordinary Least square regression for long term (2000-2015) and short term (2010-2015) at EU-28 and nuts0 scale.

3.5. Key trend at EU level

The long term trend test indicated a decadal change of -7% for 2000-2015. The short term trend however indicates no significant change between 2010 and 2015. Some considerations can be added.

The energy-related cooling sector is the only sector in Europe in which the use of water is estimated to have increased (by 19 %) between 1990 and 2015, but has been stable in 2000-2015. Southern and western Europe increasingly use water for cooling. In agriculture, political and socio-economic transitions in eastern Europe, combined with the economic recession in southern Europe (EC, 2013), have resulted in a decline in utilised irrigated areas (by 14 %). In turn, estimations of trends in water use for irrigation suggest a substantial decline (9 %) between 2000 and 2015. In the coming years, a slight increase in the water requirement for irrigation (EEA, 2014a), associated with a decrease in precipitation in southern Europe (EEA, 2015b), together with the lengthening of the thermal growing season, may be expected.

Because of technological improvements combined with high efficiency gains, it is estimated that there has been an absolute decoupling of the gross added value generated by the manufacturing and mining industry and water use, with an estimated decline of 13 % between 2000 and 2015. Changing production processes, technological improvements, and recycling and reusing water all lead to gains in efficiency and, in turn, reduce water use. The highest efficiency gains in water use were achieved in southern Europe (-52 %) followed by western Europe (-45 %) and northern Europe (-12 %). In eastern Europe, efficiency is low, with a relative increase in water use (8 %) by the manufacturing industries.

Improvements in water conveyance systems have resulted in an estimated decrease of water use for public water supply by 15 %, whereas Europe's population has increased by around 10 % in the last two decades. Substantial water savings have been achieved in western Europe, with the water supply to households declining from 230 litres per capita in 1990 to 134 litres per capita in 2015. However, European metropoles and dry regions are still the most vulnerable to water stress.

The important reductions in water abstractions from 1990 to 2010 may thus not continue in the foreseeable horizon. In the light of these considerations, abstractions till 2020 are considered to remain stable and similar to 2010.

Fact sheet 3.6.201: Chemical status of European rivers and lakes

1. General information

- Freshwater ecosystems
- Condition: Environmental quality
- Chemical status of rivers and lakes
- Classes: Good, Failing to achieve good, or Unknown

2. Data sources

- Data holder: EEA and Commission (DG ENV)
- Weblink: WISE Water Framework Directive Database, WISE-Freshwater WFD dashboards on Chemical status of surface water bodies
- Years: 2010-2015 (second River Basin Management Program RBMPs round; note that many RBMPs only included results up to 2012/13), and before 2009 (first RBMPs)
- Access date: July 2019
- Reference: EEA 2018, European waters – assessment of status and pressures 2018. EEA Report No 7/2018. Available at https://www.eea.europa.eu/publications/state-of-water
  After this publication data are updated with Ireland (and Norway).
- Spatial Resolution: River Basin Districts excluding Lithuania, Greece, and Slovenia

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The contamination of European waters with hazardous substances is a major environmental concern addressed by a number of EU legislative measures and policies. The Water Framework Directive (EU, 2000) stipulates that EU Member States should aim to achieve good status in all bodies of surface water and groundwater. For surface waters, good chemical status is defined by limits (environmental quality standards, EQS) on the concentration of certain pollutants found across the EU, known as priority substances.

Good chemical status means that no concentrations of priority substances exceed the relevant EQS established in the Environmental Quality Standards Directive 2008/105/EC (EU, 2008; as amended by the Priority Substances Directive 2013/39/EU, EU, 2013). EQS aim to protect the most sensitive species from direct toxicity, including predators and humans via secondary poisoning.

Chemical status is reported by Member States to monitor progress in implementing the WFD. Chemical status is reported per water body as “good”, “failing to achieve good”, or “unknown”. The indicator covers the current status of surface waters as reported in the second River Basin Management Plans (RBMPs).

3.2. Maps

Based on the second River Basin Management Plans (RBMPs) from 2015, which use data from 25 Member States (EU-28 except Greece, Lithuania and Slovenia), 36 % of river and lake water bodies are in good chemical status, while 45 % have not achieved good chemical status and for 19 % their status is unknown. The percentage of water bodies in less than ‘good’ chemical status varies between river basin districts (RBDs, Figure 1). Some RBDs report that over 90 % of their surface water bodies are in good chemical status, while others report this for fewer than 10 %. In addition, the proportion of water bodies whose status is reported as 'unknown' (not shown) differs widely between Member States.

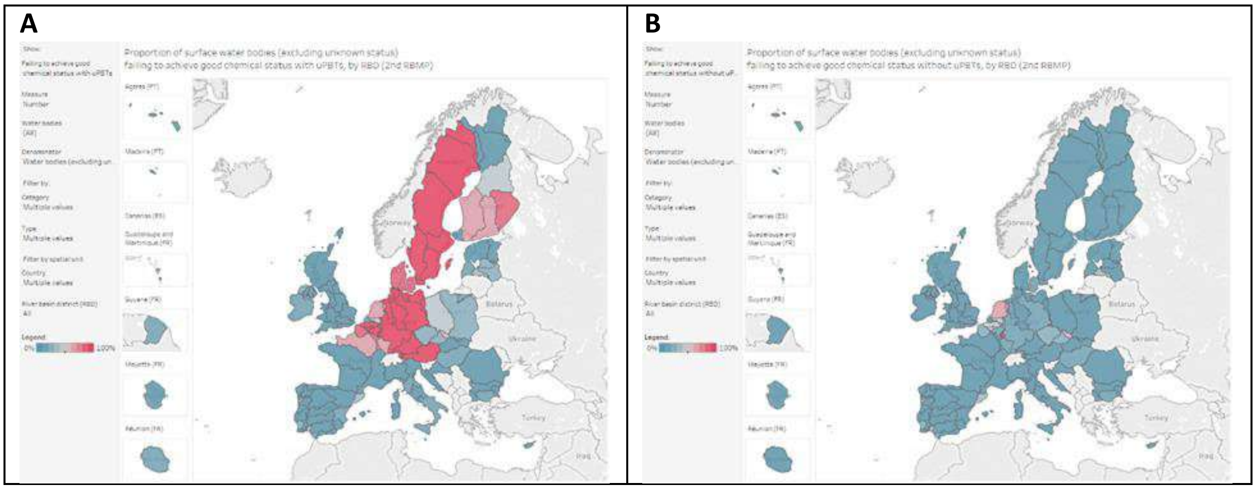
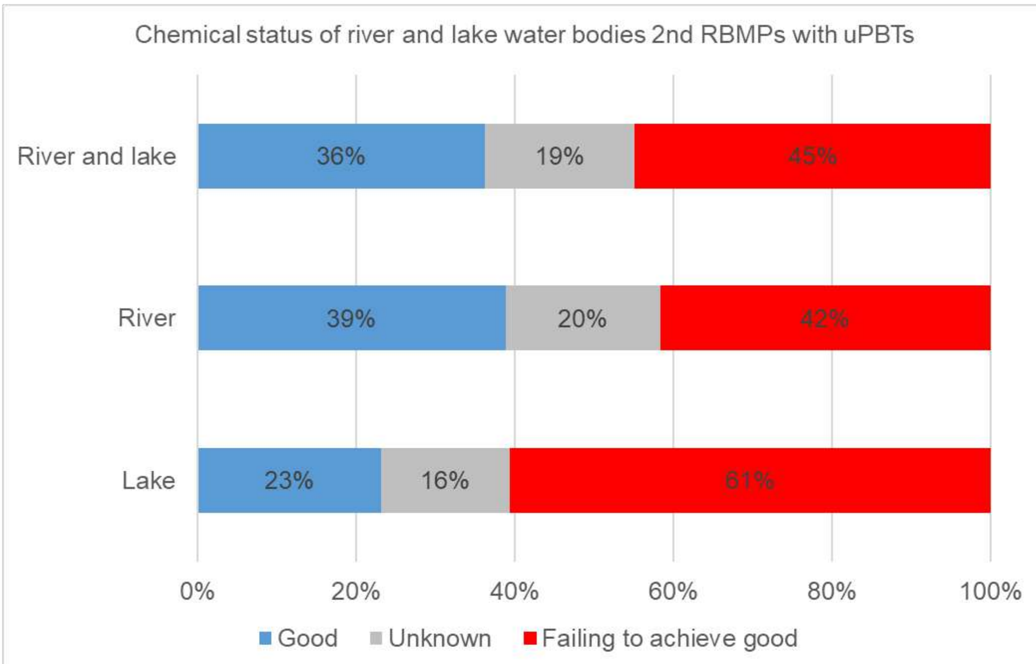


Figure 1. Percentage of river and lake water bodies not in good chemical status in Europe’s river basin districts in second River Basin Management Plans (RBMPs). A) Chemical status per RBD with uPBTs; and B) Chemical status per RBD without uPBTs. Source: Results are based on WISE-SoW database including data from 25 Member States (EU-28 except Greece, Lithuania and Slovenia). Surface water bodies: Chemical status with and without uPBT maps, by RBD.

In many Member States, relatively few substances are responsible for failure to achieve good chemical status. Mercury causes failure in a large number of water bodies. If the widespread pollution by ubiquitous priority substances (uPBTs[41]), including mercury, is omitted, the proportion of water bodies in good chemical status increases to 78 %, with 3 % that have not achieved good status and 19 % whose status is unknown (Figure 1B and Figure 2).

The main pressures leading to failure to achieve good chemical status are atmospheric deposition and discharges from urban wastewater treatment plants. Atmospheric deposition leads to contamination with mercury in over 45,000 water bodies failing good chemical status. Inputs from urban wastewater treatment plants lead to contamination of over 13,000 water bodies with polyaromatic hydrocarbons (PAHs), mercury, cadmium, lead and nickel.

[41] The uPBTs are mercury, pBDEs, tributyltin and certain PAHs. The widespread presence of mercury and, to a lesser extent, pBDE leads to significant failure to achieve good chemical status, as can be seen in Figure 1 and Map 1b, which shows that the omission of the uPBTs results in 3 % of surface water bodies not being in good chemical status.



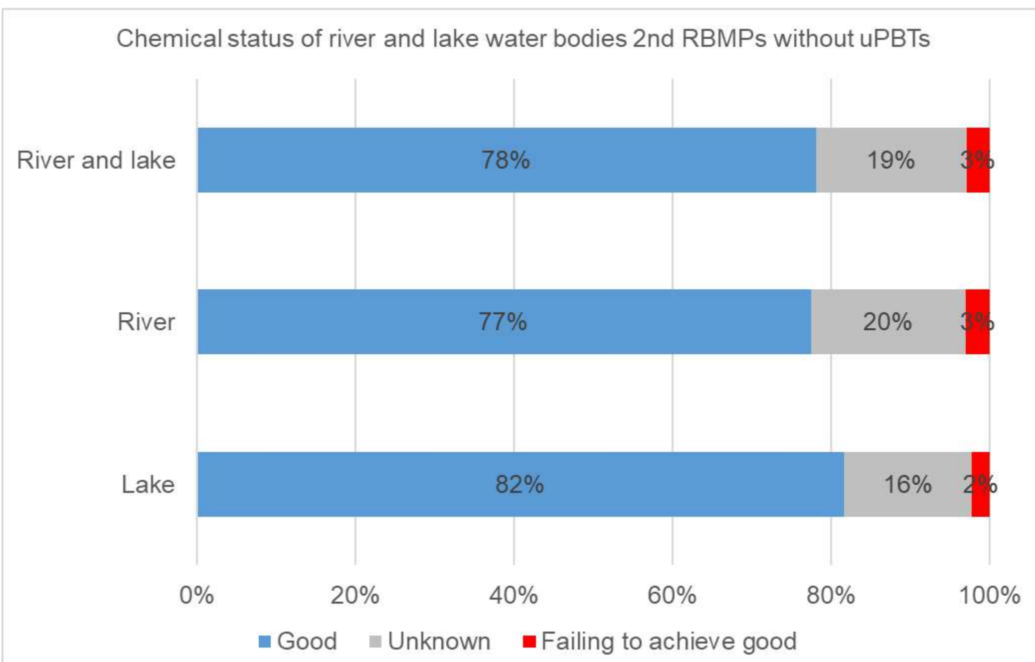


Figure 2. Chemical status of river and lakes water bodies, EU and second River Basin Management Plans (RBMPs). Source: Results based on WISE-SoW database including data from 26 Member States (EU-28 except Greece and Lithuania). Surface water bodies: Chemical status with and without uPBT, by category. uPBT = ubiquitous priority substances

3.3. Statistical analysis of the trend

- Methodological differences between the two RBMP reporting periods precluded analysis of temporal trends. However at the European scale conditions can be assessed as stable from the first to the second RBMPs round. Because of the differences in the two reporting periods, there is no trend assessment of this indicator at unit scale

3.4. Key trend at EU level

In 2015 At EU scale 36% of rivers and lakes have been reported to achieve good chemical status. This figure increases to 78% when uPBTs are not considered. Comparing chemical status in the two RBMPs is complicated because there was more pollutant monitoring for the second RBMPs, and some Member States reported mercury as causing all of their surface water bodies failing to achieve good chemical status.

A comparison of the chemical status reported in the first and second RBMP periods shows that the proportion of water bodies with unknown chemical status has dropped significantly, from 40% to 19 % (Figure 3). Chemical status remained similar in rivers and declined slightly in lakes. Consequently, knowledge on chemical status has improved, but, in return, a larger number of water bodies has been classified as failing to achieve good chemical status.

However, it seems that Member States are making significant progress in tackling certain individual priority substances, apart from mercury, pBDEs and PAHs. During the first RBMP cycle, Member States made progress in tackling several other priority substances, such as metals (cadmium, lead and nickel) and several pesticides, suggesting that some effective measures were implemented.

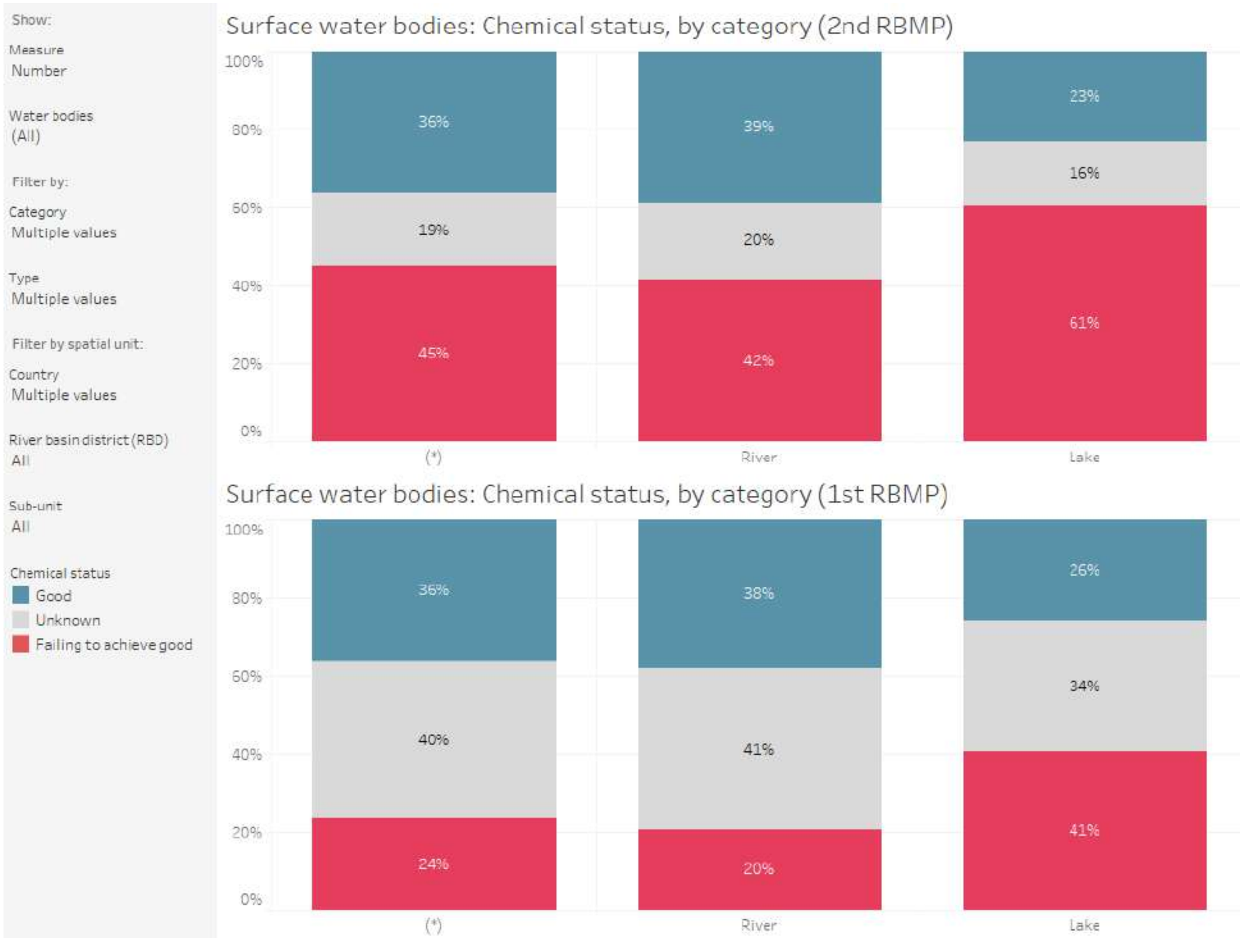


Figure 3. Change in chemical status of surface water bodies, by water category. Source: Results are based on WISE-SoW database including data from 26 Member States (EU-28 except Greece and Lithuania). Surface water bodies: Chemical status, by category.

Further references

EU, 2008. Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/ EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council (http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0105).

EU, 2013. Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy (OJ L 226, 24.8.2013, p. 1-17) (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:226:0001:0017:EN:PDF)

European Commission (EC). 2000. Water Framework Directive (WFD) 2000/60/EC. http://ec.europa.eu/environment/water/water-framework/index_en.html

Fact sheet 3.6.202a: Water quality in rivers

1. General information

- Freshwater ecosystems
- Environmental quality
- Water quality in rivers
- River concentration data on BOD5, ammonium, nitrate and phosphate.

2. Data sources

- Data holder: EEA
- Weblink: EEA Waterbase Water Quality : https://www.eea.europa.eu/data-and-maps/data/waterbase-water-quality-2
- Years: 1992-2017
- Access date: Sept 2019
- Reference: EEA 2019, CSI019 Oxygen consuming substances in European rivers. Available at https://www.eea.europa.eu/data-and-maps/indicators/oxygen-consuming-substances-in-rivers/oxygen-consuming-substances-in-rivers-8 & EEA 2019, CSI020 Nutrients in freshwater in Europe https://www.eea.europa.eu/data-and-maps/indicators/nutrients-in-freshwater/nutrients-in-freshwater-assessment-published-8.
- Spatial Resolution: River Basin District.

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

These indicators reflect water quality in rivers. Specifically, five pollutant concentrations in rivers were considered: Biological Oxygen Demand over five days (BOD5), ammonium, nitrate, orthophosphate and total phosphorous. The monitoring network use to produce the indicators comprised more than 6000 sites, and data were averaged at River Basin District (RBD) scale but the number of monitoring sites vary between RBDs. Not all RBDs are always represented. As some of the year-to-year variation can be explained by variations in precipitation and runoff, data were averaged over periods to reduce inter-annual variability due to hydrologic conditions or heterogeneity of monitoring network. Specifically, periods were defined as: 1990-1995, 1996-2000; 2001-2005, 2006-2010, and After 2010 (2011-2017).

Biochemical oxygen demand (BOD) and ammonium are key indicators of organic pollution in water. BOD shows how much dissolved oxygen is needed for the decomposition of organic matter present in water. Concentrations of these parameters normally increase as a result of organic pollution. Severe organic pollution may lead to rapid de-oxygenation of river water, high concentrations of ammonia and the disappearance of fish and aquatic invertebrates. The most important sources of organic waste load are: household wastewater; industries such as the paper or food processing industry; and silage effluents and manure from agriculture. Increased industrial and agricultural production in most European countries after the 1940s, coupled with a greater share of population being connected to sewerage systems, initially resulted in increases in the discharge of organic waste into surface water. Over the past 20 to 40 years, however, the biological treatment (secondary treatment) of waste water has increased, and organic discharges have consequently decreased throughout Europe.

Nitrate and phosphate in rivers are key indicators of nutrient pollution. Large inputs of nitrogen and phosphorus to water bodies from urban areas, industry and agricultural areas can lead to eutrophication. This causes ecological changes that can result in a loss of plant and animal species (reduction in ecological status) and have negative impacts on the use of water for human consumption and other purposes.

3.3. Statistical analysis of the trend

- Statistical method used to evaluate the long term only from 2000 to 2017 by Ordinary Least square regressions. The short term trends from 2010 were not calculated since this is too short a time for observing changes.

3.4. Key trend at EU level

The bar charts in Figure 2 show the distribution of RBDs into classes of water quality for the five pollutants.

Over the past few decades, clear progress has been made in reducing emissions from point sources. The implementation of the Urban Waste Water Treatment Directive (UWWTD), together with national legislation, has led to improvements in waste water treatment across much of the European continent. In Europe's rivers, oxygen consuming substances have been decreasing over the period 1992 to 2017. On average, BOD has been halved down to 51 % compared to the 1992 level, but after decreasing to less than 2 mg/l in 2010, it remains more stable without marked further decrease.

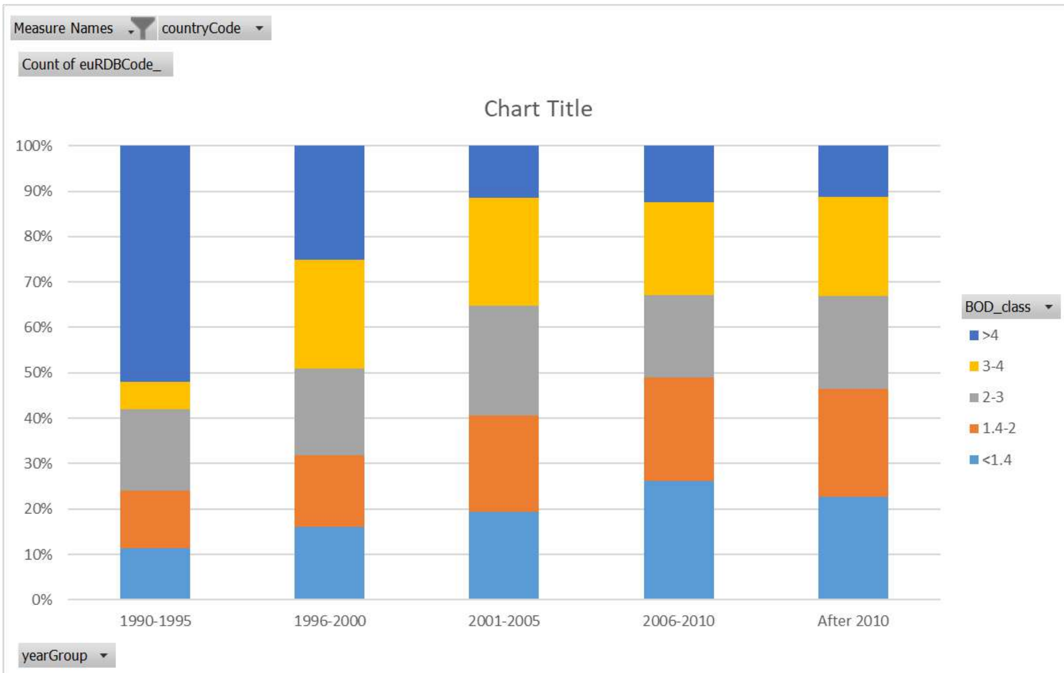


Figure 2a. Distribution of River Basin Districts in BOD5 concentration classe s.

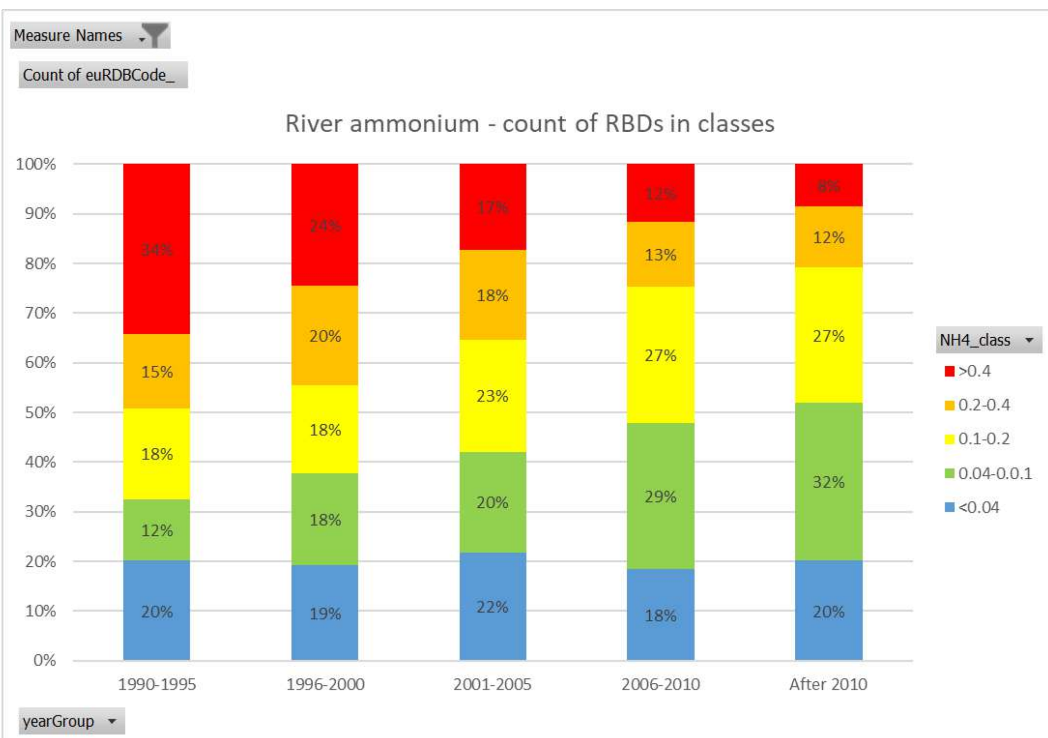


Figure 2b. Distribution of River Basin Districts in ammonium concentration classes.

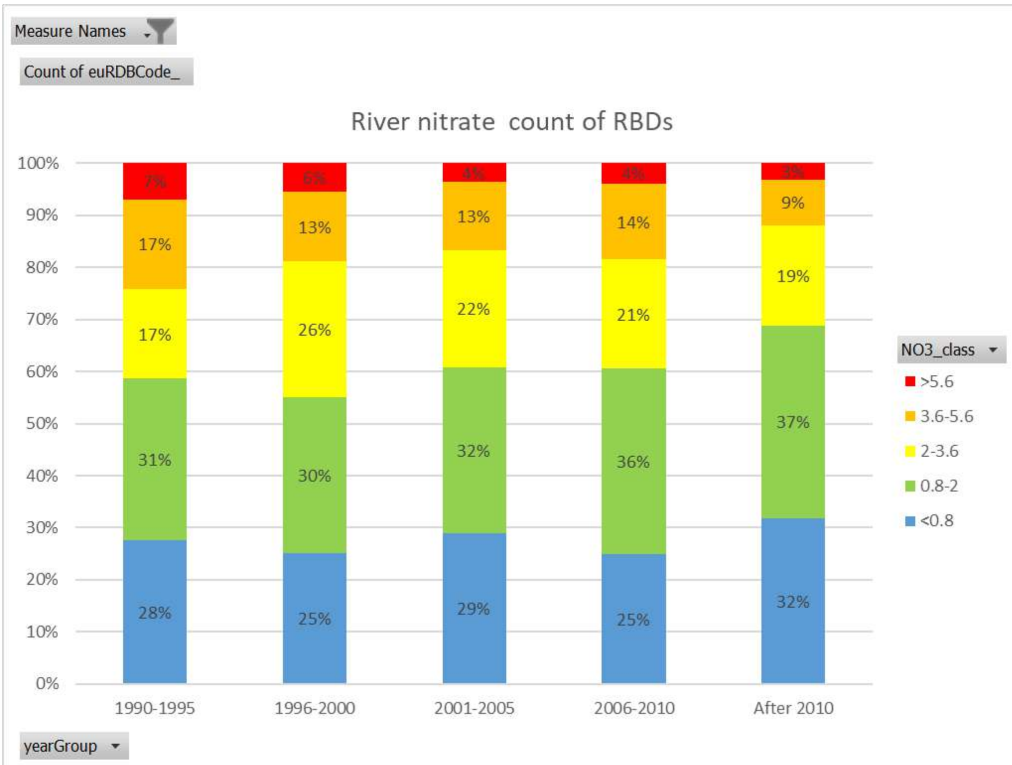


Figure 2c. Distribution of River Basin Districts in nitrate concentration classes.

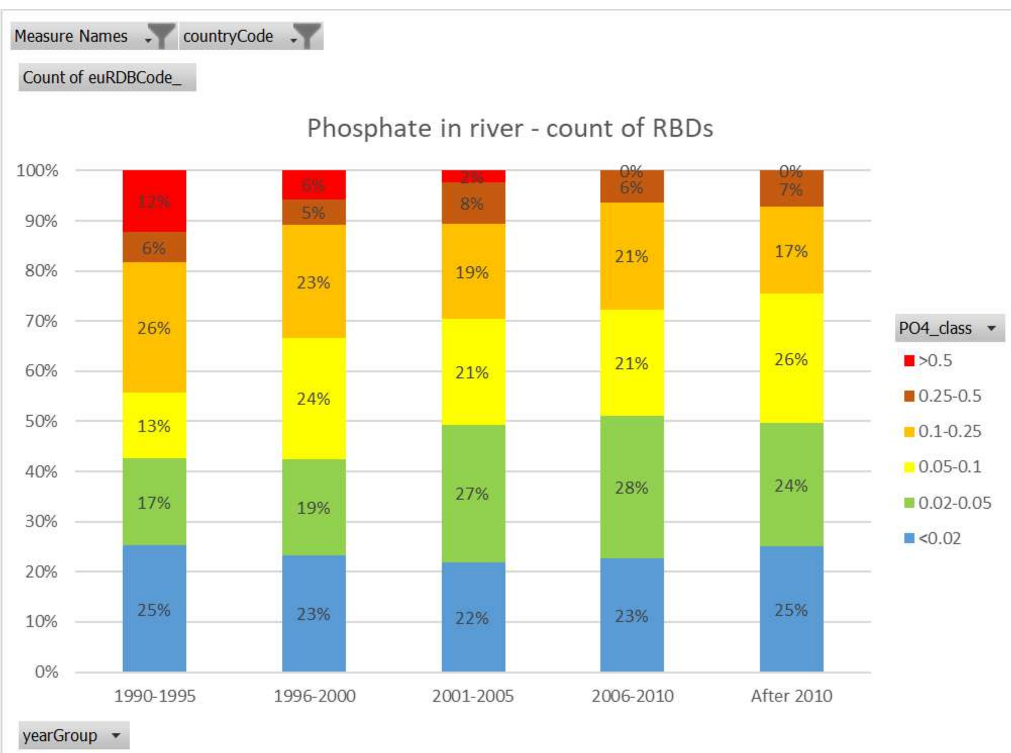


Figure 2d. Distribution of River Basin Districts in ortophosphate concentrati on classes.

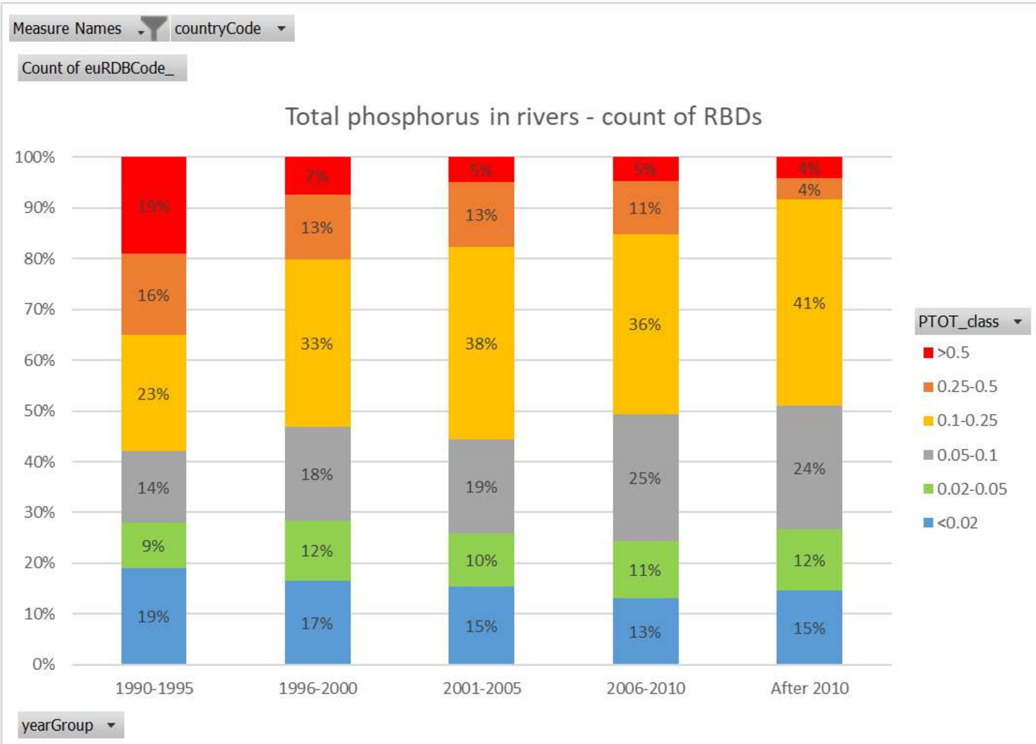


Figure 2e. Distribution of River Basin Districts in total phosphorous concentration classes.

Ammonium concentrations decreased even more substantially in the period 1992 to 2017, down to 22 % of the 1992 level. However, decrease was less pronounced since 2010, and an increase is marked in the recent two years. The decrease in BOD and ammonium concentrations is mainly due to general improvement in wastewater treatment.

On average, nitrate concentration in European rivers decreased by 0.02 milligrams per litre of nitrogen (mg N/l), or 0.8 %, per year over the period 1992-2017, but the concentration has levelled off in recent years. The decrease in nitrate concentration reflects the effect of measures to reduce agricultural inputs of nitrate, as well as improvements in waste water treatment.

Similarly, concentrations of phosphate in European rivers more than halved over the period 1992 to 2017. The decrease in river orthophosphate is due to the measures introduced by national and European legislation, in particular the Urban Waste Water Treatment Directive, which involves the removal of nutrients. Also the change to the use of phosphate-free detergents has contributed to lower phosphorus concentrations. The average orthophosphate concentration in European rivers has decreased markedly over the last two-three decades (by 0.002 mg/l of P-PO4, or 1.6 %, per year).

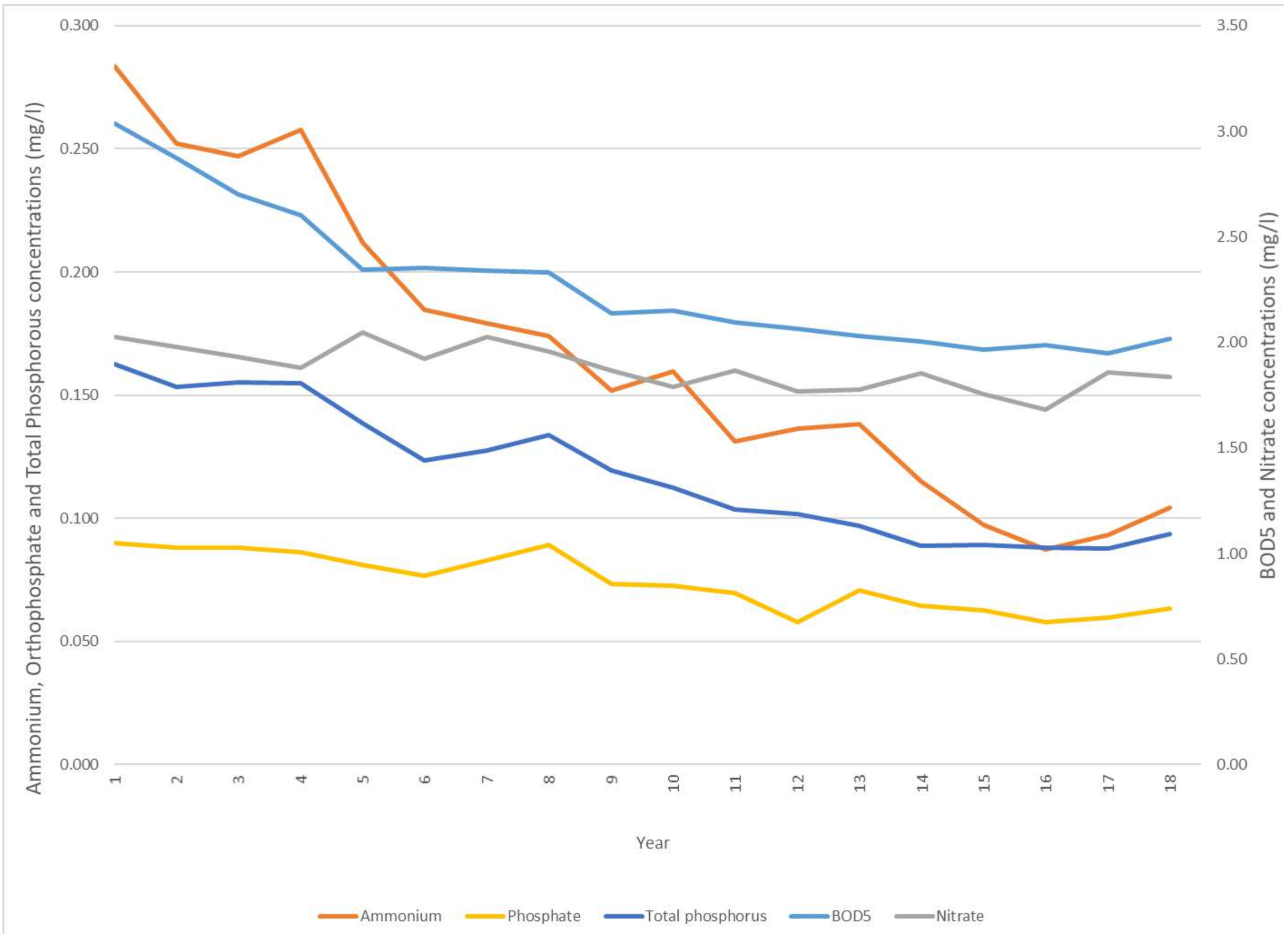


Figure 4. Water quality trends in EU time series for European rivers 2000 (year 1) - 2017 (year 18).

References

EEA 2019, European bathing water quality in 2018. EEA Report No 3/2019, , European Environment Agency. Available at https://www.eea.europa.eu/publications/european-bathing-water-quality-in-2018

EU, 1976, Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water (archived).

EU, 2006, Council Directive 2006/7/EC concerning the management of bathing water quality and repealing Directive 76/160/EEC (OJ L 64, 4.3.2006, p. 37–51).

Fact sheet 3.6.202b: Nutrient concentration in rivers (nitrogen, phosphorous, and Biochemical Oxygen Demand - BOD5)

1. General information

- Freshwater ecosystems
- Condition: Environmental quality
- Fraction of rivers not exceeding threshold levels
- Fraction of river length (km/km) where nutrient concentration is below a given threshold

2. Data sources

- Data holder: JRC
- Weblink: https://data.jrc.ec.europa.eu/collection/wpi
- Years: 2010 (mean annual conditions on a longer time period)
- Access date: 15/07/2019
- Spatial Resolution: Nuts2 scale

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

High nutrient concentrations in rivers are conducive to eutrophication. The Water Framework Directive indicates threshold conditions to define high or good ecological status. To obtain a European-wide homogeneous information dataset, mean annual nutrient concentrations (mg/L) of nitrogen, phosphorous and Biochemical Oxygen Demand (BOD5) were obtained with conceptual pollution source-fate models. Specifically nitrogen and phosphorous concentrations were modelled with GREEN (Grizzetti et al., 2012) as mean annual values for the 2005-2012 hydrological conditions. BOD5 was modelled as in Vigiak et al. (2019) for 2008-2012 mean hydrological conditions. The indicators are presented as fraction of river length (in km/km, aggregated at NUTS2 level) where concentrations meet high or good ecological standrds, i.e. are below the following thresholds: nitrogen <= 4 mg/L; phosphorous <= 0.1 mg/L, and BOD5 <= 5 mg/L as per Pistocchi et al. (in preparation).

3.2. Maps

Figure 1 shows the fraction of river length where nutrient concentrations are below the thresholds. At the EU-28 scale, 76.2% of rivers are in high or good conditions for nitrogen concentration, 55.6% for phosphorous concentration, and 86.1% for BOD5 concentration.

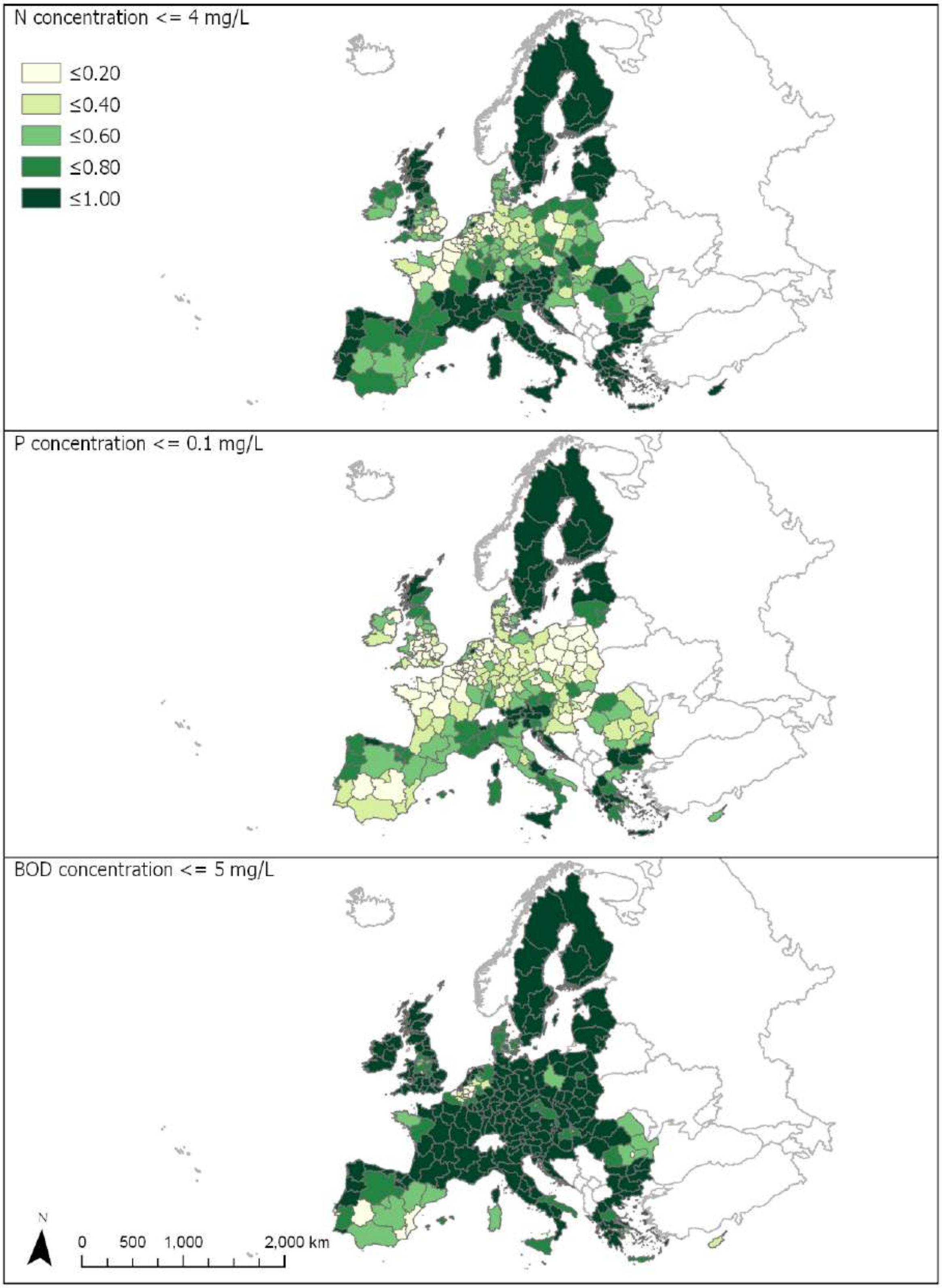


Figure 1. Fraction of river length (km/km) where nutrient concentrations meet high or good ecological status, i.e. are below given thresholds. Data source: JRC

3.3. Key trend at EU level

Hydrological conditions affect streamflow and nutrient concentration, and annual variations in concentrations may be due to changes in hydrological conditions rather in in pollution loads. The conceptual models that inform these indicators are relatively static in terms of pollution sources, thus only mean annual average conditions over simulation periods are reported and no trend was calculated.

References

Grizzetti, B., Bouraoui, F., Aloe, A., 2012. Changes of nitrogen and phosphorus loads to European seas. Global Change Biology 18, 769-782.

Pistocchi, A., Dorati, C., Grizzetti, B., Udias, A., Vigiak, O., Zanni, M. in preparation. Water quality in Europe: effects of the Urban Wastewater Treatment Directive. JRC Science for Policy report.

Vigiak O., Grizzetti B., Udias-Moniello A., Zanni M., Dorati C., Bouraoui, F., Aloe A., Pistocchi A. 2019. Predicting Biochemical Oxygen Demand in European freshwater bodies. Paper in preparation for submission. Science of the Total Environment 666, 1089-1105

Fact sheet 3.6.203: Bathing water quality of European rivers and lakes

1. General information

- Freshwater ecosystems
- Condition: Environmental quality
- Bathing water quality of rivers and lakes
- Bathing water quality classes: 'excellent', 'good', 'sufficient', or 'poor', as well as those bathing waters that could not be classified.

2. Data sources

- Data holder: EEA and Commission (DG ENV)
- Weblink: EEA bathing water site: https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/state-of-bathing-water/state-of-bathing-water-3
- Years: 2014-2018.
- Access date: July 2019
- Reference: EEA 2019, European bathing water quality in 2018. EEA Report No 3/2019. Available at https://www.eea.europa.eu/publications/european-bathing-water-quality-in-2018.
- Spatial Resolution: Member States and bathing water sites.

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Bathing water quality is a cause for concern for public and ecosystem health, and for economic activities such as tourism. The major sources of pollution responsible for faecal bacteria are sewage and water draining from farms and farmland. Such pollution increases during heavy rain and floods, when pollution is washed into rivers and seas, and as a result of overflowing sewerage networks.

The EU's efforts to ensure clean and healthy bathing water began 40 years ago with the first Bathing Water Directive[42]. The Bathing Water Directive (EU, 2006) has the aim of increasing the number of bathing waters classified as 'excellent' or 'good'. It also stipulates that by 2015 all waters should have been of at least 'sufficient' quality.

During the bathing season samples from inland bathing waters are taken and analyzed against two microbiological parameters that may indicate the presence of faecal pollution, namely intestinal enterococci and Escherichia coli (also known as E. coli). Bathing waters are classified base d on the 90th and 95th percentile concentrations in samples collected in four years (minimum of 16 samples) into one of the bathing water quality classes (excellent, good, sufficient or poor). Bathing water sites classified as 'poor' must be closed throughout the following bathing season and measures to eliminate hazards to the health of bathers must be put in place. Finally, bathing waters cannot be classified where (i) there were insufficient samples, or (ii) they are new, or (iii) sites have undergone changes affecting water quality.

[42] http://ec.europa.eu/environment/water/water-bathing/index_en.html

3.2. Maps

In 2018, EU Member States monitored 6,622 rivers and lakes across Europe. Almost 90 % of all inland bathing waters are situated on lakes, whereas less than 900 bathing water sites are located on rivers. Inland site where monitored in 26 EU Member States. No inland bathing waters were identified in Cyprus and Malta. Water quality was classified as at least 'sufficient' in 91.6 % of all EU inland bathing water sites for the 2018-bathing season (Figure 1). Only 128 (1.9%) bathing water sites had poor quality.

In 2018, the share of unclassified bathing waters was relatively high, particularly in Poland, mainly due to the opening of new bathing water sites for which an insufficient number of samples had been taken. In fi ve EU countries, 3 % or more of bathing waters were of poor quality: Spain (15.6 %; 41 bathing waters), Ireland (11.1 %; one bathing waters), the Netherlands (3.9 %, 25 bathing waters), Hungary (3.2 %, eight bathing waters) and Slovakia (3.1 %, one bathing water).

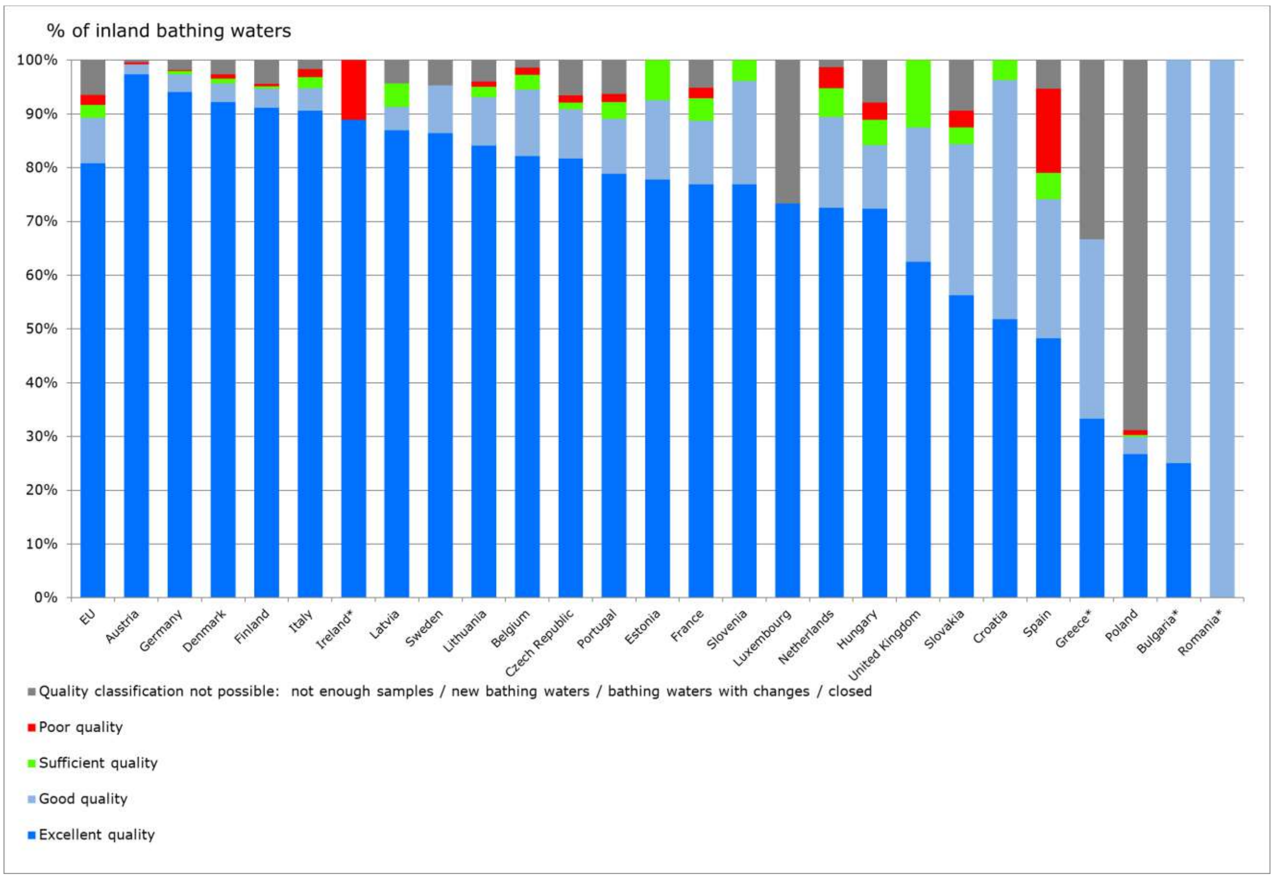


Figure 1. Inland bathing water quality in 2018 for the EU Member States. Note: No inland bathing waters in Cyprus and Malta and Member States with * have less than 10 inland bathing water sites.

3.3. Statistical analysis of the trend

The time series analyzed here is limited to 2014-2018 because of the revision of the bathing water directive, thus data collected before 2014 cannot be compared to current. Rates of change were assessed by Ordinary Least Square regression for 2014-2018 and resulted in no significant change of poor water quality class (stable conditions with a significant probability of 5%), indicating that conditions in the most recent period have been stable. No data was available per country so this indicator remains unresolve d at scale lower than EU-28.

3.4. Key trend at EU level

Europe's bathing water quality has improved markedly over the last 40 years, following the introduction of the EU Bathing Water Directive. Effective monitoring and management has led to a drastic re duction in pollutants released through untreated or partially treated urban wastewaters. As a result, more and more bathing sites are not only meeting the minimum 'sufficient' quality standards but have reached 'excellent' quality.

In the five-year period 2014-2018, the share of excellent inland bathing waters increased from 78.2 % to 80.8 % (Figure 2). The share of poor quality bathing waters decreased from 2.4 % in 2014 to 1.9 % in 2018.

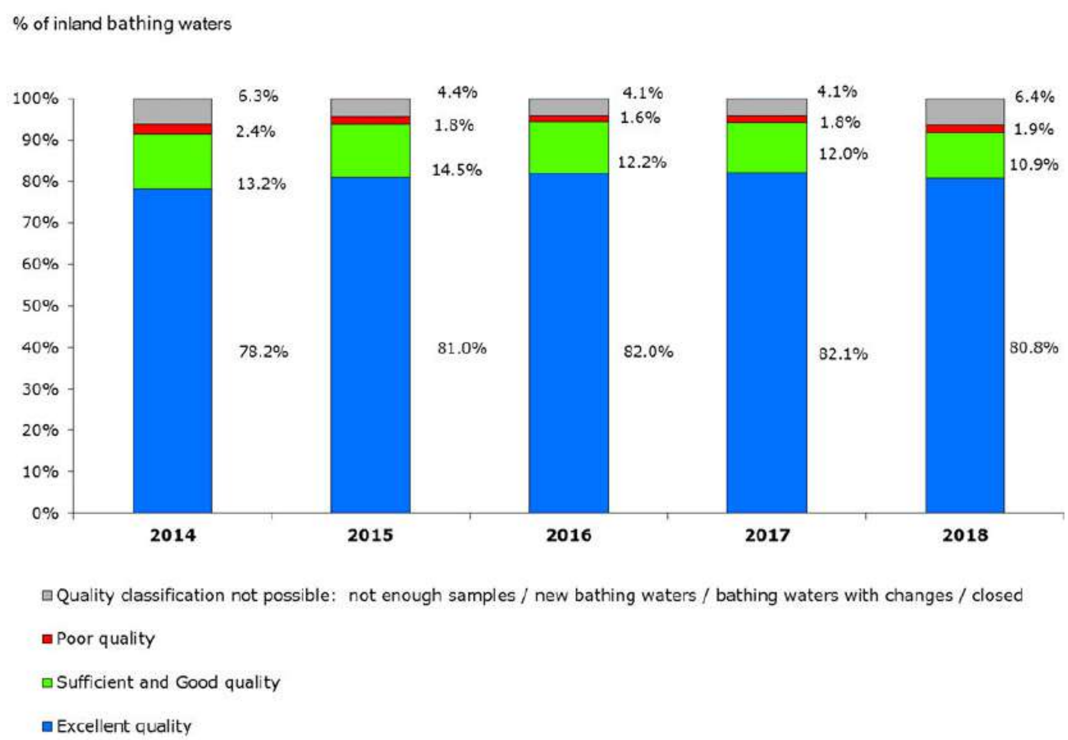


Figure 2. Inland bathing water quality in the EU between 2014 and 2018. Source: WISE bathing water quality database (data from annual reporting by EU Member States).

References

EEA 2019, European bathing water quality in 2018. EEA Report No 3/2019, , European Environment Agency. Available at https://www.eea.europa.eu/publications/european-bathing-water-quality-in-2018

EU, 1976, Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water (archived).

EU, 2006, Council Directive 2006/7/EC concerning the management of bathing water quality and repealing Directive 76/160/EEC (OJ L 64, 4.3.2006, p. 37–51).

Fact sheet 3.6.204: Frequency of low flow - Q10 alteration

1. General information

- Freshwater ecosystems
- Environmental quality
- Occurrence of streamflow below the natural 10th percentile (Q10)
- Frequency (0-1)

2. Data sources

- Data holder: JRC
- Weblink:
- Years: Average 2000-2018
- Access date:
- Reference: Bisselink, B., Bernhard J, Gelati E., Adamovic M, Guenter S, Mentaschi L, De Roo A. Impact of a changing climate, land use, and water usage on Europe's water resources, EUR29130EN, Publication Office of the European Union, Luxemburg, 2018. ISBN 978-92-79-80288-1, doi: 10.2760/09027, JRC110927
- Spatial Resolution: 5x5 km^2

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Heavy water abstractions may reduce streamflow in aquatic freshwater systems to levels that threaten biodiversity survival and ecosystem services delivery, to the point that some countries forbid abstractions when streamflow is below given thresholds. However, at the European level there is no agreement on what threshold to define for sustainable environmental flows. For the MAES, we use as reference the 10th percentile of streamflow that would occur in natural conditions (i.e the level below which streamflow would occur on average 36.5 days a year in the absence of any abstraction and flow regulations), and calculated the frequency with which streamflow is below the reference in current hydrological conditions. A frequency below 0.1 means that the natural low flow occurrence is respected, whereas values above the 0.10 thresholds indicate increasing alteration of low flows.

The indicator is calculated with Lisflood 2.0 model (Bisselink et al., 2018) for historical records of 2000-2018 for current conditions. Natural conditions are simulated by taking out water abstractions and flow regulations (reservoirs). The indicator Q10 is calculated at pixel size of 5 x 5 km^2.

3.2. Map

Figure 1 shows the distribution of low flow occurrence in Europe for the average conditions for 2000-2018. Currently in 39% of EU-28 territory the occurrence of low flow is unaltered compared to natural flow conditions (i.e. the frequency of streamflow above the Q10 threshold is met in at least for 90% of time), leaving 61% of freshwaters affected to some degree of alteration. In 5% of EU-28 territory streamflow is extreme, and below the natural 10th percentile for more than 50% of time. This includes 100% of Malta, 27% of Spain, and 10% of Bulgaria.

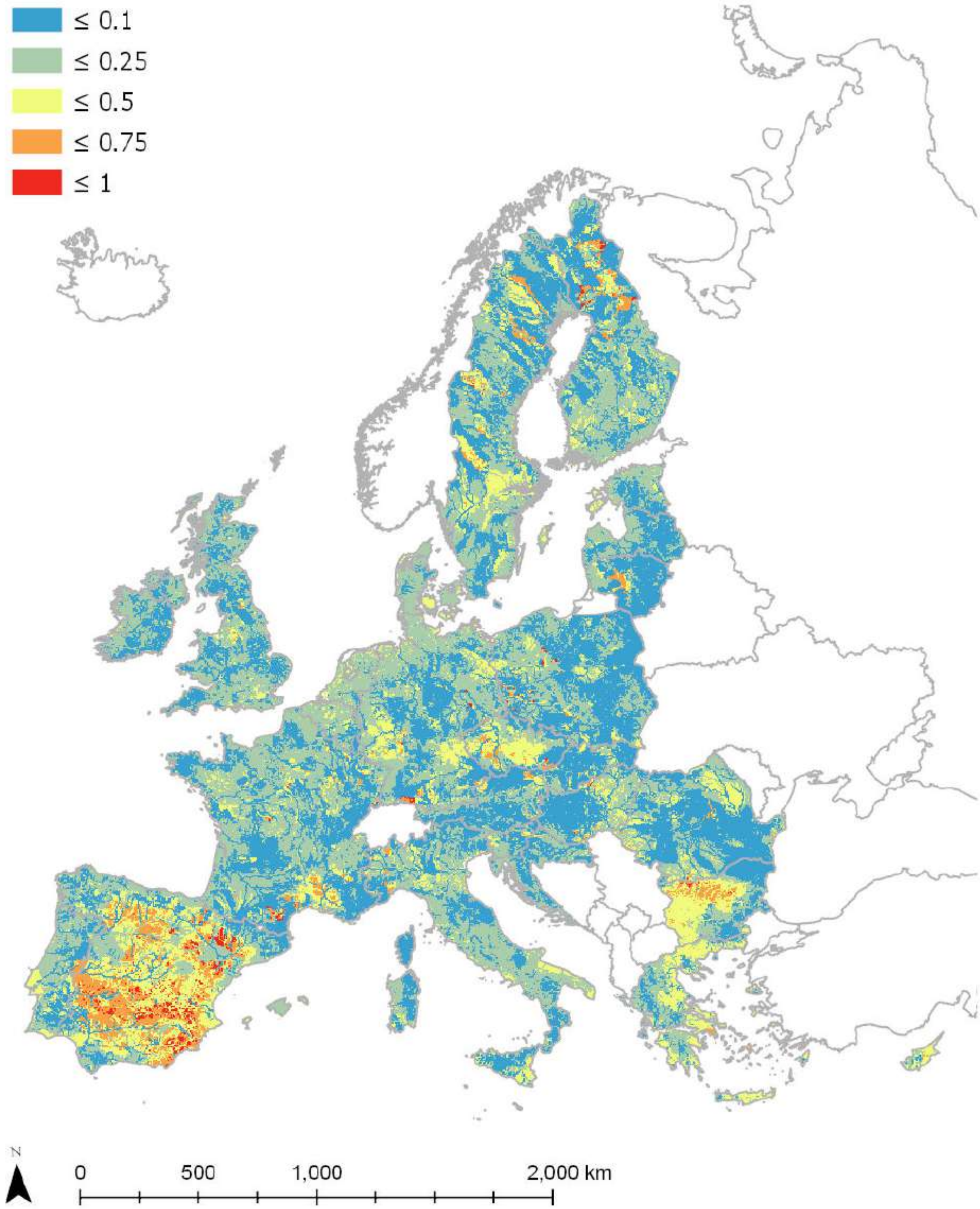


Figure 1. Occurrence of streamflow below the 10th percentile of natural conditions. Mean conditions for 2000-2018.

3.3. Key trend at EU level

Water abstractions in the model are assumed constant in time, thus only hydrologic conditions may alter annual outputs; for this reason average conditions in the 2010s were used and no trend was derived.

Fact sheet 3.6.205: Water Exploitation Index (Consumption) – WEIc

1. General information

- Freshwater ecosystems
- Environmental quality
- Water Exploitation Index (water consumption/availability)
- Fraction (of available water resources)

2. Data sources

- Data holder: JRC
- Weblink: JRC data portal (in progress)
- Years: Average 2000-2018
- Access date:
- Reference: Bisselink, B., Bernhard J, Gelati E., Adamovic M, Guenter S, Mentaschi L, De Roo A. Impact of a changing climate, land use, and water usage on Europe's water resources, EUR29130EN, Publication Office of the European Union, Luxemburg, 2018. ISBN 978-92-79-80288-1, doi: 10.2760/09027, JRC110927
- Spatial Resolution: River basins

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Water abstractions pose heavy pressure on aquatic freshwater ecosystems, especially where water availability is limited. The Water Exploitation Index on consumption (WEIC) is the ratio of net water consumption divided by the freshwater resources of a region. Water consumption considers net abstractions, i.e. total abstractions less the amount of water that returns to the system after usage. WEIC above 0.20 indicates water stress, and WEIC above 0.4 indicates severe water stress.

The indicator is calculated with the Lisflood 2.0 model (Bisselink et al., 2018). Water abstractions and consumption rates are defined for five main sectors. Water demand from domestic, industrial, and energy and cooling are based on national statistics reported in EUROSTAT/AQUASTAT and downscaled according to the distribution of population and industries. Livestock water demand is based on livestock density maps. Water demand for irrigation is estimated within LISFLOOD based on crop water requirements.

Freshwater resources taken into account include locally generated runoff, inflowing surface waters, lakes and reservoirs storage and outflow, and groundwater recharge (Bisselink et al. 2018). WEIC is calculated for sub-river basin districts within an EU Member State. While the model can predict monthly values, the average for 2000-2018 was used for the purposes of this assessment.

3.2. Map

Figure 1 shows WEIC distribution in Europe; water scarce areas concentrates in South Europe, however seasonal water stress may be more diffuse. Currently 8% of EU-28 suffers of water stress (WEIC => 0.20), including 100% of Malta and Cyprus, 55% of Greece, 42% of Spain, and about 15% of Italy and Portugal.

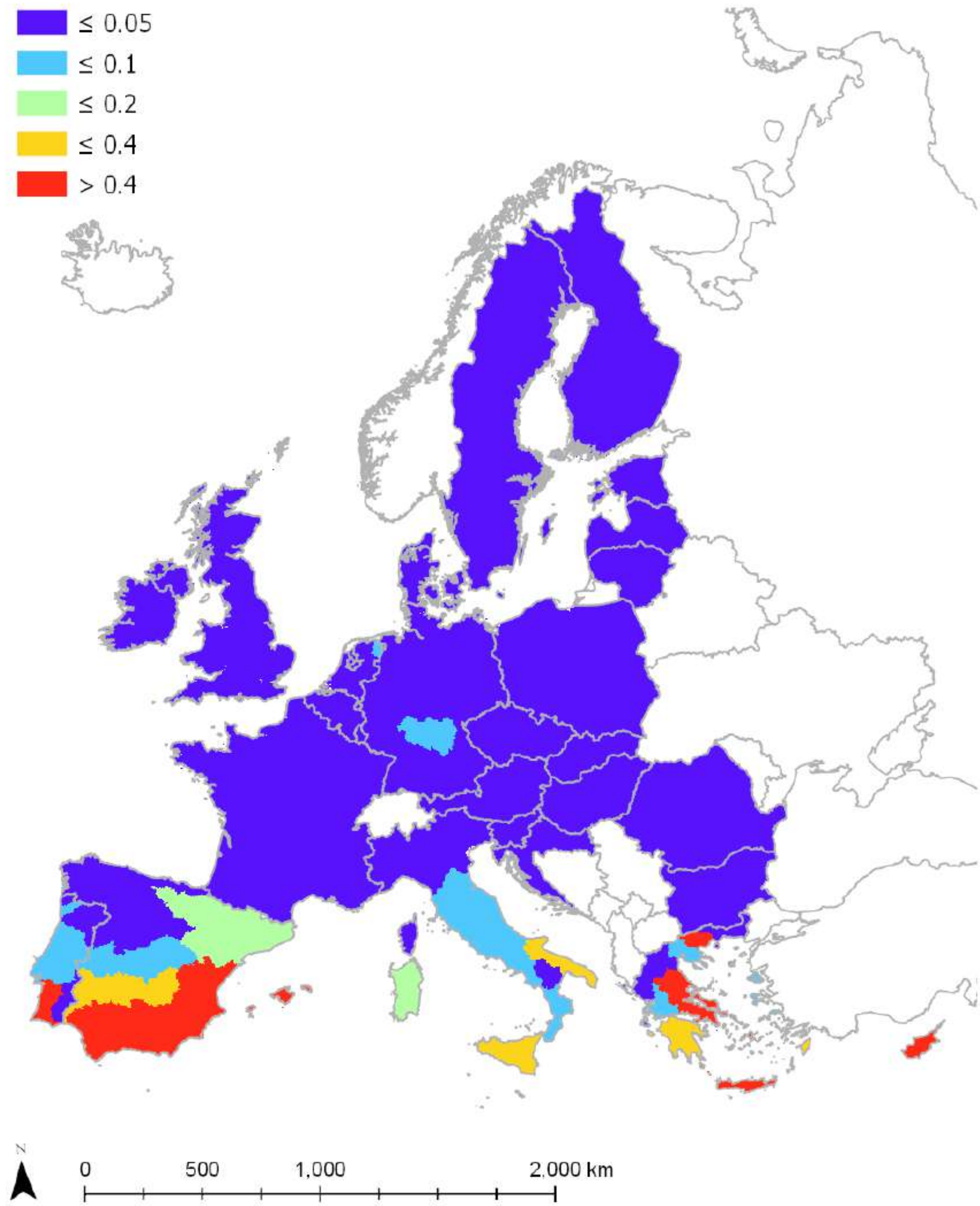


Figure 1. Water Exploitation Index (consumption) WEIC for European River Basin Districts. Mean conditions for 2000-2018.

3.3. Key trend at EU level

Water demands and consumption rates in this model application were assumed constant in time, and were estimated for average conditions in the 2010s. No trend was derived.

Fact sheet 3.6.206a: Land cover in riparian areas

1. General information

- Freshwater ecosystems
- Condition: Environmental quality
- Land cover share in riparian areas (artificial areas, agricultural areas, natural areas)
- %

2. Data sources

- Data holder: JRC
- Weblink: https://land.copernicus.eu/pan-european/corine-land-cover V18
- Years: 2000, 2006, 2012, 2018
- Access date: 15/06/2019
- Reference: CLC2000, CLC2006, CLC2012 V18; CLC2018 release V20b2
- Spatial Resolution: Nuts2

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

Riparian areas exert important regulatory services like water purification and provide habitats to freshwater biota. Encroachment of these areas by anthropogenic activities limit these functionalities (Pistocchi et al., 2015; 2018). For this assessment, riparian areas were identified according to Weissteiner et al. (2013) riparian land map. Land cover was taken from CORINE CLC status, so the indicators could be calculated for years 2000, 2006, 2012 and 2018. The share of artificial land use is taken from CORINE Land Cover level 1 category 1, divided by riparian land area. The share of agricultural land use is taken from CORINE Land Cover level 1 category 2. The share of natural land is taken from CORINE Land Cover level 1 categories 3 and 4.

3.2. Maps

Figures 1 to 3 show the extent of artificial, agricultural, and natural land cover in riparian areas from 2006 to 2018, as well as the change of artificial land share (if significant at probability level of P = 5% in the period 2000-2018; note that no significant change was observed in the period 2006-2018). In 2012, agricultural land covered 46.7% of riparian areas, artificial land covered 6.8% and natural vegetation covered 21%.

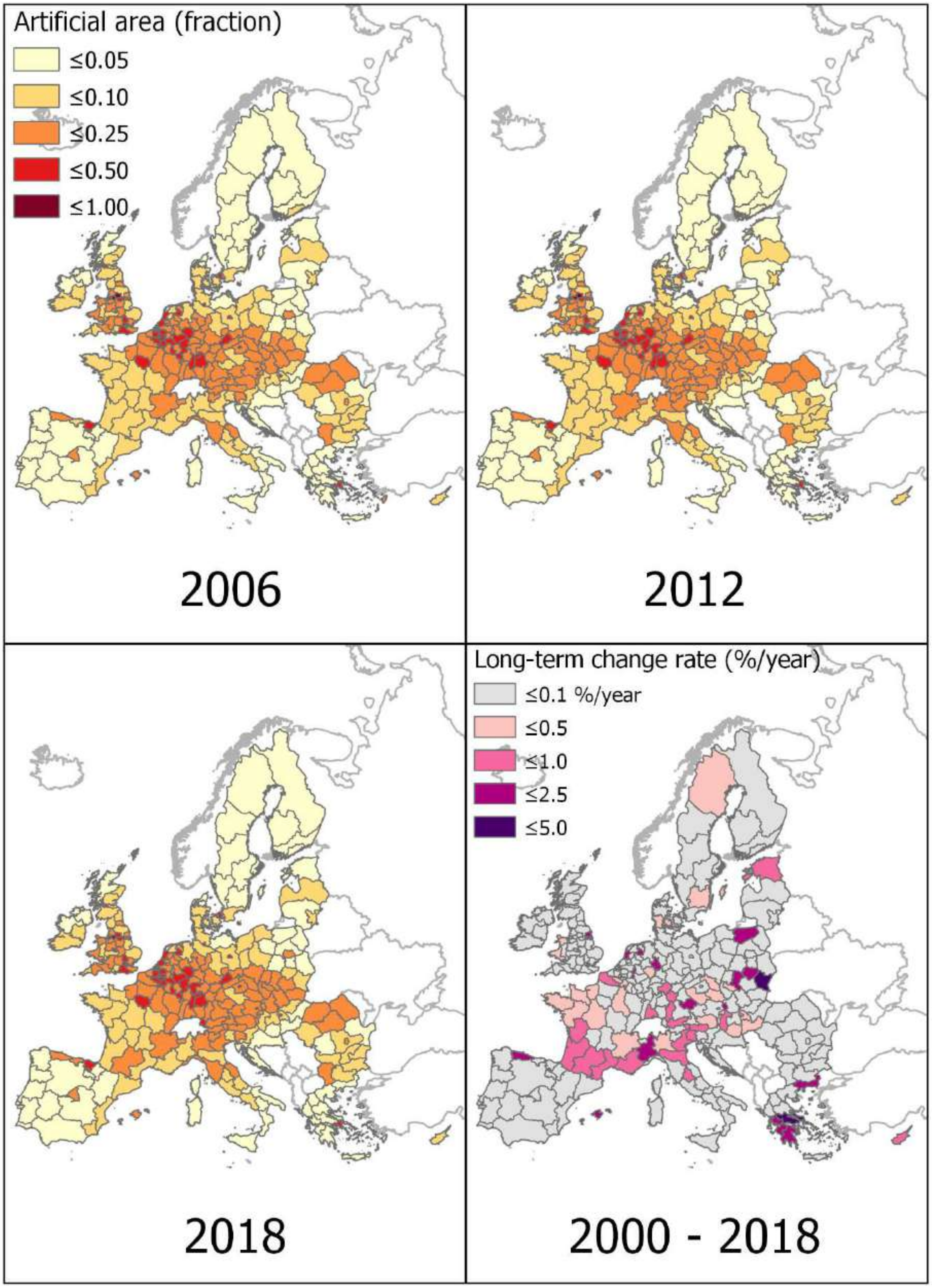


Figure 1. Artificial land cover (fraction) in riparian areas (2006-2018) and rate of change in 2000-2018.

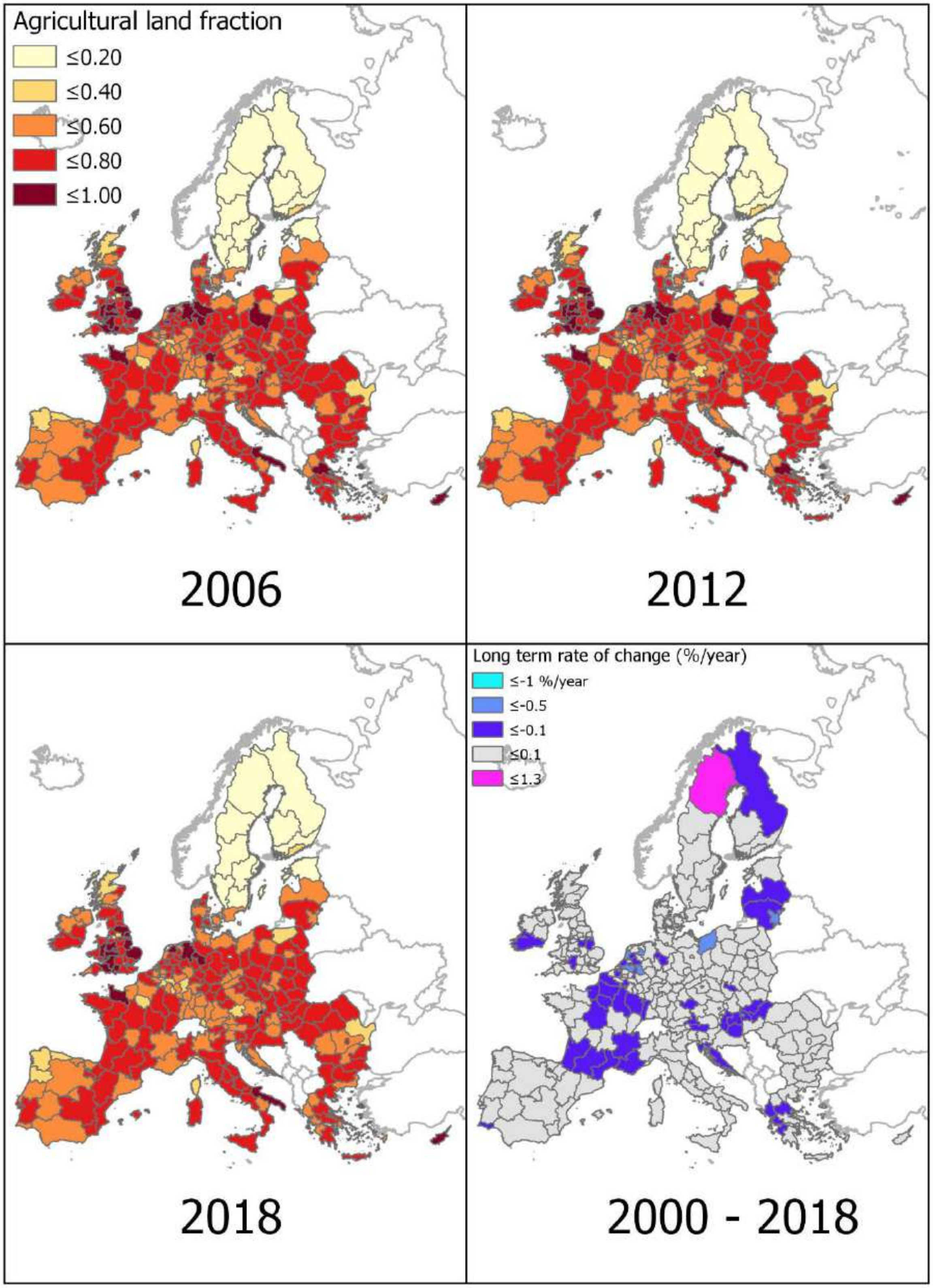


Figure 2. Agricultural land cover (fraction) in riparian areas (2006-2018) and rate of change in 2000-2018.

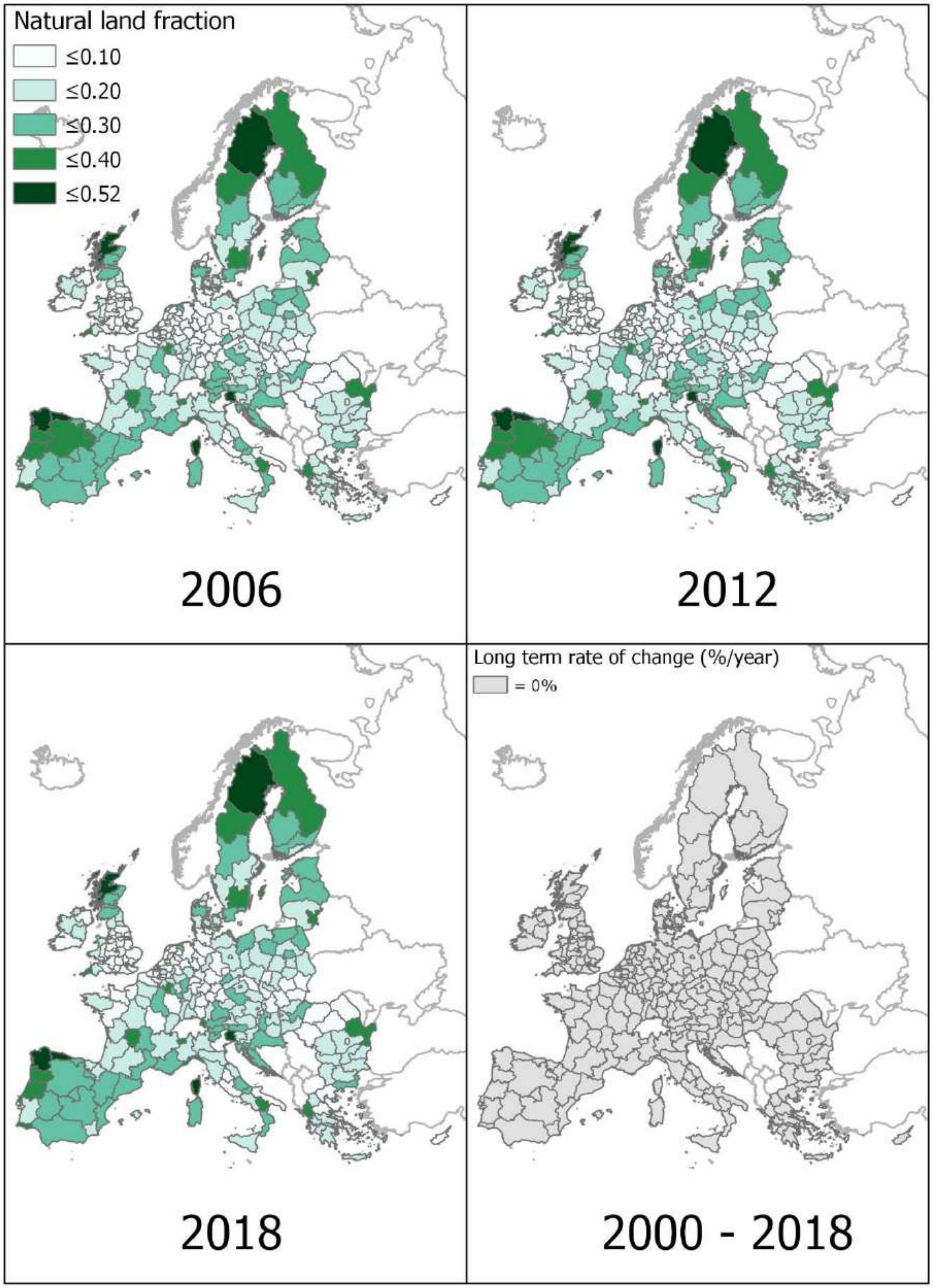


Figure 3. Natural land cover (fraction) in riparian areas (2006-2018) and rate of change in 2000-2018.

3.3. Statistical analysis of the trend

- Rate of change was assessed with Ordinary Least Square regression on the 4 data entries from 2000 to 2018; significant changes are shown in Figures 1-3. In the shorter term, changes from 2012 to 2018 were checked with Wilcoxon tests using distribution of land cover at Nuts2 level scale and resulted in no significant change, indicating stable conditions.

3.4. Key trend at EU level

Figures 2 indicates changes in time of riparian land cover at EU-28 scale. Statistical tests indicated a significant decrease in agricultural land at a rate of -2%/decade and an increase in artificial land cover at a rate of +6.8%/decade (indicating degrading conditions), but no change in natural land cover fractions (stable conditions).

In the shorter term of 2006-2018 no significant change was detected in riparian land cover indicating stability.

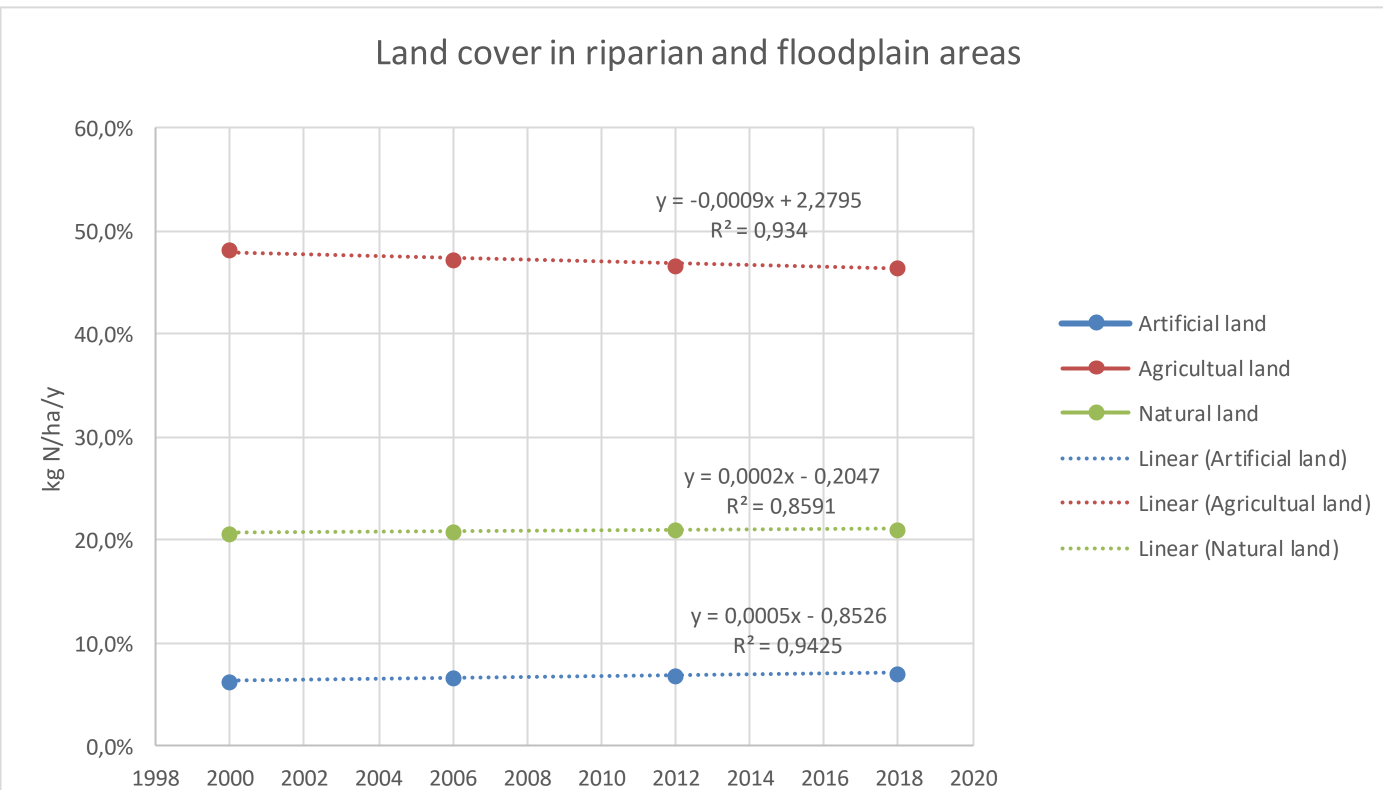


Figure 2. Land cover in riparian and floodplain areas from 2000 to 2018. Data source: JRC.

These indicators suggest urbanization of riparian land at the cost of agricultural land (cropland and grassaland). This is corroborated by conclusions from land take indicator in potential floodplains based on CLC accounting datasets.

References

Weissteiner, C.J., Martin Ickerott, M., Ott, H., probeck, M., Ramminger, G., Clerici , N., Dufourmont, H., Ribeiro de Souse, A.M. 2016. Europe's green arteries – a continental dataset of riparian zones. Remote Sensing 8, 925: doi: 10.3390/rs8110925

Pistocchi, A., Aloe, A., Bizzi, S., Bouraoui, F., Burek, P., de Roo, A., Grizzetti, B., van de Bund, W., Liquete, C., Pastori, M., Sala, F., Stips, A., Weissteiner, C., Bidoglio, G. 2015. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures. Part I – Pan-European screening of the pressures addressed by member states. JRC Technical Reports, report EUR27465EN. http://publications.jrc.ec.europa.eu/repository/handle/JRC96943

Pistocchi, A., Aloe, A., Grizzetti, B., Udias Moinelo, A., Vigiak, O., Bisselink, B., Bouraoui, F., de Roo, A., Gelati, E., Pastori, M., Van De Bund, W. 2018. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures - Part III – JRC Pressure Indicators v.2.0: nutrients, urban runoff, flow regime and hydromorphological alteration. JRC Technical Reports, report EUR 29045 EN.

Fact sheet 3.6.206b: Hydromorphological alteration (density of infrastructures in riparian areas)

1. General information

- Freshwater ecosystems
- Environmental quality
- Hydromorphological alteration by infrastructures in riparian/floodplain areas
- km of infrastructure/km^2 of riparian-floodplain areas

2. Data sources

- Data holder: JRC
- Weblink: https://data.jrc.ec.europa.eu/collection/wpi
- Years: 2015
- Access date: July 2019
- Reference: Pistocchi, A., Aloe, A., Grizzetti, B., Udias Moinelo, A., Vigiak, O., Bisselink, B., Bouraoui, F., de Roo, A., Gelati, E., Pastori, M., Van De Bund, W. 2018. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures - Part III – JRC Pressure Indicators v.2.0: nutrients, urban runoff, flow regime and hydromorphological alteration. JRC Technical Reports, report EUR 29045 EN
- Spatial Resolution: Nuts2

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The presence of infrastructures in riparian areas can be considered a proxy for human pressures on the aquatic habitats, disturbing the natural setting. Linear infrastructures (roads and railways) in riparian areas were mapped on the basis of the OpenStreetMap road and railway segments accessed in 2016. The extent of riparian areas was mapped by Weissteiner et al. (2013). Density is expressed in km of linear infrastructure per km^2 of riparian areas, and for the purposes of MAES has been aggregated at NUTS2 level.

3.2. Maps

Figure 1 shows the density of infrastructures in riparian land. At EU-28 level, the mean density is 2.03 km/km^2. Besides urbanized areas, high infrastructure densities can be observed in central Europe and in mountain ranges (e.g. Alps).

3.3. Key trend at EU level

The indicator is static in time, and representative for 2015 conditions. No trend is available.

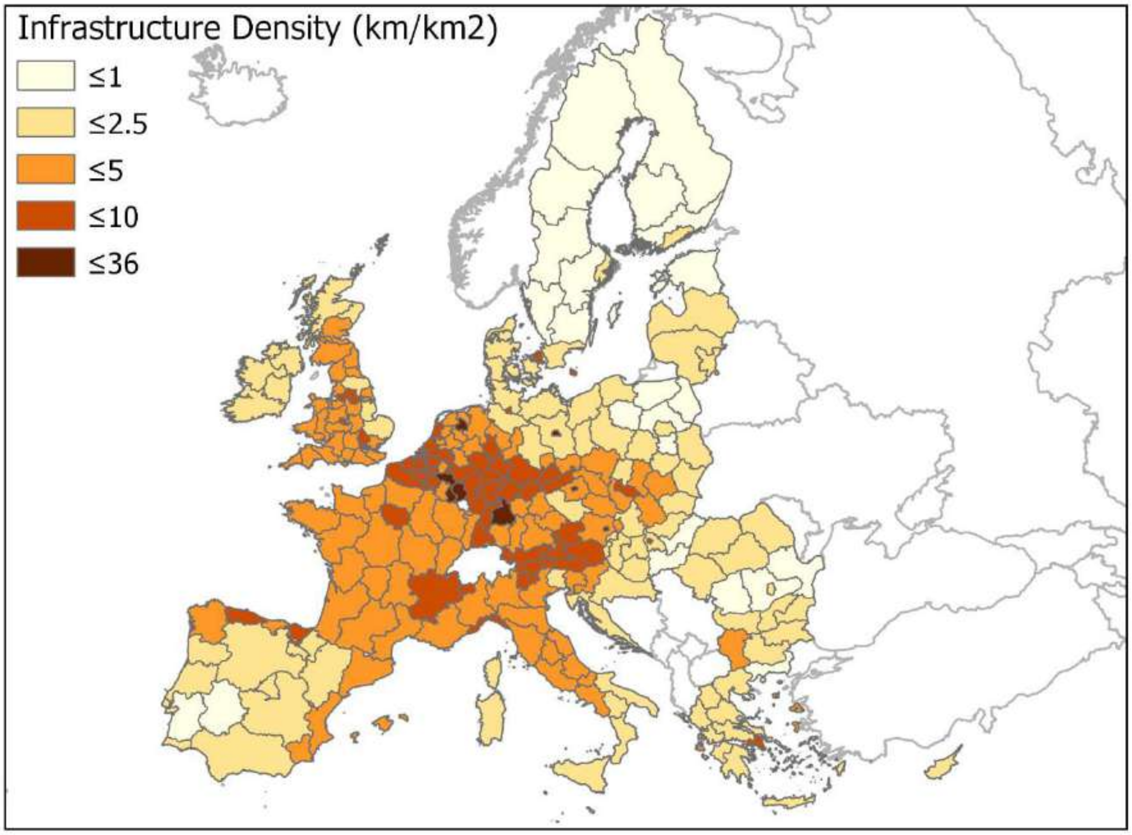


Figure 1. Density of infrastructures in riparian/floodplain areas (km/km^2), indicating a degree of disturbance of aquatic habitats by anthropogenic presence.

References

Weissteiner, C.J., Martin Ickerott, M., Ott, H., Probeck, M., Ramminger, G., Clerici , N., Dufourmont, H., Ribeiro de Sousе, A.M. 2016. Europe's green arteries – a continental dataset of riparian zones. Remote Sensing 8, 925: doi: 10.3390/rs8110925

Pistocchi, A., Aloe, A., Bizzi, S., Bouraoui, F., Burek, P., de Roo, A., Grizzetti, B., van de Bund, W., Liquete, C., Pastori, M., Sala, F., Stips, A., Weissteiner, C., Bidoglio, G. 2015. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures. Part I – Pan-European screening of the pressures addressed by member states. JRC Technical Reports, report EUR27465EN. http://publications.jrc.ec.europa.eu/repository/handle/JRC96943

Pistocchi, A., Aloe, A., Grizzetti, B., Udias Moinelo, A., Vigiak, O., Bisselink, B., Bouraoui, F., de Roo, A., Gelati, E., Pastori, M., Van De Bund, W. 2018. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures - Part III – JRC Pressure Indicators v.2.0: nutrients, urban runoff, flow regime and hydromorphological alteration. JRC Technical Reports, report EUR 29045 EN.

Fact sheet 3.6.207: Hydromorphological alteration by barriers (dams)

1. General information

- Freshwater ecosystems
- Ecosystem condition: Environmental quality
- Hydromorphological alteration by barriers (fraction of streamflow interception, share of free accessible stream network)
- %

2. Data sources

- Data holder: JRC
- Weblink: https://data.jrc.ec.europa.eu/collection/wpi
- Years: 2015
- Access date: July 2019
- Reference: Pistocchi, A., Aloe, A., Grizzetti, B., Udias Moinelo, A., Vigiak, O., Bisselink, B., Bouraoui, F., de Roo, A., Gelati, E., Pastori, M., Van De Bund, W. 2018. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures - Part III – JRC Pressure Indicators v.2.0: nutrients, urban runoff, flow regime and hydromorphological alteration. JRC Technical Reports, report EUR 29045 EN
- Spatial Resolution: Nuts2

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The presence of dams, locks and other barriers along streams reduces the fluxes of water, materials and species along the stream network, interrupting the longitudinal connectivity of aquatic habitats. Barriers limits sediment supply and impacts natural flow regimes, and therefore may induce river bed aggradation and alter channel-alluvium exchanges (Pistocchi et al., 2018).

Two indicators were selected to provide information on the disturbance of barriers along freshwater systems (Pistocchi et al., 2015; 2018), namely:

1) the fraction of streamflow intercepted by dams/barriers, giving an indication of longitudinal hydrological disconnectivity; and
2) the fraction of the stream network that is dams-free , i.e. the ratio of the stream length theoretically accessible between barriers divided by the total length of stream network, providing an indication of longitudinal morphological disconnectivity.

For the first indicator, mean annual streamflow at each reach length was modelled with a long-term water balance approach. For the second indicator, for each river segment (mapped with CCM2 tessellation), the total length of stream network to which it belongs (from headwater to sea outlet) is calculated. Then, the sum of lengths of segments that are accessible in the presence of dams is calculated. A segment is accessible if there is no dam in between. The indicator is the ratio of the total accessible length over the total length of the stream network and represents the share of naturally available habitat. The analysis was conducted at 1 km resolution. Dams, weirs and locks were delineated enlarging the EuroRegionalMap v6.04, including some 3000 dams with a reservoir of at least 0.4 km^2 surface, with other sources.

The dataset can be considered valid for 2015, however mapped barriers are likely incomplete. Further, presence of mitigation measures could not be considered.

3.2. Maps

Figure 1 shows the distribution of hydromorphological indicators in EU-28 for the year 2015. At the EU-28 scale, 60.3% of streamflow is intercepted by barriers that alter material fluxes, whereas the accessible network (both upstream and downstream) is 3.8% of what would be in the absence of barriers. The areas more impacted by barriers are the Iberian Peninsula, South of France, Central Europe and most of the Danube basin. Regions that appear to be less impacted by barriers are the Baltic countries, Ireland and the United Kingdom in the North, and Greece, centre and South of Italy, Malta and Cyprus in the South.

3.3. Key trend at EU level

Information used to calculate these indicators is static, and no trend can be provided.

References

Pistocchi, A., Aloe, A., Bizzi, S., Bouraoui, F., Burek, P., de Roo, A., Grizzetti, B., van de Bund, W., Liquete, C., Pastori, M., Sala, F., Stips, A., Weissteiner, C., Bidoglio, G. 2015. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures. Part I – Pan-European screening of the pressures addressed by member states. JRC Technical Reports, report EUR27465EN. http://publications.jrc.ec.europa.eu/repository/handle/JRC96943

Pistocchi, A., Aloe, A., Grizzetti, B., Udias Moinelo, A., Vigiak, O., Bisselink, B., Bouraoui, F., de Roo, A., Gelati, E., Pastori, M., Van De Bund, W. 2018. Assessment of the effectiveness of reported Water Framework Directive Programmes of Measures - Part III – JRC Pressure Indicators v.2.0: nutrients, urban runoff, flow regime and hydromorphological alteration. JRC Technical Reports, report EUR 29045 EN.

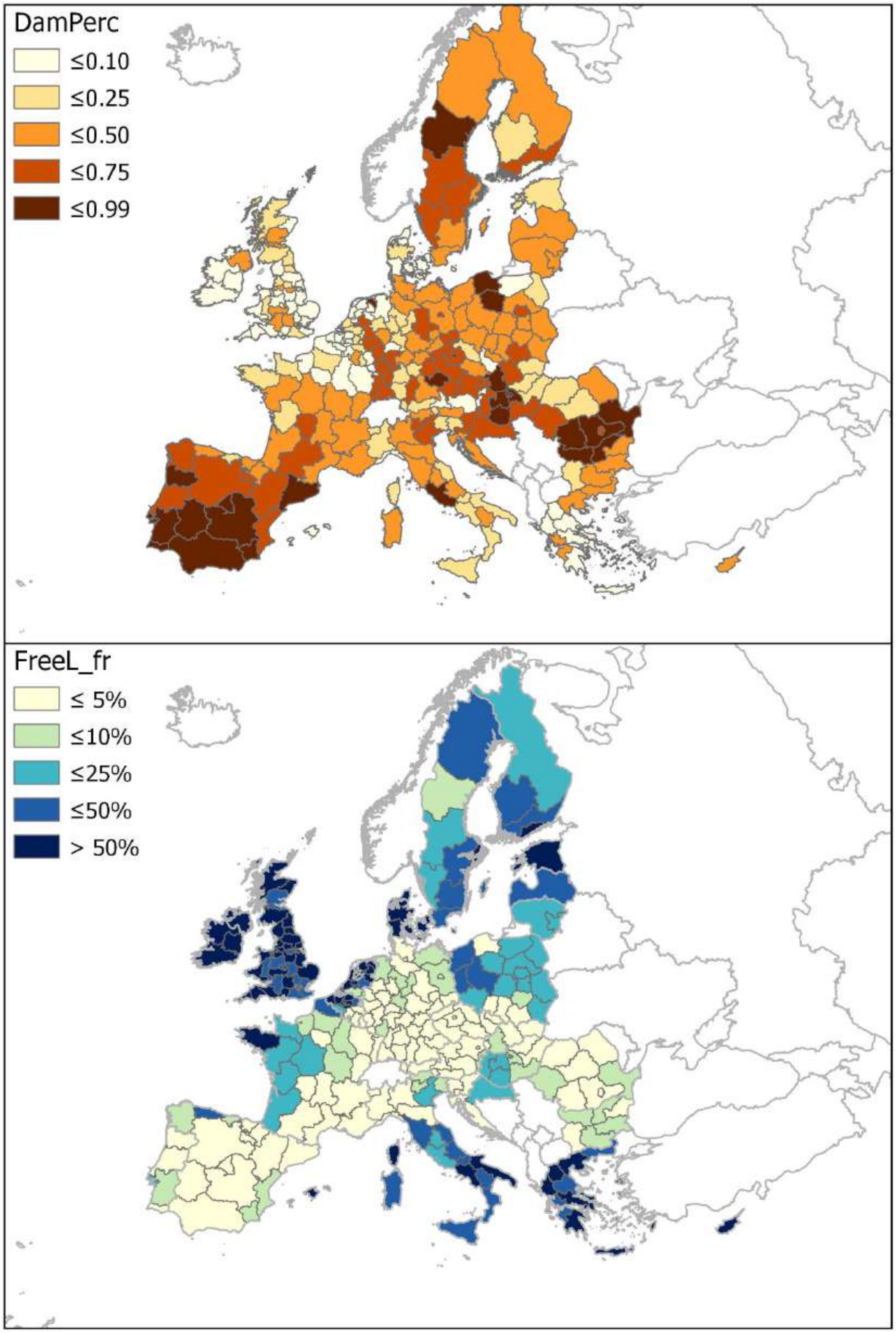


Figure 1. Indicators hydromorphological alteration due to dams and barriers. Above: fraction of streamflow intercepted by barriers. Below: fraction of accessible stream network. Source: JRC.

Fact sheet 3.6.208: Ecological status or potential of European rivers and lakes

1. General information

- Freshwater ecosystems
- Environmental quality
- Ecological status or potential of rivers and lakes
- Classes: High, Good, Moderate, Bad, Poor, or Unknown

2. Data sources

- Data holder: EEA and Commission (DG ENV)
- Weblink: WISE Water Framework Directive Database, WISE-Freshwater WFD dashboards on Ecological status of surface water bodies
- Years: 2010-2015 (second River Basin Management Program RBMPs round; note that many RBMPs only included results up to 2012/13), and before 2009 (first RBMPs)
- Access date: July 2019
- Reference: EEA 2018, European waters – assessment of status and pressures 2018. EEA Report No 7/2018. Available at https://www.eea.europa.eu/publications/state-of-water
  After this publication data are updated with Ireland (and Norway).
- Spatial Resolution: River basin districts excluding Lithuania and Greece who have not yet finalized the data reporting for the 2nd RBMPs

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

According to the Water Framework Directive (EC, 2000) the ecological status of surface water bodies is assessed on the basis of several standards for the ecology, chemistry, morphology and quantity of waters. These criteria for the quality of the structure and functioning of surface water ecosystems. In general terms, good status means that water shows only a slight change from what would normally be expected under undisturbed conditions (i.e. with a low human impact). More specifically, a surface water body has achieved good ecological status when 'the values of the biological quality elements for the surface water body type show low levels of distortion resulting from human activity, but deviate only slightly from those normally associated with the surface water body type under undisturbed conditions' (EU, 2000). Ecological status is used here as a proxy for the overall status of waters. This is because ecological status is influenced by water quality (e.g. pollution levels of all types), hydromorphological pressures as well as by the amount of available water.

The indicator is defined as the number of surface water bodies not achieving at least 'good' ecological status or 'good' ecological potential. The indicator covers the current status of surface waters as reported in the second River Basin Management Plans (RBMPs, with reference period 2010-2015), based on the information reported by Member States and stored in the WISE-WFD database. It is aggregated at the scale of river basin management district. A comparison is made with the data reported in the first RBMPs (EEA, 2018).

3.2. Maps

The percentage of water bodies in less than ‘good’ ecological status varies between river basin districts. Surface water bodies in north-western Europe have the lowest status. In Belgium (Flanders), northern Germany and the Netherlands, the ecological status of more than 90 % of surface waters is reported to be ‘less than good’ (i.e. moderate, poor or bad). Other problem areas include the Czech Republic, southern England, northern France, southern Germany, Hungary and Poland, as well as several individual river basin districts in other EU Member States, where the status of 70-90 % of freshwater bodies (lakes and rivers) is reported to be ‘less than good’.

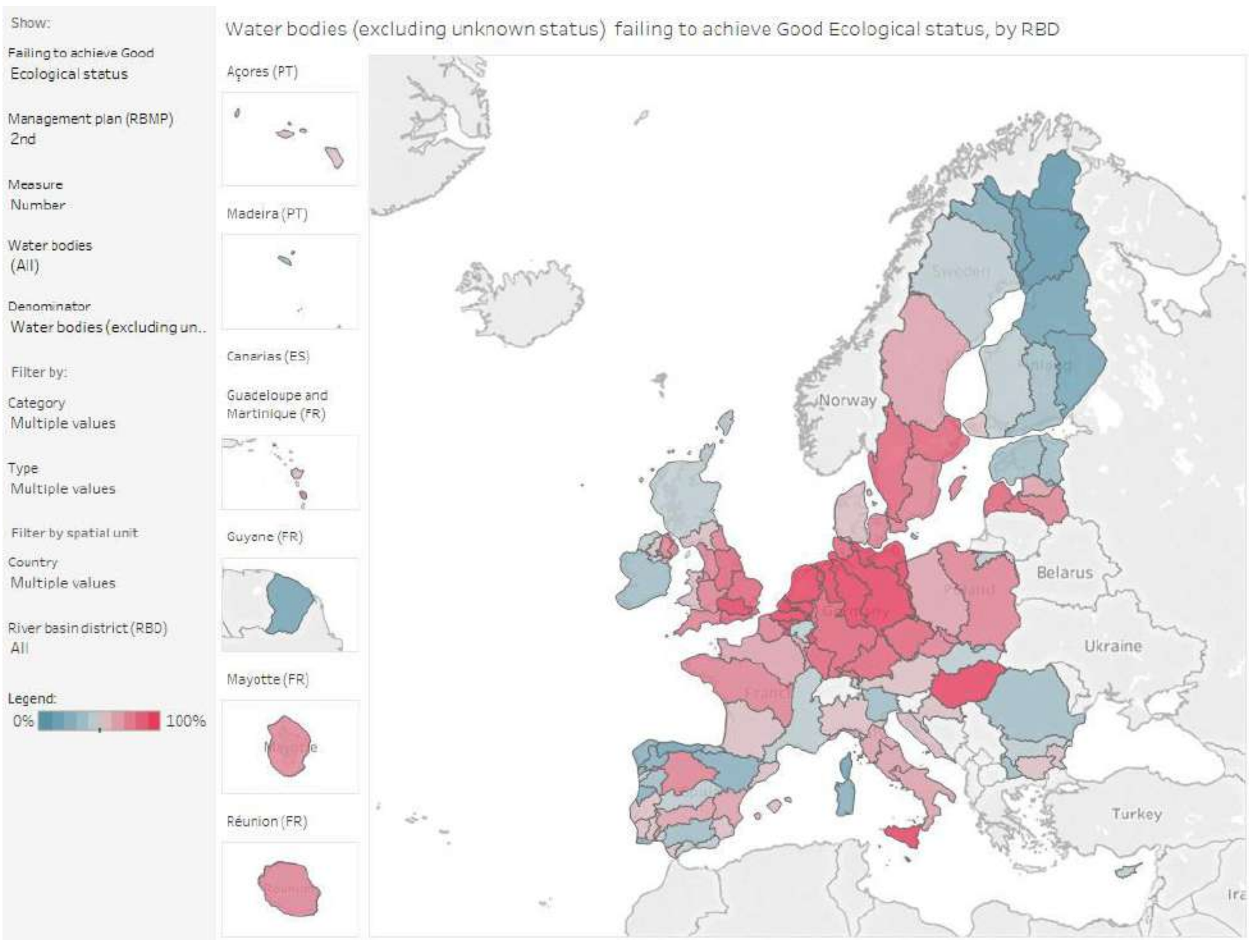


Figure 1. Percentage of water bodies not in good ecological status/potential in Europe’s river basin districts in second River Basin Management Plans (RBMPs). Source: Results are based on WISE-SoW database including data from 25 Member States (EU-28 except Greece, Lithuania and Slovenia). Water bodies failing to achieve good status, by RBD.

The main pressures causing the failure of achievement of good status are point (e.g. waste water) and diffuse source pollution (e.g. agriculture), and various hydromorphological pressures. Diffuse source pollution affects 37 % of surface water bodies and point source pollution affects 17 %, while hydromorphological pressures affect 40 %. The main impacts of the pressures on surface water bodies are nutrient enrichment, chemical pollution and altered habitats due to morphological changes.

3.3. Statistical analysis of the trend

- Methodological differences between the two River basin Management Plans reporting periods precluded analysis of temporal trends.

3.4. Key trend at EU level

Based on the second River Basin Management Plans (RBMPs) from 2015, which use data from 26 Member States (excluding Lithuania and Greece), around 40 % of river and lake water bodies have achieved good ecological status. Lakes are generally having better status than rivers, partly due to many of the lakes located in relative sparsely populated regions ((Sweden and Finland).

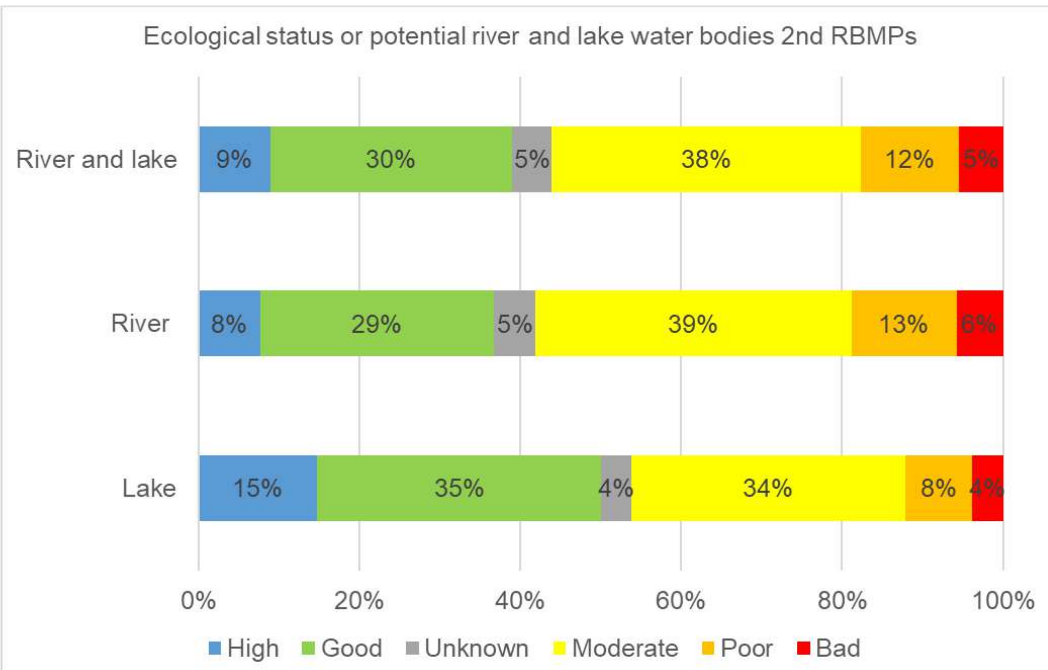


Figure 2. Ecological status or potential of river and lakes water bodies in the EU (second River Basin Management Plans, RBMPs). Source: Results based on WISE-SoW database including data from 26 Member States (EU-28 except Greece and Lithuania). Surface water bodies: Water body category and Ecological status or potential

The quality of ecological status classification has largely improved from the first to the second RBMPs. There is a marked reduction in water bodies of unknown status, a large improvement in confidence in classification and an important increase in intercalibrated biological assessment methods. This complicates the comparison of status between the first and second RBMPs. Overall, the second RBMPs show limited change in ecological status compared with the first RBMPs (from 2009); for most water bodies the ecological status remained similar in both sets of RBMPs. A closer look at the change in quality elements shows some improvement (EEA, 2018). The improvements are seen in all the most commonly used biological quality elements in rivers, but they are less clear in phytoplankton in lakes.

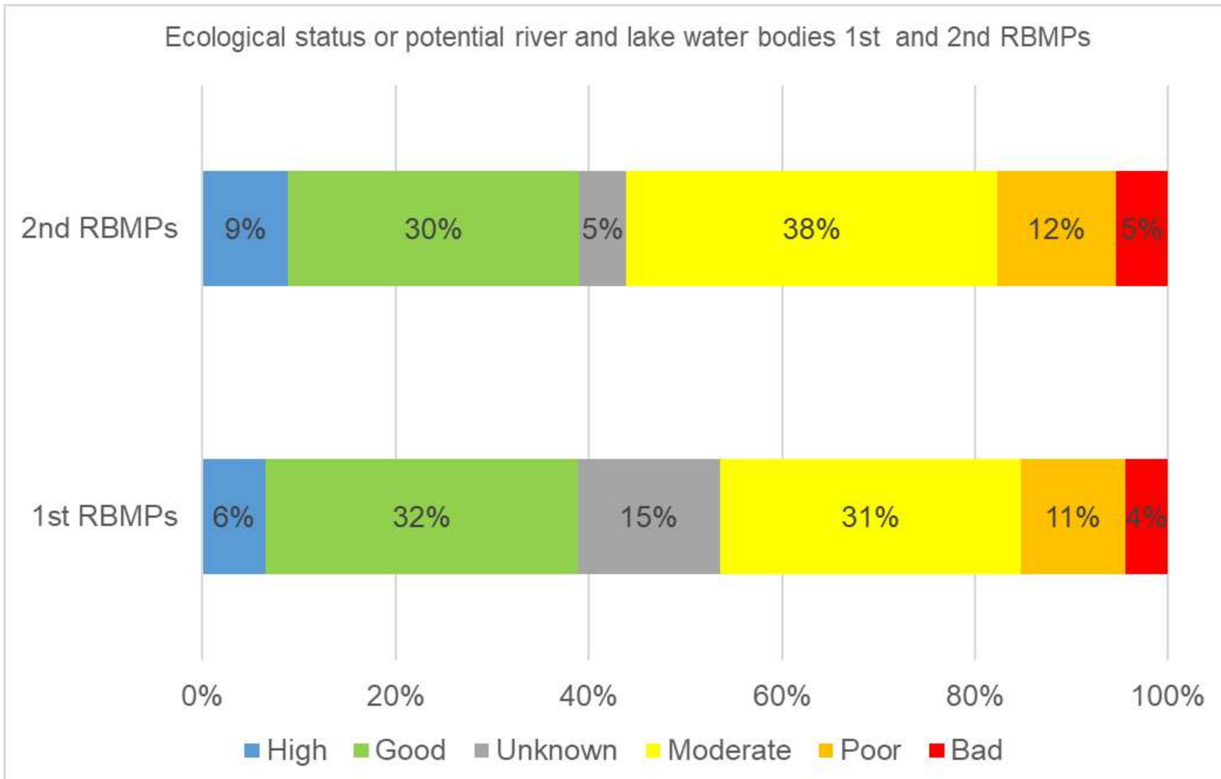


Figure 3. Comparison of ecological status reported in the second RBMPs (2010-2015) and the first RBMPs (2009). Source: Results are based on WISE-SoW database including data from 26 Member States (EU-28 except Greece and Lithuania). Surface water bodies ecological status or potential in first and second RBMPs.

Further references

European Commission (EC). 2000. Water Framework Directive (WFD) 2000/60/EC. http://ec.europa.eu/environment/water/water-framework/index_en.html

Fact sheet 3.6.209: Fraction of freshwater habitats protected by Natura 2000 sites and/or Nationally designated areas - CDDA

1. General information

- Freshwater ecosystems
- Condition: Structural ecosystem attributes monitored under the EU Nature directives
- Fraction of ecosystem covered by protected areas (by Natura 2000 sites; by nationally designated areas – CDDA; and by the overlapping of both networks) from 2000 to 2018
- Percentage (%)

2. Data sources

- Data holder: EEA
- Weblinks:
- Corine Land Cover https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers#tab-european-data
- Natura 2000 data - the European network of protected sites: https://www.eea.europa.eu/data-and-maps/data/natura-10
- CDDA data - Nationally designated areas: https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-13
- Year or time-series range 2000 / 2006 / 2012 / 2018
- Versions
  - Corine Land Cover 2000 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2006 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2012 (raster 100m) version 20 accounting layer, Jun. 2019
  - Corine Land Cover 2018 (raster 100m) version 20 accounting layer, Jun. 2019
  - Natura 2000 End 2018 – Shapefile
  - Natura 2000 End 2013 rev1 – Shapefile
  - CDDA 2018 – Shapefile

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The EU Nature Directives (Birds and Habitats) are the centerpiece of its nature legislation and biodiversity policy. The Natura 2000 sites are one of the Nature Directive's main tools that contribute to ensuring the conservation of many species and habitats of EU interest. Its purpose is primarily to ensure the conservation of targeted species and habitats of European interest. Every country has designated Natura 2000 sites to help conserve the rare habitats and species present in their territory. Progress in designating sites was slow at first but currently the protected area is over 18 % of the EU's land, being the largest network of protected areas in the world (EEA, 2012). The Natura 2000 network is largely complete as far as the terrestrial environment is concerned and connectivity — spatial and functional — of Natura 2000 sites across national borders is relatively good.

The 'nationally designated protected area' (CDDA) is an area designated by a national designation instrument, based on national legislation. If a country has included sites designated under international agreements such as the EU Birds and Habitats Directives, or the Bern or Ramsar Convention in its legislation, those figures overlap spatially. The degree of overlap between Natura 2000 sites and CDDA sites illustrates the extent to which countries have made use of their nationally designated areas to underpin Natura 2000 and to what e xtent Natura 2000 sites extend beyond national systems.

The overlap of Natura 2000 boundaries with the boundaries of nationally designated sites shows very different patterns across the EU. While the Natura 2000 digital maps fully reflect the actual extension of the network, the CDDA digital maps only reflects what countries have reported on a voluntary basis to the European Environment Agency. Moreover, in the case of a few countries, there are issues regarding the completeness of some of the IUCN data they have included in the CDDA database.

In this assessment for each biogeoregion we report the area fraction of river and lakes (as indicated in CLC 1 ha raster layers) covered by Natura 2000 sites and/or CDDA as well as the fraction of ecosystem that is not covered by protection regulation. The indicators are calculated from spatial overlap of rivers and lakes indicated in CLC 2000, 2006, 2012 with Natura 2000 network informed by MS at the end of 2013 (previous versions of spatial data of Natura 2000 present gaps and geometric inconsistences), and from CLC 2018 with Natura 2000 version provided by 2018, and the nationally designated areas informed by MS in 2018. Changes in time of the indicators could be due to changes in the extent of either the ecosystem or of the protection zones, e.g. by the designation of new areas or by the modification of the limits of those already existing. Both cases are included in this assessment and no attempt is made to distinguish the two cases. Due to partial overlap between Natura2000 sites and CDDA, also the fraction of unprotected areas is reported.

3.2. Maps

The indicators are provided as tabular information aggregated at biogeographical region. Figure 1 shows the fractions of protected or not protected areas for the year 2012.

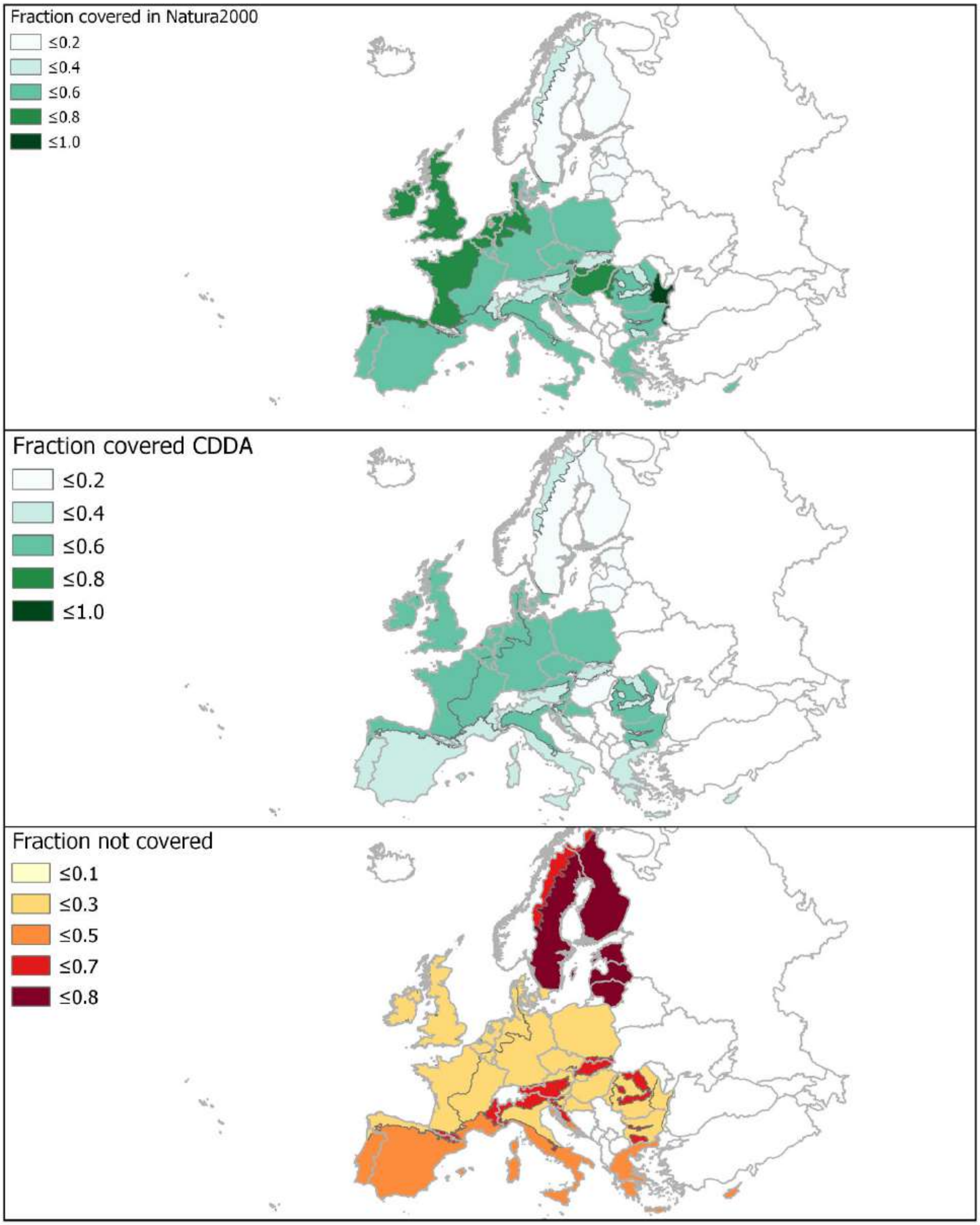


Figure 1. Fraction of rivers and lakes area covered by Natura 2000, Nationally Designated areas (CDDA), or not covered by protected European networks in 2012. Data source: EEA.

3.3. Statistical analysis of the trend

- Changes in fractions of protected and not protected areas for the long term on the basis of 4 observations (2000, 2006, 2012, and 2018) was assessed with Ordinary Least Square Regression. No attempt was made to assess changes in the short term (after 2010) due to limited number of observations.

3.4. Key trend at EU level

In the EU-28 territory the fraction of river and lakes covered by Natura 2000 sites in 2010 was estimated at 32.4% and the fraction of areas protected by Nationally Designated areas was estimated at 19.9%. The overlapping between the two networks was such that the fraction of rivers and lakes not covered by regulation was estimated at 63.4%. A large variability between bio-geographical regions (of variable size too) can be observed in Figure 1. In the Black Sea and Steppic regions, Natura 2000 sites cover more than 80% of river and lakes, whereas in the boreal region they cover 19.8%. CDDA areas covers more than 90% of Macaronesian rivers and lakes, but only 7.5% of the boreal region. The fraction of unprotected river and lakes ranged from less than 4% in Black sea and Macaronesian regions to 80% in the boreal region. Practically, these fractions did not change through time at EU-28 scale. However, in three bio-geographical regions, a slight reduction of rivers and lakes protected by Natura2000 and CDDA since 2000 to 2018 is noted (Table 1).

Table 1. Decadal rate of change (%) of fractions of rivers and lakes protected by Natura 2000 sites, National Designated (CDDA) Areas, or not protected by regulation for the 2000-2018 period. Only changes significant at 5% probability levels are reported.

Bio-geographical region	Change in Natura 2000 sites (%/10 years)	Change in CDDA areas (%/10 years)	Change in unprotected areas (%/10years)
Alpine	0	0	0
Atlantic	-0.7%	-0.5%	1.5%
Black Sea	0	0	0
Boreal	0	0	0
Continental	-1.0%	-0.8%	1.9%
Macaronesian	0	0	0
Mediterranean	0	0	0
Pannonian	-0.9%	0	2.4%
Steppic	0	0	0
EU-28	0	0	0

References

EEA, 2012. *Protected areas in Europe - an overview. European Environment Agency. EEA Report / No 5/2012,* s.l.: s.n.

Fact sheet 3.7.101: Acidification

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressure/Climate change
- Name of the indicator: Acidification
- Units: pH

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1993-2015 (25 years of time-window and 75 depth levels).
- Reference:
  - Copernicus, CMEMS, GLOBAL_REANALYSIS_BIO_001_029 weblink: http://marine.copernicus.eu/services-portfolio/access-to-products/ http://marine.copernicus.eu/ocean-monitoring-indicators-acidity/

3. Assessment of the indicator

The seawater pH is used to assess the pressure of the climate change due to human activities.

3.1. Short description of the scope of the indicator

The indicator expresses the ocean acidification. It provides an indirect measure of CO2 production . The rationale of the indicator is based on the following assumption: ocean acidification is quantified by decreases in pH, which represents the concentration of hydrogen ions (H+) in the water. A decrease in the pH value means an increase in acidity, known as acidification. The pH of a solution is usually between 0 and 14, where pH >7 means that the solution is basic. At pH 7, the solution is neutral and if pH < 7, the solution is acidic. Seawater pH is hence slightly basic as it is around 8.1 and it is becoming more acidic overtime (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

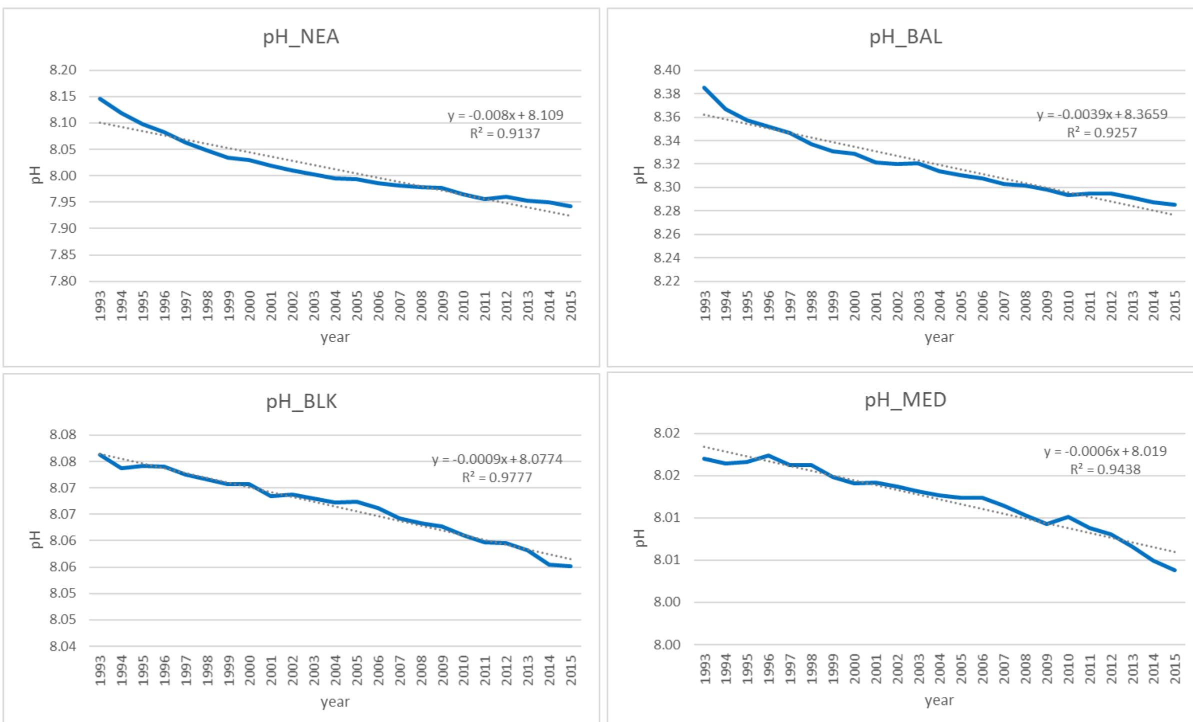
The indicator is calculated as follows: dataset are derived from the extraction of the year-mean for each depth levels, where the average of the seawater parameter for each year is computed from the monthly sub dataset relative of each year and EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the acidification trend in the EU marine regions shows it has dropped continuously and significantly overtime (Figure 1, Table 1).

Figure 1. The pH and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: seawater acidification, 1993-2015.



Parameters	Acidification_NEA	Acidification_BAL	Acidification_BLK	Acidification_MED
intercept	15.9253	12.0142	10.5910	10.5609
slope	-0.0040	-0.0019	-0.0013	-0.0013
p-values	**0.0048**	**0.0218**	**0.0012**	**0.0000**
R^2	0.8892	0.7691	0.9430	0.9904
ST_% change per decade	-0.4973	-0.2230	-0.1561	-0.1584
ST_trend direction	decrease	decrease	decrease	decrease
MARINE CONDITION_ST	DEGRADATION	DEGRADATION	DEGRADATION	DEGRADATION
intercept	24.1028	16.0970	9.8876	9.1392
slope	-0.0080	-0.0039	-0.0009	-0.0006
p-values	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R^2	0.9137	0.9257	0.9777	0.9438
LT_% change per decade	-1.0081	-0.4678	-0.1127	-0.0702
LT_trend direction	decrease	decrease	decrease	decrease
MARINE CONDITION_LT	DEGRADATION	DEGRADATION	DEGRADATION	DEGRADATION

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2015) and long term (LT: 1993-2015) for NEA, BAL, BLK and MED.

Further references

IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

von Schuckmann, K. ((Editor)) et al. (2019) Copernicus Marine Service Ocean State Report, Issue 3, Journal of Operational Oceanography, 12:sup1, S1-S123, DOI: 10.1080/1755876X.2019.1633075

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.102: Sea surface temperature

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressure/Climate change
- Name of the indicator: Sea surface temperature
- Units: Kelvin

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1993-2015 (25 years of time-window and 75 depth levels)
- Reference:
  - Copernicus, CMEMS, GLOBAL_REANALYSIS_PHY_001_025 weblink: http://marine.copernicus.eu/services-portfolio/access-to-products/; http://marine.copernicus.eu/training/education/ocean-parameters/temperature/

3. Assessment of the indicator

The sea surface temperature is used to assess the impact of human activities to marine ecosystem.

3.1. Short description of the scope of the indicator.

The indicator expresses the impact of human activities to marine ecosystem. It provides a direct measure of the temperature of the ocean near the surface. The rationale of the indicator is based on the following assumption: sea surface temperature (SST) is the temperature of the ocean near the surface. Knowing the temperature of this part of the ocean is absolutely essential for many reasons: e.g. 1) it is the signs/results of the exchange of energy between the ocean and the atmosphere, 2) it is the parameter that determines the development of different biological organisms 3), important temperature variations as seen on a map (thermal fronts) indicate prolific fishing zones. Sea surface temperature (SST) is increasing overtime (see Figure 1).

Sea surface temperature (SST) is the temperature of the ocean near the surface. Knowing the temperature of this part of the ocean is absolutely essential for many reasons. For oceanographers, meteorologists and climatologists, it is one of the signs/results of the exchange of energy between the ocean and the atmosphere. For marine biologists, it is the parameter that determines the development of different biological organisms. For fishermen, important temperature variations as seen on a map (thermal fronts) indicate prolific fishing zones.

Meteorological phenomena such as El Niño or tropical hurricanes/cyclones are the direct consequences of specific temperature variations at the sea-surface

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

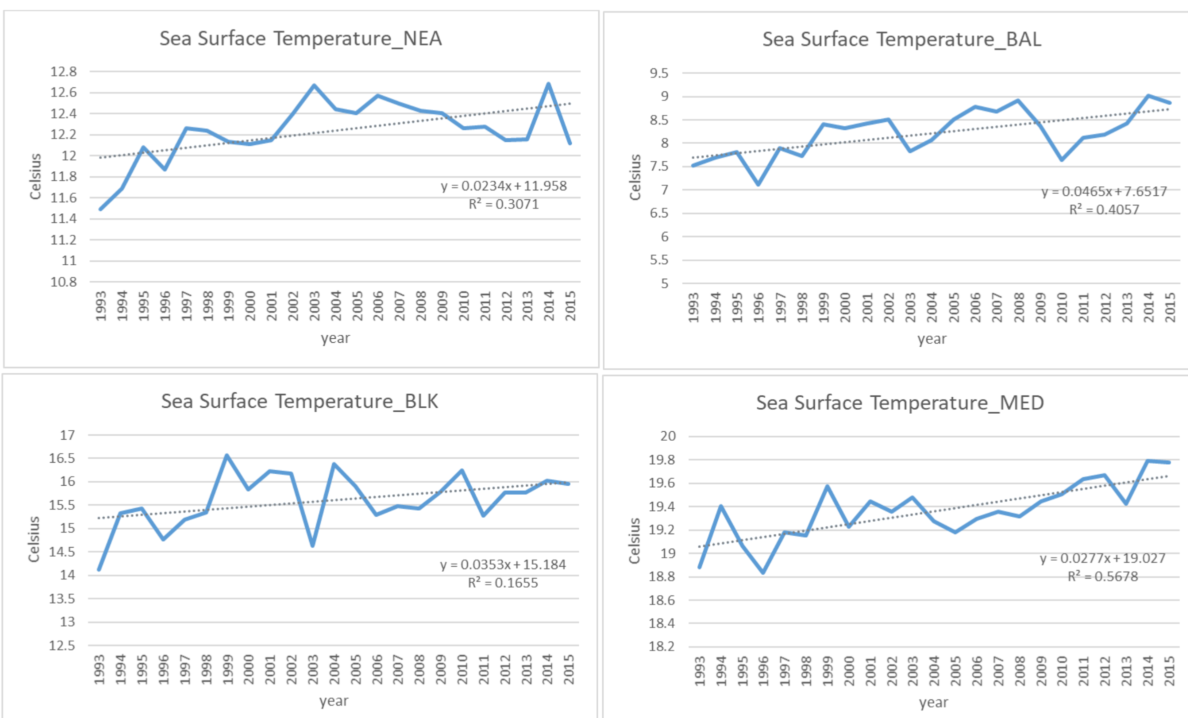
The indicator is calculated as follows: dataset are derived from the extraction of the year-mean for each depth levels, where the average of the seawater parameter for each year is computed from the monthly sub dataset relative of each year and EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the sea surface temperature trend in the EU marine regions shows it has increased continuously and significantly overtime (Figure 1, Table 1-2).

Figure 1. Sea surface temperature and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: sea surface temperature, 1993-2015.



Parameters	SST_NEA	SST_BAL	SST_BLK	SST_MED
intercept	-34.6815	-85.0371	-55.1990	-36.1025
slope	0.0234	0.0465	0.0353	0.0277
p-values	**0.0061**	**0.0011**	0.0541	**0.0000**
R2	0.3071	0.4057	0.1655	0.5678
ST_% change per decade	1.8913	5.4811	2.2335	1.4174
ST_trend direction	increase	increase	no change	increase
MARINE CONDITION_ST	DEGRADATION	DEGRADATION	NO CHANGE	DEGRADATION
intercept	-17.4341	-513.8541	-27.2230	-70.9607
slope	0.0148	0.2595	0.0214	0.0450
p-values	**0.8043**	**0.0039**	0.8178	**0.2308**
R2	0.0172	0.9000	0.0149	0.3327
LT_% change per decade	1.2063	33.5913	1.3555	2.3060
LT_trend direction	increase	increase	no change	increase
MARINE CONDITION_LT	DEGRADATION	DEGRADATION	NO CHANGE	DEGRADATION

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2015) and long term (LT: 1993-2015) for NEA, BAL, BLK and MED.

Further references

IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

von Schuckmann, K. ((Editor)) et al. (2019) Copernicus Marine Service Ocean State Report, Issue 3, Journal of Operational Oceanography, 12:sup1, S1-S123, DOI: 10.1080/1755876X.2019.1633075

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.103: Sea level anomaly

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressure/Climate change
- Name of the indicator: Sea level anomaly
- Units: meter

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1993-2015 (25 years of time-window)
- Reference:
  - Copernicus, CMEMS, GLOBAL_REANALYSIS_PHY_001_025 weblink: http://marine.copernicus.eu/services-portfolio/access-to-products/; http://marine.copernicus.eu/training/education/ocean-parameters/sea-level/

3. Assessment of the indicator

The sea level anomaly is used to assess the sea level rise.

3.1. Short description of the scope of the indicator.

The indicator expresses the sea level anomaly. It provides an indirect measure of sea level rise. Sea level anomaly is the height of water over the mean sea surface in a given time and region. The rationale of the indicator is based on the following assumption: the sea surface is anything but flat. There are bumps and troughs, all due to different physical characteristics such as gravity, currents, temperature and salinity. Since it is not know much about the ocean's bottom, it is easier to refer to "sea height" instead of sea depth. Sea level is measured with reference to a fixed surface height. By analyzing variations from this reference point, scientists determine ocean circulation (currents and eddies at the edges of holes and bumps), seasonal or inter-annual variations, or even longer periods (long-term rise in sea level)[43]. Sea level is quantified by increase in sea level anomaly (SLA). An increase in the SLA value means an increase in sea level. Sea level anomaly is increasing overtime (see Figure 1).

3.2. Maps

Not available.

[43] http://marine.copernicus.eu/training/education/ocean-parameters/sea-level/

3.3. Statistical analysis of the trend

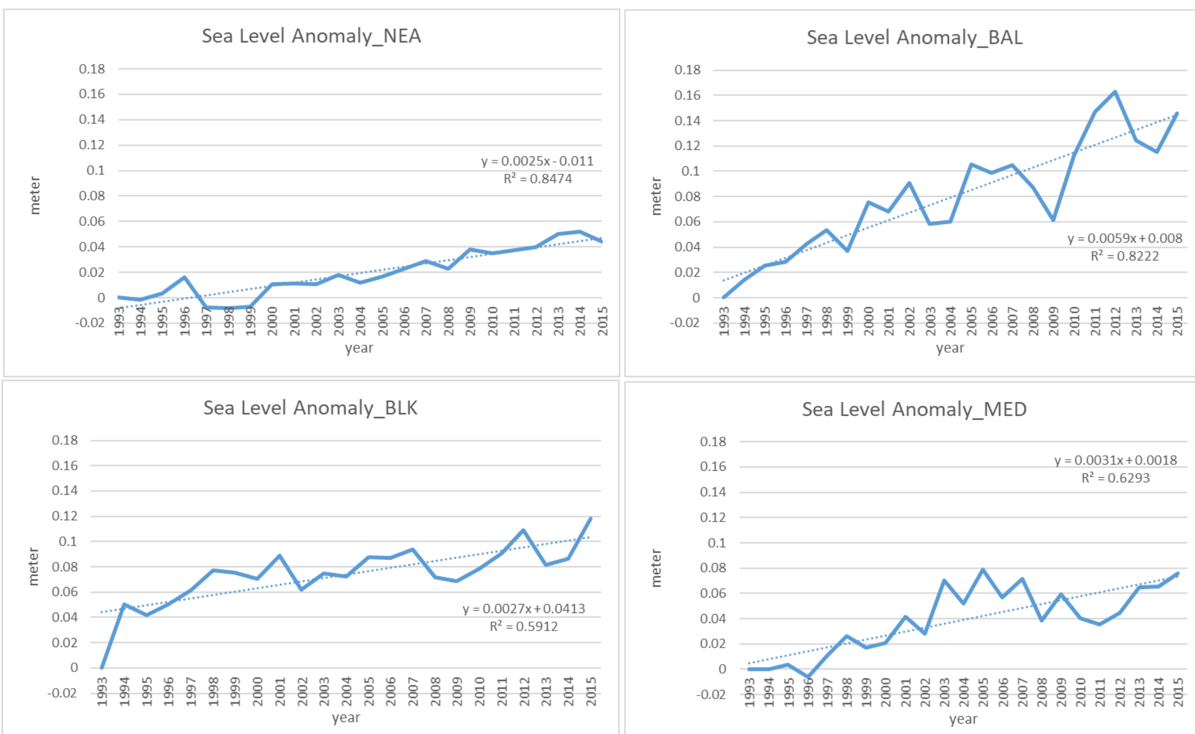
The indicator is calculated as follows: dataset are derived from global dataset of sea surface height (SSH) and Mean Dynamic Topography (MDT). The SLA is obtain from the formula SLAx=SSHx-MDTx where x indicate the mean of SSH and MDT for each year and EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the sea level anomaly trend in the EU marine regions shows it has increased continuously and significantly overtime (Figure 1, Table 1-2).

Figure 1. Sea level anomaly and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: sea surface height, 1993-2015.



Parameters	SLA_NEA	SLA_BAL	SLA_BLK	SLA_MED
intercept	-7.0388	0.6686	-8.9748	-15.8973
slope	0.0028	0.0009	0.0045	0.0082
p-values	0.0803	0.8798	0.2761	**0.0057**
R2	0.5756	0.0064	0.2842	0.8797
*ST_% change per decade**	2.0766	0.3591	52.1930	16.6445
ST_trend direction	no change	no change	no change	increase
MARINE CONDITION_ST	NO CHANGE	NO CHANGE	NO CHANGE	DEGRADATION
intercept	-6.4433	-9.5334	-5.3732	-5.7309
slope	0.0025	0.0059	0.0027	0.0031
p-values	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R2	0.8474	0.8222	0.5912	0.6293
*LT_% change per decade**	1.8561	2.4854	29.0271	6.0516
LT_trend_direction	increase	increase	increase	increase
MARINE CONDITION_LT	DEGRADATION	DEGRADATION	DEGRADATION	DEGRADATION

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2015) and long term (LT: 1993-2015) for NEA, BAL, BLK and MED. *absolute value.

Further references

IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

von Schuckmann, K. ((Editor)) et al. (2019) Copernicus Marine Service Ocean State Report, Issue 3, Journal of Operational Oceanography, 12:sup1, S1-S123, DOI: 10.1080/1755876X.2019.1633075

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.104: Seawater salinity

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressure/Climate change
- Name of the indicator: Seawater salinity
- Units: psu (practical salinity unit)

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1993-2015 (25 years of time-window and 75 depth levels)
- Reference:
  - Copernicus, CMEMS, GLOBAL_REANALYSIS_PHY_001_025 weblink: http://marine.copernicus.eu/services-portfolio/access-to-products/; http://marine.copernicus.eu/ocean-monitoring-indicators-acidity/

3. Assessment of the indicator

The seawater salinity is used to assess the environmental quality of marine environment.

3.1. Short description of the scope of the indicator.

The indicator expresses the seawater quality, and a driver of the world's ocean circulation. It provides an indirect measure of water density: where density changes due to both salinity changes and temperature changes at the surface of the ocean produce changes in buoyancy, which cause the sinking and rising of water masses. The rationale of the indicator is based on the following assumption: the salinity is quantified by the amount of salt dissolved in a body of water (i.e. practical salinity unit -psu). A decrease of psu value means a decrease of salinity. Changes in the salinity of the oceans are thought to contribute to global changes in carbon dioxide (i.e. higher seawater salinity, lower soluble to carbon dioxide). Changes in salinity can occur as a result of weather patterns or events such as increased urban runoff and sewer discharge. These events can change the condition of the water as the concentration of dissolved mineral salts typically increases with these types of events (which tend to decrease general water quality). Seawater salinity is variable over time and marine region (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

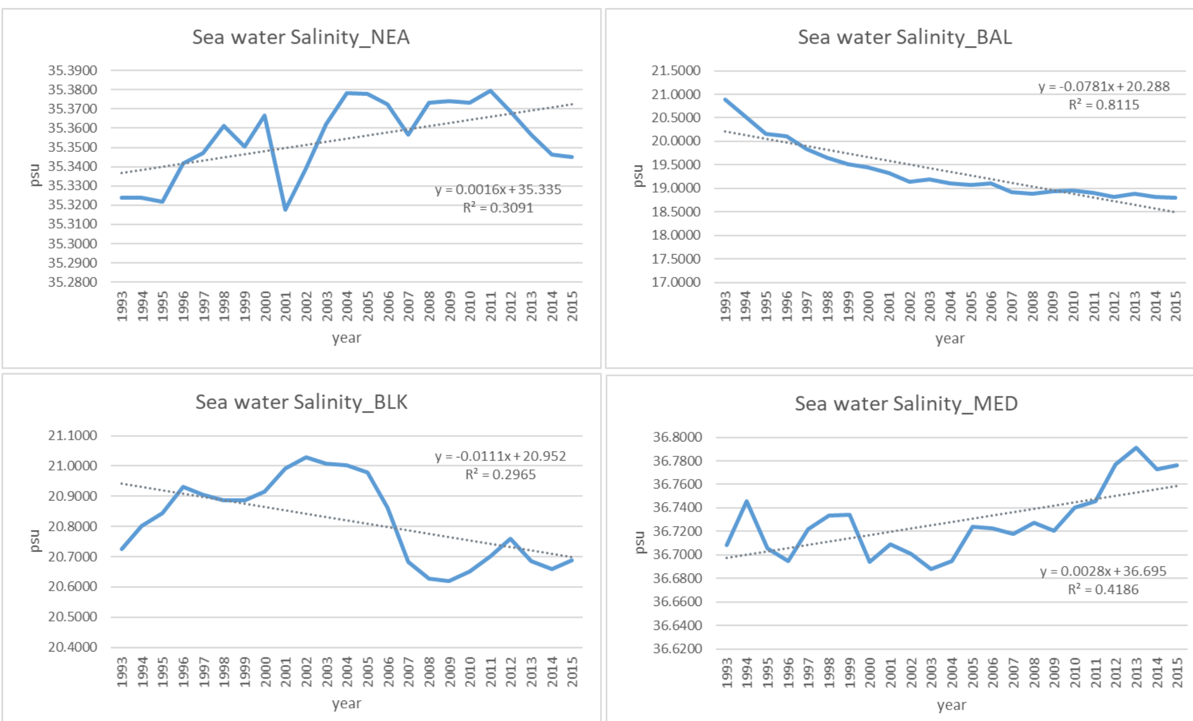
The indicator is calculated as follows: dataset are derived from the extraction of the year-mean for each depth levels, where the average of the mean seawater parameter for each year is computed from the monthly sub dataset relative of each year and EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the mean seawater salinity trend in the EU marine regions, except Baltic Sea), shows it has increased continuously overtime (Figure 1, Table 1-2).

Figure 1. Mean seawater salinity and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: seawater salinity, 1993-2015.



Parameters	Salinity_NEA	Salinity_BAL	Salinity_BLK	Salinity_MED
intercept	49.8660	73.5543	21.2015	20.9777
slope	-0.0072	-0.0272	-0.0003	0.0078
p-values	**0.0061**	**0.0389**	0.9814	0.0938
R^2	0.8749	0.6961	0.0002	0.5450
ST_% change per decade	-0.2037	-1.4353	-0.0123	0.2135
ST_trend direction	decrease	decrease	no change	no change
MARINE CONDITION_ST	DEGRADATION	DEGRADATION	NO CHANGE	NO CHANGE
intercept	32.1208	175.8504	42.9971	31.1448
slope	0.0016	-0.0781	-0.0111	0.0028
p-values	**0.0059**	**0.0000**	**0.0072**	**0.0008**
R^2	0.3091	0.8115	0.2965	0.4186
LT_% change per decade	0.0456	-4.1359	-0.5333	0.0758
LT_trend direction	increase	decrease	decrease	increase
MARINE CONDITION_LT	DEGRADATION	DEGRADATION	DEGRADATION	DEGRADATION

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short-term (ST: 2010-2015) and long-term (LT: 1993-2015) for NEA, BAL, BLK and MED.

Note: the indicators is also strictly linked to change in freshwater load to sea and sea ice (http://marine.copernicus.eu/training/education/ocean-parameters/sea-ice/), which should be included as marine indicator in MAES exercise.

Further references

IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.- O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press.

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

von Schuckmann, K. ((Editor)) et al. (2019) Copernicus Marine Service Ocean State Report, Issue 3, Journal of Operational Oceanography, 12:sup1, S1-S123, DOI: 10.1080/1755876X.2019.1633075

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.105: Chemicals load to sea

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressures/Climate Change
- Name of the indicator: Chemicals load to sea
- Units: tonnes/year

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: not available. Point-in-time: 2010
- Reference:
  - Pistocchi et al, 2019; *River pollution by priority chemical substances under the Water Framework Directive: A provisional pan-European assessment*. Science of the Total Environment 662:434-445; https://doi.org/10.1016/j.scitotenv.2018.12.354

3. Assessment of the indicator

Chemicals load is used to assess the amount of contaminants load to sea from riverine system.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of the water load to sea. It provides a direct measure of contaminants load to sea from human activities. The rationale of the indicator is based on the following assumption: the chemicals load is quantified by the amount of chemicals waste from urban and other human activities. A decrease in chemicals load to sea means an increase in water quality, contributing to reaching "good environmental status". Chemicals load to sea needs further analysis with a time-series dataset, which is not available yet (se Figure 1-2).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

No trend assessment of this indicator. Chemicals Load to EU seas, survey period: 2009-2014. Modelled estimation, values have been calibrated with data from 2009-2014 (chemicals) and 2008-2012 (BOD). Data should be considered as central value for 2010. Chemicals considered: 37 pollutants: *1_2_dichloroethane,Alachlor, Anthracene, Atrazine, Benzene, Bifenox, Cadmium, Chlorfenvinphos, Chloroalkanes_C10_13, Chloroform, Chlorpyrifos, Cypermethrin, Di_2_ethylhexyl_phthalate, Dichloromethane,* *Dichlorvos, Diclofenac, Dicofol, Diuron, Endosulfan, Fluoranthene, Heptachlor, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclohexane, Isoproturon, Lead, Mercury, Naphtalene, Nickel, Nonylphenol, Pentachlorobenzene, Pentachlorophenol, Quinoxyfen, Simazine, Terbutryn, Tributyltin, Trifluralin* .

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

Figure 1. Quantity of chemicals load in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Point-in-time: chemical loads, 2010.

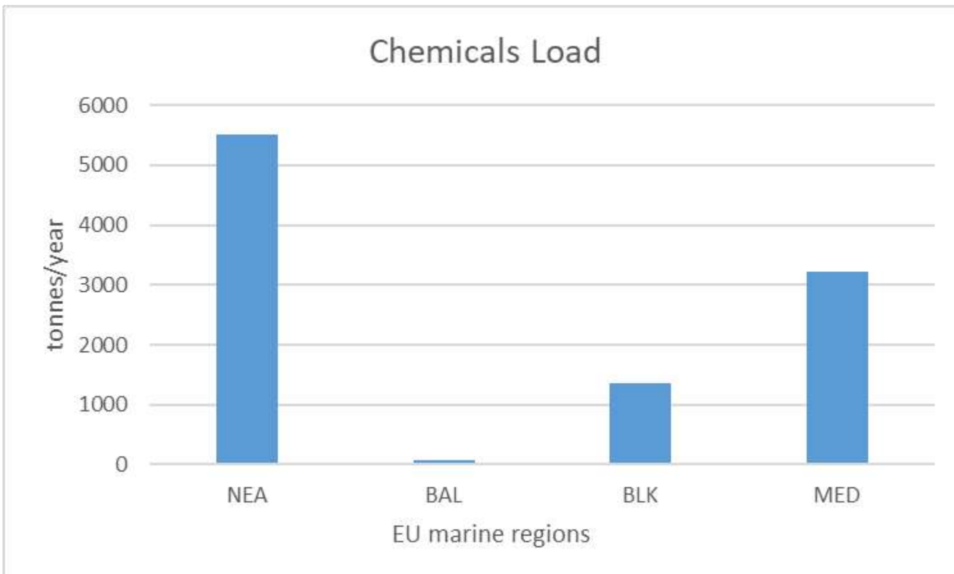
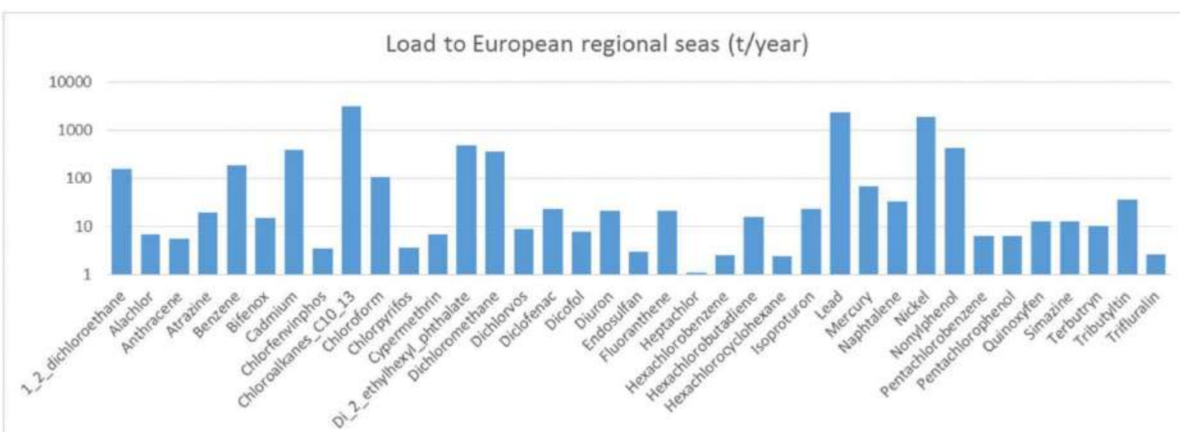


Figure 2. Loads to European seas from the 28 EU member states. Source: Pistocchi et al. 2019



Note: Information data is poor. Further analysis with a time-series dataset are needed.

Further references

EEA Report No 25/2018 Contaminants in Europe's Seas. Moving towards a clean, non-toxic marine environment (2018) https://www.eea.europa.eu/publications/contaminants-in-europes-seas

EEA Report No 18/2018 Chemicals in European water. Knowledge developments. 80 pp. DOI:10.2000/265000

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.106: Riverine litter load to sea

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressures/Pollution and nutrients enrichment
- Name of the indicator: Riverine litter load to sea
- Units: item/hr/year

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: not available. Point-in-time: 2016
- Reference:
  - JRC Technical Report; González-Fernández, D., Hanke, G., and the RiLON network, Floating Macro Litter in European Rivers - Top Items, EUR 29383 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96373-5, doi:10.2760/316058, JRC108172; weblink: https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108172/floating_macro_litter_in_european_rivers_-_top_items_eur_29383_en_28_11_2018.pdf

3. Assessment of the indicator

Riverine litter is used to assess the amount of litter loading to sea due to human activities. The number of item have been scaled by number of surveys.

3.1. Short description of the scope of the indicator.

The indicator expresses the environmental quality of estuarine and marine waters. It provides a direct measure of amount of riverine litter load to sea. The rationale of the indicator is based on the following assumption: environmental quality of estuarine and marine water is quantified by decreases in amount and type of riverine litter. A decrease in riverine litter load to sea means an increase in environmental quality of estuarine, contributing to reaching "good environmental status". Riverine litter to sea needs further analysis with a time-series dataset, which is not available yet (see Figure 1).

3.2. Maps

Not available.

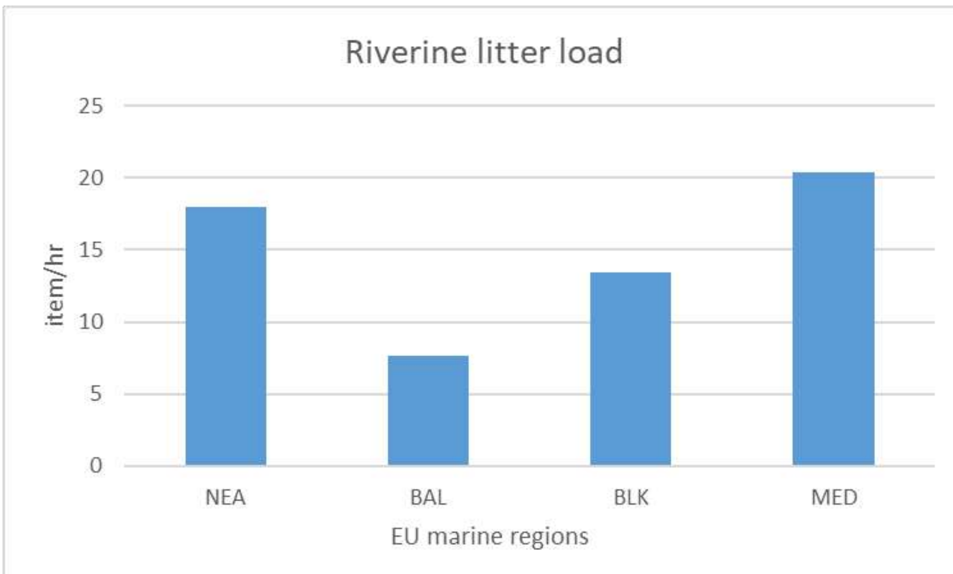
3.3. Statistical analysis of the trend

No trend assessment of this indicator. Riverine litter is used to assess the amount of litter loading to sea due to human activities. The concentration of contaminants has been scaled with the sampling size (value/number of survey).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

Figure 1. Amount of riverine litter and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Point-in-time: riverine litter load to sea, 2016.



Note: Information data is poor. Further analysis with a time-series dataset are needed.

Further references

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.107: Nutrient loads

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressures/Climate Change
- Name of the indicator: Nutrients loads
- Units: tonnes/year

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1985-2012 AND 2005-2012. Trend is not possible. Point-in-time: 2010.
- Reference:
  - Grizzetti, B., Bouraoui, F. and Aloe, A. (2012), Changes of nitrogen and phosphorus loads to European seas. Glob Change Biol, 18: 769-782. doi:10.1111/j.1365-2486.2011.02576.x
  - Grizzetti B., Vigiak O., Udias A., Aloe A., Zanni M., Bouraoui F., Pistocchi A., Dorati C., Friedland R., De Roo A., Benitez Sanz C., Leip A., Bielza M. Present and future nutrient pressures in European fresh and coastal water (submitted). - Time-series 2005-2012. Nutrient loads for calibration/reference year 2010, analyzed and received from R. Friedland on 26/03/2020.

3. Assessment of the indicator

Nutrients loads is used to assess the amount of total nitrogen and total phosphorus load to sea from riverine system.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of the water load to sea. It provides a direct measure of nutrients load to sea from human activities. The nitrogen and phosphorus load to sea are estimated (by modelling) considering different sources (such as fertilizers, atmospheric deposition, human and industrial waste), pathways and retention processes in the river basins. A decrease in nutrients load means an increase in water quality, contributing to reaching "good environmental status". Nutrients load to sea needs further analysis with a time-series dataset, whose trend is not available yet (see Figure 1-5).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

Nutrients loads to EU seas, survey periods: 1985-2005 (Figure 1-2) and 2005-2012 (Figure 3-4), which should be considered as central value for year 2010 (Figure 5). Nutrients considered: N, P, and ratio N:P. For the time being, no trend assessment of this indicator due to the differences in model set up, simulation, spatial resolution and aggregation between the two time-series and hydrological variation between the different years (the presence of a wet or dry year influences the amount of nutrients exported to the sea).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

Figure 1. Total nitrogen (N) and total phosphorus (P) loads (thousand tonnes/year) discharged from land into the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Source: Time-series 1985-2005 (data source Grizzetti et al, 2012)

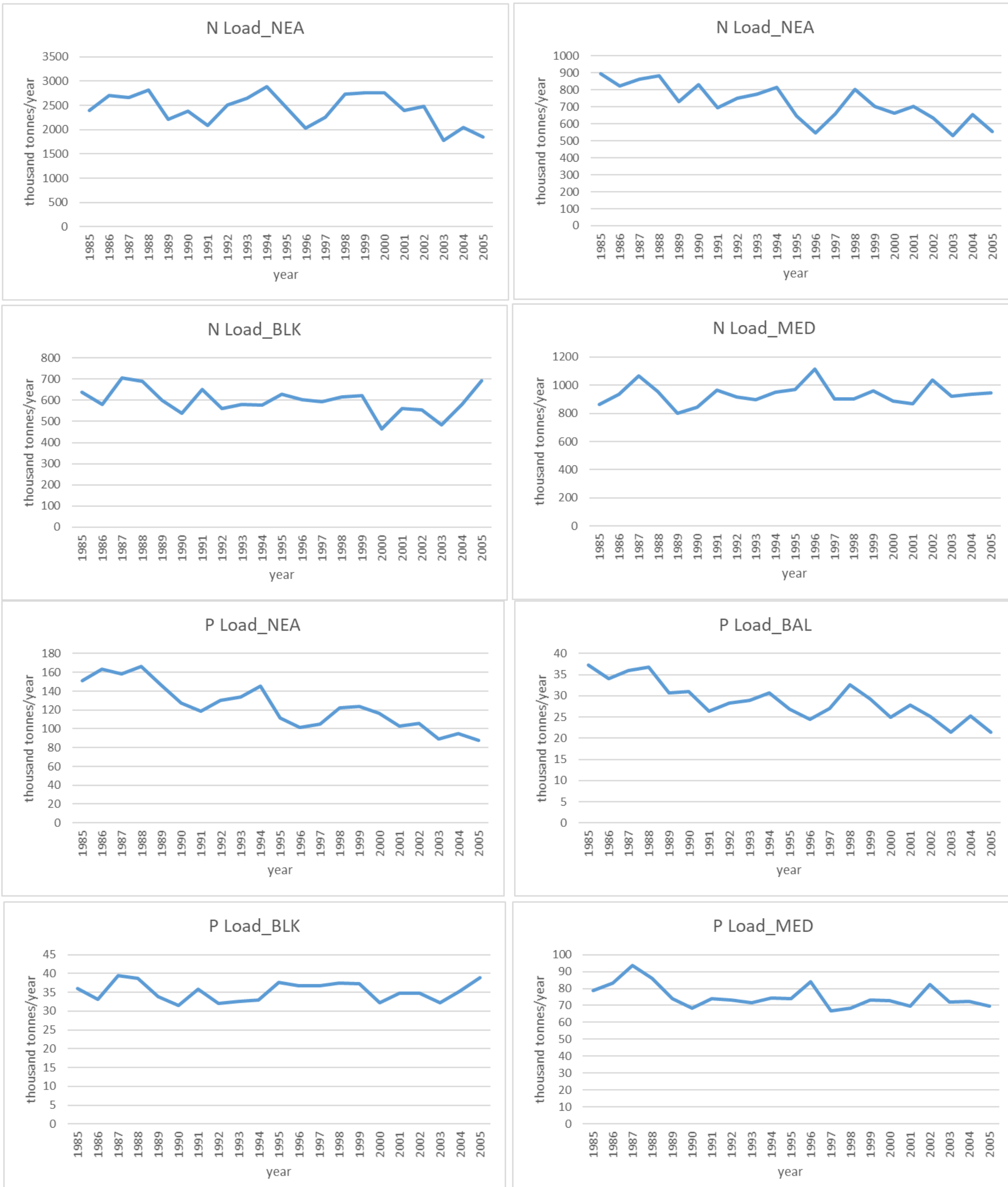


Figure 2. Nutrients ratio (N:P) in waters discharged from land into the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Source: Time-series 1985-2005 (data source Grizzetti et al, 2012)

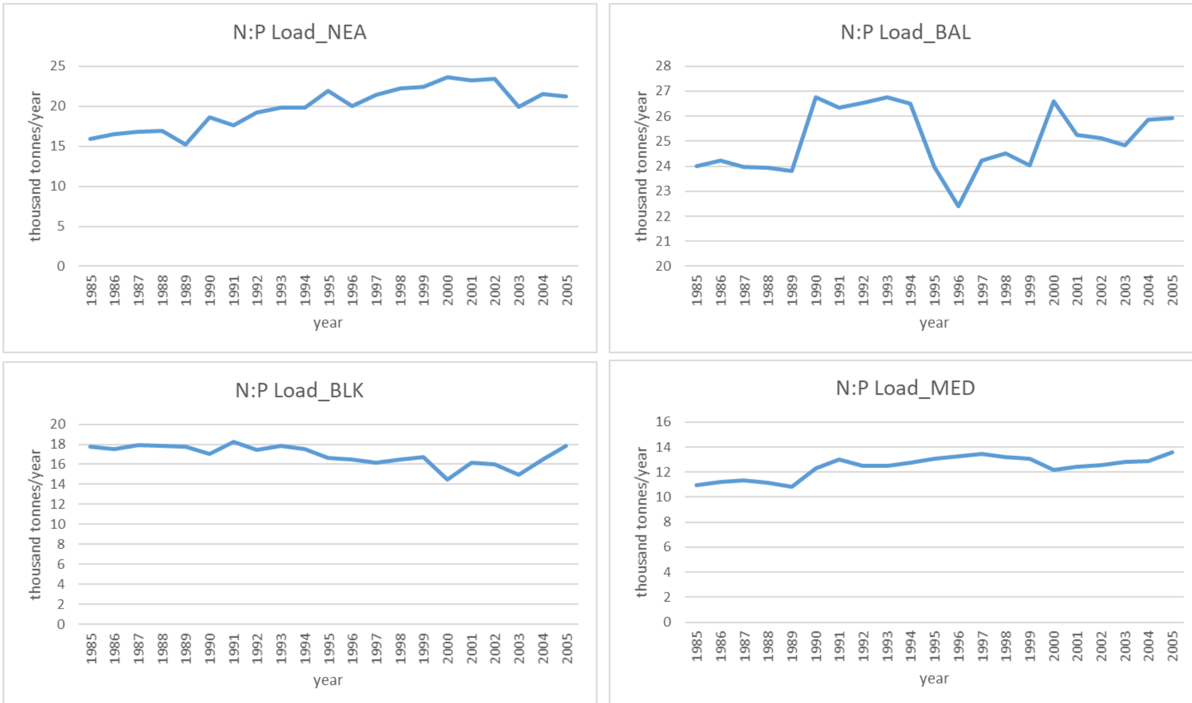
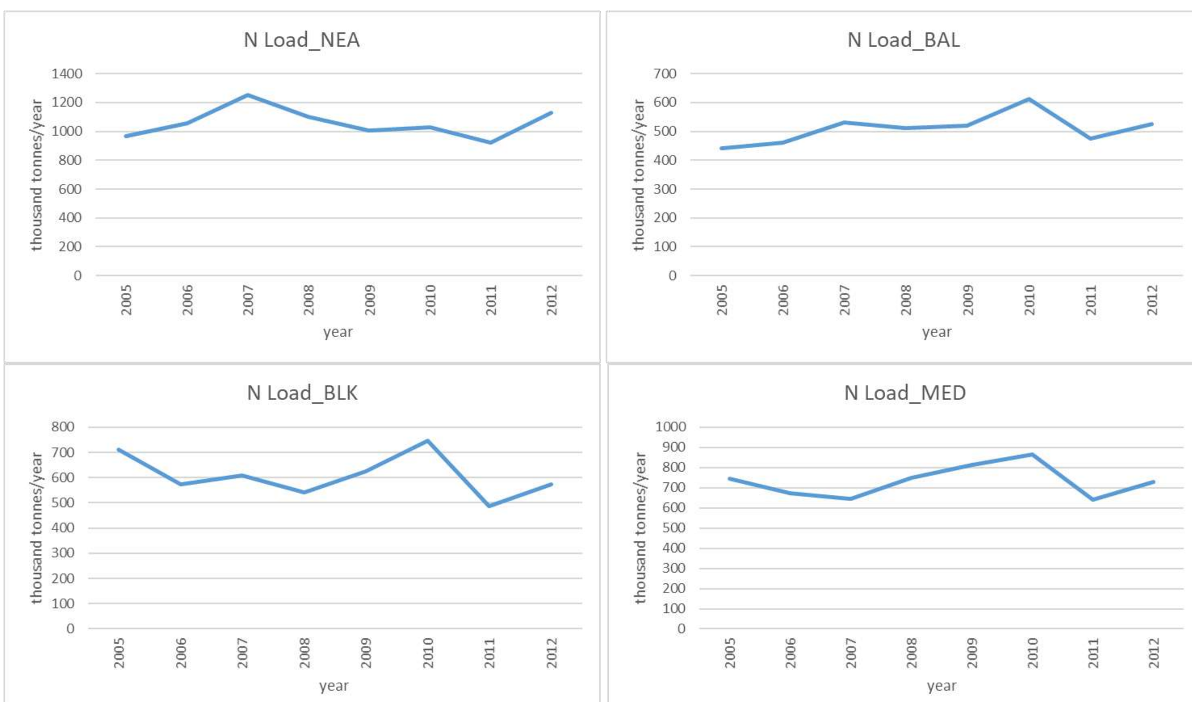


Figure 3. Total nitrogen (N) and total phosphorus (P) loads (thousand tonnes/year) discharged from land into the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Source: Time-series 2005-2012 (data source Grizzetti et al, upcoming)



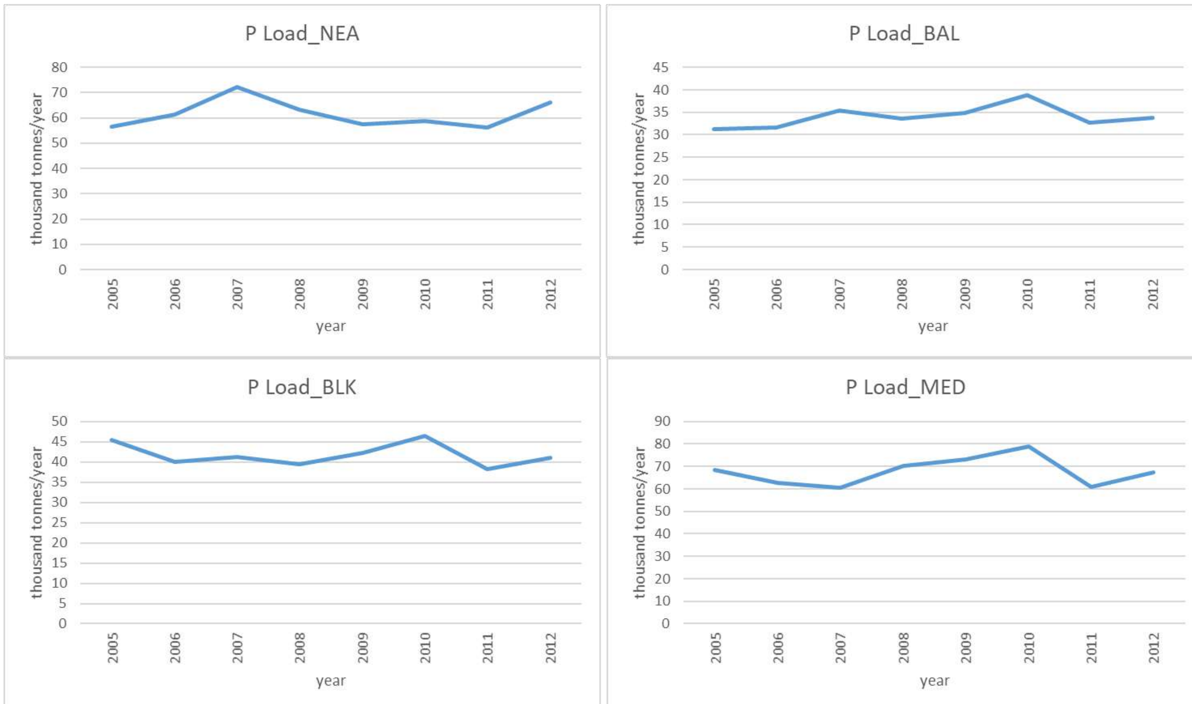


Figure 4. Nutrients ratio (N:P) in waters discharged from land into the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Source: Time-series 2005-2015 (data source Grizzetti et al, upcoming)

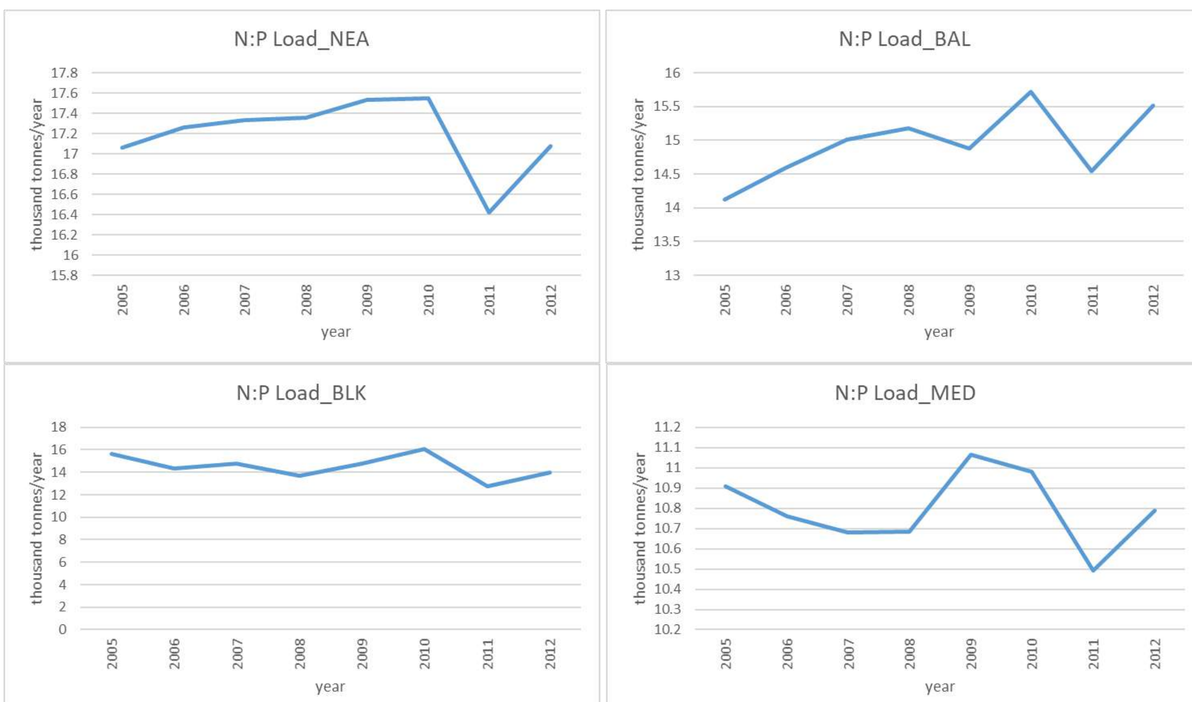
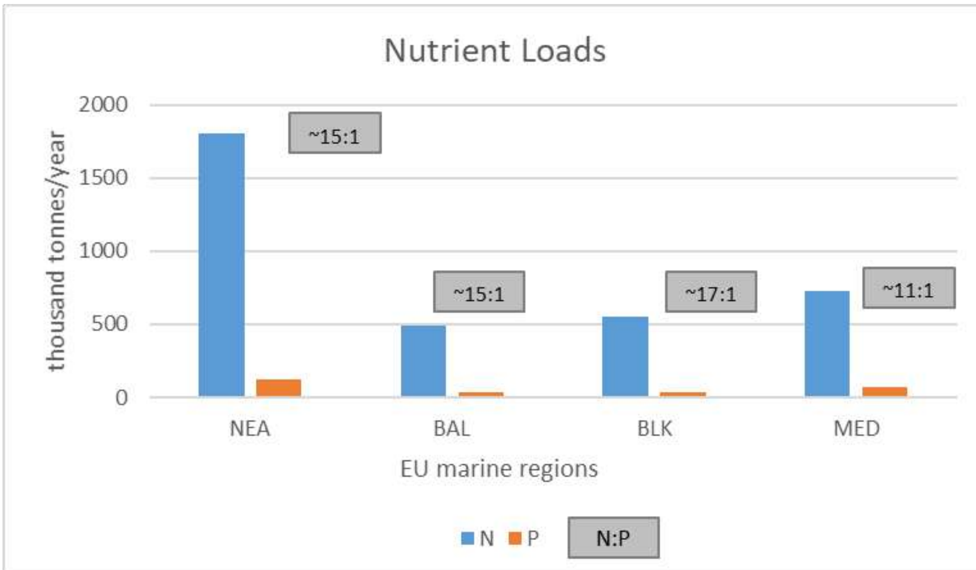


Figure 5. Total nitrogen (N) and total phosphorus (P) loads (thousand tonnes/year) and relative ratio N:P for the <u>reference year 2010</u> discharged from land into the European marine regions: North-East Atlantic (NEA), Baltic

Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Source: Time-series 2005-2012 (data source Grizzetti et al, upcoming)



Further references

EEA Report N0 14/2019 Nutrient enrichment and eutrophication in Europe's Seas. Moving towards a healthy marine environment (2019) https://www.eea.europa.eu/publications/nutrient-enrichment-and-eutrophication-in#tab-figures-used

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

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Fact sheet 3.7.109: Fish mortality (f) of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (f_{msy})

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressure/Over-exploitation
- Name of the indicator: Fish mortality (F) of commercially exploited fish and shellfish exceeding fishing mortality at maximum sustainable yield (F_{MSY})
- Units: F/F_{MSY} (rate/year)

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Data holder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 2003-2017
- Reference:
  - Report STECF2018-01, weblink: https://stecf.jrc.ec.europa.eu/reports/cfp-monitoring;
  - Report STECF2019-01, weblink: https://stecf.jrc.ec.europa.eu/reports/cfp-monitoring;

3. Assessment of the indicator

The rate of mortality of commercially exploited fish and shellfish F exceeding F_{MSY} (fishing mortality at maximum sustainable yield) is used to assess the status of fish stocks.

3.1. Short description of the scope of the indicator.

The indicator expresses the status of fish and shellfish stocks. It provides a direct measure of rate of mortality of commercially exploited fish and shellfish F exceeding F_{MSY} (fishing mortality at maximum sustainable yield). The rationale of the indicator is based on the following assumption: fish and shellfish stocks is quantified by the rate of F/F_{MSY}, which represent the mortality of commercially exploited fish and shellfish F exceeding F_{MSY} (fishing mortality at maximum sustainable yield). The rate of F/F_{MSY} of sustainable status of fish and shellfish stocks is around 1. A decrease in the rate value means a decrease in fishing mortality, contributing to reaching "good environmental status". Fish catch is slightly decreasing over time (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

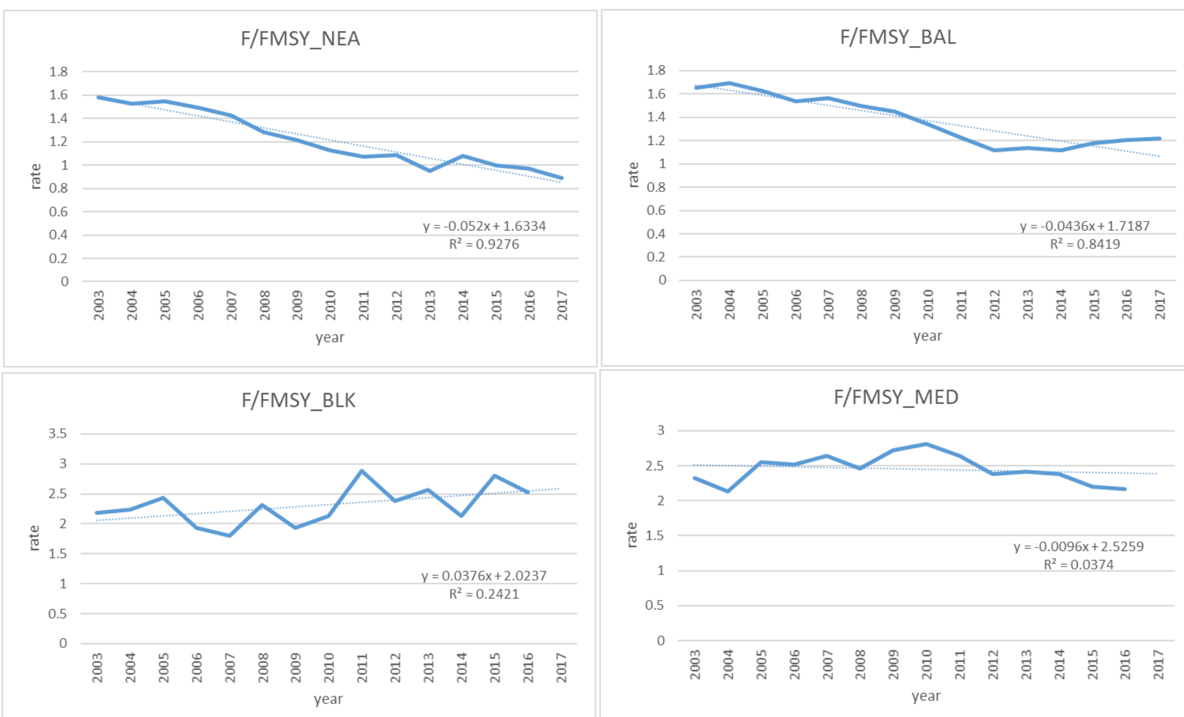
The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of rate of fishing mortality of commercially-exploited species rate F/F_{MSY} trend in the EU marine regions shows it has reached the threshold value = 1 only for NEA, while threshold value =2 for BLK and MED (Figure 1, Table 1).

Figure 1. Rate of fishing mortality of commercially-exploited species rate F/F_{MSY} and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: rate of fishing mortality, 2003-2017.



Parameters	F/Fmsy_NEA	F/Fmsy_BAL	F/Fmsy_BLK	F/Fmsy_MED
intercept	56.2603	21.0986	-53.5285	204.8880
slope	-0.0274	-0.0099	0.0278	-0.1006
p-values	**0.0123**	0.4283	0.6651	**0.0013**
R2	0.6753	0.1073	0.0405	0.8937
ST__% change per decade	-24.5314	-8.0636	11.5671	-36.8422
ST_trend direction	decrease	no change	no change	decrease
MARINE CONDITION_ST	IMPROVEMENT	NO CHANGE	NO CHANGE	IMPROVEMENT
intercept	105.8028	88.9453	-73.3454	21.6965
slope	-0.0520	-0.0436	0.0376	-0.0096
p-values	**0.0000**	**0.0000**	0.0739	0.5074
R2	0.9276	0.8419	0.2421	0.0374
LT_% change per decade	-42.7500	-31.7990	16.1928	-3.9095
LT_trend_direction	decrease	decrease	no change	no change
MARINE CONDITION_LT	IMPROVEMENT	IMPROVEMENT	NO CHANGE	NO CHANGE

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2017) and long term (LT: 2003-2017) for North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK).

Note: Baseline set up by STECF: 2003.

Further references

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.110: Number of newly introduced non-indigenous species

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressures/Introduction of invasive alien species
- Name of the indicator: Number of newly introduced non-indigenous species (number/year)
- Units: number of species

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 2000-2017
- Reference:
  - EASIN, weblink: http://easin.jrc.ec.europea.eu;

3. Assessment of the indicator

The number of newly introduced non-indigenous species is used to assess the negative impact on habitats and autochthonous species.

3.1. Short description of the scope of the indicator.

The indicator expresses the negative impact on habitats and autochthonous species. It provides a direct measure of number of newly introduced non-indigenous species. The rationale of the indicator is based on the following assumption: NIS is quantified by amount in number of different species newly introduced. A decrease in introduced value means a decrease in diversity species might have a cumulative negative impact on marine ecosystem, contributing to reaching "good environmental status". Number of newly introduced non-indigenous species is increasing overtime (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

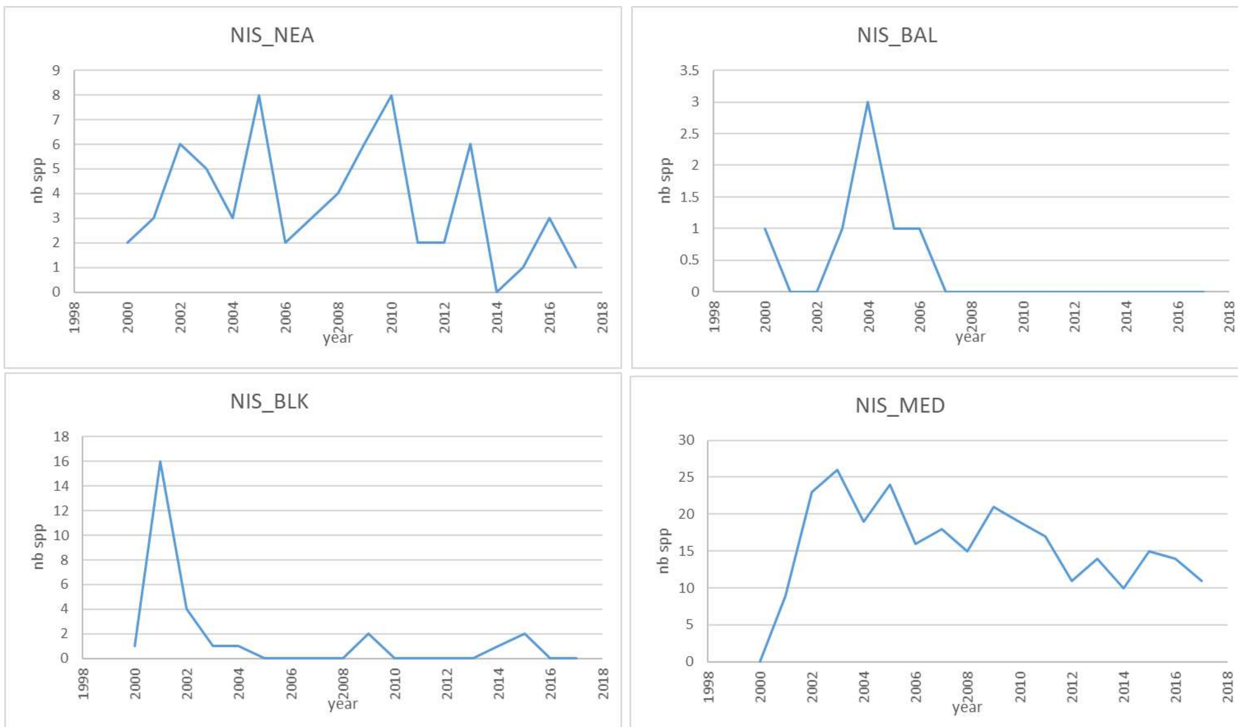
The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of th e slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of newly introduced non-indigenous species trend in the EU marine regions shows variable patterns (Figure 1, Table 1).

Figure 1. The number of newly introduced non-indigenous species and related trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: number of new NIS, 2000-2017.



Parameters	**Number of newly introduced non-indigenous species NIS (number/year)_ NEA**	**Number of newly introduced non-indigenous species NIS (number/year)_ BAL**	**Number of newly introduced non-indigenous species NIS (number/year)_ BLK**	**Number of newly introduced non-indigenous species NIS (number/year)_ MED**
intercept	1273.2976	0.0000	-167.4167	1524.0000
slope	-0.6310	0.0000	0.0833	-0.7500
p-values	0.1468		0.5108	0.1271
R2	0.3162	0.0599	0.0753	0.3430
ST_% change per decade	-124.1218		1000.0000	-45.4545
ST_trend direction	decrease	NA	increase	decrease
MARINE CONDITION_ST	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*
intercept	283.4331	139.2635	602.6546	305.8524
slope	-0.1393	-0.0691	-0.2993	-0.1445
p-values	0.2067	**0.0465**	0.0789	0.6246
R2	0.0977	0.0977	0.1805	0.0153
LT_% change per decade	-40.9505	-242.4608	-270.4383	-9.3514
LT_trend direction	decrease	decrease	decrease	decrease
MARINE CONDITION_LT	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2017) and long term (LT: 2000-2017) for NEA, BAL, BLK and MED.*based on expert judgement.

Note: EASIN dataset indicates the new introduction in EU and not in each marine regions. Dataset of NIS in the Black Sea is incomplete due to the lack of continuous reporting by MS and stakeholders. Baseline set up by EASIN: 2012.

Further references

EEA Report Pathways of introduction of marine non-indigenous species to European seas (2019) https://www.eea.europa.eu/data-and-maps/indicators/trends-in-marine-alien-species-1/assessment

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

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Fact sheet 3.7.111: Number of newly introduced non-indigenous species from human activities-transport

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Pressures/Introduction of invasive alien species
- Name of the indicator: Number of newly introduced non-indigenous species from human activities-*transport*
- Units: number/year

2. Data sources

The indicator is based on readily available and derived from data, which have been downscale d to European Marine Regions.

References for the **derived dataset** which required a calculation:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 2000-2017
- Reference:
  - EASIN, weblink: http://easin.jrc.ec.europea.eu;

3. Assessment of the indicator

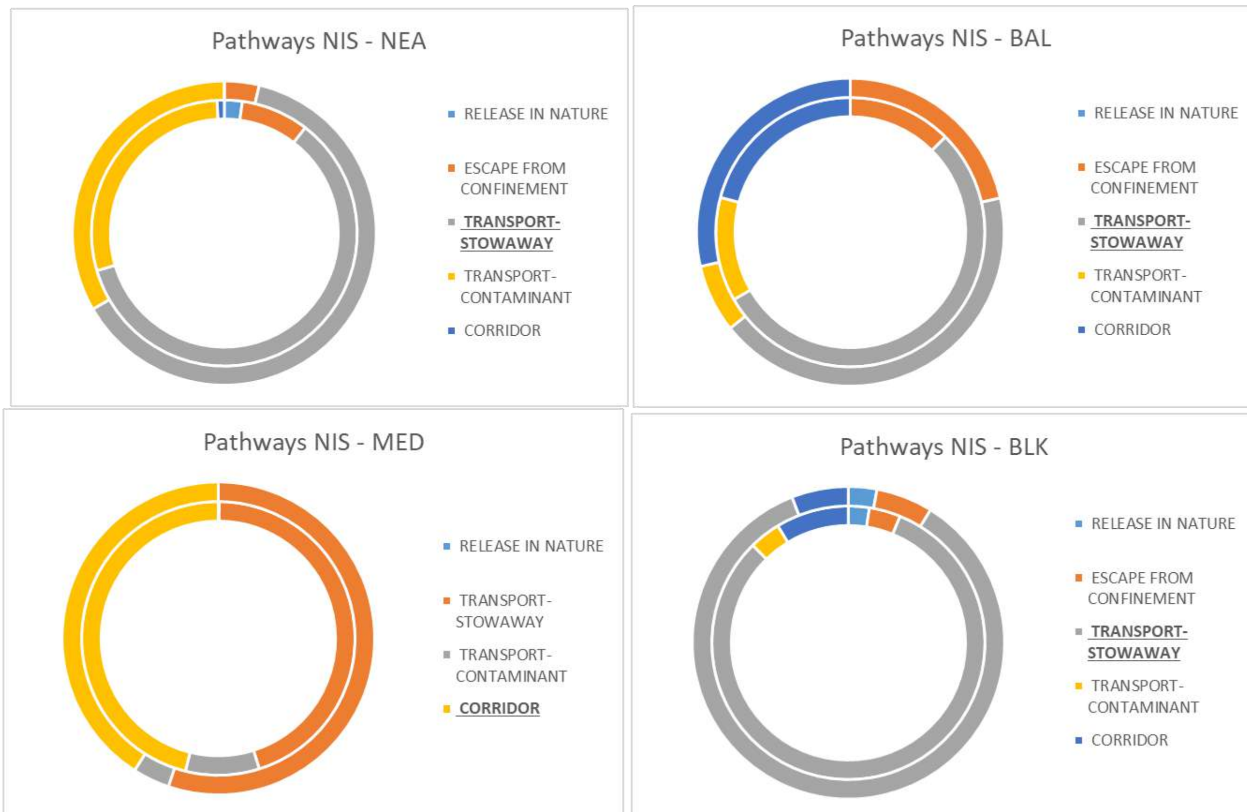
The number of newly introduced non-indigenous species from human activity - *transport* is used to assess the negative impact on habitats and autochthonous species. The category *transport* include the different subcategories[44].

3.1. Short description of the scope of the indicator.

The indicator expresses the negative impact on habitats and autochthonous species due to a specific human activity – *transport*. It provides a direct measure of number of newly introduced non-indigenous species through the transport activities. The rationale of the indicator is based on the following assumption: NIS is quantified by amount in number of different species newly introduced by different pathways, whose transp ort has the major impact (Figure 1). A decrease/controlled in introduced value by transport means a decrease in diversity species might have a cumulative negative impact on marine ecosystem, contributing to reaching "good environmental status". Number of newly introduced non-indigenous species is increasing overtime (see Figure 2).

[44] TRANSPORT- STOWAWAY: Ship/boat ballast water; TRANSPORT- STOWAWAY: Other means of transport; TRANSPORT-STOWAWAY: Ship/boat hull fouling; TRANSPORT- STOWAWAY: Angling/fishing equipment; TRANSPORT- CONTAMINANT: Contaminant on animals (except parasites, species tra nsported by host/vector); TRANSPORT- CONTAMINANT: Parasites on animals (including species transported by host and vector)

Figure 1. The number of newly introduced non-indigenous species through the pathway categories of *Human Activities* at marine regional level: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK).



3.2. Maps

Not available.

3.3. Statistical analysis of the trend

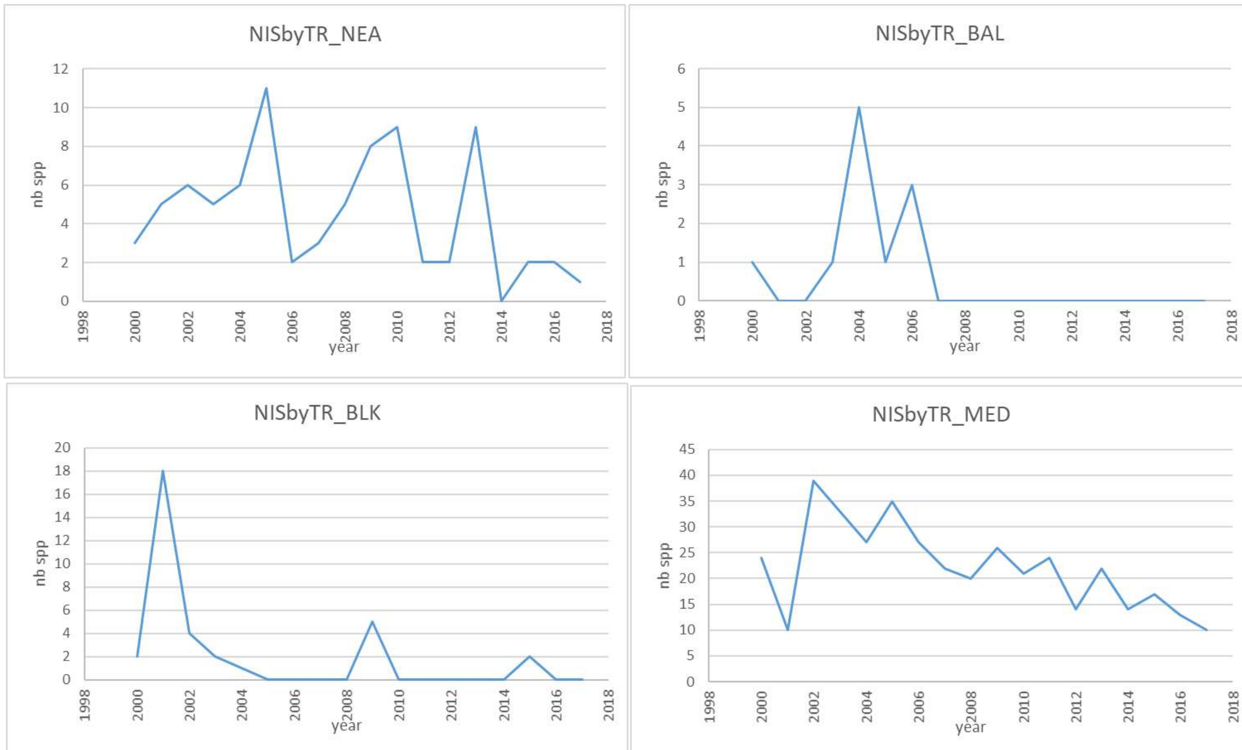
The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.3. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of newly introduced non-indigenous species by transport trend in the EU marine regions shows variable patterns (Figure 1, Table 1).

Figure 2. The number of newly introduced non-indigenous species through the pathway category of *Transport* and relative trend at marine regional level: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: number of new NIS of IAS, 2000-2017



Parameters	**Number of introduced non-indigenous species NIS from human activities/TRANSPORT (number/year)_ NEA**	**Number of introduced non-indigenous species NIS from human activities/TRANSPORT (number/year)_ BAL**	**Number of introduced non-indigenous species NIS from human activities/TRANSPORT (number/year)_ BLK**	**Number of introduced non-indigenous species NIS from human activities/TRANSPORT (number/year)_ MED**
intercept	1561.4405	0.0000	-143.5714	3156.9762
slope	-0.7738	0.0000	0.0714	-1.5595
p-values	0.1719		0.5546	**0.0258**
R2	0.2862	0.0599	0.0612	0.5909
ST_% change per decade	-127.2016			-69.8294
ST_trend direction	decrease	NA	increase	decrease
MARINE CONDITION_ST	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*
intercept	421.1238	197.5229	739.7898	1871.0089
slope	-0.2074	-0.0980	-0.3674	-0.9205
p-values	0.1523	0.1075	0.0569	**0.0100**
R2	0.1237	0.1538	0.2084	0.3480
LT_% change per decade	-49.5196	-211.2676	-274.6207	-44.4054
LT_trend direction	decrease	decrease	decrease	decrease
MARINE CONDITION_LT	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short-term (ST: 2010-2017) and long-term (LT: 2000-2017) for NEA, BAL, BLK and MED.*based on expert judgment.

Note: EASIN dataset indicates the new introduction in EU and not in each marine regions. Dataset of NIS in the Black Sea is incomplete due to the lack of continuous reporting by MS and stakeholders. Baseline set up by EASIN: 2012.

Further references

EEA Report Pathways of introduction of marine non-indigenous species to European seas (2019) https://www.eea.europa.eu/data-and-maps/indicators/trends-in-marine-alien-species-1/assessment

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

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Fact sheet 3.7.200: Chemical status (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Environmental quality
- Name of the indicator: Chemical Status
- Units: class

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Point-in-time: 1st RBMP (2010) – 2nd RBMP (2016) reporting exercises[45]
- Reference:
  - WISE WFD database version 3, accessed through EEA WISE-Marine Tableau, weblink: https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WFD_Marine_status/Chemical?iframeSizedToWindow=true&%3Aembed=y&%3AshowAppBanner=false&%3Adisplay_count=no&%3AshowVizHome=no&%3Aorigin=viz_share_link;

3. Assessment of the indicator

Chemical Status is used to assess the environmental quality of coastal and transitional waters.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of coastal and transitional waters. It provides a direct measure of water quality. The rationale of the indicator is based on the following assumption: the chemical status is quantified by the concentrations of priority substances and whether they exceed or not the relevant EQS[46] established in the Environmental Quality Standards Directive 2008/105/EC, and included in the Water Framework Directive

[45] Caution is advised when comparing Member States and when comparing the first and second RBMPs, as the results are affected by the methods Member States have used to collect data and often cannot be compared directly. The major contribution to variability seems to arise from the approach taken to monitoring, modelling and extrapolating results and from the choice of monitoring matrix: water, sediment or biota (e.g. fish). Some countries extrapolated failure to meet the standard at monitoring sites to all water bodies, while others reported failure only where failure was confirmed. Typically, measurements of mercury in biota extrapolated to all similar water bodies lead to widespread failure to meet the EQS. Further info in https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water-assessment/water-assessments/chemical-status-of-surface-water-bodies

[46] EQS aim to protect the most sensitive species from direct toxicity, including predators and humans via secondary poisoning. A smaller group of priority hazardous substances were identified in the Priority Substances Directive as uPBT (ubiquitous (present, appearing or found everywhere), persistent, bioaccumulative and toxic). The uPBTs are mercury, brominated diphenyl ethers (pBDE), tributyltin and certain polyaromatic hydrocarbons (PAHs).

(WFD). An improvement in the chemical status means an improvement in the health of the ecosystem. Chemical status is slightly improving overtime (see Figure 1-2).

Chemical status is reported by Member States to monitor progress in implementing the WFD. Chemical status is reported per water body as "good", "failing to achieve good", or "unknown". The indicator covers the current status of coastal and transitional waters as reported in the 1st and 2nd River Basin Management Plans (RBMPs).

The indicator is calculated as follows: dataset are derived from the 1st and 2nd river basin management plans (RBMP) reporting exercises, for evaluating the chemical status of each EU marine region (see Table 1).

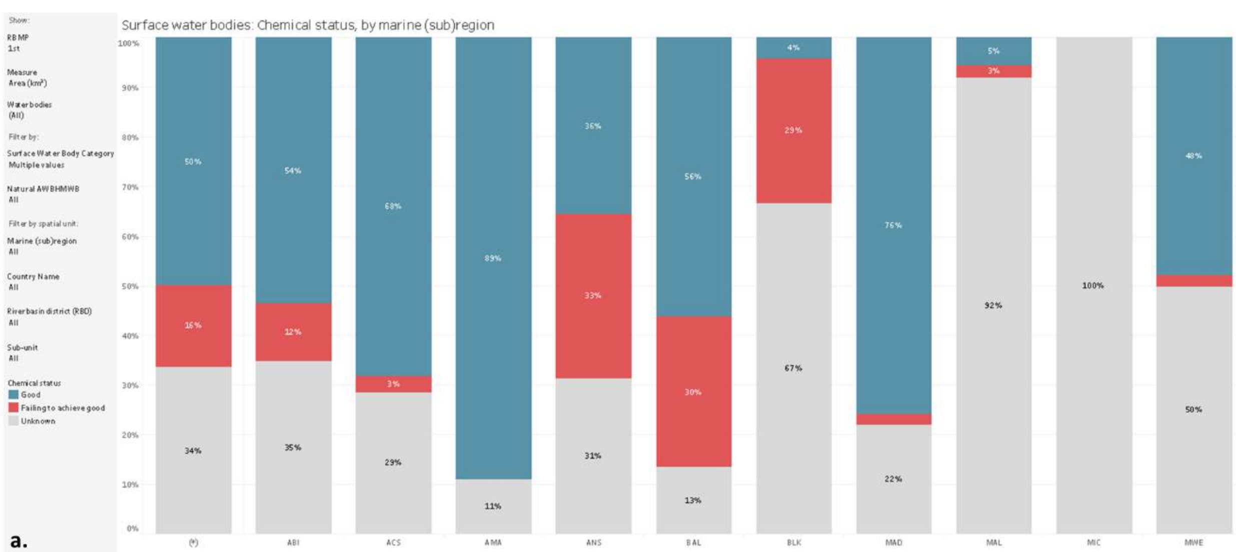
3.2. Maps

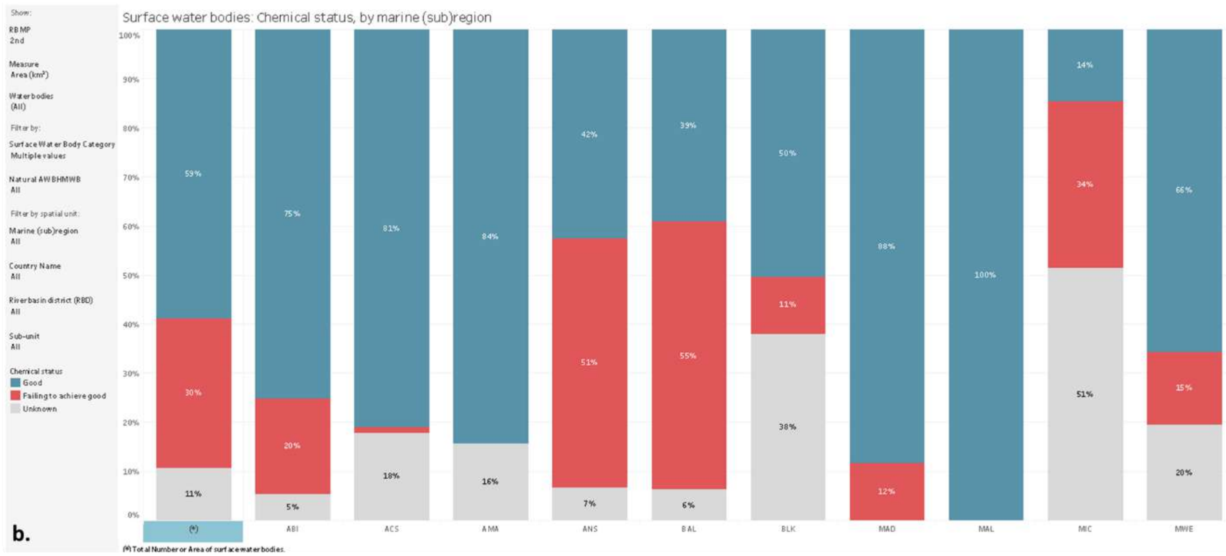
Not available.

3.3. Statistical analysis of the trend

Methodological differences between the two RBMP reporting exercises precluded analysis of temporal trends. Since the differences in the two reporting periods, there is no trend assessment of this indicator at unit scale. However, at the European scale conditions can be assessed as improvement from the first to the second RBMPs reporting period.

Figure 1. Change in chemical status of transitional and coastal water bodies (area in km^2) by EU marine subregions, for the a) 1st – 2010, and b) 2nd – 2016 River Basin Management Plans (RBMPs) reporting exercises. Source: the results are based on WISE WFD Database (Water Framework Directive Database) version 3, including data from 22 Member States (EU-23 except Lithuania for 2010, and EU-23 except Lithuania and Greece for 2016).



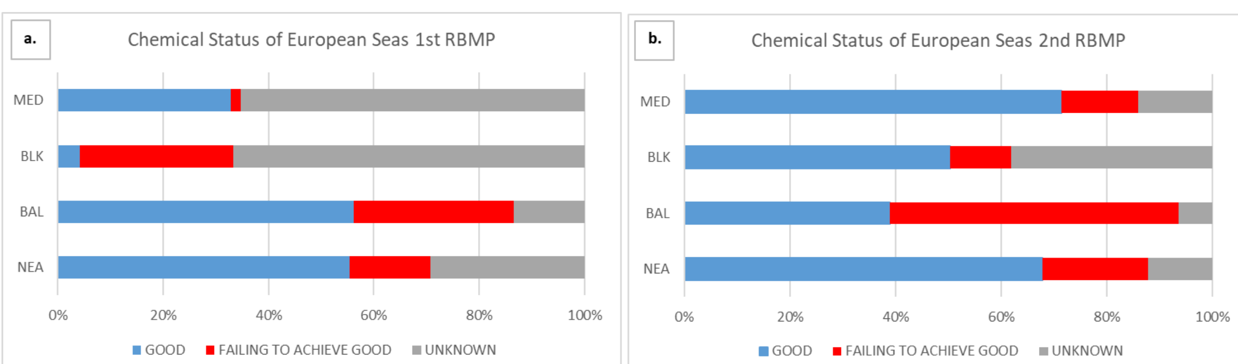


3.4 Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of Europe's seas. Mapping requires additional assumptions on the data.

A comparison of the chemical status reported in the first and second RBMP periods shows that the proportion of coastal and transitional waters with unknown chemical status has dropped significantly, from 68 % to 39 % (Figure 2, Table 1).

Figure 2. The chemical status (% of area) in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Point-in-time indicator: chemical status, a) 1st RBMP – 2010, and b) 2nd RBMP – 2016 reporting exercises.



RBMP	Class	Chemical Status_%_NEA	Chemical Status_%_BAL	Chemical Status_%_BLK	Chemical Status_%_MED
1st RBMP	GOOD	55.32%	56.23%	4.18%	32.81%
	FAILING TO ACHIEVE GOOD	15.44%	30.28%	29.08%	1.94%
	UNKNOWN	29.24%	13.48%	66.74%	65.26%
2nd RBMP	GOOD	67.80%	38.97%	50.36%	71.47%
	FAILING TO ACHIEVE GOOD	20.00%	54.71%	11.49%	14.52%
	UNKNOWN	12.19%	6.32%	38.15%	14.01%

Table 1. The chemical status (% of area) in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Percentage per each class for marine region.

Further references

European Commission (EC). 2000. Water Framework Directive (WFD) 2000/60/EC. http://ec.europa.eu/environment/water/water-framework/index_en.html

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.201: Nutrients (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Environmental quality
- Name of the indicator: Concentration of phosphate and nitrate, and N:P
- Units: mmol/m3

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1993-2015 (25 years of time-window and 75 depth levels)
- Reference:
  - Copernicus, CMEMS, GLOBAL_REANALYSIS_BIO_001_029 weblink: http://marine.copernicus.eu/services-portfolio/access-to-products/;

3. Assessment of the indicator

Phosphate and nitrate are used to assess the environmental quality of the marine ecosystem due to ecological process and human activities.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of the water load to sea. It provides a direct measure of nutrients in the sea from human activities and ecological process. The rationale of the indicator is based on the following assumption: the nutrients in the sea is quantified by the amount of nitrate and phosphate from ecological process and human activities. A decrease in nutrients load means an increase in water quality, contributing to reaching "good environmental status". Nutrients analysis is based on time-series dataset and nutrient anomalies, which are differences relative to the concentrations determined in the 1993 profile (see Figure 1).

3.2. Maps

Not available

3.3. Statistical analysis of the trend

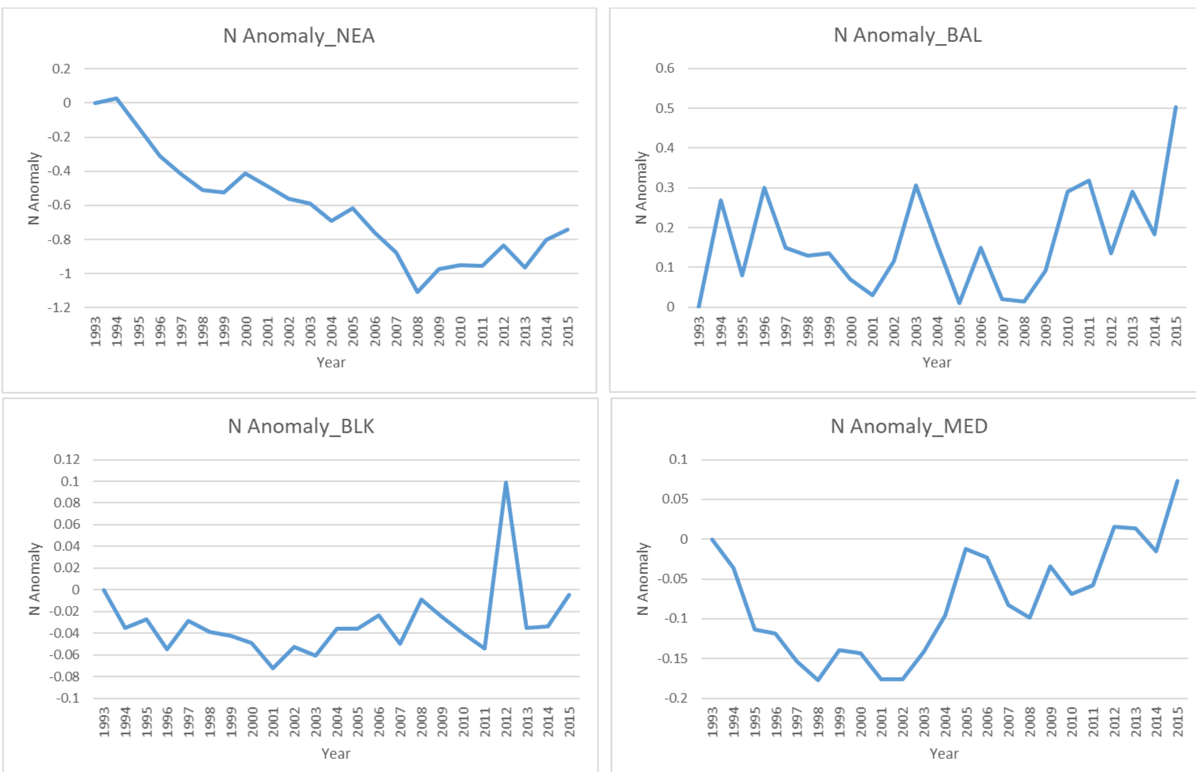
The indicator is calculated as follows: dataset are derived from the extraction of the year-mean for each EU marine region and up to max depth of photic zone basin-specific [NEA max 150 m, BAL max 20 m, BLK max 50 m, MED max 150], and in the entire sea basin excluding differences between marine areas (i.e. coastal, open ocean etc.). The average of the seawater parameter for each year is computed from the monthly sub dataset relative of each year and EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is base d on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

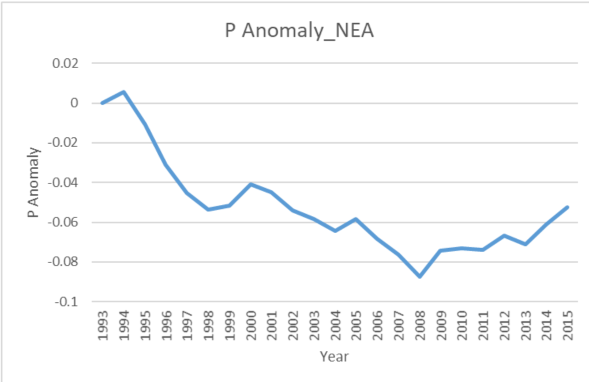
3.4. Key trend at EU level

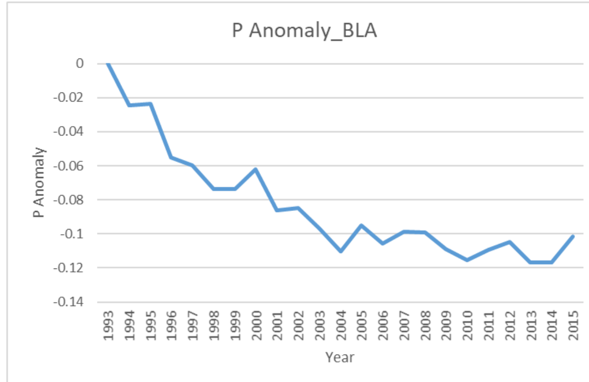
The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

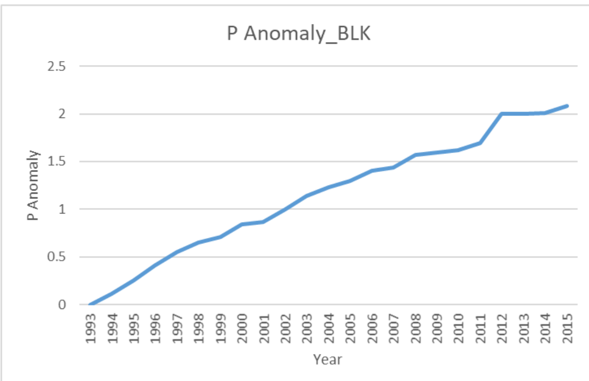
A comparison of the nutrients concertation trend in the EU marine regions shows variable patterns (Figure 1, Table 1).

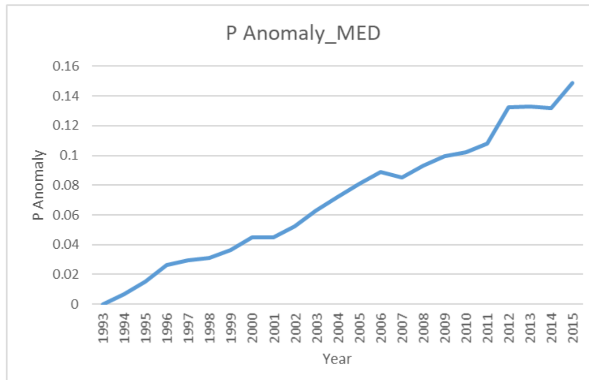
Figure 1. Concentration of phosphate and nitrate, and relative trend in the European marine regions (mean value of nutrients up to max depth of photic zone basin-specific; NEA max 150 m, BAL max 20 m, BLK max 50 m, MED max 150 m): North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: nutrients concentration, 1993-2015.

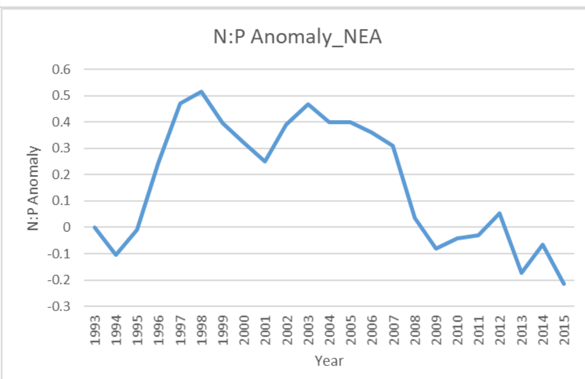


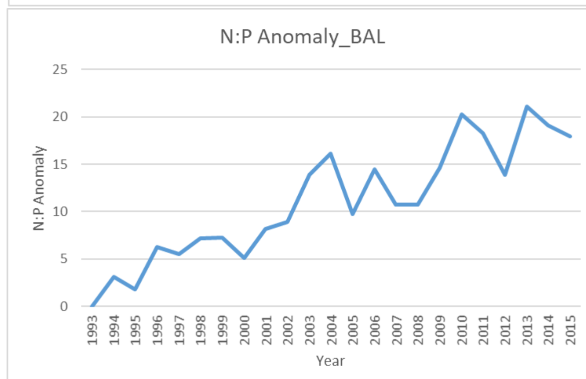

P Anomaly_NEA
P Anomaly
Year

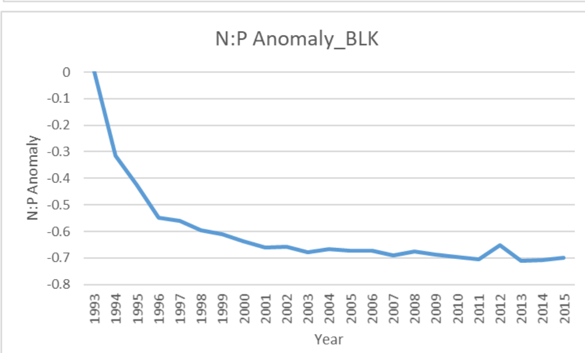

P Anomaly_BLA
P Anomaly
Year

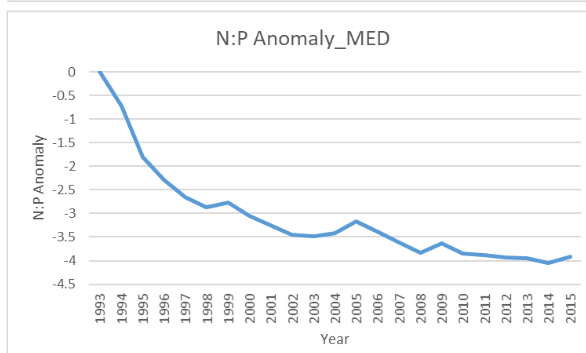

P Anomaly_BLK
P Anomaly
Year


P Anomaly_MED
P Anomaly
Year


N:P Anomaly_NEA
N:P Anomaly
Year


N:P Anomaly_BAL
N:P Anomaly
Year


N:P Anomaly_BLK
N:P Anomaly
Year


N:P Anomaly_MED
N:P Anomaly
Year

Parameters	NO3_anomaly_NEA	NO3_anomaly_BAL	NO3_anomaly_BLK	NO3_anomaly_MED
intercept	-79.1877	-46.0823	-6.1128	-48.2127
slope	0.0389	0.0230	0.0030	0.0240
p-values	0.0715	0.5120	0.8497	**0.0320**
R2	0.5975	0.1144	0.0101	0.7230
*ST_% change per decade**	39.9971	100.3845	159.0771	360.6987
ST_trend direction	no change	no change	no change	Increase
Parameters	**PO4_anomaly_NEA**	**PO4_anomaly_BAL**	**PO4_anomaly_BLK**	**PO4_anomaly_MED**
intercept	-8.0378	-2.0925	-184.3988	-17.4082
slope	0.0040	0.0010	0.0926	0.0087
p-values	**0.0194**	0.5895	**0.0135**	**0.0065**
R2	0.7814	0.0790	0.8161	0.8161
*ST_% change per decade**	51.9696	8.6950	55.5043	83.6778
ST_trend direction	decrease	no change	increase	increase
LIMITING NUTRIENT	N	N	N	P
MARINE CONDITION_ST	IMPROVEMENT	NO CHANGE	DEGRADATION	DEGRADATION

Parameters	NO3_anomaly_NEA	NO3_anomaly_BAL	NO3_anomaly_BLK	NO3_anomaly_MED
intercept	80.9435	-13.1669	-2.6629	-11.9158
slope	-0.0407	0.0067	0.0013	0.0059
p-values	**0.0000**	0.0980	0.2161	**0.0053**
R2	0.7792	0.1249	0.0719	0.3148
*LT_% change per decade**	47.2402	32.7647	57.3519	143.7094
LT_trend direction	decrease	no change	no change	Increase
Parameters	**PO4_anomaly_NEA**	**PO4_anomaly_BAL**	**PO4_anomaly_BLK**	**PO4_anomaly_MED**
intercept	5.5004	8.3805	-185.2162	-12.7667
slope	-0.0028	-0.0042	0.0930	0.0064
p-values	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R2	0.6082	0.7724	0.9875	0.9872
*LT_% change per decade**	39.9682	38.7778	54.4320	58.6986
LT_trend direction	decrease	decrease	increase	increase
LIMITING NUTRIENT	N	N	N	P
MARINE CONDITION_LT	IMPROVEMENT	IMPROVEMENT	DEGRADATION	DEGRADATION

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2015) and long term (LT: 1993-2015) for NEA, BAL, BLK and MED.*absolute value.

Note: N and P are completely different compound used in different ways by phytoplankton. Since they are not independent or interchangeable, the sum of N+P is not a meaningful biogeochemical variable, but the independent data (N and P). Furthermore, only the concertation of the limiting nutrient determines EXCLUSIVELY the eutrophication of this basin. Thus, the no-limiting nutrient is always in excess because it can´t be use due to the lack of limiting nutrient. Hence, the trend of no-limiting nutrient (which is positive) is fully IRRELEVANT to the eutrophication trend in the basin. The limiting nutrient is basin specific. For all these considerations, in this context we used:

- the N:P ratio in the marine basin to determine the limiting nutrient, also based on the scientific literature (limiting nutrients: P in MED; N in NEA, BAL and BLK)
- only the limiting nutrient trend for each marine basin in order to understand if this pressure is increasing or not, and determine the marine condition.

Further references

EEA Report N0 14/2019 Nutrient enrichment and eutrophication in Europe's Seas. Moving towards a healthy marine environment (2019) https://www.eea.europa.eu/publications/nutrient-enrichment-and-eutrophication-in#tab-figures-used

Fact sheet 3.7.202: Dissolved oxygen (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Environmental quality
- Name of the indicator: Dissolved Oxygen
- Units: mg/L

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived datase t and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1993-2018 (25 years of time-window and 75 depth levels)
- Reference:
  - Copernicus, CMEMS, GLOBAL_REANALYSIS_BIO_001_029 weblink: http://marine.copernicus.eu/services-portfolio/access-to-products/;

3. Assessment of the indicator

Dissolved oxygen is used to assess the environmental quality of marine waters.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of the marine waters. It provides a direct measure of concentration of oxygen dissolved in the water column. The rationale of the indicator is based on the following assumption: a decrease in oxygen levels means an increase of the oxidation of organic matter. In case of eutrophication, the organic matter in the water increase. The oxidation of this excess organic matter will reduce the oxygen dissolved in the water, affecting physiology, composition and abundance of marine species, impeding to reaching "good environmental status". Oxygen depletion can occur episodically (less than once per year), periodically (several times per year for short periods) and seasonally (each summer), and eventually it can become persistent. Dissolved oxygen is stable overtime (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

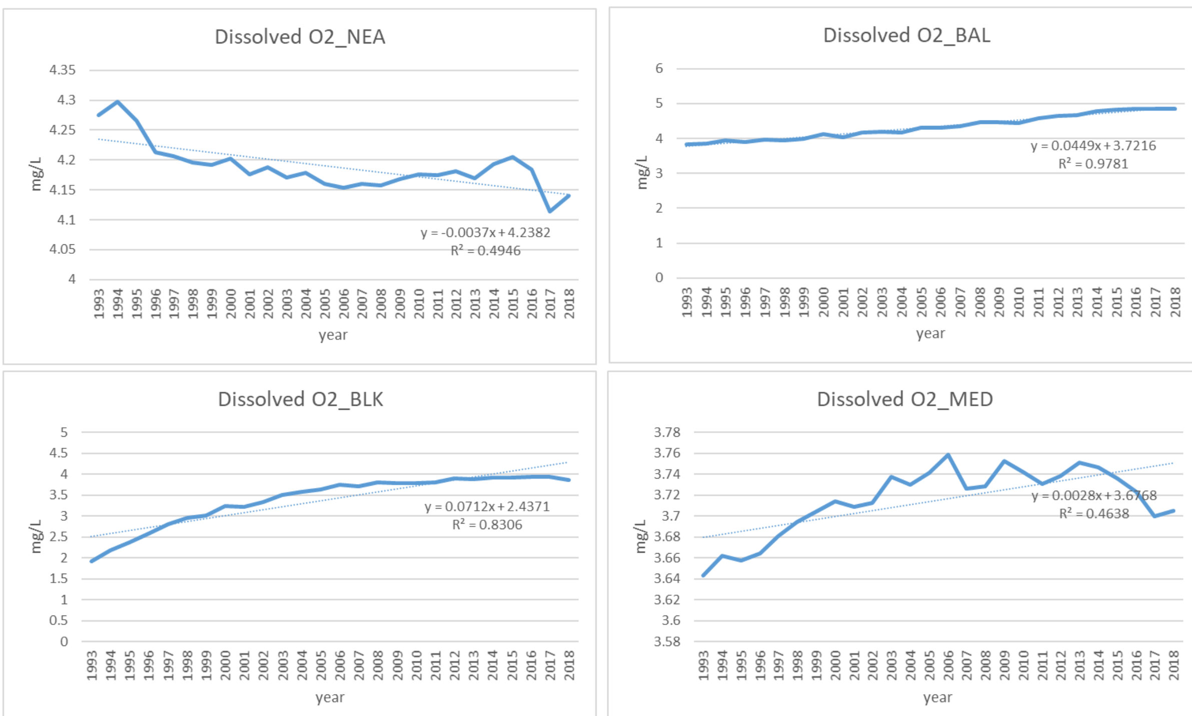
The indicator is calculated as follows: dataset are derived from the extraction of the year-mean concentration of oxygen is expressed as mg/l for each EU marine region, only near sea bottom (i.e. 50-150 m) in the entire sea basin excluding differences between marine areas (i.e. coastal, open ocean etc.). Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the dissolved oxygen trend in the EU marine regions shows variable patterns (Figure 1-2, Table 1).

Figure 1. The dissolved oxygen and relative trend in the European marine regions (<u>only</u> near sea bottom 50 - 150 m): North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: dissolved oxygen, 1993-2018.



Parameters	DissolvedO2_mg/l_NEA	DissolvedO2_mg/l_BAL	DissolvedO2_mg/l_BLK	DissolvedO2_mg/l_MED
intercept	13.6358	-93.1418	-24.2778	13.3762
slope	-0.0047	0.0486	0.0140	-0.0048
p-values	0.2061	**0.0003**	**0.0365**	**0.0244**
R2	0.2172	0.8637	0.4873	0.5386
ST_% change per decade	-1.1217	10.7303	3.6523	-1.2773
ST_trend direction	no change	increase	increase	decrease
MARINE CONDITION_LT	NO CHANGE	IMPROVEMENT	IMPROVEMENT	DEGRADATION
intercept	11.5909	-85.6924	-139.4624	-1.9592
slope	-0.0037	0.0449	0.0712	0.0028
p-values	**0.0001**	**0.0000**	**0.0000**	**0.0001**
R2	0.4946	0.9781	0.8306	0.8306
LT_%c hange perdecade	-0.8848	9.9098	19.1528	0.7590
LT_trend direction	decrease	increase	increase	increase
MARINE CONDITION_LT	DEGRADATION	IMPROVEMENT	IMPROVEMENT	IMPROVEMENT

Table. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2018) and long term (LT: 1993-2018) for NEA, BAL, BLK and MED.

Further references

EEA Report Oxygen concentrations in European coastal and marine waters, 2019, weblink: https://www.eea.europa.eu/data-and-maps/indicators/oxygen-concentrations-in-coastal-and/assessment

Laffoley, D. & Baxter, J.M. (eds.) (2019). Ocean deoxygenation: Everyone's problem - Causes, impacts, consequences and solutions. Full report. Gland, Switzerland: IUCN. 580pp.

EEA Report No 14/2019 Nutrient enrichment and eutrophication in Europe's seas. Moving towards a healthy marine environment. 50pp. DOI:10.2800/092643

Fact sheet 3.7.203: Chlorophyll-a (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Environmental quality
- Name of the indicator: Chlorophyll-a concentration
- Units: mg/m3

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1993-2015 (25 years of time-window and 75 depth levels)
- Reference:
  - Copernicus, CMEMS, GLOBAL_REANALYSIS_BIO_001_029 weblink: http://marine.copernicus.eu/services-portfolio/access-to-products/; http://marine.copernicus.eu/training/education/ocean-parameters/biogeochemistry/

3. Assessment of the indicator

The concentration of Chlorophyll-a is used to assess the environmental quality and the productivity in the sea.

3.1. Short description of the scope of the indicator

The indicator expresses the chrolophyll-a content in seawater. It provides an indirect measure of environmental quality, phytoplankton production, and biomass in the seawater. The rationale of the indicator is based on the following assumption: phytoplankton is the first link in the ocean's food chain, and is the main source of food for most fish. It contains chlorophyll, which instigates photosynthesis in the ocean, absorbs atmospheric CO2 and releases oxygen in sunlight. More than any land-based plant, phytoplankton is the biggest producer of oxygen on Earth. Sustainable management of marine resources has become a major preoccupation for today's society, and knowing the chlorophyll content of the ocean's surface levels is an important way to measure primary production, as well as of global ocean health. An increase in Chl-a content indicates an increase in phytoplankton production. Chlorophyll-a is slightly increasing overtime (see Figure 1).

IMPORTANT NOTE: In shelf regions, Chl-a trends switched from negative to positive in more recent years (since 1980), consistent with reported Chl-a increases due to intensifying coastal eutrophication and land runoff[47].

[47] Gregg, W. W., Casey, N. W. & McClain, C. R. Recent trends in global ocean chlorophyll. Geophys. Res. Lett. 32, 1–5 (2005); Boyce, D., Lewis, M. R. & Worm, B. Global phytoplankton decline over the past century. Nature 466, 591-596 (2010)

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

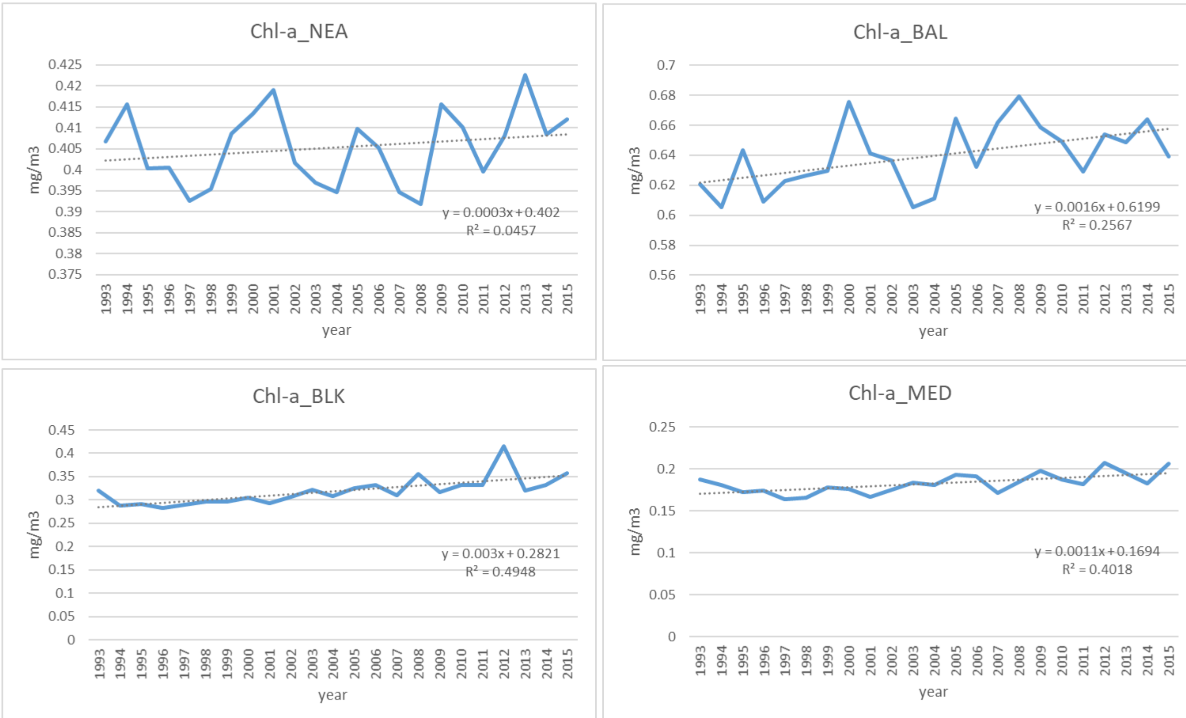
The indicator is calculated as follows: dataset are derived from the extraction of the year-mean for each EU marine region and up to max depth of photic zone basin-specific [NEA max 150 m, BAL max 20 m, BLK max 50 m, MED max 150], and in the entire sea basin excluding differences between marine areas (i.e. coastal, open ocean etc.). The average of the seawater parameter for each year is computed from the monthly sub dataset relative of each year and EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of Chlorophyll-a content trend in the EU marine regions shows variable patterns (Figure 1, Table 1).

Figure 1. The concentration of Chlorophyll-a and relative trend in the European marine regions (mean value of nutrients up to max depth of photic zone basin-specific; NEA max 150 m, BAL max 20 m, BLK max 50 m, MED max 150 m): North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: Chlorophyll-a content, 1993-2015.



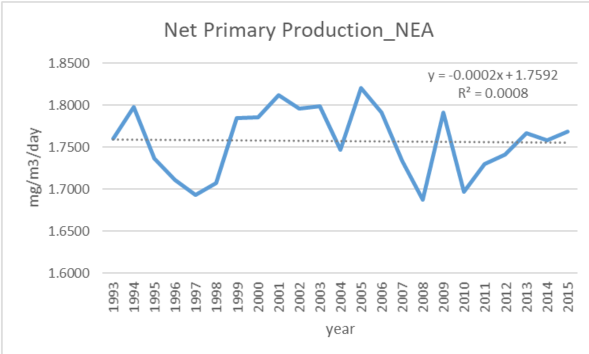
Parameters	CHLOROPHYLL-a_NEA	CHLOROPHYLL-a_BAL	CHLOROPHYLL-a_BLK	CHLOROPHYLL-a_MED
intercept	-2.4983	-2.2822	-1.6944	-4.3812
slope	0.0014	0.0015	0.0010	0.0023
p-values	0.4772	0.6656	0.9187	0.4649
R2	0.1330	0.0514	0.0029	0.1400
ST_% change per decade	3.5549	2.2615	2.9395	12.1247
ST_trend direction	no change	no change	no change	no change
MARINE CONDITION_ST	NO CHANGE	NO CHANGE	NO CHANGE	NO CHANGE
intercept	-0.1523	-2.6231	-5.7745	-2.0320
slope	0.0003	0.0016	0.0030	0.0011
p-values	0.3272	**0.0136**	**0.0002**	**0.0012**
R2	0.0457	0.2567	0.4948	0.4018
LT_% change per decade	0.6837	2.5077	9.0279	5.8389
LT_trend direction	no change	increase	increase	increase
MARINE CONDITION_LT	NO CHANGE	DEGRADATION	DEGRADATION	DEGRADATION

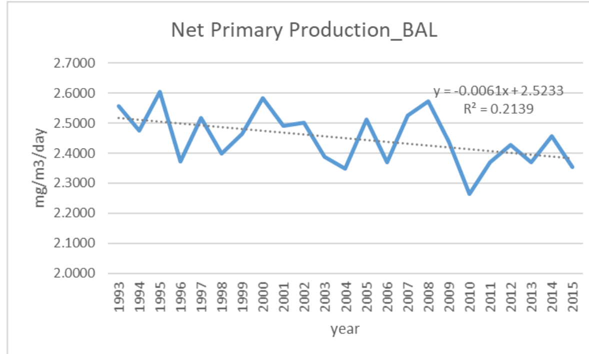
Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2015) and long term (LT: 1993-2015) for NEA, BAL, BLK and MED.

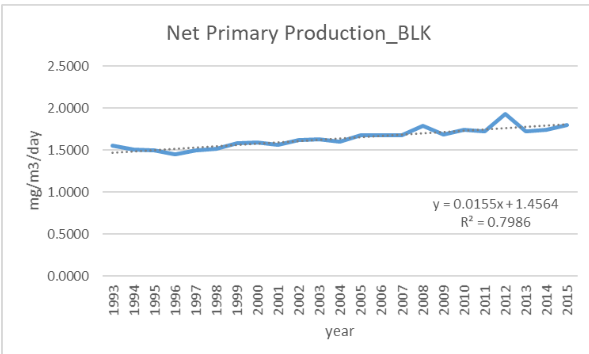
Other associated indicators:

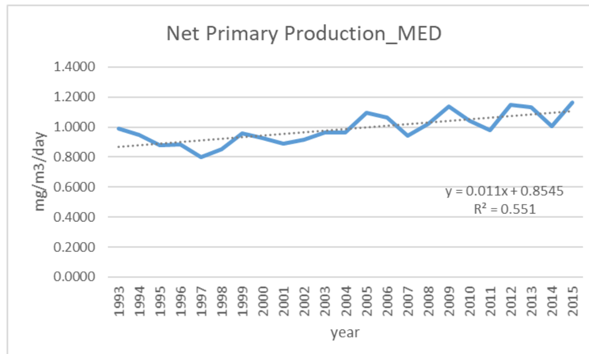
1. The net primary production is used to assess the environmental quality of the ocean. The net primary production and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK) (Figure 2).

Figure 2. Time-series indicator: net primary production in NEA, BAL, BLK and MED.



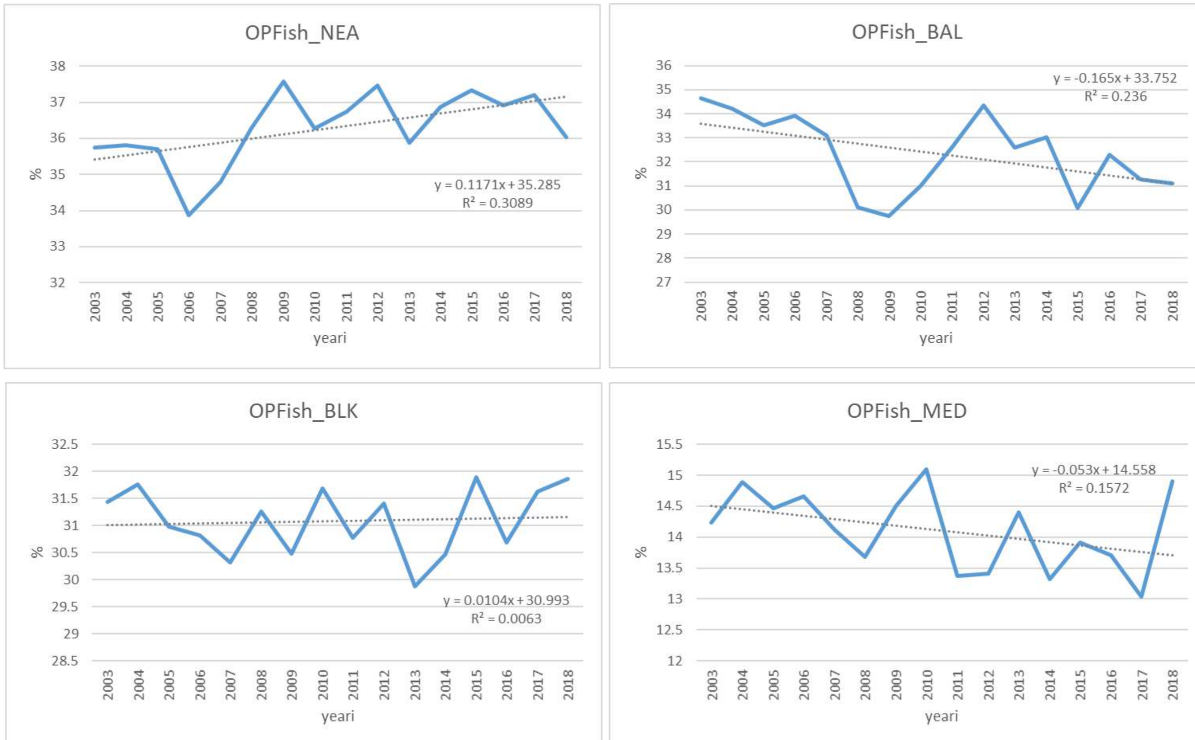






2. Ocean productivity index for fish (OPFish) is used to assess the quality on marine environment. The OPFish value relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK) (Figure 3).

Figure 3. Time-series indicator: net primary production in NEA, BAL, BLK and MED.



Further references

EEA Report N0 14/2019 Nutrient enrichment and eutrophication in Europe's Seas. Moving towards a healthy marine environment (2019) https://www.eea.europa.eu/publications/nutrient-enrichment-and-eutrophication-in#tab-figures-used

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

von Schuckmann, K. ((Editor)) et al. (2019) Copernicus Marine Service Ocean State Report, Issue 3, Journal of Operational Oceanography, 12:sup1, S1-S123, DOI: 10.1080/1755876X.2019.1633075

Fact sheet 3.7.204: Bathing water quality (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Environmental quality
- Name of the indicator: Bathing water quality
- Units: quality level[48]/year

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 1990-2018
- Reference:
  - EEA, update 23rd May 2019 through O. Vigiak (JRC) and Peter Kristensen (EEA); EEA Report No 3/2019 European Bathing Water Quality in 2018, weblink: https://www.eea.europa.eu/themes/water/europes-seas-and-coasts/assessments/state-of-bathing-water; https://www.eea.europa.eu/publications/european-bathing-water-quality-in-2018

3. Assessment of the indicator

Bathing water quality is used to assess the environmental quality of coastal and transitional waters.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of the coastal waters and beaches. It provides a direct measure of water quality. The rationale of the indicator is based on the following assumption: the bathing water is quantified by two parameters of (faecal) bacteria and other parameters. An increase in bathing water quality means an increase in safeguard public health and clean bathing waters. Bathing water quality is improving overtime (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

The indicator is calculated as follows: dataset are derived from the extraction of the year-mean for each beach by EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of

[48] Quality levels or categories: Not classified/NA (0); Poor (1); Sufficient (2); Good or Sufficient (3); Good (4) Excellent (5).

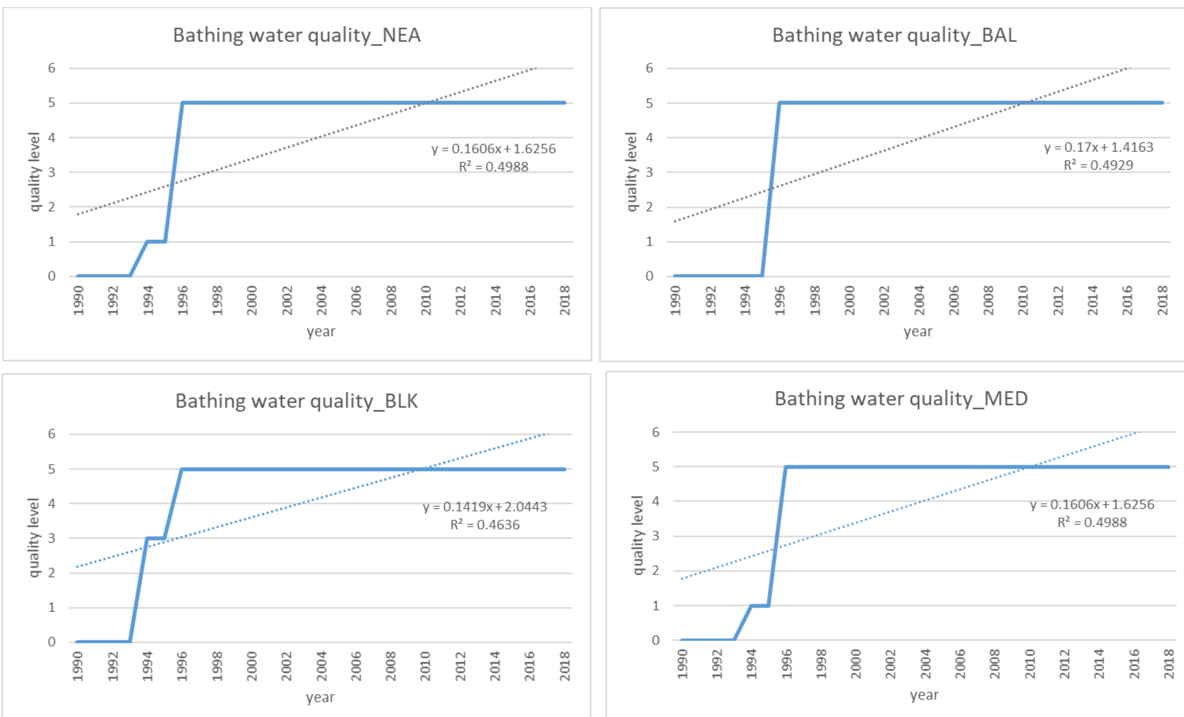
the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of Europe's seas. Mapping requires additional assumptions on the data.

A comparison of the quality level of bathing water trend in the EU marine regions shows it has reached a stable quality over the last two decades (Figure 1, Table 1).

Figure 1. The quality level of bathing water and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: bathing water quality, 1990-2018.



Parameters	Bathing water quality_NEA	Bathing water quality_BAL	Bathing water quality_BLK	Bathing water quality_MED
intercept	5.0000	5.0000	5.0000	5.0000
slope	0.0000	0.0000	0.0000	0.0000
p-values	na	na	na	na
R2	1.0000	2.0000	3.0000	4.0000
ST_% change per decade	0.0000	0.0000	0.0000	0.0000
ST_trend direction	NA	NA	NA	NA
MARINE CONDITION_ST	NO CHANGE	NO CHANGE	NO CHANGE	NO CHANGE
intercept	-317.7901	-336.6158	-280.1389	-317.7901
slope	0.1606	0.1700	0.1419	0.1606
p-values	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R2	0.4988	0.4929	0.4636	0.4988
LT_% change per decade	32.1309	34.0909	28.2408	32.1309
LT_trend direction	increase	increase	increase	increase
MARINE CONDITION_LT	IMPROVEMENT	IMPROVEMENT	IMPROVEMENT	IMPROVEMENT

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2018) and long term (LT: 1990-2018) for NEA, BAL, BLK and MED.

Further references

EEA Report No 2/2019 European Bathing water Quality in 2018. 22 pp. DOI:10.2800/997525

Fact sheet 3.7.205: Contaminants in biota (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Ecosystem condition/ Environmental quality
- Name of the indicator: Contaminants concentration in biota
- Units: µg/kg

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: variable, 2000-2017 or shorter
- Reference:
  - EMODnet Chemistry, weblink http://ec.oceanbrowser.net/emodnet/;

3. Assessment of the indicator

Contaminants in biota is used to assess the impact of human activities to marine organisms.

3.1. Short description of the scope of the indicator.

The indicator expresses the impact of human activities to marine organism. It provides a direct measure of contaminants in marine organisms. The rationale of the indicator is based on the following assumption: contaminants in biota is quantified by decreases in pollutants concentration and type in marine biota. A decrease in contaminants concentration means an increase in water quality, contributing to reaching "good environmental status". Contaminants in biota do not represent a clear pattern of trend (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

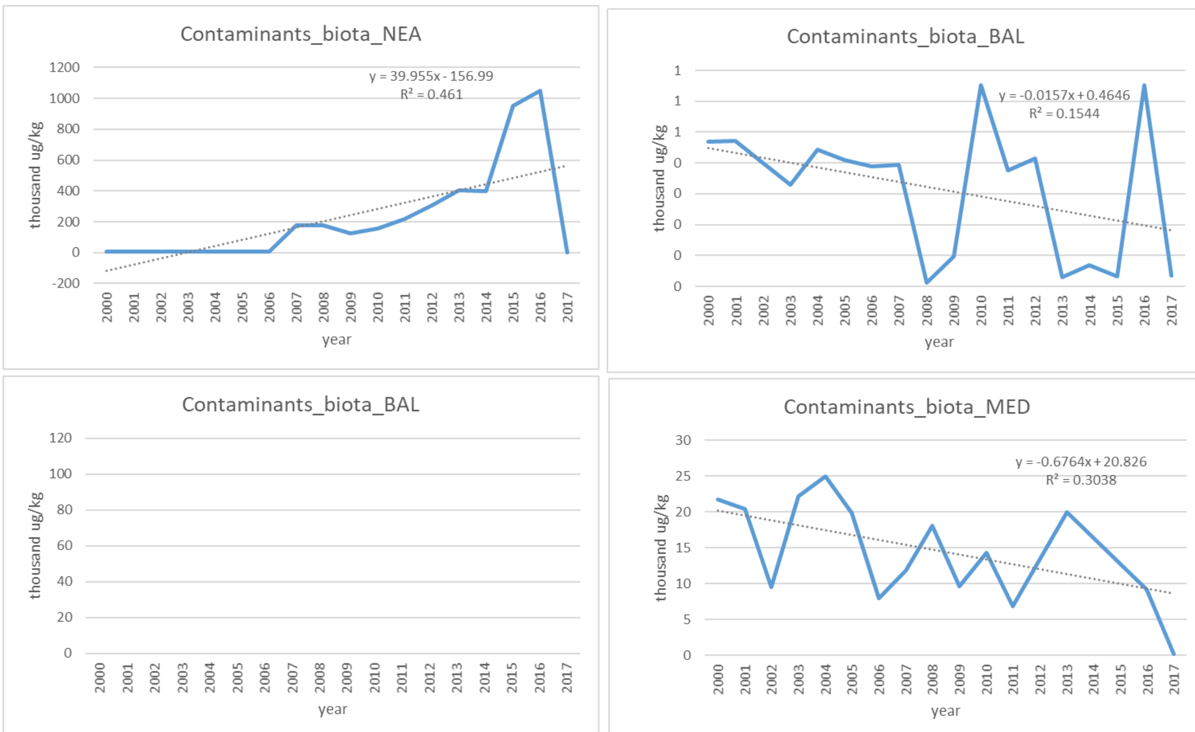
The concentration of contaminants has been scaled with the sampling size (value/nb. entries). The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the contaminants in biota trend in the EU marine regions shows no clear pattern (Figure 1, Table 1).

Figure 1. The concentration of contaminants in biota and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED), Back Sea (BLK). Time-series indicator: contaminants in biota, 2000-2017.



Parameters	Contaminants_biota_ NEA	Contaminants_biota_ BAL	Contaminants_biota_ BLK	Contaminants_biota_ MED
intercept	-118633054.7547	97358.0734		2234903.6257
slope	59135.1991	-48.2123		-1104.1911
p-values	0.3416	0.2902		0.2759
R2	0.1509	0.1831		0.1932
ST_% change per decade	258.5762	-106.8187		-71.3328
ST_trend direction	no change	no change	NA	no change
MARINE CONDITION_ST	UNRESOLVED*	UNRESOLVED*	NA	UNRESOLVED*
intercept	-80027758.6846	31861.1119		1372869.7932
slope	39955.3598	-15.7061		-676.3598
p-values	**0.0019**	0.1067		**0.0178**
R2	0.4610	0.1544		0.8354
LT_% change per decade	141.4276	-53.8140		-50.5255
LT_trend direction	increase	no change	NA	decrease
MARINE CONDITION_LT	UNRESOLVED*	UNRESOLVED*	NA	UNRESOLVED*

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2017) and long term (LT: 2000-2017) for NEA, BAL, BLK and MED.*based on expert judgment.

Further references

EEA Report No 25/2018 Contaminants in Europe's Seas. Moving towards a clean, non-toxic marine environment (2018) https://www.eea.europa.eu/publications/contaminants-in-europes-seas

EEA Report No 18/2018 Chemicals in European water. Knowledge developments. 80 pp. DOI:10.2000/265000

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.206: Contaminants in sediment (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Ecosystem condition/ Environmental quality
- Name of the indicator: Contaminants concentration in sediment
- Units: µg/kg

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: variable, 2000-2017 or shorter
- Reference:
  - EMODnet Chemistry, weblink http://ec.oceanbrowser.net/emodnet/;

3. Assessment of the indicator

Contaminants in sediment is used to assess the environmental quality and integrity of seafloor due to human activities.

3.1. Short description of the scope of the indicator.

The indicator expresses the impact of human activities to quality and integrity of seafloor. It provides a direct measure of contaminants in the seafloor. The rationale of the indicator is based on the following assumption: contaminants in sediment is quantified by decreases in pollutants concentration and type in the seafloor. A decrease in contaminants concentration means an increase in quality of water, seafloor and habitats, contributing to reaching "good environmental status". Contaminants in sediment do not represent a clear pattern of trend (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

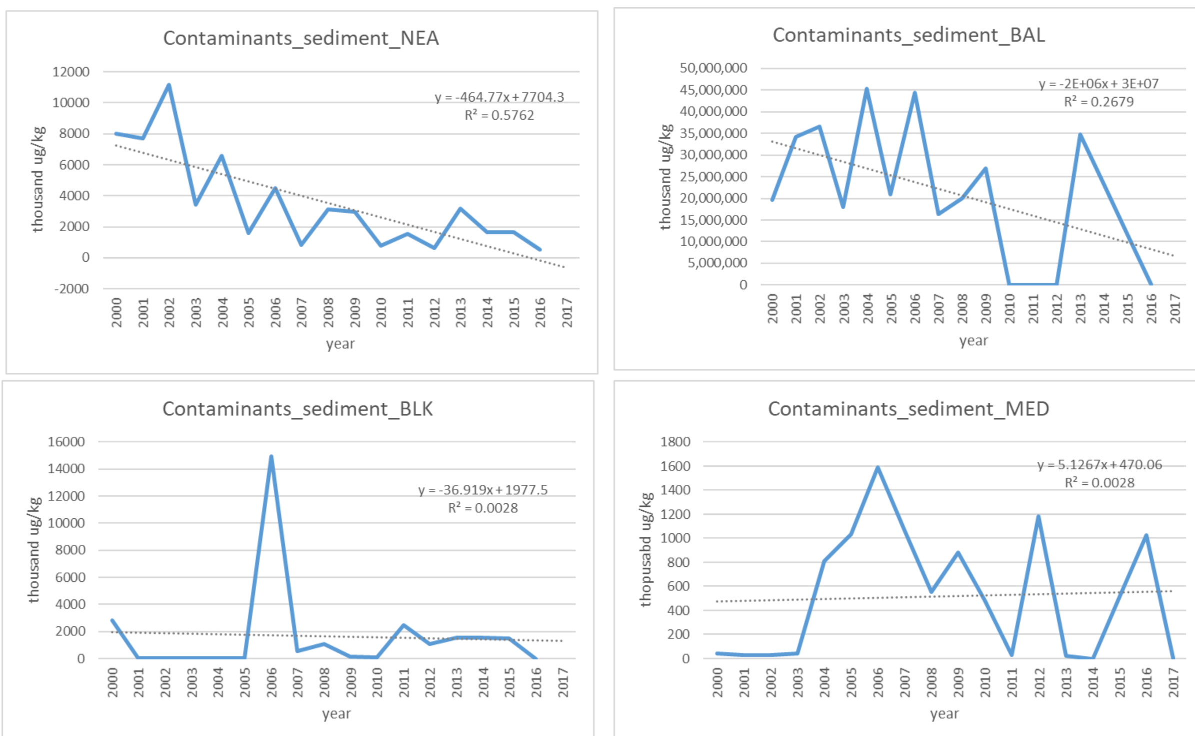
The concentration of contaminants has been scaled with the sampling size (value/nb. entries). The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the contaminants in sediment trend in the EU marine regions shows no clear pattern (Figure 1, Table 1-2).

Figure 1. The concentration of contaminants in sediment and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED), Back Sea (BLK). Time-series indicator: contaminants in sediment, 2000-2017.



Parameters	Contaminants_ sediment_NEA	Contaminants_ sediment_BAL	Contaminants_ sediment_BLK	Contaminants_ sediment_MED
intercept	-22973993.0412	-3337062983992.8300	-278263685.8516	9309713.2965
slope	12121.1570	1662710112.3982	138943.8727	-4421.0516
p-values	0.9513	0.5806	0.5219	0.9577
R2	**0.0008**	0.0652	0.1094	**0.0005**
ST_% change per decade	8.7232	333.5867	137.0934	-10.4418
ST_trend direction	increase	no change	no change	decrease
MARINE CONDITION_ST	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*
intercept	936788229.7715	3137559415356.3700	8116835.7929	-9778211.7753
slope	-464774.3448	-1552212587.6906	-3172.5136	5126.6997
p-values	**0.0004**	**0.0333**	0.9878	0.8354
R2	0.5762	0.2679	0.0000	0.0028
LT_% change per decade	-179.3252	-88.1332	-1.8232	9.7382
LT_trend direction	decrease	decrease	no change	no change
MARINE CONDITION_LT	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2017) and long term (LT: 2000-2017) for NEA, BAL, BLK and MED. *based on expert judgement.

Further references

EEA Report No 25/2018 Contaminants in Europe's Seas. Moving towards a clean, non-toxic marine environment (2018) https://www.eea.europa.eu/publications/contaminants-in-europes-seas

EEA Report No 18/2018 Chemicals in European water. Knowledge developments. 80 pp. DOI:10.2000/265000

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.207: Beach litter

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Environmental quality
- Name of the indicator: Beach litter
- Units: number of item/100m

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact Anna M. Addamo
- Time-series range: 2001-2018 or earlier
- Reference:
  - EMODnet Human Activities, weblink: http://www.emodnet-humanactivities.eu/view-data.php;

3. Assessment of the indicator

The quantity of beach litter is used to assess impact of human activities to coastal beaches.

3.1. Short description of the scope of the indicator.

The indicator expresses the environmental quality of the coastal beaches. It provides a direct measure of amount of litter in EU beaches. The rationale of the indicator is based on the following assumption: environmental quality of coastal beaches is quantified by decreases in amount and type of litter. A decrease in beach litter means an increase in environmental coastal quality, contributing to reaching "good environmental status". Beach litter do not represent a common pattern of trend across the EU marine regions (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

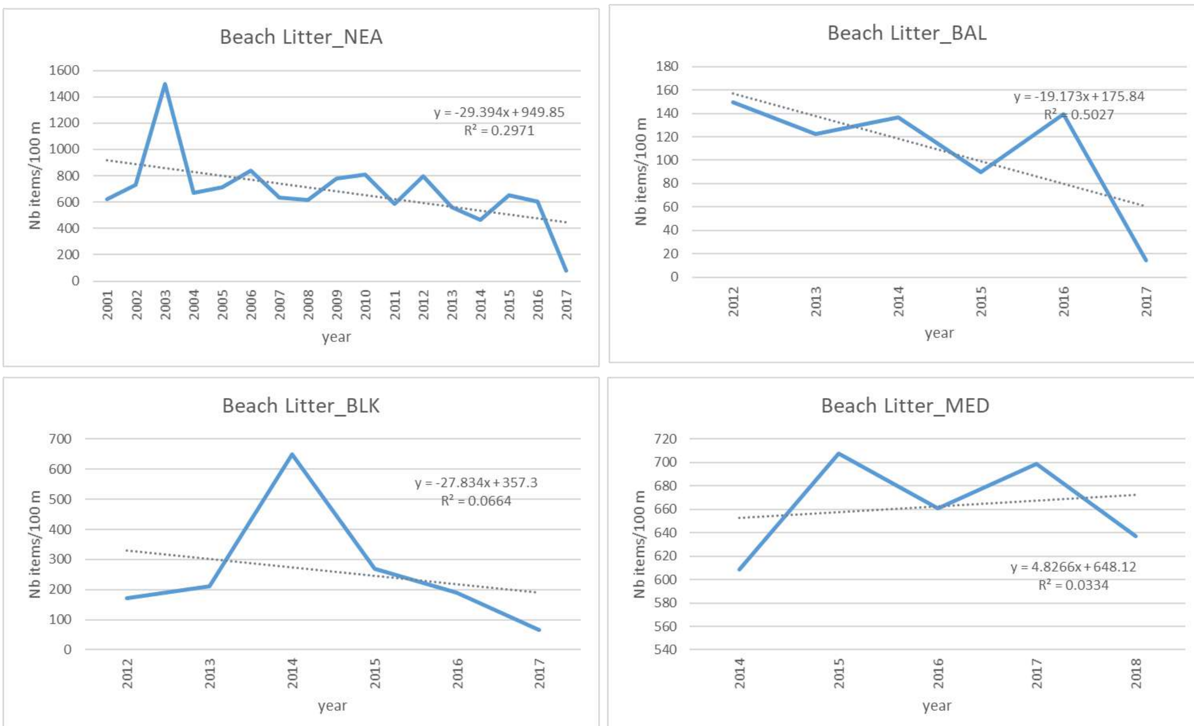
The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the beach litter trend in the EU marine regions shows no clear pattern, except for NEA (Figure 1, Table 1).

Figure 1. Amount of beach litter and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: beach litter, 2001-2018.



Parameters	Beach litter_ATL	Beach litter_BAL	Beach litter_BLK	Beach litter_MED
intercept	133464.5612	38732.4558	56331.6911	-9067.8882
slope	-66.0025	-19.1729	-27.8341	4.8266
p-values	**0.0495**	0.1147	0.6221	0.7686
R2	0.5010	0.5027	0.0664	0.0334
ST_% change per decade	-82.5522	-98.3177	-72.2712	7.6173
ST_trend direction	decrease	no change	no change	no change
MARINE CONDITION_ST	IMPROVEMENT	NO CHANGE	NO CHANGE	NO CHANGE
intercept	59737.8374			
slope	-29.3940			
p-values	**0.0236**			
R2	0.2971			
LT_% change per decade	-44.8140			
LT_trend direction	decrease			
MARINE CONDITION_LT	IMPROVEMENT	NA	NA	NA

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2018) and long term (LT: 2001-2018) for NEA, BAL, BLK and MED.

Note: No EU baseline and threshold from TG Marine Litter yet. Floating litter should be also considered as indicators in the MAES.

Further references

Addamo A.M., Laroche P., Hanke G. 2017. Top Marine Beach Litter Items in Europe, EUR 29249 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-87711-7, doi:10.2760/496717.

Hanke G., Walvoort, D., Van Loon, W., Addamo, A.M., Brosich, A., del Mar Chaves Montero, M., Molina Jack, M.E., Vinci, M., Giorgetti, A. EU Marine Beach Litter Baselines, EUR 30022 EN, Publications Office of the European Union, Luxemburg, 2019, ISBN 978-92-76-14243-0, doi:10.2760/16903.

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.208: Seafloor litter

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Environmental quality
- Name of the indicator: Seafloor litter
- Units: number of item/haul[49]

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: variable, 2007-2018 or earlier
- Reference:
  - EMODnet Human Activities, weblink: http://www.emodnet-humanactivities.eu/view-data.php;

3. Assessment of the indicator

The amount of seafloor litter is used to assess the environmental quality due to human activities.

3.1. Short description of the scope of the indicator.

The indicator expresses the environmental quality of the seafloor. It provides a direct measure of amount of litter in the seafloor. The rationale of the indicator is based on the following assumption: environmental quality of seafloor is quantified by decreases in amount and type of litter. A decrease in seafloor litter value means an increase in environmental seafloor quality, contributing to reaching "good environmental status". Seafloor litter do not represent a common pattern of trend across the EU marine regions. Further analysis with a time-series dataset, which is not available yet, are needed (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

[49] or "swept area"

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the seafloor litter trend in the EU marine regions shows no clear patterns (Figure 1, Table 1).

Figure 1. Amount of seafloor litter and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: seafloor litter, 2007-2018.

Parameters	Seafloor litter_ATL	Seafloor litter_BAL	Seafloor litter_BLK	Seafloor litter_MED
intercept	-128.0537	187.1290	-102.3080	-421.2658
slope	0.0641	-0.0921	0.0515	0.2102
p-values	0.3083	0.4053	**0.0174**	0.0850
R2	0.1471	0.1007	0.8839	0.4143
ST_% change per decade	82.3713	-44.1354	43.0168	174.0749
ST_trend direction	no change	no change	increase	no change
MARINE CONDITION_ST	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*
intercept	-220.9464			
slope	0.1102			
p-values	**0.0034**			
R2	0.5576			
LT_% change per decade	204.9287			
LT_trend direction	increase			
MARINE CONDITION_LT	UNRESOLVED*	NA	NA	NA

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2018) and long term (LT: 2007-2018) for NEA, BAL, BLK and MED.*based on expert judgment.

Note: information data is poor. Further analysis with a time-series dataset are needed.

Further references

Vlachogianni T, Somarakis S (2014) Methodology for monitoring marine litter on the seafloor (continental shelf). Bottom trawl surveys. http://mio-ecsde.org/wp-content/uploads/2014/12/Seafloor-litter_monitoring-methodology_continental-selves_final.pdf

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.210: Underwater impulsive noise

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Environmental quality
- Name of the indicator: Spatial distribution, temporal extent, and levels of anthropogenic impulsive sound sources
- Units: pulse/day

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 2014-2018 or earlier
- Reference:
  - EMODnet Human Activities, weblink: http://www.emodnet-humanactivities.eu/view-data.php; [Input of impulsive anthropogenic sound was created by combining pulse-block-days (PBD) data from the ICES Registry (for HELCOM and OSPAR areas) and ACCOMBAS (for the Mediterranean Sea)]

3. Assessment of the indicator

The underwater noise is used to assess the noise impact of human activities to marine ecosystem.

3.1. Short description of the scope of the indicator.

The indicator expresses the noise impact of human activities to marine ecosystem. It provides a direct measure of underwater noise. The rationale of the indicator is based on the following assumption: underwater noise is quantified by amount of impulsive and continuous low-frequency sound sources (pulse). A decrease in the pulse value means a decrease in impact of underwater noise, contributing to reaching "good environmental status". Underwater noise does not represent a common pattern of trend across the EU marine regions. Further analysis with a time-series dataset, which is not available yet, are needed (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope.

Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

Figure 1. Underwater impulsive noise and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: underwater noise, 2014-2018.

Parameters	UnderwaterNoise _NEA	UnderwaterNoise _BAL	UnderwaterNoise _BLK	UnderwaterNoise _MED
intercept	-2204591.4583	-390664.1667		5650631.6164
slope	1097.0750	194.8000		-2798.9589
p-values	0.1667	0.6139		0.1775
R2	0.4160	0.0694		0.5066
ST_% change per decade	2072.7230	220.4035		-113.2072
ST_trend direction	increase	increase	**NA**	decrease
MARINE CONDITION_ST	UNRESOLVED*	UNRESOLVED*	**NA**	UNRESOLVED*

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2014-2018) for NEA, BAL, BLK and MED.

Note: Information data is poor. Further analysis with a time-series dataset are needed.

Further references

EEA (2020) Estimated distribution of impulsive underwater noise in Europe's seas https://www.eea.europa.eu/data-and-maps/figures/input-of-impulsive-anthropogenic-sound

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.212: Ecological status (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Ecosystem attributes/Structural ecosystem attributes (general)
- Name of the indicator: Ecological Status
- Units: class

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Point-in-time: 1st RBMP (2010) – 2nd RBMP (2016) reporting exercises[50]
- Reference:
  - WISE WFD database version 3, accessed through EEA WISE-Marine Tableau, weblink: https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WFD_Marine_status/Ecological?iframeSizedToWindow=true&:embed=y&:showAppBanner=false&:display_count=no&:showVizHome=no&:origin=viz_share_link;

3. Assessment of the indicator

Ecological Status is used to assess the environmental quality of coastal and transitional water bodies.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of the structure and functioning of transitional and coastal waters ecosystems. It provides an indirect measure of water quality. The rationale of the indicator is based on the following assumption: the ecological status is quantified by the combination of several parameters (biological, physico-chemical and hydromorphological quality elements[51]) included in the Water Framework Directive (WFD). The overall ecological status classification for a water body is determined, according to the 'one out, all out' principle, by the element with the worst status out of all the biological and supporting quality elements. An improvement in the ecological status means an improvement in the health of the ecosystem. Ecological Status is slightly improving overtime (see Figure 1-2).

[50] Caution is advised when comparing Member States and when comparing the first and second RBMPs, as the results are affected by the methods Member States have used to collect data and often cannot be compared directly. Further info in https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water-assessment/water-assessments/ecological-status-of-surface-water-bodies

[51] BQEs: phytoplankton; macroalgae; angiosperms, macrophytes, phytobenthos; benthic invertebrates; fish; HQEs: hydrological or tidal regime; river continuity conditions; morphological conditions; CPQEs: transparency conditions; thermal conditions; oxygenation conditions; salinity conditions; acidification conditions; nutrients conditions; phosphorous conditions.

Ecological status is reported by Member States to monitor progress in implementing the WFD. Ecological status is reported per water body as “high”, “good”, “moderate”, “poor”, “bad”, or “unknown”. The indicator covers the current status of coastal and transitional waters as reported in the 1st and 2nd River Basin Management Plans (RBMPs).

The indicator is calculated as follows: dataset are derived from the 1st and 2nd river basin management plan (RBMP) reporting exercises, for evaluating the ecological status or potential of each EU marine region (see Table 1).

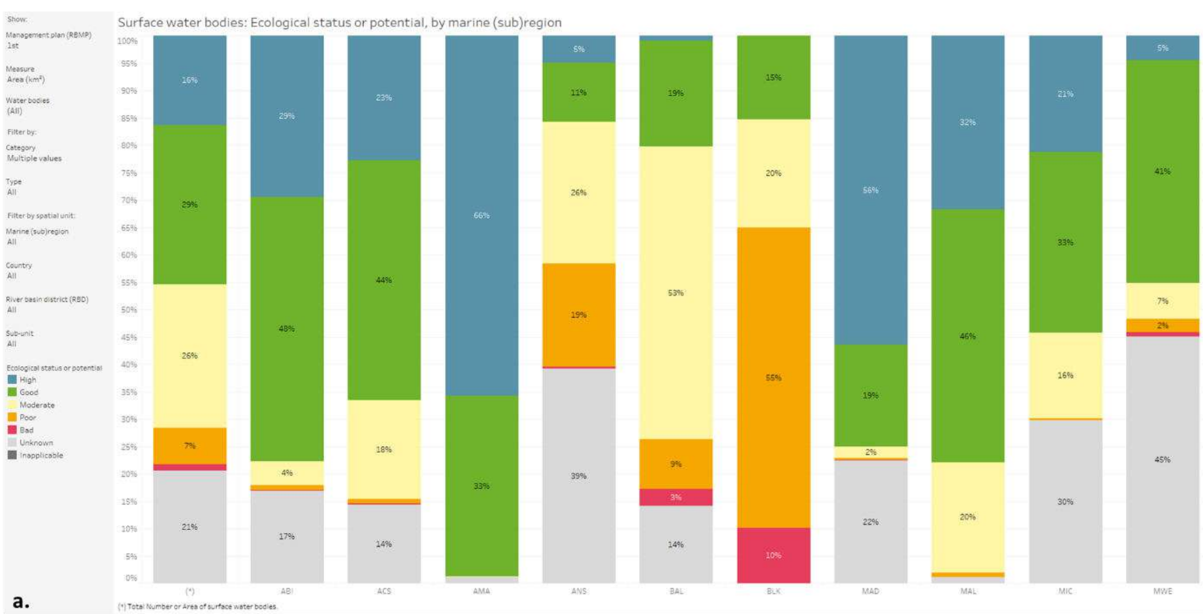
3.2. Maps

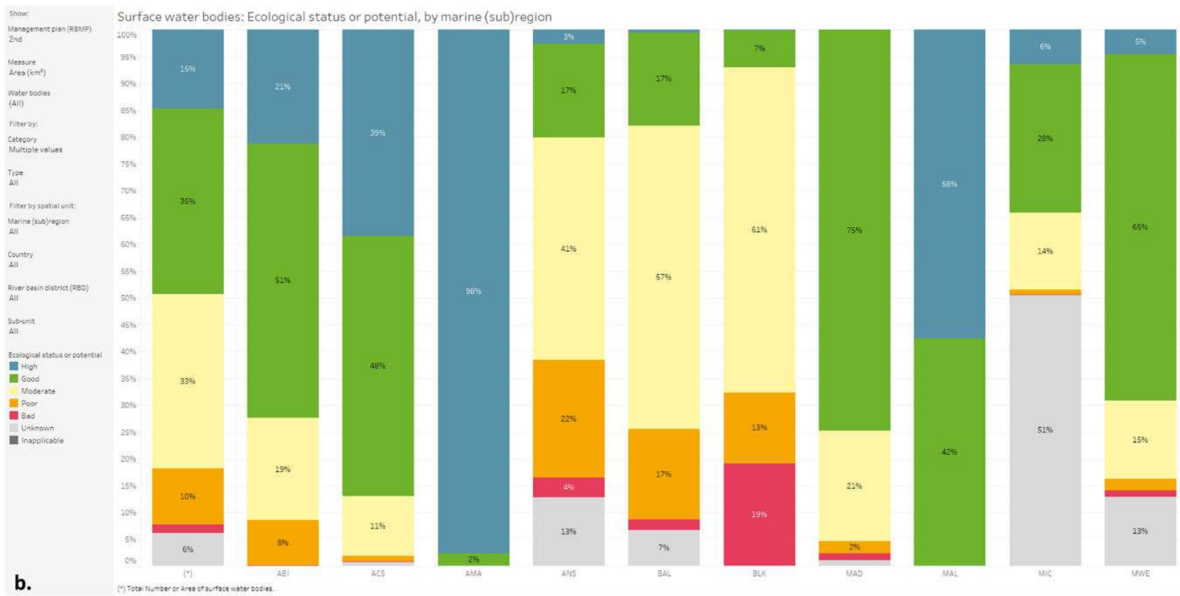
Not available.

3.3. Statistical analysis of the trend

Methodological differences between the two RBMP reporting exercises precluded analysis of temporal trends. Due to the differences in the two reporting periods, there is no trend assessment of this indicator at unit scale. However at the European scale conditions can be assessed as improvement from the first to the second RBMPs reporting period.

Figure 1. Change in ecological status of coastal and transitional water bodies (area in km^2) by EU submarine regions, for the a) 1st – 2010, and b) 2nd – 2016 River Basin Management Plans (RBMPs) reporting exercises. Source: the results are based on WISE WFD Database (Water Framework Directive Database) version 3, including data from 22 Member States (EU-23 except Lithuania for 2010, and EU-23 except Lithuania and Greece for 2016).



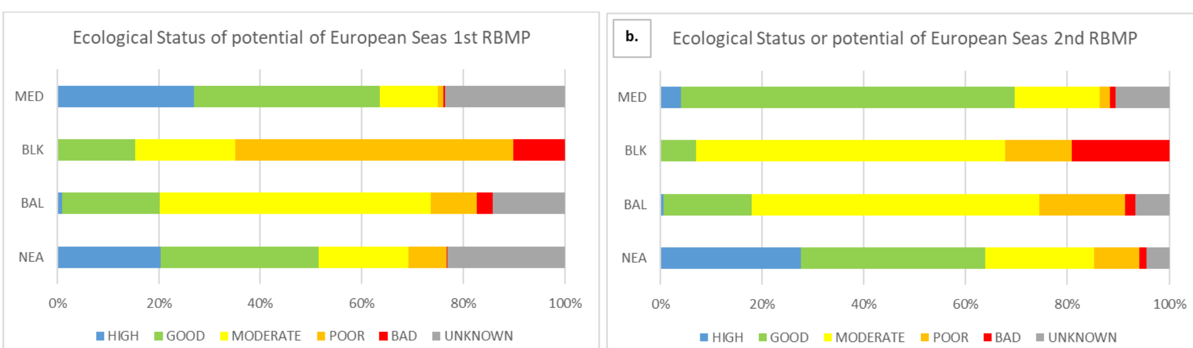


3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the ecological status reported in the first and second RBMP periods shows that the proportion of marine coastal and transitional waters with high ecological status has dropped significantly, from a total of 48 % to 32 % (Figure 2, Table 1).

Figure. The ecological status (% of area) in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Point-in-time indicator: ecological status, a) 1st RBMP – 2010, and b) 2nd RBMP – 2016 reporting exercises.



RBMP	Class	Ecological Status_NEA	Ecological Status_BAL	Ecological Status_BLK	Ecological Status_MED
1st RBMP	HIGH	20.28%	0.90%		26.93%
	GOOD	31.18%	19.36%	15.29%	36.65%
	MODERATE	17.67%	53.42%	19.73%	11.36%
	POOR	7.53%	9.05%	54.85%	1.16%
	BAD	0.20%	3.11%	10.12%	0.25%
	UNKNOWN	23.13%	14.16%		23.65%
2nd RBMP	HIGH	27.64%	0.59%		3.91%
	GOOD	36.13%	17.30%	6.98%	65.74%
	MODERATE	21.44%	56.57%	60.74%	16.60%
	POOR	8.90%	16.86%	13.15%	2.10%
	BAD	1.50%	2.02%	19.13%	1.08%
	UNKNOWN	4.39%	6.66%		10.57%

Table 1. The ecological status (% of area) in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Percentage per each class for marine region.

Further references

European Commission (EC). 2000. Water Framework Directive (WFD) 2000/60/EC. http://ec.europa.eu/environment/water/water-framework/index_en.html

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.213: Physical loss and disturbance to seabed

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Ecosystem attributes/Structural ecosystem attributes (general)
- Name of the indicator: Spatial extent and distribution of physical loss and disturbance to seabed
- Units: km^2

2. Data sources

The indicator is derived from the merge of different data sources. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Point-in-time: 2016[52]
- Reference:
  - EEA data thru Irene Del Barrio Alvarellos update 16 Jan 2020,
  - ETC/ICM Technical Report 4/2019 *Multiple pressures and their combined effects in Europe's seas* (2020). weblink: https://www.eionet.europa.eu/etcs/etc-icm/products/etc-icm-report-4-2019-multiple-pressures-and-their-combined-effects-in-europes-seas

3. Assessment of the indicator

Spatial extent and distribution of physical loss and disturbance to seabed is used to assess the status of seabed habitat.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of the habitat structure of marine ecosystem. It provides a direct measure of human activity. The rationale of the indicator is based on the following assumption: th e physical loss and disturbance to seabed is quantified by the increase of human activity to seabed. A decrease in percentage of habitats loss and/or damaged means an increase in health marine ecosystem, contributing to reaching "good environmental status". Physical loss and disturbance to seabed is slightly improving overtime (see Figure 1).

3.2. Maps

Not available.

[52] Data with time range 2011-2016 have been used in the study of the upcoming report, however results have to be considered as point-in-time;

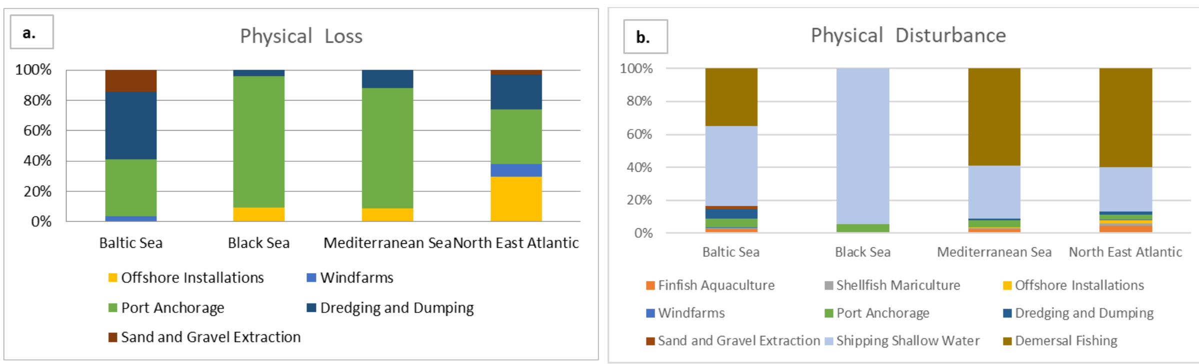
3.3. Statistical analysis of the trend

No trend assessment of this indicator. The indicator is calculated as follows: datasets have been prepared with the compilation of very different data sources on human activities, for evaluating the status of seabed habitats of each EU marine region (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

Figure 1. The physical loss (a) and disturbance (b) in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Point-in-time indicator: physical loss and disturbance, 2016.



	North East Atlantic	Baltic Sea	Black Sea	Mediterranean Sea
Physical loss (km2)	1861	760	74	692
Physical disturbance (km2)	25167	5526	1333	12863

Table 1. Physical loss and disturbance by human activities, km^2 per each marine region NEA, BAL, BLK and MED.

Further references

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

ETC/ICM Report 1/2019: Development of a pilot 'European seafloor integrity account' assessing fishing pressure on seabed habitats (2019) https://www.eionet.europa.eu/etcs/etc-icm/products/etc-icm-reports/development-of-a-pilot-european-seafloor-integrity-account-assessing-fishing-pressure-on-seabed-habitats

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.218: Population abundance (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Ecosystem condition/Ecosystem attributes (biological quality)/ Structural ecosystem attributes/ Structural ecosystem attributes based on species diversity and abundance
- Name of the indicator: Population abundance
- Units: Number of individual/species

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Data holder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: variable, 1911-2018
- Reference:
  - EMODnet Biology, weblink: http://www.emodnet-biology.eu/portal/index.php[53][54];

3. Assessment of the indicator

The population abundance of marine species is used to assess the biomass status of marine ecosystem.

3.1. Short description of the scope of the indicator.

The indicator expresses the biomass status of marine ecosystem. It provides a direct measure of biomass of marine organism. The rationale of the indicator is based on the following assumption: population abundance is quantified by increases in biomass. An increase in biomass value means an increase in population abundance, contributing to reaching "good environmental status". Population abundance represent a common pattern of trend across the EU marine regions. Further analysis with a time-series dataset, which is not available yet, are needed (see Figure 1-2).

3.2. Maps

Not available.

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[53] Dataset of benthic macroinvertebrates: the series products display the main functional type of benthic macroinvertebrates derived from a multivariate analysis of 13 life history traits. Further info in https://www.emodnet-biology.eu/distribution-benthic-macroinvertebrate-living-modes-european-seas

[54] Dataset of fish: the series products display the main functional type of fish derived from a multivariate analysis of 8 life history traits. Further info in https://www.emodnet-biology.eu/distribution-fish-living-modes-european-seas

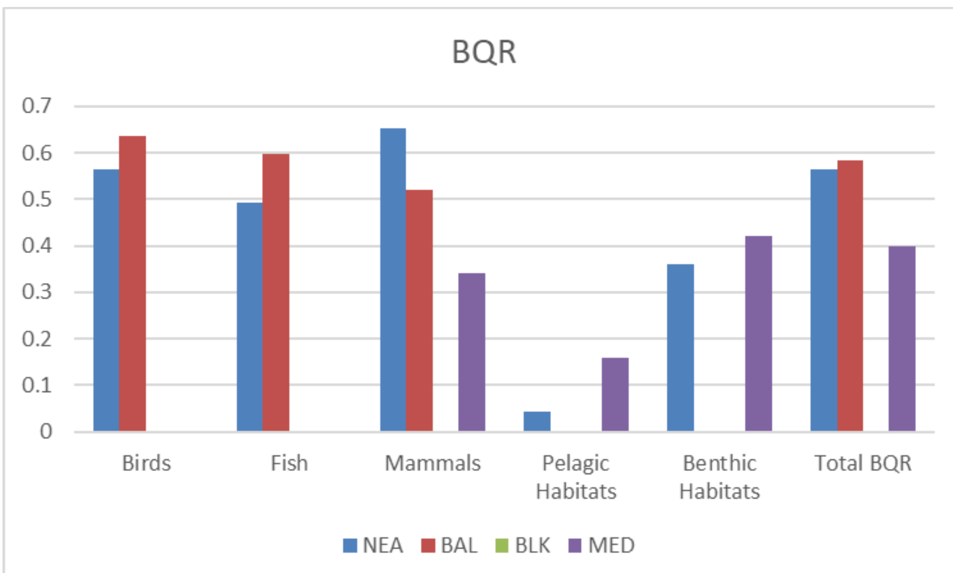
3.3. Statistical analysis of the trend

The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

Figure 1. Average of Biodiversity Quality Ratio (BQR)[55] by species groups in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Source: EEA update 24 Jan 2020, (ETC/ICM, 2019).



A comparison of the population abundance of marine species shows a particular patterns in EU marine region (except for BLK), where population abundance reported in several dataset might have direct influences form the number of surveys, technology applied and recent interest in some habitats (e.g. deep sea) (Figure 2, Table 1).

Figure 2. The number of individual per species and relative trend of marine population abundance in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: population abundance of marine species, 1911-2018.

[55] Methodology for classification of "biodiversity status," employing a tool named Biodiversity Assessment Tool (BEAT) 2.0. The BQR approach used in this assessment marks the ratio (0–1) between observations of the present state of biological diversity (Obs) and reference conditions (RefCon). For indicators with a positive response the BQR is given by RefCon/Obs. For those having a negative response the BQR is the inverse, i.e., Obs/RefCon. Further info in Andersen et al., 2014.

Parameters	Population abundance_NEA	Population abundance_BAL	Population abundance_BLK	Population abundance_MED
intercept	47727013.1725	15435024.1185		53676.2323
slope	-23622.7736	-7647.5508		-18.4034
p-values	**0.0172**	**0.0008**		**0.0418**
R2	0.5797	0.8196		0.6857
ST_% change per decade	-96.3258	-120.5344		-1.1030
ST_trend direction	decrease	decrease	**NA**	decrease
MARINE CONDITION_ST	UNRESOLVED*	UNRESOLVED*	**NA**	UNRESOLVED*
intercept	-4686417.062	-704736.904		-1981707.833
slope	2424.760644	374.6491592		993.7126453
p-values	**9.33949E-24**	**5.7449E-17**		**2.34616E-08**
R2	0.615837935	0.485171068		0.748967875
LT_% change per decade	12.94228412	7.755441913		63.47742147
LT_trend direction	increase	increase	**NA**	increase
MARINE CONDITION_LT	UNRESOLVED*	UNRESOLVED*	**NA**	UNRESOLVED*

Table 2. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2017) and long term (LT: 1911-2017) for NEA, BAL, BLK and MED.

Note: Information data is poor. Many species are missing. Datasets need harmonization. Further analysis with a time-series dataset is needed. Should MAES indicators identify a number of species as bioindicators for the status of marine biomass (e.g. list of species might be selected in MSFD Descriptor 1 – Biodiversity)?

Further references

ETC/ICM Report 3/2019. Biodiversity in Europes's Seas (2019). https://www.eionet.europa.eu/etcs/etc-icm/products/biodiversity-in-europes-seas

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Andersen JHM, Dahl K, Göke C, Hartvig M, Murray C, Rindorf A, Skov H, Vinther M and Korpinen S (2014). Integrated assessment of marine biodiversity status using a prototype indicator-based assessment tool. Frontiers in Marine Science, 1:55. doi: 10.3389/fmars.2014.00055

Fact sheet 3.7.221: Spawning stock biomass relative to reference biomass

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Ecosystem condition/Ecosystem attributes (biological quality)/ Structural ecosystem attributes/ Structural ecosystem attributes based on species diversity and abundance
- Name of the indicator: Spawning Stock Biomass relative to reference biomass
- Units: Rate B/B_{2003}

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Data holder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 2003-2017
- Reference:
- Report STECF2018-01, weblink: https://stecf.jrc.ec.europa.eu/reports/cfp-monitoring;
- Report STECF2019-01, weblink: https://stecf.jrc.ec.europa.eu/reports/cfp-monitoring;;

3. Assessment of the indicator

The spawning stock biomass of population of commercially-exploited species relative to reference biomass (B_{2003}) is used to assess the reproductive status of fish stocks.

3.1. Short description of the scope of the indicator.

The indicator expresses the reproductive status of fish and shellfish stocks. It provides an indirect measure of spawning stock biomass. The rationale of the indicator is based on the following assumption: reproductive status of fish and shellfish stocks is quantified by increases in rate of spawning stock biomass related to reference biomass. A decrease in the rate value means an increase in reproductive status of fish and shellfish stocks, contributing to reaching "good environmental status". Spawning stock biomass has a different trend over time across marine region (see Figure 1).

The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.2. Maps

Not available.

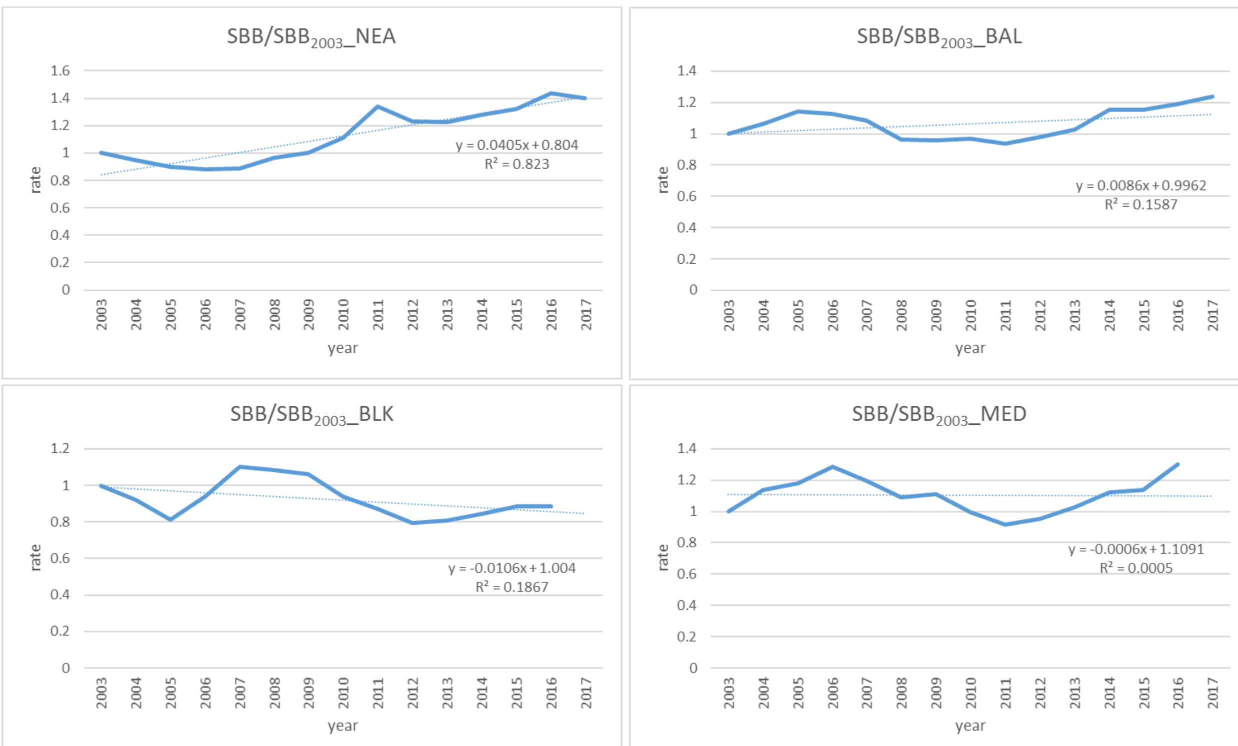
3.3. Statistical analysis of the trend

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the sea surface temperature trend in the EU marine regions shows it has reached a stable quality over the last two decades (Figure 1, Table 1).

Figure 1. Rate and relative trend of spawning stock biomass of population of commercially-exploited species relative to reference biomass (B_{2003}) in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: rate of spawning stock biomass, 2003-2017.



Parameters	SSB/SSB_{2003}_NEA	SSB/SSB_{2003}_BAL	SSB/SSB_{2003}_BLK	SSB/SSB_{2003}_MED
intercept	-67	-90	8	-109
slope	0.0339	0.0451	-0.0035	0.0548
p-values	**0.0189**	**0.0002**	0.7437	**0.0074**
R2	0.6287	0.9140	0.0233	0.7903
ST__% change per decade	28.8858	48.8758	-4.0460	60.7754
ST_trend direction	increase	increase	no change	increase
MARINE CONDITION_ST	IMPROVEMENT	IMPROVEMENT	NO CHANGE	IMPROVEMENT
intercept	-80	-16	22	2
slope	0.0405	0.0086	-0.0106	-0.0006
p-values	**0.0000**	0.1414	0.1228	0.9415
R2	0.8230	0.1587	0.1867	0.0005
LT_% change per decade	35.9224	8.1032	-11.5802	-0.5468
LT_trend_direction	increase	no change	no change	no change
MARINE CONDITION_LT	IMPROVEMENT	NO CHANGE	NO CHANGE	NO CHANGE

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2017) and long term (LT: 2003-2017) for FAO AREA 27 (NEA, BAL) and FAO AREA 37 (BLK, MED).

Note: Baseline set up by STECF: 2003.

Further references

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.223: Biological quality elements (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Ecosystem attributes/Structural ecosystem attributes based on species diversity and abundance
- Name of the indicator: Biological quality elements (BQEs) collected to assess ecological status
- Units: class

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Point-in-time: 1st RBMP (2010) – 2nd RBMP (2016) reporting exercises[56]
- Reference:
  - WISE WFD database version 3, accessed through EEA WISE Marine Tableau: https://tableau.discomap.eea.europa.eu/t/Wateronline/views/WFD_Marine_status/QualityElements?iframeSizedToWindow=true&%3Aembed=y&%3AshowAppBanner=false&%3Adisplay_count=no&%3AshowVizHome=no&%3Aorigin=viz_share_link;

3. Assessment of the indicator

Biological quality elements are used to assess the environmental quality of coastal and transitional waters.

3.1. Short description of the scope of the indicator.

The indicator expresses the quality of the biological structure and functioning of transitional and coastal waters ecosystems. It provides a direct measure of water quality. The rationale of the indicator is based on the following assumption: the biological quality elements are quantified by the status of several biological indicators included in the Water Framework Directive (WFD)[57]. An improvement of the biological quality elements means an increase in the health of the ecosystem. Biological quality elements are slightly improving overtime (see Figure below).

Biological quality elements are reported by Member States to monitor progress in implementing the WFD. Biological quality elements are reported per water body as “high”, “good”, “moderate”, “poor”, or “unknown”.

[56] Caution is advised when comparing Member States and when comparing the first and second RBMPs, as the results are affected by the methods Member States have used to collect data and often cannot be compared directly. Further info in https://www.eea.europa.eu/themes/water/european-waters/water-quality-and-water-assessment/water-assessments/quality-elements-of-water-bodies

[57] BQEs: phytoplankton; macroalgae; angiosperms, macrophytes, phytobenthos; benthic invertebrates; fish.

The indicator covers the current status of coastal and transitional waters as reported in the 1st and 2nd River Basin Management Plans (RBMPs).

The indicator is calculated as follows: dataset are derived from the 1st and 2nd river basin management plan (RBMP) reporting exercises, for evaluating the ecological status or potential of each EU marine region (see Table 1 below).

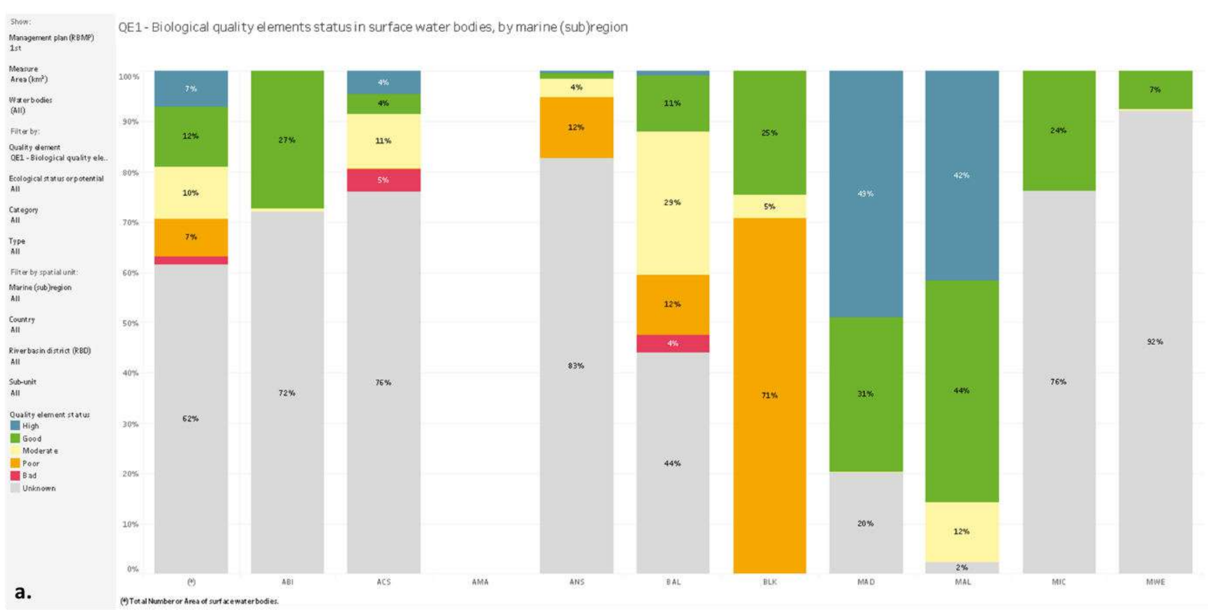
3.2. Maps

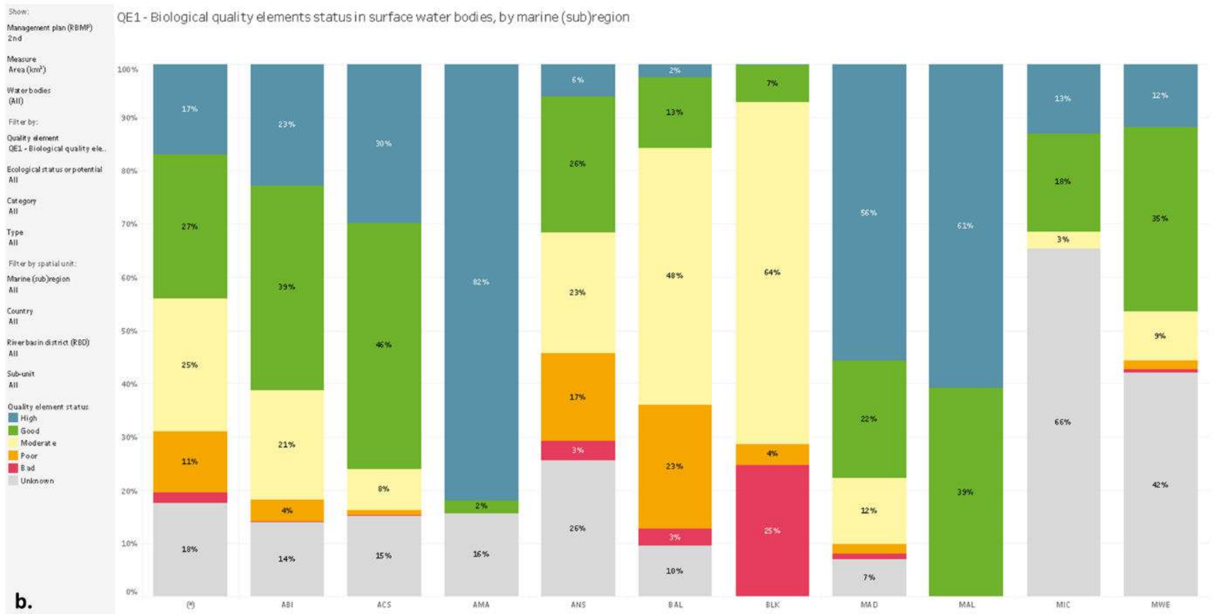
Not available.

3.3. Statistical analysis of the trend

Methodological differences between the two RBMP reporting exercises precluded analysis of temporal trends. Since the differences in the two reporting periods, there is no trend assessment of this indicator at unit scale. However at the European scale conditions can be assessed as improvement from the first to the second RBMPs reporting period.

Figure 1. Change in biological quality elements of coastal and transitional water bodies by EU submarine regions, for the a) 1st – 2010, and b) 2nd – 2016 River Basin Management Plans (RBMPs) reporting exercise. Source: the results are based on WISE WFD Database (Water Framework Directive Database) version 3, including data from 22 Member States (EU-23 except Lithuania for 2010, and EU-23 except Lithuania and Greece for 2016).



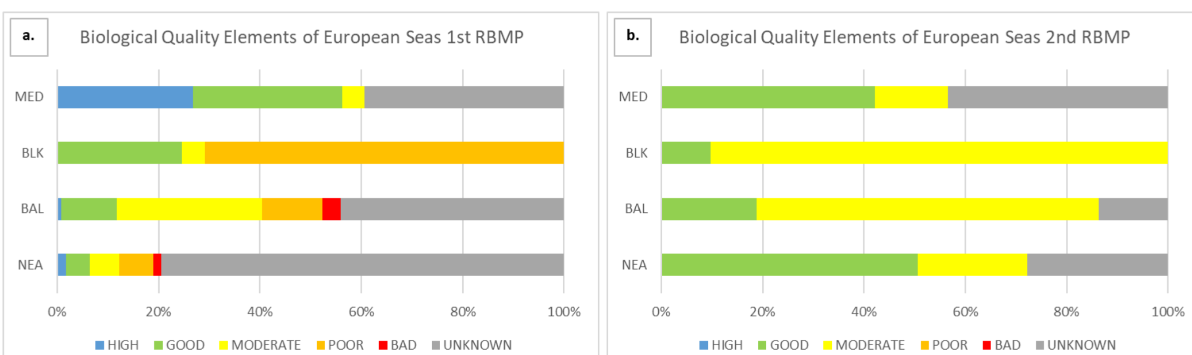


3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of the biological quality elements reported in the first and second RBMP periods shows that the proportion of coastal and transitional waters with unknown biological quality elements has dropped significantly, from 79% to 43 % (Figure 2, Table 1).

Figure 2. The biological quality elements assessment (% of area) in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Point-in-time indicator: biological quality elements in a) 1st RBMP – 2010, and b) 2nd RBMP – 2016 reporting exercises.



RBMP	Class	Biological Quality Elements_NEA	Biological Quality Elements_BAL	Biological Quality Elements_BLK	Biological Quality Elements_MED
1st RBMP	HIGH	1.68%	0.73%		26.75%
	GOOD	4.80%	11.10%		29.54%
	MODERATE	5.77%	28.64%		4.29%
	POOR	6.78%	11.82%		
	BAD	1.57%	3.59%		
	UNKNOWN	79.39%	44.13%		39.42%
2nd RBMP	HIGH				
	GOOD	50.54%	18.78%	9.80%	42.13%
	MODERATE	21.62%	67.57%	90.20%	14.41%
	POOR				
	BAD				
	UNKNOWN	27.84%	13.65%		43.46%

Table 1. Biological quality elements assessment (% of area) in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Percentage per each class.

Further references

European Commission (EC). 2000. Water Framework Directive (WFD) 2000/60/EC. http://ec.europa.eu/environment/water/water-framework/index_en.html

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.224: Presence of invasive alien species (marine ecosystems)

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Ecosystem condition/Ecosystem attributes (biological quality)/ Structural ecosystem attributes/ Structural ecosystem attributes based on species diversity and abundance
- Name of the indicator: Occurrence of invasive alien species
- Units: number of occurrences

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset and has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: 2000-2016
- Reference:
  - EASIN, weblink: http://easin.jrc.ec.europea.eu;

3. Assessment of the indicator

The occurrence of invasive alien species is used to assess the negative impact on habitats and autochthonous species.

3.1. Short description of the scope of the indicator.

The indicator expresses the negative impact on habitats and autochthonous species. It provides an direct measure of occurrence of invasive alien species. The rationale of the indicator is based on the following assumption: negative impact is quantified by increases in occurrence of invasive alien species. A decrease in occurrence value means a decrease in negative impact due to IAS, contributing to reaching "good environmental status". Occurrence of IAS is increasing overtime (see Figure 1).

3.2. Maps

Not available.

3.3. Statistical analysis of the trend

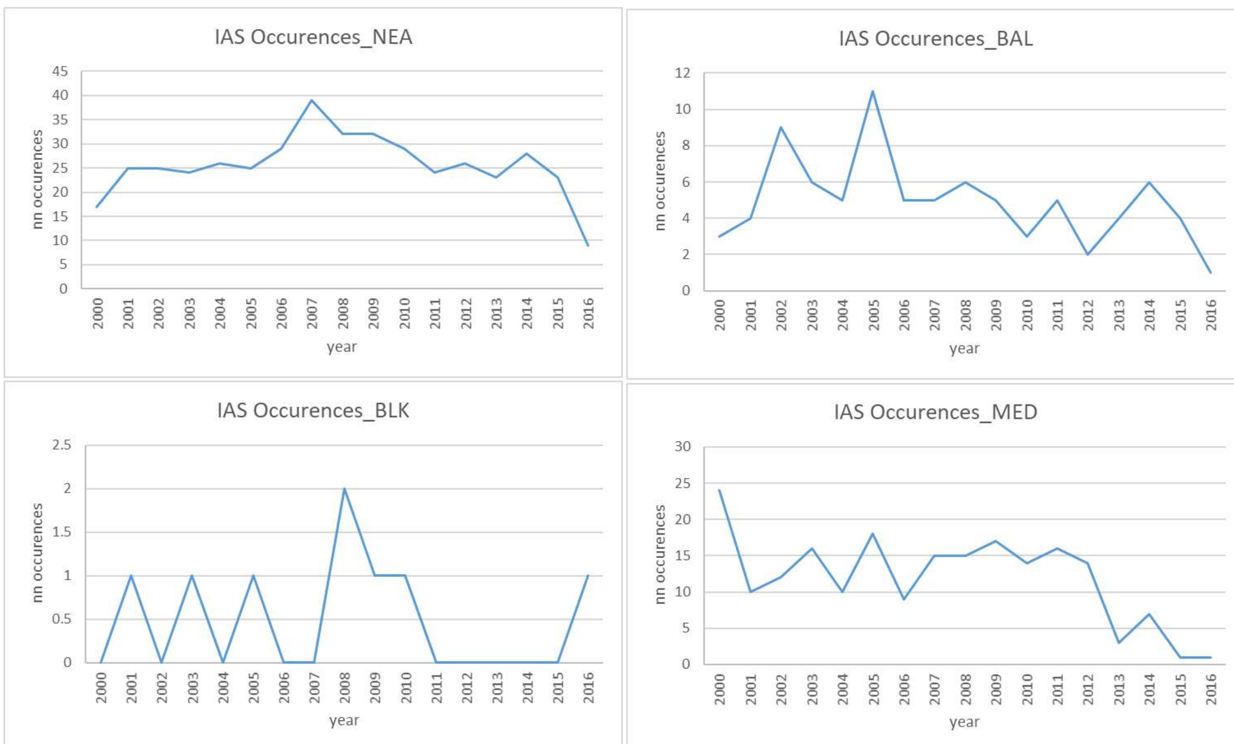
The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of European' seas. Mapping requires additional assumptions on the data.

A comparison of newly introduced non-indigenous species trend in the EU marine regions shows variable patterns (Figure 1, Table 1).

Figure 1. The number of occurrences of invasive alien species and related trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: occurrences of invasive alien species, 2000-2016.



Parameters	**Number of newly introduced non-indigenous species NIS (number/year)_ NEA**	**Number of newly introduced non-indigenous species NIS (number/year)_ BAL**	**Number of newly introduced non-indigenous species NIS (number/year)_ BLK**	**Number of newly introduced non-indigenous species NIS (number/year)_ MED**
intercept	4336.7143	291.1429	0.2857	5471.8571
slope	-2.1429	-0.1429	0.0000	-2.7143
p-values	0.0836	0.7000	1.0000	**0.0071**
R2	0.4818	0.0323	0.0000	0.7934
ST_% change per decade	-72.4638	-35.7143	0.0000	-168.1416
ST_trend direction	no change	no change	no change	decrease
ST_trend direction	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*
intercept	394.7647	388.8235	20.1569	1586.7843
slope	-0.1838	-0.1912	-0.0098	-0.7843
p-values	0.5799	0.1069	0.7622	**0.0065**
R2	0.0209	0.1640	0.0063	0.3998
LT_% change per decade	-7.2717	-41.9355	-21.7391	-76.0456
LT_trend direction	no change	no change	no change	decrease
LT_trend direction	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*	UNRESOLVED*

Table 1. OLS regression coefficients, percentage change per decade and trend direction of short term (ST: 2010-2016) and long term (LT: 2000-2016) for NEA, BAL, BLK and MED.*based on expert judgment.

Note: Dataset of NIS in the Black Sea is incomplete due to the lack of continuous reporting by MS and stakeholders. Baseline set up by EASIN: 2012.

Further references

EEA Report Pathways of introduction of marine non-indigenous species to European seas (2019) https://www.eea.europa.eu/data-and-maps/indicators/trends-in-marine-alien-species-1/assessment

Korpinen, S., Klančnik, K., Peterlin, M., Nurmi, M., Laamanen, L., Zupančič, G., Murray, C., Harvey, T., Andersen, J.H., Zenetos, A., Stein, U., Tunesi, L., Abhold, K., Piet, G., Kallenbach, E., Agnesi, S., Bolman, B., Vaughan, D., Reker, J. & Royo Gelabert, E., 2019, Multiple pressures and their combined effects in Europe's seas. ETC/ICM Technical Report 4/2019: European Topic Centre on Inland, Coastal and Marine waters, 164 pp.

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 3.7.225: Marine protected area

1. General information

- Thematic ecosystem assessment: Marine ecosystems
- Indicator class: Condition/Structural ecosystem attributes monitored (under the EU nature directives)
- Name of the indicator: Marine Protected Areas
- Units: %

2. Data sources

The indicator is derived from the merge of readily available datasets. The derived dataset has been resampled at EU Marine Regions scale.

References for the **derived dataset**:

- Dataholder: JRC; Contact: Anna M. Addamo, Francesca Somma
- Time-series range: variable, 1897-2019 (or shorter)
- Reference:
  - WDPA[58], World database of Protected Areas, weblink: https://www.protectedplanet.net/c/world-database-on-protected-areas;

3. Assessment of the indicator

Marine protected areas is used to assess the quantity of conservation and management of marine protected area.

There are five types of MPAs in Europe that are designated under different policy instruments and can overlap (meaning that a single protected area can be designated under one or more types):

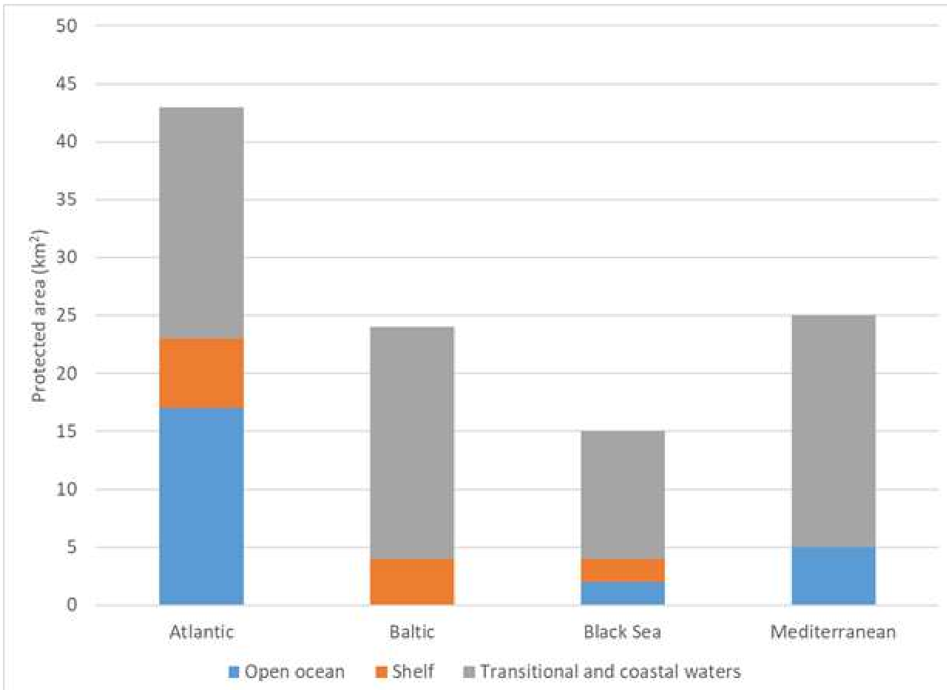
- Natura 2000 site[59]: SPA (Special Protection Area, designated under the Birds Directive) and/or SCI/SAC (Sites and proposed Sites of Community Importance and Special Areas of Conservation, designated under the Habitats Directive).
- Nationally designated area[60]: area designated by a national designation instrument, based on national legislation.
- MPAs designated by HELCOM (the Baltic Marine Environment Protection Commission - Helsinki Commission).
- MPAs designated by OSPAR (Commission for the Oslo-Paris Convention for the Protection of the Marine Environment of the North-East Atlantic).

[58] Data available only up to Sept. 2019.
[59] For more information, see https://www.eea.europa.eu/data-and-maps/data/external/natura-2000-barometer and https://www.eea.europa.eu/data-and-maps/indicators/sites-designated-under-the-eu-2/assessment
[60] For more information, see https://www.eea.europa.eu/data-and-maps/indicators/nationally-designated-protected-areas-10/assessment

- SPAMI (Specially Protected Areas of Mediterranean Importance) designated by the United Nations Environment Programme - Mediterranean Action Plan (Barcelona Convention).

The coverage of marine ecosystem types by MPAs is based on the marine habitats map (EEA, 2019) and the crosswalks developed by the ETC-BD (Condé et al, 2018). The ecosystems with the highest area coverage are the transitional and coastal waters (Figure 1).

Figure 1. Marine ecosystems surface area covered by MPAs per region. Source: EEA update 28.08.2019



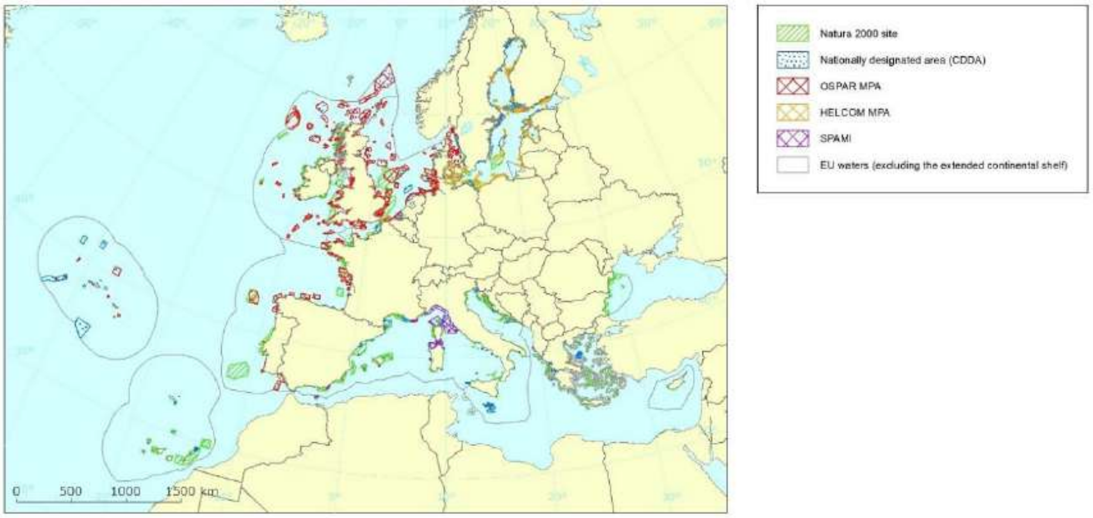
3.1. Short description of the scope of the indicator.

The indicator expresses the percentage of marine protected area. It provides a direct measure of amount of marine protected area in km^2. The rationale of the indicator is based on the following assumption: percentage of marine protected area is quantified by increase in km^2 of MPAs. An increase in the km^2 means an increase in marine ecosystem preserved and maintained as health ecosystems, contributing to reaching "good environmental status". MPAs is increasing overtime (see Figure 4).

3.2. Maps

The MPAs designated under the Regional Sea Conventions (HELCOM, OSPAR and UNEP/MAP) can be located beyond the EU waters, but in the present analysis only those falling within the EU waters have been considered (Figure 2).

Figure 2. MPAs in EU marine waters. Source: EEA update 28.08.2019



3.3. Statistical analysis of the trend

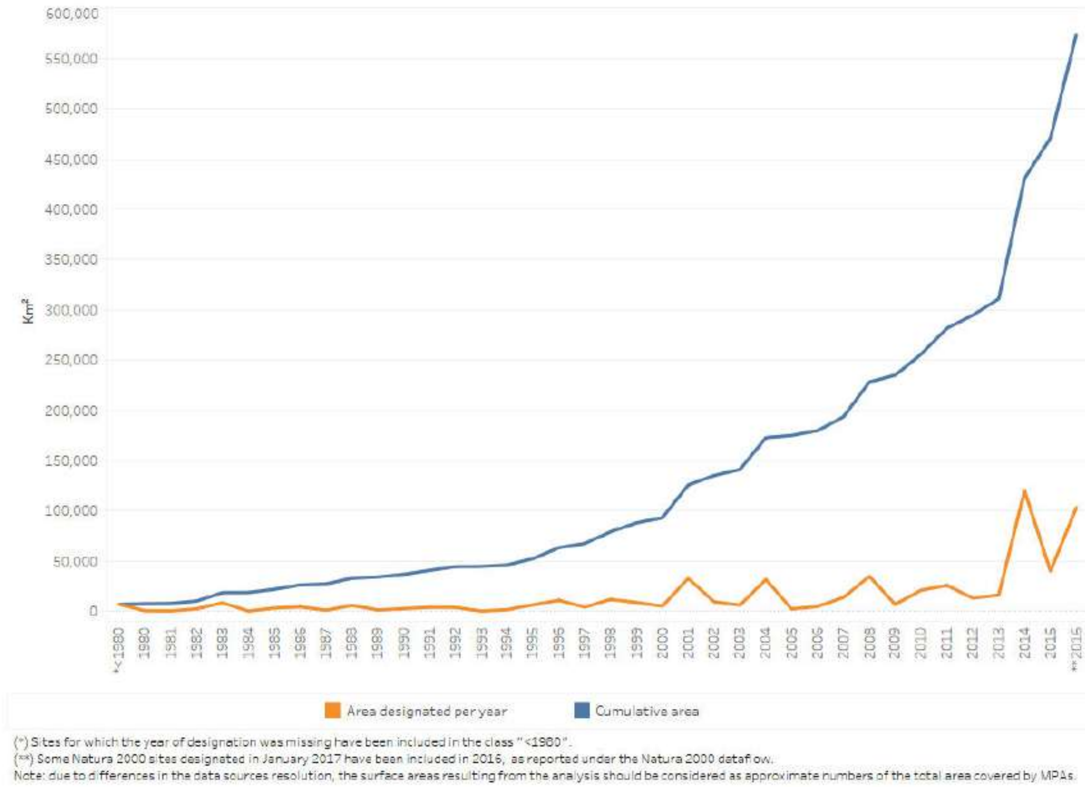
The indicator is calculated as follows: dataset are derived from the extraction of the year-sum for each EU marine region. Statistical test that fit a regression model through the observed data against time (in years) is performed per each EU marine regions, so that the change per decade is based on an assessment of the slope. Analysis Toolpack, available in Excel, is used to calculate the ordinary least squares (OLS) regression coefficients with their significance levels (see Table 1).

3.4. Key trend at EU level

The indicator cannot be assessed at aggregated EU level, but only at the scale of Europe's seas. Mapping requires additional assumptions on the data.

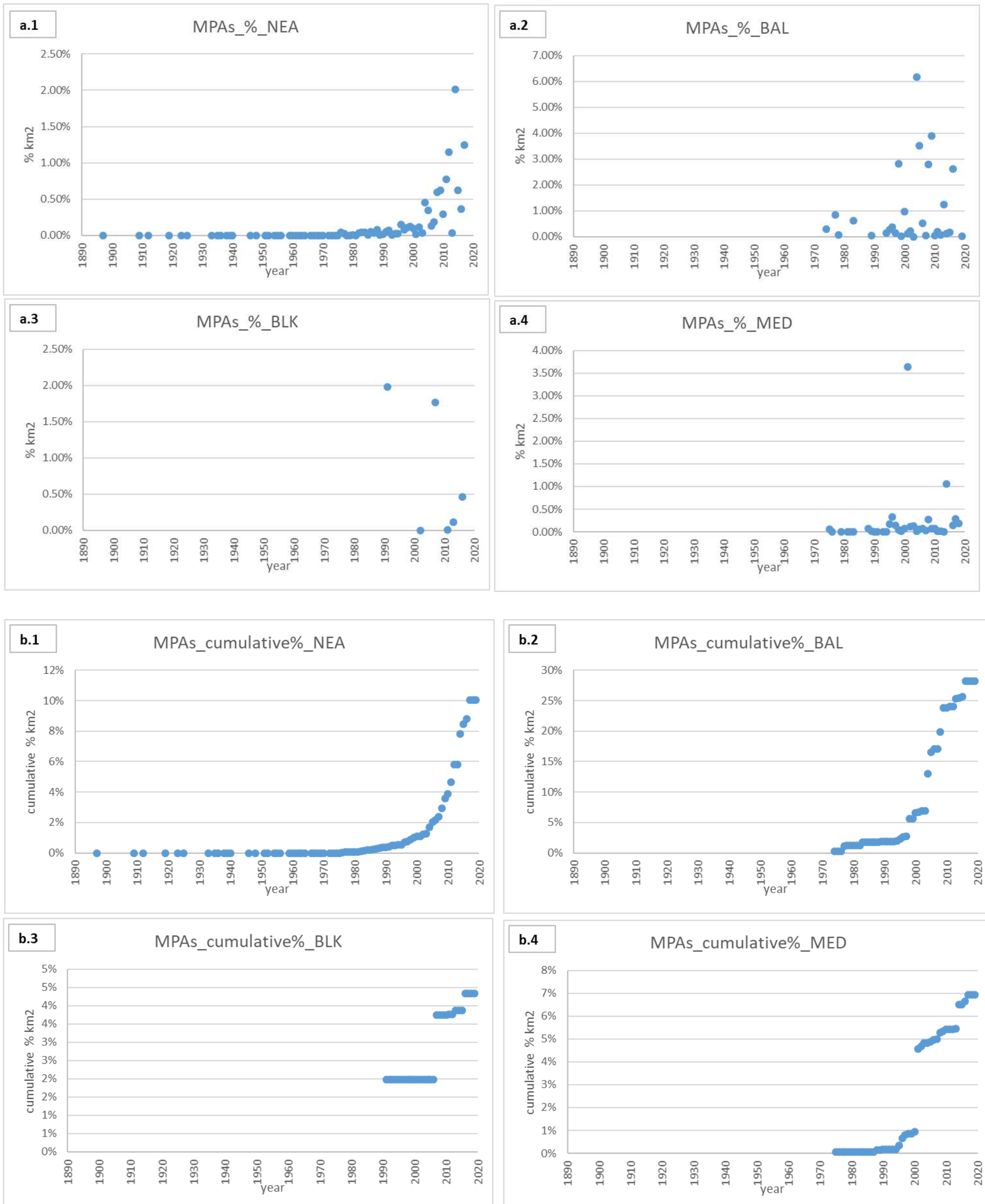
The area covered by MPAs in EU waters has increased substantially along the years, especially from 2000 onward (Figure 3).

Figure 3. Trends in marine protected area coverage in EU waters. Source: EEA update 28.08.2019



A comparison of the marine protected area trend in the EU marine regions shows an increasing amount of MPAs in the last decades with high variation in percentage per each marine region (Figure 4, Table 1).

Figure 4. The percentage of a) km^2 and b) cumulative km^2 of marine protected areas and relative trend in the European marine regions: North-East Atlantic (NEA), Baltic Sea (BAL), Mediterranean Sea (MED) and Back Sea (BLK). Time-series indicator: marine protected area, 1897-2019.


a.1
MPAs_%_NEA
% km2
year
a.2
MPAs_%_BAL
% km2
year
a.3
MPAs_%_BLK
% km2
year
a.4
MPAs_%_MED
% km2
year
b.1
MPAs_cumulative%_NEA
cumulative % km2
year
b.2
MPAs_cumulative%_BAL
cumulative % km2
year
b.3
MPAs_cumulative%_BLK
cumulative % km2
year
b.4
MPAs_cumulative%_MED
cumulative % km2
year

Parameters	**Marine protected area_NEA**	**Marine protected area_BAL**	**Marine protected area_BLK**	**Marine protected area_MED**
intercept	-15.1542	-11.8004	-1.6392	-4.2400
slope	0.0076	0.0060	0.0008	0.0021
p-values	**0.0000**	**0.0000**	**0.0002**	**0.0001**
R2	0.9505	0.8966	0.8331	0.8661
ST_% change per decade	182.5349	25.5524	22.8424	40.6450
ST_trend direction	increase	increase	increase	increase
MARINE CONDITION_ST	IMPROVEMENT	IMPROVEMENT	IMPROVEMENT	IMPROVEMENT
intercept	-1.0767	-4.3234	-0.7663	-1.1154
slope	0.0006	0.0022	0.0004	0.0006
p-values	**0.0000**	**0.0000**	**0.0000**	**0.0000**
R2	0.3780	0.4892	0.5701	0.4789
LT_% change per decade	17.3619	16.8637	16.4723	16.9838
LT_trend direction	increase	increase	increase	increase
MARINE CONDITION_LT	IMPROVEMENT	IMPROVEMENT	IMPROVEMENT	IMPROVEMENT

Table 1. OLS regression coefficients, percentage change per decade cumulative km^2 of marine protected areas and trend direction of short term (ST: 2010-2019) and long term (LT: 1897-2019) for NEA, BAL, BLK and MED.

Note: CBD and Biodiversity Strategy's targets (i.e. 10% coverage by 2020) have been reached by NEA and BAL. Increase MPAs as total protection - no fishing zone. Ongoing discussion about effective MPAs size: small vs large. Controversial management: *paper MPAs* vs MPAs.

Further references

EEA Briefing No 13/2018 Marine protected areas. Designed to conserve Europe's marine life, marine protected areas are a globally recognised tool for managing and enhancing our marine ecosystems. https://www.eea.europa.eu/publications/marine-protected-areas

Condé, S., Royo Gelabert, E., Parry, M., Lillis, H., Evans, D., Mo, G., & Agnesi, S., 2018. Updated crosswalks between European marine habitat typologies - A contribution to the MAES marine assessment. ETC/BD Technical paper N°7/2018. https://bd.eionet.europa.eu/Reports/ETCBDTechnicalWorkingpapers/Crosswalks_EU_marine_hab_typologies

EEA, 2019. Mapping Europe's ecosystems. European Environment Agency (EEA), Copenhagen, Denmark. https://www.eea.europa.eu/themes/biodiversity/mapping-europes-ecosystems/mapping-europes-ecosystems

EEA (2019) The European environment – state and outlook 2020. Knowledge for transition to a sustainable Europe. 499 pp. DOI: 10.2800/96.749.

Fact sheet 4.1.101: Climate indicators

1. Data sources

The observational climate databases E-OBS and MARS were used to derive the indicators.

E-OBS

• Data holder: EU-FP6 project UERRA (http://www.uerra.eu) and the Copernicus Climate Change Service, and the data providers in the ECA&D project (https://www.ecad.eu)

• Weblink: http://surfobs.climate.copernicus.eu/dataaccess/access_eobs.php

• Time-series range: 1950-2018

• Version: 19.0e

• Access date: 20/03/2019

• Reference: Cornes, R. C., van der Schrier, G., van den Besselaar, E. J. M., & Jones, P. D. (2018). An Ensemble Version of the E-OBS Temperature and Precipitation Data Sets. Journal of Geophysical Research: Atmospheres, 123(17), 9391-9409, doi:10.1029/2017jd028200.

E-OBS ensemble version 19.0e (Cornes et al. 2018) at 0.1 degree horizontal resolution was sourced from the EU-FP6 project UERRA and the Copernicus Climate Change Service, and the data providers in the ECA&D project. E-OBS is a European high-resolution gridded daily data set of surface mean temperature, minimum temperature, maximum temperature, precipitation sum and averaged sea level pressure. E-OBS covers the land areas within 25–75°N latitude and 40W–75°E longitude. A summary of the limitations of E-OBS is presented in Annex B.

MARS

• Data holder: European commission, Joint Research Centre (JRC)

• Weblink: https://agri4cast.jrc.ec.europa.eu/DataPortal/

• Time-series range: 1985 – 2018

• Access date: 20/05/2019

The MARS meteorological database contains gridded meteorological data on maximum air temperature (°C), minimum air temperature (°C), mean air temperature (°C), mean daily wind speed at 10m (m/s), vapour pressure (hPa), sum of precipitation (mm/day), potential evaporation from a free water surface (mm/day), potential evapotranspiration from a crop canopy (mm/day), potential evaporation from a moist bare soil surface (mm/day), total global radiation (KJ/m2/day), snow depth. The parameters are interpolated from weather station data on a 25 x 25 km grid. The data is available on a daily basis from 1975 up to near real time, covering the EU Member States, neighbouring European countries and the Mediterranean countries. In the present assessment the MARS data series starting from 1985 is used to avoid potential inhomogeneities that can lead to uncertainties in the trend analysis.

2. Assessment of the indicators

Trends for each indicator were calculated at EU level (Table 1) and at grid cell level (Figures 1-7, 9-13 and 15-17) covering the whole terrestrial domain of the EU. To avoid bias in the trend analysis, some grid cells with incomplete data series were excluded from the E-OBS data analysis and the period 1985-2018 was selected from the MARS database.

For each indicator the annual value was calculated on each grid cell based on the algorithms shown in Table 2 in Annex A. Annual spatial data were used for detecting trends on each grid cell. We used robust regression to mitigate the effect of anomalous years. Regression slopes were estimated using the non-parametric Theil-Sen estimator (Sen 1968; Wilcox 2012) because it accommodates non-normal distributions and is a robust trend slope estimator resistant to the effects of outliers. Additionally, a two-sided Mann-Kendall (Gilbert 1987; Kendall 1975; Mann 1945) non-parametric trend test was used to assess the significance of monotonic trends.

At EU level, the following indicators show a significant trend, therefore representing a major pressure on ecosystems: annual mean temperature, mean temperature of warmest and coldest quarter, effective rainfall, extreme drought event frequency, summer days and growing season length (Table 1). The rest of the indicators do not exhibit significant trends at EU level, but for all indicators there are regions where they show a significant trend locally. The maps (Figures 1-7, 9-13 and 15-17) show these regions for each of the studied indicators.

Table 1 Bioclimatic indicators for ecosystem condition assessment. Trends significant at α = 0.05 according to Mann-Kendall trend test.

Indicators typology	Indicator	Range	Data source	Spatial resolution	Trend at EU level
Climate means	Annual mean temperature (°C)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	**Significant +0.325 °C/decade**
	Mean temperature of warmest quarter (°C)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	**Significant +0.311 °C/decade**
	Mean temperature of coldest quarter (°C)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	**Significant +0.350 °C/decade**
	Annual precipitation (mm)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend
	Precipitation of wettest quarter (mm)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend
	Precipitation of driest quarter (mm)	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend
	Effective rainfall (mm)	1960–2016	PET: CRU TS 4.01. P: Full data monthly (v2018) GPCC DWD	0.5 degree (~43x43 km)	**Significant -12mm/decade**
Climate extremes	Extreme drought events frequency (number of extreme drought events in 5 years)	1950-2018	E-OBS (v 19.0e), EDO**	0.25 degree (~25x25 km)	**Significant +0.017 events/decade**
	Drought events frequency (number of drought events in 5 years)	1950-2018	E-OBS (v 19.0e), EDO**	0.25 degree (~25x25 km)	No significant trend
	Total drought severity (5 year-accumulated index)	1950-2018	E-OBS (v 19.0e), EDO**	0.25 degree (~25x25 km)	No significant trend
	Summer days (number of days where daily max. temp > 25 °C)	1985-2018	MARS database***	25x25 km	**Significant +3.76 days/decade**
	Soil moisture (soil water deficit)[1]	1951-2013	E-OBS (v 19.0e), EDO (Cammalleri et al., 2016)	5x5 km	No significant trend (chart not available)
Climate	Growing season length (number	1985-2018	MARS database***	25x25 km	**Significant +5.46 days/decade**

seasonality	of days)				
	Temperature seasonality (coefficient of variation [% of values in K])	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend
	Precipitation seasonality (coefficient of variation [%])	1960-2018	E-OBS (v 19.0e)*	0.1 degrees (~10x10 km)	No significant trend

* https://www.ecad.eu/download/ensembles/download.php

** http://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000

*** https://agri4cast.jrc.ec.europa.eu/DataPortal/

Change in average climate

Maps of trends in average climate

Figure 1 Trends in annual mean temperature 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

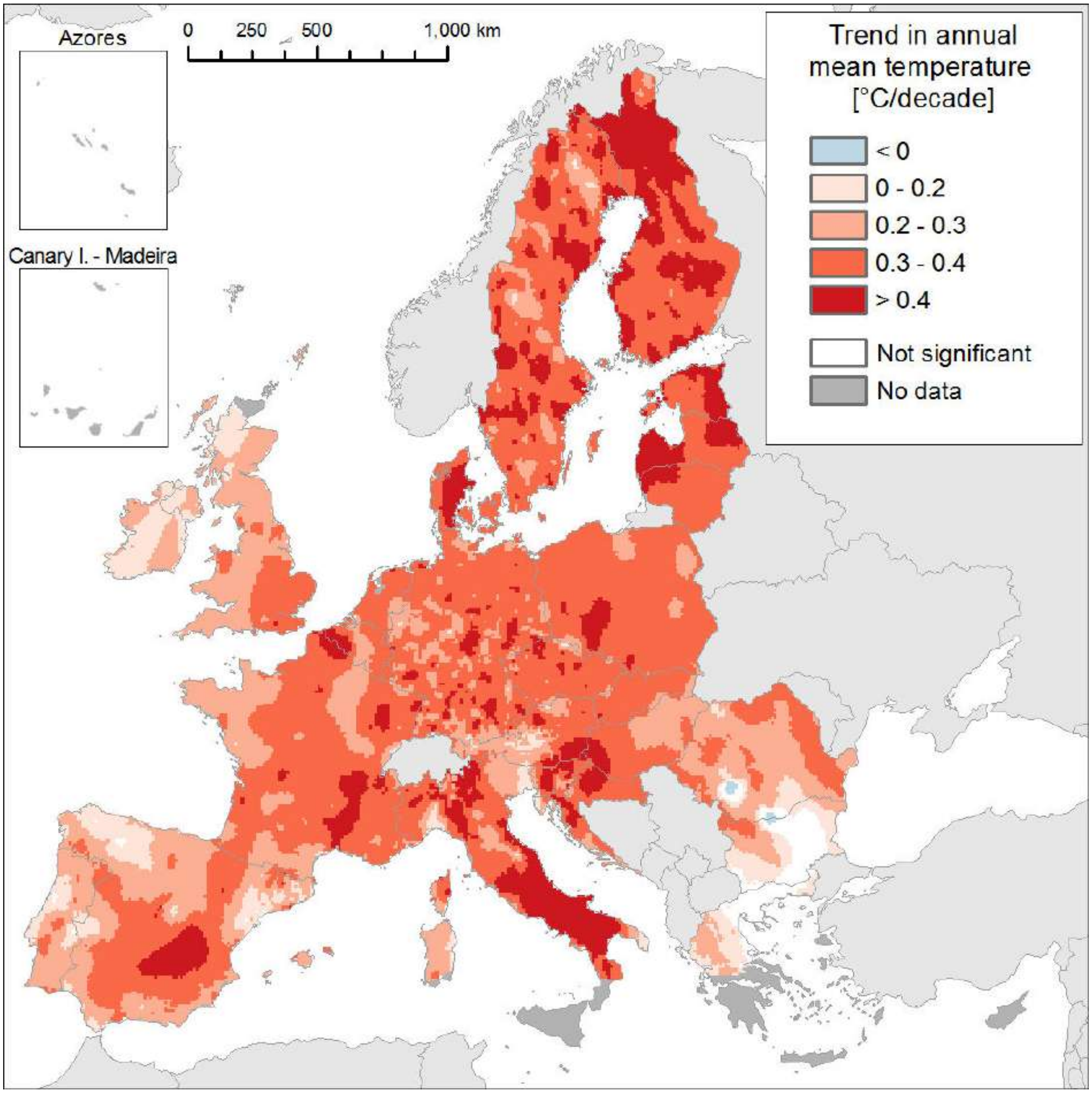


Figure 2 Trends in mean temperature of warmest quarter 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

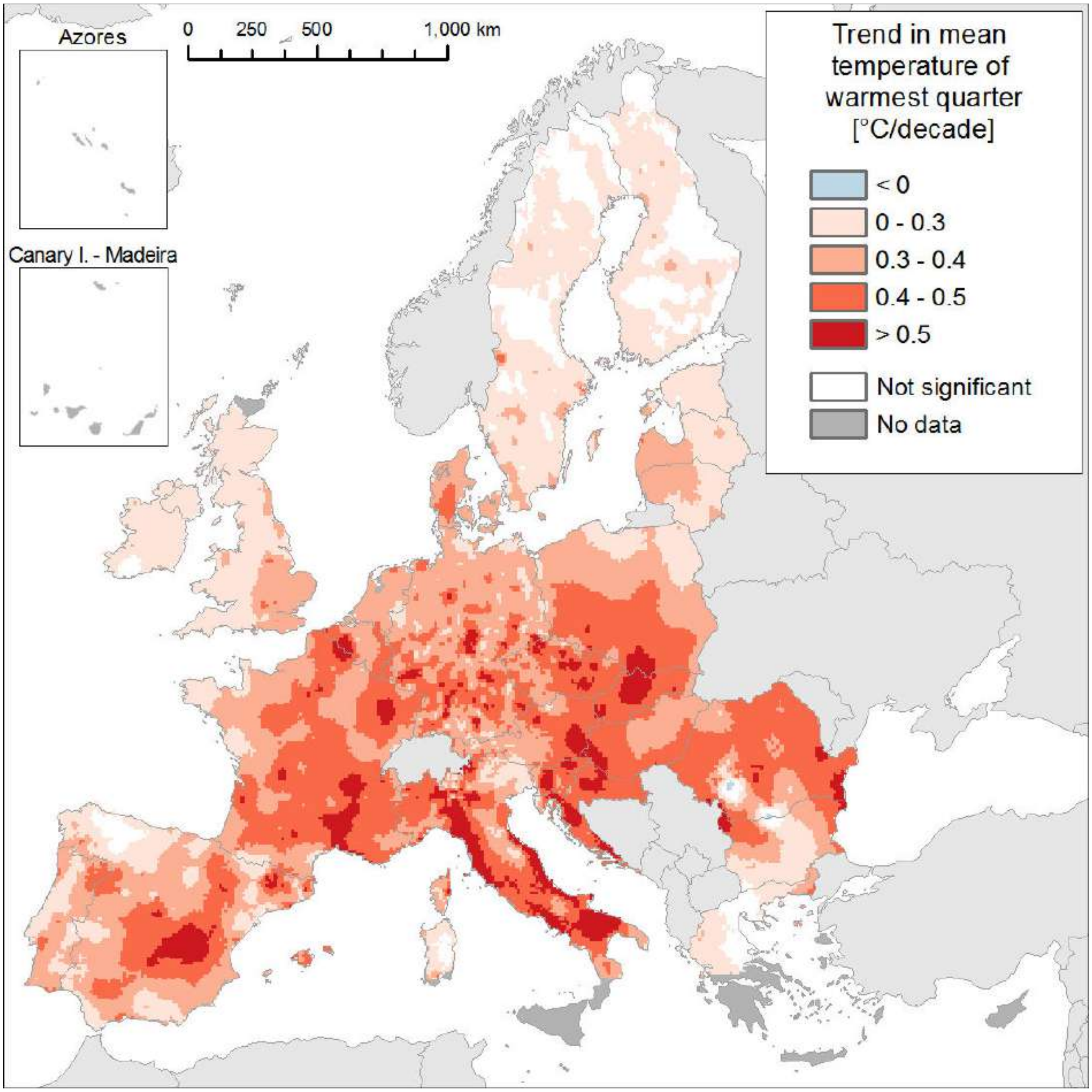


Figure 3 Trends in mean temperature of coldest quarter 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

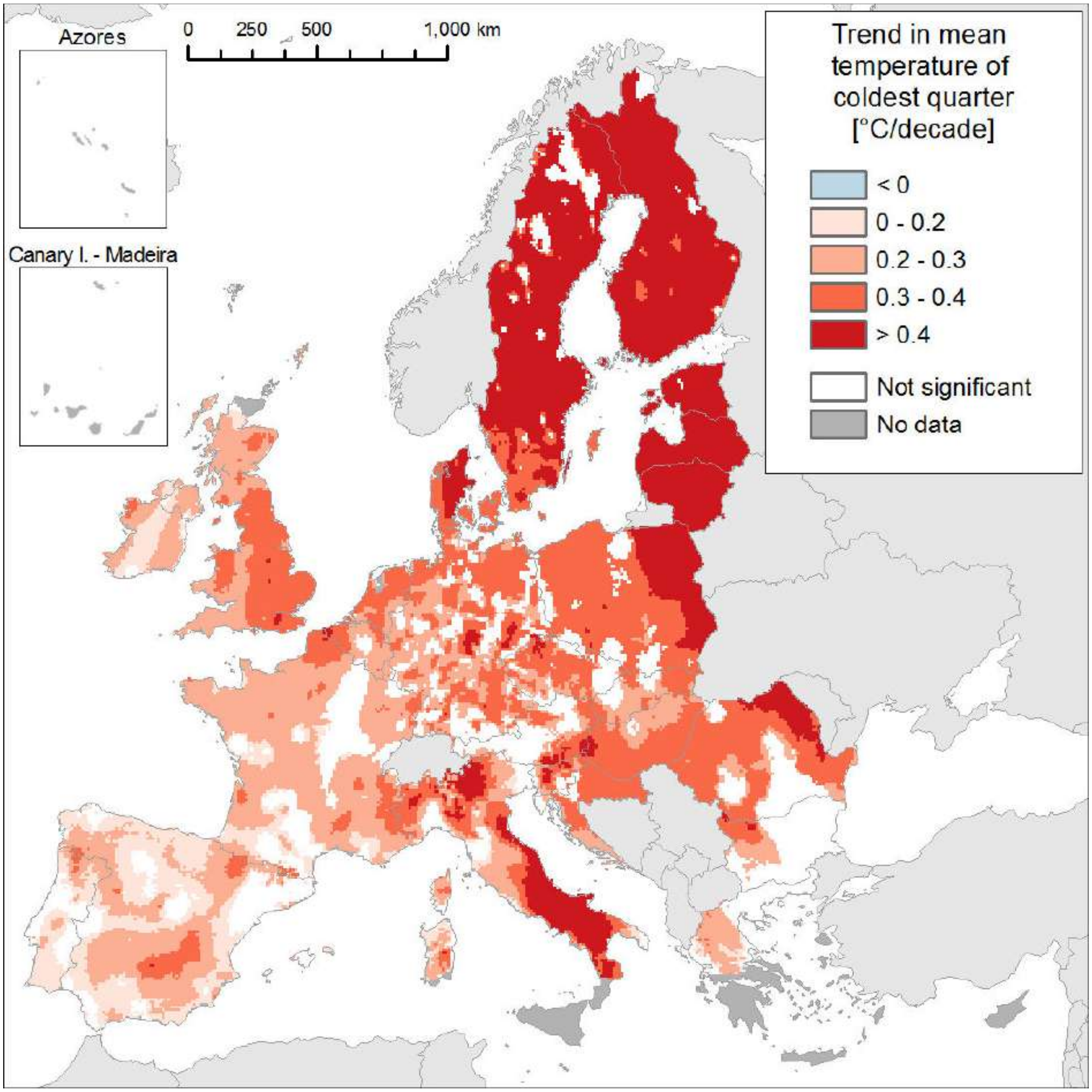


Figure 4 Trends in annual precipitation 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

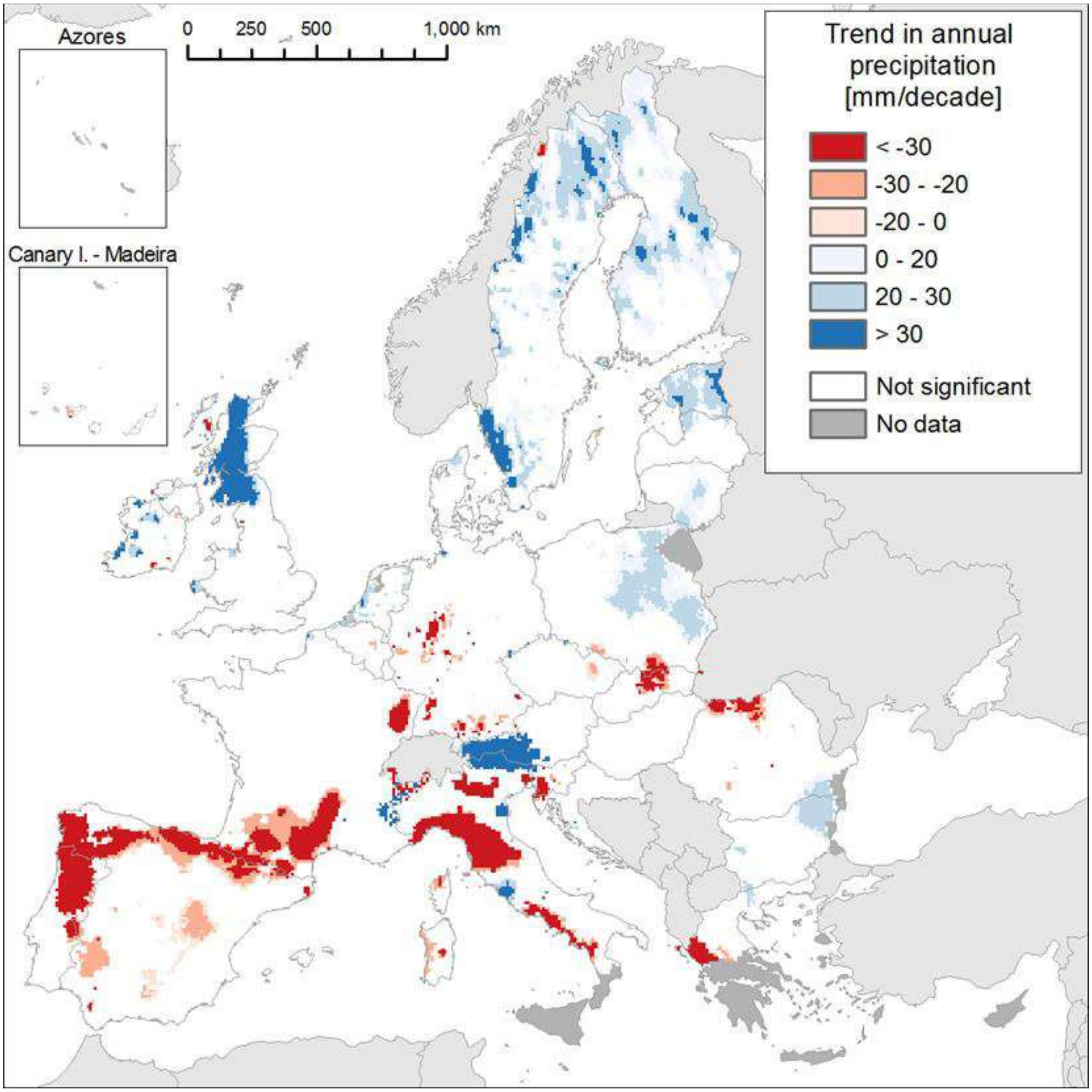


Figure 5 Trends in precipitation of the wettest quarter 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

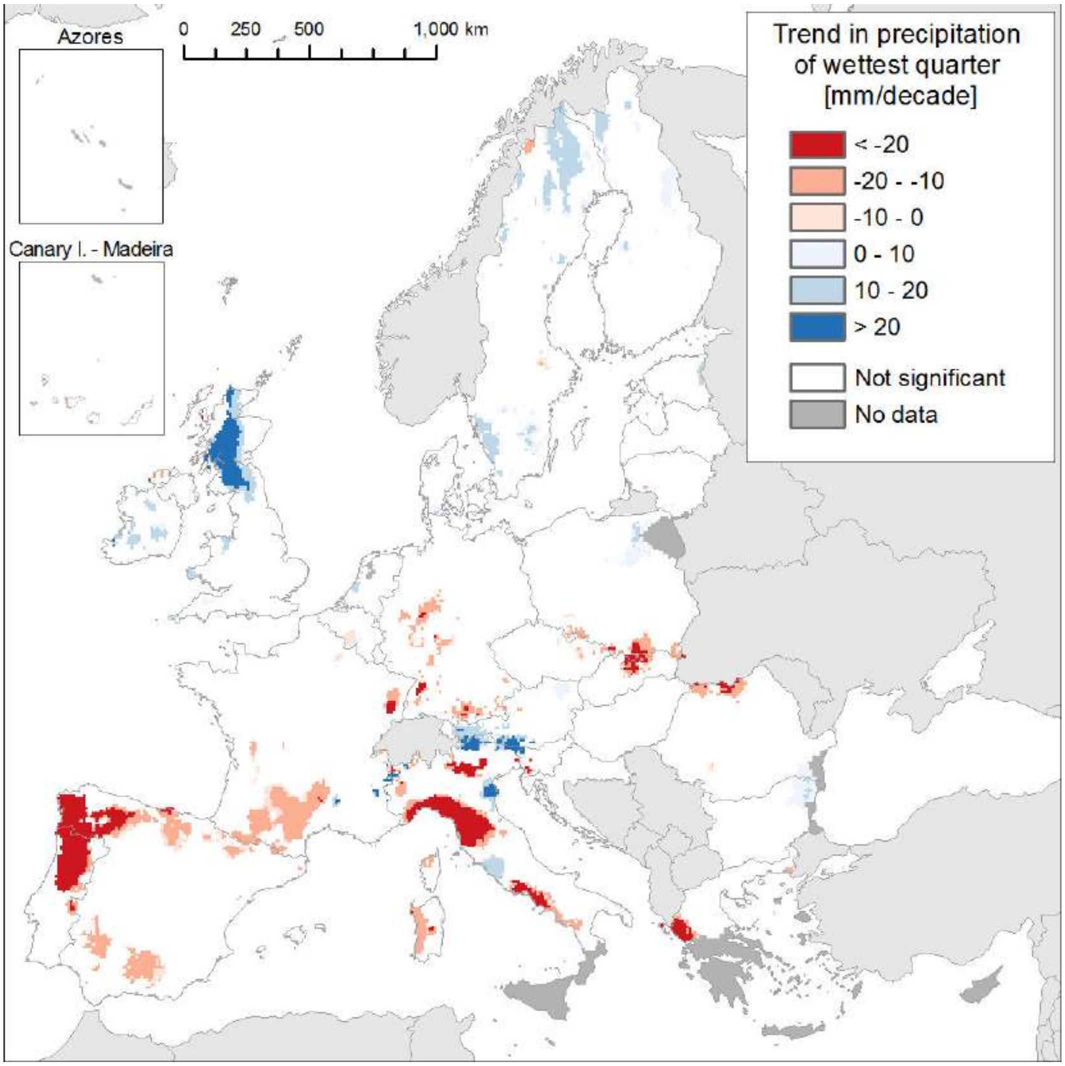


Figure 6 Trends in precipitation of the driest quarter 1960-2018 (significant at the 5% level according to the Mann-Kendall test).

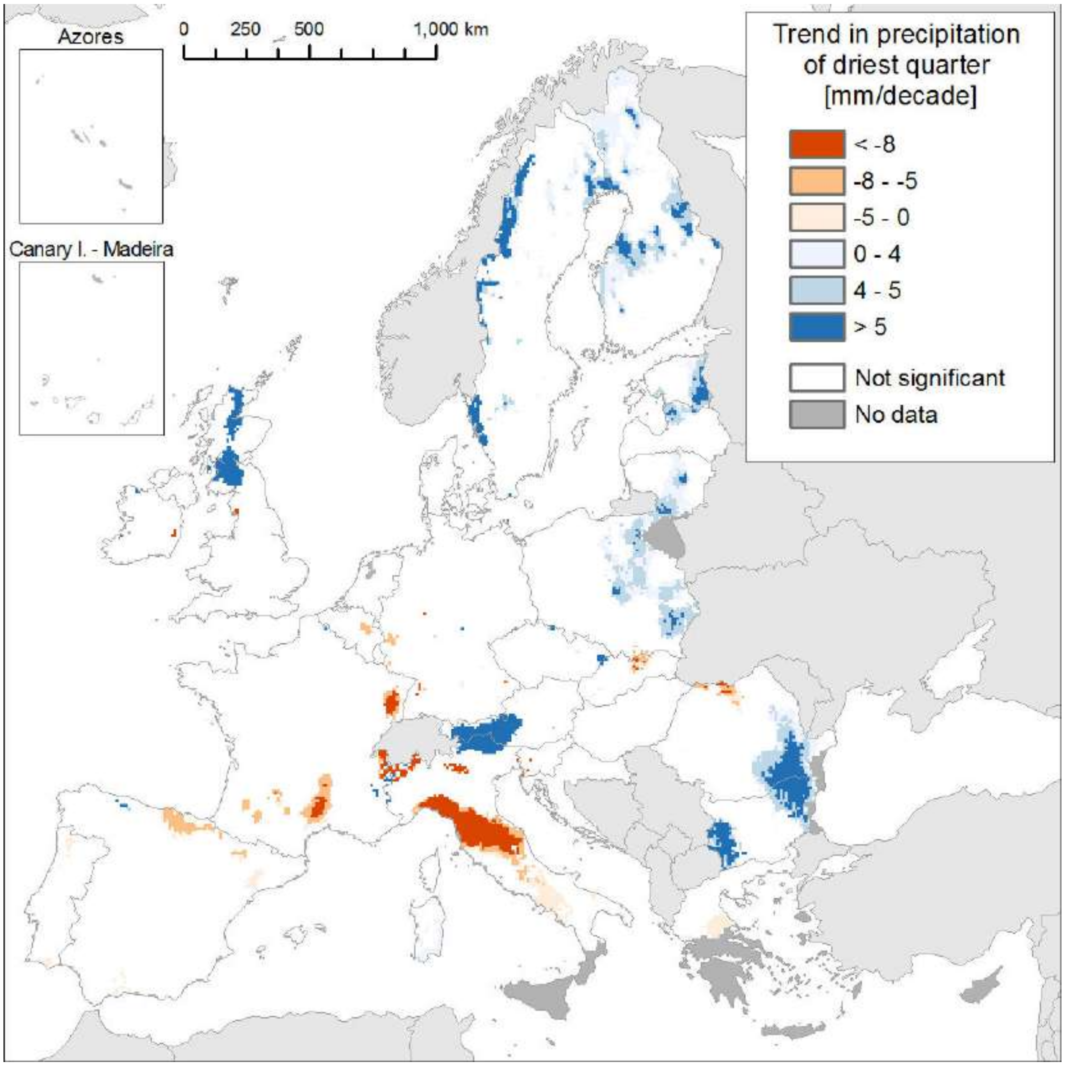
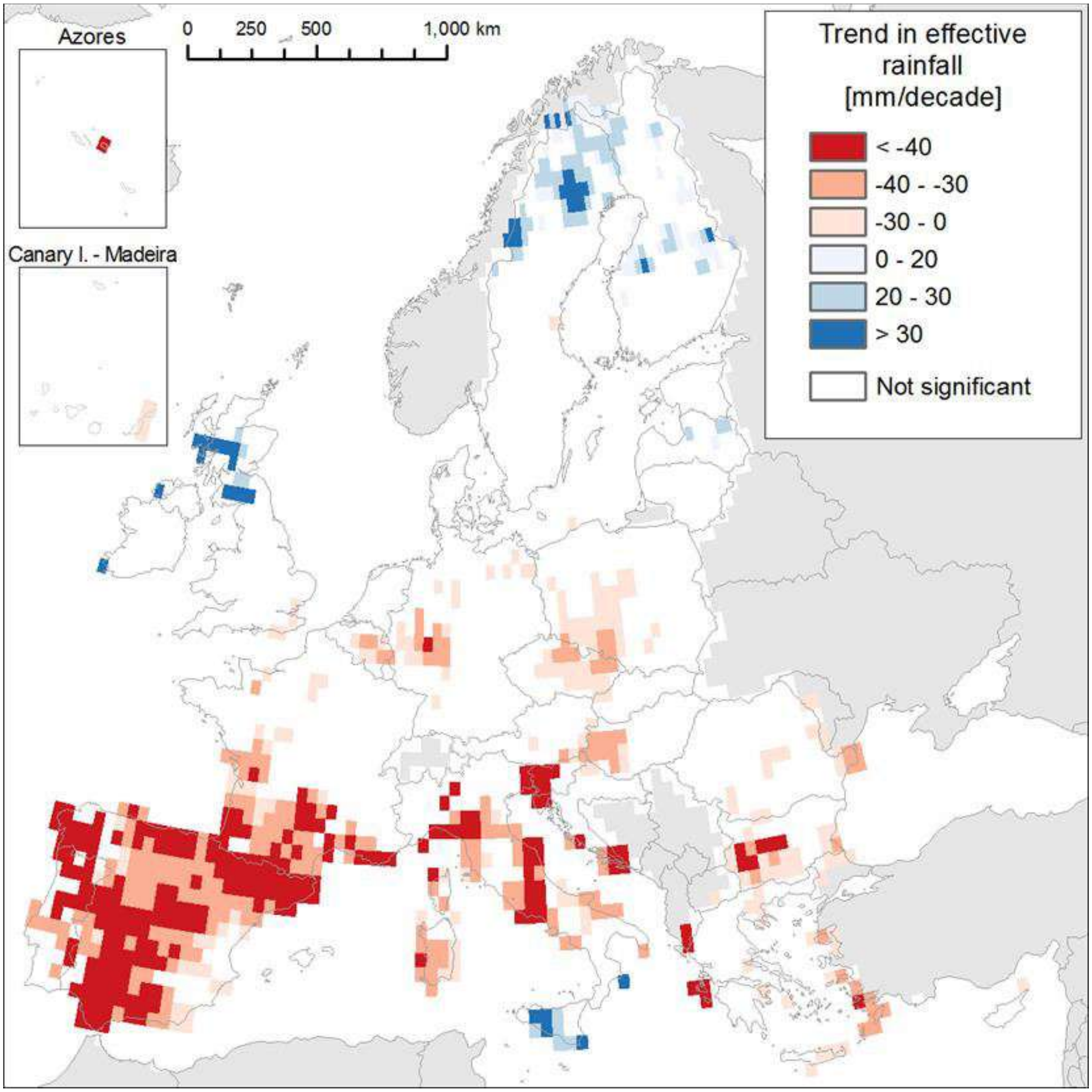
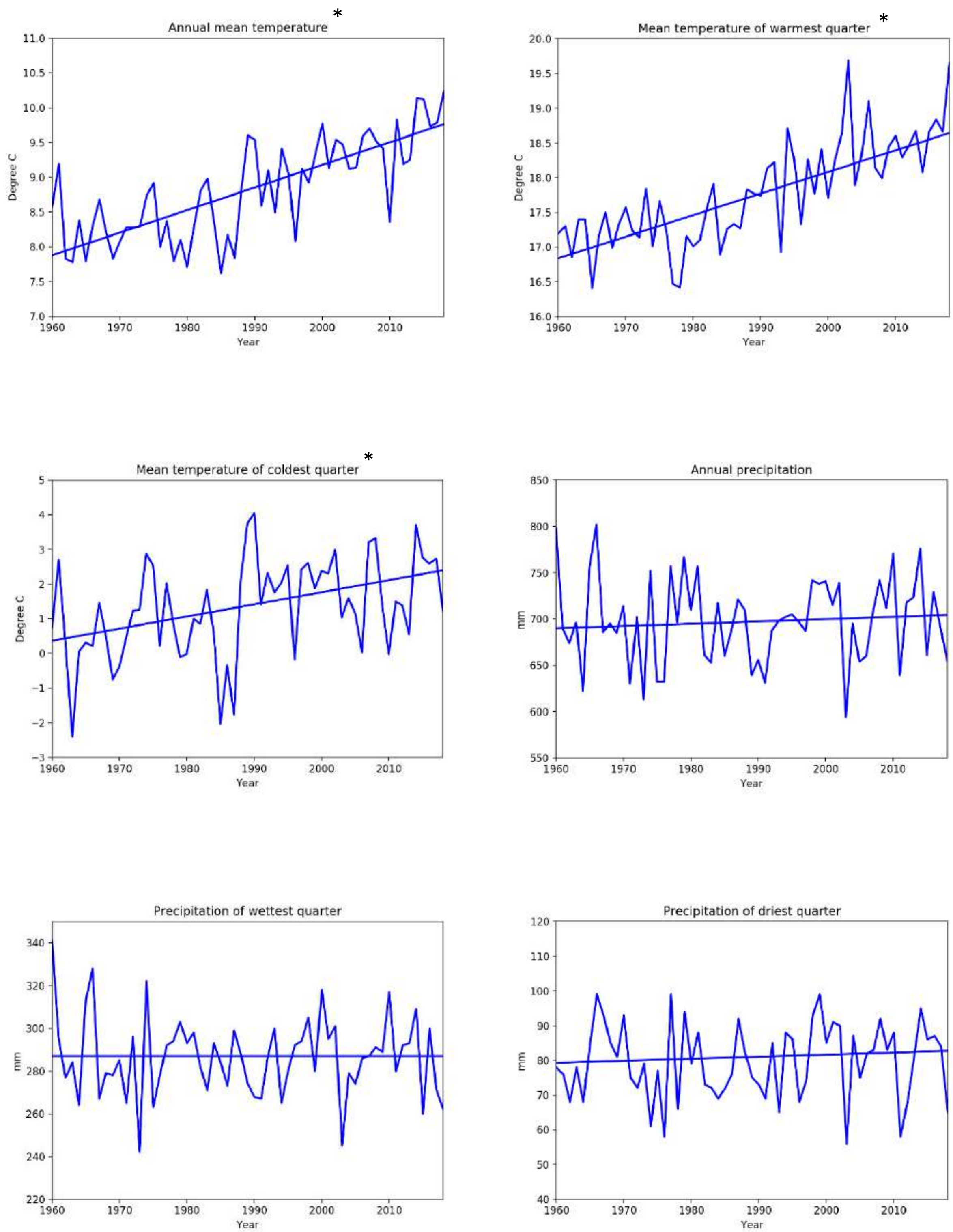


Figure 7 Trends in effective rainfall 1960-2016 (significant at the 5% level according to the Mann-Kendall test).

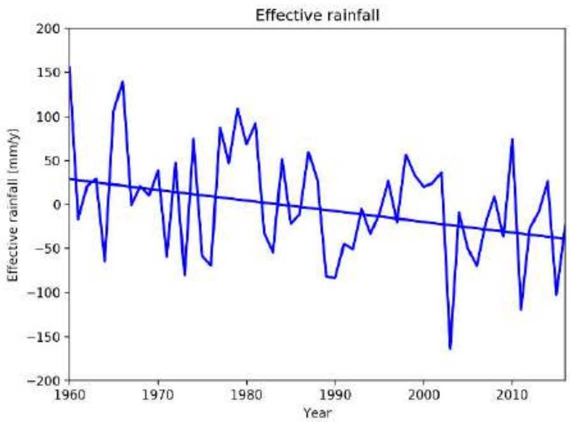


Trends of average climate at EU level

Figure 8 Time series and trends of average climate indicators. Trend line computed using the Theil–Sen non-parametric estimator. * Significant at 5% according to Mann-Kendall trend test.



*



Change in climate extremes

Short description of the scope of the indicators

A meteorological drought is an extreme event with an abnormal precipitation deficit compared to long-term average conditions. Trends in the frequency and severity of drought events are used to assess pressures of extreme events on biodiversity and ecosystems, specifically lack of precipitation and drying effects of rising temperatures.

Maps of trends in climate extremes

Figure 9 Trends in drought frequency 1950—2018 (significant at the 5% level according to the Mann-Kendall test).

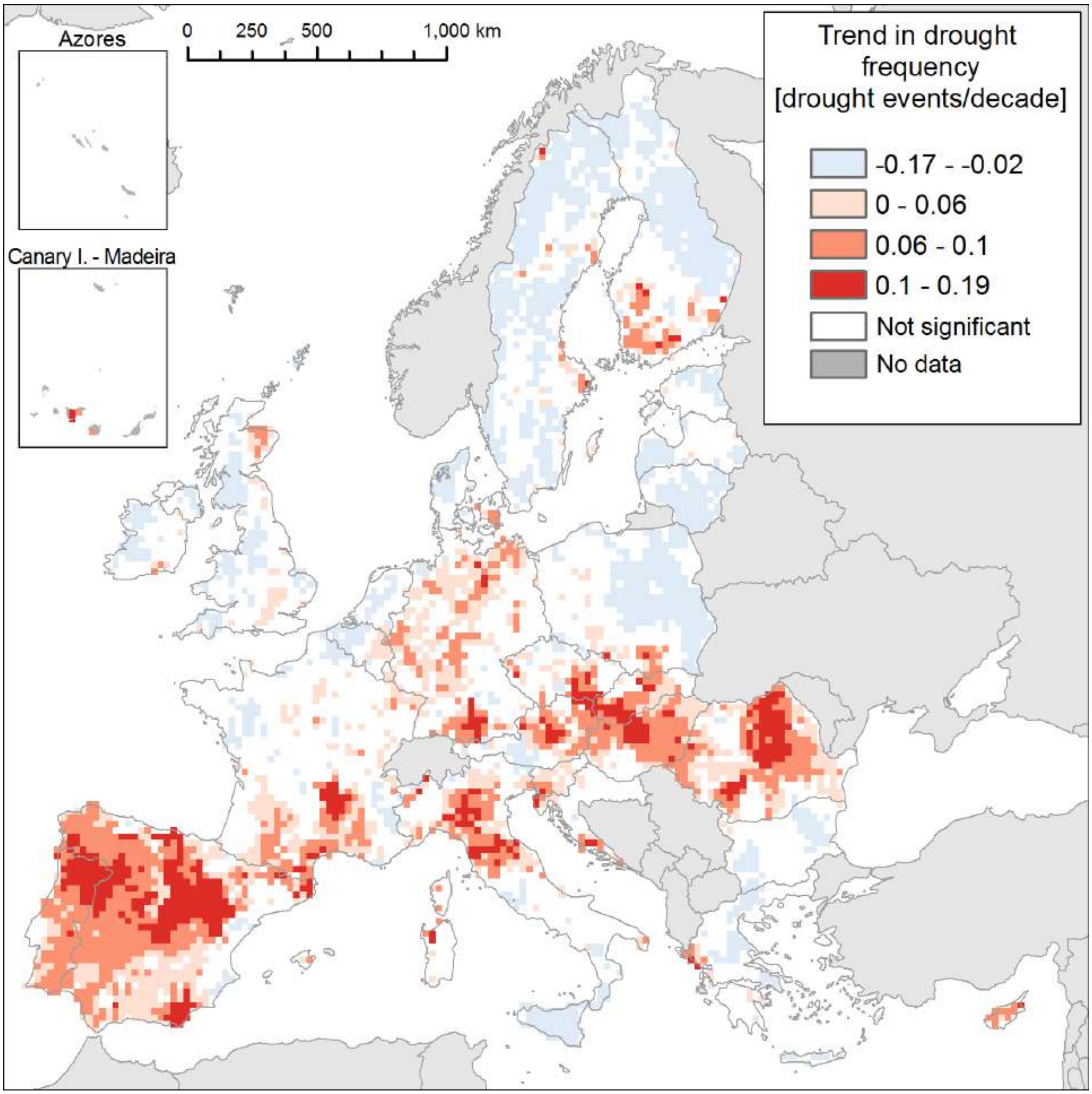


Figure 10 Trends in extreme drought frequency 1950-2018 (significant at the 5% level according to the Mann-Kendall test).

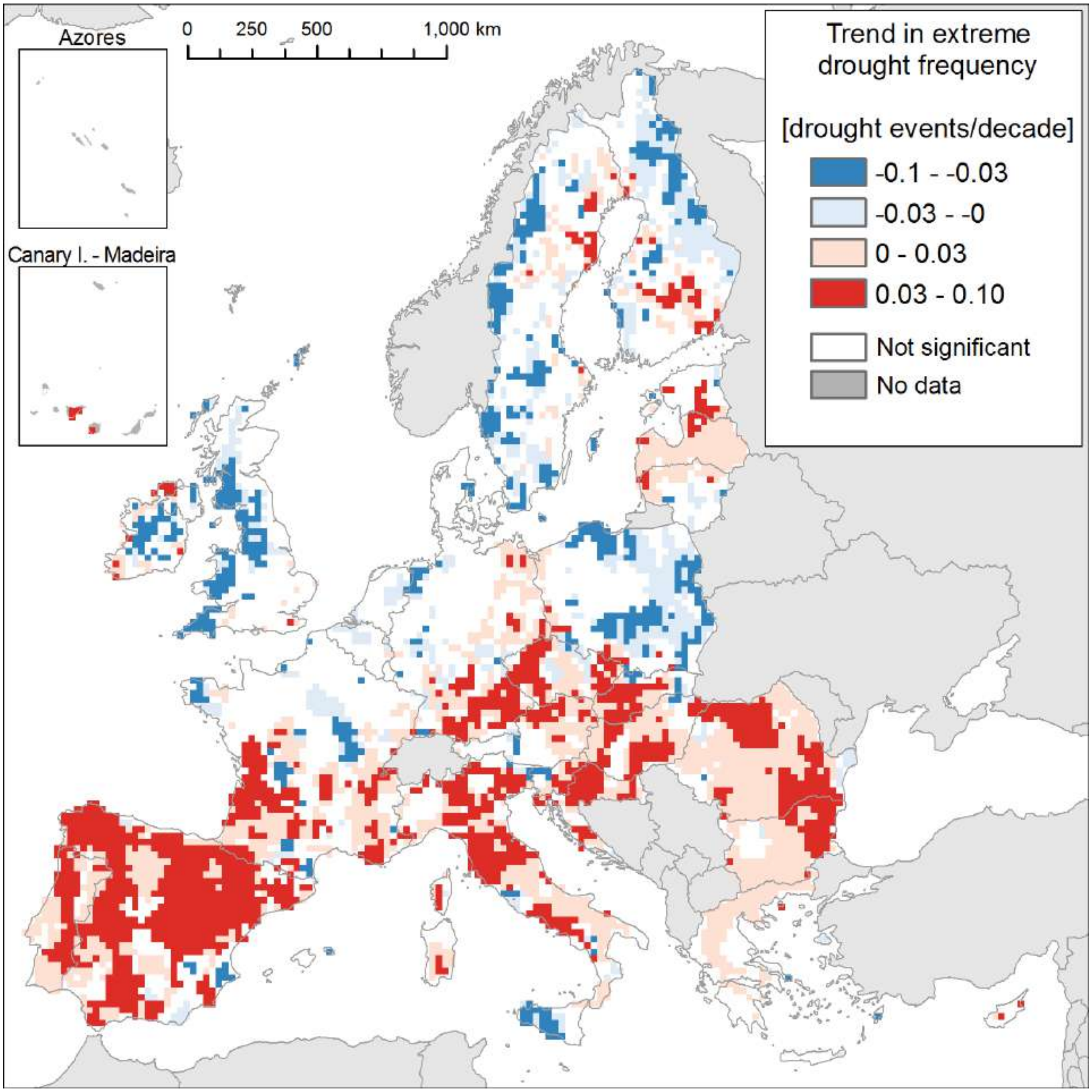


Figure 11 Trends in drought severity 1950—2018 (significant at the 5% level according to the Mann-Kendall test).

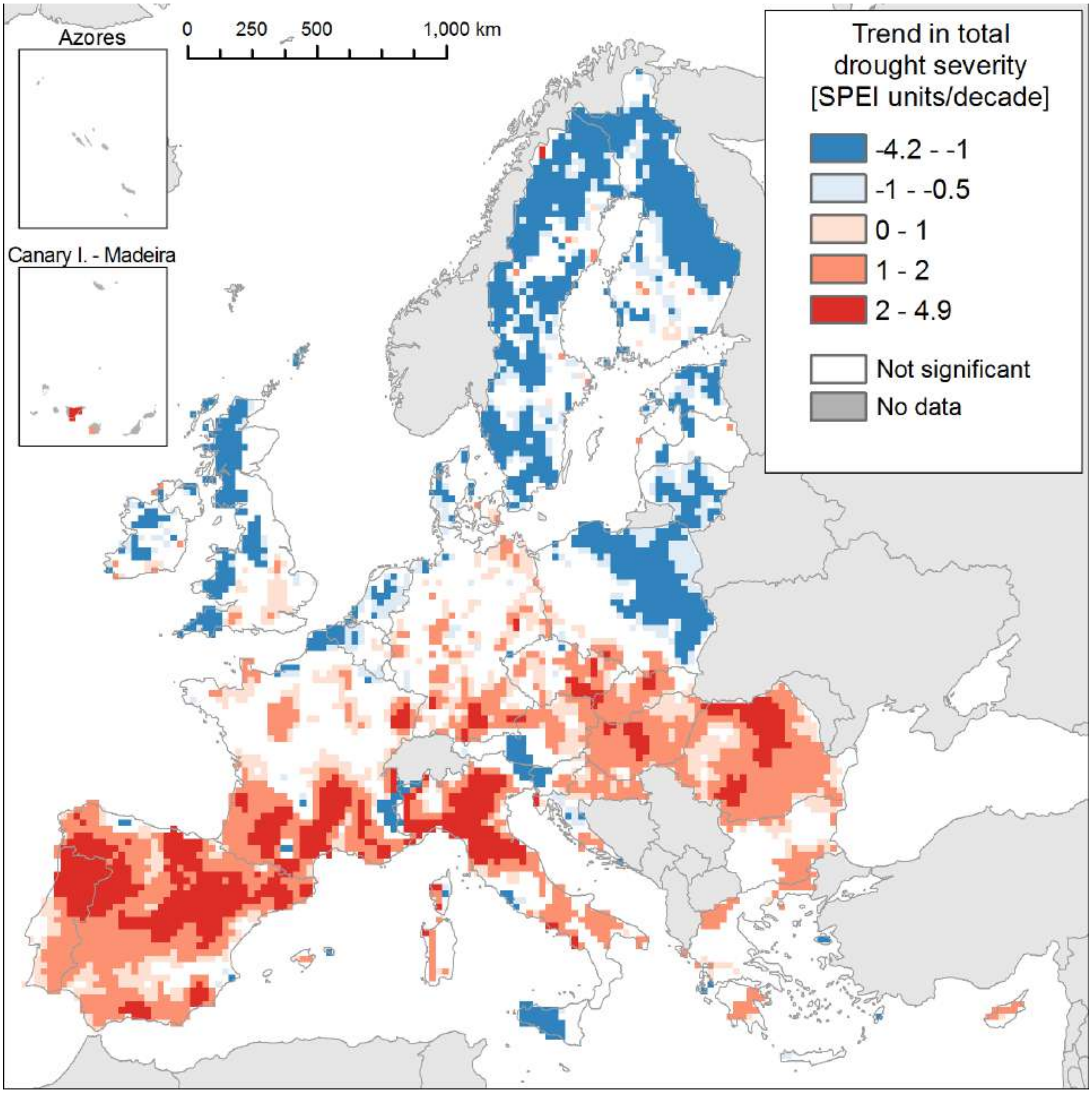


Figure 12 Trends in summer days (days with daily maximum temperature > 25 °C) 1985-2018 (significant at the 5% level according to the Mann-Kendall test).

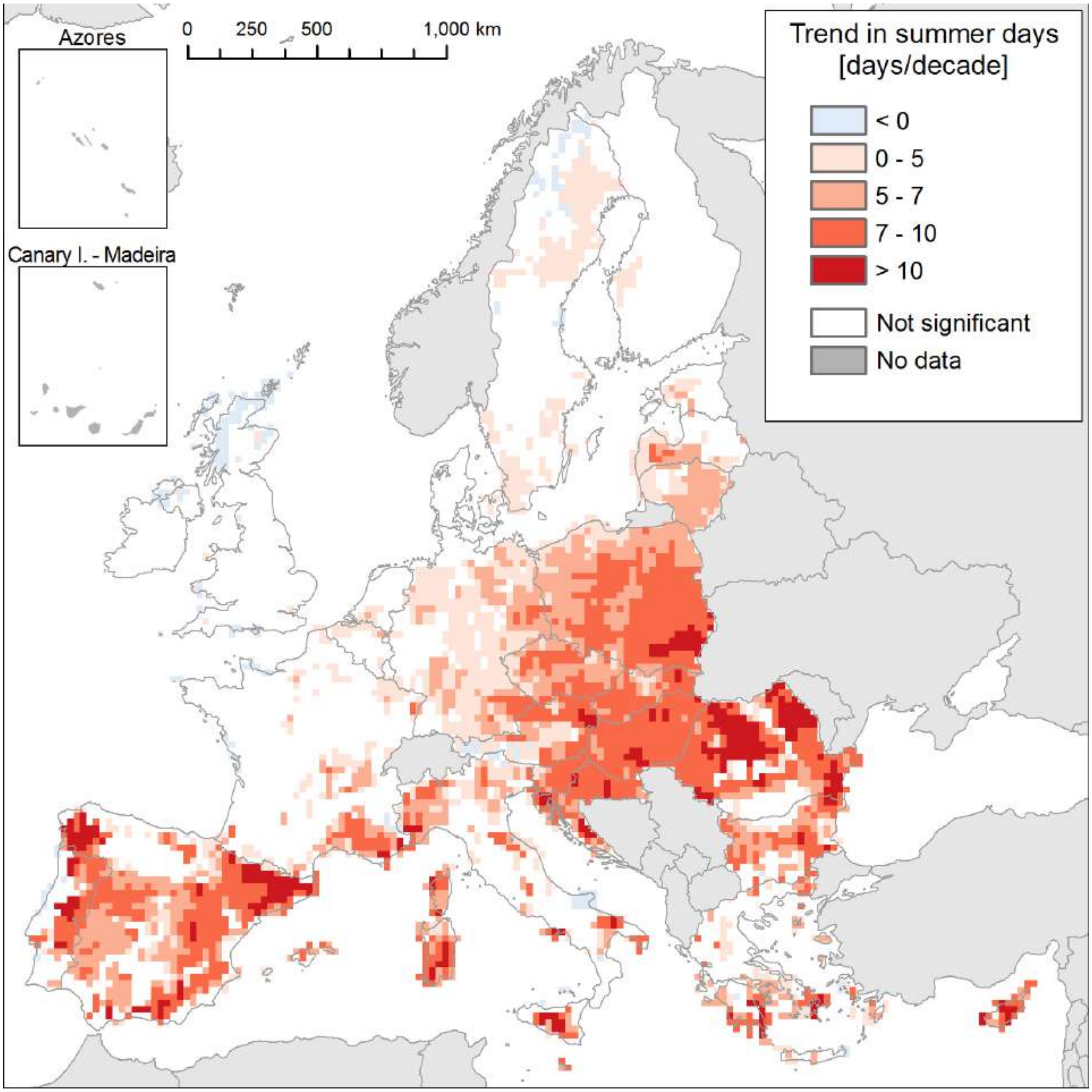
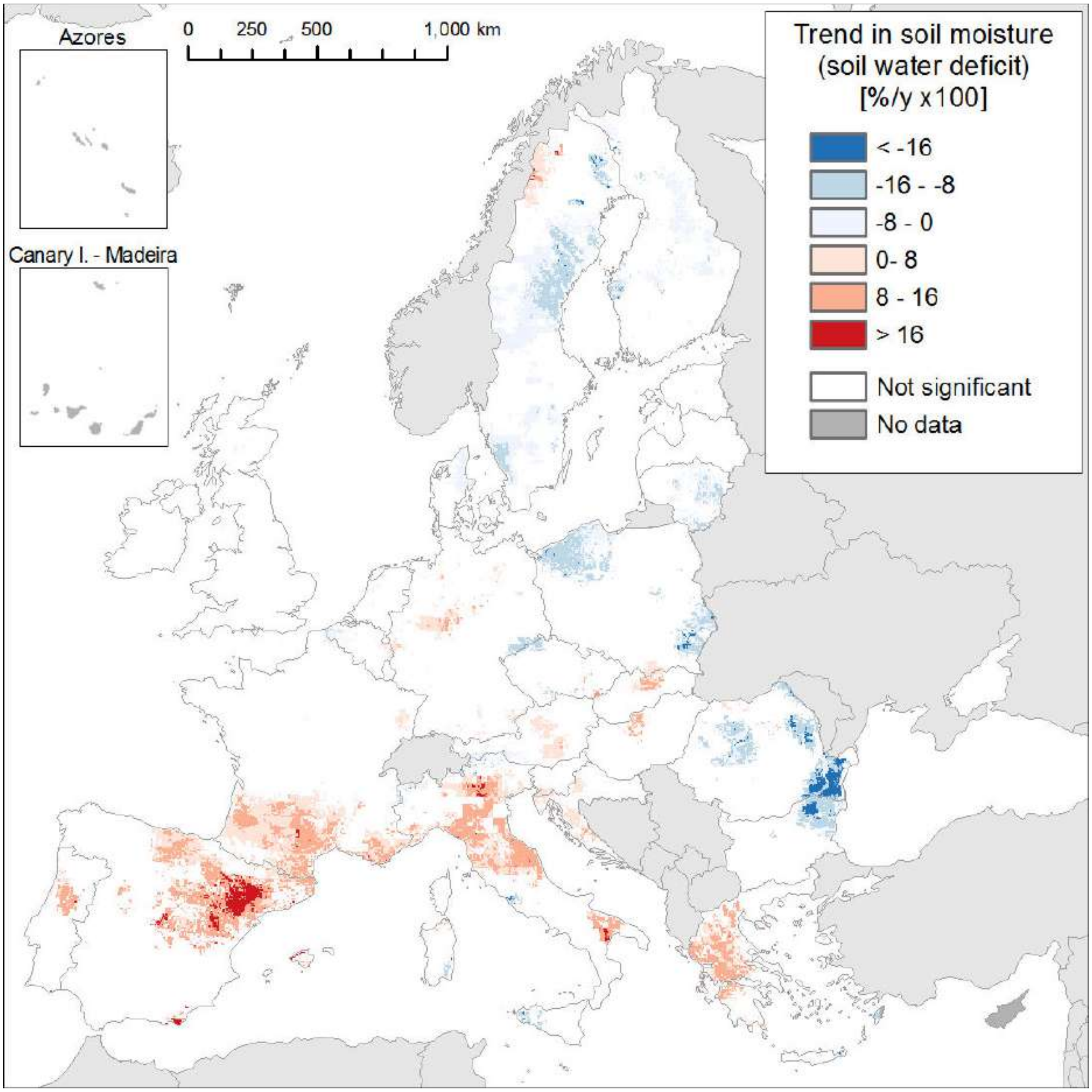
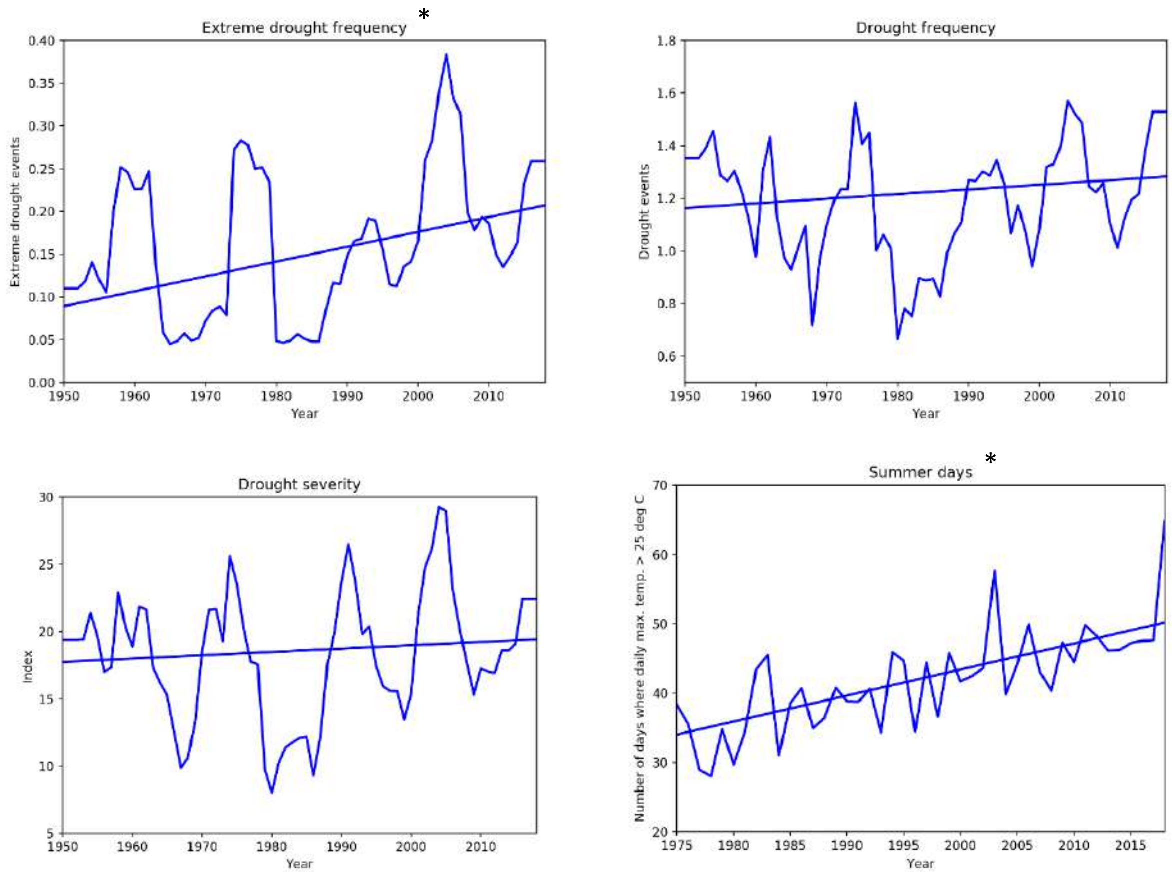


Figure 13 Trends in soil moisture deficit 1985-2018 (significant at the 5% level according to the Mann-Kendall test).



Trends of climate extremes at EU level

Figure 14 Time series and trends of climate extremes indicators. Trend line computed using the Theil–Sen non-parametric estimator. * Significant at 5% according to Mann-Kendall trend test.



Change in seasonality

Maps of trends in seasonality

Figure 15 Trends in growing season length 1985-2018 (significant at the 5% level according to the Mann-Kendall test).

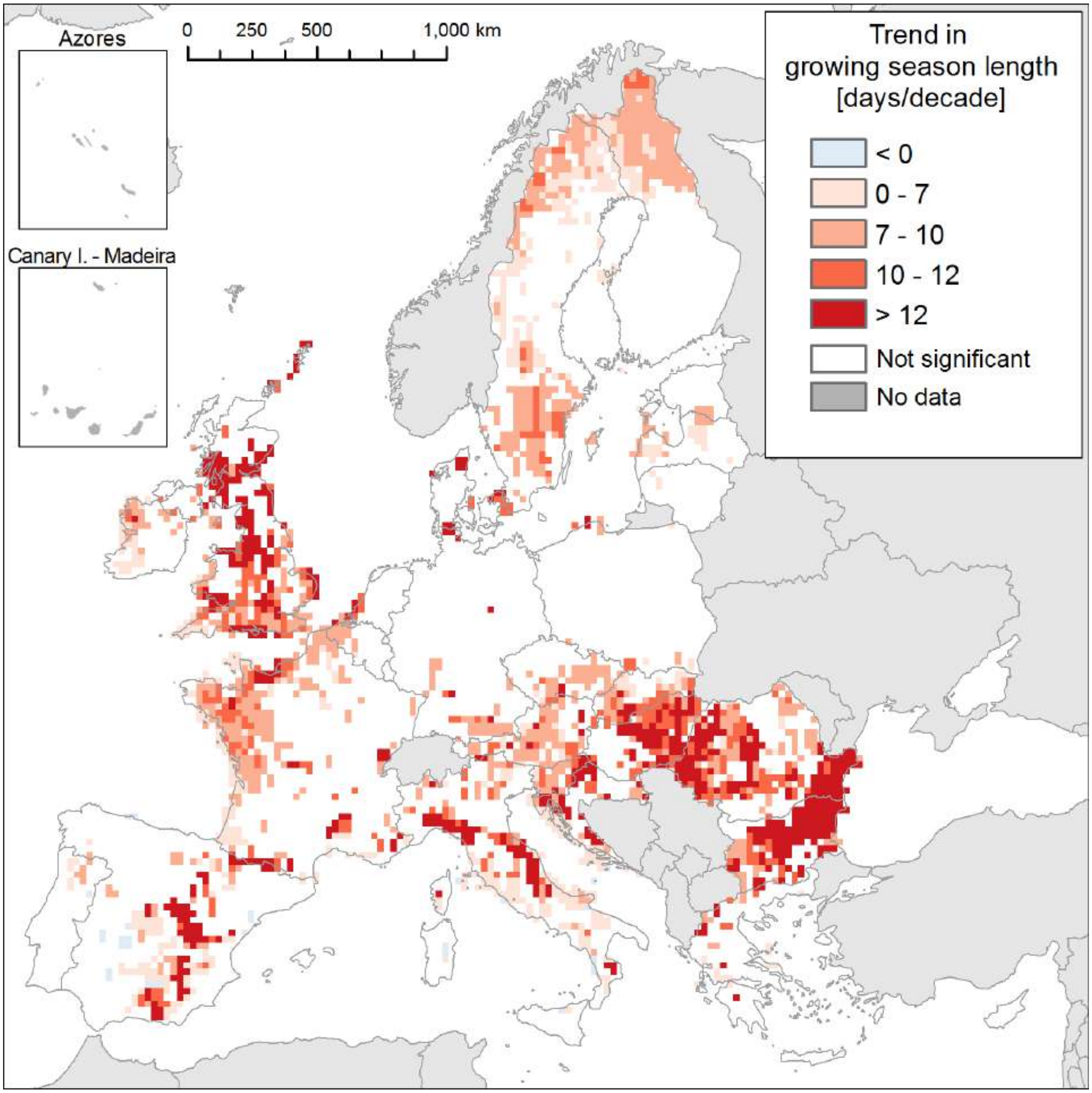


Figure 16 Trends in temperature seasonality (coefficient of variation [%] – Temperature in °K) 1960—2018 (significant at the 5% level according to the Mann-Kendall test).

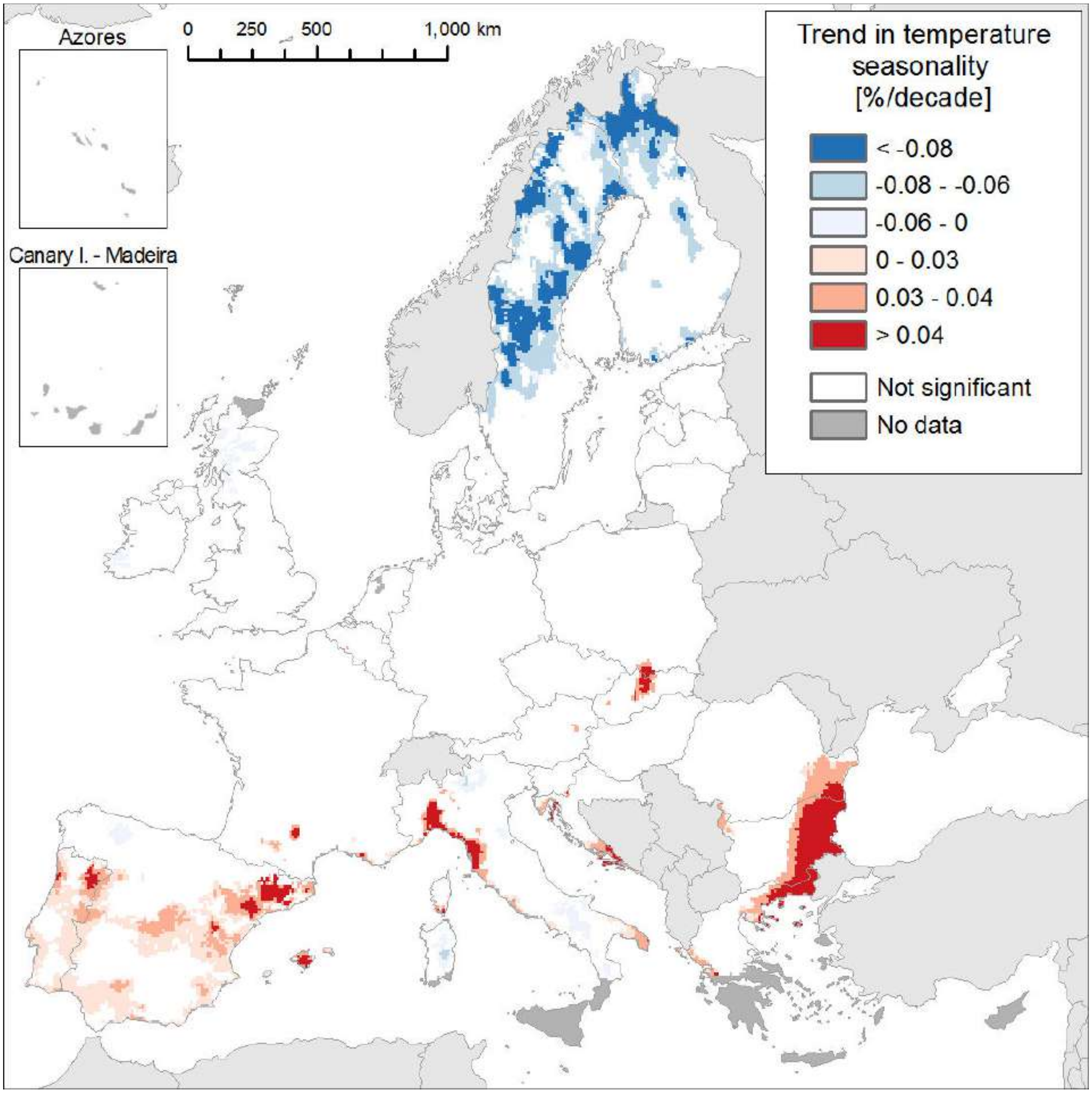
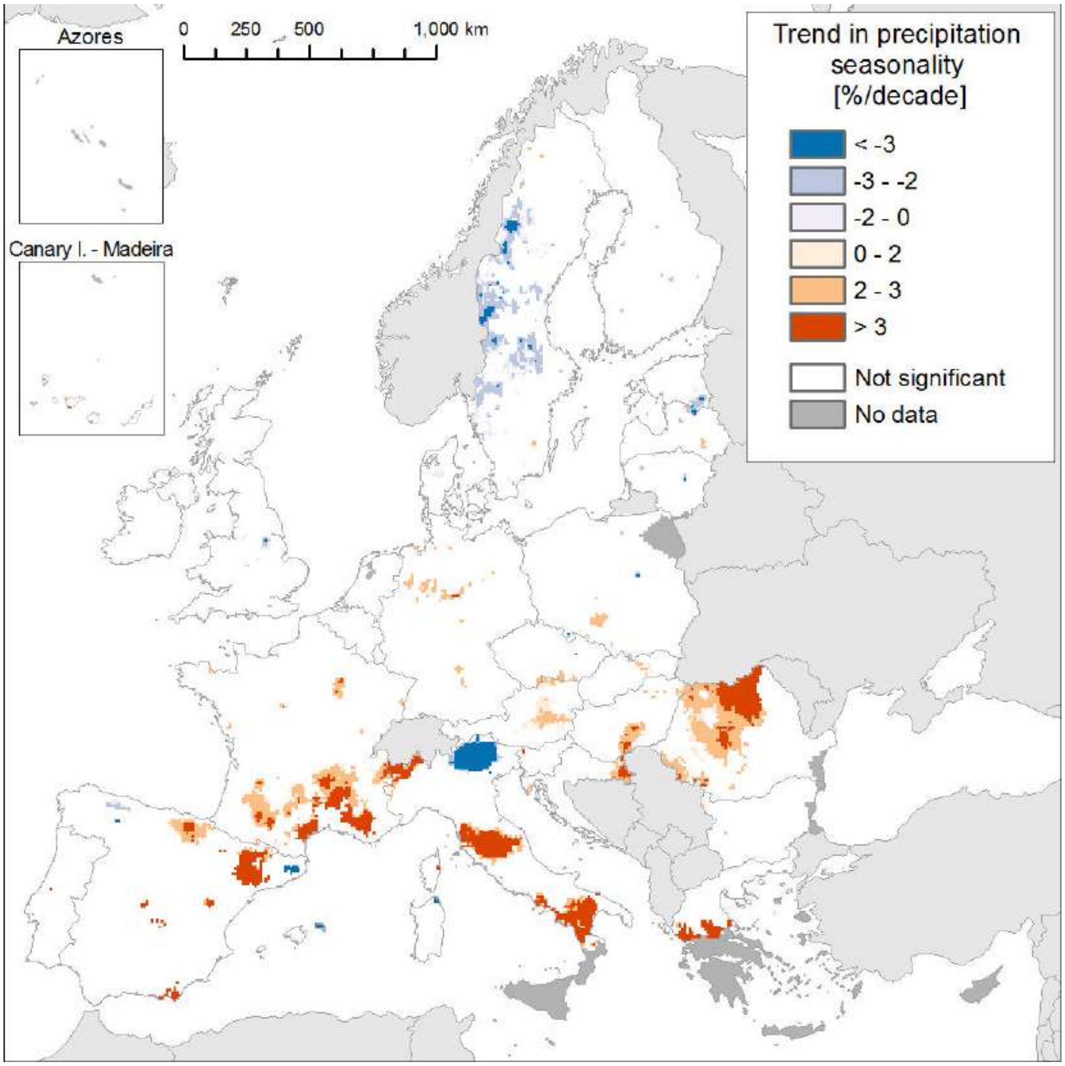


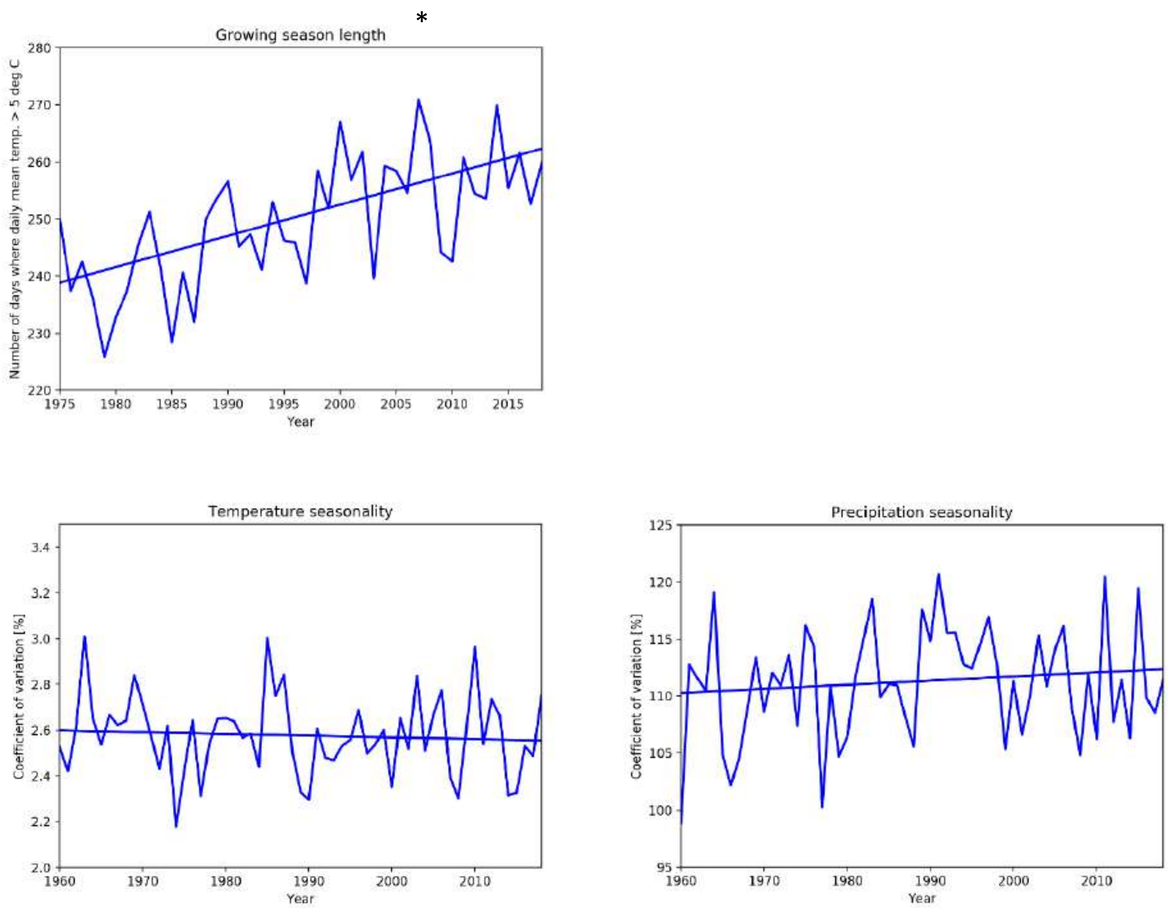
Figure 17 Trends in precipitation seasonality (coefficient of variation [%]) 1960—2018 (significant at the 5% level according to the Mann-Kendall test).



Trend of seasonality at EU level

Figure 18 Time series and trends of seasonality indicators. Trend line computed using the Theil–Sen non-parametric estimator.

* Significant at 5% according to Mann-Kendall trend test.



References

Booth, T. H., Nix, H. A., Busby, J. R., & Hutchinson, M. F. (2014). bioclim: the first species distribution modelling package, its early applications and relevance to most current MaxEnt studies. Diversity and Distributions, 20(1), 1-9, doi:10.1111/ddi.12144.

Cammalleri, C., Micale, F., & Vogt, J. (2016). Recent temporal trend in modelled soil water deficit over Europe driven by meteorological observations. International Journal of Climatology, 36(15), 4903-4912, doi:10.1002/joc.4677.

Cornes, R. C., van der Schrier, G., van den Besselaar, E. J. M., & Jones, P. D. (2018). An Ensemble Version of the E-OBS Temperature and Precipitation Data Sets. Journal of Geophysical Research: Atmospheres, 123(17), 9391-9409, doi:10.1029/2017jd028200.

European Environment Agency (2017) Climate change, impacts and vulnerability in Europe 2016. An indicator-based report. doi:10.2800/534806.

Garcia, R. A., Cabeza, M., Rahbek, C., & Araújo, M. B. (2014). Multiple Dimensions of Climate Change and Their Implications for Biodiversity. Science, 344(6183), doi:10.1126/science.1247579.

Gilbert, R. O. (1987). Statistical Methods for Environmental Pollution Monitoring. NY, USA: Wiley.

Kendall, M. G. (1975). Rank Correlation Methods (4th edition). London: Charles Griffin.

Mann, H. B. (1945). Nonparametric Tests Against Trend. Econometrica, 13(3), 245-259, doi:10.2307/1907187.

Nix, H. A. (1986). A biogeographic analysis of Australian elapid snakes. In R. Longmore (Ed.), Atlas of elapid snakes of Australia: Australian flora and fauna series 7 (pp. 4-15). Canberra: Bureau of Flora and Fauna.

O'Donnell, M. S., & Ignizio, D. A. (2012). Bioclimatic predictors for supporting ecological applications in the conterminous United States. (pp. 10): U.S. Geological Survey.

Sen, P. K. (1968). Estimates of the Regression Coefficient Based on Kendall's Tau. Journal of the American Statistical Association, 63(324), 1379-1389, doi:10.2307/2285891.

Spinoni, J., Naumann, G., Vogt, J.V., 2017. Pan-European seasonal trends and recent changes of drought frequency and severity. Global and Planetary Change. 148: 113-130.

Trnka, M., Olesen, J. E., Kersebaum, K. C., Skjelvåg, A. O., Eitzinger, J., Seguin, B., Peltonen-Sainio, P., Rötter, R., Iglesias, A., Orlandini, S., Dubrovský, M., Hlavinka, P., Balek, J., Eckersten, H., Cloppet, E., Calanca, P., Gobin, A., Vučetić, V., Nejedlik, P. et al., 2011, 'Agroclimatic conditions in Europe under climate change', Global Change Biology 17(7), 2 298–2 318 (doi:10.1111/j.1365-2486.2011.02396.x).

Wilcox, R. R. (2012). Introduction to Robust Estimation and Hypothesis Testing. San Diego, California, USA: Academic Press.

Xu, T., & Hutchinson, M. F. (2011). ANUCLIM Version 6.1 User Guide. Canberra: The Australian National University, Fenner School of Environment and Society.

Zhang, X., Alexander, L., Hegerl, G. C., Jones, P., Tank, A. K., Peterson, T. C., et al. (2011). Indices for monitoring changes in extremes based on daily temperature and precipitation data. Wiley Interdisciplinary Reviews: Climate Change, 2(6), 851-870, doi:10.1002/wcc.147.

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ANNEX A - Methodology

The definition and approach for computing the indicators and the rational to use them in the ecosystem assessment are shown in Table 2.

Metrics	**Definition and interpretation**
Annual mean temperature (℃)	For computing annual mean temperature the average temperature for each month is averaged across the year. The annual mean temperature approximates the total energy inputs for an ecosystem.
Mean temperature of warmest quarter (°C)	This quarterly metric approximates mean temperatures occurred during the warmest quarter. To calculate this metric we first identified the warmest quarter of the year, i.e. consecutive 13 weeks. We then calculated the average temperature for the 13 weeks in the warmest quarter. This metric provides mean temperatures during the warmest 13 weeks of the year, which is a useful indicator for examining how such environmental conditions may affect species seasonal distributions.
Mean temperature of coldest quarter (°C)	The same as previous but for the coldest quarter.
Annual precipitation (mm)	This metric is the sum of total precipitation across the year. Annual precipitation describes the total water input and is useful for determining the importance of water availability to a species distribution.
Precipitation of wettest quarter (mm)	This quarterly metric approximates total precipitation occurred during the wettest quarter of the year. To calculate this metric we first identified the quarter with the highest cumulative precipitation of the year, i.e. consecutive 13 weeks. We then calculated the cumulative precipitation for the 13 weeks in the quarter. This metric can be useful for examining how such environmental conditions may affect species seasonal distributions.
Precipitation of driest quarter (mm)	The same as previous but for the driest quarter.
Effective rainfall (mm)	Effective rainfall is the difference between mean annual precipitation and mean annual potential evapotranspiration. This metric is an index of plant productivity, where values below zero indicate that evaporative demands exceeds precipitation and values above zero that precipitation exceeds evaporative demands. The productivity of land biological systems is related to available moisture, which in turn is related to rainfall and the evaporative demand of the system. In forest ecosystems the amount of biomass is largely controlled by the productivity of the system.
Drought frequency (DRF)	Drought events were defined based on the Standardised Precipitation-Evapotranspiration Index (SPEI). SPEI is one of the most widely used indices to describe climatological droughts. It takes into account not only precipitation but also potential evapotranspiration. SPEI was computed for 12-month accumulation periods. It means that the sum of 12 monthly values of difference (actual months and 11

	months before) were compared to the long-term values. SPEI is in units of standard deviation from the long-term mean. A drought event happens when the SPEI is below -1 for at least 2 months. The period starts when the SPEI falls below -1. It ends when SPEI returns back above zero, so the recovery period is included. The number of drought events in 5 years was calculated using a 5-year moving window. The initial input data was E-OBS daily grids (Haylock et al., 2015a, 2015b) of temperature and precipitation. PET was calculated with Hargreaves method as the available data is not sufficient to calculate Penman-Monteith PET. So, PET is driven by temperature only. Monthly values were calculated from the daily data for the calculation of SPEI. The spatial resolution of the data is0.25. The results have to be considered the "upper bound case" because potential evapotranspiration is driven by temperature only in the calculation of SPEI. Trend in frequency of drought events are used to assess the pressures of lack of precipitation and the drying effects of rising temperatures on the condition of ecosystems.
Extreme drought frequency (ExDRF)	An extreme drought event happens when the SPEI value is below -2 for at least 2 months. It starts when the SPEI falls below -2 and ends when SPEI returns back above 0. The number of extreme drought events in 5 years was calculated using a 5-year moving window. This metric can be used to assess the impact of drought on the condition of ecosystems. Trend in frequency of extreme drought events are used to assess the pressures of lack of precipitation and the drying effects of rising temperatures on the condition of ecosystems.
Total drought severity (DRS)	Total drought severity was defined as the sum of all negative SPEI values (in absolute values) during the drought events in 5 years. The drought severity values were smoothed using a 5-year moving window weighted average. This metric can be used to assess the impact of drought on the condition of ecosystems. Trend in severity of drought events are used to assess the pressures of lack of precipitation and the drying effects of rising temperatures on the condition of ecosystems.
Summer days (number of days where daily max. temp > 25 °C)	Summer days were defined as days with maximum temperature above 25 °C. This metric can be used to assess the impact of heat stress on the condition of ecosystems.
Soil moisture (soil water deficit) (%)	Soil water deficit was obtained from modelled soil moisture in the top-soil root zone by Cammalleri et al. (2016). Water deficit is measured in percentage, therefore it ranges between 0 (no deficit) and 100 (full deficit). This metric is a synthetic descriptor of the actual water available to plants for their primary processes. Thus, it is considered an important parameter for describing the condition of ecosystems in the long term. The central role of soil moisture as feedback into the atmospheric system, as well as a key environmental variable in the

	terrestrial biosphere, suggests the possibility to obtain relevant synthetic information on the hydrological balance from its analysis.
Growing season length (number of days)	Growing season length is defined as the number of days in a year above a base temperature. The base temperature is 5°C in present study as this can be used as a temperature threshold for active growth of most temperate crops grown in Europe (Trnka, Olesen, et al., 2011). The period starts with the fifth day of the first 5 consecutive days in the year having daily average temperature (T_{avg}) above 5°C. The end of the period was defined as the fifth day when at least 5 consecutive days have their average daily temperature below 5°C. This metric can be used to assess the pressure of changing temperature- based seasonality on the condition of ecosystems and species distribution.
Temperature seasonality (coefficient of variation [%])	Temperature seasonality describes the amount of temperature variation over a given year based on the coefficient of variation (variation) of weekly temperature means expressed as a percentage. This metric is a measure of temperature change over the course of the year. The larger the coefficient of variation, the greater the variability of temperature. This metric can be useful for examining how intra-annual seasonality may affect species distributions.
Precipitation seasonality (coefficient of variation [%])	Precipitation seasonality described the amount of precipitation variation over a given year based on the coefficient of variation (variation) of weekly precipitation expressed as a percentage. This metric is a measure of precipitation change over the course of the year. The larger the coefficient of variation, the greater the variability of precipitation. This metric can be useful for examining how intra-annual seasonality may affect species distributions. Species distributions can be strongly influenced by variability in precipitation, therefore this metric provides a measure of precipitation variability where larger percentages represent greater variability of precipitation and *vice versa*.

Table 2. Climatic metrics definition and interpretation according to O'Donnell and Ignizio (2012), Xu and Hutchinson (2011), and Cammalleri et al. (2016).

ANNEX A - Methodology

The definition and approach for computing the indicators and the rational to use them in the ecosystem assessment are shown in Table 2.

Metrics	**Definition and interpretation**
Annual mean temperature (℃)	For computing annual mean temperature the average temperature for each month is averaged across the year. The annual mean temperature approximates the total energy inputs for an ecosystem.
Mean temperature of warmest quarter (°C)	This quarterly metric approximates mean temperatures occurred during the warmest quarter. To calculate this metric we first identified the warmest quarter of the year, i.e. consecutive 13 weeks. We then calculated the average temperature for the 13 weeks in the warmest quarter. This metric provides mean temperatures during the warmest 13 weeks of the year, which is a useful indicator for examining how such environmental conditions may affect species seasonal distributions.
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	months before) were compared to the long-term values. SPEI is in units of standard deviation from the long-term mean. A drought event happens when the SPEI is below -1 for at least 2 months. The period starts when the SPEI falls below -1. It ends when SPEI returns back above zero, so the recovery period is included. The number of drought events in 5 years was calculated using a 5-year moving window. The initial input data was E-OBS daily grids (Haylock et al., 2015a, 2015b) of temperature and precipitation. PET was calculated with Hargreaves method as the available data is not sufficient to calculate Penman-Monteith PET. So, PET is driven by temperature only. Monthly values were calculated from the daily data for the calculation of SPEI. The spatial resolution of the data is0.25. The results have to be considered the "upper bound case" because potential evapotranspiration is driven by temperature only in the calculation of SPEI. Trend in frequency of drought events are used to assess the pressures of lack of precipitation and the drying effects of rising temperatures on the condition of ecosystems.
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Total drought severity (DRS)	Total drought severity was defined as the sum of all negative SPEI values (in absolute values) during the drought events in 5 years. The drought severity values were smoothed using a 5-year moving window weighted average. This metric can be used to assess the impact of drought on the condition of ecosystems. Trend in severity of drought events are used to assess the pressures of lack of precipitation and the drying effects of rising temperatures on the condition of ecosystems.
Summer days (number of days where daily max. temp > 25 °C)	Summer days were defined as days with maximum temperature above 25 °C. This metric can be used to assess the impact of heat stress on the condition of ecosystems.
Soil moisture (soil water deficit) (%)	Soil water deficit was obtained from modelled soil moisture in the top-soil root zone by Cammalleri et al. (2016). Water deficit is measured in percentage, therefore it ranges between 0 (no deficit) and 100 (full deficit). This metric is a synthetic descriptor of the actual water available to plants for their primary processes. Thus, it is considered an important parameter for describing the condition of ecosystems in the long term. The central role of soil moisture as feedback into the atmospheric system, as well as a key environmental variable in the

	terrestrial biosphere, suggests the possibility to obtain relevant synthetic information on the hydrological balance from its analysis.
Growing season length (number of days)	Growing season length is defined as the number of days in a year above a base temperature. The base temperature is 5°C in present study as this can be used as a temperature threshold for active growth of most temperate crops grown in Europe (Trnka, Olesen, et al., 2011). The period starts with the fifth day of the first 5 consecutive days in the year having daily average temperature (T_{avg}) above 5°C. The end of the period was defined as the fifth day when at least 5 consecutive days have their average daily temperature below 5°C. This metric can be used to assess the pressure of changing temperature- based seasonality on the condition of ecosystems and species distribution.
Temperature seasonality (coefficient of variation [%])	Temperature seasonality describes the amount of temperature variation over a given year based on the coefficient of variation (variation) of weekly temperature means expressed as a percentage. This metric is a measure of temperature change over the course of the year. The larger the coefficient of variation, the greater the variability of temperature. This metric can be useful for examining how intra-annual seasonality may affect species distributions.
Precipitation seasonality (coefficient of variation [%])	Precipitation seasonality described the amount of precipitation variation over a given year based on the coefficient of variation (variation) of weekly precipitation expressed as a percentage. This metric is a measure of precipitation change over the course of the year. The larger the coefficient of variation, the greater the variability of precipitation. This metric can be useful for examining how intra-annual seasonality may affect species distributions. Species distributions can be strongly influenced by variability in precipitation, therefore this metric provides a measure of precipitation variability where larger percentages represent greater variability of precipitation and *vice versa*.

Table 2. Climatic metrics definition and interpretation according to O'Donnell and Ignizio (2012), Xu and Hutchinson (2011), and Cammalleri et al. (2016).

ANNEX B – limitations of E-OBS

E-OBS is a comprehensive database of observational climate in Europe that is widely used by a large number of research organisations and projects, e.g. the EEA[61]. However, a number of limitations have been documented in the literature. We present here a summary of these limitations. Cornes et al. (2018) indicate that some temporal changes computed with E-OBS are likely attributable to inhomogeneities in the reference stations rather than particular changes in the gridded data. In light of this, they suggest that caution should be used when using the E-OBS data set. Similarly, Spinoni et al. (2017) indicate that some grid cells of E-OBS can be derived from non-homogeneous station data. Nevertheless, quality checks on the monthly series performed by Spinoni et al. (2017) indicate that only a minor fraction (0.7%) of monthly data grid cells did not pass all the tests. The "problematic" grid cells were mainly located in Turkey, Scandinavian Mountains, Russia, and Latvia.

Cornes, R. C., van der Schrier, G., van den Besselaar, E. J. M., & Jones, P. D. (2018). An Ensemble Version of the E-OBS Temperature and Precipitation Data Sets. Journal of Geophysical Research: Atmospheres, 123(17), 9391-9409, doi:10.1029/2017jd028200.

Spinoni, J., Naumann, G., & Vogt, J. V. (2017). Pan-European seasonal trends and recent changes of drought frequency and severity. Global and Planetary Change, 148, 113-130, doi:10.1016/j.gloplacha.2016.11.013.

[61] https://www.eea.europa.eu/data-and-maps/indicators/global-and-european-temperature-9/assessment
https://www.eea.europa.eu/data-and-maps/indicators/european-precipitation-2/assessment

Fact sheet 4.2.101: Pressure by Invasive Alien Species on terrestrial ecosystems

1. General information

The pressure by Invasive Alien Species (IAS) is a spatially explicit crosscutting indicator that can contribute to assess the pressures acting on ecosystems.

The indicator quantifies the cumulative and relative pressure by IAS on **each terrestrial ecosystem type**, using a unitless figure directly related to the relative extent of each ecosystem type negatively affected, over a reference grid of 10 km spatial resolution.

- (Thematic ecosystem assessment): Common indicators for pressures and ecosystem condition
- Indicator class:
    - Pressure class: Invasive alien species;
    - Condition class: Environmental quality
- Name of the indicator: Pressure by Invasive Alien Species on terrestrial ecosystems
- Units: unitless [between 0 and the number of IAS recorded in one area].

2. Data sources

The indicator requires processing of the following input data (Table 1):

- Distribution of IAS (10 km spatial resolution);
- Affected ecosystems, for each IAS;
- CORINE land cover 2012 (100 m spatial resolution).

The derived data are:

- Reclassification of CORINE land cover classes into MAES Ecosystem Types (Maes et al., 2013);
- Relative cover (i.e. the share) of each MAES Ecosystem Type (ET), for each 10 km grid cell covering the extent of EU-28;
- Cumulative pressure for each grid cell and for each ET (total pressure);
- Relative pressure for each ET occurring within a given grid cell (percent).

Table 1. *Input data*

Data	Source	Notes	Data holder	Reference year	Access date
CORINE Land Cover 2012	CORINE land cover 2012 Version 20: https://land.copernicus.eu/pan-european/corine-land-cover/clc-2012?tab=download	Minimum mapping unit: 25 ha or 100 m width	EEA	2012	January 2019
Invasive Alien Species	EASIN: https://easin.jrc.ec.europa.eu/easin	Distribution records on the 10 km reference grid	JRC	Compiled over time	February 2019
Reference grid covering EU-28	EEA: https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2	10 km spatial resolution	EEA	Not applicable	January 2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The species considered for this indicator are the 49 species listed as IAS of Union Concern up to 2017 (EU, 2017). For 47 of them spatial distribution data exist. The exception are *Persicaria perfoliata* and *Microstegium vimineum*, both plants, which were not present in the EU at the time of establishment of the baselines (and they are still absent to our knowledge).

For each IAS, pressure was identified for four macro-categories of ecosystems based on the traits of the IAS. Specifically, the information on the known impacts caused on invaded ecosystems and reported in Table 4 of Tsiamis et al. (2017; 2019) was linked to the pressure on one or more MAES ecosystem types (Maes et al., 2013). The link between CORINE LCC, MAES ecosystem types and macro-categories of ecosystems is shown in Annex 1.

Their negative impact was identified for four macro groups of ecosystem types (Table 2) by the EASIN team (Tsiamis et al., 2017; Tsiamis et al., 2019), using literature and exert knowledge; each macro group of ecosystem type was then linked to the one or more MAES ecosystem types (Maes et al., 2013). The link between MAES ecosystem type and impact group is shown in Annex 1, together with the link between the MAES ecosystem type and the CORINE land cover classes.

For every grid cell (*c*) where an IAS was recorded, the per-species pressure ($w_{s,e}$) corresponds to the relative extent (the proportion from 0 to 1) of each ecosystem type within the cell, that could be affected by the IAS. Hence, the cumulative pressure (*I*) for each grid cell (*c*) is the sum of the individual pressures of all IAS present within a cell and affecting negatively one or more ET of that cell:

$$I_c = \sum_{s=1}^{S}\sum_{e=1}^{E} O_s H_e w_{s,e}$$

Where:

- I_c = Cumulative pressure for cell *c* (0 to S);
- *s* = Invasive Alien Species;
- *e* = Ecosystem type;
- O_s = Occurrence for species *s* in cell *c* (0, 1);
- H_e = Proportion, share, of ecosystem type *e* within cell *c* (0 to 1);
- $w_{s,e}$ = Evidence of pressure of species *s* on the ecosystem type *e* (0, 1).

Table 2. List of the 49 Invasive Alien Species of Union Concern, and pressure caused to macro-categories of ecosystems. 1 = evidence of pressure; 0 = absence of evidence. See Annex 1 for the correspondence between macro-categories of ecosystems, ecosystem types, and CORINE LC classes.

Species Name	Artificial	Agriculture	Forests & Semi-natural	Freshwater
Alopochen aegyptiacus	0	1	1	1
Alternanthera philoxeroides	1	1	1	1
Asclepias syriaca	1	1	1	0
Baccharis halimifolia	1	0	1	0
Cabomba caroliniana	0	1	0	1
Callosciurus erythraeus	0	0	1	0
Corvus splendens	1	1	1	0
Eichhornia crassipes	1	0	0	1
Elodea nuttallii	1	0	0	1
Eriocheir sinensis	0	0	0	1
Gunnera tinctoria	0	0	1	0
Heracleum mantegazzianum	1	0	1	0
Heracleum persicum	1	0	1	0
Heracleum sosnowskyi	1	0	1	0
Herpestes javanicus	1	1	1	0
Hydrocotyle ranunculoides	1	0	0	1
Impatiens glandulifera	0	0	1	0
Lagarosiphon major	1	0	0	1
Lithobates catesbeianus	0	0	0	1
Ludwigia grandiflora	1	0	0	1
Ludwigia peploides	1	0	0	1
Lysichiton americanus	0	0	1	0
Microstegium vimineum	1	0	1	0
Muntiacus reevesi	0	1	1	0
Myocastor coypus	1	1	1	1
Myriophyllum aquaticum	1	0	0	1
Myriophyllum heterophyllum	1	0	0	1
Nasua nasua	0	0	1	0
Nyctereutes procyonoides	1	0	1	0
Ondatra zibethicus	1	1	1	1
Orconectes limosus	0	0	0	1
Orconectes virilis	0	0	0	1
Oxyura jamaicensis	0	0	1	1
Pacifastacus leniusculus	0	0	0	1
Parthenium hysterophorus	1	1	1	0
Pennisetum setaceum	0	0	1	0

Species Name	Artificial	Agriculture	Forests & Semi-natural	Freshwater
Perccottus glenii	0	0	0	1
Persicaria perfoliata	0	1	1	0
Procambarus clarkii	1	1	0	1
Procambarus fallax f. virginalis	0	0	0	1
Procyon lotor	1	1	1	0
Pseudorasbora parva	0	0	0	1
Pueraria montana var. lobata	1	1	1	0
Sciurus carolinensis	0	0	1	0
Sciurus niger	1	0	1	0
Tamias sibiricus	0	1	1	0
Threskiornis aethiopicus	0	0	1	1
Trachemys scripta	0	0	0	1
Vespa velutina nigrithorax	1	1	1	0

3.2. Maps and tables

The analysis and comments of the resulting pressures are found in Chapter 4.2 'Invasive Alien Species'.

Summary statistics and maps for each ET are found in:

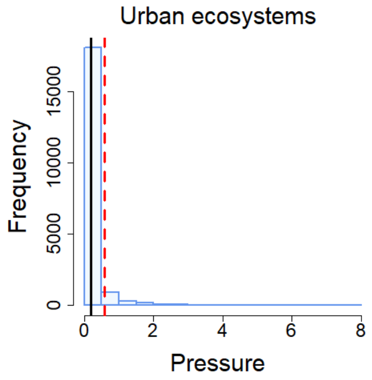
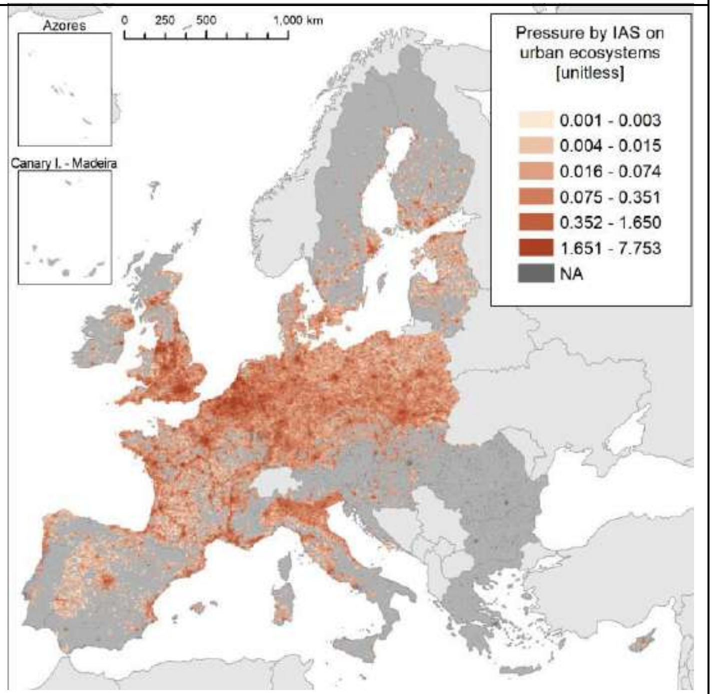
- **Table 3**: the cumulative pressure, i.e. the total pressure by the IAS occurring across the 10 km reference grid;

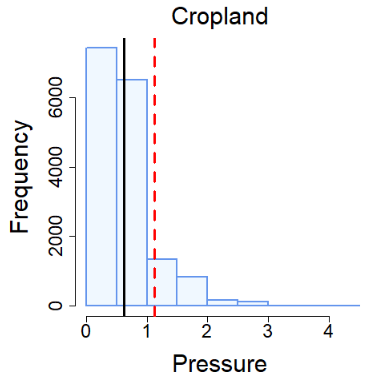
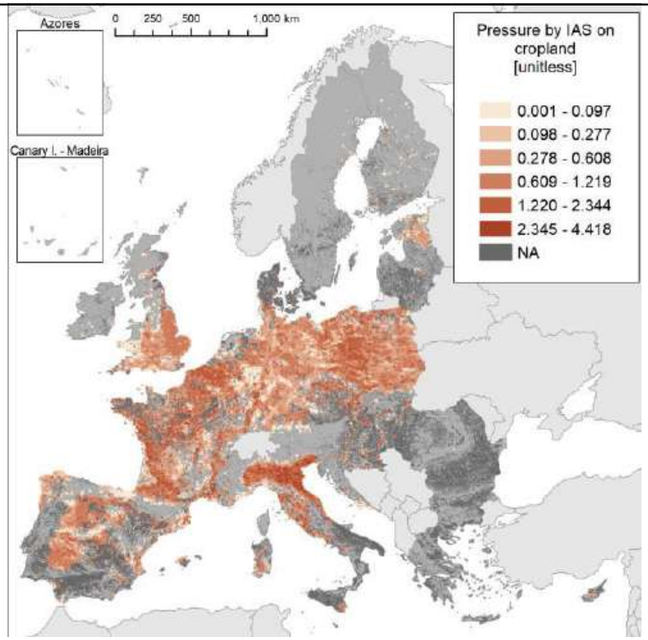
Spatially explicit information (i.e. the cumulative and relative score for each cell and ET) is found within the file: IASpressure_LAND.xlsx (the same information is found also within the corresponding csv file: IASpressure_LAND.csv).

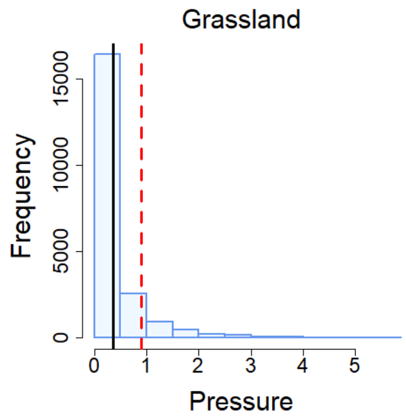
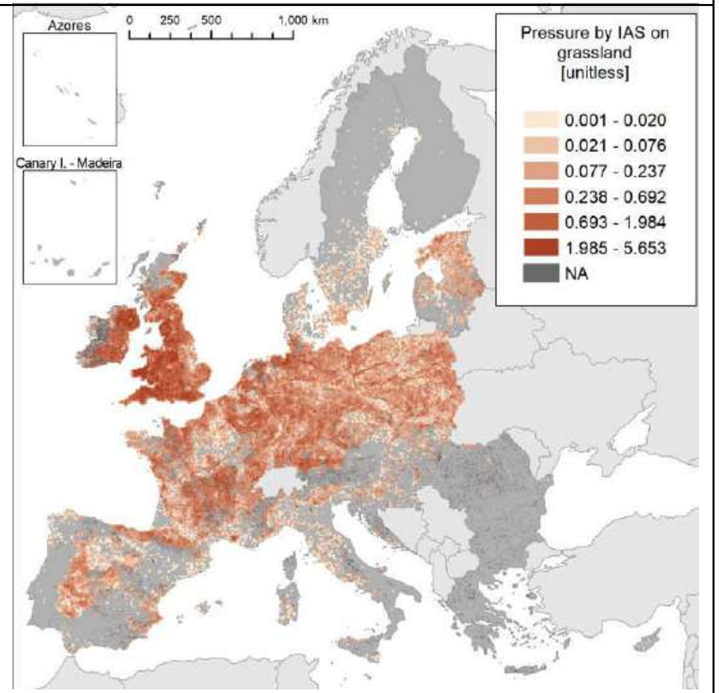
3.4. Key trend at EU level

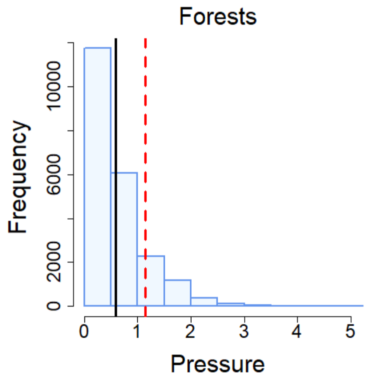
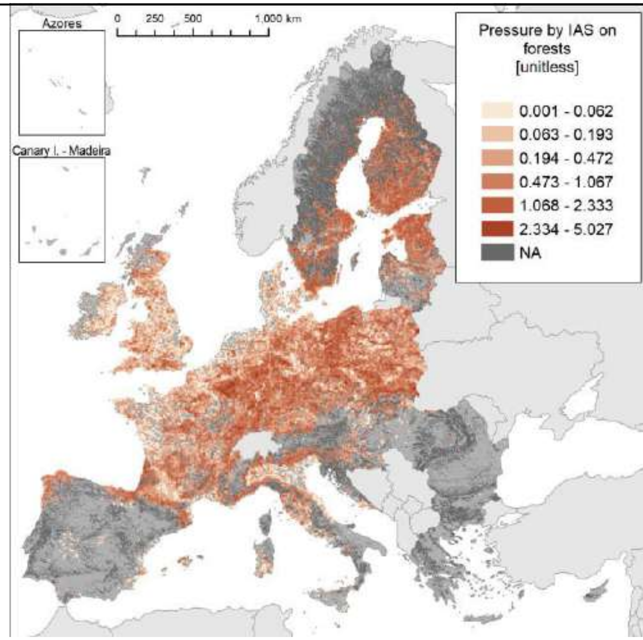
Not applicable because only the baseline information is available.

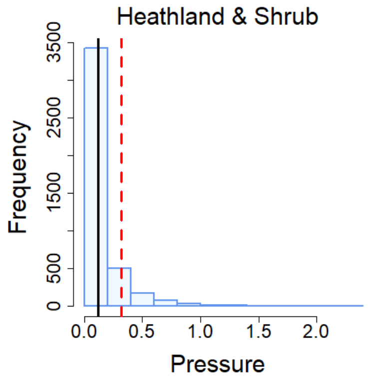
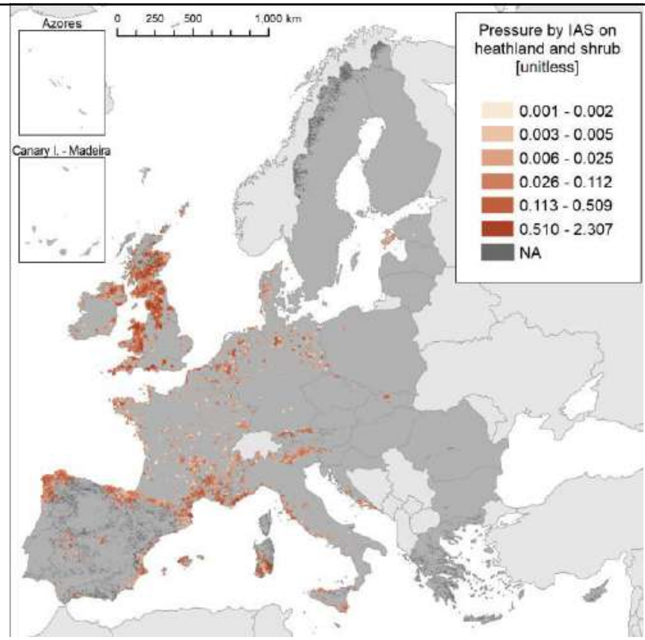
Table 3. ***Cumulative impact by IAS for each ecosystem type.***

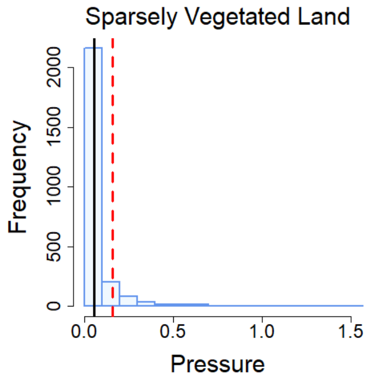
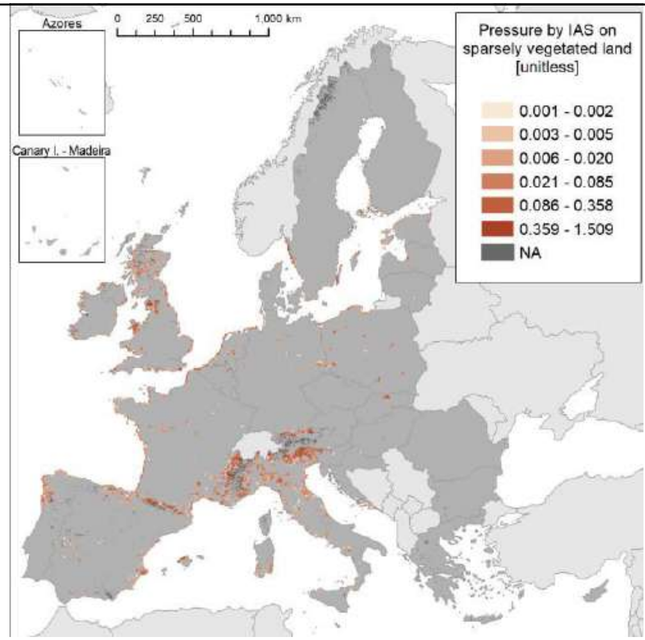
Ecosystem type	**Invaded extent (%)**	**Cumulative pressure**			**Histogram for areas where pressure >0 (Mean + SD)**	**Map of areas where pressure % > 0**
		Mean ± SD	**Min (> 0)**	**Max**		
Urban	69.29	0.181 ± 0.402	0.001	7.753		

Ecosystem type	Invaded extent (%)	Cumulative pressure			Histogram for areas where pressure >0 (Mean + SD)	Map of areas where pressure % > 0
		Mean ± SD	Min (> 0)	Max		
Cropland	46.75	0.630 ± 0.495	0.001	4.418		

Ecosystem type	Invaded extent (%)	Cumulative pressure			Histogram for areas where pressure >0 (Mean + SD)	Map of areas where pressure % > 0
		Mean ± SD	Min (> 0)	Max		
Grassland	65.96	0.363 ± 0.541	0.001	5.653		

Ecosystem type	Invaded extent (%)	Cumulative pressure			Histogram for areas where pressure >0 (Mean + SD)	Map of areas where pressure % > 0
		Mean ± SD	Min (> 0)	Max		
Forest	43.51	0.595± 0.556	0.001	5.027		

Ecosystem type	Invaded extent (%)	Cumulative pressure			Histogram for areas where pressure >0 (Mean + SD)	Map of areas where pressure % > 0
		Mean ± SD	Min (> 0)	Max		
Heathland and shrub	16.87	0.122 ± 0.197	0.001	2.307		

Ecosystem type	Invaded extent (%)	Cumulative pressure			Histogram for areas where pressure >0 (Mean + SD)	Map of areas where pressure % > 0
		Mean ± SD	Min (> 0)	Max		
Sparsely vegetated land	16.42	0.056 ± 0.105	0.001	1.509		

References

EU, 'Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 Updating the List of Invasive Alien Species of Union Concern Established by Implementing Regulation (EU) 2016/1141 Pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council', *Official Journal of the European Union*, Vol. L 182, 2017, pp. 37–39.

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., Paracchini, M., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P., Condé, S., Schägner, J., San Miguel, J., et al., *Mapping and Assessment of Ecosystems and Their Services. An Analytical Framework for Ecosystem Assessments under Action 5 of the EU Biodiversity Strategy to 2020 (1stTechnical Report)*, 2013.

Tsiamis, K., Gervasini, E., Deriu, I., D'Amico, F., Nunes, A., Addamo, A., De Jesus Cardoso, A., *Baseline Distribution of Invasive Alien Species of Union Concern*, 2017, doi:10.2760/345310.

Tsiamis, K., Gervasini, E., Deriu, I., D'amico, F., Katsanevakis, S., De Jesus Cardoso, A., *Baseline Distribution of Species Listed in the 1st Update of Invasive Alien Species of Union Concern*, 2019, doi:10.2760/75328.

Annex 1. Correspondence between CORINE LC classes' level 3, MAES ecosystem types' level 2, and macro-category of ecosystems adopted to identify the presence of pressure.

CORINE LC level 3	MAES level 2 ecosystem type	Macro-category of ecosystems
Continuous urban fabric	Urban	Artificial
Discontinuous urban fabric		
Industrial or commercial units		
Road and rail networks and associated land		
Port areas		
Airports		
Mineral extraction sites		
Dump sites		
Construction sites		
Green urban areas		
Sport and leisure facilities		
Non-irrigated arable land	Cropland	Agriculture
Permanently irrigated land		
Rice fields		
Vineyards		
Fruit trees and berry plantations		
Olive groves		
Pastures	Grassland	
Annual crops associated with permanent crops	Cropland	
Complex cultivation patterns		
Land principally occupied by agriculture with significant areas of natural vegetation		
Agro-forestry areas		
Broad-leaved forest	Woodland and forest ('Forest')	Forest & Semi-natural
Coniferous forest		
Mixed forest		
Natural grasslands	Grassland	
Moors and heathland	Heathland and shrub	
Sclerophyllous vegetation		
Transitional woodland-shrub	Woodland and forest ('Forest')	
Beaches dunes sands	Sparsely vegetated land	
Bare rocks		
Sparsely vegetated areas		
Burnt areas		
Glaciers and perpetual snow		
Inland marshes	Wetlands	Freshwater
Peat bogs		
Salt marshes	Marine inlets and transitional waters	Excluded
Salines		
Intertidal flats		
Water courses	Rivers and lakes	Freshwater

CORINE LC level 3	MAES level 2 ecosystem type	Macro-category of ecosystems
Water bodies		
Coastal lagoons	Excluded	Excluded
Estuaries		
Sea and ocean		

Fact sheet 4.2.102: Pressure by Invasive Alien Species on freshwater ecosystems

1. General information

The pressure by Invasive Alien Species (IAS) is a spatially explicit crosscutting indicator that can contribute to assess the pressures acting on ecosystems.

The indicator quantifies the cumulative pressure by IAS on **freshwater ecosystems**, using a unitless figure directly related to the relative extent of freshwater negatively affected, over a reference grid of 10 km spatial resolution.

- (Thematic ecosystem assessment): Common indicators for pressures and ecosystem condition
- Indicator class:
    - Pressure class: Invasive alien species;
    - Condition class: Environmental quality
- Name of the indicator: Pressure by Invasive Alien Species on freshwater ecosystems
- Units: unitless [between 0 and the number of IAS recorded in one area].

2. Data sources

The indicator requires processing of the following input data (Table 1):

- Distribution of IAS (10 km spatial resolution);
- Affected ecosystems, for each IAS;
- Global Surface Water (GSW) (Pekel et al., 2016), using the presence of waters for each month in 2012;
- Catchment Characterisation Model (CCM2) database (De Jager and Vogt, 2007), rasterized to 25 m spatial resolution;
- CORINE land cover 2012 (100 m spatial resolution).

The derived data are:

- Extent of freshwater for each 10 km reference grid cell, derived from the sum of waters from CCM2 and GSW, from which the extent of brackish waters from CORINE (classes 37, 38, 39, 42, 43 and 44) are removed.
- Cumulative pressure by IAS for each grid cell (total pressure).

Table 1. Input data

Data	Source	Notes	Data holder	Reference year	Access date
Catchment Characterisation Model (CCM2)	http://data.europa.eu/89h/fe1878e8-7541-4c66-8453-afdae7469221	Rasterized to 25 m	JRC		February 2019
Global Surface Water	https://global-surface-water.appspot.com/		JRC	2012	
CORINE Land Cover 2012	CORINE land cover 2012 Version 20: https://land.copernicus.eu/pan-european/corine-land-cover/clc-2012?tab=download	Minimum mapping unit: 25 ha or 100 m width	EEA	2012	
Invasive Alien Species	EASIN https://easin.jrc.ec.europa.eu/easin	Distribution records on the 10 km reference grid	JRC	Compiled over time	February 2019
Reference grid covering EU-28	EEA: https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2	10 km spatial resolution	EEA	Not applicable	January 2019

3. Assessment of the indicator

3.1. Short description of the scope of the indicator.

The species considered for this indicator are the 49 species listed as IAS of Union Concern up to 2017 (EU, 2017). For 47 of them spatial distribution data exist. The exception are *Persicaria perfoliata* and *Microstegium vimineum*, both plants, which were not present in the EU at the time of establishment of the baselines (and they are still absent to our knowledge).

For each IAS, pressure was identified for four macro-categories of ecosystems based on the traits of the IAS. Specifically, the information on the known impacts caused on invaded ecosystems and reported in Table 4 of Tsiamis et al. (2017; 2019) was linked to the pressure on one or more MAES ecosystem types (Maes et al., 2013). The link between CORINE LCC, MAES ecosystem types and macro-categories of ecosystems is shown in Annex 1.

For this indicator, only species affecting negatively freshwater ecosystems are considered:

- *Alopochen aegyptiacus*
- *Alternanthera philoxeroides*
- *Cabomba caroliniana*
- *Eichhornia crassipes*
- *Elodea nuttallii*
- *Eriocheir sinensis*
- *Hydrocotyle ranunculoides*
- *Lagarosiphon major*
- *Lithobates catesbeianus*
- *Ludwigia grandiflora*
- *Ludwigia peploides*
- *Myocastor coypus*
- *Myriophyllum aquaticum*
- *Myriophyllum heterophyllum*
- *Ondatra zibethicus*
- *Orconectes limosus*
- *Orconectes virilis*
- *Oxyura jamaicensis*
- *Pacifastacus leniusculus*
- *Perccottus glenii*
- *Procambarus clarkii*
- *Procambarus fallax f. virginalis*
- *Pseudorasbora parva*
- *Threskiornis aethiopicus*
- *Trachemys scripta*

For every grid cell (c) where an IAS was recorded, the per-species pressure ($w_{s,e}$) corresponds to the relative extent (the proportion from 0 to 1) of freshwater within the cell, that could be affected by the IAS. Hence, the cumulative pressure (I) for each grid cell (c) is the sum of the individual pressures of all IAS present within a cell and affecting negatively freshwater ecosystems:

$$I_c = \sum_{s=1}^{S} \sum_{e=1}^{E} O_s H_e w_{s,e}$$

Where:

- I_c = Cumulative pressure for cell c (0 to S);
- s = Invasive Alien Species;
- e = Ecosystem type;
- O_s = Occurrence for species s in cell c (0, 1);
- H_e = Proportion, share, of ecosystem type e within cell c (0 to 1);
- $w_{s,e}$ = Evidence of pressure of species s on the ecosystem type e (0, 1).

For this indicator, freshwater ecosystems are represented by one type only, which includes inland water bodies and rivers (from CCM2 and GSW), excluding brackish and salt waters as classified in CORINE.

Hence, the indicator can be simplified in:

$$I_c = \sum_{s=1}^{S} O_s H_e w_{s,e}$$

3.2. Maps and tables

The analysis and comments of the resulting pressures are found in Chapter 4.2 'Invasive Alien Species'.

Summary statistics and maps for freshwater ecosystem are found in:

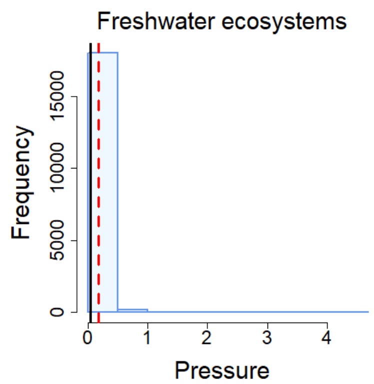
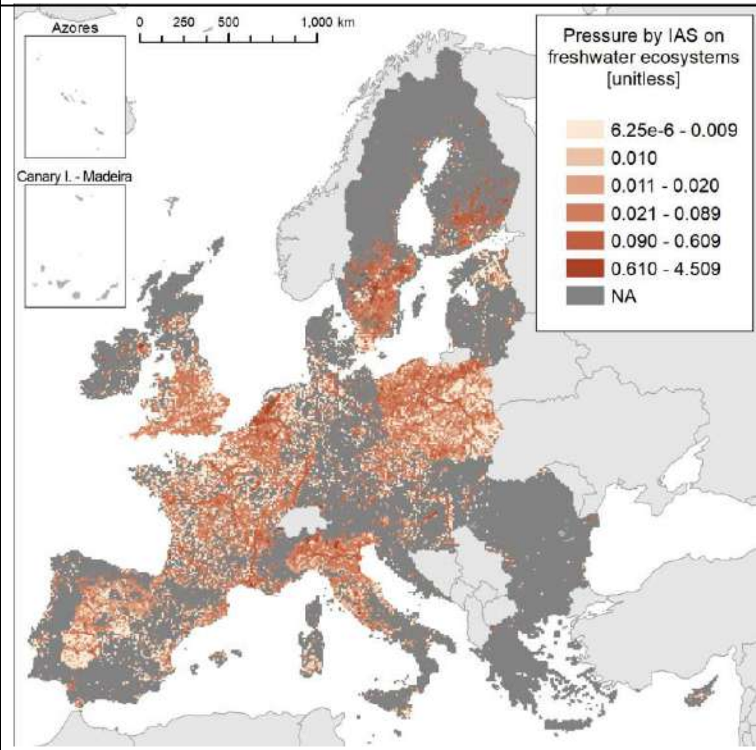
- **Table 2**: the cumulative pressure, i.e. the total pressure by the IAS occurring across the 10 km reference grid for which water data exist.

Spatially explicit information (i.e. the cumulative score for each cell having freshwater, and the extent of water for all grid cells for which water data exist) is found within the file: IASpressure_WATER.xlsx (the cumulative pressure for each cell is found also within the corresponding csv file: IASpressure_WATER.csv).

3.4. Key trend at EU level

Not applicable because only the baseline information is available.

Table 2. Cumulative pressure by IAS for freshwater ecosystems.

Ecosystem type	Invaded extent (%)	Cumulative pressure			Histogram for areas where pressure >0 (Mean + SD)	Map of areas where pressure > 0
		Mean ± SD	Min (> 0)	Max		
Freshwater	36.68	0.050 ± 0.132	6.250e-06	4.509		

References

De Jager, A., Vogt, J., *Rivers and Catchments of Europe - Catchment Characterisation Model (CCM)*, [Dataset] PID: http://data.europa.eu/89h/fe1878e8-7541-4c66-8453-afdae7469221, 2007, doi:PID: http://data.europa.eu/89h/fe1878e8-7541-4c66-8453-afdae7469221.

EU, 'Commission Implementing Regulation (EU) 2017/1263 of 12 July 2017 Updating the List of Invasive Alien Species of Union Concern Established by Implementing Regulation (EU) 2016/1141 Pursuant to Regulation (EU) No 1143/2014 of the European Parliament and of the Council', *Official Journal of the European Union*, Vol. L 182, 2017, pp. 37–39.

Maes, J., Teller, A., Erhard, M., Liquete, C., Braat, L., Berry, P., Egoh, B., Puydarrieux, P., Fiorina, C., Santos, F., Paracchini, M., Keune, H., Wittmer, H., Hauck, J., Fiala, I., Verburg, P., Condé, S., Schägner, J., San Miguel, J., et al., *Mapping and Assessment of Ecosystems and Their Services. An Analytical Framework for Ecosystem Assessments under Action 5 of the EU Biodiversity Strategy to 2020 (1stTechnical Report)*, 2013.

Pekel, J.-F., Cottam, A., Gorelick, N., Belward, A. S., 'High-Resolution Mapping of Global Surface Water and Its Long-Term Changes', *Nature*, Vol. 540, Macmillan Publishers Limited, part of Springer Nature. All rights reserved., 2016, p. 418, http://dx.doi.org/10.1038/nature20584.

Tsiamis, K., Gervasini, E., Deriu, I., D'Amico, F., Nunes, A., Addamo, A., De Jesus Cardoso, A., *Baseline Distribution of Invasive Alien Species of Union Concern*, 2017, doi:10.2760/345310.

Tsiamis, K., Gervasini, E., Deriu, I., D'amico, F., Katsanevakis, S., De Jesus Cardoso, A., *Baseline Distribution of Species Listed in the 1st Update of Invasive Alien Species of Union Concern*, 2019, doi:10.2760/75328.

Annex 1. Correspondence between CORINE LC classes' level 3, MAES ecosystem types' level 2, and macro-category of ecosystems adopted to identify the presence of pressure.

CORINE LC level 3	MAES level 2 ecosystem type	Macro-category of ecosystems
Continuous urban fabric	Urban	Artificial
Discontinuous urban fabric	Urban	Artificial
Industrial or commercial units	Urban	Artificial
Road and rail networks and associated land	Urban	Artificial
Port areas	Urban	Artificial
Airports	Urban	Artificial
Mineral extraction sites	Urban	Artificial
Dump sites	Urban	Artificial
Construction sites	Urban	Artificial
Green urban areas	Urban	Artificial
Sport and leisure facilities	Urban	Artificial
Non-irrigated arable land	Cropland	Agriculture
Permanently irrigated land	Cropland	Agriculture
Rice fields	Cropland	Agriculture
Vineyards	Cropland	Agriculture
Fruit trees and berry plantations	Cropland	Agriculture
Olive groves	Cropland	Agriculture
Pastures	Grassland	Agriculture
Annual crops associated with permanent crops	Cropland	Agriculture
Complex cultivation patterns	Cropland	Agriculture
Land principally occupied by agriculture with significant areas of natural vegetation	Cropland	Agriculture
Agro-forestry areas	Cropland	Agriculture
Broad-leaved forest	Woodland and forest ('Forest')	Forest & Semi-natural
Coniferous forest	Woodland and forest ('Forest')	Forest & Semi-natural
Mixed forest	Woodland and forest ('Forest')	Forest & Semi-natural
Natural grasslands	Grassland	Forest & Semi-natural
Moors and heathland	Heathland and shrub	Forest & Semi-natural
Sclerophyllous vegetation	Heathland and shrub	Forest & Semi-natural
Transitional woodland-shrub	Woodland and forest ('Forest')	Forest & Semi-natural
Beaches dunes sands	Sparsely vegetated land	Forest & Semi-natural
Bare rocks	Sparsely vegetated land	Forest & Semi-natural
Sparsely vegetated areas	Sparsely vegetated land	Forest & Semi-natural
Burnt areas	Sparsely vegetated land	Forest & Semi-natural
Glaciers and perpetual snow	Sparsely vegetated land	Forest & Semi-natural
Inland marshes	Wetlands	Freshwater
Peat bogs	Wetlands	Freshwater
Salt marshes	Marine inlets and transitional waters	Excluded
Salines	Marine inlets and transitional waters	Excluded
Intertidal flats	Marine inlets and transitional waters	Excluded
Water courses	Rivers and lakes	Freshwater

CORINE LC level 3	**MAES level 2 ecosystem type**	**Macro-category of ecosystems**
Water bodies		
Coastal lagoons	Excluded	Excluded
Estuaries		
Sea and ocean		

Fact sheet 4.3.201: Landscape Mosaic

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: Ecosystem condition
- Name of the indicator: Landscape mosaic in agricultural land
- Units: percent; 7 mosaic summary classes

2. Data sources

The indicator is derived from CORINE (v20) land cover data:
https://land.copernicus.eu/pan-european/corine-land-cover

- Data holder, data source: JRC; MAES collection. Contact: Peter Vogt
- Year or time-series range: 2000, 2006, 2012, 2018
- Access date: 17/10/2019
- Reference: Summary in Vogt (2018)

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

The Landscape Mosaic (LM) describes landscape composition or the degree of landscape heterogeneity. The LM is based on the CORINE (CLC) land cover maps (https://land.copernicus.eu/pan-european/corine-land-cover) containing 44 land cover classes at a spatial resolution of 1 hectare (100 m X 100 m) per pixel for a series of assessment years over Europe. Firstly, the 38 terrestrial land cover classes are aggregated into three main land cover type - Agriculture, Natural and Developed - according to the following Table 1. For each cell, relative proportions of these three types are then measured via a moving window algorithm using a fixed neighborhood area, i.e. a square window of size 23x23 pixels (= 529 hectares). Based on this, each pixel belonging to agroecosystem was classified in one of the seven LM classes shown in Figure 1 Developed pixels in its neighborhood.

Table 1 Aggregation of Corine Land Cover (CLC) terrestrial land use classes into three main Landscape Mosaic (LM) classes

Main land cover type	CLC Label 1	CLC Label 2	CLC Label 3
Developed	Artificial surfaces	Urban fabric	Continuous urban fabric
			Discontinuous urban fabric
		Industrial, commercial and transport units	Industrial or commercial units
			Road and rail networks and
			Port areas
			Airports
		Mine, dump and construction sites	Mineral extraction sites
			Dump sites
			Construction sites
		Artificial, non-agricultural vegetated	Green urban areas
			Sport and leisure facilities
Agriculture	Agricultural areas	Arable land	Non-irrigated arable land
			Permanently irrigated land
			Rice fields
		Permanent crops	Vineyards
			Fruit trees and berry plantations
			Olive groves
		Pastures	Pastures
		Heterogeneous agricultural areas	Annual crops associated with
			Complex cultivation patterns
			Land principally occupied by
			Agro-forestry areas
Natural	Forest and semi natural areas	Forests	Broad-leaved forest
			Coniferous forest
			Mixed forest
		Scrub and/or herbaceous vegetation associations	Natural grasslands
			Moors and heathland
			Sclerophyllous vegetation
			Transitional woodland-shrub
		Open spaces with little or no vegetation	Beaches, dunes, sands
			Bare rocks
			Sparsely vegetated areas
			Burnt areas
			Glaciers and perpetual snow
	Wetlands	Inland wetlands	Inland marshes
			Peat bogs
	Water bodies	Inland waters	Water courses
			Water bodies

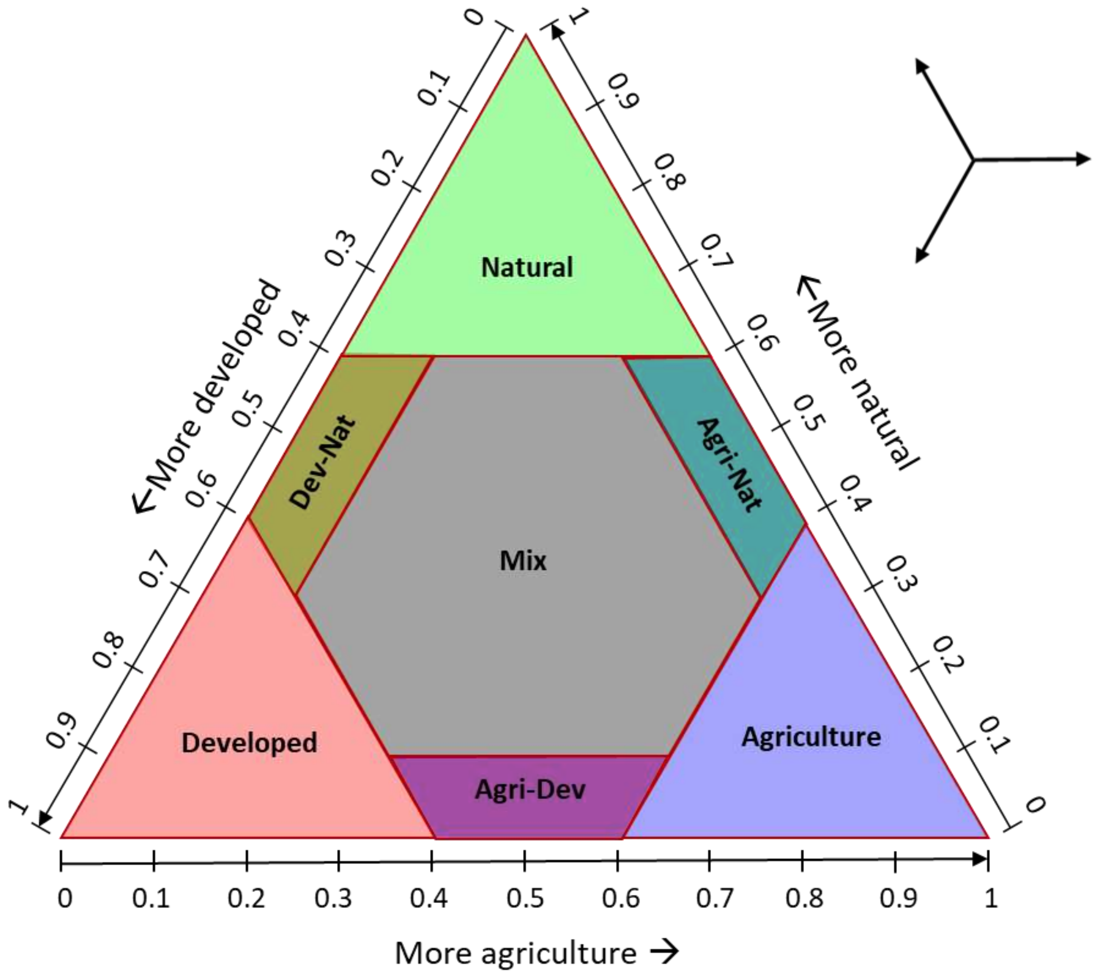


Figure 1 Landscape Mosaic for agricultural area, showing 7 mosaic classes and their proportions of the three main cover types - Agriculture, Natural and Developed

To assess changes in the condition, transitions from one class to another (in total 49 possible transitions, including no changes) were computed on the long term (2000-2018) and on the short term (2012-2018) trend, according to the rules showed in the following table.

Figure 168 Seven classes landscape mosaic based on relative shares of

Table 2 Landscape mosaic classes transitions in the period 2000-2018, percentage of agricultural cells involved in each transition and trend assessment associated to each transition

Transition	Percentage of cells 2000-2018	Trend
from Nat to Dev-nat	0.0028%	Degradation
from Nat to Mix	0.0629%	Degradation
from Agri-nat to Mix	0.3697%	Degradation
from Mix to Dev	0.0201%	Degradation
from Nat to Agri	0.3941%	Degradation
from Agri to Mix	**0.7780%**	Degradation
from Dev-nat to Dev	0.0009%	Degradation
from Mix to Agri-dev	0.0394%	Degradation
from Agri to Agri-dev	0.3525%	Degradation
from Agri-dev to Dev	0.0677%	Degradation
from Agri-nat to Agri-dev	0.0005%	Degradation
from Agri to Dev	0.0149%	Degradation
from Nat to Dev	0.0003%	Degradation
from Agri-nat to Dev	0.0003%	Degradation
from Nat to Agri-dev	0.0004%	Degradation
from Agri-nat to Dev-nat	0.0007%	Degradation
from Agri to Dev-nat	0.0002%	Degradation
from Dev-nat to Agri-dev	0.0005%	Degradation
from Mix to Nat	0.0475%	Improvement
from Mix to Agri-nat	0.1392%	Improvement
from Dev-nat to Nat	0.0013%	Improvement
from Agri-nat to Nat	**0.9569%**	Improvement
from Dev to Mix	0.0079%	Improvement
from Agri-dev to Mix	0.0410%	Improvement
from Agri to Nat	0.3037%	Improvement
from Dev to Dev-nat	0.0007%	Improvement
from Agri-dev to Nat	0.0001%	Improvement
from Agri-dev to Agri-nat	0.0007%	Improvement
from Dev to Nat	0.0007%	Improvement
from Dev to Agri	0.0041%	Improvement
from Dev to Agri-nat	0.0005%	Improvement
from Dev-nat to Agri-nat	0.0005%	Improvement
from Dev-nat to Agri	0.0002%	Improvement
from Nat to Nat	9.1892%	No change
from Mix to Mix	2.0830%	No change
from Dev-nat to Dev-nat	0.0057%	No change
from Agri-nat to Agri-nat	7.6738%	No change
from Dev to Dev	0.1101%	No change
from Agri to Agri	73.0848%	No change
from Agri-dev to Agri-dev	0.4085%	No change
from Agri to Agri-nat	**1.8878%**	Unresolved
from Dev-nat to Mix	0.0042%	Unresolved
from Mix to Dev-nat	0.0067%	Unresolved
from Nat to Agri-nat	0.6402%	Unresolved
from Agri-nat to Agri	**1.0040%**	Unresolved

from Mix to Agri	0.2269%	Unresolved
from Agri-dev to Agri	0.0556%	Unresolved
from Dev to Agri-dev	0.0085%	Unresolved
from Agri-dev to Dev-nat	0.0004%	Unresolved

The rationale is that any transition entailing an increase of the proportion of developed area in the neighborhood or a decrease of the share of natural area is assessed as a degradation, whilst any transition entailing an increase of natural area is considered an improvement, under the assumption that more natural areas provide potentially more Ecosystem services and exert less pressure on the agricultural compared to artificial land or other agricultural areas. In some cases, transitions from two classes were assessed considering the most likely land-use change that can determine it: for example a transition from Agriculture to Agri-nat could occur even with a decrease of natural area and an increase of developed area, but these increases would be necessarily very small (see Figure 1) whilst in most cases the transition would imply a significant increase of the share of natural areas. This transition is therefore assessed as an improvement. Trends should however be interpreted carefully, considering that in most cases the increase of natural area in the surrounding occurs at the expense of other agricultural land, land use changes from artificial areas to natural ones being very rare in Europe. Therefore, they should be evaluated jointly with trends in ecosystems extents and (agricultural) land abandonment.

3.2. Maps

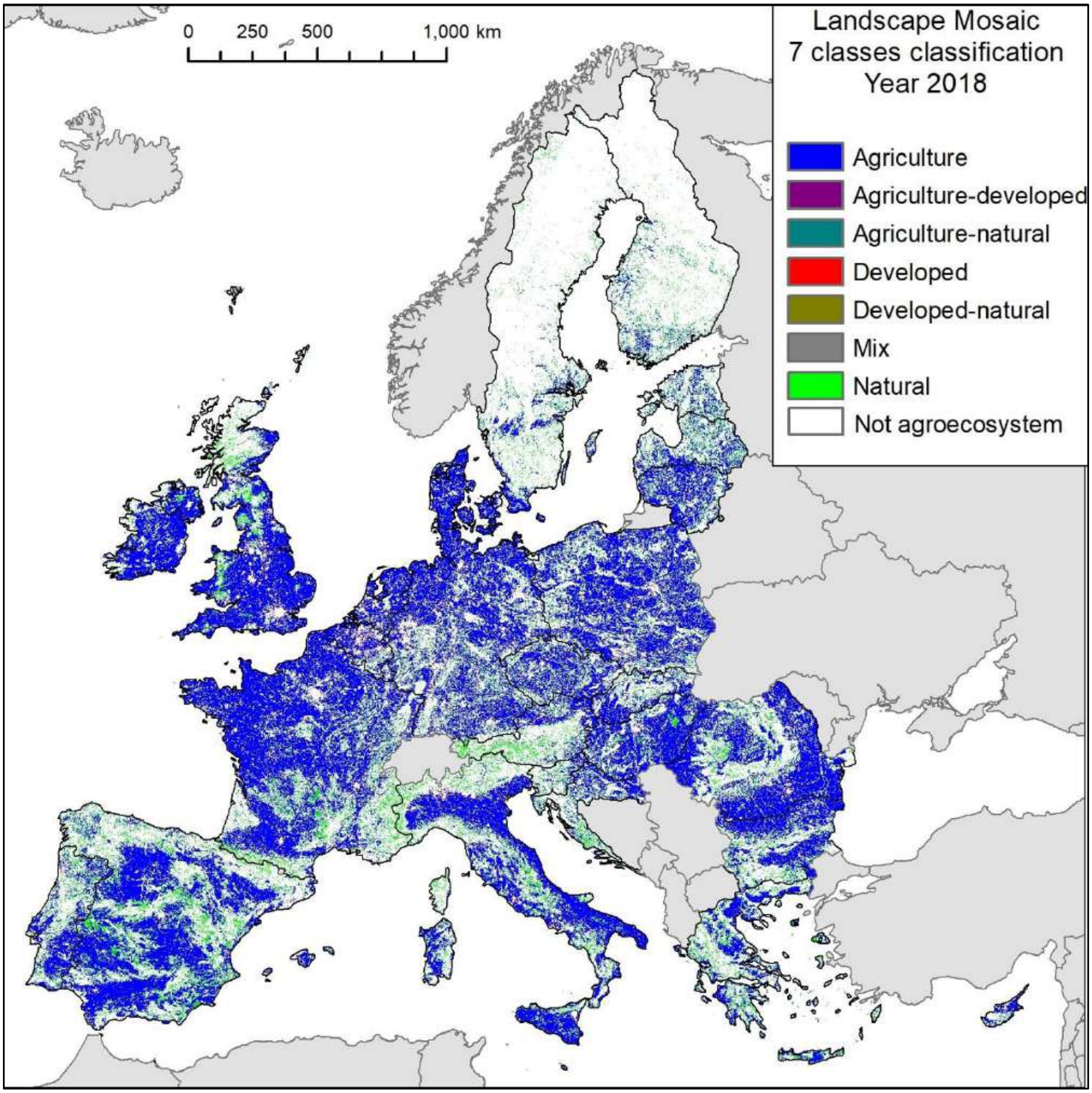


Figure 2 shows the Landscape Mosaic classification in agroecosystems for the year 2018.

Expectedly, most of cropland is classified in the LM as "Agriculture", whilst most of grassland area in the "Natural" LM class. The occurrence of other classes is comparatively much smaller and no clearly identifiable at EU level. Developed, and Agri-Dev classes represent peri-urban agricultural areas or remnants of fields interspersed in a developed matrix, as shown in the following figure, representing the metropolitan area of Milan, Northern Italy

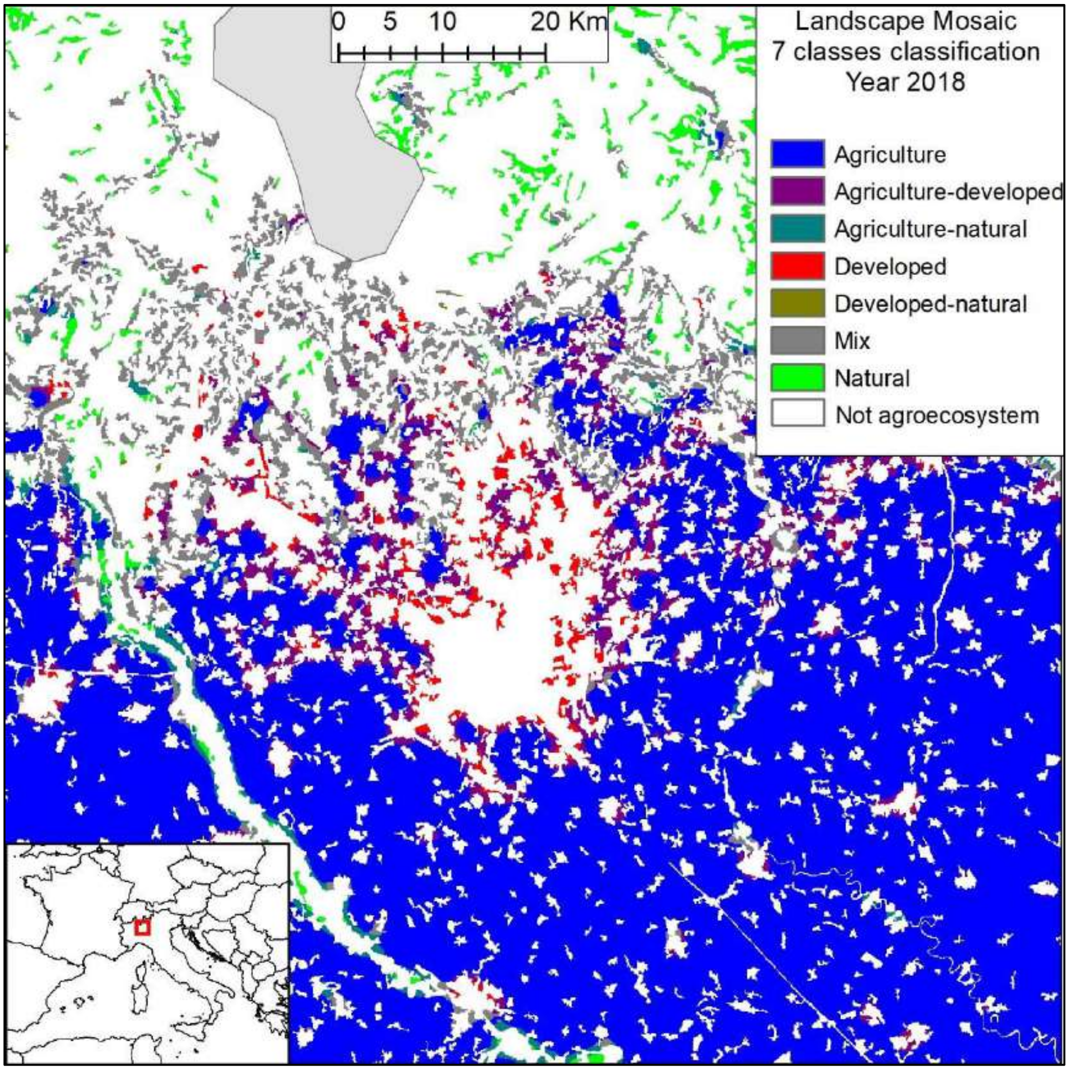


Figure 3. Landscape Mosaic - zoom of the metropolitan area of Milan, Northern Italy

3.3. Statistical analysis of the trend

In this case the indicator is not a physical quantity that varies over time, but a categorical index. The trend was thus calculated in a slightly different way compared to other indicators. The LM transitions from 2000 to 2018 (long term) and from 2012 to 2018 (short term) were considered, and the percentage of cropland/grassland cells that experienced improvement, degradation, no change or unresolved changes, (based on Table 1) were calculated. The cells trends at 100 m where then aggregate at 1 km to provide a more meaningful information at a landscape scale and for visual purpose to detect spatial patterns. A majority rule was applied in the aggregation procedure (i.e. if in a 1km cell, improving cells are more than degrading one, the cell is classified as improving, and vice versa)

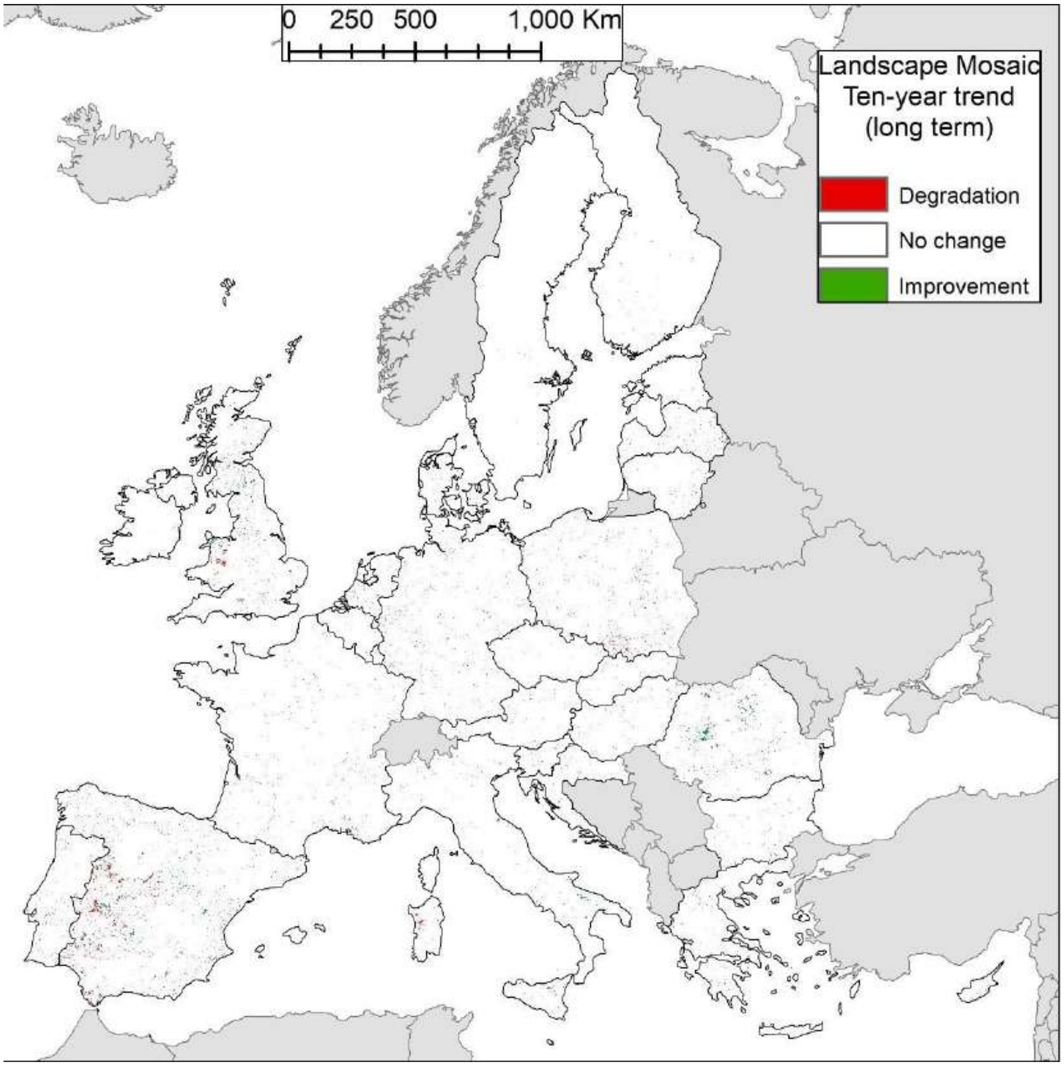


Figure 4. Trends in the landscape mosaic at 1 km resolution. Ten-year trend based on the long period (changes between 2000 and 2018)

Significant spatial pattern are identifiable in western Spain partly related to transformation processes and abandonment of traditional agroforestry areas; in Transylvania (Central Romania, improvement), degradation has also occurred in Wales, where traditional grasslands have been converted to arable land.

3.4. Key trend at EU level

At EU level, the ten-year trends, measured as share of cropland/grassland cells experiencing changes in their LM classification, show that overall degradation is occurring at a greater pace than improvement, although the absolute values are low. Ten-year trends calculated over the long period are more marked than those calculated over the short period, indicating that the speed of land-cover change is decreasing in more recent years. However, in both cases degradation is higher than improvement: 1.17% vs 0.84% in the first case, and 0.25% vs 0.10% in the second one Table 3.

It is worth to remark that trends for this indicator should be evaluated considering its specificity and the source data on which it is based. Changes in land use from Corine Land Cover can be detected only above a certain area involved, due to the Minimum Mapping Unit of the layer (25 ha). As such, Corine is considered to underestimate for example land take by urban sprawl, as no transition to artificial area is recorded until the interested area reaches a certain surface. The landscape mosaic, in turn, considers for each cell a neighborhood of 529 cells, meaning that a change in the mosaic class requires a relevant number of cells in the neighborhood to change their status from one time step to another.

Table 3 Ten-year trend on the Landscape Mosaic indicator based on the long and short term changes

Trend assessment	Ten-year trend	
	Long term (2000-2018)	short term (2012-2018)
Degradation	1.17%	0.25%
Improvement	0.84%	0.10%
No change	95.86%	99.43%
Unresolved	2.13%	0.23%

Fact sheet 4.4.101: Spatial assessment of trend in soil erosion by water

1. General information

- Thematic ecosystem assessment: Cropland and grassland
- Indicator class: pressure
- Name of the indicator: soil erosion by water
- Units: tonnes of soil/hectare/year (t ha^{-1} yr^{-1})

2. Data sources

- Data holder, data source: JRC
- Year or time-series range: 2000, 2010, 2016
- Access date--- 31/01/2020
- **References**: Panagos, P., Ballabio, C., Scarpa, S., Borrelli, P., Lugato, E. & Montanarella, L., 2020. Soil related indicators to support agri-environmental policies, EUR 30090 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978- 92-76-15644-4, doi:10.2760/011194, JRC119220
- Panagos, P.; Ballabio, C.; Poesen, J.; Lugato, E.; Scarpa, S.; Montanarella, L.; Borrelli, P. 2020. A Soil erosion indicator for supporting agricultural, environmental and climate policies in the European Union. Remote Sensing, 12, 1365

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Soil erosion is the physical removal of soil particles. It is a natural process that can be amplified by human activities that affect the soil surface (in particular vegetation cover) or by changes in climatic factors. The land surface of the EU is primarily subject to erosion by water, wind and as a result of harvesting root crops. Other types of natural processes include coastal erosion and glacial erosion. Water erosion can be divided into four categories,

- splash - where soil particles are displaced by the impact of raindrops
- sheet – occurs when the soil is saturated (i.e. all pore spaces are full of water) or when precipitation is greater than the rate at which water can infiltrate into the soil. In these conditions, and with sufficient gradient, a sheet of water will runs across the surface transporting loose soil particles down the slope.
- rill - this is a small, shallow channel (only a few cm deep and wide), that usually develops when sheet flow becomes concentrated. Rills can affect significant areas and when taken collectively can account for significant soil movement.
- gully – this is a well defined channel (usually several metres deep and wide) where large volumes of water can flow during or after heavy rainfall. Gullys can move considerable amounts of soil through the landscape.

Eroded soil is eventually redeposited either at the bottom of slopes (if moved by water) but it may also enter terrestrial water bodies or even transported hundreds or thousands of kilometers through the atmosphere.

This indicator assess the extent of soil erosion by sheet and rill erosion. The data presented in this assessment are derived from a modified version of the Revised Universal Loss Equation (RUSLE) model (Renard et al. 1991) that has been adapted for European conditions (Panagos et al., 2015). RUSLE2015 improves the quality of calculating soil erosion by sheet and rill erosion by using the most current high-resolution (100m) input layers.

Annual soil loss rates by water erosion (measure in t ha^{-1} yr^{-1}) is based on the following equation:

$E = R \times K \times C \times LS \times P$ where:

- R: Rainfall Erosivity factor (MJ mm ha-1 h-1 yr-1) – denotes the erosive power of precipitation events
- K: Soil Erodibility factor (t ha h ha-1 MJ-1 mm-1) – reflects the capacity of the soil to withstand erosion (based on texture, structure and organic matter content)
- C: Cover-Management factor (dimensionless) – describes the nature of the vegetation protecting the soil
- LS: Slope Length and Slope Steepness factor (dimensionless) – describes the topographic setting of the soil
- P: Support practices factor (dimensionless) – land management practices designed to reduce or prevent erosion

From the above equation, it is clear that the magnitude of erosion by water can be augmented through land cover change (e.g. deforestation or conversion of grasslands to croplands) or land management practices such as leaving the soil bare after harvest, ploughing in the direction of the slope (plough lines act as rills) or removing natural erosion barriers in the landscape e.g. walls, hedges, grass strips, etc.). In addition, climate change scenarios with more intense precipitation events will lead to an increased vulnerability to soil erosion by water, especially in regions where vegetation cover is generally low.

Soil erosion is a degradational processes as its impacts include a reduction in soil fertility, a loss of organic carbon, disruption of soil water and gas fluxes, the silting up of waterbodies and reservoirs, and potentially a complete loss of the soil body. In fact, soil erosion has been identified as the most widespread land degradation processes on the planet. In terms of soil-related ecosystems services, soil erosion should be reduced to sustainable levels.

Soil erosion is one of the eight main threats to soil functions identified by the EU Soil Thematic Strategy (COM(2006) 231 final). Soil erosion by water is a CAP Context Indicator, part of the EU Core SDG Indicator Set and a Impact Indicator in the post-2020 Common Agricultural Policy.

The potentially erosive area of the EU is about 3,912 x 10^3 km^2, which is 88.9% of the soil ecosystem.

Data are available for 2000, 2010 and 2016.

3.2. Maps

Figure 1 below shows the soil erosion rates for the baseline year 2010 (resolution: 1 km^2). Areas with high erosion are depicted red and yellow colours, intermediate levels are shown in yellow while low erosion rates are show in green. Broadly speaking, soil erosion rates are lower in northern parts of the EU, increasing southwards as the vegetation cover decreases while terrain conditions become more evident. Changes in the values of this indicator are generally slow but can occur relatively quickly if there are marked changes in land management practices or climatic patterns.

Panagos et al. (2015) reported that mean soil erosion by water for EU in 2010 was 2.46 t ha^{-1} yr^{-1}, resulting in a total annual soil loss of 970 Mt. This covers a wide range of land use types, with around 70% occurring on land under agricultural systems. Around 24% of the EU exhibits unsustainable soil water erosion rates (>2 t ha^{-1}).

Figure 2 shows the situation for 2016, aggregated for NUTS2 regions. The estimated soil erosion rates in 2016 was 2.45 t ha^{-1} yr^{-1}. This reflects a limited decrease of 0.4% in all lands and 0.8% in arable lands compared to 2010. Regions with high levels of erosion (e.g. the Mediterranean) show limited improvements, probably reflecting a combination of limited soil cover, limited implementation of control measures, increasingly erosive rainfall patterns and terrain conditions.

Figure 1: Baseline soil erosion by water (2010)

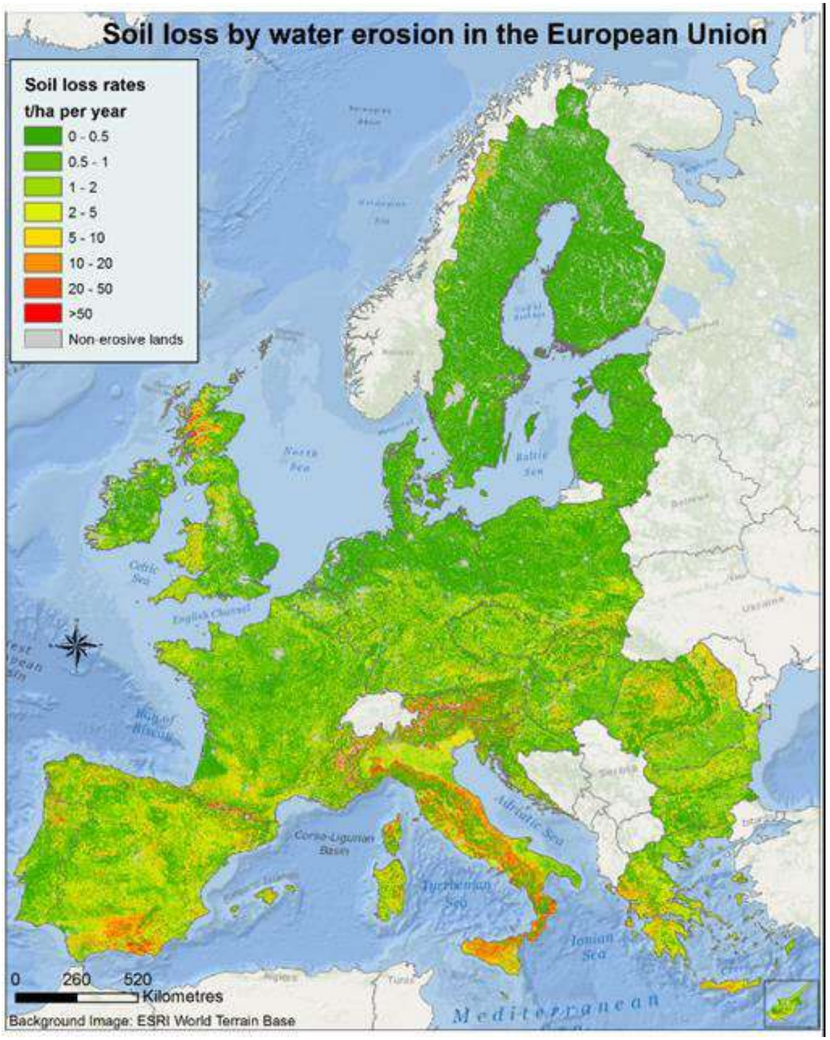
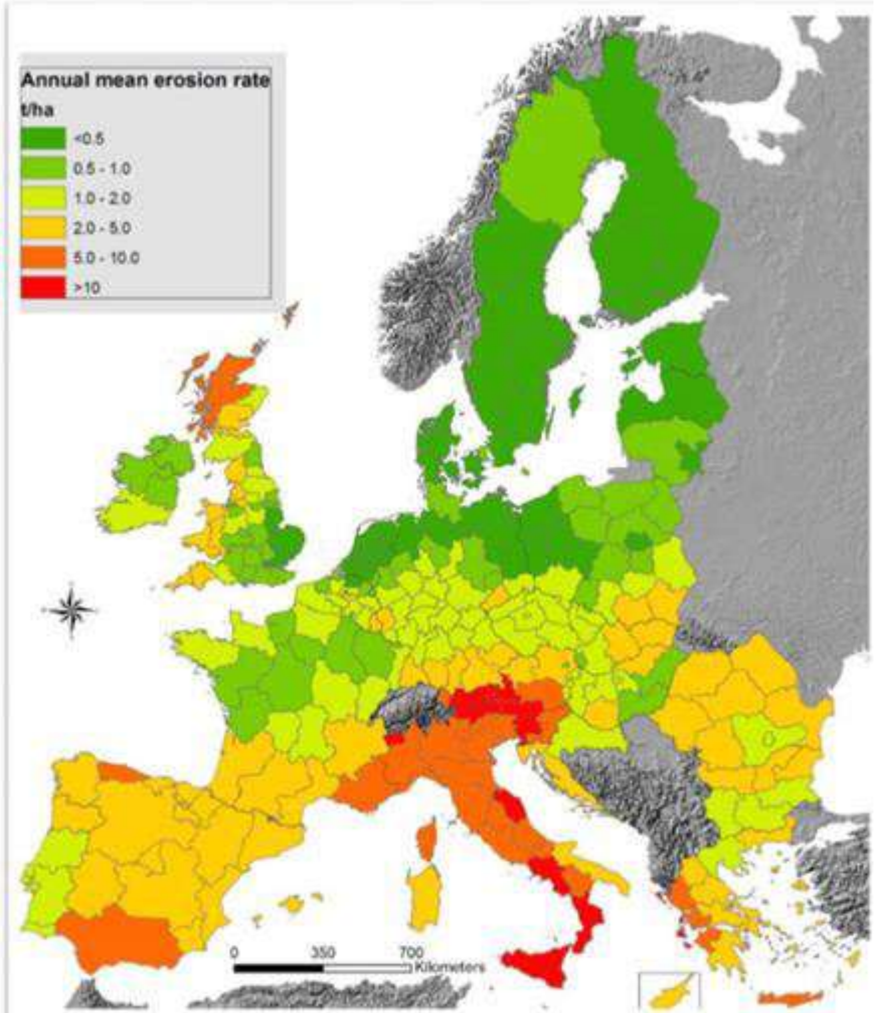


Figure 169: Aggregated soil erosion by water 2016



3.3. Statistical analysis of the trend

Figure 3 shows the key trends in soil erosion by water for the EU. The long-term trend (2000-2010) saw a significant reduction in soil erosion by water in all soils and especially in agricultural soil, falling by 9% and 19% respectively.

The current short-term assessment does not show any statistically significant ($p < 0.01$) change in soil erosion between 2010 and 2016. While there is an overall reduction in the comparison between arable soils and all lands, soil erosion by water on agricultural soils remains higher. In 2016 is erosion on agricultural land is 10% greater than the mean for the EU.

Figure 1: Baseline soil erosion by water (2000-2016)

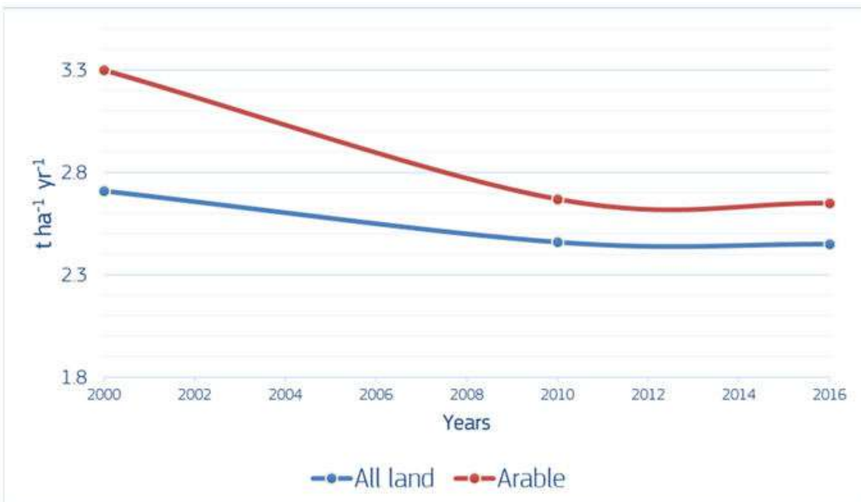
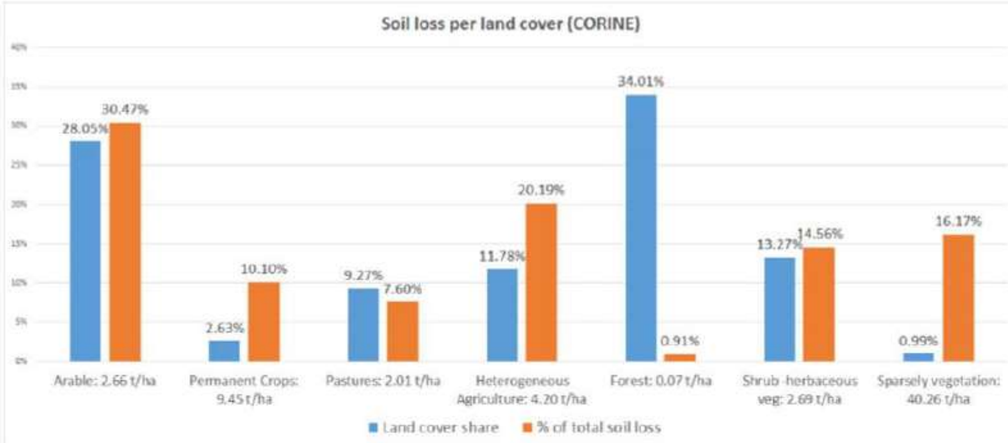


Figure 3 shows soil erosion rates by land cover type. Arable land shows annual erosion rates of 2.66 t ha^{-1} while show the permanent crops show the highest soil erosion rates for managed land (9.45 t ha^{-1} yr^{-1}). Erosion rates on grasslands (2.01 t ha^{-1} yr^{-1}) are close to being sustainable. Despite the fact that woodlands occupy more around 34% of the EU erosive land, they have by far the lowest rate of soil loss (0.07 t ha^{-1} yr^{-1}), contributing less than 1% of the total soil loss in Europe.

In addition, there are notable erosion rates on shrublands and sparse vegetation with mean soil loss rate of 2.69 t ha^{-1} yr^{-1} and 4026 t ha^{-1} yr^{-1}, respectively, on around 14% of the EU.

Figure 3. Analysis of soil erosion rates by land cover types


Soil loss per land cover (CORINE)
28.05%
30.47%
2.63%
10.10%
9.27%
7.60%
11.78%
20.19%
34.01%
0.91%
13.27%
14.56%
0.99%
16.17%
Arable: 2.66 t/ha
Permanent Crops: 9.45 t/ha
Pastures: 2.01 t/ha
Heterogeneous Agriculture: 4.20 t/ha
Forest: 0.07 t/ha
Shrub-herbaceous veg: 2.69 t/ha
Sparsely vegetation: 40.26 t/ha
Land cover share
% of total soil loss

3.4. Key trend at EU level

Table 1 reports the value of the indicators at 2000, 2010 and 2016.

Table 1 Average soil erosion values at EU level from 2000 to 2016

Year	Average soil erosion rates – all soils (t/ha/yr)
2000	2.7
2010	2.46
2016	2.45

The short-term trend for soil erosion by water with the baseline year of 2010 is -0.677% per decade. This is not a significant change.

The long-term trend for soil erosion by water (2000-2010) is -9% per decade.

Soil erosion by water across the EU is above accepted soil formation rates, which means that the soil ecosystem will continue to degrade. In this context, efforts to reduce soil erosion should be reinforced with more agro-environmental friendly measures and a better targeting of areas that are vulnerable to erosio

References

Panagos, P., Borrelli, P., Poesen, J., Ballabio, C., Lugato, E., Meusburger, K., Montanarella, L. and Alewell, C. 2015. The new assessment of soil loss by water erosion in Europe. Environmental Science and policy 54:438-447. http://dx.doi.org/10.1016/j.envsci.2015.08.012

Panagos, P., Ballabio, C., Scarpa, S., Borrelli, P., Lugato, E. & Montanarella, L., 2020. Soil related indicators to support agri-environmental policies, EUR 30090 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978- 92-76-15644-4, doi:10.2760/011194, JRC119220

Renard KG, Foster GR, Weesies GA, McCool DK, Yoder DC (1991) Predicting soil erosion by water: a guide to conservation planning with the revised universal soil loss equation (RUSLE). Agriculture Handbook No. 703. Agricultural Research Service, Washington, DC

Fact sheet 5.0.100: Ecosystem service: crop provision

1. General information

- Provisioning ecosystem service (CICES V.5.1);
- Crop provision: ecological contribution to the growth of cultivated crops that can be harvested and used as raw material (yield provision derived from human inputs is not included);
- Components assessed for crop provision:
    - Use: share of crop production derived only from the ecosystem contribution (tonne/year and tonne/ha/year).

2. Data sources

The assessment of crop provision is described in Vallecillo et al. 2019[62]. For consistency with the official statistics, the mapping of the changes for the EU-wide ecosystem assessment is based on the allocation of the values obtained from official Eurostat statistics to the locations where changes take place: agriculture areas except permanent crops (not covered in this assessment). Accounting layers of CORINE land cover (codes 211, 212, 213, 231, 241, 242, 243, 244) are used for the mapping and we refer to these areas as 'arable land' for simplification.

- Data holder: JRC at the JRC data catalogue in MAES collection[63]
- Format and spatial resolution: raster maps with the status for 2012 (1 x 1 km) based on the distribution of CAPRI data[64] and maps of changes between 2000 and 2012 at 100 x 100 m resolution.
- Spatial coverage: EU-25 (excluding Cyprus, Malta and Croatia because of the lack of data to assess ecosystem contribution)
- Years available: data at country level for 2000, 2006 and 2012

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Crop provision as ecosystem service is assessed by disentangling the yield generated by the ecosystem (i.e., ecosystem service) from what is generated by human inputs such as planting, irrigation and chemical inputs. Analyses of changes over time are based on Eurostat statistics [apro_cpnh1] for 13 crop types: soft wheat, durum, wheat, barley, oats, maize, other cereals, rape, sunflower, fodder maize, other fodder on arable land, pulses, potatoes and sugar beet. These crop types represent about 82% of the extent of all arable land in Europe.

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[62] Vallecillo, S., La Notte, A., Kakoulaki, G., Kamberaj, J., Robert, N., Dottori, F., Feyen, L., Rega, C. & Maes, J. (2019) Ecosystem services accounting. Part II-Pilot accounts for crop and timber provision, global climate regulation and flood control, EUR 29731 EN, Publications Office of the European Union, Luxembourg. Retrieved from http://publications.jrc.ec.europa.eu/repository/handle/JRC116334.

[63] https://data.jrc.ec.europa.eu/collection/maes

[64] Britz, W., & Witzke, H. P., (Eds.),. (2014). *CAPRI model documentation 2014*. Retrieved from University of Bonn, Germany: http://www.capri-model.org/docs/CAPRI_documentation.pdf

3.2. Maps

The contribution of ecosystems to crop provision is about 21% of the total yield. This means that the remaining 79% of yield is derived from human inputs. Crop provision as ecosystem service shows high values in Germany, Belgium, Latvia and West of France (Figure 1).

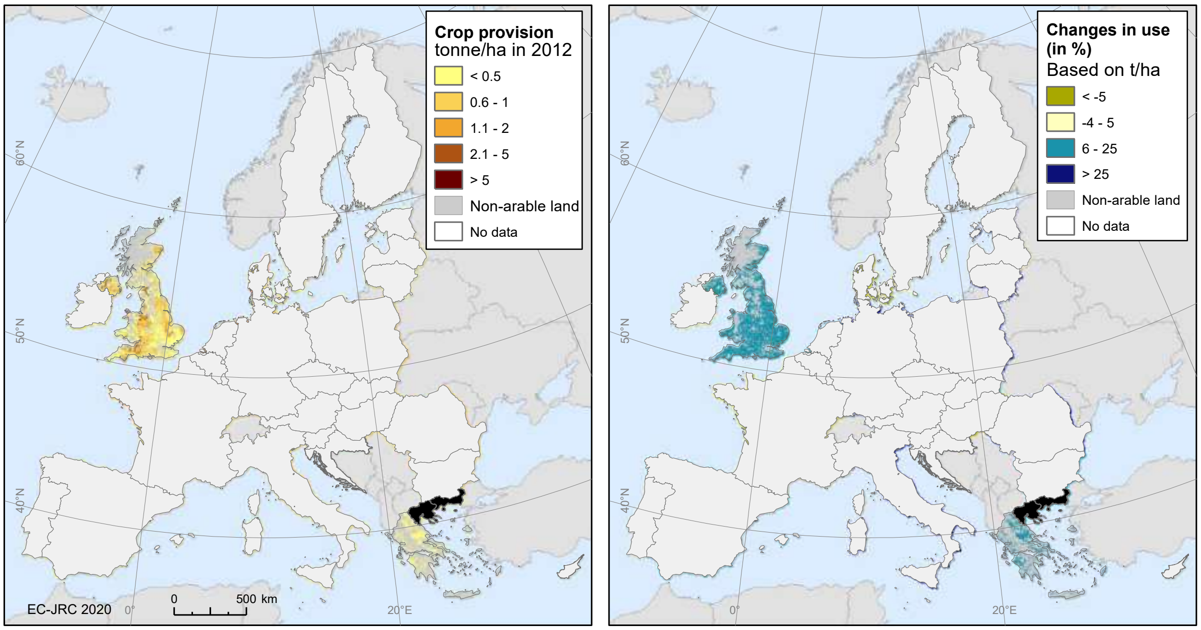

Figure 1. Maps of crop provision and changes between 2000 and 2012.

Most of the EU countries show an increase of crop provision in terms of the amount of tonnes of yield produced by hectare (Figure 1). In the lead of this increase are Poland, Estonia and Lithuania. Countries showing a decrease in crop provision are Belgium, Luxembourg, Denmark, France and Hungary.

3.3. Statistical analysis of the trend

Changes for timber provision at the EU level were analysed between 2000 and 2010 for all countries. Changes at the EU level larger than ±5% per decade were considered to be significant. If changes were smaller than ±5%, the non-parametric Wilcoxon test was applied considering significant changes when p-value was lower than 0.05.

3.4. Key trend at EU level[65]

Crop provision by ecosystems shows an overall positive trend for the period assessed (between 2000 and 2012) in absolute (tonne) and relative terms (tonne/ha). There was only a slight decrease of crop provision between 2000 and 2006 (Table 1, Figure 2). From the ecological point of view, it is especially relevant the change in crop productivity (in tonne per hectare), showing an increase per decade of 10% (Table 1). The increase in crop provision might be a consequence of the economic need to make crop

[65] EU-25 (excluding Cyprus, Malta and Croatia because of the lack of data)

production more gainful. Other drivers that might explain the increasing crop productivity are the possible improvement of weather conditions or also changes in crops types.

When looking separately to the different periods covered in the assessment (between 2000 and 2006 and between 2006 and 2012) trends significantly differ. While in the first period, there was a decrease in the tonnes of yield produced (with no significant changes in the productivity), between 2006 and 2012 takes place an important increase of the yield produced in absolute and relative terms (Figure 2).

Table 1. CROP PROVISION AT THE EU LEVEL

Components of the service	Year 2000	Year 2006	Year 2010*	Year 2012	Change (% per decade)**
Use (million tonne)	144	138	149	155	7%
Use (tonne/ha)	1.88	1.90	2.03	2.09	10%

*Calculated by interpolation

**Based on the changes between 2000 and 2012

Unfortunately, the estimation of the ecosystem contribution (in about 21%), considered to quantify the effective role of ecosystems in delivering the ecosystem service, was fixed over time. Therefore, the increase of crop provision reported is simply explained by the increase in the total yield production, and not to a more active role of the ecosystem contributing to the yield growth.

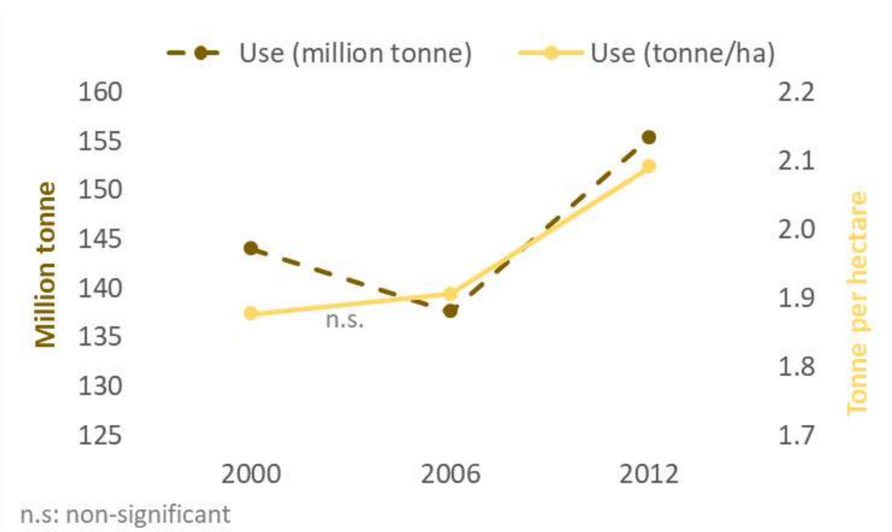

Figure 2. Crop provision derived from the ecosystem contribution in the EU over time

Fact sheet 5.0.200: Ecosystem service: timber provision

1. General information

- Provisioning ecosystem service (CICES V.5.1);
- Timber provision: contribution of ecosystems to the growth of wood harvested as raw material for different purposes;
- Components assessed for timber provision:
  - Potential: net annual increments of growing stocks (m^3/year and m^3/ha/year)
  - Use/demand: annual standing volume of all trees, living or dead, that are felled during the given reference period, including the volume of trees or parts of trees that are not removed from the forest, other wooded land or other felling site (m^3/year and m^3/ha/year)

2. Data sources

The assessment of timber provision is based on EUROSTAT data[66]. The source of these data is Joint Forest Sector Questionnaire from FAO, UNECE, ITTO and Eurostat. These data are also used for Forest Europe.

- Data holder: JRC at the JRC data catalogue in MAES collection[67]
- Format and spatial resolution: raster maps for potential and use/demand are based on a simple allocation of the values provided by official statistics (in m^3/ha) to forest areas according to the accounting layers of CORINE land cover (codes 311, 312 and 313). Transitional woodland-shrub (code 324) was not included in the mapping since official statistics refer only to forest available for wood supply.
- Spatial coverage: EU-28 except Malta, which does not report any forest available for wood supply)
- Years available: data at country level for 2000, 2005 and 2010 (for the integration with other ecosystem services we used 2005 matching with 2006, and 2010 with 2012)

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Timber provision as ecosystem service is assessed using two different indicators: potential and use. The potential timber provision is measured as the net annual increment (NAI) of timber which represents the annual amount of timber that forest can offer. Data available for NAI refer only to forest available for wood supply; therefore the whole assessment refers to this type of forest only. Timber provision use is quantified as annual fellings, including also the amount of timber that is not removed from the forest.

[66] https://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=for_vol&lang=en
[67] https://data.jrc.ec.europa.eu/collection/maes

For provisioning services, the use is considered to be equal to the demand[68], when referring to national wood (imports from other countries are not considered). Analyses of changes over time are based on Eurostat statistics[1] available at country level.

3.2. Maps

For the reference year 2010 of the EU-wide ecosystem assessment, the potential timber provision is 5.5 m^3/ha, while 3.9 m^3/ha are felled in the EU (Table 1). The highest potential to provide timber is measured in Germany, Denmark and Ireland, while the lowest is found in Spain and Greece (Figure 1). The use of timber follows a spatial pattern similar to the potential, with the highest values also found in Central Europe (Figure 1). In 2010, at country level, only Sweden had fellings above net annual increments mainly due to storm events and sanitary harvesting to limit the propagation of parasites. Fellings above net annual increments is translated into a pressure for forest ecosystems: see forest harvesting intensity indicator.

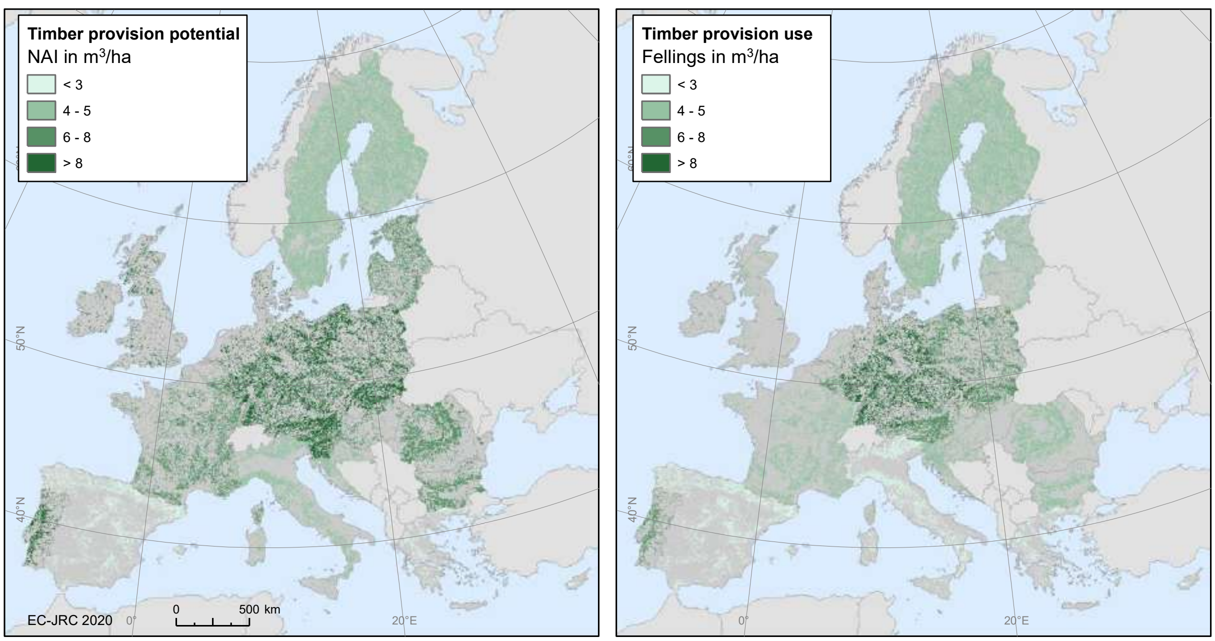

Figure 1. Maps of the potential and use of timber provision in 2010.

Although at the EU level there are no significant changes in timber provision (Table 1), at country level there is more variability. Increases[69] in the potential timber provision are taking place for 12 countries, with Denmark, Slovenia and Finland in the lead. On the other hand, France, Austria and Sweden experienced a decrease of potential timber provision.

Comparison of the maps of changes for the potential timber provision and the actual use shows some relevant results (Figure 2). In Sweden and Austria in spite of the decrease in the amount of timber that

[68] Wolff, S., Schulp, C.J.E. and Verburg, P.H. (2015) Mapping ecosystem services demand: A review of current research and future perspectives. Ecological Indicators, 55, 159-171. https://doi.org/10.1016/j.ecolind.2015.03.016
[69] Changes at country level were considered significant when larger than ±5% per decade

forest can offer (NAI), there was an increase in the use of timber provision. Although fellings in these countries are also due to storm events and sanitary harvesting to limit the propagation of parasites, this situation maintained over time may lead to a reduction of timber stocks in the forest, affecting the ecosystem condition. Therefore, differences in the trends between NAI and fellings could be used as early warning of possible overuse of timber provision in the future.

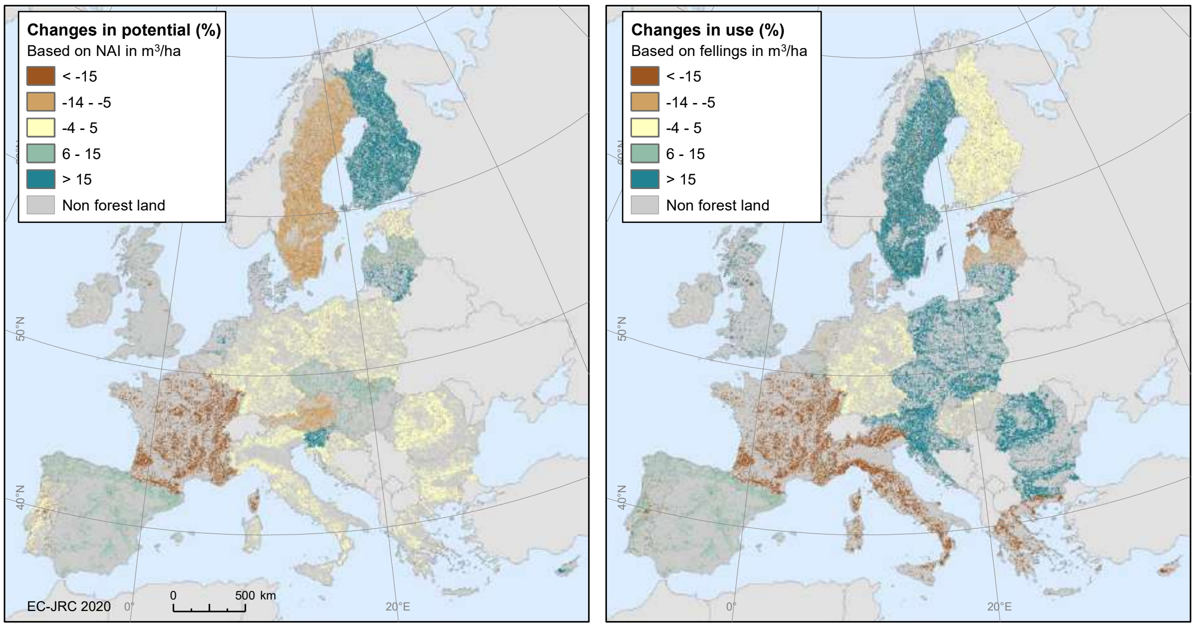

Figure 2. Maps of changes in potential and use of timber provision between 2000 and 2010.

3.3. Statistical analysis of the trend

Changes for timber provision at the EU level were analysed between 2000 and 2010 for all countries. Changes at the EU level larger than ±5% per decade were considered to be significant. If changes were smaller than ±5%, the non-parametric Wilcoxon test was applied considering significant changes when p-value was lower than 0.05.

3.4. Key trend at EU level[70]

At the EU level, the potential, use and demand for timber provision reveal no significant changes for the period between 2000 and 2010 in absolute terms (m^3). Only in relative terms (in m^3/ha), there was a significant (although very small) decrease in the average potential timber provision per hectare. Given the uncertainty of the data (estimates from the National Forest Inventories), this trend can be considered negligible.

[70] EU-27 (excluding Malta: no forestry data)

Table 1. TIMBER PROVISION AT THE EU LEVEL				
Components of the service	**Year 2000**	**Year 2005**	**Year 2010**	**Change (% per decade)**
Potential (million m^3)	739	722	744	0.7%$^{n.s.}$
Potential (m^3/ha)	5.56	5.39	5.54	-0.3%
Use/demand (million m^3)	504	539	523	4%$^{n.s.}$
Use/demand (m^3/ha)	3.78	4.02	3.89	3%$^{n.s.}$

$^{n.s.}$Changes between 2000 and 2010 non statistically significant

The lack of changes between 2000 and 2010 are due to the opposing trends found over time within this period. The potential timber provision shows a decrease between 2000 and 2005, compensated by an increase the period after (between 2005 and 2010). Conversely, the use/demand for timber provision increase for the first period, while decreased between 2005 and 2010 (Figure 3).

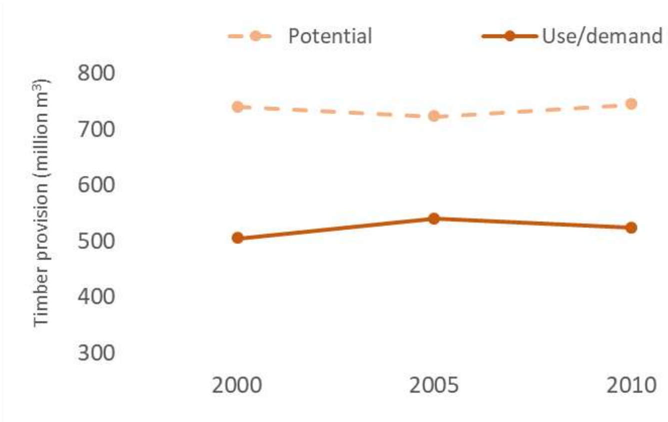

Figure 3. Changes of timber provision as ecosystem service

Fact sheet 5.0.300: Ecosystem service: carbon sequestration

1. General information

- Regulating and maintenance ecosystem service (CICES V.5.1);
- Carbon sequestration from the atmosphere by ecosystems;
- Components assessed for carbon sequestration:
    - Use: net CO_2 sequestration by ecosystems (tonne/year)
    - Demand: CO_2 concentration in the atmosphere (ppm)

2. Data sources

The assessment of carbon sequestration by ecosystems is based on data of the greenhouse gases (GHG) inventory for the Land Use, Land Use Change and Forestry (LULUCF) sector reported annually[71]. LULUCF data provide net emissions and removal of CO_2 per different land use categories that roughly match different MAES ecosystem types. Land uses reported in LULUCF data are forest land, cropland, grassland, wetland and settlements (forestry is not included since in the accounting framework, it corresponds to an economic sector and not to the ecosystem role). Although there might be some slight differences in the ecosystem definitions provided by LULUCF and MAES (Table 1), we consider them as negligible. Lack of perfect correspondence of definitions of land cover and ecosystem types is a common issue when integrating data derived from different data sources. However, in this case, we pose that there are no major differences that might affect the main outcome of this assessment.

The use of the service was considered as the net CO_2 sequestration (net ecosystem removals minus net ecosystem emissions[72,73]). LULUCF data were used to make maps of the CO_2 sequestration at country level. The assessment is further described in Vallecillo et al. 2019[74].

The demand (need) for this ecosystem service is arising from the accumulation of CO_2 in the atmosphere. Data for the assessment of the demand are provided by the National Oceanic and Atmospheric Administration (NOAA)[75].

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[71] https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

[72] EEA (2018) National emissions reported to the UNFCCC and to the EU Greenhouse Gas Monitoring Mechanism. Published by Eurostat (update 05/06/2018). Downloaded on the 06/06/2018. Retrieved from http://appsso.eurostat.ec.europa.eu/nui/show.do?lang=en&dataset=env_air_gge

[73] Ecosystem uptake corresponds to the negative net emissions reported in the LULUCF data, while ecosystem emissions are the positive net values of the inventory.

[74] Vallecillo, S., La Notte, A., Kakoulaki, G., Kamberaj, J., Robert, N., Dottori, F., Feyen, L., Rega, C. & Maes, J. (2019) Ecosystem services accounting. Part II-Pilot accounts for crop and timber provision, global climate regulation and flood control, EUR 29731 EN, Publications Office of the European Union, Luxembourg. Retrieved from http://publications.jrc.ec.europa.eu/repository/handle/JRC116334.

[75] Available at: https://www.eea.europa.eu/data-and-maps/daviz/atmospheric-concentration-of-carbon-dioxide-4#tab-chart_5_filters=%7B%22rowFilters%22%3A%7B%7D%3B%22columnFilters%22%3A%7B%22pre_config_polutant%22%3A%5B%22CO2%20(PPM)%22%5D%7D%7D

- Data holder: JRC at the JRC data catalogue in MAES collection[76];
- Format and spatial resolution: vector maps at country level (based on EU National Inventory Report 2018)[4];
- Spatial coverage: EU-28;
- Years available: data at country level for 2000, 2006 and 2012 (changes over time are based on the comparison between 2000 and 2012)

Table 1. Correspondence between land use categories and ecosystem types.

LULUCF land categories[1]	MAES ecosystem types[2]
Forest land (*land with woody vegetation consistent with thresholds used to define forest land in the national GHG inventory*)	**Woodland and forest** (*forest and transitional woodland shrub*)
Cropland (*arable and tillage land, and agro-forestry systems where vegetation falls below the thresholds used for the forest land category*)	**Cropland** (*arable land, permanent crops and heterogeneous agricultural areas*)
Grassland (*rangelands and pasture land that is not considered as cropland*)	**Grassland** (*pastures and natural grassland*)
Wetlands (*land that is covered or saturated by water for all or part of the year (e.g., peatland) and that does not fall into the forest land, cropland, grassland or settlements categories. It includes reservoirs as a managed sub-division and natural rivers and lakes as unmanaged sub-divisions*)	**Wetlands** (*Inland marshes and peatbogs*)
Settlements (*all developed land, including transportation infrastructure and human settlements of any size*)	**Urban** (*artificial surfaces*)
Other land (*bare soil, rock, ice, and all unmanaged land areas that do not fall into any of the other five categories. It allows the total of identified land areas to match the national area, where data are available*)	**Sparsely vegetated land** (*unvegetated or sparsely vegetated habitats (naturally unvegetated areas). Often these ecosystems have extreme natural conditions that might support particular species. They include bare rocks, glaciers and dunes, beaches and sand plains*)
[1]https://www.ipcc.ch/site/assets/uploads/2018/03/GPG_LULUCF_FULLEN.pdf [2]http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf. Detailed description of CORINE land cover classes can be found in https://land.copernicus.eu/user-corner/technical-library/corine-land-cover-nomenclature-guidelines/html	

[76] https://data.jrc.ec.europa.eu/collection/maes

3. Assessment of the indicator

3.1. Short description of the scope of the indicator

Carbon sequestration as ecosystem service is considered as the net removal by ecosystems of carbon dioxide from the atmosphere, contributing therefore to mitigate climate change. Forest land is the only ecosystem type reported as net sink of CO_2, while the others act as net sources releasing CO_2 to the atmosphere.

For consistency with the assessment of other ecosystem services, we considered data only for 2000, 2006 and 2012. However, longer periods, based on the annually reported data since 1990, are assessed in dedicated reports[77], where other GHG are also included.

3.2. Maps

High net CO_2 sequestration by ecosystems can be found in countries such as Spain, France, Poland, Sweden and Finland, showing that the balance between removals and emissions by ecosystems results in a net CO_2 sequestration contributing to an important mitigation of CO_2 emissions from fossil fuels. On the contrary, in countries such as the Netherlands and Ireland ecosystems are reported as net sinks CO_2 contributing therefore to increase CO_2 in the atmosphere.

Net CO_2 sequestration by ecosystems increased in 10 countries out of 28, with Hungary, France, Finland and Greece showing the most important growth. In contrast, countries such as Cyprus, Denmark, and Austria show a decrease in the net role of ecosystems sequestering CO_2 from the atmosphere.

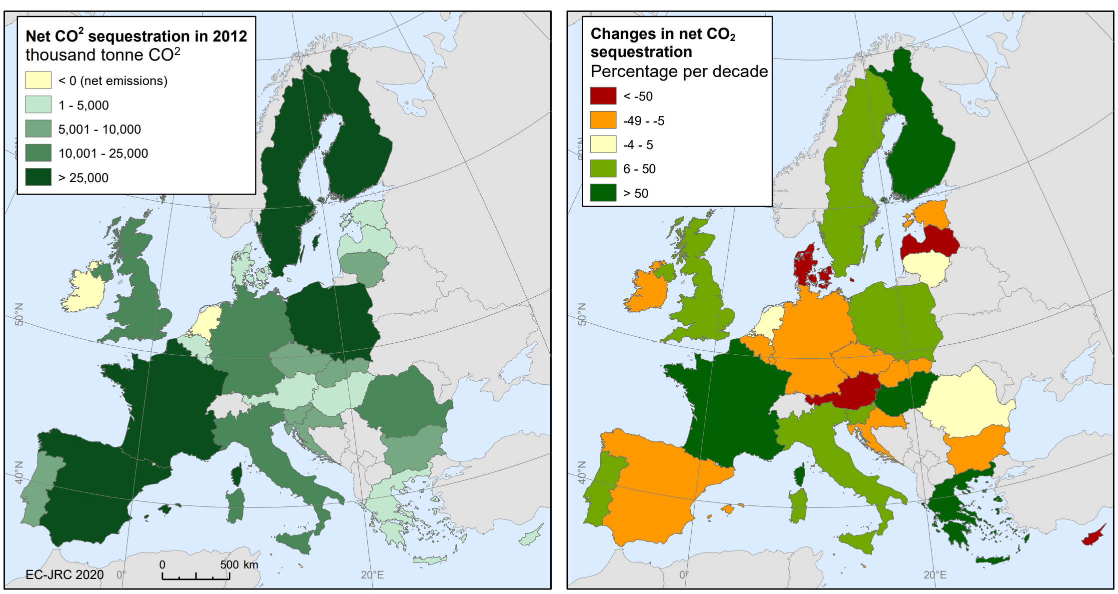

Figure 1. Maps of net CO_2 sequestration and changes between 2000 and 2012.

77 https://unfccc.int/process-and-meetings/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories-annex-i-parties/national-inventory-submissions-2019

3.3. Statistical analysis of the trend

Changes for the sequestration of GHG were analysed between 2000 and 2012 for all EU-28 countries. Changes at EU level larger than ±5% per decade were considered to be significant. If changes were smaller than ±5%, the non-parametric Wilcoxon test was applied considering significant changes when p-value was lower than 0.05.

3.4. Key trend at EU level[78]

The role of ecosystem sequestering CO_2 shows no significant changes for the period assessed (between 2000 and 2012). However, it should be considered that a relatively high inter-annual variation in the net CO_2 flow exists (not fully displayed in this assessment), mainly due to the CO_2 emissions derived natural disturbances (fires, wind throws).

Table 2. CARBON SEQUESTRATION AT THE EU LEVEL

Components of the service	Year 2000	Year 2006	Year 2010*	Year 2012	Change (% per decade)
Use (million tonne CO_2)	292	292	302	306	4%$^{n.s.}$
Ecosystem emissions (million tonne CO_2)	181	182	189	174	4%$^{n.s.}$
Demand (ppm CO_2)	369	381	389	393	5%
Fossil fuel emissions (million tonne CO_2)	4,906	5,102	4,681	4,470	-7%
Mitigation (%)	5.9	5.7	6.5	6.9	13%

*Values calculated by interpolation

$^{n.s.}$Changes between 2000 and 2012 not statistically significant

When looking separately to the different periods covered in the assessment (between 2000 and 2006 and between 2006 and 2012); there are different patterns of changes. Although in general terms there are no significant changes, for the second period (between 2006 and 2012) there is an increase of the net flow of CO_2 sequestration (Figure 7). This increase is explained by the decrease of ecosystem emissions, given that ecosystem uptake (mainly by forest) showed no changes for the same period.

[78] EU-25 (excluding Cyprus, Malta and Croatia because of the lack of data)

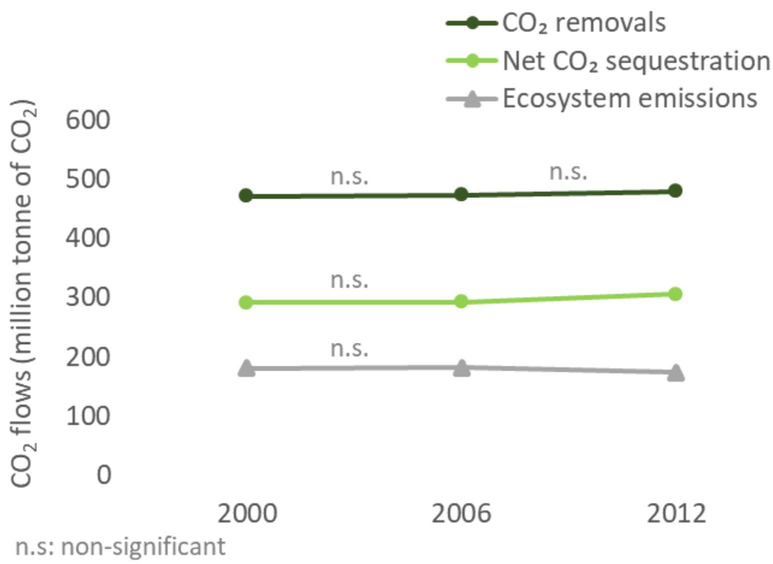

Figure 2. CO_2 ecosystem flows in the EU over time.

Fact sheet 5.0.400: Ecosystem service: crop pollination

1. General information

- Regulating and maintenance ecosystem service (CICES V.5.1);
- Crop pollination: transfer of crop pollen by wild bees resulting in the fertilization of crops; maintaining and/or increasing the crop production. This assessment estimates only pollination by wild bees;
- Components assessed for crop pollination:
  - Potential: dimensionless indicator of environmental suitability to support wild insect pollinators (between 0 and 1)
  - Demand: extent of pollinator-dependent crops (in km^2)
  - Use: area where high pollination potential (environmental suitability > 0.2) and demand overlap (in km^2)
  - Unmet demand: extent of pollinator-dependent crops not covered by high pollination potential (in km^2)

2. Data sources

The assessment of crop pollination is described in Vallecillo et al. 2018[79].

- Data holder: JRC at the JRC data catalogue in MAES collection[80];
- Format and spatial resolution:
  - Indicator environmental suitability: raster, 1 km x 1 km;
  - Other ecosystems services components: vector data at local administrative level;
- Spatial coverage: minimum common coverage for all maps is EU-25 (excluding Croatia, Cyprus and Malta);
- Years available: 2000, 2006 and 2012 (because of the lack of data, we assumed the demand between 2006 and 2012 was the same). Changes over time are based on the comparison between 2000 and 2012

3. Assessment of the indicators

3.1. Short description of the scope of the indicators

The **ecosystem service potential** reports the environmental suitability to support wild insect pollinators. Environmental suitability is calculated based on the integration of two different models (for bumblebees[81] and solitary bees). The main environmental factors included to assess suitability are climate and variables related to different land covers and landscape structure. The indicator can potentially vary between 0 (lack of environmental suitability) and 1 (maximum suitability). After

[79] Vallecillo, S., La Notte, A., Polce, C., Zulian, G., Alexandris, N., Ferrini S. & Maes, J. (2018) Ecosystem services accounting: Part I - Outdoor recreation and crop pollination, EUR 29024 EN; Publications Office of the European Union, Luxembourg. Retrieved from http://publications.jrc.ec.europa.eu/repository/handle/JRC110321.

[80] https://data.jrc.ec.europa.eu/collection/maes

[81] https://oneecosystem.pensoft.net/article/28143/list/9/

integrating the two models, the maximum value reached within this assessment was 0.5. This indicator has been used to delineate areas with high pollination potential (also known as Service Providing Areas, SPA), where environmental suitability was above 0.2. SPA were used to calculate the use area.

The **demand for crop pollination** shows in a spatially explicit way where crop pollination is needed by pollinator-dependent crops for 2004 (matched with 2000) and 2008 (matched with 2006 and also 2012).

The **use of pollination** by crops is quantified as the overlapping area between SPA (environmental suitability > 0.2). We assumed that crop production attributable to the role of pollinators was only generated in the use area.

The **unmet demand for crop pollination** is quantified as the extent of pollinator-dependent crops (in km^2) not covered by SPA (i.e., environmental suitability lower than 0.2). In areas of unmet demand, the contribution of pollinators to crop production can potentially be compromised.

3.2. Maps

Ecosystem potential to support pollinators shows higher values in central-eastern Europe (Figure 1). This pattern is driven especially by the suitability of these areas for bumblebees. Increase of the pollination potential between 2000 and 2012 took place especially in the south of Europe, while decreases show a more widespread pattern.

The map of the **demand for crop pollination** shows large areas in Romania, Hungary, but also in many other countries of central-eastern Europe, and Mediterranean countries (Figure 1). Scandinavian countries show the smallest demand. The demand reveals larger increases in Poland, Lithuania, Latvia, and Estonia.

The **use of crop pollination** is especially high in Czechia, Hungary, Poland and West Germany as a result of the overlap between pollinator-dependent crops and high environmental suitability for pollinators (Figure 1). A careful look at these maps (Figure 1) shows that in some areas there is correspondence between areas of expansion of pollinator-dependent crops ('areas of demand') and areas with enhancement of pollination potential (mainly in Spain and Greece). The parallel increase of demand and potential in these areas, translates into an increase of their overlapping areas, in other words in the area of use. It is important to bear in mind that the use of crop pollination could also have been quantified as the yield attributable to pollinators; however, this other indicator would be very much influenced by the human inputs in agriculture increasing yield growth, and may result in a misleading messages for this assessment.

The **unmet demand** for crop pollination is very low in north and central Europe, due to high environmental suitability to support pollinators (bumblebees and solitary bees) in these areas (Figure 2). Overall, we can see larger changes in the unmet demand in areas where pollination potential presents low-intermediate values (north and south of the EU). It is in these areas where the impact of change in the pollination potential may have larger consequence on the contribution of pollination to human well-being, requiring therefore especial attention.

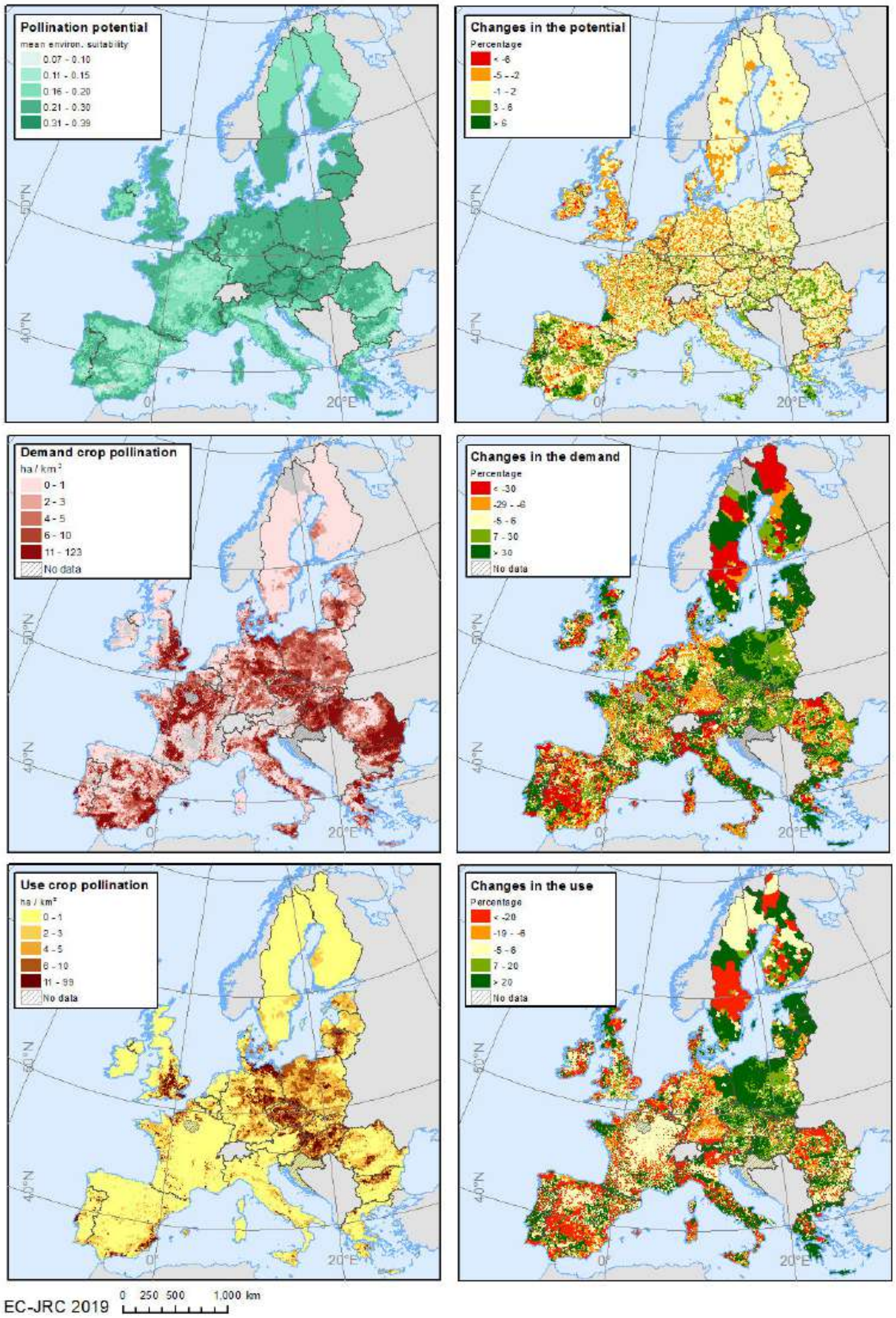

Figure 1. Maps of crop pollination indicators for 2012 and changes between 2000 and 2012

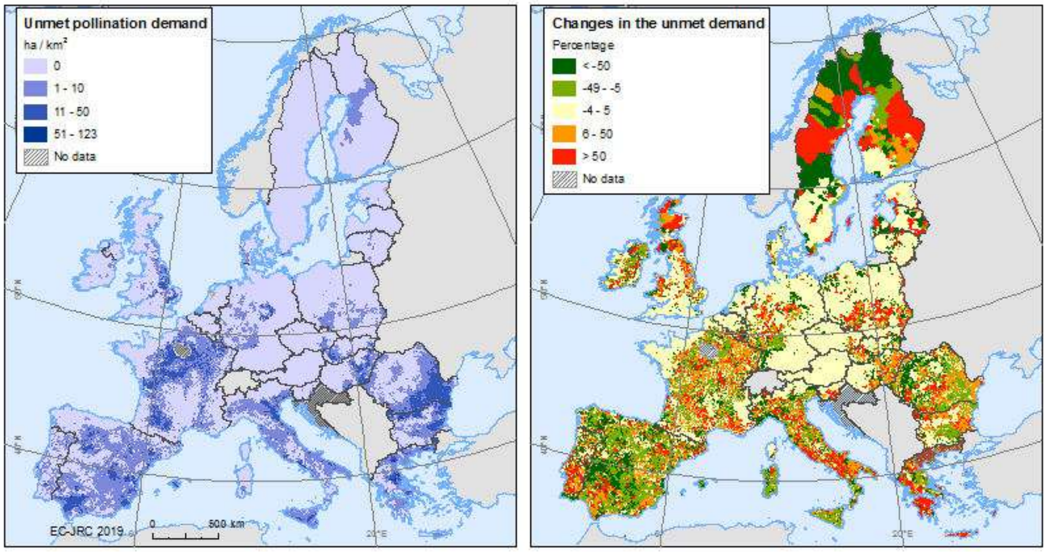

Figure 2. Maps of unmet demand for crop pollination in 2012 and changes between 2000 and 2012

3.3. Statistical analysis of the trend

Changes for the different indicators of crop pollination were analysed for the values of the indicators aggregated at municipal level (i.e., local administrative units) between 2000 and 2012. Changes larger than ±5% per decade were considered to be significant. If changes at EU level were smaller than ±5%, the non-parametric Wilcoxon test was applied using bootstrapping (sampling 1% of the reference units, 1000 times). Changes were considered to be significant when p-value was lower than 0.05.

3.4. Key trend at EU level[82]

At the EU level, pollination potential decreased by about 1% per decade. This change is relatively important if we take into account that it is an average value, with a lot of spatial variability across the EU (Figure 1). Furthermore, had we considered other environmental pressures affecting pollinators; this decreased in environmental suitability might be even larger. The downward trend of pollination potential is also found in Natura 2000 sites at the same rate as at EU level.

Although spatial data to assess the demand for crop pollination were limited (not available for 2012), the demand between 2004 and 2008 shows an upward trend, equivalent to a 5% raise per decade.

In spite of the observed decrease in the pollination potential, the use of crop pollination increases by 8% per decade (based on the comparison between 2000 and 2012) (Table 1).

[82] EU-26 (excluding Cyprus and Malta. Croatia not included in the maps of demand and use)

Table 1. CROP POLLINATION AT THE EU LEVEL					
Components of the service	**Year 2000**	**Year 2006**	**Year 2010***	**Year 2012**	**Change (% per decade)**
Potential (dimensionless indicator [0-1])	0.212	0.213	0.211	0.210	-1%
Potential Natura 2000 (indicator [0-1])	0.219	NA	0.218	0.218	-1%
Demand (thousand km^2)	153	162	162**	162**	5%
Use (thousand km^2)	72	81	79	79	8%
Unmet demand (thousand km^2)	81.4	81.2	82.7	83.5	2%[n.s.]
Share of demand unmet (%)	53	50	51	52	-5%

*Values calculated by interpolation

**Due to the lack of data, we used the same demand as in 162

[n.s.] Differences between 2000 and 2012 are non-statistically significant

NA - not assessed

Analysis of the different periods assessed (between 2000 and 2006, and between 2006 and 2012) shows different performance of crop pollination (Figure 3). While pollination potential, demand and use by crops are increasing for the first period, for the second one (between 2006 and 2012) there is a decrease of the pollination potential (-1.4%) and the use area (-3%) due to the shrinkage of pollination potential where pollinators are needed[83]. Given the intrinsic spatial nature of this indicators, in fact, it is important not only to analyse gains and losses of the pollination potential, but also where they take place. Ultimately, downward trends will have heavier impacts in the use of crop pollination when observed in areas of high pollination demand, than when observed in areas of lower pollination demand. Importantly, the extent of pollinator-dependent crops in the absence of suitable areas for pollinators (unmet demand) increases for the second period (2.8%).

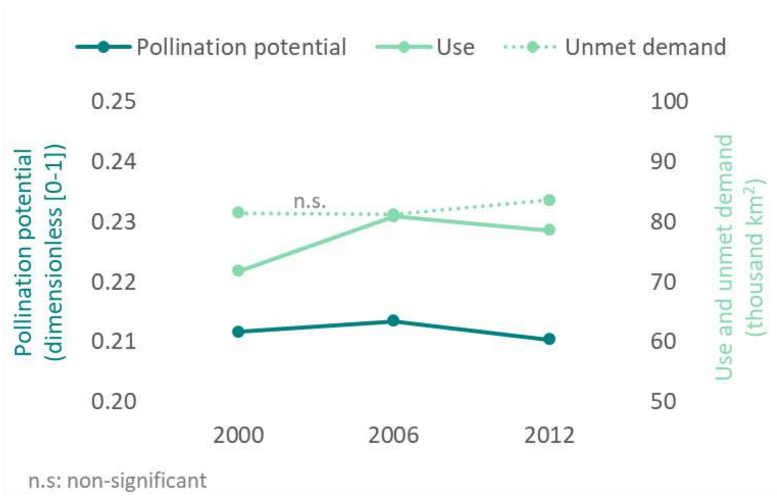

Figure 3. Changes in crop pollination in the EU

[83] We assumed no changes in the demand because of the lack of data.

Fact sheet 5.0.500: Ecosystem service: flood control

1. General information

- Regulating and maintenance ecosystem service (CICES V.5.1);
- Flood control: regulation of water flow (runoff) by ecosystems that mitigates or prevents potential damage to land assets (i.e., infrastructure, agriculture) and human lives. The current assessment covers only riverine floods for artificial surfaces (i.e. urban MAES ecosystems);
- Components assessed for flood control:
    - Potential: dimensionless indicator of potential runoff retention (between 0 and 100)
    - Demand: extent of artificial surfaces (in km^2) located in floodplains (for a return period of 500 years)
    - Use: extent of the demand (artificial areas) protected by upstream ecosystems (in km^2)
    - Unmet demand: extent of the demand not protected by upstream ecosystems (in km^2).

2. Data sources

The assessment of flood control is described in Vallecillo et al. 2019[84] and Vallecillo et al. 2020[85].

- Data holder: JRC at the JRC data catalogue in MAES collection[86];
- Format and spatial resolution:
    - Indicator potential runoff retention: raster, 100 m x 100 m;
    - Ecosystems services components: vector data at sub-catchment level;
- Spatial coverage: EU-26 (excluding Cyprus and Malta, and some regions in Croatia, Bulgaria and Finland);
- Years available: 2006 and 2012.

3. Assessment of the indicators

3.1. Short description of the scope of the indicators

The **ecosystem service potential** to reduce runoff is quantified by means of a dimensionless indicator of potential runoff retention (zero means no runoff retention, while a value of 100 indicates the maximum runoff retention).

The **demand for flood control** shows in a spatially explicit way where flood control is needed by artificial areas.

[84] Vallecillo, S., La Notte, A., Kakoulaki, G., Kamberaj, J., Robert, N., Dottori, F., Feyen, L., Rega, C. & Maes, J. (2019) Ecosystem services accounting. Part II-Pilot accounts for crop and timber provision, global climate regulation and flood control, EUR 29731 EN, Publications Office of the European Union, Luxembourg. Retrieved from http://publications.jrc.ec.europa.eu/repository/handle/JRC116334.
[85] Vallecillo, S., Kakoulaki, G., La Notte, A., Feyen, L., Dottori, F., & Maes, J. (2020). Accounting for changes in flood control delivered by ecosystems at the EU level. *Ecosystem Services, (in press)*
[86] https://data.jrc.ec.europa.eu/collection/maes

Flood control by ecosystems is considered to be used only when areas of high runoff retention[87] are located upstream to demand areas, and contributing therefore to reduce downstream runoff. Areas of high runoff retention are considered 'Service Providing Areas' (SPA). In this way, the **use of flood control by ecosystems** is quantified as the extent of artificial areas in floodplains protected by upstream ecosystems (in km^2). The use of flood control reaches the minimum value when upstream areas from the demand present 0% of SPA, and maximized when 100% of the upstream area presents SPA. Flood control accounts developed under KIP INCA also includes the protection of agricultural areas. However, for the sake of simplicity, only the protection of artificial areas is presented here. Further methodological details can be found in Vallecillo et al. 2019[88] and Vallecillo et al, 2020[89].

3.2. Maps

Visual comparison of maps for flood control potential and flood control demand shows some complementarity: areas with high potential (mainly mountain and forested areas) spatially match with areas of none or low demand and *vice versa* (Figure 1). This is usually translated in large areas of unmet demand, like for instance the Po Valley in Italy or the east of Hungary. However, the spatial distribution of the use of flood control as ecosystem service does not only depend on the amount of ES potential and demand, but also how it is located. For instance, in some areas in the Netherlands, there is high demand and relatively low ES potential; however, they present a high use of the service due to the role of upstream ecosystems in south of the Netherlands and Belgium.

Map of changes (Figure 2) shows a more widespread pattern of a downward trend in flood control potential all over the EU, although some areas in Czechia, Hungary, Portugal and Finland show also an improvement in the potential of ecosystems to reduce runoff. The demand for flood control by artificial areas is mainly increasing (with very limited number of municipalities showing a decrease). Changes in the demand for flood control are related to urban sprawl and land take taking place in floodplains (return period of 500 years). Both, changes in the potential or in the demand drive fluctuations in the use of flood control as ecosystem service. In the case of the Netherlands, the increase in the use is mainly due to an increase in the demand, while in Czechia the use increases due to the enhancement of natural capital to reduce runoff. Importantly, there is an overall increase of the unmet demand, which demonstrates that more ecosystems would be needed to contribute to reduce runoff and control flooding.

Increases in the unmet demand follow a similar patter to the increase in the demand (Figure 2), demonstrating that there is a lack of flood control by ecosystems for the new built up areas in flood plains. Only in the case of the Netherlands, the level of protection by artificial defense measures is high

[87] Thresholds vary by ecosystem type: 61 for natural and semi-natural ecosystems, 52 for agriculture areas, 27 for artificial areas. For further details see Vallecillo et al. 2020.
[88] Vallecillo, S., La Notte, A., Kakoulaki, G., Kamberaj, J., Robert, N., Dottori, F., Feyen, L., Rega, C. & Maes, J. (2019) Ecosystem services accounting. Part II-Pilot accounts for crop and timber provision, global climate regulation and flood control, EUR 29731 EN, Publications Office of the European Union, Luxembourg. Retrieved from http://publications.jrc.ec.europa.eu/repository/handle/JRC116334.
[89] Vallecillo, S., Kakoulaki, G., La Notte, A., Feyen, L., Dottori, F., & Maes, J. (2020). Accounting for changes in flood control delivered by ecosystems at the EU level. *Ecosystem Services, (in press)*

enough to safeguard all land assets from flooding for the maximum return period considered (500 years). Therefore, for this country we considered that the demand for flood control was always satisfied by the current level of protection and thus, the unmet demand was considered to be equal to zero.

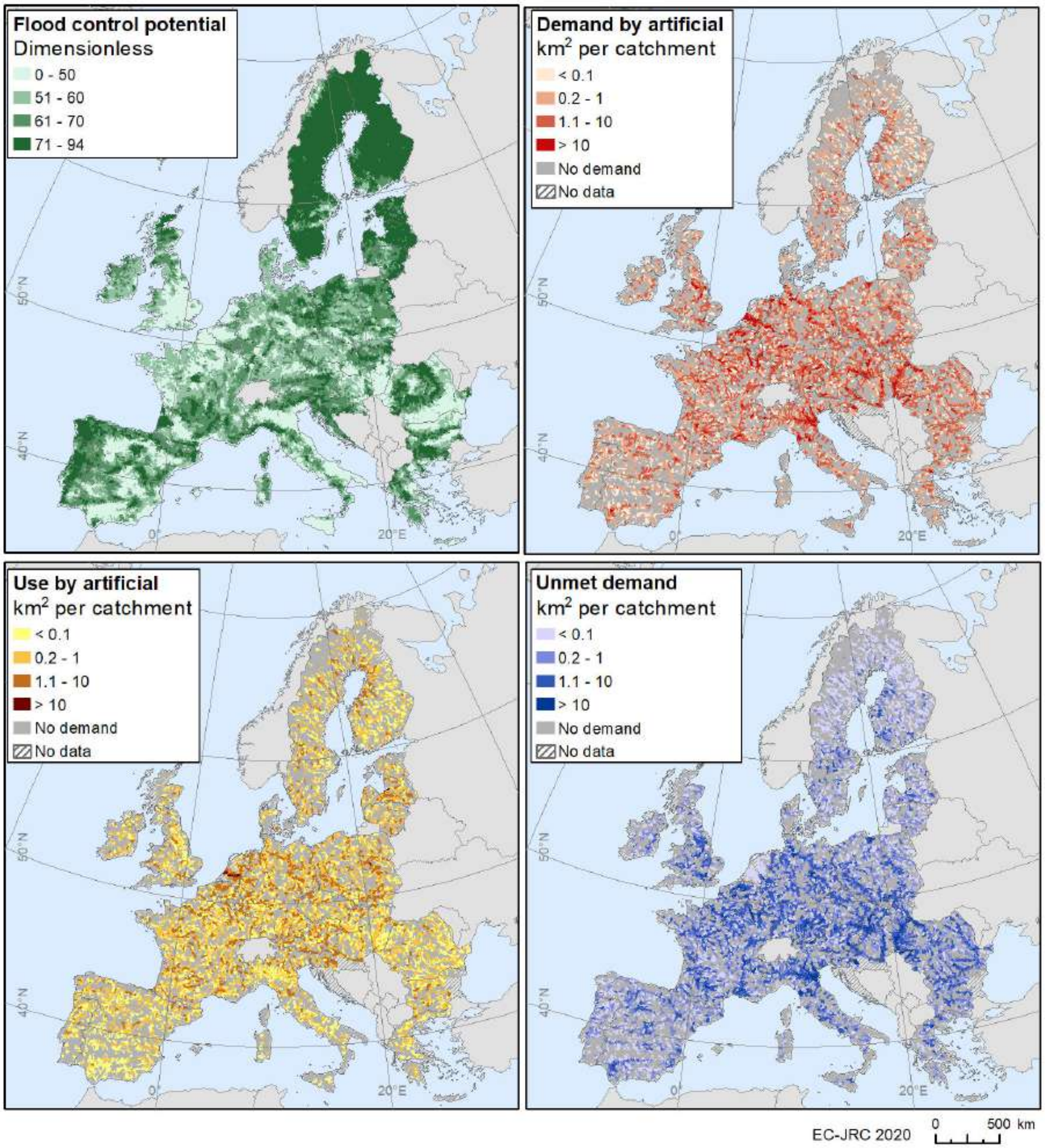

Figure 1. Maps of flood control by ecosystems in 2012.

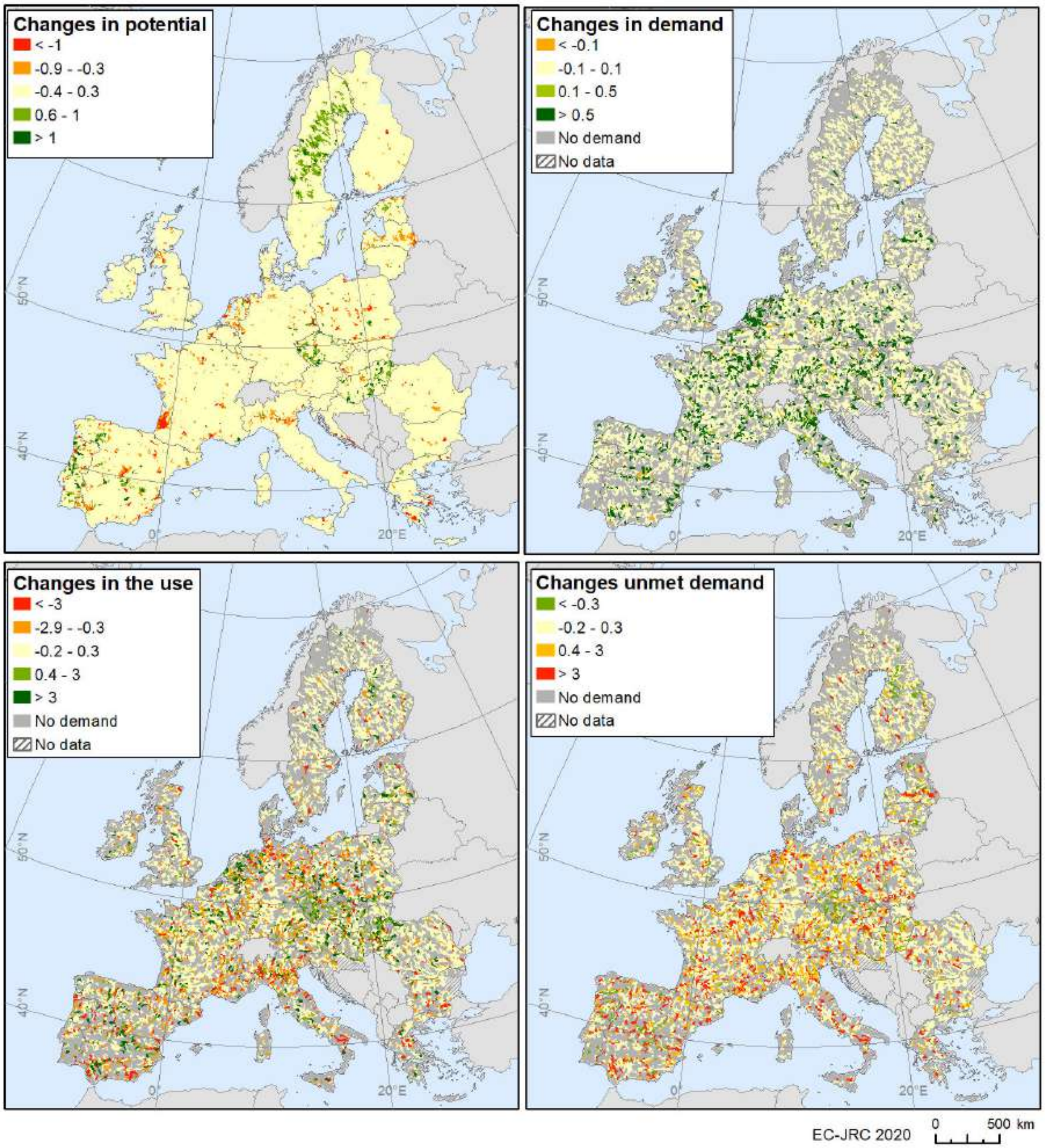

Figure 2. Maps of changes in flood control by ecosystems between 2006 and 2012 (in %).

3.3. Statistical analysis of the trend

Changes for the different indicators of flood control were analysed for the values of the indicators aggregated at municipal level (i.e., local administrative units) between 2006 and 2012. Changes larger than ±5% per decade were considered to be significant. If changes at EU level were smaller than ±5%, the non-parametric Wilcoxon test was applied using bootstrapping (sampling 1% of the reference units, 1000 times). Changes were considered to be significant when p-value was lower than 0.05.

3.4. Key trend at EU level[90]

Between 2006 and 2012, there was a very slight, but significant, decrease in the flood control potential (by 0.1%) (Table 1). Although the magnitude is not large, the Wilcoxon test applied shows that the number of municipalities undergoing a decrease in flood control potential is significantly larger than the municipalities with an increase (as also shown in Figure 2). The average value at the EU level is masking the large spatial variability of the changes in flood control potential across the EU territory. In the EU, 43 000 km^2 of land show a significant[91] increase in flood control potential, while 55 000 km^2 experience a decrease (Figure 3). It should also be noted that these changes refer only to a period of 6 years, which is considered a relative short period to track changes in ecosystem services at European scale.

Table 1. FLOOD CONTROL BY ECOSYSTEMS AT THE EU LEVEL (for artificial land)

Components of the service	Year 2000*	Year 2006	Year 2010*	Year 2012	Change (% per decade)
Potential (dimensionless indicator [0-100])	62.22	62.20	62.18	62.18	-0.1%
Demand (thousand km^2)	18.26	18.56	18.76	18.86	3%
Use (thousand km^2)	4.95	4.97	4.98	4.98	0.5%$^{n.s.}$
Unmet demand (thousand km^2)	12.31	12.54	12.70	12.78	3%$^{n.s.}$
Share of demand unmet (%)	67.4	67.6	67.7	67.8	0.5%$^{n.s.}$

*Values calculated by interpolation

$^{n.s.}$ Differences between 2006 and 2012 are non-statistically significant

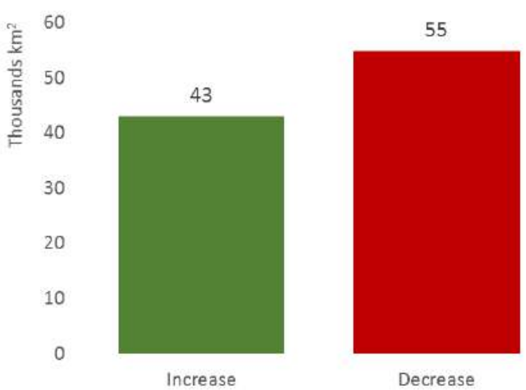

Figure 3. Areas where flood control potential changes between 2006 and 2012 in the EU.

At the other side of the supply of flood control, the demand for this ecosystem service by artificial land increased by 3 % per decade. As a result of the mismatch between the changes in ES potential and demand, the use of flood control by ecosystems is stable for this period, even in spite of the generalized increase of the demand.

[90] EU-26 (excluding Cyprus and Malta, and some regions in Croatia, Bulgaria and Finland)

[91] When changes are larger than 5% per decade

Complementarily, the unmet demand shows a lack of flood control by ecosystems: 7 % of the artificial areas in the EU were not protected by ecosystems (which represent 68 % of artificial areas in floodplains, Table 1 showing the share of the unmet demand) (Figure 4). Although in many cases, flood control by ecosystems is complemented with artificial defence measures for flood protection, the role of ecosystems is still very relevant. In fact, ecosystems act in synergy with man-made infrastructure reducing flood peaks and keeping it within safe operational limits. If the ecosystem potential to reduce water runoff decreases, man-made infrastructure will have to withstand higher amounts of runoff for which they were initially not designed. Importantly, we found that the unmet demand increased by 3 % per decade, at the same rate as the demand, confirming the worsening protective role of ecosystems.

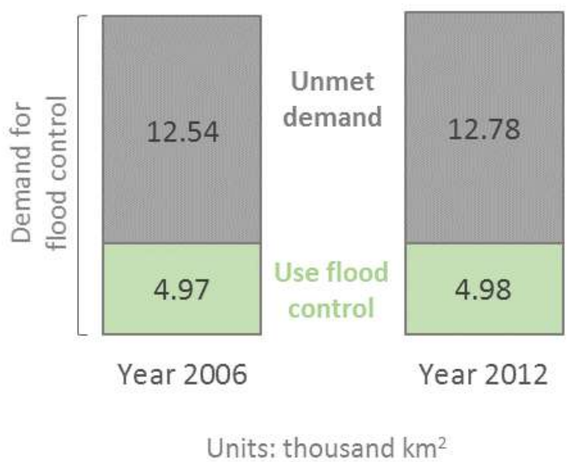

Figure 4. Demand, use and unmet demand for flood control over time.

Fact sheet 5.0.600: Ecosystem service: daily nature-based recreation

1. General information

- Cultural ecosystem service (CICES V.5.1);
- Daily nature-based recreation: biophysical characteristics or qualities of ecosystems that are viewed, observed, experienced or enjoyed in a passive, or active, way by people on a daily basis;
- Components assessed for nature-based recreation:
    - Potential: A) Ecosystem-based potential: a dimensionless indicator of the availability of opportunities provided by nature (between 0 and 1), and B) Extent of suitable areas for daily recreation (proximal high-quality areas considered as Service Providing Areas - SPA- for daily recreation; in km^2)
    - Demand: population (inhabitants)
    - Use: potential visits to suitable areas for daily recreation (number of visits)
    - Unmet demand: people living beyond 4 km from suitable areas for daily recreation

2. Data sources

The assessment of daily nature-based recreation is based on the spatial model described in Vallecillo et al. 2019[92].

- Data holder: JRC at the JRC data catalogue in MAES collection[93]
- Format and spatial resolution: vector data at local administrative units equivalent to municipalities
- Spatial coverage: EU-28 for 2012; while for 2000 comparisons in the ecosystem service potential and use can only be made for the EU-15 (Austria, Belgium, Germany, Denmark, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden and United Kingdom)
- Years available: 2000, 2006 and 2012 for the potential and years 2000 and 2012 for demand, use and unmet demand.

3. Assessment of the indicator

3.1. Short description of the scope of the indicators

The **ecosystem-based potential** is a dimensionless indicator of the availability of opportunities provided by nature. It mainly includes a suitability score to support recreation for each land cover type (i.e. zero/very low for artificial areas, close to one for semi-natural areas), quality and distance to water bodies and the presence of protected areas. However, proximity of areas with high recreation potential to infrastructure such as roads and residential areas is of especial relevance for the assessment of recreation on a daily basis. For this reason, only locations with high recreation opportunities but close to

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[92] Vallecillo, S., La Notte, A., Zulian, G., Ferrini, S. & Maes, J. (2019) Ecosystem services accounts: Valuing the actual flow of nature-based recreation from ecosystems to people. Ecological Modelling, 392, 196-211. https://doi.org/10.1016/j.ecolmodel.2018.09.023

[93] https://data.jrc.ec.europa.eu/collection/maes

urban areas and roads were considered suitable to be used on a daily basis. We refer to these locations as '**suitable areas for daily recreation**'.

The **demand for nature-based recreation** was assessed as the number of inhabitants, since population need natural sites for recreation purposes.

The **use of nature-based recreation** was estimated as the number of potential visits that inhabitants will do depending on the distance to the 'suitable areas for daily recreation'. Visits were calculated considering only the inhabitants that live closer than 4 km from suitable areas for daily recreation. Then, a mobility function was applied. See further details in Vallecillo et al. 2019[94].

The **unmet demand for nature-based recreation** was assessed as the inhabitants living beyond 4 km from suitable areas for daily recreation. Beyond this distance, population may need to take a car to reach 'suitable areas for daily recreation' or might use recreational areas with lower opportunities for, or lower quality of, nature-based recreation, therefore generating fewer benefits from nature.

3.2. Maps

Nature-based recreation potential shows high values especially in forest areas and also in Natura 2000 sites. Low values of recreation potential in vast areas of arable land or in built-up-dominated regions demonstrate that the landscape does not offer high quality recreation opportunities. Map of changes in the recreation potential between 2000 and 2012 shows the largest increases in Belgium, Germany and Greece, mainly due to the designation of new Natura 2000 sites (Figure 1). Designation of Natura 2000 sites does not necessarily imply any improvement in the physical suitability or condition of ecosystems supporting recreation. However, new protected areas usually involve the development of recreation services and facilities, such as adding walking paths and informative signs about designated areas with high natural value, increasing the recreation potential.

Complementarily to the nature-based potential, the delineation of 'suitable areas for daily recreation' show where areas with high recreation potential are close to roads or urban areas (Figure 2). Changes in 'suitable areas for daily recreation' are explained by change in the potential, but also by the sprawl of artificial areas into natural sites which increase the proximity of users and therefore their suitability to be used for daily-based recreation activities.

Regions in Central Europe, but also capital cities of each country show large **demand for nature-based recreation**. Demand decreases between 2000 and 2012 in Romania, Bulgaria, Portugal, and Latvia (Figure 1). The **use of nature-based recreation potential** is high where high potential is located nearby demand areas (i.e. where population live): Germany, Poland and Belgium among others. The use of the service decreases in some areas such as Easter Germany and Portugal because of a decline in demand. While in other countries such as the Netherlands and Belgium, the increase of the use coincide with increases in the demand (Figure 1).

[94] Vallecillo, S., La Notte, A., Zulian, G., Ferrini, S. & Maes, J. (2019) Ecosystem services accounts: Valuing the actual flow of nature-based recreation from ecosystems to people. Ecological Modelling, 392, 196-211. https://doi.org/10.1016/j.ecolmodel.2018.09.023

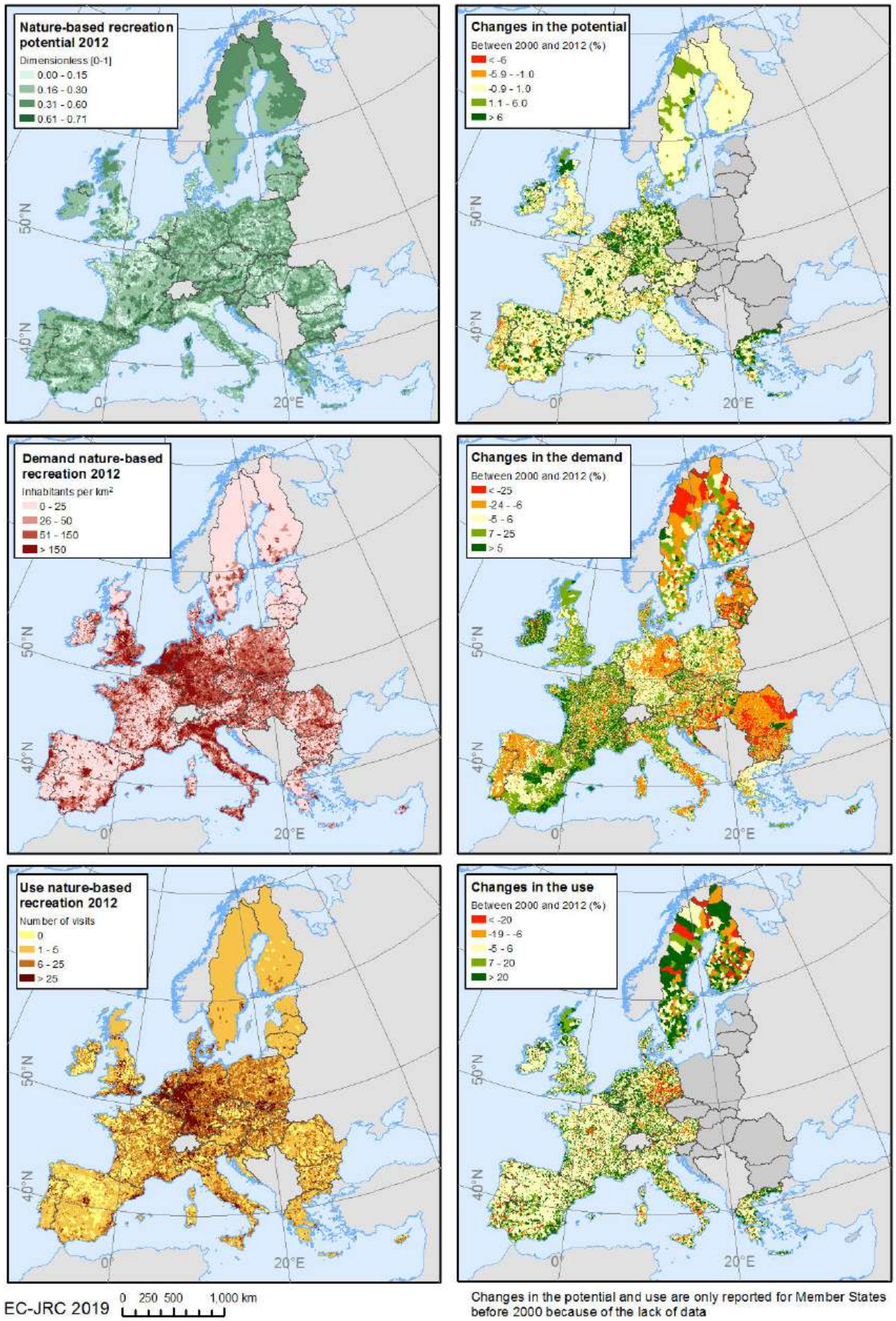

Figure 1. Maps of the different indicators of nature-based recreation and changes over time.

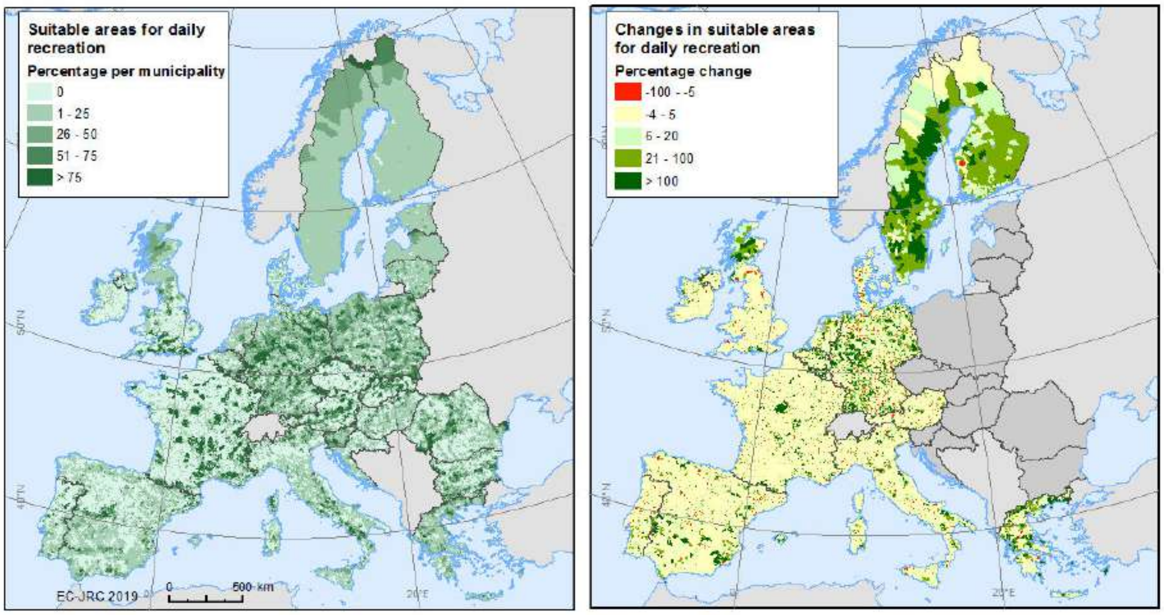

Figure 2. Maps of suitable areas for daily recreation.

The **unmet demand** for nature-based recreation shows high values in countries such as Ireland, Spain and Croatia (Figure 3). High unmet demand is also found in some municipalities of Sweden and Finland. Although there are not very large urban areas in these municipalities, a high share of the population lives further away from the few 'suitable areas for daily recreation' (Figure 2), since these cities are mainly surrounded by arable land, which offers low nature-based recreation opportunities. By contrast, countries such as Germany have low unmet demand because of the proximity of 'suitable areas for daily recreation' to urban centres.

3.3. Statistical analysis of the trend

Changes for the different indicators of nature-based recreation were analysed for the values of the indicators aggregated at municipal level (i.e., local administrative units) between 2000 and 2012. Changes larger than ±5% per decade were considered to be significant. If changes at EU level were smaller than ±5%, the non-parametric Wilcoxon test was applied using bootstrapping (sampling 1% of the reference units, 1000 times). Changes were considered to be significant when p-value was lower than 0.05.

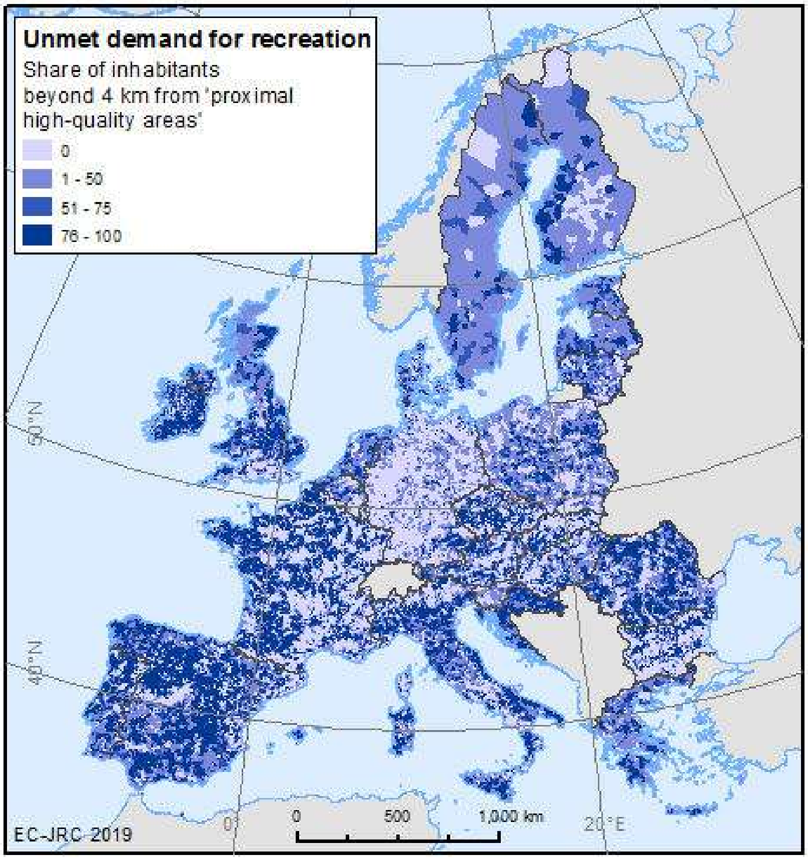

Figure 3. Maps of unmet demand for nature-based recreation.

3.4. Key trend at EU level[95]

Assessment of nature-based recreation on a daily basis shows that in spite of the stable trend in the ecosystem-based potential, there is a notable increase in the suitable areas for daily recreation that led to a higher use of this service, by 17% per decade. This increase in the use is also due to the increase in the demand, although at smaller extent (Table 1).

The recreation potential is especially relevant for the EU Biodiversity Strategy to 2020 showing a stable trend between 2000 and 2012. The lack of changes for this period can be explained by the importance of two offsetting drivers; while designation of Natura 2000 sites enhances the ecosystem-based potential, sprawl of artificial land decreases it. Only for the first period analysed (between 2000 and 2006), there was an upward trend in the ecosystem-service potential (Figure 4).

[95] Values are based on the EU-15 (Austria, Belgium, Germany, Denmark, Spain, Finland, France, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden and United Kingdom)

Table 1. DAILY NATURE-BASED RECREATION AT THE EU LEVEL					
Components of the service	**Year 2000**	**Year 2006**	**Year 2010***	**Year 2012**	**Change (% per decade)**
Potential (dimensionless indicator [0-1])	0.269	0.276	0.279	0.280	3%$^{n.s.}$
Suitable areas for daily recreation (thousand km^2)	440	516	532	540	19%
Demand (million inhabitants)	342	NA	357	360	4%
Use (million potential visits)	26	NA	31	32	17%
Unmet demand (million inhabitants)	164	NA	150	147	-8%
Share of demand unmet (%)	48	NA	42	41	-12%

*Values calculated by interpolation

$^{n.s.}$ Differences between 2000 and 2012 are non-statistically significant

NA - not available

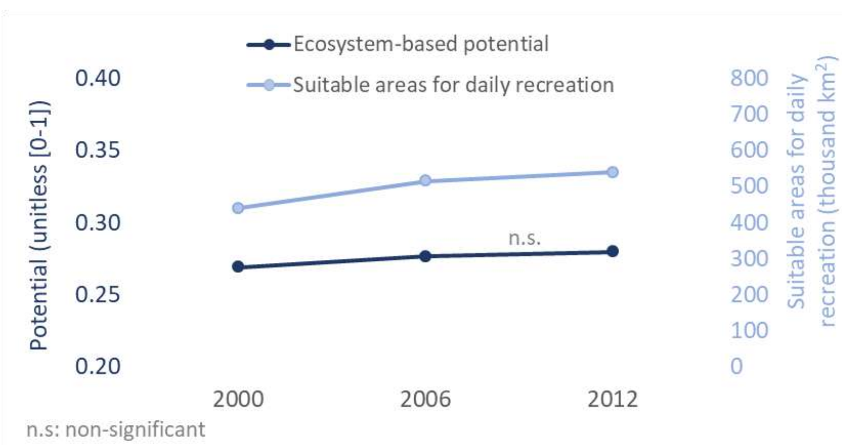

Figure 4. Nature-based recreation over time in the EU-15.

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