European Environment Agency

European Topic Centre on Urban, Land and Soil Systems

Policy relevance analysis of geospatial indicators

Final Deliverable under Task 1.8.2.5

Updated final version (v1.1)
Date: 18.12.2019

Prepared by/compiled by:
Ana Frelih-Larsen
Sophie Ittner
Sandra Naumann
Mirko Gregor
Gerard Hazeu
Bas Pedroli

umweltbundesamt

WAGENINGEN UNIVERSITY & RESEARCH

gisat

UAB Universitat Autònoma de Barcelona

Budapest Főváros Kormányhivatala

eco logic

ICLEI Local Governments for Sustainability

space 4 environment

Table of contents

1 INTRODUCTION

This report provides an assessment of the policy relevance of EEA's geospatial indicators, and examines gaps and opportunities for improvement of their policy relevance. The report supports the long-term objective of building up the knowledge base at EEA on land and soil through a set of policy relevant indicators to better inform policy.

The structure of the report is as follows. First, the conceptual framework within which we examine the indicators is outlined. As next, the policy context for land and soil management is outlined, focusing on those policies where there are specific and targeted soil-related objectives. The main geospatial indicators are then characterized according to a set of evaluation criteria, and their policy relevance. Finally, gaps in the coverage or other aspects of geospatial indicators are identified along with the opportunities for improvements.

1.1 CONCEPTUAL FRAMEWORK

The overall purpose of environmental indicators, including geospatial indicators, is to facilitate communication on environmental matters to the wider public and to inform policymaking.

We can use four different, but complementary conceptual framings, in order to contextualise the geospatial indicators in the policy process and enable the assessment of their policy relevance, i.e.:

- EEA policy cycle[1]
- Land Systems Approach (as an extension of the DPSIR model of intervention)
- MDIAK – Monitoring, Data, Indicators, Assessment and Knowledge framework
- EEA typology of indicators

First, it is useful to determine at what stages of the policy process indicators can be used to inform decisions. The EEA policy cycle identifies six main stages in the policy process (see Figure 1). It is useful to understand where in the policy process geospatial indicators are most relevant. The environmental indicators have a major role in particular in three of the six stages (EEA, 1999):

- Issue identification (1): indicators supply information on environmental problems which allows policy makers to evaluate the degree of seriousness and provides a rationale for action
- Issue framing (2): indicators also support policy development and setting of priorities by identifying key factors that cause pressure on the environment
- Effects and effectiveness of policies (6): indicators enable the monitoring of the effects of policy responses

1 1

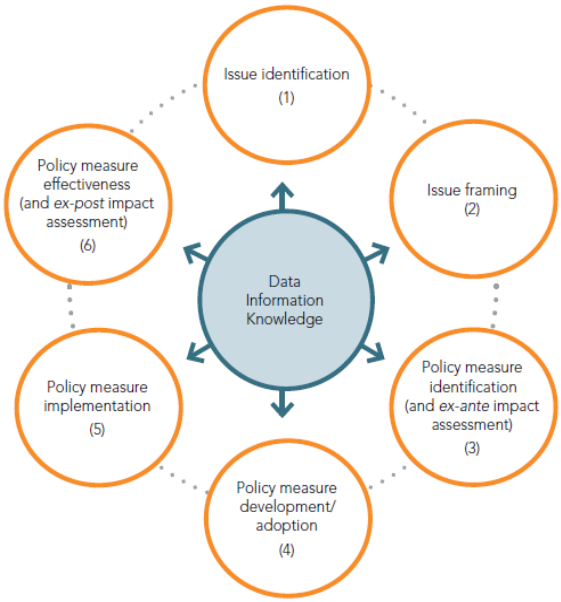

Figure 1.1 Main stages in the policy cycle, supported by data, information and knowledge. In this report, the policy process is taken to include all 6 stages of this policy cycle (Source: EEA).

Secondly, the Land Use System approach, which slightly extends the DPSIR model, allows a higher degree of granularity in understanding how the policy interventions affect the environment, i.e. how they influence the pressures, state and impact in the different environmental media.

The DPSIR provides a systemic view of the human– environment interactions and a framing for determining causality between policy interventions and their impacts, and as such is an important tool for policy making because it enables evidence-based policy making and the assessments of whether the policies are reaching their objectives, and are effective. Ideally, the environmental (geospatial) indicators should cover all the elements of the DPSIR causal chain.

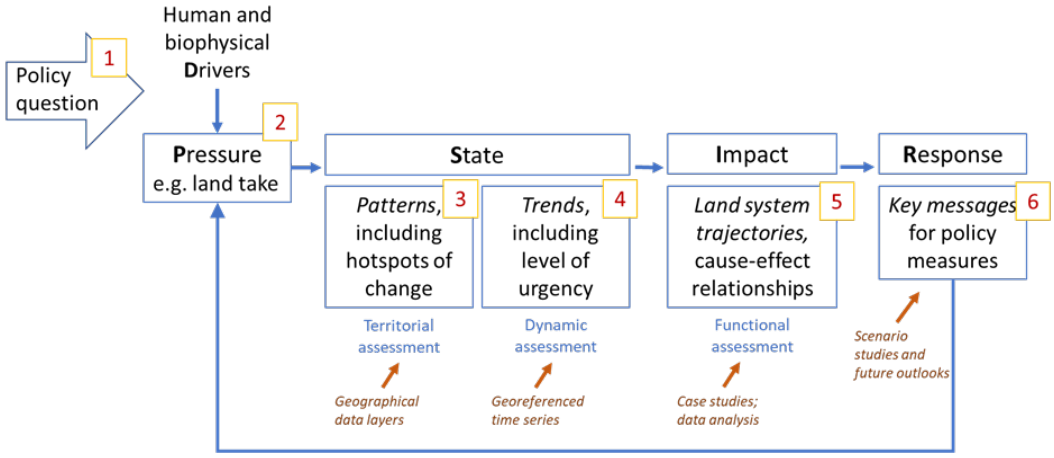

Figure 1. DPSIR approach of land systems policy strategies[2].

The Land Systems approach in addition differentiates between patterns and trends in the state component. The patterns component is static and describes the situation as it is at a specific point in time, whereas the trends component is dynamic, illustrating the changes between two of reference

[2] https://www.eea.europa.eu/themes/landuse/land-systems

points in time. The dynamic assessment is central to understanding the direction of travel and also to understand the impact of policies, i.e. are the policies contributing to a positive trend.

The third framing that is useful in this context is that of "MDIAK – Monitoring, Data, Indicators, Assessment, Knowledge". Both MDIAK and DPSIR conceptual frameworks are useful tools to clarify the type of information that forms the basis of the assessments undertaken in the context of these two frameworks. The MDIAK reporting chain specifically supports the analysis on the basis of the information used in the assessment and pays attention to the sourcing / tracing of this information, thus underpinning credibility. DPSIR helps to structure thinking about the interplay between environment and socio-economics. In both cases, the frameworks identify the types of parameters (e.g. monitoring, data availability) that will enable us to understand the policy relevance of indicators.

Finally, it is useful to understand what types of indicators we have at disposal. The EEA typology differentiates between four main categories of indicators, depending on what type of question they address:

- Descriptive indicators - 'What is happening to the environment and to humans?'
- Performance indicators - they monitor the effect of policy measures, indicating whether or not targets will be met, and communicate the need for additional measures (for example, land take). Some descriptive indicators become performance indicators if there is a policy goal / target linked to them.
- Efficiency indicators – which express the relation between separate elements of the causal chain. Most relevant for policy-making are the indicators that relate environmental pressures to human activities. These indicators provide insight in the efficiency of products and processes. Efficiency in terms of the resources used, the emissions and waste generated per unit of desired output.
- Total Welfare indicators – 'Are we on the whole better off?' – they express a measure of total sustainability (aggregate indicators).

The DPSIR indicators are primarily descriptive indicators. Part of the policy relevance assessment is the question to what extent can geospatial indicators express the different descriptive and relational information.

These four frameworks are complementary and inform the analysis.

1.2 POLICY CONTEXT

Sustainable soil and land management underpins the delivery of a wide range of ecosystem services in Europe. As the Soil Thematic Strategy published in 2006 pointed out, these services are compromised by ongoing degradation processes, including soil erosion, floods and landslides, loss of soil organic matter, salinisation, contamination, compaction, sealing, and loss of soil biodiversity (COM 2006). The European Union has put in place a wide range of policies which, mostly indirectly and not as their primary focus, address these soil degradation processes. Because the number of policies that address soil management is very large and there is no overarching binding framing for these diverse policies, the policy context for sustainable soil and land management is diffuse. The lacking coherence, consistency and coverage of policies limit the potential for better soil management and should be kept in mind when evaluating the policy relevance of geospatial indicators.

For the purpose of this report we focus only on the most directly relevant policies to outline the policy context. However, in looking forward we also need to consider potential emerging developments. I.e. to some degree assessing the policy relevance also needs to consider where the policies might be moving.

The most relevant policy instruments and objectives to which the geospatial indicators can provide targeted support include:

- *Overarching policies relevant to land management and soil protection (Soil Thematic Strategy, 7th EAP, Roadmap to resource efficient Europe)*
- *Climate and Energy (in particular LULUCF)*
- *Common Agricultural Policy*
- *Natural capital (biodiversity and ecosystem services)*

The specific objectives and targets included in these areas are examined in Chapter 4.

Geospatial indicators in support of policies

Indicators are a key policy tool that serve a number of purposes. As outlined in chapter 1, geospatial indicators have in particular a role to play in (EEA, 1999, see also specifically (COM (2006) 508 final)3):

- Issue identification (1): indicators supply information on environmental problems which allows policy makers to evaluate the degree of seriousness and provides a rationale for action
- Issue framing (2): indicators also support policy development and setting of priorities by identifying key factors that cause pressure on the environment
- Effects and effectiveness of policies (6): indicators enable the monitoring of the effects of policy responses

Geospatial indicators are those indicators where the data / information / indicators have a geographic aspect to them, relating to terrestrial activities and, most importantly, can be geo-referenced (i.e. possess coordinates, an address, a zip or postal code). Table 1 gives an overview of the key EEA geospatial indicators, which are examined in this report, and their position within the land systems framework (described in chapter 1.1).

Table 1 Key geospatial indicators categorised according to the land systems framework

Indicator code	Indicator	Land systems					
		Driver	Pressure	State Patterns	State Trends	Impact	Response
LSI 001, CSI 014	Land take		x				
LSI 004, CSI 054	Landscape fragmentation		x				
LSI 008	Land recycling		x				x
LSI 003	Remediation of contaminated sites						x
LSI 002	Imperviousness and imperviousness change		x	x	x		
LSI 007	Soil moisture			x			
LSI 005	Soil Organic Carbon			x			
CSI 008, SEBI 007	Nationally designated protected areas			x			x
SEBI 020	Agriculture: area under management practices potentially supporting biodiversity			x			
SEBI 008	Sites designated under the EU Habitats and Bird Directive			x			x
SEBI 004	Ecosystem coverage (and changes)		x	x	x		
FSS	Structure of agricultural holdings	x					

[3] Communication from the Commission to the Council and the European Environment. Development of agri-environmental indicators for monitoring the integration of environmental concerns into the Common Agricultural Policy. COM (2006) 508 final.

2 CHARACTERIZATION OF EXISTING GEOSPATIAL INDICATORS

In this section the main EEA geospatial indicators are characterised:

- Land take (LSI 001, CSI 014)
- Landscape fragmentation pressure from urban and transport infrastructure expansion (LSI 004, CSI 054)
- Land recycling and densification (LSI 008)
- Imperviousness and imperviousness change (LSI 002)
- Progress in the management of contaminated sites (LSI 003/CSI015)
- Soil moisture (LSI 007)
- Soil Organic Carbon (LSI 005)
- Nationally designated protected areas (SEBI 007, CSI 008)
- Agriculture: area under management practices potentially supporting biodiversity (SEBI 020)
- Sites designated under the EU Habitats and Bird Directive (SEBI 008)
- Ecosystem coverage and changes (SEBI 004)
- Agriculture: Structure of agricultural holdings (collected through Farm Structure Surveys - FSS), including cropping patterns and livestock patterns https://ec.europa.eu/eurostat/cache/metadata/en/ef_esms.htm

The table 2 below provides an overview of these geospatial indicators in terms of their explanatory power and data quality, i.e.: What is the scale at which indicator is compiled, what is the frequency of update, source and quality of data for the indicator, granularity of data, fit of update frequencies with policy processes?

Table 2 Characterisation of indicators, breaking down the previous guiding questions

Land take (LSI 001, CSI 014)[4]	
Definition and purpose	Land take is defined as the area of land that is 'taken' by infrastructure itself and other facilities that necessarily go along with the infrastructure, such as filling stations on roads and railway stations, and as the process as such. It includes areas sealed by construction and urban infrastructure, as well as urban green areas, and sport and leisure facilities. The indicator aims at answering the key policy question “how much is agricultural, forest and other semi-natural and natural land being taken for urban and other artificial land development”, specifically focussing on the location and the drivers of the land taken. 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.
Scale	EEA39, processed according to land accounting methodology, i.e. 1km² cell size; MMU of input data 25ha (status) and 5ha (change), respectively
Update frequency	Every 6 years (so far reference years 2000, 2006, 2012 and 2018)
Data source	Based on CORINE Land Cover (CLC) and derived Land Cover Flows (LCFs)
Data quality	National production and QC (CLC)
Data granularity	1km²
Strengths and weaknesses	Strengths: Available on a pan-European level wall-to-wall Long time series

[4] https://www.eea.europa.eu/data-and-maps/indicators/land-take-2

	Consistent definition and methodology Weaknesses: 6-year update period might be too long for certain applications MMU of 25ha and 1km² resolution could be too coarse for certain (local) applications
Analytical soundness	Operational (indicator is based on a European reference data set that is produced according to standard procedures and a methodology that has been published in an EEA report)
Measurability	Operational (input data are produced every six years on a national level according to a standard methodology, external QC procedure, data widely accepted)
Possible improvement	There are two possible levels of improvement: Spatial resolution; the current indicator is based on CLC with a minimum mapping unit of 25ha. Bringing the MMU down to e.g. 1ha or 0,5ha (as planned with CLC+ and implemented in the Urban Atlas for around 900 FUAs) would clearly improve granularity. Temporal resolution; the 6-year intervals of CLC mapping might lead to missing important processes.

Landscape fragmentation pressure from urban and transport infrastructure expansion (LSI 004, CSI 054)[5]	
Definition and purpose	Landscape fragmentation, as described in this indicator, is understood to be the physical disintegration of continuous ecosystems, habitats or landscape units, excluding freshwater ecosystems. It is the result of transforming large habitat patches into smaller, more isolated fragments of habitat. In urbanised or otherwise intensively used regions, fragmentation is the product of linking built-up areas via linear infrastructure, such as roads and railroads. This indicator is based on the Effective Mesh Size (meff) method. The meff value expresses the probability that any two points chosen randomly in an area are connected, i.e. not separated by barriers. The combination of all barriers in a landscape is called Fragmentation Geometry (FG). Hence, meff is a measure of landscape (structural) connectivity, i.e. the degree to which movements between different parts of the landscape are possible. The larger the meff, the more connected the landscape. The Effective Mesh Density (seff) is a measure of landscape fragmentation, i.e. the degree to which movement between different parts of the landscape is interrupted by Fragmentation Geometry. It gives the effective number of meshes (or landscape patches) per 1 000 km2, in other words, the density of the meshes. The seff value is calculated as 1 000 km2/meff, hence, the number of meshes per 1 000 km2. The more barriers fragmenting the landscape, the higher the effective mesh density.
Scale	EEA39, meff and seff are reported within the cells of a 1 km² regular grid.
Update frequency	Every 3 years (so far reference years 2009, 2012 and 2015)
Data source	Based on HRL Imperviousness and OpenStreetMap
Data quality	Centralised production, external quality control
Data granularity	1km²
Strengths and weaknesses	Strengths: Available on a pan-European level wall-to-wall 3-year update interval Weaknesses: Methodology has been published in peer-reviewed papers and reports, but is questioned from several sides Interpretation sometimes difficult to communicate

[5] https://www.eea.europa.eu/data-and-maps/indicators/mobility-and-urbanisation-pressure-on-ecosystems/assessment

Analytical soundness	Intermediate/uncertain (despite the many papers and reports that have been published, the method is not yet fully accepted in policy-making circles, see box on strengths and weaknesses)
Measurability	Operational (the input data are quality-controlled European reference data that are produced based on a documented procedure)
Possible improvement	The main criticism that the indicator experiences today is the methodology that is used for its production (mesh size and mesh density). For a better acceptance of the product, further discussions and possible slight adaptations of the method are required.

Land recycling and densification (LSI 008)[6]	
Definition and purpose	This indicator addresses the use of urban land for further urban development, whether that urban land is currently in use or not. The indicator comprises two concepts of urban development: land recycling and land densification. Land recycling is defined as the reuse of abandoned, vacant or underused land for redevelopment. It includes 'grey recycling' and 'green recycling'. Grey recycling is when 'grey' urban objects, such as buildings or transport infrastructures, are built under redevelopment. Green recycling is when 'green' urban objects, such as green urban areas or sport facilities, are built. Land densification is defined as the land development that takes place within existing communities, making maximum use of the existing infrastructure instead of building on previously undeveloped land. The indicator examines land recycling relative to total land consumption. Total land consumption is understood as all the land use processes occurring on or ending up in developed land, i.e. urban redevelopment, urban and infrastructure sprawl, and any change in previously developed land. Land recycling includes both the densification and the recycling phenomena. Therefore, land recycling is understood broadly and includes three components: land densification, grey land recycling and green land recycling.
Scale	EU-28, 301 Functional Urban Areas for which the change between 2006 and 2012 is available.
Update frequency	Every 6 years (so far reference years 2006 and 2012)
Data source	Based on Copernicus Urban Atlas data
Data quality	Centralised production and quality control by ETC/ULS
Data granularity	10m resolution of VHR satellite images that form the basis of the Urban Atlas MMU of the Urban Atlas is 0.25ha for urban classes and 1ha for non-urban ones.
Strengths and weaknesses	Strengths: Consistent definition and methodology Weaknesses: 6-year update period might be too long for certain applications Not available wall-to-wall, but for around 900 Functional Urban Areas; changes even only for around 300 FUAs as the Urban Atlas 2006 had a smaller coverage than the Urban Atlas 2012. So far only two reference years, 2018 to be finalised soon, though
Analytical soundness	Operational (the production methodology has been published on the EEA website and discussed during several meetings and conferences)
Measurability	Operational (the input data set is a European reference layer that is produced and controlled according to a well-documented methodology)
Possible improvement	As for land take, two main areas of improvements: Temporal coverage; a 6-year interval might be too coarse and important changes might be missed.

[6] https://www.eea.europa.eu/data-and-maps/indicators/land-recycling-and-densification/assessment-1

	Spatial coverage; while the spatial resolution is very acceptable (0,25ha and 1ha), the coverage is not wall-to-wall, but only covers around 900 FUAs. A full wall-to-wall mapping would also allow to capture land recycling activities in smaller cities and towns.

Progress in the management of (Remediation of?) contaminated sites (LSI 003/CSI015)	
Definition and purpose	Management of contaminated sites aims to assess and, where necessary, reduce the risk of adverse impacts on receptors to an acceptable level. This management process starts with a basic desk study or historical investigation, which may lead to more detailed site investigations and, depending on the outcome of these, remediation measures. The indicator shows progress in four key management steps: preliminary study/site identification, preliminary investigation, main site investigation, and implementation of risk reduction measures. In 2011 it was extended with parameters on the number of sites were introduced, specifically the parameters “potentially contaminated sites”, “contaminated sites” and “sites under remediation”. Each sub-indicators is related to specific policy question: Number of sites managed (or requiring management), at the different management steps Percentage of sites: sites where a specific management step is completed over the estimated total number of sites in need of this specific management step Expenditure is provided in EUR per capita per year and million EUR per gross domestic product (GDP), expressed in billion EUR Contribution of economic activities to soil contamination is calculated in terms of the percentage of sites in which the activity is present over the total number of investigated sites Percentage of sites per risk reduction measure undertaken by each country The key policy question to be addressed is “ How is the problem of contaminated sites being addressed (clean-up of historical contamination and prevention of new contamination)?”. More specific policy questions to be answered are: “What is the estimated extent of soil contamination?”, “How much progress is being achieved in the management and control of soil contamination?”, “Which sectors contribute most to soil contamination ?“, “Which are the main contaminants affecting soil and groundwater in and around contaminated sites?” and “How much is being spent on cleaning-up soil contamination ? How much of the public budget is being used ?”. According to DSPIR it is a Response indicator of Type A – What is happening to the environment and humans (descriptive)?
Scale	EEA39 (2011), before limited number of MS. Variable per sub-indicator.
Update frequency	Updates are scheduled every 5 years (2006, 2011....?)
Data source	National data reported through EIONET. Gaps in 2011 data collection are filled with 2006 data. Eurostat Population, Soil datasets JRC
Data quality	Data not harmonised over Europe.
Data granularity	Sites (?)
Strengths and weaknesses	Strengths: National data stream Weaknesses: Not yet harmonised data, difficult to compare Not covering entire EU, not same time stamp Limited time trends Differences in integration of information within coutries Assessment are is not yet stable -evolving management practices
Analytical soundness	• Uncertain (Intermediate): Description of methodology is available (Panagos et al., 2013) and RC Reference Report "Progress in the Management of Contaminated Sites in Europe"; data can be downloaded for free; update frequency not clear, country level data

Measurability	• Intermediate (uncertain): Data to be provided by NRC Soils; not harmonised at EU level – differences between MS; not known update frequency – last version is based on NRC data from 2011/2012 (and previous similar exercise in 2007)
Possible improvements	• Better harmonisation of national data will improve comparison between MS • Extension of indicator to entire EU 28 to have complete EU picture • Stabilization of methodology and updates at regular time stamps will make monitoring in time possible

Imperviousness and imperviousness change (LSI 002)[7]	
Definition and purpose	The imperviousness indicator is defined as the yearly average imperviousness change between two reference years, as measured by the imperviousness change products. The change is aggregated for a certain reference unit and expressed as relative to the size of that unit (as a percentage). The imperviousness change value for a 100 m raster cell is based on the 100 m imperviousness change products. The default reference unit is the country, but the indicator can be aggregated based on different spatial units.
Scale	EEA-39
Update frequency	Every 3 years (so far reference years 2006, 2009, 2012 and 2015)
Data source	Based on Copernicus HRL Imperviousness layer (100m change product)
Data quality	Centralised production and quality control by ETC/ULS
Data granularity	100m raster cells
Strengths and weaknesses	Strengths: Available on a pan-European level wall-to-wall Long time series (2006, 2009, 2012, 2015, 2018 in production) Consistent definition and methodology Weaknesses: The spatial resolution of 100m cells might be too coarse in certain areas, such as linear elements of along the borders between sealed and unsealed surfaces.
Analytical soundness	Operational (both the production as well as the validation methods have been published[8] and are well-documented)
Measurability	Operational (the input data set is a European reference layer that is produced and controlled according to a well-documented methodology)
Possible improvement	For the moment, the main possible improvement is the spatial resolution of 100m, which could be improved by taking the original EO-derived product.

Soil moisture (LSI 007)[9]	
Definition and purpose	Water retention is a major hydrological property of soil that governs soil functioning in ecosystems. Maintaining water retention capacity and porosity in soils can also reduce the

[7] https://www.eea.europa.eu/data-and-maps/indicators/imperviousness-change-1/assessment

[8] https://www.researchgate.net/profile/Juergen_Weichselbaum2/publication/233397872_Update_of_the_European_High-resolution_Layer_of_Built-up_Areas_and_Soil_Sealing_2006_with_Image2009_Data/links/0912f50a268746a492000000/Update-of-the-European-High-resolution-Layer-of-Built-up-Areas-and-Soil-Sealing-2006-with-Image2009-Data.pdf, http://spatial-accuracy.org/system/files/Accuracy%202016%20Proceedings.pdf

[9] https://www.eea.europa.eu/data-and-maps/indicators/water-retention-4/assessment

	effects of extreme precipitation events. While water retention capacity is an intrinsic soil property based on clay content, structure and organic matter levels, soil moisture content is highly dynamic and is, if based on natural factors only, the balance between rainfall, evapotranspiration, surface run-off and deep percolation. Changes in temperature as well as precipitation patterns and intensity will affect evapotranspiration and infiltration rates, and thus soil moisture. As harmonised in-situ data of soil moisture are not available across Europe, the indicator consists of two sub-indicators: • modelled data of past trends (litres per cubic metre per decade); and • projections into the future using the change in the Palmer Drought Severity Index (unitless).
Scale	EEA-39 with gaps
Update frequency	Climatic data are available for the period 1950-2006. Therefore, we assume that the trend has so far been calculated for this period. It is not known whether it has been updated for a longer period, i.e. until e.g. 2015.
Data source	The model uses a range of inputs. Daily meteorological station data were obtained from the European Climate Assessment and Data set (ECA&D), compiled by the Royal Netherlands Meteorological Institute (KNMI). Where station data were not available in ECA&D, data were completed for precipitation, temperature and sea level pressure with data from their interpolated version E-OBS version 5 and for daily wind speed, global radiation and relative humidity with data from the MARS-STAT database. Land cover information from the Corine Land Cover 2006 project (CLC2006) was used to identify the type of land cover and to calculate the crop coefficient for three phenological stages (start, middle and end of season). Intra-annual variation of the crop coefficient kc was calculated from the Normalised Difference Vegetation Index (NDVI), applying the same linear relationship between kc and NDVI for all stations and over the whole validation period. Hydrological soil properties (namely soil saturation point, field capacity and wilting point) were calculated using soil characteristics (soil texture and soil organic matter) from the European Soil map (ESDB version 2.0). Calculation of the Palmer Drought Severity Index (PDSI) opposes atmospheric water supply to soil water demand using a rather simple soil-water balance model. The PDSI measures the deviation from climatically normal soil moisture conditions for the current month without regarding conditions of preceding months, accounting for local climate features.
Data quality	Past trends: The average error of the swbEWA model varies between 9 and 30%, depending on the season and the climate zone. Moreover, the model simulates SWC particularly well during agricultural droughts. For the projections there is only information on input data uncertainty: The eight RCMs indicate deviations from the observed climatological monthly mean values ranging from −12.0% to +10.9% for precipitation. Air temperature indicates a range between −0.5 K and +0.9 K.
Data granularity	0.25dd for the past trends and horizontal grid spacing of around 25km for the projections.
Strengths and weaknesses	Strengths: Available on a pan-European level wall-to-wall Long time series/observation period Consistent definition and methodology Weaknesses: For the projections, only 8 out of 20 ENSEMBLES models were used. Spatial resolution is coarse compared to e.g. the other indicators which are based in 1km² grid cells. 6-year update period might be too long for certain applications MMU of 25ha and 1km² resolution could be too coarse for certain (local) applications

Analytical soundness	Operational (indicator methodology is based on peer-reviewed publications[10] which provides scientific soundness; in addition, the PDSI is used in operational terms for measuring the intensity of dryness conditions (e.g. US Drought Monitor), thus falling under international consensus concerning its validity; PDSI can be linked to forecasting and information systems)
Measurability	Operational (the input data sets are reference in-situ as well as mapping data, complemented by modelled index data that are produced based on a well-documented and accepted methodology; in addition, input data are free of charge and regularly updated following a standard procedure)
Possible improvement	Regarding the indicator of past trends, it could be improved by using input data of enhanced spatial resolution. Currently, there are available modelled time series of soil moisture over Europe with a spatial resolution of 5x5km, and globally with 0.1dd that could replace the EOBS data at 0.25dd[11]. Also, because these time series are developed in the operational setting and updated frequently (i.e. every 10 days), then the indicator could be updated more frequently. Regarding projections, the use of PDSI is questionable, as it needs many parameters to fine-tune its values to different geographical regions. The use of standardized indices, such as the Soil Moisture Anomaly produced by the JRC, could be more adequate to produce unbiased projections of soil moisture into the near- and far-future.

Soil Organic Carbon (LSI 005)	
Definition and purpose	Variations in topsoil organic carbon content (%) across Europe. Soil Organic Carbon is one of the indicators to monitor the EU Adaptation Strategy to climate change. On the long term the impact of climate change on environmental systems is reflected in the topsoil organic carbon content. On the short term changes in topsoil organic carbon content are driven by land management practices and land use change, which can mask the evidence of climate impact on soil carbon stocks. The key policy question to be answered by this indicator is "What is the trend in soil organic carbon in Europe?". Soil organic carbon, the major component of soil organic matter, is extremely important in all soil processes. Organic material in the soil is essentially derived from residual plant and animal material, synthesised by microbes and decomposed under the influence of temperature, moisture and ambient soil conditions. The annual rate of loss of organic matter can vary greatly, depending on cultivation practices, the type of plant/crop cover, drainage status of the soil and weather conditions. There are two groups of factors that influence inherent organic matter content: natural factors (climate, soil parent material, land cover and/or vegetation and topography), and human-induced factors (land use, management and degradation). According to DSPIR it is an Impact indicator of Type A – What is happening to the environment and humans (descriptive)?
Scale	1 km2
Update frequency	Scheduled for every 4 years
Data source	European Soil Database 2003, http://eusoils.jrc.ec.europa.eu/ESDB_Archive/octop/octop_data.html.

[10] Kurnik et al. (2014): Analysing Seasonal Differences between a Soil Water Balance Model and in Situ Soil Moisture Measurements at Nine Locations Across Europe. Kurnik, B., Louwagie, G., Erhard, M., Ceglar, A., Bogataj Kajfež, L. (2014) Analysing Seasonal Differences between a Soil Water Balance Model and in Situ Soil Moisture Measurements at Nine Locations Across Europe. Environmental Modeling & Assessment 19 (1), 19-34. doi: 10.1007/s10666-013-9377-z. and Heinrich and Gobiet (2012): The future of dry and wet spells in Europe: a comprehensive study based on the ENSEMBLES regional climate models. Heinrich, G. and Gobiet, A. (2012) The future of dry and wet spells in Europe: a comprehensive study based on the ENSEMBLES regional climate models. International Journal of Climatology 32, 1951–1970. doi:10.1002/joc.2421

[11] https://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_soilmoisture.pdf

	Spatial data from the European Soil Database v2.0 (soil), Global Historical Climatology Network (http://www.ncdc.noaa.gov/oa/climate/ghcn-daily/) (climate), CORINE Land Cover 1990 and USGS Global Land Cover Characterization (http://edc2.usgs.gov/glcc/glcc.php) (land cover).
Data quality	Best general picture of OC/OM in Europe. New and harmonized local data is needed before new European map is produced. See Jones, R.J.A, R. Hiederer, E. Rusco, P.J. Loveland and L. Montanarella (2005). Estimating organic carbon in the soils of Europe for policy support. European Journal of Soil Science, October 2005, 56, p.655-671.
Data granularity	1km2
Strengths and weaknesses	Strengths: Sound well described scientific method Weaknesses: No time series of soil info/SOC at EU level -> difficult to track long-term changes (signal related to climate) given the significant short-term variations (noise related to land management) Improvements needed in local data availability
Analytical soundness	Operational: methodology is published (Jones et al., 2005); well described; easy to be used in modelling exercises; Brogniez et al. 2014
Measurability	Uncertain: data are freely available; only one snapshot i.e. no data available for multiple reference years update frequency foreseen is 4 years but I am not aware if this is a wish or actually taking place; well documented in scientific articles; LUCAS soil survey information on SOC is collected regularly as point data – recently (2015) an updated predicted Topsoil SOC for EU25 is released on basis of LUCAS data
Possible improvements	Improvement regarding the availability of local data is needed to have better extrapolations Time series needed on SOC and differentiation between long and short term changes in SOC is needed to monitor changes related to climate change

Nationally designated protected areas (SEBI 007, CSI 008)[12]	
Definition and purpose	A '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, the corresponding protected sites, such as the Natura 2000, Emerald or Ramsar sites, of this country are included. The indicator illustrates the rate of growth in the number and total area of nationally protected areas over time. The indicator can be disaggregated by IUCN category, by terrestrial and marine ecosystems and by country. The indicator is represented as surface area (km2) of nationally designated protected areas or number of nationally designated protected areas.
Scale	EU-28 for Natura 2000 related indicator, EEA-39 for CDDA-related indicators,
Update frequency	annual
Data source	National reporting, based on the 'linked approach', divided into two components: • Type 1 data (spatial data) • Type 2 data (tabular data) It is important to note that, for this indicator, and for any other indicators based on the Common Database on Designated Areas (CDDA; https://www.eea.europa.eu/data-and-maps/data/nationally-designated-areas-national-cdda-12#tab-european-data), information on national protection is based not on protected areas sensu stricto but on designated areas, and that a number of included sites may not meet internationally adopted definitions of protected areas.
Data quality	Known good quality, national data
Data granularity	Country

[12] https://www.eea.europa.eu/data-and-maps/indicators/nationally-designated-protected-areas-10/assessment

Strengths and weaknesses	Strengths: High resolution of spatial data Yearly updated Weaknesses: The resolution may vary from country to country Overestimation of protected area because of overlapping sites
Analytical soundness	Operational (there is international acceptance of the use of the indicator at the global, regional and national scales, i.e. the indicator provides information that can be used at different scales; moreover, information on sites that have been designated for conservation purposes is, in theory, readily available for every country)
Measurability	Operational (the available CDDA data delivered previously to the EEA are provided in templates based on Eionet's Data Dictionary specifications and the CDDA reporting guidelines, delivery is done by the countries).
Possible improvement	A property of the data set is that different areas can overlap each other. For example, a protected site can be located entirely within another protected site. This leads to an overestimation of the protected area in the statistics based on the table values. One solution for this problem is the use of netto CDDA dataset – a spatial dataset without overlapping sites. This data set should have more influence on the statistics in future analyses. The number of indicators where the nationally designated protected areas are combined with other geodata is still very small. At this point, considerations should be made as to which spatial analyses would be of interest as indicators: • Forest/grassland/urban,…. cover inside/outside CDDA sites; or • LandCover/LandUse changes inside/outside CDDA sites.

Agriculture: area under management practices potentially supporting biodiversity (SEBI 020)	
Definition and purpose	The indicator is based on two sub-indicators and shows trends in area (as proportion of the total utilised area) of two categories of agricultural land that are not mutually exclusive: a. High nature value farmland area. b. Area under organic farming. (c. Area under Agri-environmental commitment – discontinued since 2017) Ad. a. 'High nature value farmland area' (ha) indicates the area where farming systems are sustaining a high level of biodiversity. They are often characterised by extensive farming practices, associated with a high species and habitat diversity or the presence of species of European conservation concern. High nature value farmland areas mostly coincide with traditional or extensive agricultural systems. They have one or more of following characteristics: dominated by semi-natural vegetation; dominated by a mosaic of different low intensity agricultural land uses, and natural and structural elements; hosting rare species or supporting a high proportion of their European or global populations. Loss of high nature value farmland is a result of intensification, abandonment and urbanisation. Ad. b. 'Area under organic farming' (ha) indicates trends in the organic farming area and the share of the organic farming area in the total utilised agricultural area. Farming is only considered to be organic at the European Union (EU) level if it complies with Council Regulation (EC) No 834/2007, which provides a comprehensive framework for production of crops and livestock; labelling, processing and marketing of organic products; and the import of organic products into the EU. By caring for the whole system, organic farming generally favours biodiversity (Hole et al. 2005), though more productive farming systems may also support opportunities for biodiversity.

	Recent literature reviews provide more information on the environmental impacts of organic agriculture compared with conventional management systems. The results are not always unambiguous: the environmental benefits of organic farming are most clearly documented for biodiversity and for water and soil conservation, but there is no clear evidence of reduced greenhouse gas emissions. Organic agriculture is likely to have a more positive environmental impact in areas with highly intensive agriculture than in areas with low input farming systems. The regional uptake of organic farming has so far been concentrated in extensive grassland regions where fewer changes are needed to convert to organic farming than in regions dominated by intensive, arable farming, where the benefits would be greater (EEA 2005). Question to be answered is "To what extent is European agriculture geared towards the prevention of biodiversity loss?". (Ad c. "Area under agri-environmental commitment" (ha). This indicator monitored trends in agricultural land enrolled in agri-environmental measures (AEM) as the share of total utilised agricultural area (UAA). For EU15, the data include agri-environmental contracts under Regulation (EC) 2078/1992 and contracts signed in 2000-2005 under the Regulation (EC) 1257/1999. For countries from the 2004 enlargement, agri-environmental contracts under regulation (EC) 1257/1999 started from their accession to the EU. This indicator has been discontinued since 14 Nov 2017.)
Scale	1:100 000
Update frequency	Ad. a. 6 yearly (2000, 2006, 2012, ...2018.....) Ad. b. Yearly
Data source	Ad. a. HNV Farmland database: CORINE Land Cover data (vector) Natura 2000 data - the European network of protected sites Ad. b. Certified organic crop area by crops products by Eurostat Indicator on organic farming provided by FOEN
Data quality	Harmonised European product
Data granularity	100*100m aggregated to 1km2
Strengths and weaknesses	Strengths: Direct links to EU policies (organic agriculture and agri-environment schemes Established methodology: included in the agri-environmental indicators set Allows for easy comparison between countries Indicates the agricultural area with a potentially high level of biodiversity and gives a clear and simple message on the biodiversity therein (Ad. a.) Annually available (Ad. b.) Weaknesses: Ad. a. Even if Corine Land Cover is updated every 5/6 years instead of the initial 10 year cycle, the regularity is not considered sufficient for monitoring area changes. Current European level data sets only allow for the provision of area estimates at NUTS2 level. Ad. b. Proxy-indicator: there is a reasonable correlation between organic farming and biodiversity, but there are exceptions as organic farms can also be intensively managed (even without chemical inputs). Therefore it may be necessary to consider selecting a sub-set of organic farms only, e.g. mixed farms. The area under organic farming does not give the total area of agriculture managed with biodiversity in mind, as biodiversity concerns can also be integrated into non-organic farming.
Analytical soundness	Operational: established methodology; easy comparison between countries
Measurability	Operational: regularly updated, however update frequency should increase; good documentation and stable methodology, clear straightforward definitions

Possible improvements	Ad a: Update frequency and spatial resolution should be increased to reliably monitor changes in the area under management practices potentially supporting biodiversity; this would imply considerable efforts in all EEA member states. Ad b: the indicator could be improved by filtering out those farming systems that demonstrably do not support biodiversity, and by including extensive grazing systems.

Sites designated under the EU Habitats and Bird Directive (SEBI 008)[13]	
Definition and purpose	Within the legal framework of the Birds and the Habitats Directives, each Member State is required to contribute to the creation of Natura 2000 by designating sites in proportion to the natural habitat types and the habitats of species of European interest present within its territory. This indicator shows the current status of implementation of the Habitats (92/43/EEC) and the Birds Directives (79/409/EEC) by EU Member States. It does this by showing trends in spatial coverage of designated Special Protection Areas (SPAs), proposed Sites of Community Importance (SCIs) and Special Areas of Conservation (SACs), as well as the net area of the Natura 2000 network. The units used in the indicator are the square kilometre (km^2) for area and percent (%).
Scale	EU-28
Update frequency	annual
Data source	The Natura 2000 Barometer[14] gives an overview of where we are in establishing the Natura 2000 network, both under the Birds and the Habitats Directives. It is managed by DG Environment with the technical assistance of the European Environment Agency and is based on information officially transmitted by Member States.
Data quality	Known good quality, national data, quality control by ETC/BD
Data granularity	Country
Strengths and weaknesses	Strengths: National data flows Yearly updated Weaknesses: The resolution may vary from country to country
Analytical soundness	Operational (established mechanism and methodology; within the EU Member States there are already processes in place for the compilation of information on Natura 2000 sites at both national and regional levels; this indicator is clear and shows growth in total area of the network)
Measurability	Operational (data are delivered by the countries)
Possible improvement	The data delivery and analysis mechanism could be improved by linking it to the Integrated Data Platform (IDP) which allows an easier connection to other spatial data for more elaborated and detailed analyses of the data.

Ecosystem coverage and changes (SEBI 004)[15]	
Definition and purpose	The indicator describes the proportional and absolute change in extent and turnover of land cover categories aggregated to relate to MAES ecosystem types in Europe from 2006 to 2012. MAES ecosystem types are: (1) urban; (2) cropland; (3) grassland; (4) woodland and forest; (5) heathland and shrub; (6) sparsely vegetated land; (7) inland wetlands; (8) rivers and lakes; (9)

[13] https://www.eea.europa.eu/data-and-maps/indicators/sites-designated-under-the-eu-2/assessment

[14] http://ec.europa.eu/environment/nature/natura2000/barometer/index_en.htm

[15] https://www.eea.europa.eu/data-and-maps/indicators/ecosystem-coverage-3/assessment

	marine inlets and transitional waters; and (10) marine. This indicator is based on photo-interpretation of satellite imagery and gives a 'wall-to-wall' picture of the changes and dynamics in Europe with respect to ecosystems. The area change is MAES ecosystem classes is measured in hectares (ha) or square kilometres (km²). The change in MAES ecosystem classes coverage is measured in percentage (%).
Scale	EEA-39
Update frequency	Every 6 years (so far reference years 2006 and 2012)
Data source	CORINE Land Cover, aggregated to the MAES categories according to a correspondence table.
Data quality	National production and QC (CLC)
Data granularity	1km
Strengths and weaknesses	Strengths: Available on a pan-European level wall-to-wall Consistent definition and methodology (crosswalk table between CLC and MAES) Weaknesses: 6-year update period might be too long for certain applications MMU of 25ha and 1km² resolution could be too coarse for certain (local) applications
Analytical soundness	Operational (the aggregation of CLC classes into MAES categories follows an agreed crosswalk table that has been developed on the European level)
Measurability	Operational (the input data set CLC is a European reference data set)
Possible improvement	As this indicator is based on CLC, the same areas of possible improvement are valid as e.g. for the land take indicator: Spatial resolution; the current indicator is based on CLC with a minimum mapping unit of 25ha. Bringing the MMU down to e.g. 1ha or 0,5ha (as planned with CLC+ and implemented in the Urban Atlas for around 900 FUAs) would clearly improve granularity. Temporal resolution; the 6-year intervals of CLC mapping might lead to missing important processes.

Structure of agricultural holdings (collected through Farm Structure Surveys - FSS), including cropping patterns and livestock patterns https://ec.europa.eu/eurostat/cache/metadata/en/ef_esms.htm	
Definition and purpose	The FSS provides a large amount of data on agricultural structure for the area represented by agricultural holdings. The information follows up the changes in the agricultural sector and provides a basis for decision-making in the Common Agricultural Policy (CAP) and other European Union policies. The FSS surveys are organised in all countries in a harmonised way. For a given survey year, countries have to conduct their surveys within the agreed time-frame. Whereas the characteristics are based on Community legislation, the same data are available for all countries in case of each survey. Thus all the data are as comparable as possible. Among other data, the following information is available: General information: location of the holding and farming system (organic farming, owner- or tenant farmed agricultural area). Land area and its utilisation: size and distribution of the land area of the holding, in particular utilised agricultural area (UAA) which comprises arable land, permanent grassland, permanent crops and kitchen gardens. Livestock: animals kept on the holding (cattle, sheep, goats, pigs, poultry, equidae and other animals expressed in heads or in livestock units (LSU) where 1 LSU is the grazing equivalent of one adult dairy cow). Machinery and equipment necessary to cultivate the land or manage the holding activity. Secondary activities (activities directly related to the holding using the resources and/or products of the holding) and agro-environmental aspects, among which cropping and livestock patterns https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_cropping_patterns. https://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_livestock_patterns

Scale	Various: Data for censuses carried out every 10 years are available in a three-level geographical breakdowns of the whole country, the regions and the districts; while data for intermediate sample-based surveys are only available upon the two-levels of country and regions. Since FSS 1999/2000, information about local farm location is collected in most countries, so the data can also be disseminated by NUTS and are robust regarding the changes in the NUTS definition.
Update frequency	FSS data are available for the following years: 1989/1990, 1993, 1995, 1997, 1999/2000, 2003, 2005, 2007, 2009/2010 and 2013. The agricultural censuses are in line with the FAO recommendations and are carried out every 10 years. The intermediate surveys are organised 3 (until 2007) or 2 times (since 2010) between the censuses. The exact reference periods are determined in legislation.
Data source	FSS (Eurostat)
Data quality	Harmonised European product governed by legislation
Data granularity	Average values for types of holdings, aggregated for different scales; restrictions apply for cells with small numbers of holdings
Strengths and weaknesses	Strengths: Established and legally secured methodology Allows for easy comparison between countries Extensive map tool available https://ec.europa.eu/eurostat/tgm/table.do?tab=table&plugin=1&language=en&pcode=tec00115 Weaknesses: Even if FSS is updated with intermediate time steps within every 10 years, the regularity is not considered sufficient for monitoring area changes. Many small farms (e.g. hobby farming; part-time farming; subsistence farming) as well as periodical multifunctional use of nature protection areas for grazing, are not covered by agricultural statistics, though potentially contributing significantly to landscape and ecosystem diversity. Current European level data sets only allow for the provision of area estimates at NUTS2 level. Proxy-indicator: there is a reasonable correlation between some of the indicator variables and biodiversity, ecosystem services and the probability of HNV-farmland, but this should be underpinned with professional judgement.
Analytical soundness	Operational
Measurability	Operational
Possible improvements	Provision of spatially explicit data (instead of NUTS-aggregated data) would substantially improve the monitoring of area changes in HNV farming It would be worthwhile to experiment with an improved indicator that would go beyond FSS data by including small farms as indicated above, and multifunctional farming.

3 POLICY RELEVANCE OF GEOSPATIAL INDICATORS

To examine the policy relevance of existing geospatial indicators and where there might be gaps for further development we first need to look at the policy needs: i.e. what are already existing objectives and targets set out, or which might be anticipated to come up in the near future, and what sorts of questions for evaluation and monitoring emerge from these.

This chapter is therefore structured as follows. For selected policy areas, the main objectives and relevant targets for these policies are first outlined, along with some relevant context. Based on this, the main types of questions or evaluation / monitoring needs are given. The available indicators are then evaluated in terms of their policy relevance, and finally the gaps in terms of indicators are outlined.

3.1 POLICY OBJECTIVES, TARGETS AND QUESTIONS FOR EVALUATION / MONITORING

3.1.1 Overarching policies for soil protection

Policy	Brief description – including aims, objectives
Soil Thematic Strategy	The Thematic Strategy offers a framework of action and identifies priorities for soil protection, identifying soil threats and soil functions relevant in the EU context. It does not define or set out binding requirements. The overall objective is to ensure the protection and sustainable use of soil, preventing further soil degradation and preservation of soil functions. • 'when soil is used and its functions are exploited, action has to be taken on soil use and management patterns, when soil acts as a sink/receptor of the effects of human activities or environmental phenomena, action has to be taken at source' It sets out four pillars of action: 1) legislation – binding framework legislation; 2) integration of soil protection in the formulation and implementation of EU policies; 3) closing research and knowledge gaps; 4) increasing public awareness of the need to protect soil
7th Environment Action Programme	Among the 7th EAP priority objectives, objective 1 has the aim to "protect, conserve and enhance the Union's natural capital". With regard to soil protection, this aim to achieve that by 2020 "land is managed sustainably in the Union, soil is adequately protected and the remediation of contaminated sites is well underway" (para 28(e)). To do so "increasing efforts to reduce soil erosion and increase soil organic matter, to remediate contaminated sites and to enhance the integration of land use aspects into coordinated decision-making involving all relevant levels of government, supported by the adoption of targets on soil and on land as a resource, and land planning objectives (para 28 (vi))" are necessary.
Roadmap to Resource Efficient Europe	The Roadmap to a Resource Efficient Europe provides an overarching framework for policy transformation towards a European Union where resources, including soil, are sustainability managed. In the relation to soil protection, the Roadmap has the aim to achieve that "[b]y 2020, EU policies take into account their direct and indirect impact on land use in the EU and globally, and the rate of land take is on track with an aim to achieve no net land take by 2050; soil erosion is reduced and the soil organic matter increased, with remedial work on contaminated sites well underway." The above mentioned milestone is achieved through two main objectives: • EU policies take into account their direct and indirect impact on land use in the EU globally, and keep on track the rate of land take with an aim *to achieve no net land take by 2050;* • Continuously implement the action needed for reducing soil erosion and increasing organic matter and set up a schedule for remedial work on contaminated sites.
Sustainable Development Goals (SDGs) – SDG 15.3	By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

The above table shows that there is an absence of direct quantitative targets, except for land take, which would provide a direct and immediate focus and mandate for monitoring on whether a specific target is being achieved or not.

Some of the key themes or challenges where geospatial indicators are relevant include:

- What are the status and trends in soil threats, in particular erosion, soil organic matter, land take and the status of remediation in contaminated sites?
- What is the status of soil functions (ecosystem services) and its trends?
- What are the trends in pressures?

These questions are relevant for evaluating the degree to which action is needed and rationale for where to target policy action (issue identification), for framing the policy priorities, and examining whether policies are adequately addressing these priorities.

3.1.2 Biodiversity and natural capital

Policy	**Brief description – including aims, objectives**
Biodiversity Strategy	The EU Biodiversity Strategy (COM (2011) 0244 final) sets the EU's 2050 long-term vision and a 2020 heading target for maintaining and protecting biodiversity within the EU. The Strategy's framework for action builds upon six targets and associated actions, with the aim to help halving biodiversity loss and ecosystem services conservation in the EU. The two most relevant targets for soil protection are: • Maintaining and enhancing ecosystem and their services Target 2: "By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15 % of degraded ecosystems." • Ensuring the sustainability of agriculture, forestry and fisheries Target 3A: Agriculture: "By 2020, maximise areas under agriculture across grasslands, arable land and permanent crops that are covered by biodiversity-related measures under the CAP so as to ensure the conservation of biodiversity and to bring about a measurable improvement(*) in the conservation status of species and habitats that depend on or are affected by agriculture and in the provision of ecosystem services as compared to the EU2010 Baseline, thus contributing to enhance sustainable management." By setting a long-term vision by 2050 and a 2020 heading target for maintaining biodiversity within the EU beyond 2010, the strategy has positive implications for a wide number of soil threats and functions.
Birds and Habitat Directives	The aim of the Habitats Directive (92/43/EEC) is the: 'maintenance or restoration, at favourable conservation status, of the natural habitats and species of wild fauna and flora of Community Interest (article 2). The aim of the Birds Directive (2009/147/EC) is to: 'maintain the population of the species referred to in Article 1' [all species of naturally occurring birds in the wild state in the EU] 'at a level which corresponds in particular to ecological, scientific and cultural requirements, while taking account of economic and recreational requirements, or to adapt the population of these species to that level'.
Green Infrastructure Strategy	The EU Green Infrastructure Strategy (COM 2013, 249 final) aims to ensure that the protection, restoration, creation and enhancement of green infrastructure (GI) becomes an integral part of spatial planning and territorial development. This also pertains to an increased connectivity of Natura 2000 areas and the support of GI projects, which contribute to an EU-wide, coherent GI network (formerly referred to as TEN-G) and the enhanced delivery of ecosystem services. While there is no quantitative EU target for GI, Target 2 of the EU 2020 Biodiversity Strategy requires that "by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems". The GI Strategy is also expected to contribute to the full implementation of the Birds and Habitats Directives (Target 1) and to maintain and enhance biodiversity in the wider countryside (Target 3) and marine environment (Target 4).

3.1.3 Climate and energy policy

The Effort Sharing legislation establishes binding annual greenhouse gas emission targets for Member States for the periods 2013–2020 and 2021–2030. Land use, land use change and forestry (LULUCF) is exempt from targets set in the Effort Sharing Regulation. However, the LULUCF Regulation from 2018 sets a binding commitment for each Member State to ensure that accounted emissions from land use are entirely compensated by an equivalent removal of CO_2 from the atmosphere through action in the sector (no debit rule). Via the link with LULUCF emissions and sinks, climate policy is highly relevant to soil management and land use, in particular through soil carbon, as well as land use and land use conversion trends.

The LULUCF sector is at present already a net sink in the EU (appr 300million tonnes of CO2 per year); however, to move towards net zero greenhouse gas emissions by 2050 further large scale deployment of land based carbon sinks is required (COM (2018) 773 final). Maintaining and further increasing land based carbon sinks is a crucial strategy to offset residual emissions from sectors where emissions cannot be fully mitigated, thus reducing the impact of agriculture sector itself , and contributing more widely to net zero targets within the period from 2030 – 2050. In the 1.5LIFE Scenario (COM (2018) 773 final) the LULUCF sector accounts for -464 Mt CO2e in 2050, an increase of over 50% compared to current sinks. This illustrates the scale of the challenge, given that these sinks would need to be increased while meeting projected increasing demand for food, feed, and wood and biomass for bio-economy.

Broadly speaking, the maintenance and increase in land carbon sinks requires a combination of several categories of measures to deliver the necessary sequestration potential in line with net-zero 2050 targets:

- Increasing above ground biomass through afforestation (new forests) and restoration of existing degraded forests
- Maintaining and increasing landscape features (hedges, trees) in agricultural landscapes
- Sustainable management of forests (ensuring that the wood harvested is at a lower rate and that cascading uses are prioritized)
- Sustainable management of soils and restoration of degraded agricultural soils and restoration of peatlands / wetlands
- Extending agro-forestry systems

These nature-based measures in general also have multiple synergies for increasing the ability to adapt to climate change, and to meet environmental objectives, provided that they are implemented using sustainability criteria (e.g. afforestation through native species and using techniques that are in line with sustainable soil management) (Kay et al 2019).

The large heterogeneity of biophysical, climate conditions and production systems which are involved in managing carbon sinks means that baseline and benchmarks are not readily available against which to measure progress and to break down EU-level targets down to specific geographies and production systems. The management of carbon sinks is an area where additional indicator development and/or improvement would be beneficial.

Policy questions related to land / soil:

- What is the current status and what are the trends in above ground and below ground carbon sinks?
- Where do the main pressures / risks on carbon sinks come from?
- Are EU policies leading to improvements in carbon sinks (increase in SOC and above ground biomass)?

3.1.4 Common Agricultural Policy

What are the objectives of the policy areas, what sorts of questions does the policy area need to respond to?

Common Agricultural Policy (CAP)	The CAP is an important economic driver for farming decisions across the EU and has the potential to advance soil protection in both agriculture and forestry through Member States' and land managers' implementation of its measures and associated obligations. The key elements relevant to soil protection by influencing directly or indirectly the day-to-day decisions of individual land managers currently are: • CAP cross-compliance standards of Good Agricultural and Environmental Condition (GAEC) • CAP Pillar 1 greening payments • CAP Pillar 2 Rural Development Programmes (RDPs) Soil protection concerns are most explicitly addressed in three GAECs • GAEC 4 minimum soil cover • GAEC 5 minimum land management reflecting site specific conditions to limit erosion • GAEC6 maintenance of soil organic matter level through appropriate practices including ban on burning arable stubble, except for plant health reasons The future CAP post 2020 is currently under negotiation. In particular: • Good agricultural and environmental conditions standard 9 (GAEC 9) foresees the retention of landscape features; a minimum of 5% of land under non-productive features and a ban cutting of hedges and trees during breeding periods.

A central element of the new CAP (2021 – 2027) is the so-called 'new delivery model' where the Commission would set basic parameters, the Member States would bear more responsibility and flexibility to define objectives and meeting agreed targets, by developing CAP Strategic Plans. These would be assessed by the Commission who would also oversee the delivery of results and respect of basic rule (COM (2017)713 final). This new approach would increase the emphasis on assessing the achievements of CAP against the objectives and targets. Indicators are also important in terms of providing baseline information and the needs assessment on the basis of which objectives and targets would be defined. The EC aims to introduce a new performance monitoring and evaluation framework with three types of indicators:

- CAP impact indicators to assess the performance at the level of overall objectives
- CAP result indicators for setting targets in CAP planning and monitoring their progress
- CAP output indicators for linking expenditure to output.

A common set of EU indicators would be put in place, complemented by additional indicators at Member State level, to ensure some comparability.

3.2 POLICY RELEVANCE OF EXISTING INDICATORS

In this section we look at the extent to which existing indicators address the policy objectives (and, where relevant, specific policy targets) related to soil/land management. Table 3 gives a schematic overview of these linkages. The policy relevance is then assessed.

Table 3: Link between key geospatial indicators and policy objectives / targets

Indicators	Soil Thematic Strategy	7th EAP	Roadmap to a Resource Efficient Europe	Biodiversity Strategy	Habitats and Birds Directive	Adaptation Strategy	CAP	Climate Policy
Land take (LSI 001, CSI 014)	+	++	++					
Landscape fragmentation pressure from urban and transport infrastructure expansion (LSI 004, CSI 054)	+	+		+	+	+		
Land recycling and densification (LSI 008)	+	+	+					
Progress in the management of contaminated sites (LSI 003/CSI015)	+		+					
Imperviousness and imperviousness change (LSI 002)	+	+						
Soil moisture (LSI 007)	+							
Soil Organic Carbon (LSI 005)	++	+	+	+		+	++	+
Nationally designated protected areas (SEBI 007, CSI 008)					++	+		
Agriculture: area under management practices potentially supporting biodiversity (SEBI 020)	+	+	+	++	++		++	
Sites designated under the Habitats and Bird Directive (SEBI 008)		+	+	++	++	+	++	
Ecosystem coverage and changes (SEBI 004)		+		+	+	+	+	+
Structure of agricultural holdings			+		+		++	

++ the indicator is explicitly mentioned in or required by the respective policy document(s) or legislation)

+ the indicator may not be explicitly mentioned, but there is a direct (strong) link between what it captures and the objectives set out in the policy document or legislation

Indicators can be classified according to policy relevance in three categories: high, medium, low policy relevance, based on the following criteria:

- Low policy relevance: the indicator does not provide guidance to the respective policy area, the current relevance is very limited either because the indicator has not been updated, or because the scale, the granularity of data is not sufficient, or because there is not a clear policy objective to which it links

- Medium policy relevance: the indicator is linked to a policy objective, but the objective is either not mandatory (soft target) or is not within the mandate of the EU, but rather in mandate of the Member States (e.g. land-take)
- High policy relevance: the indicator responds directly to an EU policy objective or target and the EU also has the mandate for the monitoring of progress towards this objective (e.g. within the climate or biodiversity policy area)

Table 4: Policy relevance of existing indicators

Indicator	Fit to policy process	Policy relevance
Land take (LSI 001, CSI 014)	Fits to policy process as the target is "no net land take by 2050", so 6-year intervals are well suited to inform about the trend towards achieving or missing the target; suited for assessing progress towards the long-term target "no net land take by 2050", but might not be suited for more short-term national targets	Medium
Landscape fragmentation pressure from urban and transport infrastructure expansion (LSI 004, CSI 054)	Combatting fragmentation is one of the key elements of the 7th EAP priority objective 1 to "protect, conserve and enhance the Union's natural capital". Likewise, overcoming fragmentation by implementing green infrastructure measures can play an important role in priority objective 7 to "improve environmental integration and policy coherence". Reducing fragmentation is also targeted in several targets of the EU 2020 Biodiversity Strategy and the Habitats and Bird Directives. Data set is ready, but there is no quantitative / direct European policy target that it can address.	Medium
Land recycling and densification (LSI 008)	There are no specific quantitative targets for land recycling in Europe. Land recycling is mentioned in several policy documents as a response to reduce the negative impact of soil sealing, land take and/or urban sprawl when it comes to urban development. The Roadmap to resource-efficient Europe contains the no net land take by 2050 objective, which is repeated in the 7th EAP (no net land take by 2050). data set is ready, but there is no direct European policy target that it can address	Medium
Imperviousness and imperviousness change (LSI 002)	There are no specific quantitative targets for the degree of imperviousness and imperviousness change in Europe. But as for land recycling, the no net land take objective formulated in the Roadmap to resource-efficient Europe and the 7th EAP, no net land take by 2050 are of highest relevance. In addition, the aim of Land Degradation Neutrality (LDN) as formulated during the Rio+20 (UNCSD) conference confirms this on a global level.	Medium
Progress in the management of contaminated sites (LSI 003/CSI015)	No European targets to reduce local soil contamination have yet been established. National targets exist in many EEA member and cooperating countries. Assessment is not yet very stable; no reference value or threshold is known but it is dealing with monitoring developments in PCS/CS (number of sites, sources of contamination, expenditures on management of CS etc....); national/MS comparison possible with restriction on heterogeneous data sources	Low
Soil moisture (LSI 007)	There are no specific quantitative targets for soil moisture content in Europe. The EU Adaptation Strategy, objective "Better informed decision-making", trying to bridge the knowledge gap. the indicator is produced and available, but there is no direct target	Low
Soil Organic Carbon (LSI 005)	indicator is related to climate policy (EU Climate adaptation strategy, mitigation targets); no trend figures; difficult to interpret as values on SOC should be interpreted together with other environmental information (must not be seen as stand-alone values); short term vs long term changes: detected changes cannot not always be attributed to climate effects;	Medium
Nationally designated protected areas (SEBI 007, CSI 008)	The establishment of protected areas is a direct response to concerns over biodiversity loss, so an indicator that measures protected area coverage is a valuable indication of commitment to conserving biodiversity and reducing biodiversity loss at a range of levels. Direct response to binding legislation, i.e. Bird and Habitat Directive	High

Agriculture: area under management practices potentially supporting biodiversity (SEBI 020)	Direct links to EU policies (organic agriculture and agri-environment schemes). EU 2020 Biodiversity Strategy - target 3. Two sub-indicators: 1) area of High Nature Value farmland indicates an area that, historically, has been managed at low intensity and not been converted to intensive farming. This area represents important biodiversity in agricultural systems. -> Loss of high nature value farmland is a result of intensification, abandonment and urbanisation. 2. Organic farming, which may be low or high intensity, is contributes to sustainable management in that it does not negatively impact on systems outside the area under organic farming, and although it does not necessarily benefit above ground biodiversity, it does benefit soil biodiversity in comparison with intensive agriculture)	Medium
Sites designated under the EU Habitats and Bird Directive (SEBI 008)	The establishment of designated sites under the Habitats and the Birds Directives is a direct response to concerns over biodiversity loss. An indicator on the change in coverage of these sites is a valuable indication of commitment to conserving biodiversity and reducing its loss. It directly supports Target 1 of the 2020 EU Biodiversity Strategy to "fully implement the Birds and the Habitats Directives", Action 1: Complete the establishment of the Natura 2000 network and ensure good management. the indicator provides direct evidence of the implementation of the Habitats and Birds Directives, making it highly relevant for Member States and EU nature conservation policy	High
Ecosystem coverage and changes (SEBI 004)	The indicator is highly relevant for the EU 2020 (headline target and target 2) and global biodiversity targets. Ecosystems are components of biodiversity as defined by the Convention on Biological Diversity.	High
Structure of agricultural holdings (FSS)	The indicator is relevant for understanding the drivers (agricultural activities, intensity of production) behind agricultural management and pressures on different environmental media. As such, it is relevant proxy indicator as there are reasonable correlations between some variables and biodiversity, ecosystem services and thus connection to several policy areas, including biodiversity and soil protection. The infrequent collection of data every 10 years limits the relevance of the indicator, as well as the lack of explicit spatial reference, instead of NUTS-aggregated data.	Low

Land take, land recycling, imperviousness and imperviousness change, and landscape fragmentation

Regarding land and soil policies, binding targets are lacking at European level. The Seventh Environment Action Programme (7th EAP) and the EU Roadmap to a resource efficient Europe promote 'no net land take' in the EU by 2050, aiming to mitigate the effect of urban sprawl. 'No net land take' supports the land degradation neutrality target of the United Nations Convention to Combat Desertification (UNCCD), aiming to maintain the amount and quality of land resources. Land degradation neutrality is promoted by Target 15.3 of the UN Sustainable Development Goals (SDGs), which, by 2030, strives to combat desertification and to restore degraded land and soil. SDG 2 (to eliminate hunger) connects soils, food production and healthy living. Land and soils are also bound to goals that address poverty reduction (SDG 1), health and well-being through reduced pollution (SDG 3), access to clean water and sanitation (SDG 6), the environmental impact of urban sprawl (SDG 11) and climate change (SDG 13).

Soil sealing is the only soil threat that is directly connected to an explicit quantitative, although non-binding target at EU level. In turn, the three indicators *land take, land recycling and imperviousness and imperviousness change* have a direct link to soil sealing.

Land take is the process in which urban areas and sealed surfaces occupy agricultural, forest or other semi-natural and natural areas (EEA, 2017). In some cases, artificial land is returned to other land categories (recultivation). The balance between taken and recultivated land is net land take — the concept behind the EU's 'no net land take' target. The Resource Efficiency Roadmap and 7th EAP explicitly address soil sealing via the no net land take objective by 2050. To archive the target the Roadmap to a Resource Efficient Europe notes that land take should be reduced to an average of 800 km² per year in the period 2000-2020. The land take indicator is updated every six years and is well suited to inform on trends towards achieving or missing the target on a broad scale. However, on local level or in the case of more short-term national targets the updated period might be too long and the resolution of 25ha and 1km² to coarse.

The imperviousness and imperviousness change and land recycling indicators are both related to the no net land take target, although there are no specific quantitative targets for these two indicators. The imperviousness indicator is updated every three years and can be used for long-term as well as short-term development. However, the spatial resolution of 100m cells might be too coarse in certain areas, such as linear elements of along the borders between sealed and unsealed surfaces. Several policy documents mention land recycling as a response to reduce the negative impact of soil sealing, land take and/or urban sprawl when it comes to urban development.

It's important to keep in mind that soil sealing and land take is an area where the policy mandate to set up binding legislation (spatial planning) and manage the soil threat lies solely with the Member States. So, while the indicator is among the most developed ones, it potentially has limited use for guiding action taking place at national level since the COM does not have a lever to enforce action.

The expansion of urban areas and transport networks transforms large habitat patches into smaller, more isolated fragments, leading to habitat fragmentation. Fragmentation often jeopardises the provision of many ecosystem services and affects the stability and resilience of habitats. Although the EU biodiversity strategy to 2020 has a target to 'restore at least 15 % of degraded ecosystems in the Union and to expand the use of Green Infrastructure', there are only a few signs that pressure of land fragmentation has reached its peak.

Biodiversity relevant indicators

The indicators: Nationally designated protected areas (SEBI 007, CSI 008), Sites designated under the EU Habitats and Bird Directive (SEBI 008), and Ecosystem coverage and changes (SEBI 004) are all directly relevant to existing targets and binding legislation.

In addition to these already existing core indicators, there are several GI indicators that are available:

- Increase of green and blue areas (in ha), Urban Atlas Data
- Urban GI (see map viewer on green infrastructure indicators[16])
- Mapping of GI elements, including protected and non-protected areas as well as areas which should be conserved and/or restored as part of the GI network (building on the methodology outlined in see EEA 2014: Spatial analysis of green infrastructure in Europe)

3.3 GAPS AND NEEDS FOR IMPROVEMENT IN RELATION TO GEOSPATIAL INDICATORS

A comparison of policy needs with policy relevance of existing indicators points to the following gaps and opportunities for improvement.

In relation *to overarching policies for soil protection*

- Soil Thematic Strategy sets out the need to understand the current status, areas at risk for soil threats, and monitoring in improvement of the status (trends over time and space) for soil threats.
- Several of the soil threats and soil functions are not at all covered by the existing EEA geospatial indicators: compaction, salinization and desertification. In relation to soil compaction, there is no direct reference to the threat in existing policies, nor any voluntary or other kind of framing for the issue. Nonetheless, literature shows that up to 30% of arable land in the EU is affected subsoil compaction, an effectively permanent and irreversible process which affects all soil functions (Thorsøe et al. 2019 and Schjønning et al. 2018). In relation to salinization and desertification, there are also no immediate policy objectives or targets beyond general objectives in the Soil

[16] https://www.eea.europa.eu/themes/sustainability-transitions/urban-environment/urban-green-infrastructure/urban-green-infrastructure-1

Thematic Strategy. These soil threats, however, are addressed in the JRC-lead European Soil Data Centre (ESDAC) which contains data for all soil threats.[17]

- What are the status and trends in erosion, soil carbon, and the status of remediation in contaminated sites?
    - For status of contaminated sites, the data is patchy and inconsistent, so the value of the indicator to policy is limited.
    - There is no clear data on remediated sites and area.
    - Soil erosion (area vulnerable to erosion – risk area) is modelled in the EU, but is not part of the land use / soil indicator set (modelling done at JRC)
    - The indicator on soil carbon is included, but its use for policy is limited due to limitations in data availability and methodology (to expand on this)
    - These soil threats and related indicators would have higher direct policy significance, since they are either directly relevant for existing targets or objectives (biodiversity, water), or expected ones (climate)
- SDG 15.3 land degradation neutrality is as of yet non-existent on EU level – the EU will need to be reporting on this, so there is a question of how this reporting will be done (at EU level, or a compilation of 28 different reports?).

Biodiversity / Natural capital

To more fully assess progress towards green infrastructure policy objectives, further indicators and data would be needed including, for example:

- Change in the delivery of ecosystem services (e.g. water retention rate, air quality and urban heat; development of new recreation areas (in ha))
- Change in connectivity of Natura 2000 areas (in %)
- Contribution to 15% restoration target (area in ha restored in and outside of Natura 2000 areas) including a definition/shared understanding of what is meant by 'restoration'
- Integrated GI assessment (combining GI connectivity, status of habitats and species, delivery of ES) – *currently under development as part of T1.7.5.3*
- Advanced mapping of GI elements at landscape level (encompassing protected areas, natural and semi-natural areas across ecosystems, and multifunctional urban green areas)

In relation to the EU's biodiversity strategy, reporting under the Article 12 and Article 17 of Birds and Habitats Directives, respectively, can be used to measure the progress towards Targets 1 and 3. Data derived from the MAES process, GI assessment and changes in the conservation status of habitats can contribute to measuring progress towards Target 2. And finally, the SEBI indicator on Invasive Alien Species (SEBI 010[18]) can support to measure the progress towards Target 5.

Climate and energy policy

Responding to questions raised by the policy objectives about the status and trends in carbon sinks, work can build on existing indicators for biodiversity (land cover, biodiversity indicators). Possible additional proxy indicators in this context, in relation to carbon sinks would include:

- Presence of hedgerows and other landscape features

[17] https://esdac.jrc.ec.europa.eu/resource-type/soil-threats-data

[18] https://www.eea.europa.eu/data-and-maps/indicators/invasive-alien-species-in-europe/invasive-alien-species-in-europe

- Area under agro-forestry (different types)
- Area of afforested land
- Area of peatlands under drainage for agricultural purposes (limited more to N Europe)
- Cropping patterns and plant cover on peatlands
- Change in area under permanent grasslands
- Soil cover – percent of time where arable land is covered by plants or residues
    - "could be collected via the Farm Structure Survey and/or via the Member States' IACS/LPIS system. This could be improved to make the indicators the 'total area of arable land with soil cover' and 'proportion of arable land with soil cover' and could be broken down to cover the proportion of farmland on a slope of more than x degrees under soil conservation measures (e.g., permanent grass cover, no tillage, contour vegetation)" (Hart et al. 2018).
- Water content on peat soils
- Soil organic matter on arable land
- Topsoil carbon indicator (based on LUCAS) (work / research on monitoring of SOC in the context of climate policy is ongoing)

Data on drivers and responses

- While there are good data on land cover, there is a general lack of European-wide geospatial data on land use, i.e. possible drivers of change. A key missing source of data is at the level of management activities (i.e. driver and response components of the DPSIR). For example, what types of cropping and management patterns (fertilisation or machinery use) are applied where and what are the spatial and temporal trends? Such knowledge enables the understanding of where the risk areas and drivers can be found, so that policy can respond in a more targeted way.
- The Farm Structure Survey and FADN (Eurostat) collects some data, but this data is not spatially explicit beyond NUTS2 level and has limited use for supporting the assessment of changes in drivers because of either infrequent data collection (FSS every 10 years) or limited geographic coverage / sampling (FADN). The issue of missing land management activity data is also central in improving national GHG accounting.

Data sourcing

- The FSS currently does not collect data on soil management practices – this could be changed in the future
- The IACS / LPIS system set up by Member States could be used to collect data on at least some management practices
- The potential of remote sensing can be explored further to see what kind of data on management activities (cropping, permanent grassland area, peat soil cover) could be collected
- Frequency of update and its synchronisation with the policy processes, in particular with the 7-year cycles of the financial programming periods, is potentially an important limitation for the policy relevance of indicators. For example, the CAP context indicators provide a basis for the SWOT and needs analysis within the CAP strategic programming, yet if the latest update is available only after the programming has been conducted, it does not provide the latest data
- Benchmark and baseline setting can also be explored by bringing together data collected via carbon auditing at farm level

4 CONCLUSION

The report assesses the policy relevance of selected EEA geospatial indicators and examines gaps and opportunities for improvement of their policy relevance. To address this aim, the report first identified relevant elements of a conceptual framework as a basis to inform the examination of the indicators, which include: 1) consideration of the stages in the policy cycle, 2) the Land system approach as an extension of the DPSIR model of intervention, and 3) the EEA typology of indicators. Twelve geospatial EEA indicators were selected for analysis, with each characterised in terms of their explanatory power and quality. Specifically, scale, update frequency, data source, quality, granularity, strengths and weaknesses, analytical soundness, and measurability were examined (see Chapter 2).

The characterisation of indicators points to several potential improvements of the existing indicators, in particular:

- Improving the spatial resolution to improve granularity and to allow to capture activities and changes at a more precise scale (e.g. land take, imperviousness and imperviousness change).
- Improving temporal resolution by increasing the frequency of the data series. For example, 6 year intervals for land take / land recycling and densification may be too coarse and miss important processes or changes occurring, and allow for improved monitoring in time (e.g. land take, progress in management of contaminated sites)
- Methodology improvements: in some cases, the methodology of the indicator does not have full acceptance and would require adaptation (e.g. landscape fragmentation pressure) and increase analytical soundness of the product
- Better data harmonisation among the national data which can lead to improved comparison between Member States (e.g. contaminated sites)
- Improving the data delivery and analysis mechanism, to enable easier connection to other spatial data for more detailed analyses (e.g. Sites designated under the EU Habitats and Bird Directive)

The analysis of the policy context for land and soil management shows that geospatial indicators are particularly relevant for addressing questions such as:

- the status and trends in soil threats, functions, and trends in drivers and pressures driving soil degradation
- the drivers, status and trends in the maintenance of biodiversity and ecosystem services, as well as green infrastructure elements
- the status and trends in above ground and below ground carbon sinks; as well as pressures leading to loss of sinks
- the evaluation of the achievements of existing policy targets and more broadly policy objectives (impacts of policies)

The following observations can be made on the policy relevance of existing indicators:

- Only three biodiversity indicators have a high policy relevance (nationally designated protected areas, ecosystem coverage and changes, sites designated under the EU Habitats and Birds Directive). These indicators respond to clear, legally binding requirements set out in the nature conservation legislation and the EU has a clear mandate for the monitoring of progress towards the objectives set out in the legislation.

- Six indicators have medium policy relevance (land take, landscape fragmentation, land recycling and densification, imperviousness and imperviousness change, soil organic carbon, and agriculture area under management practices potentially supporting biodiversity). In the case of these indicators, there are either no specific quantitative targets or legally binding targets for which the EU has a monitoring mandate, or there are limitations in terms of the spatial / temporal resolution that limits the value of the indicator for informing and evaluating policy.
- Three indicators (progress in management of contaminated sites, soil moisture, structure of agricultural holdings) have low policy relevance because the indicator provides limited information either because the indicator has not been updated, or because the scale, the granularity of data is not sufficient, or because there is not a clear policy objective to which it links
- Most of the indicators focus on state / patterns, and partially on pressures / response. There exists one indicator of driving forces, and impacts are not addressed at all, or to a very limited degree, by the existing geospatial indicators.

Moreover, a comparison of policy needs with policy relevance of existing indicators points to several gaps and opportunities for improvement:

- In relation to overarching policies for soil protection, there are clear gaps in terms of understanding the status, areas at risk and improvement in status (trends over time and space), in particular for compaction, salinization, desertification. Moreover, the status and trends in soil erosion, soil carbon and status of remediation of contaminated sites cannot be addressed sufficiently with current indicators. These three soil threats and indicators would have higher policy relevance because of existing targets and objectives (biodiversity, water) or expected ones (climate). Regarding salinization and desertification, work at EEA could be advanced in the context of the development of a land degradation indicator and the European version of the world soil atlas on desertification. With regards to compaction, a proxy for compaction could be explored through the use of the High Resolution Layer on Vegetation Productivity and Phenology.
- In relation to biodiversity and natural capital, improvements are needed to better assess progress towards green infrastructure policy objectives, for example through:
    - Change in the delivery of ecosystem services (e.g. water retention rate, air quality and urban heat; development of new recreation areas (in ha))
    - Change in connectivity of Natura 2000 areas (in %)
    - Contribution to 15% restoration target (area in ha restored in and outside of Natura 2000 areas) including a definition/shared understanding of what is meant by ‘restoration’
    - Integrated GI assessment (combining GI connectivity, status of habitats and species, delivery of ES) – *currently under development as part of T1.7.5.3*
    - Advanced mapping of GI elements at landscape level (encompassing protected areas, natural and semi-natural areas across ecosystems, and multifunctional urban green areas)
- Climate policy, and the issue of carbon sinks, is gaining increasing importance on the policy agenda. Responding to policy developments around measuring / monitoring the status of carbon sinks, additional work is needed to better align EEA indicators with the policy needs. While soil organic carbon data could be used to approximate the capacity of soils to act as carbon sink, the HRLs Forest and Water and Wetness could serve as a proxy for the presence

of forest and wetlands. In addition, in the context of CLC+[19], a dedicated CLC+ LULUCF instance is prepared which will be aimed at the assessment of carbon sources and sinks. Then, several other potential proxy indicators could be explored in this context. For example, one key indicator includes the presence of hedgerows and other landscape features, which links to requirements under the future CAP. Such landscape elements are captured by the new High Resolution Layer Small Woody Features (SWF) which provides information on linear structures (such as hedgerows) and patches of woody features across Europe[20]. Alternatively, agro-forestry systems, their classification and occurrence, or area of peatlands under drainage for agricultural purpose.

- Moreover, in relation to agricultural management and the drivers and responses – which are not sufficiently covered by EEA indicators. For example, while there are good data on land cover, there is a general lack of European-wide geospatial data on land use, i.e. possible drivers of change. A key missing source of data is at the level of management activities (i.e. driver and response components of the DPSIR). For example, what types of cropping and management patterns (fertilisation or machinery use) are applied where and what are the spatial and temporal trends? In this context, a planned new HRL on Crop Types could become a relevant source of information. Such knowledge enables the understanding of where the risk areas and drivers can be found, so that policy can respond in a more targeted way.
- Finally, improvements in data sourcing and management are required to match the frequency of update with the policy processes, in particular 7-year cycles of the financial programming periods

In conclusion, opportunities for improvement include both 1) technical improvements in existing indicators to make them more policy relevant; 2) as well as better alignment of existing and future indicators with the existing and evolving policy needs.

This report has sketched out ideas for improving policy relevance of EEA indicators, which will be further explored in the upcoming task 1.8.2.3. as defined in the AP2020. This 2020 task will update the policy assessment considering in particular the implications from the European Green Deal in terms of setting new impulses / priorities for the EU policy landscape, the CAP legislative proposals, conclusions from the SOER 2020 reporting, and other work relating to climate and natural capital. These updated policy requirements will be further assessed in more detail against the geospatial data availability, drawing on the land functions framework. The Task 1.8.2.3. will identify key policy requirements relevant to each land function, which data sets are relevant and what the quality of the data sets is. It will identify a list of concrete steps for indicator work from 2021 onwards (short-term and medium-term directions).

[19] https://land.copernicus.eu/user-corner/technical-library/upcoming-product-clc

[20] https://land.copernicus.eu/pan-european/high-resolution-layers/small-woody-features

5 LITERATURE

EEA, 2017, 'Land take (CSI 014/LSI 001)', European Environment Agency (https://www.eea.europa.eu/data-and-maps/indicators/land-take-2/assessment-1) accessed 20 September 2019.

Hart, K., Baldock, D. and Tucker, G. (2018). Ideas for Defining Environmental Objectives and Monitoring Systems for a Results-Oriented CAP Post 2020. The Institute for European Environmental Policy (IEEP), Brussels and London.

Kay, S., Rega, C., Moreno, G., den Herder, M., Palma, J. H., Borek, R., Crous-Duran, J., Freese, D.,Giannitsopoulos, M., Graves, A., Jäger, M.,Lamersdorf, N., Memedemin, D.,Mosquera-Losada, R., Pantera, A., Paracchini, M.L., Paris, P.,Roces-Díaz, J.V., Rolo, V., Rosati, A.,Sandor, M.,Smith, J.,Szerencsits, E.,Varga, A.,Viaud, V., Wawer, R., Burgess, P.J. and Herzog, F. (2019). Agroforestry creates carbon sinks whilst enhancing the environment in agricultural landscapes in Europe. Land Use Policy, 83, 581-593.

Wawer, R., Siebielec, G. and Łopatka, A. (2019 Draft Version). Potential of Earth Observation for improved soil monitoring. Project report. European Commission, DG Environment.

Schjønning, P., Frelih-Larsen, A., Lamandé, M. and Thorsøe, M. H. (2018). Subsoil Compaction – A threat to sustainable food production and soil ecosystem services. RECARE Policy Brief. Aarhus University, Ecologic Institute. Aarhus, Berlin.

Smith, P., Soussana, J. F., Angers, D., Schipper, L., Chenu, C., Rasse, D. P, Niels H. Batjes, N.H., van Egmond, F., McNeill, S., Kuhnert, M.,Arias-Navarro, C., Olesen, J.E., Chirinda, N., Fornara, D.,Wollenberg, E., Álvaro-Fuentes, J., Sanz-Cobena, A. and Klumpp, K. (2019). How to measure, report and verify soil carbon change to realise the potential of soil carbon sequestration for atmospheric greenhouse gas removal. Global change biology.

Thorsøe, M. H., Noe, E. B., Lamandé, M., Frelih-Larsen, A., Kjeldsen, C., Zandersen, M., & Schjønning, P. (2019). Sustainable soil management-Farmers' perspectives on subsoil compaction and the opportunities and barriers for intervention. Land Use Policy, 86, 427-437.

Turpin, N., Ten Berge, H., Grignani, C., Guzmán, G., Vanderlinden, K., Steinmann, H. H., Siebielech, G., Spiegel, A., Perret, E., Ruysschaert, G., Laguna, A., Giráldez, J. V., Werner, M., Raschke, I., Zavattaro, L., Costamagna, C., Schlatter, N., Berthold, H., Sandénj, T. and Baumgarten, A.. (2017). An assessment of policies affecting Sustainable Soil Management in Europe and selected member states. Land Use Policy, 66, 241-249.