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European Joint Programme

Towards climate-smart sustainable management of agricultural soils

Deliverable 2.2

Stocktaking on soil quality indicators and associated decision support tools, including ICT tools

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AUTHOR:	L. Pavlů, J. Sobocká, L. Borůvka, V. Penížek
CO-AUTHOR:	B. Adamczyk, A. Baumgarten, I. V. Castro, S. Cornu, M. De Boever, A. Don, D. Feiziene, G. Garland, B.S. Gimeno, H. Grčman, F. Hawotte, A. Higgins, R. Kasparinskis, M. Kasper, L. Kukk, P. Laszlo, S. Madenoğlu, K. Meurer, P. Schjønning, K. Skaalsveen, L. O'Sullivan, S. Vanino, W. Vervuurt, R. Wawer.
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Abstract

This synthesis shows recent and current efforts in Europe related to the establishment of soil indicators as parameters used to quantify and valuate impacts of agricultural soil management practices on soil quality. It also shows how the existing indicators have been used. Among the best captured soil parameters across all participating countries are carbon concentration in soils and its changes in time, macronutrients (N, P, K) and micronutrients (Cu, Mn) contents in soils, soil pH, cation exchange capacity and base saturation of soils, soil texture and bulk density, and contamination with potentially toxic elements, especially Cd, Co, Cr, Cu, Ni, Pb and Zn. However, there is only partial agreement between the measured parameters and the indicators used in the national legislations and as policy maker´s tools.

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List of acronyms and abbreviations

ALN – Alpine North
ALS – Alpine South
ANA – Anatolian
ATC – Atlantic Central
ATN – Atlantic North
BOR – Boral
BS – base saturation
C10-C40 – petroleum hydrocarbons in the range of C10-C40).
CAP – Common Agricultural Policy of the European Union
CEC – cation exchange capacity
CON – Continental
GAEC – Good Agricultural and Environmental Conditions
ICT – Information and Communication Technologies
LUCAS – Land Use and Coverage Area frame Survey
LUS – Lusitanian
MDM – Mediterranean Mountains
MDN – Mediterranean North
MDS – Mediterranean South
NATURA 2000 network – Europe-wide ecological network of nature conservation areas
NEM – Nemoral
N_{oth} – content of other N forms
N_{tot} – total N content
OCPs – organochlorine pesticides
PAHs – polycyclic aromatic hydrocarbons
PAN – Pannonian
PCBs – polychlorinated biphenyls
pH_{act} – active pH measured in soil solution or water extract of soil
pH_{pot} – potential pH measured in salt (KCl, or $CaCl_2$) solution extract of soil
POPs – persistent organic pollutants
PTE – potentially toxic elements
SOM – Soil organic matter
UNFCCC – United Nations Framework Convention on Climate Change
USDA Soil Taxonomy – United States Department of Agriculture Soil Taxonomy
WRB – World Reference Base of Soil Resources
X_{av} – contents of available nutrients form

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1. Executive summary

The aim of this survey was to obtain information on soil quality indicators, what indicators are used to assess soil quality, for the purposes of its protection, valuation or effective use, including information on the availability and sources of this data. For this purpose, a questionnaire was prepared and sent to all participants (participating countries) of the EJP SOIL programme. In this questionnaire survey, we obtained questionnaires from all project countries. Almost 200 sources of information on soil qualitative characteristics were identified in these questionnaires. Sources contain country-wide information (98), region-wide information (26), local information (8), and 61 sources were further unprocessed because they did not contain data on the evaluated soil parameters, or were focused on forest soils, or were focused very narrowly and did not provide more general information about the indicators of soil quality.

It was found that in most countries and thus in all environmental zones and European regions, there is a wide range of information on soil properties, obtained from both national (regional in the case of specific state arrangements) monitoring and single sampling campaigns. These data are in the form of databases or geodatabases publicly available as soil information geoportals, or available in specific circumstances, for example, only to landowners, or available with permission of data owners. In most countries, information on the entire depth of the soil profile is available, only in two are data declared only from topsoil.

The soil quality indicators themselves, which include a number of soil properties, were divided into 8 groups: 1. Evaluation of soil organic matter status in terms of quantity, stocks and quality, as well as the time frame, i.e. changes in carbon content over time; 2. evaluation of nutrient status of soils including contents of main macronutrients and also micronutrients; 3. evaluation of soil pH and evaluation of related information about soil sorption complex; 4. evaluation of physical parameters of soil as texture, stoniness, porosity, and bulk density; 5. evaluation of soil water content and behaviour through water field capacity, wilting point, available water capacity, and infiltration; 6. description of physical degradation of soils including soil compaction, soil structure degradation, and soil erosion; 7. description of chemical degradation of soils including contamination with potentially toxic elements and organic pollutants, and salinization; 8. evaluation of biological parameters of soils especially biological activity, potentially mineralizable nitrogen, microbial biomass content, abundance of specific group of organisms, or various enzymes measurement.

Among the best captured soil parameters across all participating countries are organic carbon concentration in soils and its changes in time, macronutrients (N, P, K) and micronutrients (Cu, Mn) contents in soils, soil pH, cation exchange capacity and base saturation of soils, soil texture and bulk density, and contamination with potentially toxic elements especially Cd, Co, Cr, Cu, Ni, Pb and Zn.

Evaluation of water content is one of the less monitored soil characteristics in participating countries. Contamination with organic pollutants is addressed in only about one third of countries. Biological parameters are generally the least frequently evaluated indicators of soil quality in Europe. Biological activity is most often evaluated through soil respiration, but also only in seven of the participating countries.

With regard to the general goal of the questionnaire (usage of soil quality indicators) there are some soil quality indicators frequently used in national legislations and as policy maker´s tools (e.g., nutrient contents, heavy metals contents, pH, hazard of soil erosion, organic pollutants contents) whereas soil

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organic carbon was mentioned the most. As mentioned above, a lot of information about the soil is freely available on the Internet, either in the form of the data itself or geodatabases with map outputs. The range of ICP tools used is based on this. Computers and smartphones are most often mentioned in the questionnaire. But the questionnaire also showed that many respondents are not familiar with national or EU legislation relating to soil issue and many respondents do not distinguish terms: legislation and policy maker´s tools, answers are the same or similar.

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2. Introduction

Implementing a sustainable management of agricultural soils requires to be able to assess soil functions and the provision of ecosystem services. A good knowledge of (i) the frameworks of evaluation being used in the different partner countries, (ii) soil quality indicators and associated decision support tools, including ICT tools (information and communication technologies) being used, and (iii) reference values of indicators is necessary before proposing research projects in this area.

The general goal of the report presented here is the synthesis on the development and usage of soil quality indicators and associated decision support tools, from past and on-going projects in European countries. The objective is to evaluate the existing efforts on this topic across Europe to come up with a roadmap in order to harmonize and standardize the soil quality indicators. Soil quality in this sense means an account of the ability of soil to provide ecosystem and social services through its capacities to perform its functions and respond to external influences (Tóth et al., 2007). The term soil quality encompasses a broad spectrum of features and considers functional ability together with the response properties of the soil. Soil quality therefore provides a complex information on the sum of different soil characteristics, with regards to the level of ecosystem services a soil can provide. Soil quality indicator is perceived as a parameter used to quantify and valuate impacts of agricultural soil management practices on soil quality and the environment to draw conclusions for the farming practice or agricultural policy.

The first sub-objective is to stocktake available data and knowledge on soil quality indicators across agricultural land in Europe in order to provide a synthesis on recent and current achievements as well as availability of such data for researchers and users. The second sub-objective is to review the comparability of the soil indicators used in terms of methods of their acquisition (sampling, spatial and temporal distribution, etc.). The third sub-objective is to assess the use of soil quality indicators for specific Decision Supporting Tools and ICT among the European countries. Identification of soil indicators used for decision support tools like in legislation measures, policy strategies or markers is an added value of the questionnaire.

Obtained results should show all recent and current efforts in Europe related to the development/establishment of soil indicators. A synthesis will show how this is done in different countries and how the existing indicators have been used. This report will give a guidance to develop and create a roadmap for soil science research on this topic. Realized stocktakes could synthetize and provide knowledge over almost all European countries needed for general assessment of the potential of research, development and harmonization activities in this topic.

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3. Methodology and source data

3.1. Data collecting

The EJP SOIL partners collected the information for this stocktake and delivered the data by filling a questionnaire in excel relating to soil quality indicators. It was a simply structured excel database for stocktake of all indicators commonly used in countries and/or specially used for decision support tools. The questionnaire consisted of four sections:

A. Data sources
- What sources of soil data are used?
- For each data source following questions of sections B and C were asked:

B. Information about the data
- Availability/non availability of the data
- Spatial and temporal resolution of the data
- Sampling strategy (monitoring/single campaign)
- Format of data (databases, geodatabases)
- Additional data availability (e.g. soil chemical or physical degradation, land use)

C. List of soil quality measurements and indicators
- General (e.g. terrain information, depth of sampling, soil classification system)
- Chemical (e.g. Carbon content, soil pH, cation exchange capacity, nutrients content)
- Physical (e.g. soil texture, bulk density, soil water content)
- Biological (e.g. respiration, microbial biomass, edaphon groups abundance)

D. Soil parameters/indicators used for decision support tools
- Which parameters and indicators are used in national legislation (limits)?
- Which parameters and indicators are used as policy makers' tool?
- Which parameters and indicators are used to exclude certain measures (e.g. using selected fertilizers)?
- Which parameters and indicators are used to recommend certain soil protection measures?
- If you have no national indicators what is done with the data?
- Do you produce maps or reference values for the country (if yes, for which measurements)?
- Have you compared your results with the LUCAS data/results/maps?

3.2. General data description

In this questionnaire survey, we obtained 24 completed questionnaires from all EJP participating countries. Almost 200 sources of information on soil qualitative characteristics were identified in these questionnaires (see the annex I). The amount of studies per country are as follows: Austria 16, Belgium 17, Czech Republic 7, Denmark 6, Estonia 4, Finland 9, France 6, Germany 9, Hungary 3, Ireland 5, Italy 8, Latvia 8, Lithuania 1, Netherlands 10, Norway 2, Poland 6, Portugal 20, Slovakia 6, Slovenia 6, Spain 6, Sweden 5, Switzerland 7, Turkey 1, United Kingdom 25. Information sources were divided to four categories (figure 1): 1. Sources containing country-wide information; 2. Sources containing region-wide information; 3. Sources containing local information; 4. Unprocessed sources. Unprocessed sources were qualified as such because they did not contain data on the evaluated soil parameters,

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were focused on forest soils, or were focused very narrowly and did not provide more general information about the indication of soil quality. A frequent example of unprocessed sources of information were soil maps containing information only on soil types. These are themselves an indicator of soil quality, but other quality indicators will be addressed more precisely in this study. However, even here one of the problems of soil assessment can be seen, and that is the harmonization of taxonomic systems of European countries. Most countries of the questionnaires reported the use of the national soil types classification (12). In six countries, the national taxonomic system and the World Reference Base of Soil Resources (WRB) are used in parallel, and in Turkey, The American taxonomic system (USDA Soil Taxonomy) is used.

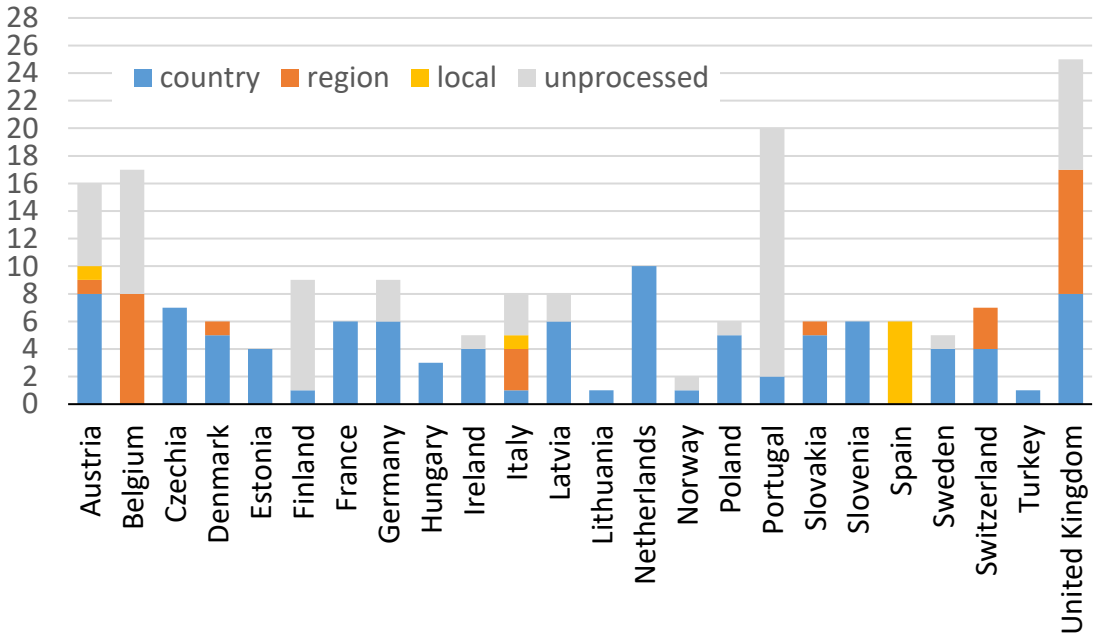

Figure 1: Categories of data sources (number of sources containing country-wide information, region-wide information, local information, and sources unprocessed in report from different reasons).

4. Results

The further processed sources (the most important of them are in the annex II – largescale data sources) of information are either geodatabases with map outputs or only databases without a map expression (figure 2). In many cases, the data are freely available, but there are also countries (Finland, Hungary, Spain, and Turkey) where there is no such source of information and everything is subject to the consent of the data holder. For some sources, part of the data is public and another part requires some permission (figure 3).

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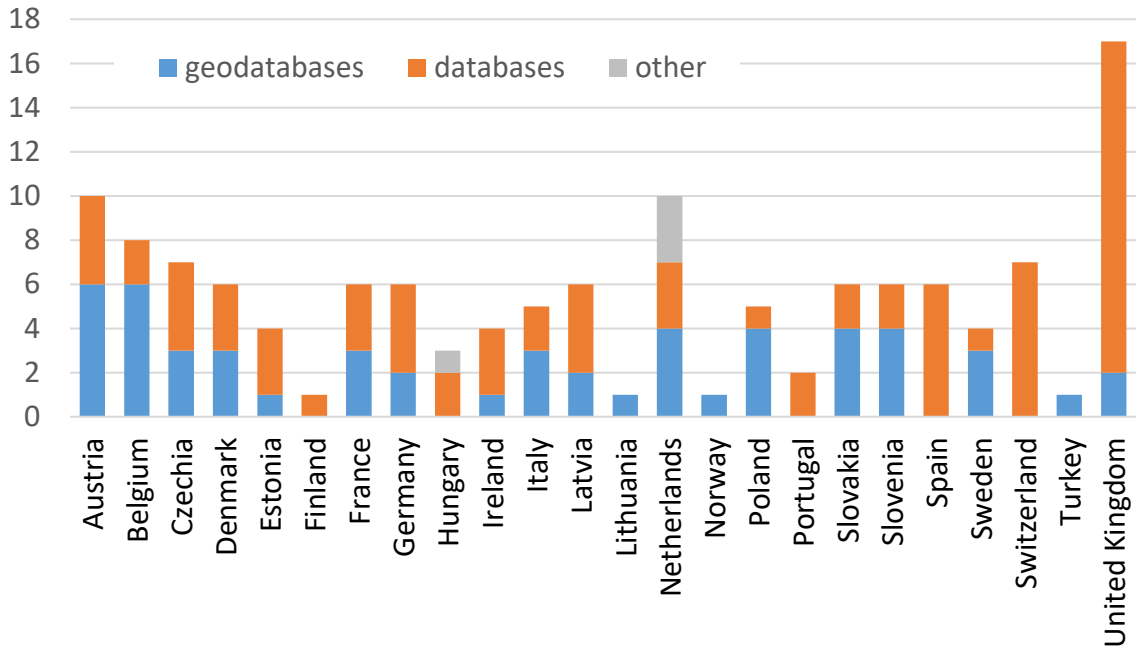

Figure 2: Format of data sources (description "other" represents sources where this information is missing).

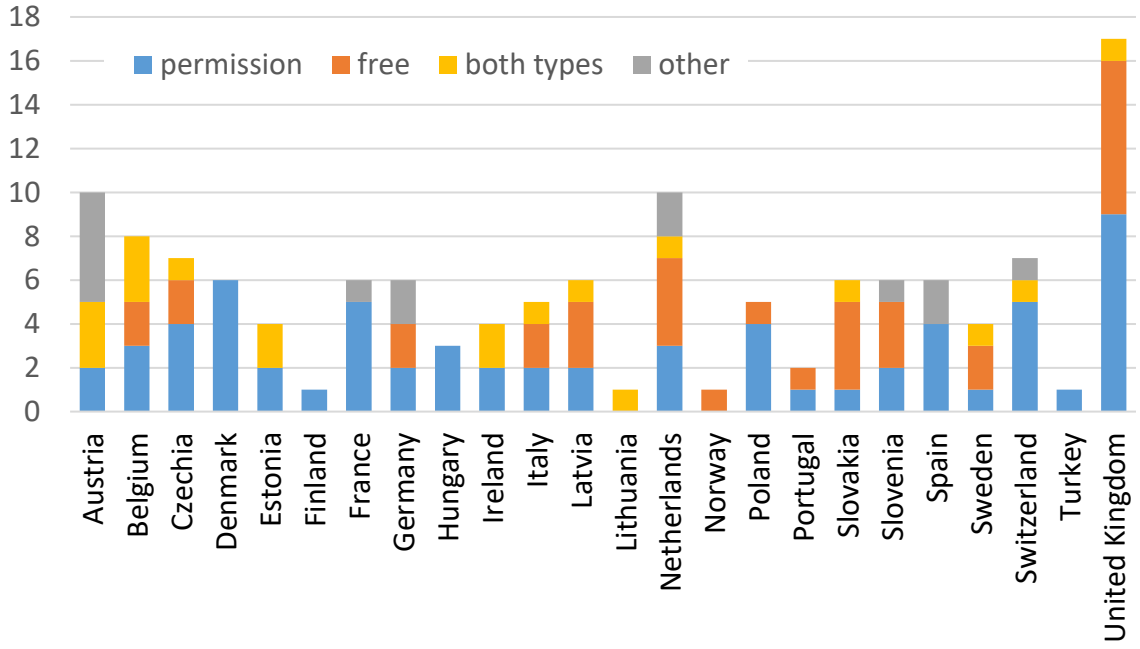

Figure 3: Availability of data sources (description "both types" represents sources for which: part of the data is public and another part requires some permission; description "other" represent sources where this information is missing).

Information on soil characteristics is mostly available from single sampling campaigns and slightly less from still active monitoring (figure 4). In some cases, the monitoring was finished, or in other cases,

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information about sampling was not provided. These information sources are included in the "other" category.

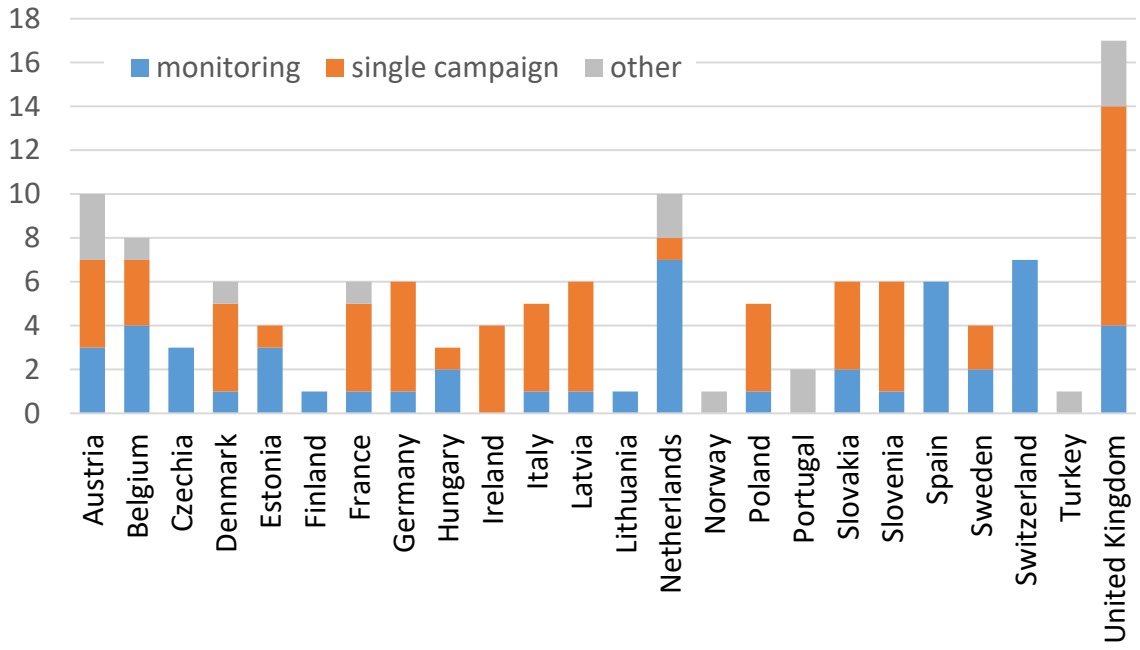

Figure 4: Sampling strategies (description "other" represents finished monitoring or sources where information about sampling strategy is missing).

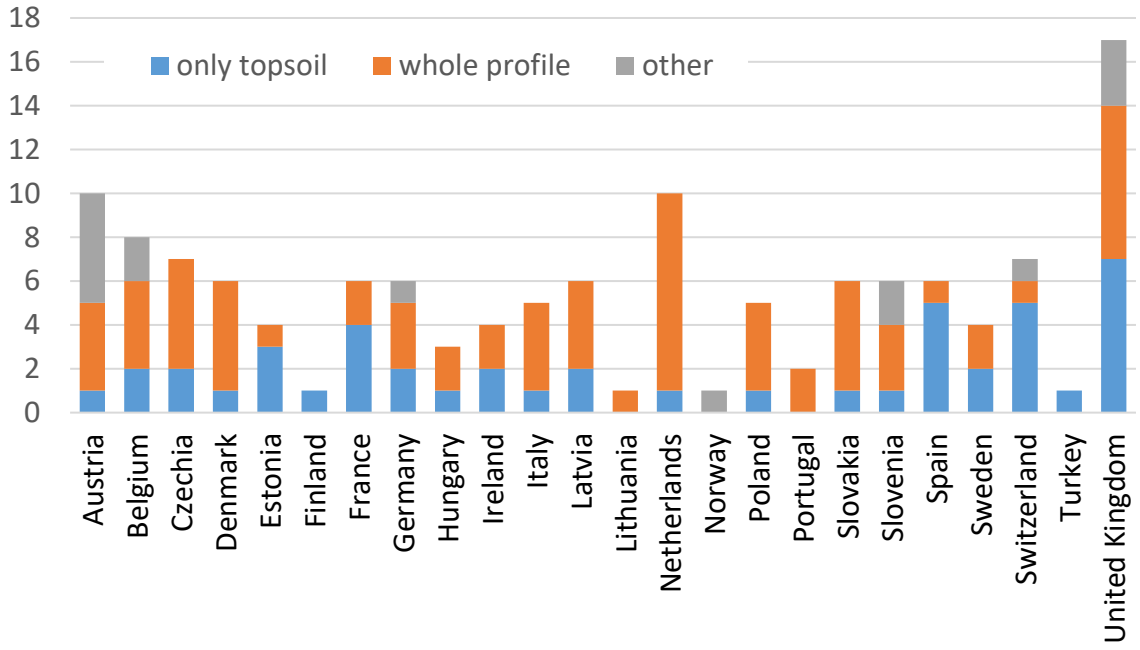

Figure 5: Sampling depth (description "other" represents sources where information about sampling depth is missing).

It can be stated that most countries have data available from the entire depth of the soil profile (figure 5). Finland and Turkey report data only from topsoil layer. In Norway questionnaire this information is

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missing. In the 21 countries, there exists a declared connection of soil quality indicators with terrain parameters (15 countries with digital terrain model and 6 countries with information about terrain slope). Finland, Sweden and Latvia do not mention this information.

4.1. Soil quality indicators (questionnaire parts A, B, C)

We selected 8 groups of soil quality indicators representing the basic properties of soils and ways of soil degradation, which together provide an overall picture of soil quality. These groups describe namely:

1) Evaluation of soil organic matter in terms of quantity, stocks and quality, as well as the time frame, i.e. changes in carbon content over time.
2) Evaluation of nutrient status of soils including contents of main macronutrients and also micronutrients.
3) Evaluation of soil reaction measured through actual and potential pH as well as evaluation of related information about soil sorption complex through cation exchange capacity and base saturation.
4) Evaluation of soil physical parameters as texture, stoniness, porosity, and bulk density.
5) Evaluation of soil water content and behaviour through water field capacity, wilting point, available water capacity, and infiltration.
6) Description of physical degradation of soils including soil compaction (as a parameter using soil resistance), soil structure degradation (as a parameter using soil structure stability measurement), and soil erosion.
7) Description of chemical degradation of soils including contamination with potentially toxic elements (mainly As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn) and organic pollutants (mainly OCPs – organochlorine pesticides; PAHs – polycyclic aromatic hydrocarbons; PCBs – polychlorinated biphenyls), and salinization (as a parameter often using electric conductivity of soils).
8) Evaluation of biological parameters of soils especially biological activity (respiration), potentially mineralizable nitrogen, microbial biomass content, abundance of specific groups of organisms (micro-, meso-, macroedaphon), or various enzymes measurement.

At the outset, it should be emphasized that the following results are based only on data from a questionnaire survey. Due to this, some data in specific countries may be actually monitored and evaluated, but they were not in the results, because they were not filled in the questionnaires.

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4.1.1. Processing of results by country

Evaluation of soil organic matter

Most countries monitor the concentration of carbon in the soil (table 1). For approximately 20 % countries, there is no information on the changing (shift) of carbon concentration over time, i.e. on a possible decrease in amount of carbon in the soil. About a third of countries lack very important information on soil carbon stock, which is used in calculations of carbon cycle fluxes. The least information is on the qualitative characteristics of organic matter. These parameters are not monitored or reported by more than half of the countries. This is a very important characteristic of the soil both in relation to vegetation and the stabilization of carbon in the soil.

Table 1: Soil organic matter evaluation in participating countries (Carbon (C) concentration, carbon stock, soil organic matter quality, and carbon concentration changing (shift) of over time.

	Soil organic matter (SOM)			
Country	C concentration	C stock	SOM quality	C shift
Austria	**yes**	**yes**	**yes**	**yes**
Belgium	**yes**	**yes**	no	no
Czechia	**yes**	no	**yes**	**yes**
Denmark	**yes**	**yes**	**yes**	**yes**
Estonia	**yes**	**yes**	no	**yes**
Finland	**yes**	**yes**	no	**yes**
France	**yes**	**yes**	**yes**	**yes**
Germany	**yes**	**yes**	no	**yes**
Hungary	**yes**	no	**yes**	**yes**
Ireland	**yes**	**yes**	**yes**	**yes**
Italy	**yes**	**yes**	no	**yes**
Latvia	**yes**	**yes**	no	**yes**
Lithuania	**yes**	**yes**	**yes**	no
Netherlands	**yes**	**yes**	**yes**	**yes**
Norway	no	no	no	no
Poland	**yes**	no	no	**yes**
Portugal	**yes**	no	no	no
Slovakia	**yes**	**yes**	**yes**	**yes**
Slovenia	**yes**	no	no	no
Spain	**yes**	**yes**	**yes**	**yes**
Sweden	**yes**	no	no	**yes**
Switzerland	**yes**	**yes**	no	**yes**
Turkey	**yes**	**yes**	no	**yes**
United Kingdom	**yes**	**yes**	no	**yes**
% *	96	71	42	79

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

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Evaluation of nutrient status of soils

Most countries collect and evaluate the amount of basic macronutrients in soils (table 2). In case of micronutrients, the contents of Cu, Mn and Zn are the most frequently determined. B, S, and Se are also monitored in about half of the countries.

Table 2: Nutrient status of soils evaluation in participating countries. (N_{tot} – total N content; N_{oth} – content of other N forms; X_{av} – contents of available nutrients form)

Nutrient status															
	macronutrients						micronutrients								
Country	N_{tot}	N_{oth}	P_{av}	K_{av}	Ca_{av}	Mg_{av}	B	Cu	Fe	Mn	S	Se	Si	Zn	other
Austria	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Na,Cl^-,F^-,SO_4^{2-}
Belgium	**yes**	no	**yes**	**yes**	**yes**	**yes**	no	**yes**	no	yes	no	no	no	**yes**	
Czechia	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	no	**yes**	Cd
Denmark	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	
Estonia	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	no	no	Co,Mo
Finland	no	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	no	**yes**	Al, Mo
France	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	yes	**yes**	**yes**	**yes**	**yes**	**yes**	Na,Al
Germany	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	
Hungary	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	no	**yes**	
Ireland	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Mo
Italy	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	no	no	**yes**	Na,Al,Pb,Ba
Latvia	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	no	no	**yes**	
Lithuania	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	
Netherlands	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	Mo
Norway	no	no	no	no	no	no	no	no	no	no	no	no	no	no	
Poland	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	
Portugal	no	no	no	no	no	no	no	no	no	no	no	no	no	no	
Slovakia	**yes**	**yes**	**yes**	**yes**	no	**yes**	no	**yes**	no	**yes**	no	no	no	**yes**	
Slovenia	**yes**	no	**yes**	**yes**	no	no	no	no	no	no	no	no	no	no	
Spain	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	no	no	no	**yes**	
Sweden	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	
Switzerland	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	no	no	no	no	no	no	no	
Turkey	no	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	no	no	no	**yes**	Cu, Mn, Zn, B
UK	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Na,Al,Co,Pb,Ni
% *	83	67	92	92	83	88	63	79	38	79	54	46	38	75	

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

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Evaluation of soil reaction and soil sorption complex

As with the amount of carbon and macronutrients, the parameters describing the soil reaction and the sorption complex are among the well-captured parameters (over 70 %) across all European countries (table 3). A problem is in case of potential pH, as some countries use the KCl extract, some other countries use $CaCl_2$ extract. Therefore, some harmonization is necessary, possibly using some coefficients.

Table 3: Soil reaction and soil sorption complex evaluation in participating countries. (pH_{act} – (active) pH measured in soil solution or water extract of soil; pH_{pot}- (potential) pH measured in salt (KCl, or $CaCl_2$)) solution extract of soil; CEC – cation exchange capacity; BS – base saturation)

	Soil reaction and sorption complex				
Country	pH_{act}	pH_{pot}	acidification	CEC	BS
Austria	**yes**	**yes**	no	**yes**	**yes**
Belgium	**yes**	**yes**	no	**yes**	no
Czechia	**yes**	**yes**	**yes**	**yes**	**yes**
Denmark	**yes**	**yes**	**yes**	**yes**	**yes**
Estonia	no	**yes**	**yes**	**yes**	**yes**
Finland	**yes**	no	**yes**	no	no
France	**yes**	**yes**	**yes**	**yes**	**yes**
Germany	**yes**	**yes**	**yes**	**yes**	**yes**
Hungary	**yes**	**yes**	**yes**	**yes**	**yes**
Ireland	**yes**	**yes**	**yes**	**yes**	**yes**
Italy	**yes**	**yes**	no	**yes**	**yes**
Latvia	**yes**	**yes**	**yes**	**yes**	**yes**
Lithuania	no	**yes**	**yes**	no	no
Netherlands	**yes**	**yes**	**yes**	**yes**	**yes**
Norway	no	no	no	no	no
Poland	**yes**	**yes**	**yes**	**yes**	**yes**
Portugal	**yes**	no	no	**yes**	**yes**
Slovakia	**yes**	**yes**	**yes**	**yes**	**yes**
Slovenia	**yes**	**yes**	**yes**	**yes**	**yes**
Spain	**yes**	no	**yes**	**yes**	no
Sweden	**yes**	no	**yes**	**yes**	**yes**
Switzerland	**yes**	**yes**	**yes**	**yes**	**yes**
Turkey	no	no	**yes**	**yes**	**yes**
United Kingdom	**yes**	**yes**	**yes**	no	**yes**
% *	83	75	79	83	79

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Evaluation of physical parameters of soil

Texture (100 % of participating countries) and bulk density (83 % of participating countries) are also well supported by soil parameters across European countries (table 4). On the contrary, porosity or stoniness are observed in only about half of the countries.

Table 4: Physical parameters evaluation in participating countries.

	Physical parameters			
Country	texture	stoniness	porosity	bulk density
Austria	**yes**	**yes**	**yes**	**yes**
Belgium	**yes**	**yes**	no	**yes**
Czechia	**yes**	**yes**	yes	**yes**
Denmark	**yes**	no	no	**yes**
Estonia	**yes**	**yes**	**yes**	**yes**
Finland	**yes**	no	no	no
France	**yes**	**yes**	no	**yes**
Germany	**yes**	**yes**	no	**yes**
Hungary	**yes**	no	**yes**	**yes**
Ireland	**yes**	**yes**	**yes**	**yes**
Italy	**yes**	**yes**	**yes**	**yes**
Latvia	**yes**	no	no	no
Lithuania	**yes**	no	**yes**	**yes**
Netherlands	**yes**	no	no	**yes**
Norway	**yes**	no	no	no
Poland	**yes**	no	no	no
Portugal	**yes**	no	**yes**	**yes**
Slovakia	**yes**	**yes**	**yes**	**yes**
Slovenia	**yes**	**yes**	**yes**	**yes**
Spain	**yes**	no	**yes**	**yes**
Sweden	**yes**	no	**yes**	**yes**
Switzerland	**yes**	**yes**	**yes**	**yes**
Turkey	**yes**	no	no	**yes**
United Kingdom	**yes**	**yes**	**yes**	**yes**
% *	100	50	58	83

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 862695

Evaluation of water content in the soil

Evaluation of water content is one of the less monitored soil characteristics in participating countries (table 5). Assessments of water infiltration into the soil are mentioned by only 4 of the 24 countries. Wilting point and available water capacity are evaluated in less than half of the countries. Just over half of the countries surveyed receive only the water field capacity measuring. This can also be considered as a knowledge gap, as this information is important in terms of water retention in the soil, influencing hydrological cycles and thus fulfilling one of the basic functions of the soil.

Table 5: Soil water content evaluation in participating countries.

	Soil water content			
Country	infiltration	water field capacity	wilting point	available water capacity
Austria	**yes**	**yes**	**yes**	**yes**
Belgium	no	no	no	no
Czechia	no	no	no	no
Denmark	no	**yes**	**yes**	**yes**
Estonia	no	no	no	no
Finland	no	no	no	no
France	no	no	no	no
Germany	no	**yes**	no	**yes**
Hungary	no	**yes**	**yes**	**yes**
Ireland	**yes**	no	no	no
Italy	no	**yes**	**yes**	**yes**
Latvia	no	no	no	no
Lithuania	no	**yes**	**yes**	**yes**
Netherlands	**yes**	**yes**	**yes**	**yes**
Norway	no	no	no	no
Poland	no	no	no	no
Portugal	no	**yes**	**yes**	**yes**
Slovakia	no	no	no	no
Slovenia	no	no	no	no
Spain	no	**yes**	**yes**	**yes**
Sweden	no	**yes**	no	no
Switzerland	no	**yes**	no	no
Turkey	no	**yes**	**yes**	**yes**
United Kingdom	**yes**	**yes**	**yes**	**yes**
% *	17	54	42	46

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

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Description of physical degradation of soils

Indicators of soil quality can also include degradation processes evaluated using various soil properties. Two types of questions were made in the questionnaire. 1) Whether the different degradation processes of the soil in a given information source are evaluated in any way (the answers were only yes or no). 2) Which specific soil parameters are evaluated in the given information source and by which method (selected of them were additionally assigned to degradation processes). Physical degradation parameters are shown in table 6. This table documents that the measurement of specific soil parameters such as soil resistance or soil structure (aggregates) stability does not completely correspond to the evaluation of the actual degradation processes. While only five countries report soil resistance measurements, more than half of the countries report soil compaction evaluation. Conversely, more than half of the countries somehow determine the stability of the soil structure, but less than half evaluate the soil structure degradation. In general, these indicators are not widely monitored soil parameters in participating countries. Compared to that, soil erosion is assessed in 71 % of the countries, which demonstrates the importance of this degradation process in agricultural soils.

Table 6: Physical soil degradation evaluation in participating countries.

	Physical degradation				
Country	soil resistance measurement	soil compaction evaluation	soil structure measurement	soil structure degradation	erosion evaluation
Austria	**yes**	**yes**	**yes**	**yes**	**yes**
Belgium	no	no	yes	no	yes
Czechia	no	**yes**	no	**yes**	**yes**
Denmark	no	no	no	no	**yes**
Estonia	no	**yes**	no	no	**yes**
Finland	no	no	no	no	no
France	no	**yes**	no	**yes**	**yes**
Germany	no	**yes**	**yes**	**yes**	**yes**
Hungary	**yes**	**yes**	no	**yes**	**yes**
Ireland	no	**yes**	**yes**	**yes**	no
Italy	no	**yes**	**yes**	**yes**	**yes**
Latvia	no	no	no	no	**yes**
Lithuania	no	no	**yes**	no	**yes**
Netherlands	**yes**	**yes**	**yes**	**yes**	**yes**
Norway	no	no	no	no	**yes**
Poland	no	no	no	no	**yes**
Portugal	no	no	no	no	no
Slovakia	no	**yes**	**yes**	no	**yes**
Slovenia	no	no	**yes**	**yes**	**yes**
Spain	no	**yes**	**yes**	**yes**	no
Sweden	**yes**	**yes**	**yes**	no	no
Switzerland	**yes**	no	**yes**	no	**yes**
Turkey	no	no	no	no	no
United Kingdom	no	**yes**	**yes**	**yes**	no
% *	21	54	54	46	71

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

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Description of chemical degradation of soils

Chemical degradation parameters are shown in tables 7 and 8. While contamination with potentially toxic elements, especially Cd, Co, Cr, Cu, Ni, Pb and Zn (less Hg and As) is one of the well-monitored soil parameters in Europe, contamination with organic pollutants is addressed in only about one third of countries. Soil salinization is also not widely monitored soil quality parameters, which, however, corresponds well with the distribution larger areas of naturally saline soils (France, Germany, Hungary, Italy, Netherlands, Slovakia, Spain, and Turkey). In countries where salinization does not represent a problem, it is not evaluated.

Table 7: Soil chemical degradation evaluation in participating countries – contamination with potentially toxic elements.

Chemical degradation – contamination with potentially toxic elements – PTE											
Country	Al	As	Cd	Co	Cr	Cu	Hg	Ni	Pb	Zn	other PTEs
Austria	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Be,V
Belgium	no	no	no	no	no	no	no	no	no	no	
Czechia	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Be,Mo,V
Denmark	no	no	no	no	no	no	no	no	no	no	0
Estonia	no	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Sn
Finland	**yes**	no	**yes**	**yes**	**yes**	**yes**	**no**	**yes**	**yes**	**yes**	
France	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Se,Mo,Tl
Germany	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Be,V
Hungary	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Ba,Mo,Sn
Ireland	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	no	Fe
Italy	no	no	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	
Latvia	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	many others
Lithuania	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	V
Netherlands	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Fe
Norway	no	no	no	no	no	no	no	no	no	no	
Poland	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Be,Sr,Ba,Li,La,Mn,Fe
Portugal	no	no	**yes**	no	no	**yes**	no	**yes**	no	**yes**	
Slovakia	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Se
Slovenia	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Mo,F^-
Spain	no	**yes**	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	Be,V
Sweden	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	V
Switzerland	no	no	no	no	no	**yes**	no	no	no	**yes**	Cu,Zn
Turkey	no	no	**yes**	**yes**	**yes**	**yes**	no	**yes**	**yes**	**yes**	
United Kingdom	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	Ag,Pt,Fe,Mn,Sb,Se, Sr,Mo,Ti,Ba,B,Li,Na
% *	25	63	83	79	79	83	63	83	79	83	

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

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Table 8: Soil chemical degradation evaluation in participating countries – contamination with organic pollutants and salinization (OCPs – organochlorine pesticides; PAHs – polycyclic aromatic hydrocarbons; PCBs – polychlorinated biphenyls; POPs – persistent organic pollutants; C10-C40 – petroleum hydrocarbons in the range of C10-C40).

Chemical degradation – contamination with organic pollutants – OP					**Salinization**	
Country	OCPs	PAHs	PCBs	other OP	salinity	electric conductivity
Austria	**yes**	**yes**	**yes**	many others (S1)	no	**yes**
Belgium	no	no	no		no	no
Czechia	**yes**	**yes**	**yes**	C10-C40, pesticides	no	no
Denmark	no	no	no		no	no
Estonia	no	no	no	Fungi-,herbi-,insecticide	no	no
Finland	no	no	no		no	**yes**
France	**yes**	**yes**	**yes**	dioxins, furans, triazines	**yes**	**yes**
Germany	**yes**	**yes**	**yes**	Relative binding strength of isoproturon and copper	**yes**	**yes**
Hungary	no	no	no		**yes**	no
Ireland	no	no	no		no	**yes**
Italy	no	no	no		**yes**	**yes**
Latvia	no	**yes**	no		no	**yes**
Lithuania	**yes**	**yes**	**yes**	C10-C40	no	**yes**
Netherlands	**yes**	**yes**	**yes**		**yes**	**yes**
Norway	no	no	no		no	no
Poland	**yes**	**yes**	no		no	**yes**
Portugal	no	no	no		no	no
Slovakia	no	**yes**	no		**yes**	**yes**
Slovenia	**yes**	**yes**	**yes**	mineral oils, phenols, benzene, ethylbenzene, toluene, xylene	no	no
Spain	no	no	no	herbicides	**yes**	**yes**
Sweden	no	no	no		no	no
Switzerland	no	no	no		no	no
Turkey	no	no	no		**yes**	**yes**
United Kingdom	no	**yes**	**yes**	POPs, dioxins, furans	no	**yes**
% *	33	46	33		33	58

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

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Evaluation of biological parameters of soils

Biological parameters are generally the least frequently evaluated indicators of soil quality in Europe, as shown in table 9. Biological activity is most often evaluated through soil respiration, but even that only in seven of the respondent countries.

Table 9: Biological parameters evaluation in participating countries.

	Biological parameters										
Country	resp.	pot. min. N	fungal biomass	bacterial biomass	microbial biomass	macro edaphon	micro edaphon	meso edaphon	earth-worms	nematodes	enzy.
Austria	**yes**	**yes**	**yes**	no	no	**yes**	**yes**	no	no	**yes**	**yes**
Belgium	no	no	no	no	no	no	no	no	no	no	no
Czechia	no	no	no	no	no	no	no	no	no	no	no
Denmark	no	no	no	no	no	no	no	no	no	no	no
Estonia	no	no	no	no	**yes**	no	no	no	**yes**	no	no
Finland	no	no	no	no	no	no	no	no	no	no	no
France	**yes**	no	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**
Germany	no	no	no	no	no	**yes**	**yes**	**yes**	no	no	no
Hungary	no	no	no	no	no	no	no	yes	no	no	no
Ireland	**yes**	no	**yes**	**yes**	**yes**	no	no	no	**yes**	**yes**	**yes**
Italy	no	no	no	**yes**	no	no	no	no	**yes**	no	no
Latvia	no	no	no	no	no	no	no	no	no	no	no
Lithuania	**yes**	no	no	no	**yes**	no	no	no	no	no	**yes**
Netherlands	**yes**	**yes**	**yes**	**yes**	**yes**	no	no	no	**yes**	**yes**	no
Norway	no	no	no	no	no	no	no	no	no	no	no
Poland	no	no	no	no	no	no	no	no	no	no	no
Portugal	no	no	no	no	no	no	no	no	no	no	no
Slovakia	no	no	no	no	no	no	no	no	no	no	no
Slovenia	no	no	no	no	no	no	no	no	no	no	no
Spain	no	no	no	no	no	no	no	no	no	no	no
Sweden	no	no	no	no	no	no	no	no	no	no	no
Switzerland	**yes**	**yes**	no	no	**yes**	no	no	no	**yes**	**yes**	**yes**
Turkey	no	no	no	no	no	no	no	no	no	no	no
UK	**yes**	**yes**	**yes**	**yes**	no	no	no	**yes**	no	no	no
% *	29	17	21	21	25	13	13	17	25	21	21

countries	**Other biological parameters**
Austria	potential nitrification, carabid beetles, hoverfly, mycorrhiza population, roots
Estonia	abundance of Collembola
France	fungal diversity, bacterial diversity, plant diversity, mesoedafon - soil microarthropods (Collembola, Mites), potential metabolic diversity, microbial taxonomic diversity, gene expression of metallothionein, small mammals: bioaccumulation of metallic elements, SET index : sum of excess of transfers in Snails, omega-3 fatty acid, 16 rRNA, pcaH
Hungary	decline of soil biodiversity, individuals/800 cm^3 soil, number of microarthropods in a given time-frame, infrared based detection of animals falling into the trap
Ireland	phospholipid fatty acids composition, next generation sequencing, 16S rRNA, ITS
Italy	QBSar
Lithuania	microbial community analysis (AWCD, richness, diversity), carbon sources
Netherlands	3H-thy incorporation, 14C-Leu incorporation, fungal activity, Enchytraeids density and diversity, Microarthropods density and diversity, root density
Switzerland	Arthropods, AMF spores, microbiome, decomposition, N_2O emissions, soil disease resistance (Pseudomonas)
UK	DNA metabarcoding

** Percentage expression of positive results in questionnaires obtained from 24 countries.*

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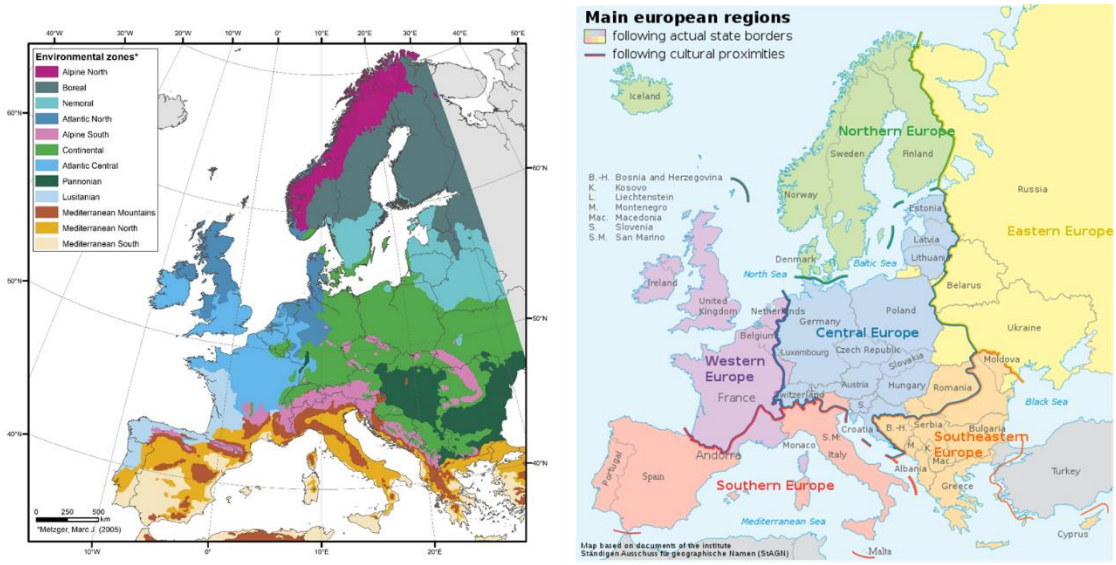
4.1.2. Processing of results by environmental zones

Our questionnaire survey was focused on soil quality indicators used, for example, in legislation or policy decisions. Therefore, the obtained information sources usually have a nationwide or regional (according to the state organization) scope and it is not easy to separate environmental zones (figure 6) in them. Our survey (24 participating countries) therefore cover all environmental zones in Europe. Table 10 shows the representation of individual environmental zones in individual states and simplifies the division of states into these zones. The countries are sorted and grouped according to the similarity of the represented environmental zones. But the division into groups according to environmental zones did not bring any fundamental and interesting outputs. The distribution by European regions provides results that are more telling.

The table also shows the classification of countries into the main European regions (figure 6).



A **B**

Figure 6: A – Pedoclimatic zones of Europe according to Metzger et al. (2005); B – Main European regions. Source: Der Ständige Ausschuss für geographische Namen (StAGN) https://commons.wikimedia.org/wiki/File:Grossgliederung_Europas-en.svg [22.7.20]

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Table 10: Representation of individual environmental zones in individual states and the classification of countries into the main European regions

Country	Relevant environmental zones	Simplified environmental zones	Main European regions
Norway	ALN (BOR, ATN, NOC)	ALN	Northern
Finland	BOR (ALN, NEM)	BOR	Northern
Sweden	BOR, ALN, NEM (CON)	BOR, NEM	Northern
Estonia	NEM (BOR)	NEM	Central
Latvia	NEM (CON, BOR)	NEM	Central
Lithuania	NEM (CON)	NEM	Central
Poland	CON (NEM)	CON	Central
Czechia	CON (ALS, PAN)	CON	Central
Germany	CON, ATN (ATC, ALS, BOR)	CON, ATN	Central
Switzerland	NOC, ALS (ATC)	CON, ALS	Central
Austria	CON, ALS	CON, ALS	Central
Slovakia	CON (ALS, PAN)	CON	Central
Hungary	PAN (MDM)	PAN	Central
Denmark	ATN (CON)	ATN	Northern
Netherlands	ATN, ATC (CON)	ATN, ATC	Western
United Kingdom	ATN, ATC	ATN, ATC	Western
Ireland	ATC (ATN)	ATC	Western
Belgium	ATC (CON)	ATC	Western
France	ATC, LUS, MDM, MDN, ALS (CON, MDS)	ATC, LUS	Western
Spain	MDS, MDN, MDM (LUS, ALS)	MDS	Southern
Portugal	LUS, MDN, MDS	LUS, MDN, MDS	Southern
Italy	MDN, MDM, ALS (MDS)	MDN, MDM	Southern
Slovenia	ALS (MDM, MDN, CON)	ALS	Central
Turkey	ANA (MDM,MDS, MDN)	ANA	Turkey

4.1.3. Processing of results by European regions

Figure 7 shows the evaluation of basic soil parameters including characteristics of soil organic matter, soil reaction, soil sorption complex and nutrient status in individual European regions. The figure shows that except for some micronutrients, all soil properties are evaluated in all European regions. Micronutrients S, Se, Si are not determined in South European countries at all. Interestingly, in some regions (northern and southern Europe) pH measurement in salt (KCl, or $CaCl_2$) solution extract of soil is not common. In general, Western and Central Europe are well covered by information on these soil quality indicators. However, it should still be emphasized that the results are influenced by the quality of the questionnaire. For example, there are few specific parameters completed in the Norwegian questionnaire, which is not negligible when evaluating 4 countries in the region of Northern Europe.

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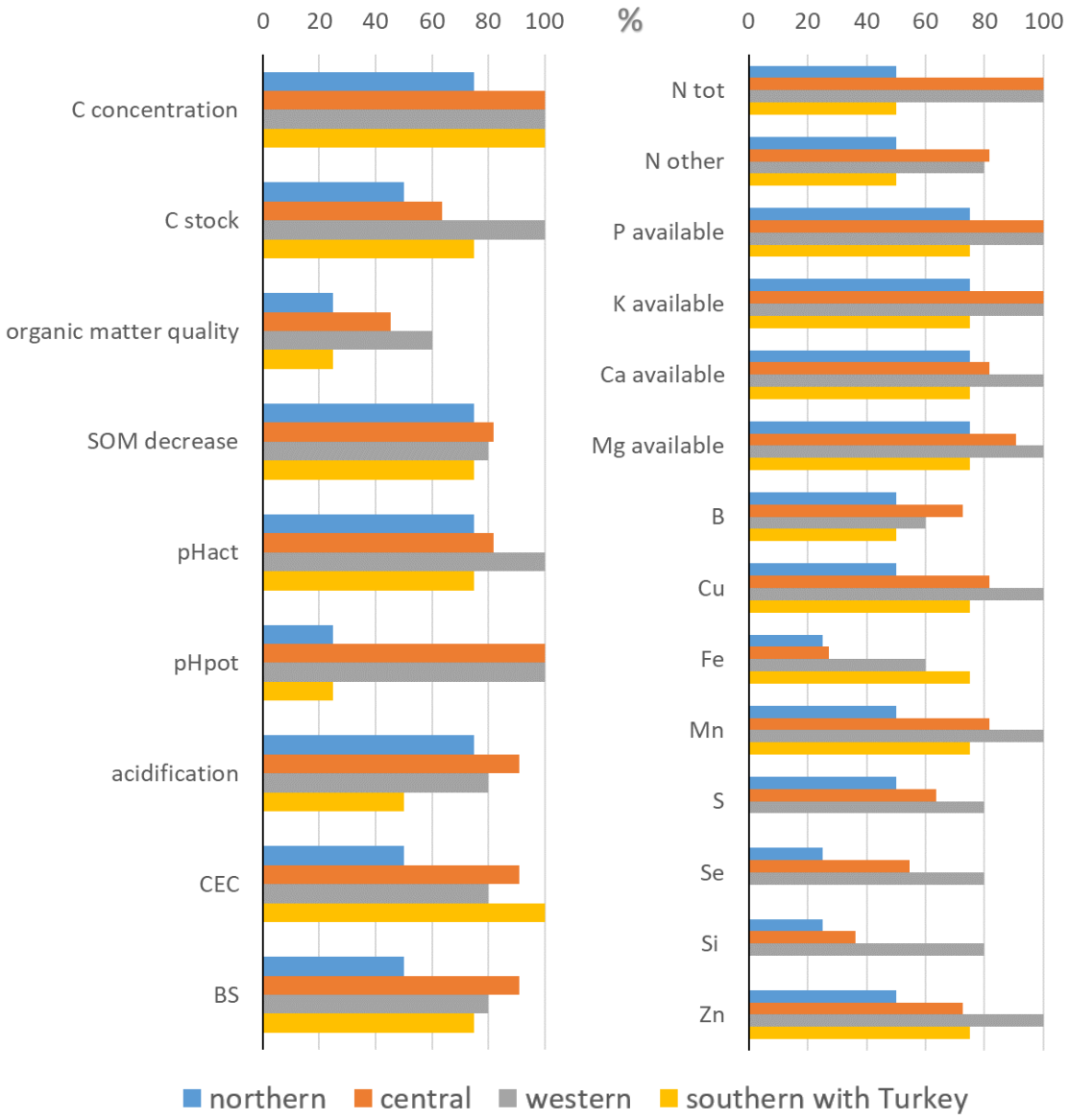

Figure 7: Soil organic matter (SOM) characteristics, soil reaction, soil sorption complex parameters, and nutrient status of soils evaluation in participating countries divided to European regions: northern (4 countries), central (11 countries), and western Europe (5 countries), and southern Europe with Turkey (4 countries). (pH_{act} – (active) pH measured in soil solution or water extract of soil; pH_{pot}- (potential) pH measured in salt (KCl, or $CaCl_2$)) solution extract of soil; CEC – cation exchange capacity; BS – base saturation; N_{tot} – total N content; N_{oth} – content of other N forms)

Much larger differences can be seen in the evaluation of physical parameters of soils and in the evaluation of soil degradation (figure 8). Only 18 of the 28 selected properties or parameters are evaluated in all regions of Europe. Contamination by organic pollutants or parameters of water infiltration into the soil are evaluated only in some countries of Western and Central Europe. The southern part of Europe stands out in the assessment of the soil water parameters.

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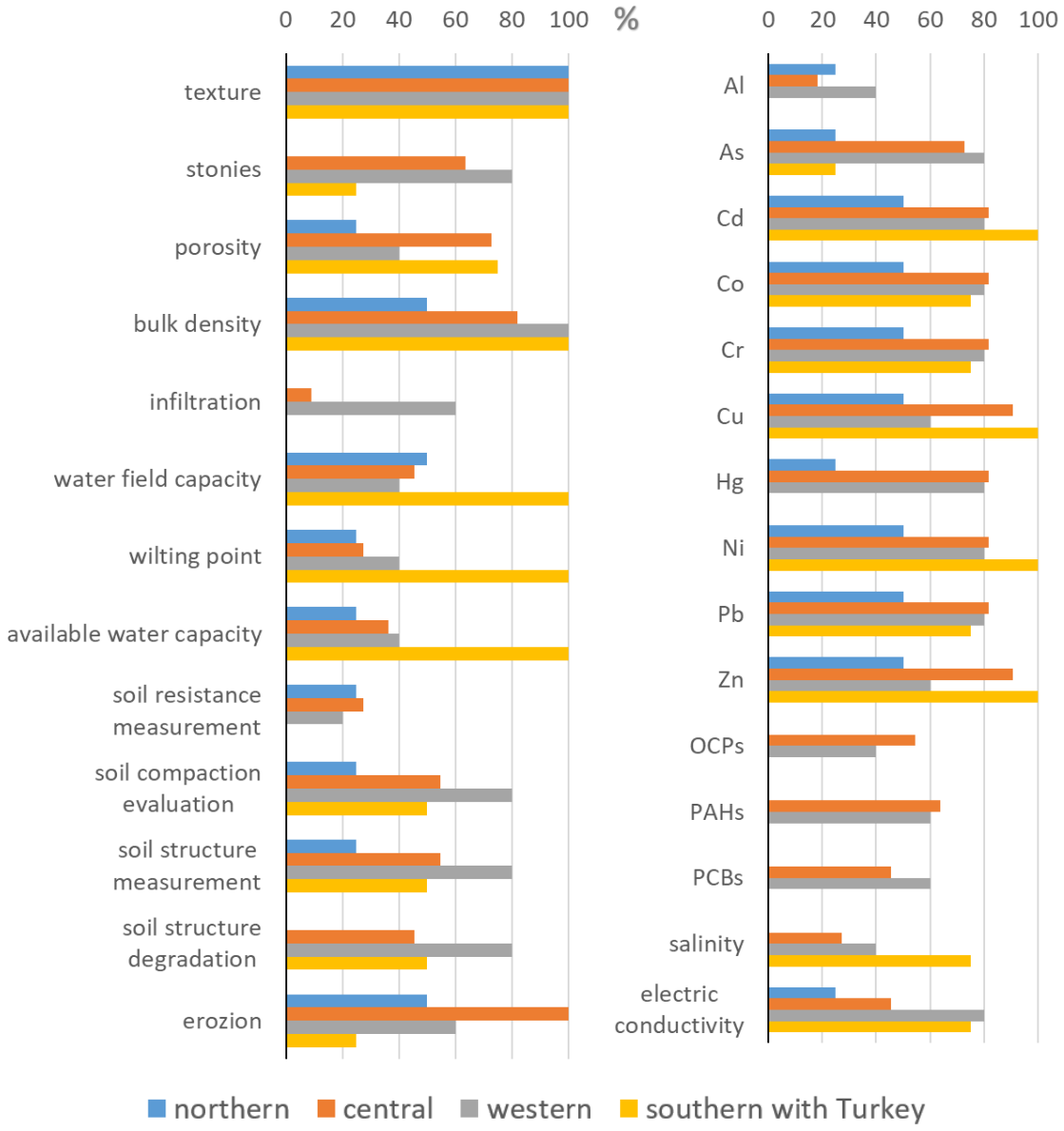

Figure 8: Physical parameters, soil water content, physical soil degradation, and soil chemical degradation evaluation in participating countries divided to European regions: northern (4 countries), central (11 countries), and western Europe (5 countries), and southern Europe with Turkey (4 countries). (OCPs – organochlorine pesticides; PAHs – polycyclic aromatic hydrocarbons; PCBs – polychlorinated biphenyls)

It is clear from figure 9 that soil biological parameters are the least measured indicators of soil quality. They are evaluated mainly in Western Europe, less in Central. Some of them are evaluated in Southern Europe. Northern Europe, there is no information on the use of these properties in terms of soil quality indicator.

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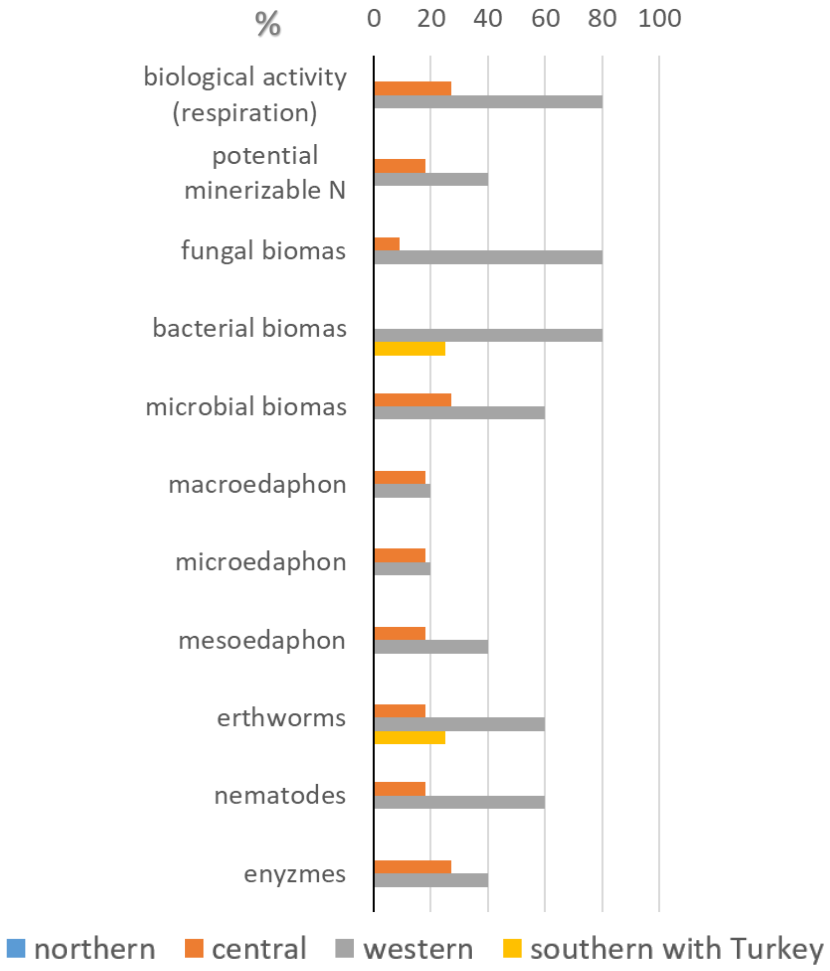

Figure 9: Biological parameters evaluation in participating countries divided to European regions: northern (4 countries), central (11 countries), and western Europe (5 countries), and southern Europe with Turkey (4 countries).

4.2. Soil quality indicators (questionnaire part D)

In this part of questionnaire survey, we obtained 24 completed questionnaires. Most of soil respondents were recruited from the scientific communities of various professions, or managers in soil management issues.

The principal questions were:

1. Which parameters and indicators are used in national legislation (limits)?
2. Which parameters and indicators are used as policy makers' tools?
3. Which parameters and indicators are used to exclude certain measures (e.g. using selected fertilizers)?
4. Which parameters and indicators are used to recommend certain soil protection measures?
5. If you have no national indicators what is done with the data?
6. Do you produce maps or references values for the country? (if yes, for what measurements)?
7. Have you compared your results with the LUCAS data/results/maps?

In the questionnaire there were:

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1. information containing country-wide information – 16 countries
2. information containing region-wide information – 7 countries
3. information containing local information – 1 country

To the question 1: Which parameters and indicators are used in national legislation (limits)?

- 18 country respondents can are familiar with national legislation and its indicators/parameters;
- Other country respondents are not sure on legislation, blank answers
- Legislation is referring to the soil protection, Nutrient Action programme, Code of Practice, Soil Contamination legislation, Water Framework Directive, Nitrate directive, Sewage Sludge regulations, CAP – GAEC, UNFCCC climate change – emission indicators, soil sealing regulations.

(see the annex III for more details)

To the question 2: Which parameters and indicators are used as policy maker's tools?

- Most country respondents can clearly distinguish policy maker´s tools from legislation what are e.g. soil monitoring, strategies, action plans, etc.
- for 15 country respondents consider both terms as the same or similar, so their answers were "see above"

(see the annex IV for more details)

To the question 3: Which parameters and indicators are used to exclude certain measures (e.g., using selected fertilizers)?

- Informing the indicator is compulsory for administrate their use, limits of application – this question was rightly understood by 11 countries, other answers were recognized as blank

(see the annex V for more details)

To the question 4: Which parameters and indicators are used to recommend certain soil protection measures?

- Most country respondents responded very similarly, all parameters/indicators relating to soil degradation like soil pH, SOM (C_{org}), heavy metals and POPs content, N & P indicators, CEC, texture, stoniness, pesticides residues, soil moisture, nutrient status, soil erosion indicator;
- Some specific indicators were included: general indicators to maintain soil functions (AT), combination index of clay/SOC (DK), abundance of biofertilirezs (PT), earthworm density, soil structure stability index (IT), penetration resistance (LT), soil sealing rate (BE);
- no real indicators known for effects of soil erosion (FR),
- indicators/parameters concerning to the main soil treats (erosion, compaction, contamination, acidification, salinization SOM decline, nutrient availability (SK)
- seven country respondents have no idea on soil protection indicators.

(see the annex VI for more details)

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To the question 5: If you have no national indicators what is done with the data?

- Half (13) country respondents do did not answer
- In other countries data are using for education and training, recommendation for farmers, data for agro-climate measures, NATURA 2000, Water Framework Directive, organic farming, greening support (CAP policy)
- passport for farmers (presented by Belgium – ILVO respondent)
- guidelines for farmers relating to agri-management
- testing methods for soil monitoring and other contexts of soil survey.
- research activities (e.g. modelling) and subsequent publications
- cantonal data (CH) brought together into the Competence Centre on soils in Switzerland

(see the annex VII for more details)

To the question 6: Do you produce maps or references values for the country? (if yes, for what measurements)?

- 20 country respondents answered yes
- Some answers were from institutions not producing maps.
- Maps production is very diverse, from basic soil maps, soil classification maps, soil model data to specific maps (index, indicator´s maps).
- Urgent need for recent data were declared (e.g. BE produced maps of potential soil erosion (based on RUSLE) and sensitivity/risk map for soil compaction, risk map for actual and potential wind erosion and sensitivity map for land slides. These are all based on models but not on actual monitoring. In Flanders, no regional monitoring is going on at the moment. There is an urgent need for recent soil data (as most basic data are outdated by at least 50 years). Furthermore, harmonisation and centralisation of existing data is also needed as basis for soil policy, research and reporting).
- A need of innovative techniques, non-invasive survey and mapping using remote sensing and satellite images were declared.
- Some country respondents have soil portal of maps (SK, FR, CZ, NO) established.

(see the annex VIII for more details)

To the question 7: Have you compared your results with the LUCAS data/results/maps?

- 14 country respondents answered no – not included into the LUCAS project.
- 10 country respondents answered yes – they have experience at various intensity. Specifically, most of respondents are not familiar with this topic. Only AT, BE, UK, GE, SK, FI answered participation at the LUCAS project. It is known that 25 European countries are involved in this. E.g. in Slovakia, the sampling scheme was analysed for Lucas 2009, 2015 and national database. The database of basic physic-chemical properties of soil parameters Lucas 2009 from Slovakia was compared with the data of the Geochemical Atlas for the surface soil A horizon.
- DE have some comments to the LUCAS project.

(see the annex IX for more details)

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5. Limitations of the synthesis

The general goal of the report presented here is the synthesis on the usage of soil quality indicators and associated decision support tools, from past and on-going projects in European countries. For this purpose, a questionnaire was prepared and all participants (participating countries) of the EJP SOIL project were sent. In this questionnaire survey, we obtained 24 completed questionnaires. Almost 200 sources of information on soil qualitative characteristics were identified in these questionnaires. The report thus provided original and relevant results for understanding the usage of soil quality indicators and associated decision support tools in participating countries. Although, it is important to point out the limitations of the analysis by enumerating the following points:

- It should be emphasized that results are based only on data from a questionnaire survey. Due to this, some data in specific countries may be actually monitored and evaluated, but they were not in the results, because they were not filled in the questionnaires.
- It should be emphasized that the results are influenced by the quality of responses in the questionnaire. For example, there are only a few specific parameters completed in one of the north European countries questionnaire, which is not negligible when evaluating of this region.
- The questionnaire also showed that many respondents are not familiar with national or EU legislation relating to soil issue and many respondents do not distinguish terms: legislation and policy maker´s tools, answers are the same or similar. Policy maker´s tool can be soil monitoring, action plans, strategies etc. not necessary legislation.

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6. Conclusions

- **The first problem identified in the general assessment of soil qualitative properties was the exclusive use of national taxonomic soil classification systems in majority of the participating countries. Harmonization with wider use of WRB classification would be beneficial for unifying some approaches.**
- **It was found that in most countries and thus in all environmental zones and European regions, there is a wide range of information on soil properties, obtained from both national (regional in the case of specific state arrangements) monitoring and single sampling campaigns. These data are in the form of databases or geodatabases often publicly available. In most countries, information on the entire depth of the soil profile is available, only in two are data declared only from topsoil.**
- **As mentioned above, a lot of information about the soil is freely available on the Internet, either in the form of the data itself or geodatabases with map outputs. The range of ICP tools used is based on this. Computers and smartphones are most often mentioned in the questionnaire.**
- **Among the best captured soil parameters across all participating countries are organic carbon concentration in soils and its changes in time, macronutrients (N, P, K) and micronutrients (Cu, Mn) contents in soils, soil pH, cation exchange capacity and base saturation of soils, soil texture and bulk density, and contamination with potentially toxic elements especially Cd, Co, Cr, Cu, Ni, Pb and Zn.**
- **While 22 countries measure soil organic carbon concentrations, about a third of countries lack very important information on soil carbon stocks, which is used in calculations of carbon cycle fluxes, in relation to agricultural soils contribution to climate change mitigation.**
- **Among the less frequently evaluated parameters appertain qualitative characteristics of organic matter. These parameters are not monitored or reported by more than half of the countries. This is a very important characteristic of the soil both in relation to vegetation and the stabilization of carbon in the soil, in the general aim of increasing the contribution of agricultural soils to climate change mitigation.**
- **Evaluation of water content is one of the less monitored soil characteristics in participating countries. This can also be considered as a knowledge gap, as this information is important in terms of water retention in the soil, influencing hydrological cycles and thus fulfilling one of the basic functions of the soil, in particular in a climate change context.**
- **Contamination with organic pollutants is addressed in only about one third of countries.**
- **Biological parameters are generally the least frequently evaluated indicators of soil quality in Europe. Biological activity is most often evaluated through soil respiration, but also only in seven of the participating countries.**
- **Some regionality in the use of specific soil quality indicators was shown only in the assessment of soil salinity. Their evaluation is tied to countries where these saline soils occur naturally. On the contrary, for example, acidification of soils, for which a certain zoning could be assumed, is assessed across all regions. The result also shows no use of specific parameters for soil quality assessment in regions with a higher proportion of organic soils.**

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- **With regard to the general goal of the questionnaire (the synthesis on usage of soil quality indicators and associated Decision Support Tools, including ICT tools in European countries) there are some soil quality indicators frequently used in national legislations and as policy maker´s tools (e.g. nutrient contents, heavy metals contents, pH, hazard of soil erosion, organic pollutants contents) whereas soil organic carbon was mentioned the most. However, a few countries did not report data on C concentration (2 countries) or C stock (8 countries).**
- **Most of recognized indicators/parameters are very similar, some of them can be named as more specific ones.**
- **Nobody from respondents mentioned ecosystem services as indicator or parameter (how to measure that?). This is rather new theme for policy makers and stakeholders which need to be carefully explained them and develop.**

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Main European regions. Source: Der Ständige Ausschuss für geographische Namen (StAGN) https://commons.wikimedia.org/wiki/File:Grossgliederung_Europas-en.svg [22.7.20]

Tóth, G., Stolbovoy, V. and Montanarella (2007). Soil Quality and Sustainability Evaluation - An integrated approach to support soil-related policies of the European Union. Luxembourg: Office for Official Publications of the European Communities.

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Annex I

Table of all data sources from questionnaires.

Country	Source name	Source link	Source purpose	code
Austria	BORIS - Soil Information System	www.borisdaten.at	Harmonisation of data, Data provision for soil protection issues	CO
	eBOD - Digital Soil Map of Austria	bodenkarte.at	Information about arable soils	CO
	Österreichische Bodenschätzung - Austrian Soil Condition Survey	www.bmf.gv.at	to tax farmers and to supply data for	CO
	Invekos - Agricultural Data	www.bmlrt.gv.at	Granting of direct payments, ÖPUL premiums or compensatory allowances	UN
	AGES - farm data & long term research sites		research about soil management	LC
	BAW - specialized project data & long term research	www.baw.at	research	CO
	IfÖL - long term research site	boku.ac.at	to assess the effects of conversion to organic agriculture in a stockless farming system in dry eastern Austria on different parameters	RG
	MobiLab - H2020 Project	www.metos.at	A mobile device for the quick on-site measurement of soil nutrients	UN
	LK-Düngerechner - Fertilizer Calculator Excel-Programme of the agricultural chamber	ooe.lko.at	This excel programme is calculating the total nutrient amount	CO
	AgrarCommander - Software (FATIMA Projekt H2020)	static.agrarcommander.at	To calculate the nutrient demand on site	CO

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	LUCAS	esdac.jrc.ec.europa.eu	Harmonizing data of soil cover/land use in EU and their change over time	CO
	FarmIT - Research Studio Austria	farmit.at	to support smart farming by using innovative technology	UN
	LBG Bodenwächter - Software	lbg-cd.at	recording and calculating cultivation measures	UN
	ACC-Austrian Carbon Calculator	www.bwsb.at	tool for carbon balancing	CO
	Fungal Diversity - Publication	link.springer.com/content/pdf/10.1007/s13225-010-0053-1.pdf	species inventory	UN
	Soil Microbiomes - Publication	www.ncbi.nlm.nih.gov/pmc/articles/PMC7261914	understanding of microbial diversity	UN
Belgium	Soil Organic Carbon Stock Map	www.dov.vlaanderen.be	Quantifying actual SOC stock	RG
	Potential soil erosion map	www.dov.vlaanderen.be	The calculation of the potential soil erosion is done based on the R.U.S.L.E. soil loss equation	RG
	Soil sealing map	www.geopunt.be	Current status on soil sealing in Flanders	UN
	Sensitivity & risk map soil compaction			UN
	Risk map potential and actual wind erosion			UN
	Map landslides & sensitivity map	www.geopunt.be		UN
	Digital Map of Walloon Soils (CNSW)	orbi.uliege.be	Soil description	UN
	Texture map		Soil description	RG
	Carbiosol map: COT content		Monitoring of total organic carbon content	RG
	Carbiosol map: COT stock		Monitoring of total organic carbon stock	RG
	Soil status (BDES)	geoportail.wallonie.be	Cartography of polluted or potentially polluted soils in Wallonia	RG
	Aardewerk database		Soil description and analytical characterization	RG
	LIDAXES		Mapping of concentrated runoff axes	UN

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	ERRUISOL - diffuse runoff risk map	geoportail.wallonie.be	diffuse runoff risk mapping	UN
	ERRUISOL - diffuse erosion risk map	geoportail.wallonie.be	diffuse erosion risk mapping	UN
	Soil map WRB			UN
	REQUASUD database	http://www.requasud.be/outils/	Soil characterization	RG
Czech Republic	Geoportal Sowac GIS	geoportal.vumop.cz	Characteristics of the area of interest	CO
	Land Registry LPIS (Land Parcel Identification System) - AZZP	eagri.cz/public/web/ukzuz	Evaluation of the content of accessible nutrients and microelements	CO
	Register of contaminated areas	www.ukzuz.cz	Determining the content of the elements in the ground soils	CO
	Basal soil monitoring - basic	www.ukzuz.cz	State and development of selected parameters over time	CO
	Basal soil monitoring - annual	www.ukzuz.cz	State and development of selected parameters over time	CO
	Basal soil monitoring - soil probe	www.ukzuz.cz	Precise description and characteristics of the soil profile at the site	CO
	Soil ecological units (land evaluation system)	www.spucr.cz/bpej spucr.maps.arcgis.com bpej.vumop.cz	Agricultural land evaluation, protection and pricing purposes	CO
Denmark	Danish Soil Profile Data Base	dx.doi.org/10.1080/ 00167223.1985.10649211		CO
	Danish Soil Classification Data Base	Madsen, H.B., Nørr, A.H. and Holst, K.A. The Danish soil classification.	National level soil mapping	CO
	Danish Soil Monitoring Data Base	dx.doi.org/10.1111/ ejss.12169	National level soil monitoring	CO
	Danish Acid Sulphate Data Base	doi.org/10.1016/S0341-8162(85)80031-X	Mappig potentially sulphate acidic soils in wetlands in Jutland	RG

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	Danish Sinks Wetland Data Base	dx.doi.org/10.1097/ ss.0000000000000066	Mapping organic soils at national level	CO
	Danish Digital Soil Maps		Various digital soil mapping projects	CO
Estonia	Large-scale soil map of Estonia	geoportaal.maaamet.ee	Detailed soil data collection covering whole Estonia	CO
	Regular monitoring of arable soils (I period)		One of the goal was to analyze the dynamics of the humus horizon both in time and space	CO
	Regular monitoring of arable soils (II period)		Long-term monitoring of changes in various soil parameters (physical, agrochemical, chemical and biological) under different management practices	CO
	Data on agrochemical parameters of Estonian arable soils		Determination of site-specific fertilisation and liming need in arable soils	CO
Finland	National monitoring of arable soil chemical quality (Valse)		Follow-up of arable soil quality, updating of key soil chemical indicators	CO
	Sentinel-hub			UN
	Veris Technologies			UN
	Geological Survey of Finland	gtkdata.gtk.fi		UN
	Eurofins, laboratory			UN
	Drone flights			UN
	National land survey of finland (NLS), lidar	avaa.tdata.fi		UN
	National land survey of finland (NLS), ortho	avaa.tdata.fi		UN
	Tomst			UN
France	BDETM	www.gissol.fr	Regulary purpose (linked to sewage sludges control, each 10 years soils are reanalysed)	CO
	IGCS	www.gissol.fr	Soil mapping	CO
	RMQS	agroenvgeo.data.inra.fr	Soil Quality assessment	CO
	BDAT	doi.org/10.15454/NFQRRB	Monitoring soil fertlility	CO
	Bioindicateur Phase 2			CO

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	RMQS-Biodiv			CO
Germany	German Agricultural Soil Inventory (public)		To obtain a first representative and consistent baseline of SOC stocks in agricultural soils across Germany	CO
	German Agricultural Soil Inventory (extended)		To obtain a first representative and consistent baseline of SOC stocks in agricultural soils across Germany	CO
	German weather station data – soil temperature & soil moisture	opendata.dwd.de/ climate_environment	Monitoring of soil temperature	UN
	Edaphobase		Compilation of published and unpublished literature, raw data and collection data to characterize species-level distributions of soil organisms	CO
	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	geoviewer.bgr.de	Providing soil maps for Germany	CO
	Long-term soil monitoring sites of German federal states		Mandate formulated in the German Federal Soil Protection Act (BBodSchG, 1998) and the Soil Protection Acts of the Federal States	CO
	Soil valuation (Bodenschätzung)		Valuation of agricultural land & basis for various taxes	CO
	Nitrogen and Sulphur deposition for Germany (PINETI-model)	gis.uba.de	Monitoring of nitrogen deposition	UN
	Thünen Atlas	www.thuenen.de	Part of agricultural census	UN
Hungary	Hungarian Soil Information and Monitoring System	portal.nebih.gov.hu	Soil properties monitoring	CO
	TDR (Soil Degradation Subsystem of the Hungarian	okir-tdr.helion.hu	Production of soil data required for soil protection; monitoring both soil state and environmental impact of agriculture; creation of an IT background in order	CO

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	Environmental Information System)		to facilitate the implementation of directives specified in the EU soil protection strategy; publishing soil data and information in order to support the implementation of related public services and information to the public.	
	ZooLog Monitoring System	www.zoolog.hu	monitoring of the activity of soil living animals	CO
Ireland	Soil Quality Assessment Research Data (SQUARE)		Soil quality assessment	CO
	Irish Soil Information System (SIS)		Soil survey soil classification	CO
	Tellus		Geochemical and geophysical seruvey	UN
	NSDB		National Soil Database	CO
	Landmark / LUCAS		To validate a pan-Europeanmonitoring scheme	CO
Italy	Lombardy Soil Information System (LOSIS)		Regional Soil Information System	RG
	Lombardy Soil Quality Monitoring		reference thresholds for land use and soil management	RG
	sardegnaportalesuolo.it			RG
	ENEA-1		Effect of biochar addition into low contaminated soil on early growth of durum wheat plants and rhizosphere microbiome	UN
	ENEA-EPPN		Effect of biochar addition to pot soil on early growth of durum wheat plants.Soil and biochar chemical-physical characterization, plant growth performance and other physiologica traits	UN
	SISI-BADASUOLI	doi.org/10.1007/ 978-94-007-5642-7_6	Creation soil map	CO
	NCBI Database: ID Project PRJNA241061		Naturally salt-affected soil survey	LC
	Soil database 250		Creation Soil maps	UN

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Latvia	Digital soil database (soil profiles)	https://geolatvija.lv/geo/p/319	National inventory of agricultural lands	CO
	Digital soil database (soil polygons)	https://geolatvija.lv/geo/p/319	National inventory of agricultural lands	CO
	LV LUCAS Topsoil 2009 data	www.dataeuropa.eu	First attempt to build a consistent spatial database of the soil cover across the European Union based on standard sampling and analytical procedures cover across the European Union based on standard sampling and analytical procedures	CO
	Geochemical Atlas of Latvia		Geochmical status of the Latvian soils	CO
	BioSoil		Inventory of forest soils	UN
	Soil agrochemical research database of the State Information System for Monitoring of Agricultural Plants (hereinafter-SISMAP)	www.vaad.gov.lv	Procedures for obtaining and compiling information on the fertility rate and change of agricultural land.	CO
	Database on the monitoring of mineral nitrogen in soils of the SISMAP	www.vaad.gov.lv	Directive 91/676/EEC Annex III, point.1, 3)	CO
	National forest inventory		Carbon stock inventory in mineral and organic farm soils	UN
Lithuania	Dirv-DR10LT	www.geoportal.lt	Soil data, soil properties for monitoring ang policy, Land use / land management data, Supplementary environmental data (land cover, topography, climate, geology, water, etc), Administrative boundaries, Spatial datasets of: (1) reclamation status and sodden soils; (2) limited land use areas; (3) abandoned land.	CO

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Netherlands	Bodemindicatoren voor Landbouwgronden in Nederland (BLN)	https://edepot.wur.nl/498307	Creation of a set of easy-to-use indicators for individuals and the government	CO
	Landelijk Meetnet Bodemkwaliteit/BOBI/Bodem Ecosysteemdiensten Onderzoek	www.rivm.nl	Assess/monitor soil quality in relation to policy measures	CO
	CC-NL	research.wur.nl	Determine whether soil carbon stocks have been decreased in the past 20 years (on the basis of the LULUCF methodology).	CO
	Landelijk Meetnet Effecten Mestbeleid (LMM)	www.rivm.nl	Assess the effect of mineral policies (Mestbeleid) and determine whether the water quality meets the ND-standards.	CO
	Open Bodem Index	www.openbodemindex.nl	To asses soil quality with an easy-to-use instrument	CO
	Eurofins Agro Bodemvruchtbaarheid	www.eurofins-agro.com	To provide farmers with information about their soil and assist them in their fertilization plan	CO
	Bodemconditiescore	mijnbodemconditie.nl	Data-collection is not the purpose. It is a tool to assist farmers in assessing their soil qualitity, based on the paper by Sonneveld et al., 2014.	CO
	Bodemkundig Informatie Systeem (BIS)	maps.bodemdata.nl		CO
	Basisregistratie ondergrond (BRO)	basisregistratieondergrond.nl	The providance of information about the (sub)soil for policy makers.	CO
	Bodematlas Brabant		Provide insights in the current status of the quality of the agricultural soil	CO
Norway	Kilden	kilden.nibio.no		CO
	The Norwegian Agricultural Environmental Monitoring Programme (JOVA)	www.nibio.no	Water monitoring (water chemistry, quality elements)	UN

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Poland	Soil Bonitation map (corr. To potential yield)		taxing	CO
	Soil-Agricultural Map 1:25000		taxing, scientific	CO
	Monitoring of Soil Chemical Properties	www.gios.gov.pl	soil quality assessment	CO
	Soil-Agricultural Map 1:5000		taxing, scientific	CO
	Soil-Agricultural Map 1:100.000		taxing, scientific	CO
	Soil-Agricultural Map 1:500.000		science	CO
Portugal	Scientific publication	dx.doi.org/10.2788/5936	Gonçalves, M. C., Ramos, T. B., Martins, J. C. 2013. Soil data from Portugal. In: Weynants et al. (eds.), European Hydropedological Data Inventory (EU-HYDI). 08/2013, Publisher: Publications Office of the European Union, pp 57-62, ISBN: 978-92-79-32355-3	CO
	Scientific publication		Boucho, A.C.M.; Carranca, C.; Pereira, P.; Mano, R. and Madeira, M. Soil chemical changes in response to high fixing pasture legumes cultivation after a phosphorus fertilization. (under revision)	UN
	Scientific publication	doi:10.1016/j.eja.2009.05.009	Carranca, C.; Torres, M.O. and Baeta, J. 2009. White lupine as a beneficial crop in Southern Europe. I - Potential for N mineralization in lupine amended soil and yield and N2 fixation by white lupine. European Journal of Agronomy, 31: 183-189.	UN
	Scientific publication	doi:10.1016/j.scitotenv.2014.10.111	Carranca, C.; Castro, I.V.; Figueiredo, N.; Redondo, R.; Rodrigues, A.R.F.; Saraiva, I.; Maricato, R. and Madeira, M.A.V. 2015. Influence of tree canopy on N2 fixation by pasture legumes and soil rhizobial abundance in Mediterranean oak woodlands. Science of the Total Environment, 506–507: 86–94.	UN
	Scientific publication	DOI: 10.13140/RG.2.1.1775.3680	Fraga, I.; Fangueiro, D.; Surgy, S.; Bezerra, R. and Coutinho, J. 2015. Application of raw or acidified	UN

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			cattle slurry: effect on soil glomalin indicators. (Poster)	
	Scientific publication	Doi: 10.1007/s10457-017-0088-3	Borges, O.; Raimundo, F.; Coutinho, J.; Gonçalves, B.; Oliveira, I.; Martins, A. and Madeira, M. 2017. Carbon fractions as indicators of organic matter dynamics in chestnut orchards under different soil management practices. Agroforestry Systems.	UN
	Scientific publication	agricultura.isa.utl.pt	Rodrigues, A.R.; Coutinho, J. and Madeira, M. 2013. Management practices and soil quality in 'Rocha' pear groves. Revista de Ciências Agrárias, 36(2): 238-249.	UN
	Scientific publication	DOI: 10.1016/j.eja.2009.05.010	Carranca, C.; Torres, M.O. and Baeta, J. 2009. White lupine as a beneficial crop in Southern Europe. II – Nitrogen recovery in a legume-oat rotation and a continuous oat-oat. European Journal of Agronomy, 31: 190-194.	UN
	Scientific publication	doi: 10.1016/j.geoderma.2009.03.012	Carranca, C., Oliveira, A., Pampulha, E., Torres, M.O., 2009. Temporal dynamics of soil nitrogen, carbon and microbial activity in conservative and disturbed fields amended with mature white lupine and oat residues. Geoderma 151, 50–59.	UN
	Scientific publication	DOI 10.1007/978-3-319-32528-6_15	Ricardo Soares, Eva Arcos, Eugénio Ferreira and Isabel Videira e Castro 2016. Microbial Inoculants with Autochthonous Bacteria for Biodiverse Legume Pastures in Portuguese Agro-Forestry Ecosystems In:Biological Nitrogen Fixation and Beneficial Plant–Microbe Interactions. F. González-Andrés and E. James (eds.), Chapter 15, 171-182.	UN
	Scientific publication		Domingues, A.M., Castelo Branco, M.A., Calouro, F., Fareleira, P. (2006) Variation in enzymatic activities after pig slurry application to soil. Canal BQ 2: 32-39.	UN

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	Technical Report	Doi: 10.13140/RG.2.2.28262.98883	Calouro F, Martins JC, Jordão P, Marcelo ME,Fernandes R, Sempiterno C, Mano R, Azevedo–Gomes A, David TS, Valdiviesso T, Silva CS. 2019. Estado de fertilidade dos solos de montado de sobro. Vida Rural, Set. 2019:32–34	UN
	Technical Report		Marcelo ME, Carrasquinho I, Jordão P, Mano R, Calouro F, Gaspar M, Azevedo– Gomes JP, Melo I, Martins S, Silva CS, Amaral MR, Borges C, Correia A,2020. Caracteristicas físicas e químicas de solos ocupados com pinheiro manso. Vida Rural, Fev. 2020:24–27	UN
	Scientific publication	Doi:10.1016/j.ecolmodel.2010.11.013	Teixeira RFM, Domingos T, Costa APSV, Oliveira R, Farropas L, Calouro F, Barradas AM, Carneiro JPBG. 2011. Soil organic matter dynamics in Portuguese natural and sown rainfed grasslands. Ecological Model, Elsevier, Vol. 222(4): 993–1001	UN
	Conference paper		Jordão P, Marcelo ME, Martins JC, Mano R, Calouro F. 2015. Estado de fertilidade de solos com olivais no Alentejo. II - Olival tradicional / Soil Fertility of olive groves in Alentejo. II - Traditional olive grove. In: O Solo na Investigação Científica em Portugal, Lisboa. Volume: Abreu MM, Fangueiro D, Santos ES (Ed): 81-84	UN
	Conference paper		Marcelo ME, Martins JC, Maricato R, Jordão P. 2015. Estado de fertilidade de solos com olivais no Alentejo. I - Olivais intensivos e superintensivos/ Soil Fertility of olive groves in Alentejo. I - Intensive and superintensive olive grove. In: O Solo na Investigação Científica em Portugal, Lisboa. Volume: Abreu MM, Fangueiro D, Santos ES (Ed): 81-84	UN

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	Scientific publication	om.ciheam.org/om/pdf/a79/00800614.pdf	Teixeira R., Domingos T., Costa A.P.S.V., Oliveira R., Farropas L., Calouro F., Barradas A., Carneiro J.P. The dynamics of soil organic matter accumulation in Portuguese grassland soils. In: Porqueddu C. (ed.), Tavares de Sousa M.M. (ed.). Sustainable Mediterranean grasslands and their multi-functions. Zaragoza: CIHEAM / FAO / ENMP / SPPF, 2008. p. 41-44. (Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 79). 12. Meeting of the Sub-Network on Mediterranean Forage Resources of the FAO-CIHEAM Inter-regional Cooperative Research and Development Network on Pastures and Fodder Crop, 2008/04/09-12, Elvas (Portugal).	UN
	Provider	pureportal.inbo.be	de Vos, B. & Cools, N. (2011). Second european forest soil condition report. Volume I: Results of the BioSoil soil survey, INBO - Research Institute for Nature and Forest, Bruxelas, 359 p. Report nº INBO.R.2011.35 [ISSN 1782-9054]	UN
	Provider		Vanmechelen, L., Groenemens, R. & Van Ranst, E. 1997. Forest Soil Condition in Europe. Results of a Large Scale Soil Survey. European Commission, United Nations Economic Commission for Europe, Ministry of the Flemish Community. 259pp. Bruxelas & Geneva. ISBN 90-76315-01-9. International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP-Forests)	UN
	Scientific publication	www.scielo.mec.pt	DIAS, R.M.S. et al. Cádmio, Cobre, Níquel e Zinco em solos com ocupação agrícola em Portugal. Rev. de	CO

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			Ciências Agrárias [online]. 2007, vol.30, n.2 [citado 2020-07-03], pp.358-368.	
Slovakia	Soil monitoring system of agricultural land	www.podnemapy.sk		CO
	General soil survey of agricultural land (Slovakia)		National inventory of agricultural land	CO
	Soil ecological units (Land evaluation system)	www.podnemapy.sk	Agricultural land evaluation and protection	CO
	Soil monitoring in the Gabčíkovo waterworks area	www.vupop.sk	Impact of hydropower plant on the agricultural soils properties	RG
	SK LUCAS Topsoil 2009 data	www.dataeuropa.eu	First attempt to build a consistent spatial database of the soil cover across the European Union based on standard sampling and analytical procedures cover across the European Union based on standard sampling and analytical procedures	CO
	Geochemical Atlas of Slovakia	www.geology.sk	Geochmical status of the Slovak soils	CO
Slovenia	Digital Soil Map of Slovenia 1:25.000 (DSM25) of Slovenia	eprostor.gov.si	For making soil map of Slovenia	CO
	Soil Profile Dataset Slovenia (SPD) of Slovenia	geonetwork.alpinesoils.eu	Collected within the elaboration of the Digital Soil Map 1:25.000	CO
	Agricultural Soil Suitability Value (ASSV) of Slovenia	rkg.gov.si	Index of soil productivity evaluation, integer values from 7 (lowest suitability) to 100 (highest suitability) (applies 7-88 for grassland).	CO
	Soil Pollution Monitoring (SPM) of Slovenia	gis.arso.gov.si	Topsoil contamination status in Slovenia; changes in topsoil contamination status (where sampling was repeated)	CO
	Soil Organic Carbon Data (SOC) of Slovenia		agricultural topsoil organic carbon measurements	CO
	FAO GSOCmap - Slovenia		Soil Organic Carbon Assessment - part of the GSP GSOCmap	CO

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Spain	INIA - LTE-Experimental Farm La Canaleja (Madrid, Spain) - Soil fertility DB1, Food, feed, fibre DB2, erosion control DB3, climate regulation DB4, labile organic carbon DB5		Research	LC
	CSIC-LTE-Experimental Farm Tres Caminos (La Matanza - Santomera , Murcia, Spain)		Research	LC
	CSIC-LTE Semi-public farm in Cieza, Murcia, Spain		Research	LC
	CSIC-LTE Eperimental farm La Poveda, Arganda del Rey, Madrid, Spain		Research	LC
	CSIC-LTE Senes, Huesca, Soain		Research	LC
	CSIC-LTE Salamanca, Spain		Reserch study (mobility of herbicides in the soil profile)	LC
Sweden	National Arable Soil and Crop Inventory		Monitoring	CO
	National Inventory of Arable Soils	miljodata.slu.se	improve knowledge of characteristics of Swedish cultivated land	CO
	National Soil Compaction Survey	www.slu.se	Monitor the soil physical condition in Swedish arable land	CO
	Clay Content in Arable Soils	www.sgu.se	The map is made from fusion of several spatial databases	CO
	Map of Soil Types	apps.sgu.se	To give a basis for construction, research and education	UN
Switzerland	Swiss Soil Dataset 2018 (NABO)		To assess changes in soil parameters over time	CO

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	Proof of Ecological Performance		long-term development of soil phosphorus, potassium, pH, and Corg on all agricultural plots > 1 ha	CO
	Swiss Agri-Environmental Data Network (AUI)	www.agroscope.admin.ch	monitoring agricultural policy; collecting data for research	CO
	Kanton of Bern		soil monitoring	RG
	Kanton of Aargau		soil monitoring	RG
	Kanton of Graubunden		soil monitoring	RG
	Farming System and Tillage Experiment (FAST)	www.agroscope.admin.ch	Currently, agriculture is facing the challenge of producing enough food and, at the same time, minimizing environmental impact. In the Farming System and Tillage Experiment (FAST) different arable cropping systems are compared concerning productivity and ecosystem service delivery (especially the aspects of erosion protection, nutrient cycles, carbon storage, soil quality and biodiversity, climate adaptation and mitigation). The results should contribute to an improved understanding of cropping system multifunctionality and a more sustainable resource management. The systems compared are arable cropping according to the "Proofs of Ecological Performence" Guidelines (= conventional farming in CH) and organic farming, with a special focus on different tillage intensities (intensive versus conservation) and the effect of different cover crops within the different systems.	CO
Turkey	Turkish Ministry of Agriculture and Forestry Soil Fertilizer and Water Resources Central	Data available only under special permission - Sharing Rules of TAGEM		CO

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	Research Institute - Soil Information System			
United Kingdom	National Soil Inventory of Scotland (1978-88)	www.hutton.ac.uk	Characterising the soil resource of Scotland	RG
	National Soil Inventory of Scotland 2007-9	www.hutton.ac.uk	Assessing change over time in key soil properties and testing methods to detect change	RG
	National soil map of Scotland	www.hutton.ac.uk	Characterising the soil resource of Scotland	UN
	Soil map of Scotland (partial cover)	www.hutton.ac.uk	Characterising the soil resource of Scotland	RG
	Scottish Soils Database of Representative profiles		Characterising the soil resource of Scotland	RG
	Risk maps	www.hutton.ac.uk	to help manage soils and reduce water pollution	RG
	UKCEH Countryside Survey (GB, England, Wales, Scotland)	countrysidesurvey.org.uk	Understand national soil change	CO
	ERAMMP - Wales	catalogue.ceh.ac.uk	Policy support	RG
	G-BASE_Topsoil_Soil	mapapps2.bgs.ac.uk	Provide baseline information on the natural abundances of elements	CO
	G-BASE_Profile_Soil	mapapps2.bgs.ac.uk	Provide baseline information on the natural abundances of elements	CO
	NSI_Site		Soil Survey	CO
	NSI_Profile		Soil Survey	UN
	NSI_Topsoil		Soil Survey	CO
	NSI_Textures		Soil Survey	CO
	NSI_Features		Soil Survey	UN
	ECN		ECN is the UK's long-term environmental monitoring programme	CO
	ALC_England		Provisional Agricultural Land Classification Grade	UN
	BioSOIL	map.bgs.ac.uk	Forest soil monitoring	UN

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	LandIS Soil Portal		The LandIS site contains soil and soil-related information for England and Wales including spatial mapping of soils at a multiple scales, together with soil property and agro-climatological data.	UN
	TELLUS Regional A Soils	www.bgs.ac.uk	Geochemical Survey of Northern Ireland	RG
	TELLUS Regional S Soils	www.bgs.ac.uk	Geochemical Survey of Northern Ireland	RG
	UK Soil and Herbage Pollutant Survey	assets.publishing.service.gov.uk	Survey	CO
	UK Soil Observatory		Allow public access to soil map information	UN
	AFBI 1:50,000 Soil Map		Soil Survey	UN
	AFBI RSSS		To monitor soil quality across Northern Ireland (NI) in order to provide soil data to support Dept Agriculture's evidence-based responses to EU Directives	RG

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Annex II

Detail description of largescale data sources

country	country source name	data availability	sampling strategy	sampling depth	groups of soil quality indicators*							
					1)	2)	3)	4)	5)	6)	7)	8)
Austria	BORIS - Soil Information System	both	single.c.	no info	1	1	1	1	1	1	1	1
Austria	eBOD - Digital Soil Map of Austria	both	single.c.	profile	1	1	0	1	1	1	0	0
Austria	Österreichische Bodenschätzung - Austrian Soil Condition Survey	permission	single.c.	profile	0	1	0	1	1	1	0	0
Austria	BAW - specialized project data & long term research	permission	other	no info	1	1	0	1	1	1	0	0
Austria	LK-Düngerechner - Fertilizer Calculator Excel-Programme of the agricultural chamber	other	other	no info	0	0	1	0	0	0	0	0
Austria	AgrarCommander - Software (FATIMA Projekt H2020)	permission	monitoring	no info	0	0	1	0	0	0	0	0
Austria	LUCAS	both	monitoring	topsoil	1	1	1	1	0	1	0	0
Austria	ACC-Austrian Carbon Calculator	other	single.c.	profile	1	1	1	1	0	0	0	0
Czechia	Geoportal Sowac GIS	free	single.c.	topsoil	1	1	1	1	0	1	0	0
Czechia	Land Registry LPIS (Land Parcel Identification System) - AZZP	both	monitoring	profile	1	1	1	1	0	0	1	0
Czechia	Register of contaminated areas	permission	single.c.	topsoil	0	1	0	0	0	0	1	0
Czechia	Basal soil monitoring - basic	permission	monitoring	profile	1	1	1	0	0	0	1	0
Czechia	Basal soil monitoring - annual	permission	monitoring	profile	0	0	0	0	0	0	1	0
Czechia	Basal soil monitoring - soil probe	permission	single.c.	profile	1	1	1	1	0	0	1	0
Czechia	Soil ecological units (land evaluation system)	free	single.c.	profile	0	0	0	1	0	0	0	0
Denmark	Danish Soil Profile Data Base	permission	single.c.	profile	1	1	1	1	1	0	0	0
Denmark	Danish Soil Classification Data Base	permission	single.c.	topsoil	1	0	0	1	0	0	0	0

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Denmark	Danish Soil Monitoring Data Base	permission	monitoring	profile	1	0	1	1	1	0	0	0
Denmark	Danish Sinks Wetland Data Base	permission	single.c.	profile	1	1	1	1	0	0	0	0
Denmark	Danish Digital Soil Maps	permission	other	profile	1	1	0	1	1	1	0	0
Estonia	Large-scale soil map of Estonia	both	single.c.	profile	0	0	0	1	0	1	0	0
Estonia	Regular monitoring of arable soils (I period)	permission	monitoring	topsoil	1	1	1	1	0	1	1	0
Estonia	Regular monitoring of arable soils (II period)	both	monitoring	topsoil	1	1	1	1	0	1	1	1
Estonia	Data on agrochemical parameters of Estonian arable soils	permission	monitoring	topsoil	1	1	1	0	0	0	0	0
Finland	National monitoring of arable soil chemical quality (Valse)	permission	monitoring	topsoil	1	1	1	1	0	0	1	0
France	BDETM	permission	other	topsoil	1	1	0	1	0	0	1	0
France	IGCS	permission	single.c.	profile	1	1	1	1	0	0	0	0
France	RMQS	other	monitoring	profile	1	1	1	1	0	1	1	1
France	BDAT	permission	single.c.	topsoil	1	1	1	1	0	0	0	0
France	Bioindicateur Phase 2	permission	single.c.	topsoil	1	1	1	1	0	0	1	1
France	RMQS-Biodiv	permission	single.c.	topsoil	0	0	0	0	0	0	0	1
Germany	German Agricultural Soil Inventory (public)	free	single.c.	profile	1	1	1	1	0	0	0	0
Germany	German Agricultural Soil Inventory (extended)	other	single.c.	profile	1	1	1	1	0	1	0	0
Germany	Edaphobase	permission	single.c.	no info	0	0	0	0	0	0	0	1
Germany	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	free	single.c.	profile	1	0	1	1	1	1	1	0
Germany	Long-term soil monitoring sites of German federal states	permission	monitoring	topsoil	1	1	1	1	0	1	1	1
Germany	Soil valuation (Bodenschätzung)	other	single.c.	profile	0	0	0	1	0	0	0	0
Hungary	Hungarian Soil Information and Monitoring System	permission	monitoring	profile	1	1	1	1	1	0	1	0
Hungary	TDR (Soil Degradation Subsystem of the Hungarian Environmental Information System)	permission	single.c.	profile	1	1	1	1	0	1	1	1
Hungary	ZooLog Monitoring System	permission	monitoring	topsoil	0	0	0	0	0	0	0	1

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Ireland	Soil Quality Assessment Research Data (SQUARE)	permission	single.c.	profile	1	1	1	1	0	1	1	1
Ireland	Irish Soil Information System (SIS)	both	single.c.	profile	1	1	1	1	0	1	0	1
Ireland	NSDB	both	single.c.	topsoil	1	0	1	0	0	0	1	1
Ireland	Landmark / LUCAS	permission	single.c.	topsoil	0	0	0	1	1	0	0	1
Italy	SISI-BADASUOLI	free	single.c.	profile	0	1	0	1	0	1	0	0
Latvia	Digital soil database (soil profiles)	free	single.c.	profile	0	0	0	1	0	0	0	0
Latvia	Digital soil database (soil polygons)	free	single.c.	profile	0	0	0	1	0	0	0	0
Latvia	LV LUCAS Topsoil 2009 data	both	single.c.	topsiol	1	1	1	1	0	0	0	0
Latvia	Geochemical Atlas of Latvia	free	single.c.	profile	0	0	0	1	0	0	1	0
Latvia	Soil agrochemical research database of the State Information System for Monitoring of Agricultural Plants (hereinafter-SISMAP)	permission	single.c.	topsoil	1	1	1	1	0	1	1	0
Latvia	Database on the monitoring of mineral nitrogen in soils of the SISMAP	permission	monitoring	profile	1	1	1	0	0	0	0	0
Lithuania	Dirv-DR10LT	both	monitoring	profile	1	1	1	1	1	1	1	1
Netherlands	Bodemindicatoren voor Landbouwgronden in Nederland (BLN)	other	other	profile	1	1	1	1	1	1	0	1
Netherlands	Landelijk Meetnet Bodemkwaliteit/BOBI/Bodem Ecosysteemdiensten Onderzoek	permission	monitoring	profile	1	1	1	1	0	0	1	1
Netherlands	CC-NL	permission	monitoring	profile	1	1	1	1	0	1	0	1
Netherlands	Landelijk Meetnet Effecten Mestbeleid (LMM)	both	monitoring	profile	0	1	1	0	0	0	1	0
Netherlands	Open Bodem Index	free	monitoring	profile	0	1	1	1	1	1	1	1
Netherlands	Eurofins Agro Bodemvruchtbaarheid	permission	monitoring	profile	1	1	1	1	1	0	1	1
Netherlands	Bodemconditiescore	other	monitoring	profile	0	1	0	1	1	1	0	1
Netherlands	Bodemkundig Informatie Systeem (BIS)	free	other	profile	1	0	0	1	0	1	0	0
Netherlands	Basisregistratie ondergrond (BRO)	free	monitoring	profile	1	1	1	1	1	0	1	0
Netherlands	Bodematlas Brabant	free	single.c.	topsoil	1	1	1	1	1	1	1	1

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Norway	Kilden	free	monitoring	no info	0	0	0	1	0	1	0	0
Poland	Soil-Agricultural Map 1:25000	permission	single.c.	profile	0	0	0	1	0	1	0	0
Poland	Monitoring of Soil Chemical Properties	free	monitoring	topsoil	1	1	1	1	0	0	1	0
Poland	Soil-Agricultural Map 1:5000	permission	single.c.	profile	0	0	0	1	0	0	0	0
Poland	Soil-Agricultural Map 1:100.000	permission	single.c.	profile	0	0	0	1	0	0	0	0
Poland	Soil-Agricultural Map 1:500.000	permission	single.c.	profile	0	0	0	1	0	0	0	0
Portugal	Scientific publication (Soil data from Portugal)	free	other	profile	1	0	0	1	1	0	0	0
Portugal	Scientific publication (Cádmio, Cobre, Níquel e Zinco em solos com ocupação agrícola em Portugal)	permission	other	profile	1	1	0	1	0	0	1	0
Slovakia	Soil monitoring system of agricultural land	free	monitoring	profile	1	1	1	1	0	1	1	0
Slovakia	General soil survey of agricultural land (Slovakia)	free	single.c.	profile	1	1	1	1	0	1	1	0
Slovakia	Soil ecological units (Land evaluation system)	free	single.c.	profile	0	0	0	1	0	1	0	0
Slovakia	SK LUCAS Topsoil 2009 data	both	single.c.	topsoil	1	1	1	1	0	0	0	0
Slovakia	Geochemical Atlas of Slovakia	free	single.c.	profile	0	1	0	1	0	0	1	0
Slovenia	Digital Soil Map of Slovenia 1:25.000 (DSM25) of Slovenia	free	single.c.	profile	1	1	0	1	0	0	0	0
Slovenia	Soil Profile Dataset Slovenia (SPD) of Slovenia	free	single.c.	profile	1	1	1	1	0	0	0	0
Slovenia	Agricultural Soil Suitability Value (ASSV) of Slovenia	free	single.c.	no info	1	1	0	1	0	0	0	0
Slovenia	Soil Pollution Monitoring (SPM) of Slovenia	permission	monitoring	profile	1	1	0	1	0	0	1	0
Slovenia	Soil Organic Carbon Data (SOC) of Slovenia	other	single.c.	topsoil	1	1	1	1	0	1	0	0
Slovenia	FAO GSOCmap - Slovenia	permission	single.c.	no info	1	1	0	1	0	0	0	0
Sweden	National Arable Soil and Crop Inventory	permission	monitoring	profile	1	1	1	1	0	0	1	0
Sweden	National Inventory of Arable Soils	free	single.c.	topsoil	1	1	1	1	0	0	0	0
Sweden	National Soil Compaction Survey	free	monitoring	profile	0	0	0	1	1	1	0	0
Sweden	Clay Content in Arable Soils	both	single.c.	topsoil	0	0	0	1	0	0	0	0
Switzerland	Swiss Soil Dataset 2018 (NABO)	permission	monitoring	profile	1	1	0	1	0	0	0	0

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Switzerland	Proof of Ecological Performance	other	monitoring	topsoil	1	1	1	1	0	0	0	0
Switzerland	Swiss Agri-Environmental Data Network (AUI)	both	monitoring	no info	0	0	0	0	0	1	1	0
Switzerland	Farming System and Tillage Experiment (FAST)	permission	monitoring	topsoil	1	1	1	1	1	0	0	1
Turkey	Turkish Ministry of Agriculture and Forestry Soil Fertilizer and Water Resources Central Research Institute - Soil Information System	permission	other	topsoil	1	1	1	1	1	0	1	0
United Kingdom	UKCEH Countryside Survey (GB, England, Wales, Scotland)	free	monitoring	topsoil	1	1	1	1	1	1	1	1
United Kingdom	G-BASE_Topsoil_Soil	permission	monitoring	topsoil	1	1	0	0	0	0	1	0
United Kingdom	G-BASE_Profile_Soil	permission	monitoring	subsoil	0	0	0	0	0	0	1	0
United Kingdom	NSI_Site	permission	single.c.	profile	0	0	0	0	0	1	0	0
United Kingdom	NSI_Topsoil	permission	single.c.	profile	1	1	1	1	0	0	1	0
United Kingdom	NSI_Textures	permission	single.c.	topsoil	0	0	0	1	0	0	0	0
United Kingdom	ECN	permission	monitoring	profile	1	1	1	1	1	1	1	0
United Kingdom	UK Soil and Herbage Pollutant Survey	free	single.c.	topsoil	0	1	0	1	0	0	1	0

*(1) Evaluation (yes – 1; no – 0) of soil organic matter in terms of quantity, stocks and quality, as well as the time frame, i.e. changes in carbon content over time; (2) evaluation of nutrient status of soils including contents of main macronutrients and also micronutrients; (3) evaluation of soil reaction measured through actual and potential pH and evaluation of related information about soil sorption complex through cation exchange capacity and base saturation; (4) evaluation of physical parameters of soil as texture, stoniness, porosity, and bulk density; (5) evaluation of soil water content and behaviour through water field capacity, wilting point, available water capacity, and infiltration;(6) description of physical degradation of soils including soil compaction (as a parameter using soil resistance), soil structure degradation (as a parameter using soil structure stability measurement), and soil erosion; (7) description of chemical degradation of soils including contamination with potentially toxic elements (mainly As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn) and organic pollutants (mainly OCPs, PAHs, PCBs), and salinization (as a parameter often using electric conductivity of soils); (8) evaluation of biological parameters of soils especially biological activity (respiration), potentially mineralizable nitrogen, microbial biomass content, abundance of specific group of organisms (micro-, meso-, macroedaphon), or various enzymes measurement.

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country	regional source name	data availability	sampling strategy	sampling depth	groups of soil quality indicators*							
					1)	2)	3)	4)	5)	6)	7)	8)
Austria	IfÖL - long term research site	other	monitoring	profile	1	1	1	1	1	1	0	1
Belgium	Soil Organic Carbon Stock Map	free	single.c.	profile	1	0	0	1	0	0	0	0
Belgium	Potential soil erosion map	free	other	no info	0	0	0	1	0	1	0	0
Belgium	Texture map	permission	single.c.	profile	0	0	0	1	0	0	0	0
Belgium	Carbiosol map: COT content	both	monitoring	topsoil	1	0	0	0	0	0	0	0
Belgium	Carbiosol map: COT stock	both	monitoring	topsoil	1	0	0	0	0	0	0	0
Belgium	Soil status (BDES)	both	monitoring	no info	0	0	0	0	0	0	1	0
Belgium	Aardewerk database	permission	single.c.	profile	1	1	0	1	0	0	0	0
Belgium	REQUASUD database	permission	monitoring	profile	1	1	1	0	0	0	0	0
Denmark	Danish Acid Sulphate Data Base	permission	single.c.	profile	0	1	1	0	0	0	0	0
Italy	Lombardy Soil Information System (LOSIS)	permission	single.c.	profile	1	1	1	1	1	0	1	0
Italy	Lombardy Soil Quality Monitoring	permission	monitoring	topsoil	1	0	0	1	0	1	0	1
Italy	sardegnaportalesuolo.it	both	single.c.	profile	1	1	1	1	1	1	1	1
Slovakia	Soil monitoring in the Gabčíkovo waterworks area	permission	monitoring	profile	0	0	0	0	0	0	1	0
Switzerland	Kanton of Bern	permission	monitoring	topsoil	1	1	0	1	0	0	0	1
Switzerland	Kanton of Aargau	permission	monitoring	topsoil	1	1	0	1	0	0	0	1
Switzerland	Kanton of Graubunden	permission	monitoring	topsoil	1	1	0	1	0	0	0	1
United Kingdom	National Soil Inventory of Scotland (1978-88)	free	single.c.	profile	1	1	1	1	0	1	1	0
United Kingdom	National Soil Inventory of Scotland 2007-9	permission	monitoring	profile	1	1	1	1	1	1	1	1
United Kingdom	Soil map of Scotland (partial cover)	free	single.c.	no info	0	0	0	0	0	1	0	0
United Kingdom	Scottish Soils Database of Representative profiles	permission	single.c.	profile	1	1	1	1	1	1	0	0
United Kingdom	Risk maps	free	single.c.	no info	1	0	0	0	0	1	0	0
United Kingdom	ERAMMP - Wales	both	monitoring	topsoil	1	1	1	1	0	1	0	1
United Kingdom	TELLUS Regional A Soils	free	single.c.	topsoil	0	0	0	0	0	0	1	0

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United Kingdom	TELLUS Regional S Soils	free	single.c.	profile	0	0	0	0	0	0	1	0
United Kingdom	AFBI RSSS	permission	monitoring	topsoil	1	1	1	1	0	0	0	0

*(1) Evaluation (yes – 1; no – 0) of soil organic matter in terms of quantity, stocks and quality, as well as the time frame, i.e. changes in carbon content over time; (2) evaluation of nutrient status of soils including contents of main macronutrients and also micronutrients; (3) evaluation of soil reaction measured through actual and potential pH and evaluation of related information about soil sorption complex through cation exchange capacity and base saturation; (4) evaluation of physical parameters of soil as texture, stoniness, porosity, and bulk density; (5) evaluation of soil water content and behaviour through water field capacity, wilting point, available water capacity, and infiltration;(6) description of physical degradation of soils including soil compaction (as a parameter using soil resistance), soil structure degradation (as a parameter using soil structure stability measurement), and soil erosion; (7) description of chemical degradation of soils including contamination with potentially toxic elements (mainly As, Cd, Co, Cr, Cu, Hg, Ni, Pb, Zn) and organic pollutants (mainly OCPs, PAHs, PCBs), and salinization (as a parameter often using electric conductivity of soils); (8) evaluation of biological parameters of soils especially biological activity (respiration), potentially mineralizable nitrogen, microbial biomass content, abundance of specific group of organisms (micro-, meso-, macroedaphon), or various enzymes measurement.

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Annex III

Answers to the 1st question in questionnaires - Which parameters and indicators are used in national legislation (limits)?

AT (Austria)	
National legislation	**Parameter/indicator**
1. Austrian soil protection acts of the federal provinces	▪ Nutrients content ▪ Heavy metals and organic pollutants
2. Sewage sludge and waste compost regulations of the federal provinces	▪ Pollutants in sewage sludge and soil: limit values
3. Austrian Governmental Programme: policy target	▪ Land take indicator : avoiding soil erosion, conservation of soil fertility, humus formation, reduction of soil pollution, reduction of land take
4. Decree of the federal province of Burgenland;	▪ Erosion reduction
BE (Belgium, Flanders)	
National legislation	**Parameter/indicator**
1. CAP-GAEC6 (target is to have 100% of farms compliant with the GAEC 6 measures)	▪ Soil carbon content (%C)/soil acidity (pH-KCl): farmers need a certain number of soil analyses for soil carbon content (% C) and pH (KCl). When % C of the arable layer is not above minimum threshold or pH is not in optimal zone farmers need to follow an advice (i.e. they need to have to minimum number of soil analyses), but there is no result-based quantified target; for field parcels with (very) high erosion risk, farmers need to take several measures GAEC4/5
2. CAP-GAEC4/5 (target is to have 100% of farms compliant with the GAEC 4/5 measures, but there is no result-based quantified target	▪ Potential soil erosion risk maps for field parcels in Flanders (C-factor not taken into account) is modelled (based on RUSLE) and each field parcel is assigned an erosion class
3 The Flemish long term strategy (2050) for climate aims that carbon content of agricultural soils is in optimal zone by 2050 and C-content further increases or remains at high level. Carbon hotspots (peat areas and alluvial forest) are protected by 2050 and disturbed systems are being recovered.	▪ Soil carbon stock: the GSOC map of Flanders is based on old data. Currently, we do not have a carbon monitoring network. The preparations (number and locations of points, sampling protocols etc.) are nearly finished, but sampling still needs to start.

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4 LULUCF reporting	▪ Soil carbon stock: better carbon monitoring is needed to estimate carbon sequestration potential of soil. Carbon hotspots (for instance in long term permanent grasslands and in peatlands) should be mapped in order to develop a carbon protection policy.
5. Nitrate directive	▪ Soil residual nitrate: Threshold values for residual nitrate (kg nitrate-N /ha) at the field parcel level between 1 October and 15 November; threshold values are depending on crop type, soil texture and water quality area.
6. Nitrate Directive	▪ Soil phosphor availability (P-AL): o steer P availability in the soil towards a target zone (P-AL) for soil fertility and limited environmental risks, the amount of P that can be added by fertilizers is limited (depending on P-AL in soils). A national project has recently evaluated different P-indicators and P-AL appeared to be the best one for Flanders.
7. Soil sealing (area artificial soil covering/total area):	▪ % sealed surface - 20% by 2050 compared to 2015 in land use categories agriculture, nature and forest.
8. Prevention and remediation of soil contamination and clean-up historical contamination by 2036.	▪ Soil contamination: number of polluted soils per sanitation phase (not specific for agricultural soils).
9. Soil emissions (N_2O)	▪ should decrease with 19% by 2030 compared to 2005.
BE (Belgium, Walloon)	
National legislation	**Parameter/indicator**
Blank	
CZ (Czech Republic)	
National legislation	**Parameter/indicator**
1. Soil protection legislation	▪ Soil ecological unit´s system: used parameters and indicators are therefore soil ecological units themselves which consists of Climate region, soil type, texture, sloppiness, exposition skeleton presence, and soil depth

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2. Other legislative measures	▪ soil contamination (potentially risk elements and organic pollutants), and the subsequent protection of water resources, the use of fertilizers or, for example, use of pesticides
	▪ soil erosion (based on slope, exposition, soil texture, soil type and planted cultivated crops
	▪ other parameters as macro nutrient content, nitrates content and soil pH.

DK (Denmark)	
National legislation	**Parameter/indicator**
Setting maximum allowable application of nitrogen in manures plus mineral fertilizers. This is done by defining 12 soil types from the textural composition of the topsoil.	▪ Soil particle size distribution (soil texture) ▪ Soil classification (soil types) is national and not easily related to soil types defined in international classifications
It can be calculated from topographic data, is used for pointing out areas, where certain restrictions are set regarding which crops may be grown. This is in order to reduce the risk of water erosion. The limit for restrictions are set to 12 degrees.	▪ Sloppiness
EE (Estonia)	
National legislation	**Parameter/indicator**
Legislative limits	For heavy metal concentrations to define polluted soils.
National Nitrate Directive	Regulation of nitrogen and phosphorus application and restrictions in agricultural land
Specific fertilisation recommendations	According to soil-sampling, site-specific fertilisation recommendations are provided (e.g. the classes of phosphorus demand). The application of field-based nutrients (nitrogen, phosphorus) balance recording has been initiated.
FI (Finland, Luke)	
National legislation	**Parameter/indicator**
National fertilizer regulation (NFR)	Data on heavy metal contents has been used as a reference in the preparation of NFR

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FI (Finland)	
Blank	
FR (France)	
National legislation	**Parameter/indicator**
Legislation on contamination	▪ Trace elements, organic contaminants (mainly for contaminated land
Sewage sludge legislation	▪ for monitoring soils being amended with sewage sludges)
UK (United Kingdom, Scotland)	
National legislation	**Parameter/indicator**
EU standards and administered by Scottish Environment Protection Agency	▪ Legislative limits for heavy metals in soil
Water Framework directive Nitrate Directive	▪ Nitrate Vulnerable Zones
National legislation	▪ Dependent on the soil
UK (United Kingdom, Wales)	
National legislation	**Parameter/indicator**
Legislation under The Code of Practice	▪ Maximum permissible concentrations of potentially toxic elements in soils - Zn, Cu, Ni, Cd, Pb, Hg, Cr, Mo, Se, As ,F
Agricultural Use of Sewage Sludge (DoE, 1996) and the Sludge (Use in Agriculture) Regulations (UK SI, 1989)	
UK (United Kingdom, Northern Ireland)	
National legislation	**Parameter/indicator**
"The Sludge (Use in Agriculture) Regulations (Northern Ireland) 1990" implementing Council Directive 86/278/EEC	▪ Maximum permissible concentrations of potentially toxic elements in soils - Zn, Cu, Ni, Cd, Pb, Hg, Cr, Mo, Se, As, F
The Code of Practice for Agricultural Use of Sewage Sludge (DoE, 1996	
Nutrient Action Programme to identify crop requirement).	▪ Soil P (Olsen)
GE (Germany)	
National legislation	**Parameter/indicator**
It serves the basis for trade and for various taxes	The **soil value** (DE7)

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The **German Agricultural Soil Inventory** (DE1,2) are used for the national greenhouse gas reporting under the United Nations Framework Convention on Climate Change (UNFCCC)	**Soil organic carbon stocks** and its drivers recorded
It will serve as a base for evaluating site-specific soil organic matter contents according to the **Soil Protection Act** (BBodSchG, 1998);	**Soil organic carbon stocks** and its drivers recorded
Are recorded in the **Long-Term Soil Monitoring Sites** (DE6) provide a broad tool to monitor the functionality of soils as regulated the German Federal Soil Protection Act (BBodSchG, 1998) and the Soil Protection Acts of the Federal States.	**All the parameters**
HU (Hungary)	
National legislation	**Parameter/indicator**
blank	
IE (Ireland)	
National legislation	**Parameter/indicator**
???	Total Carbon (%), Dissolved organic carbon, soil organic carbon (inclusive LOI), Texture (Sand, Silt, Clay); aggregate fractions, sediments, soil moisture deficit, hydrology, stoniness, bulk density, soil structure, hydraulic conductivity, cation exchange capacity, pH (H_20, $CaCl_2$), N (Total), K, P Morgan, Total P, Mehlich3 P, Al, Fe, Ca, Heavy metals (aqua regia), Microbial biomass (+N,P), Microbial Diversity (PLFA, TRFLP, DNA), Nematodes, Protzoa, Mites, Collembola, Enchytraeids, Earthworms, Ants, Millipedes
IT (Italy)	
National legislation	**Parameter/indicator**
???	pH, CEC, heavy metals content, organic pollutants (IPA, ecc.)
LV (Latvia)	
LV6: Not used in legislation. Recommended character. LV4: Heavy metals extracted with aqua regia (Cd, Cr, Cu, Ni, Pb, Zn), Hg (using CVAAS method), As (determined with a method where the lowest limit of quantification is 1.0 mg/kg), concentration of petrolium products (determined with a method where the lowest limit of quantification of petrolium product sum is 1.0 mg/kg), PAH, PCB, cyanides, aromatic hydrocarbons,	

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organochlorines, pesticides and cyclohexane. Particle size distribution is taken into account for determining Cd, Cr, Cu, Ni, Pb, Zn, Hg, As, sum of petrolium products, PAH and PCB concentration in soil - MK nr. 804.	
LT (Lithuania)	
National legislation	**Parameter/indicator**
Nitrate Directive	Total N for fertilization agricultural crops during the year cannot exceed 170 kg/ha
NL (Nederland)	
National legislation	**Parameter/indicator**
On the National level, the 'Bodem Ecosysteemdiensten Onderzoek (BEO)' used to be a soil monitoring tool. However, this tool is terminated because of financial reasons	
.An integrated tool on National level to assess the quality of agricultural fields is missing	
The National government introduced a law which formalizes the registration of the current state of the (sub)soil. In Dutch it is called 'Basis Registratie Ondergrond' (BRO), and will align with INSPIRE	
However, some policies involve a monitoring system (see the question below). Apart from agricultural soils, a broad top- and subsoil monitoring instrument is under development.	It is still under development, and integrates two existing databases: DINO (see DS2) and BIS (see DS8). BRO will be an integrated tool (map) to assist policy-makers by providing information about groundwater quality and flows, geological aspects, soil types and soil quality. All the information gathered will be available for free for everyone.
NO (Norway)	
National legislation	**Parameter/indicator**
Limiting legislation for soil quality, but the suggested National Programme for Soil Health from 2020 suggested indicators for...	erosion, compaction and loss of organic matter and soil biodiversity as the main soil parameters
PL (Poland)	
Blank	
PT (Portugal)	
National legislation	**Parameter/indicator**

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	Chemical/pH, SOC, total N; biological/abundance of microbial biofertilizers (N_2 fixing bacteria)
SK (Slovakia)	
National legislation	**Parameter/indicator**
- Act No 220/2004 and updated version Regulation No 59/2013.	soil types and subtypes in the Land Evaluation System (BPEJ)
Soil ecological units (Land evaluation system)	soil depth - limit for water erosion(t/ha/y); limit for wind erosion (t/ha/y), bulk density, penetrometric resistance, soil moisture, porosity, minimum air capacity, maximum capillary capacity, soil texture - limit for compaction soil organic matter balance, humus content - limit for soil organic matter deficiency (t Cox/ha/y), soil texture, pH - limit for risk elements (mg/kg)
Soil monitoring system of agricultural land	hygienic limits for risk elements extracted with aqua regia (As, Cd, Co, Cr, Cu, Ni, Pb, Se, Zn), Hg (total content using AMA analyser), F water soluble and bioavailable forms (As, Cu, Ni, Zn, Cd, Pb extracted with 1M NH_4NO_3), limits for soil loss at water erosion (t/ha/yr), limits for soil compaction (soil texture, bulk density, porosity, soil moisture, maximum air capacity, maximum capillary capacity), soil organic matter balance, pH limits
SI (Slovenia)	
National legislation	**Parameter/indicator**
Soil Pollution Monitoring (SPM) of Slovenia	heavy metal concentration measurements and organic pollutants in the topsoil's (several layers; from 0 - 30 cm depth.
Slovenian legislation: *Decree on limit, warning and critical imission values of hazardous substances in soil (Official Gazette of the Republic of Slovenia, No. 68/96 and 41/04 - ZVO-1.*	Decree includes limit, warning and critical concentration values measured in Aqua Regia for selected heavy metals (Cd, Cu, Ni, Pb, Zn, Cr, Cr6+, Hg, Co, Mo and As) as well as for organic pollutants such as (aromatic compounds, PAH, PCB, plant protection products etc.).
ES (Spain)	
National legislation	**Parameter/indicator**

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Spanish legislation just regulates inputs to and outputs from farms, and also their subsequent potential environmental impacts such as water quality and soil erosion	There are not specific soil indicators related to sustainable agricultural practices
In all cases, the legislation is adapted to the large heterogeneity in pedoclimatic conditions. Different admissible thresholds for a set of indicators, and customized action plans are defined	crop types, local terrain-related parameters, and in the kind of water bodies receiving agricultural-induced impacts in Spain's territory accounting for this heterogeneity across the Spanish territory.
SE (Sweden)	
National legislation	**Parameter/indicator**
	Heavy metals (application of sludge on agricultural soils).
CH (Swiss)	
National legislation	**Parameter/indicator**
For fertilizer application rate guidance, various national extension services assess the farmers' soil nutrient reports	which describes the content of mineral N, phosphate, and other key micronutrients), and then give recommendations for fertilzer levels based on: 1) the current soil nutrient status, 2) SOM and clay content of the soil, 3) soil pH, 4) general soil moisture levels, 5) the crop(s) being grown, 6) the erosion risk (calculated by PEP), and 7) the distance from waterbodies (i.e. groundwater and lakes, streams, etc.). The idea here is to reduce nutrient leaching and other negative environmental effects due to over application of reactive nutrients, while also ensuring that the crops are not nutrient-limited.
Principles of Agricultural Crop Fertilisation in Switzerland (Grundlagen für die Düngung im Acker- und Futterbau, GRUD)	In addition to extension services, the is a widely used handbook that gives farmers an estimate of the nutrient content of different fertilizer types (i.e. slurry, compost, manure from different animals, etc.), as well as fertilization recommendations. However, because the soil nutrient status is not assessed directly after fertilization, there are no penalties if the farmers apply too much fertilizer
TR (Turkey)	
National legislation	**Parameter/indicator**
	Soil physical and chemical properties

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Annex IV

Answers to the 2nd question in questionnaires - Which parameters and indicators are used as policy maker´s tool?

AT (Austria)	
Parameters/indicators	**Policy maker´s tool**
None at the moment	National Government Programme 2020-2024 – not implemented yet. Planned, guidelines are not uniform. Generally, in Austria legal regulations and voluntary guidelines for soil protection are not uniform and contain few distinct specifications.
BE (Belgium, Flanders)	
Parameters/indicators	**Policy maker´s tool**
Soil carbon content (%C)/soil acidity (pH)	CAP (GAEC 6) - on a small sample of farms each year it is checked if farmers have required number of soil analysis results as defined in GAEC 6 but results are not transferred to a regional database and there is no regional monitoring of carbon and pH in place yet
Potential soil erosion risk maps for field parcels in Flanders	CAP, the potential soil erosion risk is modelled per field parcel (based on RUSLE; this potential soil erosion risk takes into account soil type, shape of field parcel, rain erosivity and landscape, but no crops nor measures are taken into account). Farmers need to take measures on field parcels with (very) high erosion risk
Erosion risk indicator	CAP (based on the RUSLE model, actual crops grown and measures taken for cross compliance) for Flanders is under development.
Sediment indicator	(based on WATEM/SEDEM model) for sediment transport to water courses is also under development
Soil carbon stock	The LULUCF action plan of the Flemisch climate and energy plan 2030 has the target no debit in the 2021-2030 period and more carbon storage in agricultural soils. It also mentions that a Flemish carbon market (including soil carbon sequestration) should be developed or other valorisation of C-sequestration through CAP or market based

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	initiatives. We still need an accurate and cost-effective system for carbon accounting to achieve this goal.
Soil residual nitrate (kg nitrate-N/ha measured between 1 October and 15 November	Nitrate Directive - indicator for the nitrate leaching risk in winter (manure action plan)
Soil phosphor availability	Nitrate Directive - available P measured with P-AL determines how much P can be added to soil by fertilisation (manure action plan)
Soil sealing indicator	Land information register (LIR): a soil sealing indicator for Flanders was developed as well as soil sealing maps (2012 and 2015)
Soil contamination	Land information register (LIR): which contains all known data on soil contamination in Flanders
Soil GHG emissions:	Soil emissions (N_2O) should decrease with 19 % by 2030 compared to 2005
BE (Belgium, Walloon)	
Parameters/indicators	**Policy maker´s tool**
Soil COT, texture, depth, infiltration capacity	
CZ (Czech Republic)	
Parameters/indicators	**Policy maker´s tool**
Soil ecological units system	Level of soil contamination (potentially risk elements and organic pollutants), level of soil erosion, macro nutrient content and K : Mg ratio, nitrates content, soil pH, liming, soil organic matter content
DK (Denmark)	
Parameters/indicators	**Policy maker´s tool**
See above	See above
EE (Estonia)	
Parameters/indicators	**Policy maker´s tool**
It includes various soil physical, agrochemical, chemical and biological parameters under different management practices provides long-term monitoring results of different management practices as well as soil properties	Regular monitoring of arable soils (since 2002). This sub-program under environmental monitoring system provides soil-based information being part of a concept of policy making tool.

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targets for: 1) pesticide residues in soil; 2) Corg stock of agricultural land.	New Development Plan of Agriculture and Fisheries 2030 s.
FI (Finland)	
Parameters/indicators	**Policy maker´s tool**
Blank	
FI (Finland, Luke)	
Parameters/indicators	**Policy maker´s tool**
Soil carbon content (recently the most important one).	
FR (France)	
Parameters/indicators	**Policy maker´s tool**
Trace elements, organic contaminants (mainly for contaminated land)	Legislation on contamination
For monitoring soils being amended with sewage sludge	Sewage sludge legislation
UK (United Kingdom, Wales)	
Parameters/indicators	**Policy maker´s tool**
All indicators have been used in a policy context, to help inform and guide policy development	Specific examples are Soil Organic Carbon in Wales (https://gov.wales/sites/default/files/publications/2019-06/national-indicators-for-wales-technical-document.pdf) number 13
all the ERAMMP metrics	in Wales are used by Welsh Government, the support of the state of the Natural Environment reporting (SoNaRR)
All the soil metrics from Countryside survey 2007	Defra for national reporting
Soil C	used by our LULUCF team for soil reporting usually to D
Soil carbon and C:N	Office for National Statistics for their natural capital accounts
The N and mineralisation	Air quality team used data in some of Defra reporting.
UK (United Kingdom, Northern Ireland)	
Parameters/indicators	**Policy maker´s tool**
Soil P (Olsen)	
GE (Germany)	
Parameters/indicators	**Policy maker´s tool**

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See above	See above
HU (Hungary)	
Parameters/indicators	**Policy maker´s tool**
blank	
IE (Ireland)	
Parameters/indicators	**Policy maker´s tool**
Total Carbon (%), Dissolved organic carbon, soil organic carbon (inclusive LOI), Texture (Sand, Silt, Clay); aggregate fractions, sediments, soil moisture deficit, hydrology, stoniness, bulk density, soil structure, hydraulic conductivity, cation exchange capacity, pH (H_20, $CaCl_2$), N (Total), K, P Morgan, Total P, Mehlich3 P, Al, Fe, Ca, Heavy metals (aqua regia), Microbial biomass (+N,P), Microbial Diversity (PLFA, TRFLP, DNA), Nematodes, Protzoa, Mites, Collembola, Enchytraeids, Earthworms, Ants, Millipedes	
IT (Italy)	
Parameters/indicators	**Policy maker´s tool**
SOC concentration and SOC stock; soil texture	
LV (Latvia)	
Evaluation of soil agrochemical parameters: pHKCl, organic matter (%), usable phosphorus and potassium (mg/kg); LV7: content of mineral nitrogen mg/kg in soil (0-30; 30-60; 60-90 cm layer).	
LT (Lithuania)	
Parameters/indicators	**Policy maker´s tool**
Soil carbon, soil OM, soil N (mineral), available P and K, soil structure (aggregation), soil compaction, soil carbon dioxide and methane emissions	
NL (Nederland)	
Parameters/indicators	**Policy maker´s tool**
Some examples. 1) the Nitrate Directive and Mineral Policy Samples are taken on 450 farms, and farm nutrient surplus, nitrate levels in the	Some policies involve instruments to monitor agricultural soils which are annually evaluated by the so called 'Landelijk Meetnet effecten Mestbeleid' (LMM).

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groundwater and surface water in relation to farm characteristics and environmental conditions are analysed	
2) Sustainable soils The definition of sustainable soils is not yet completely determined, but the most relevant indicators, reference values and affordable measurement techniques are set (see DS1).	The Dutch government has set the goal to manage all soils sustainably by 2030
The latter is still under development, and currently tested in several projects of Slim Landgebruik and the PPS Beter Bodembeheer.	
NO (Norway)	
Parameters/indicators	**Policy maker´s tool**
See above	See above
PL (Poland)	
Blank	
PT (Portugal)	
Parameters/indicators	**Policy maker´s tool**
Chemical/pH, SOC, total N; biological/abundance of microbial biofertilizers (N_2 fixing bacteria)	
SK (Slovakia)	
Parameters/indicators	**Policy maker´s tool**
soil organic matter (SOM) and soil water erosion	Rural Development Programme (CAP).
Database of the General soil survey of agricultural land (Slovakia)	base for the Areas with natural constrains database processing (CAP),
Soil ecological units (Land evaluation system)	soil water erosion, organic matter content, biodiversity - Rural development Programme
SI (Slovenia)	
Parameters/indicators	**Policy maker´s tool**
Please see the previous answer.	
ES (Spain)	
Parameters/indicators	**Policy maker´s tool**
This section just relies on farm inputs and outputs from farms.	Regarding farm inputs, current legislation either relies on the sustainable use of plant protection agents (RD 1311/2012 on the,

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	modified by RD 555/2019), fertilizers (RD 506/2013 and its subsequent modifications: RD 535/2017; RD 999/2017; Orden AAA/2564/2015, Orden APA/161/2020 modifying Annexes I, III and VI of RD 506/2013), and even defines the N-supply threshold from organic fertilizers (170 kg N ha-1 yr-1) that cannot be exceeded in nitrate-vulnerable zones (RD 261/1996). The autonomous communities identify and define the nitrate-vulnerable zones in their territory
Typically, they recommend periods for fertilization supply for specific types of crops, their phenological stage and the type of fertilizer. They also consider the slope and the type of terrain and provide further consideration to the application of fertilizers close to water bodies. Finally, they also define the maximum number of animals of a given livestock species that can be maintained per ha.	"Codes of good agricultural practices" and regulations for them.
In some instances, they establish specific limits to the N dose supplemented to individual groups of crops based on the expected yield	Regional Government of Andalusia regulates specific limits of N fertilization; 17 different crop types (Orden 1 de junio de 2015 – BOJA 111).
	National Action Plans (NAP) for the Sustainable Use of Plant Protection Agents are implemented, deriving from RD 1311/2012). Current NAP covers the 2018-2022 term. RD 1311/2012 also demands producers to fill in a "Farm notebook" with the application of plant protection agents and the analytical controls of their products.
SE (Sweden)	
Parameters/indicators	**Policy maker´s tool**
CO_2 and soil organic carbon	
CH (Swiss)	
Parameters/indicators	**Policy maker´s tool**

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Soil parameters and indicators are currently not widely used as policy-making tools	However, there is a current national push towards connecting soil parameters and policies by adapting the subsidy system to indicator-based payments (Agricultural Policy 22+).
	"Sachplan Fruchtfolgeflachen, FFF" is a quantitative soil protection guideline that is used to identify the "best" agricultural areas in Switzerland that are then preserved by each canton, for a total of 438,460 ha, as a way to prevent loss of these important and highly productive areas
	In 2019 we launded the Competence Center for Soil (Kompetenzzentrum Boden, KOBO), which is working towards this goal, as well as organizing all soil data across Switzerland.
	Report called the "Swiss Soil Strategy" (Bodenstrategie Schweiz) was published in May 2020 which gives a framework for how to sustainably manage soils in the future.
Data for erosion control, giving suggestions for different practices to engage in rather than quantitative measures.	Qualitative guideline, similar to soil protection measures influenced by NABO data, AUM data, and PEP goals.
TR (Turkey)	
Parameters/indicators	**Policy maker´s tool**
Soil physical and chemical properties	

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Annex V

Answers to the 3rd question in questionnaires - Which parameters and indicators are used to exclude certain measures (e.g. using selected fertilizers)?

AT (Austria)
pH; carbonates; soil erosion and compaction; (limit values of) heavy metals and organic pollutants; nitrogen (water pollution caused by nitrate loss); number of plant protection products used including quantity and area data; land take and proportion of a sealed area;
Potential soil erosion risk maps for field parcels in Flanders: measures are depending on crop type and include a.o. soil cover during winter, reduced tillage practices, buffer strips and erosion dams.
Soil residual nitrate/soil P availability: through 'Code best and innovative fertilisation practices' to improve water quality (yearly updated).
BE (Belgium, Walloon)
Parameters in Reused database
CZ (Czech Republic)
level of soil contamination (potentially risk elements and organic pollutants), level of soil erosion, macro nutrient content and K:Mg ratio, nitrates content, soil pH, liming, soil organic matter content (degree of soil contamination (excludes the use of certain materials as fertilizers (sludge)), restriction of fertilization near watercourses, erosion risk limits the crop rotation, the content of risk elements limits the cultivation of special crops (poppies), biological activity - nematode - exclusion of sugar beet cultivation, nitrates content also limits use of fertilisers)
DK (Denmark)
See above
EE (Estonia)
Blank
FI (Finland, Luke)
Heavy metal content.
FI (Finland)
Blank
FR (France)
Based on sewage sludge policies: pH, soil contaminants (trace elements and PoPs (persistent organic pollutants)), slope and land uses may exclude or restrict the use of soils.
Trace element measurements (mainly As, Cd, Pb) may restrict the use of soil (contamination linked to past pollutions).
UK (United Kingdom, Scotland)

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Blank
UK (United Kingdom, Wales)
Blank
UK (United Kingdom, Northern Ireland)
Olsen P - landowner has to demonstrate crop requirement for P via soil test before chemical P can be applied
GE (Germany)
Nitrogen deposition (DE8) to prevent over-fertilization; Pesticide residues, PCBs, bisphenol A, phthalate esters, nonylphenol from DE6
HU (Hungary)
blank
IE (Ireland)
blank
IT (Italy)
pH, CEC, heavy metals content; residual soil nitrates concentration; P_2O_5 content.
LV (Latvia)
LV6: granulometric composition; pHKCl, organic matter (%), usable phosphorus and potassium (mg/kg); and - content of mineral nitrogen in Spring (only in Nitrate vulnerable zone). Requirements for the protection of water and soil against pollution caused by nitrates from agricultural sources and the limitation of ammonia emissions in particularly sensitive areas: seasonality, slope, groundwater level, terrain position (floodplains and flood risk areas), limits for application of sewage sludge, compost, manure and digestate - MK nr. 834. and updated version MK nr. 628.
LT (Lithuania)
None
NL (Nederland)
Farmers are obliged to administrate their fertiliser use (N and P). Farms are tested randomly whether they comply with the application standards. Enforcement on fertilisers is based on the farmer's administration and norms, rather than on soil sampling. Enforcement on the use of pesticides is done on the basis of farmers' administration in combination with soil and crop sampling
NO (Norway)
Blank
PL (Poland)
Blank
PT (Portugal)

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Biological/abundance of microbial biofertilizers (N2 fixing bacteria) to exclude nitrogen (mineral) fertilizers; chemical/low SOC to exclude tillage.
SK (Slovakia)
SK1: using available macronutrients (P, K, Mg) and micronutrients (Cu, Zn, Mn) content for producers of fertilizers, risk elements for creation of environmental studies, model for soil loss on concrete field for agricultural farmers, SK3: risk elements content - limits for application of sewage sludge or bottom sediments, slope, land use, distance from the water area - limit for application nitrogen fertilizers (Nitrate Directive).
SI (Slovenia)
Blank
ES (Spain)
Spanish legislation also considers the impacts induced by the agricultural sector. Agricultural Impacts on water quality are considered in RD 817/2015, which defines the criteria for the follow-up and evaluation of water quality, considering different types of water bodies. It establishes the limits of the concentrations of several agrochemicals that should not be exceeded, expressed as annual means or maximum admissible concentrations both in waters and biota. It also defines the concentrations for ammonium, phosphates and nitrates in rivers above which water quality is deficient or bad, depending on the type of river, lake, reservoir, transitional waters, and coastal waters, and subsequent subclasses. The quality of subterranean waters is regulated by RD 1514/2009 (its annex II was modified by RD 1075/2015): it considers As, Cd, Pb, Hg, ammonium, chloride, sulphate, nitrites, nitrates and phosphates, among others. Agriculture-induced effects on soil erosion and land degradation are considered in the Action Programme against Desertification (Orden ARM/2444/2008 - BOE 19/08/2008). National Monitoring of degraded lands and desertification processes has been carried out by monitoring erosion and the evolution of organic carbon in soils within the framework of the National Action Programme against Desertification (Orden ARM/2444/2008 - BOE 19/08/2008). This programme already identifies the areas covered with rain fed woody crops on steep slopes and rain fed crops as most at risk from erosion along with overgrazed permanent pastures in local conditions. It considers hydric and wind erosion and uses the Revised Universal Soil Loss Equation model (RUSLE). This model takes into account the phytoclimatic subregion, altitude, slope, orientation, lithology, crop and vegetation cover, land uses, intensity of precipitation events (30 minutes), type of soil, land use class, crop or vegetation cover, and soil management techniques. Sampling is performed following a web of 5*5 km. Soil sample analysis cover texture, organic matter, root biomass, active lime, and apparent soil density. Measures to reduce agricultural greenhouse gas emissions are considered in the Spanish Strategy on Climate Change ad Clean Energy and the Spanish roadmap for 2020 on diffuse emissions.
SE (Sweden)
Blank
CH (Swiss)
For fertilizer application rate guidance, various national extension services assess the farmers' soil nutrient reports (i.e. which describes the content of mineral N, phosphate, and other key micronutrients), and then give recommendations for fertilizer levels based on:

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1) the current soil nutrient status, 2) SOM and clay content of the soil, 3) soil pH, 4) general soil moisture levels, 5) the crop(s) being grown, 6) the erosion risk (calculated by PEP), and 7) the distance from waterbodies (i.e. groundwater and lakes, streams, etc.). The idea here is to reduce nutrient leaching and other negative environmental effects due to over application of reactive nutrients, while also ensuring that the crops are not nutrient-limited. In addition to extension services, the Principles of Agricultural Crop Fertilisation in Switzerland (Grundlagen für die Düngung im Acker- und Futterbau, GRUD) is a widely used handbook that gives farmers an estimate of the nutrient content of different fertilizer types (i.e. slurry, compost, manure from different animals, etc.), as well as fertilization recommendations. However, because the soil nutrient status is not assessed directly after fertilization, there are no penalties if the farmers apply too much fertilizer.
TR (Turkey)
NA

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Annex VI

Answers to the 4th question in questionnaires - Which parameters and indicators are used to recommend certain soil protection measures?

AT (Austria)	
Soil protection measures	**Parameter/indicator**
to avoid/reduce compaction:	texture, Grobanteil (Skeleton?), SOM content
to avoid/reduce erosion:	texture, SOM content, soil structure
to avoid N-leaching:	N input
to protect certain sites:	soil type (e.g. marsh land
General recommendation of the ministry (ÖPUL measures) to maintain soil functions	greening of arable land, organic farming, crop rotation regulations (humus build-up), erosion control measures, mulch and direct sowing, management of arable land at risk of leaching (SOC in arable soils is monitored based on voluntary samples provided by farmers); surveillance of the use of plant protection products by the federal provinces; increase soil cover, induce buffer stripes and landscape features to protect against erosion; calculating nutrient balances to quantify and evaluate impacts of agricultural soil management;
BE (Belgium, Flanders)	
Soil protection measures	**Parameter/indicator**
For CAP farmers need to take soil samples for %C and pH-KCl, when %C is below a threshold and pH not in the optimal zone, farmers need to follow an advice.	Percentage (%) of C and pH
This map is based on topography, shape of field parcel, soil texture and rainfall erosivity (average). All field parcels are classified according to potential soil erosion risk and on field parcels with (very) high erosion risk farmers have to choose measures to mitigate soil erosion from several packages, including cover crops, technical measures such as non- tillage, grass buffer strips etc. These measures are depending on crop types grown.	Potential soil erosion risk maps for field parcels in Flanders:

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Flanders is a nitrate vulnerable zone and the manure action plan (nitrates directive) limits the amount of fertilizers that can be used. The amount of nitrate-N (kg/ha) in the soil layer 0-90 cm is measured on a selection of field parcels between 1 October and 15 November as an indicator whether the farmer has applied appropriate fertilisation and as an indicator for the nitrate leaching risk during winter	Soil residual nitrate
Field parcels are classified in 4 phosphate classes based on a P-AL measurement. The amount of P fertiliser (mineral and organic) that can be applied depends on the class, soil type and crop grown. There are some exceptions for farmyard manure and compost (only half of the P needs to be taken into account).	Soil P availability
Used to achieve land degradation neutrality by 2030 in Flanders (net no extra degraded land).	Soil sealing rate
BE (Belgium, Walloon)	
Soil protection measures	**Parameter/indicator**
	Soil COT and COT stock, sand fraction, depth, Infiltration capacity, stoniness, pH, carbonates, nitrogen, P, K, Ca, Mg, slope, concentrated runoff axes
CZ (Czech Republic)	
Soil protection measures	**Parameter/indicator**
1. level of soil contamination	potentially risk elements and organic pollutants
1. level of soil erosion	
2. level of macro nutrient content and K:Mg ratio,	
3. nitrates content	
DK (Denmark)	
Soil protection measures	**Parameter/indicator**
This index is used by some consultants to advice, whether the structural stability is sustainable. As a rule of thumb, R. Dexter should not exceed a value of 10.	Topsoil content of clay and organic carbon (SOC) is combined to form an index (called the 'Dexter-index'): R_Dexter = clay/SOC

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Risk assessment tool, Terranimo (www.terranimo.dk)	It takes use of the soil texture for estimating the sustainability of a planned traffic event for a given soil.
EE (Estonia)	
Not specifically for protection measures but farm management decisions following indicators are used	pH, Corg, P-K-Ca-Mg etc. concentration.
FI (Finland, Luke)	
Soil protection measures	**Parameter/indicator**
	Soil carbon content; to a lesser extent also P-content in water protection context
FI (Finland)	
Blank	
FR (France)	
Soil protection measures	**Parameter/indicator**
In certain areas erosion control measures are recommended.	No real indicator just known effects of soil erosion
UK (United Kingdom, Scotland)	
Soil protection measures	**Parameter/indicator**
Our Environment Protection Agency (SEPA) can help manage erosion, runoff and leaching .	We have a series of risk maps (https://soils.environment.gov.scot/maps/risk-maps/) available to the public
UK (United Kingdom, Wales)	
Blank	
UK (United Kingdom, Northern Ireland)	
Soil protection measures	**Parameter/indicator**
Planning process to protect the 'best and most versitile' soils from development/sealing	Agricultural Land Classification values (from the 1:50000 AFBI Soil Series Map)
General recommendations on soil protections are made under this guide (https://www.daera-ni.gov.uk/sites/default/files/publications/dard/code-of-good-agricultural-practice-2008.pdf),	no specific parameters as such (apart from classifications, 1,2,3A).
Protection of uncultivated/semi-natural soils is made under Environmental Impact Assessment (EIA) Northern Ireland legislation	but again there are no specific parameters/indicators used.

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GAEC guidelines and cross-compliance penalties'	Soil erosion protection
GE (Germany)	
Soil protection measures	**Parameter/indicator**
	Soil organic carbon (DE1,2,6); Abundance of earthworms (DE4); Contaminants (DE6)
HU (Hungary)	
blank	
IE (Ireland)	
blank	
IT (Italy)	
Soil protection measures	**Parameter/indicator**
	SOC concentration, SOC stock, QBSar, earthworm density, Index of Soil Structure Stability, residual soil nitrates concentration.
LV (Latvia)	
pHKCl (measures to prevent soil acidification); organic matter (measures to prevent losses of organic matter)	
LT (Lithuania)	
Soil protection measures	**Parameter/indicator**
	Soil OM content, soil N, P, K, penetration resistance, slope inclination on the hills, crop rotation structure, pH for soil liming
NL (Nederland)	
Soil protection measures	**Parameter/indicator**
In the Netherlands, soils are protected in several ways. To prevent eutrophication, strict fertilization regulations are in place. Fertilization norms are based on several aspects. Standards for P fertilization application are based on the soil state. Farmers are allowed to apply higher amounts of P_2O_5 when their soil P levels are low. Farmers have to prove their P levels on the basis of a soil analysis done by an accredited laboratory. For grasslands the soil state is analysed on the basis of P-Al and for arable soils on the basis of Pw	P level

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Standards for N application are based on the soil type and crops. Farmers are allowed to apply higher amounts of N when high yields are expected, farmers are obliged to prove their yield levels. Animal manure and slurry are not allowed to be applicated on soils with a slope >7% for bare soils and >18% for arable soils.	N level
Monitoring of soil contamination	as part of LMM and Zn, Cu, Cd, Cr, Ni, Pb and Hg are evaluated in agricultural soils
To prevent soil contamination, compost and sewage sludge have to be tested and have to comply with standards before it can be applied.	
The soil structure will be monitored as part of BLN. Regulations to prevent the degradation of the soil structure are not in place.	Indicators: bulk density (kg/m3), penetration resistance (Mpa), texture (%), water retention capability (mm) and aggregate stability (see DS1
NO (Norway)	
Soil protection measures	**Parameter/indicator**
Soil erosion risk	Soil erosion
PL (Poland)	
Blank	
PT (Portugal)	
Soil protection measures	**Parameter/indicator**
	Chemical/SOC concentration, extractable P, pH, cation exchangeable capacity; biological/abundance of biofertilizers (N2 fixing bacteria and mycorrhizae)
SK (Slovakia)	
Soil protection measures	**Parameter/indicator**
National Report of Environment of the Slovak Republic (every year)	Measured indicators (see List C) concerning main threats to soil (soil erosion, soil compaction, soil contamination, soil acidification, soil salinization and sodification, decline in soil organic matter and available nutrients)
European level (JRC,and EEA) for the creation of outputs concerning European landscape protection	
CAP – GAEC	slope, land use
SI (Slovenia)	
Blank	

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ES (Spain)	
Soil protection measures	**Parameter/indicator**
The parameters and indicators are already considered in the legislation promulgated at the national and regional (autonomous communities) levels	The adoption of beneficial agricultural practices for the environment (crop diversification, permanent pastures, and areas of ecological interest) are enhanced through direct payments related to CAP (RD 1075/2014).
SE (Sweden)	
Blank	
CH (Swiss)	
Soil protection measures	**Parameter/indicator**
Soil erosion risk	In Switzerland there is a National Soil Erosion Risk Analysis which produces high-resolution soil erosion risk maps as a tool to support policies aimed at reducing soil erosion (Prasuhn et al., 2013; Meusburger and Alewell, 2014; Bircher et al., 2019; Prasuhn, 2020). Although the data and maps produced here are only used as recommendations, not strict laws, if erosion becomes visible during these assessments, then the farmer is obligated to develop a management plan to reduce the erosion risk at the cantonal soil protection office
	.For example, there are maps at the Canton level (i.e. Naturforschende Gesellschaft des Kantons Solothurn) that use soil parameters such as soil class, subsoil skeleton, soil hydrology, and subsoil texture to visualize soils prone to compaction
Soil compaction	There are also more widely used tools (i.e. Terranimo) used to reduce soil compaction at both the Swiss and European levels. Terranimo uses soil texture, bulk density and moisture to assess the risk of soil compaction.
Soil pollution	Regarding this, there are both maps and guidelines in place to reduce spreading of soil contamination (i.e. see the tool for assessing Areas with Indications of Soil Contamination in Zurich, Prüfperimeter für Bodenverschiebungen, PBV), which is required by all cantons under the Ordinance on the Prevention and Disposal of Waste (Verordnung über die Vermeidung und die Entsorgung von Abfällen). Finally, recommendations

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	for appropriate fertilizer use as a soil protection measure is described above.
TR (Turkey)	
Soil protection measures	**Parameter/indicator**
	Soil physical and chemical properties, heavy metal contents, soil salinity, soil fertility parameters

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Annex VII

Answers to the 5th question in questionnaires - If you have no national indicators what is done with the data?

AT (Austria)	
Soil/land data type	**Data utilization**
Data and especially the data evaluation results are used wherever soil is of importance	Farm management, regional authorities, administration, education (e.g. agricultural schools) and training (e.g. for farmers), research institutions, engineering, etc.
Overall many recommendations exist (e.g. for sustainable agricultural nutrient management:	Fertilizer recommendations, guidelines helping to interpret results of soil analysis, etc.
National agri-environmental programme ÖPUL implements four area-based 14-20 RD Programme measures	Agri-environment climate measure, organic farming measures, Natura 2000 and Water Framework Directive and the animal welfare measure. Organic farming has a large share in Austria (approx. 21% of the agricultural area
Key ÖPUL approaches to maintain and enhance soil fertility	preserve nutrients; reduce erosion; improve the humus level in arable soils and, as a result, enhance their buffer, filter and storage function; promote green cover crops, enhance diversity of crops in crop rotation, reduce soil treatment;
BE (Belgium, Flanders)	
Soil/land data type	**Data utilization**
ILVO together with the department of Agriculture are developing a soil passport for farmers where soil related data (including soil analyses) will be easily accessible for farmers	Passport for farmers
BE (Belgium, Walloon	
Soil/land data type	**Data utilization**
	Applied scientific researches for public purposes and environmental protection
CZ (Czech Republic)	

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Soil/land data type	Data utilization
The data	The performance of state administration, or are obtained and evaluated for internal needs - setting up the management of farmed areas and experimental areas
DK (Denmark)	
The database is used for a range of purposes in research.	
EE (Estonia)	
Blank	
FI (Finland, Luke)	
blank	
FI (Finland)	
Blank	
FR (France)	
Soil/land data type	**Data utilization**
Data or indicators	may be used to define background values of soil or soil quality objectives Not yet implemented in regulations but used to assess soil quality and/or manage soils.
Data	Data may also be used as input parameter for transfer/behaviour models.
UK (United Kingdom, Scotland)	
Soil/land data type	**Data utilization**
Data or indicators	Used to assess change in key soil parameters over time such as soil carbon stocks and concentrations
The maps and associated database	Used to develop risk maps to help mitigate erosion and compaction and subsequent damage to the aquatic environment
The data and surveys	Used to develop and test methods for soil monitoring.
The nematode DNA profiling	Used commercially to evaluate soil physical health.
UK (United Kingdom, Wales)	
Soil/land data type	**Data utilization**
NA	

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UK (United Kingdom, Northern Ireland)	
Data is used to advise policy makers, primarily for research.	
GE (Germany)	
Blank	
HU (Hungary)	
blank	
IE (Ireland)	
blank	
IT (Italy)	
blank	
LV (Latvia)	
blank	
LT (Lithuania)	
We have national indicators	
NL (Nederland)	
Blank	
NO (Norway)	
Blank	
PL (Poland)	
Blank	
PT (Portugal)	
Blank	
SK (Slovakia)	
For other purposes, modelling, metadata etc.	
SI (Slovenia)	
Collected soil point data, polygon and raster data sources are subject of evaluations, land use planning, preparing national soil thematic maps (i.e. map of soil acidity), identify agricultural areas with natural handicaps, modelling (different national projects in agricultural and environmental sector).	
ES (Spain)	

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The 10 databases included in this questionnaire are associated to long-term experiments carried out at some experimental farms of INIA and CSIC. The length of the experiment ranges from 5 to 25 years, and their general scientific aim is to study the influence of different agricultural practices on soil texture and structure, organic matter and C, nutrient and water retention, and crop yield. Some of them consider their effects on biodiversity and soil microbiota. These experiments are carried out for scientific purposes to assess the impact of different agronomic practices on soil performance.
SE (Sweden)
Blank
CH (Swiss)
Currently most of the soil data collected is kept at the "cantonal" level. In Switzerland there are 26 cantons, which are semi-independent member states that comprise the Swiss Confederation. Currently, any soil data collected is the property of each individual canton, and is not consolidated at the national level. This data is used differently within each canton (i.e. to make soil maps, make inventories, etc.), however, there are no national regulations requiring certain data to be available or used for certain purposes. Nonetheless, part of this data is currently organized into national databases such as NABODAT and Sachplan FFF, however, as yet this is still not done in a nationally standardized way, and the data collected is not directly linked to policies. To address this issue, the new Competence Center for Soil (Kompetenzzentrum Boden, KOBO) aims to standardize, organize, and improve regional and national soil surveys, analysis methods of soil properties, and the establishment of technical standards for soil mapping. With this center, it is hoped that the available soil data at the cantonal level will be brought together and harmonized so that more national-level soil information is available to policy-makers, researchers, and practitioners across the country. Additionally, at the policy level, a new policy "Agricultural Policy 22+", aims to collect, measure and store more soil-based indicators as a way to connect the test the adaptation of the agricultural subsidy system with indicator based payments.
TR (Turkey)
The data are used to produce related soil maps, to carry out research project and it also used by other institutions for related studies.

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Annex VIII

Answers to the 6th question in questionnaires - Do you produce maps or references values for the country? (if yes, for what measurements)?

AT (Austria)	
Maps/reference values	**Reason**
Depending on the institution involved the data is displayed in maps e.g. maps of soil functions of federal provinces	due to environmental impact assessments, which assess the impact of large scale projects, assessment on soil functions: water infiltration, filter and buffer for pollutants, living space for soil biota and plants, biomass production
BE (Belgium, Flanders)	
Maps/reference values	**Reason**
Maps were produced for potential soil erosion (based on RUSLE) and sensitivity/risk map for soil compaction, risk map for actual and potential wind erosion and sensitivity map for land slides	These are all based on models but not on actual monitoring. In Flanders, no regional monitoring is going on at the moment. There is an urgent need for recent soil data (as most basic data are outdated by at least 50 years). Furthermore, harmonisation and centralisation of existing data is also needed as basis for soil policy, research and reporting.
Data on soil organic carbon, pH, bulk density, …	There is needed to fulfil (inter-)national obligations and to get insight in the current soil status. There is a need for innovative monitoring techniques based on non-invasive measurements and remote sensing to produce new soil maps.
Reference values	Reference values used for %C, pH-KCL, soil fertility (available nutrients), residual nitrate-N measured between 1 October and 15 November and phosphate classes (P-AL).
BE (Belgium, walloon)	
Maps/reference values	**Reason**
Yes	For underground water protection.
CZ (Czech Republic)	

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Maps/reference values	Reason
Maps of land use, soil erosion, macro and micro nutrient content and K : Mg ratio, nitrates content, soil pH, liming, soil organic matter content.	Many various reasons
DK (Denmark)	
Maps/reference values	**Reason**
A range of maps have been produced. Examples are: top- and subsoil textural composition, slopes, peat soils.	
EE (Estonia)	
Maps/reference values	**Reason**
Thematic maps are produced by specific need.	Routine is to provide for farmers agro-chemical and respective fertilizer recommendation maps.
FI (Finland, Luke)	
Maps/reference values	**Reason**
Recently no map presentations have been prepared.	On Luke's indicator www-pages mean carbon contents are presented by soil types.
In the most recent publication of the study	comprehensive reference values for main nutrients and pH were reported.
FI (Finland)	
Not yet.	
FR (France)	
Maps/reference values	**Reason**
Several maps were produced for France (data available on data.inra.fr or agroenvgeo.data.inra.fr) for carbon, trace elements, PoPs...	The data have also be used to define the reference values for C stocks under different land uses for IPCC reporting.
UK (United Kingdom, Scotland)	
Maps/reference values	**Reason**
We produce indicative and soil survey maps but no reference values	We provide tools by which farmers and land managers can assess C concentration values and pH against average values for similar soils (http://sifss.hutton.ac.uk/)

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UK (United Kingdom, Wales)	
Maps/reference values	**Reason**
Based on Countryside survey, maps of bulk density, C concentration. C:N ratio, LOI, Invertebrate density, Olsen-P, soil pH, N conc,soil Microbes. http://www.ukso.org/static-maps/countryside-survey-topsoil.html	
UK (United Kingdom, Northern Ireland)	
Maps/reference values	**Reason**
We produce the soil map for Northern Ireland, but do not produce thematic reference maps as such.	
GE (Germany)	
Maps/reference values	
There are gridded maps for soil organic carbon, texture, heavy metal contents, micro-nutrients, nitrogen deposition, earthworm communities and more	
HU (Hungary)	
Maps/reference values	**Reason**
Yes (TDR: Distribution of measured parameters by counties)	
IE (Ireland)	
Blank	
IT (Italy)	
Maps/reference values	**Reason**
It's depend from the data source. Where data are georeferenced, all parameters are (can be) mapped.	
LV (Latvia)	
LV4: heavy metals, soil nutrients. LV2: soil particle size distribution, qualitative assessment of soil. LV6: SPPS produces maps for customers who have applied for the service and for policy makers	
LT (Lithuania)	
Maps/reference values	**Reason**
For organic carbon, Soil N, P, K	
NL (Nederland)	

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As part of the BLN (see DS1), reference values are set for 17 soil indicators, taking into account environmental conditions.	
NO (Norway)	
NIBIO has produced "Kilden" which is the official geoportal of the institute where all the data is gathered, along with a selection of other national dataset. The datasets of Kilden are categorised as: land information, landscape, soil, husbandry (rain deer) and the forest portal and contain large amounts of data.	
PL (Poland)	
Blank	
PT (Portugal)	
No	
SK (Slovakia)	
Maps/reference values	**Reason**
We produce maps concerning soil degradation processes in Slovakia Soil Portal establishment	(soil contamination, soil erosion, soil compaction), protection against soil sealing and land take, soil degradation protection, erosion, compaction, acidification, contamination with risk elements), ANC; to be practically used in CAP, land management, etc.
SI (Slovenia)	
Maps/reference values	**Reason**
Yes.	Soil pollution maps, thematic soil maps (i.e. map of soil acidity).
ES (Spain)	
No	
SE (Sweden)	
Maps/reference values	**Reason**
Yes, for SOC - see task 2.4.3	
CH (Swiss)	
Maps/reference values	**Reason**
Switzerland does produce soil maps, but these are mostly on a canton by canton basis (see soil map availability at the National Soil Information Center, Nationales Bodeninformationssystem, NABO). These maps will soon be incorporated into KOBO (new soil competence center). The maps available are at scales of 1:200,000, 1:	Currently only ~20% of agricultural soils are mapped. However, some cantons have mapped all of their agricultural soils and even forest soils, which are available at WebGIS.

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50,000, and 1: 5,000. Most of them are in print form, but are slowly being digitalized at the moment. The main soil parameters mapped are related to soil type (classified via water regime and soil depth), soil texture, pH, and hydrology. There are additional maps available through the Swiss government, in collaboration with the cantons (https://map.geo.admin.ch/?topic=bafu&lang=en&bgLayer=ch.swisstopo.pixelkarte-grau), although these are mostly geared toward mapping erosion risk of grasslands.	
Finally, reference values for soil protection are given by the Federal Office of the Environment (BAFU) through legislation controlling the flow of organic and inorganic pollutants, soil erosion, etc.	Reference values for physical and biological parameters have been proposed by professional organizations, but have no legal influence at the moment.
TR (Turkey)	
Maps/reference values	**Reason**
National soil carbon, carbon stock and soil salinity maps have been produced in 2015 These reports contain all soil chemical, physical and fertility parameters at province level.	These maps will be updated using additional data collected every 3-4 years because soil sampling stage is still continue at national level
The national soil boron content map was produced in 2010.	In collaboration with National Boron Research Institute (BOREN) by Soil Fertilizer and Water Resources Research Institute.
National soil fertility parameters and soil pollution maps will be produced; the study is ongoing.	Based on the fertility of Turkish Soils project (TOVEP) carried out between 1982- 1999, provincial inventory reports were produced in 2000.

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Annex IX

Answers to the 7th question in questionnaires - Have you compared your results with the LUCAS data/results/maps?

AT (Austria)
Yes. At the moment this is in progress with the project LUCAS-Soil-Austria (LUCASSA) carried out by the institutions AGES, BFW and IKT.
BE (Belgium, Flanders)
As very few sampling points within the LUCAS database are located in Flanders, and no comparison was made. Even if some sampling points were located in Flanders, it was mainly at the borders of the region. Flanders is much fragmented with a mosaic of small areas with different land covers making it difficult for grid sampling as conducted in the LUCAS sampling campaigns.
BE (Belgium, Walloon)
No
CZ (Czech Republic)
Not known
DK (Denmark)
No
EE (Estonia)
Only in some specific points, no systematic analysis yet.
FI (Finland, Luke)
So far no systematic comparison has been made. (NB: Last Lucas- and Valse-sampling campaigns coincided in time (both were carried out year 2018).
FI (Finland)
Not yet.
FR (France)
Yes, the density distribution and a first attempt on soil carbon.
UK (United Kingdom, Scotland)
No, LUCAS has few data points in Scotland are is largely confined to the cultivated lowlands which is only 25% of the country.
UK (United Kingdom, Wales)
yes, the 2007 model was validated against the independent LUCAS (Toth et al., 2013) topsoil dataset (sampled in 2009) achieving r2 of 0.45, in spite of differences in sample depth between the surveys (LUCAS is 0–20 cm, compared to the CS 0–15 cm).' Thomas, A., Cosby, B.J., Henrys, P. and Emmett, B.,

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2020. Patterns and trends of topsoil carbon in the UK: Complex interactions of land use change, climate and pollution. Science of the Total Environment, p.138330.
UK (United Kingdom, Northern Ireland)
No - national datasets are usually at a higher resolution.
GE (Germany)
For soil organic carbon stocks, the German Agricultural Soil Inventory delivered a more accurate and precise national estimate: - LUCAS was missing bulk densities - LUCAS sampling sites poorly represented the true extent of German agricultural land (random distribution, less data points) - LUCAS did not inform about subsoils - LUCAS did not inform about management
HU (Hungary)
No.
IE (Ireland)
blank
IT (Italy)
Yes. Often strong difference
LV (Latvia)
Evaluation of mean C and N stocks in arable lands and pastures and comparison with LUCAS data have been done during the research project. http://petijumi.mk.gov.lv/sites/default/files/title_file/petijums_VARAM_2017_Augsnes_oglekla_krajumu_novertesana_aramzeme_un_plavas.pdf
LT (Lithuania)
No
NL (Nederland)
No
NO (Norway)
No
PL (Poland)
Blank
PT (Portugal)
No
SK (Slovakia)

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Yes, the sampling scheme (cluster, random, regular) was analysed for Lucas 2009, 2015 and national database. The database of basic physic-chemical properties of soil parameters Lucas 2009 from Slovakia was compared with the data of the Geochemical Atlas for the surface soil A horizon.
SI (Slovenia)
No
ES (Spain)
No
SE (Sweden)
Work in progress
CH (Swiss)
We do not currently compare our soil dataset with the LUCAS data, results, or maps. But perhaps this will be done by KOBO in the following years.
TR (Turkey)
No

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