Soil: how much do we value this critical resource?

Highlights from recent JRC research

European Commission

Image: woodleywonderworks

The importance of soil

Soil condition underpins food security, green growth, bioeconomies and aboveground biodiversity; it regulates climate, the hydrological and nutrient cycles, while mitigating climate change. Soils provide resilience against floods and droughts, buffer the effects of pollutants and preserve cultural heritage. Healthy, functional soils underpin several targets of the Sustainable Development Goals.

Pressures on this finite, non-renewable resource, due to competition for land or inappropriate land management choices, severely impact soil functions. Amplified by climate change, these pressures lead to degradation processes such as erosion, contamination, loss of organic matter, shallow landsliding and, in extreme cases, a complete loss of the resource.

Exacerbating factors include limited policy development (reflecting the relatively slow rate of change in soil conditions compared to policy and political cycles), a lack of awareness in increasingly urban societies of the important societal services and resilience provided by soil, and inequalities in the provision of public services as a result of land ownership.

The European Union's commitment

The European Union (EU) is committed to soil protection through the its Soil Thematic Strategy (EUSTS – COM(2006) 231, COM(2012) 46) and the 7th Environment Action Programme.

Knowledge of the condition of, and changes to, soil functions and associated ecosystem services is critical to a range of EU policies (e.g. agriculture, environmental protection, sustainable development, climate, bio-economy, international development).

At the Joint Research Centre, the Natural Capital Soil (NC-SOIL) project creates value-added knowledge on the complex interplay between soil and land management.

- The Work Package on "Securing soil as natural capital "directly supports soil issues in environmentally focused policies such as the 7th Environment Action Programme, (Eurostat) indicators on land use change, the EU Biodiversity Strategy, several Sustainable Development Goals (in particular those with a strong land component), and the four central pillars of the EU Soil Thematic Strategy (EUSTS), namely awareness raising, research, integration into other policy areas, and legislation.

- The Work Package on "Soil for Climate Change "addresses the role of soil in climate change policies such as the 2030 Climate and Energy Framework and those based on the Paris Agreement.

- The Work Package on "Soil: the foundation of agriculture" addresses issues associated with agricultural policies and instruments, and contributes to the review and post-2020 design of the Common Agricultural Policy (CAP).

- The NC-SOIL project supports the Land Use and Coverage Area Frame Survey (LUCAS) Programme, the Commission's principal mechanism for assessing the impacts of land-focused policies on soil condition and, indirectly, on the economic, environmental and cultural functions supported by soils. LUCAS Soil is used as a mechanism to assess the impact of the CAP, in the context of UNFCCC COP21 where soil is now considered a significant mitigation or adaptation factor, to assess the impact of land use on the quality and supply of terrestrial ecosystem services and as inputs to the EU statistical portfolio.

Overall, the JRC's NC-SOIL project entails the development of datasets, models and indicators that describe key soil functions, together with the extent and impact of degradation processes, for scenarios of how soil functions respond to the implementation and development of land management practices driven by EU policies. This data-centric approach is supplemented by policy-relevant best practice guidelines for soil management and novel dissemination approaches that increase societal awareness of the value of soils.

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Results recently published in *Nature Communications*[1] showed that between 2001 and 2012, over 35 billion tonnes of soil were displaced annually due to rainfall running across the land surface.

How much soil is washed away?

Soil is an essential resource that supports many societal and environmental needs. Changes in land use can put pressures on soil. If left unchecked, these can lead to a loss of this precious resource. A recent study carried out by a group of researchers from the University of Basel, the European Commission's Joint Research Centre and the Centre for Ecology & Hydrology in the UK, have undertaken the most detailed global assessment ever of soil erosion dynamics.

The study developed a high-resolution version of the Revised Universal Soil Loss Equation model, with a cell size of around 250m × 250m, to incorporate data on land use, the extent of different types of croplands and the effects of different regional cropping systems. These are coupled with assessments of rainfall erosivity dynamics and soil characteristics.

Results recently published in *Nature Communications*[1] showed that between 2001 and 2012, over 35 billion tonnes of soil were displaced annually due to rainfall running across the land surface. The main driver of this huge loss of soil, which increased by 2.5% between 2000 and 2012, is the conversion of forests to agricultural land.

The accompanying map of global soil erosion in 2012 shows that this process does not occur evenly. While 85% of the Earth's land surface is relatively free of erosion, around 9% of land surfaces experience moderate to high soil erosion. On 7.5 million km^2 erosion exceeds the generic tolerable soil erosion threshold.

The largest and most intensively eroded regions are in China (0.47 million km^2, 6.3% of the country's land area), Brazil (4.6% the country's land area) and equatorial Africa (some 0.26 million km^2).

The greatest increase in soil loss is estimated for sub-Saharan Africa, South America and Southeast Asia. South America surpasses Africa with an estimated increase in soil erosion of over 10% in 2012. This seems to be driven mostly by the large expansion of cropland areas in Argentina, Brazil, Bolivia and Peru. During the same period, soil erosion in the equatorial countries of Africa increased by 8%.

Soil erosion has financial implications and should be considered as a loss of natural capital which can result in increased burdens on the soils of other countries. Erosion can be reduced by the adoption of soil conservation practices in agriculture. The study estimates that, if applied correctly, specific land management practices could save over a billion tonnes of soil per year. Conservation agriculture currently covers about 15.3% of the observed cropland globally, reducing soil erosion by an estimated 7%.

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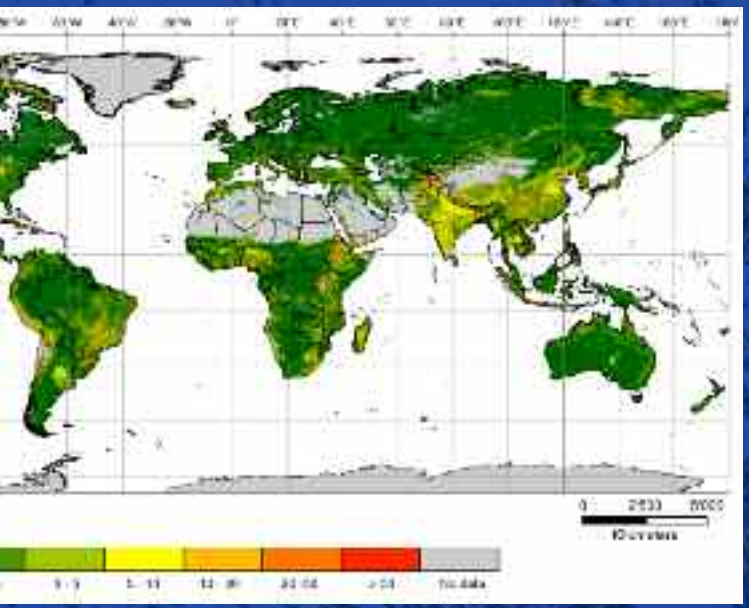
Global soil erosion



1 https://www.nature.com/articles/s41467-017-02142-7

Soil is increasingly recognised for its role in regulating climate either as a result of its ability to store organic carbon, that has been taken out of the atmosphere through photosynthesis, or as a source of greenhouse gases such as nitrous oxide or methane.

Getting a better understanding of nitrous oxide emissions from the agricultural soils of the EU

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The element nitrogen (N) is required by farmers to sustain plant productivity that can then be harvested for food, fuel and fibre. Nitrogen exists in several forms in soil. These range from inorganic and organic nitrogen compounds, ammonium (NH_4+) ions and nitrate (NO_3-) ions. Under natural conditions, these substances are constantly transformed in a process known as the Nitrogen Cycle, which contains several routes by which nitrogen can be lost from the soil. The most recognised is the leaching of nitrates as water percolates through the soil, which can lead to water quality issues in rivers and lakes. Other mechanisms are processes known as nitrification/denitrification where, during intermediate reactions, nitrogen is released as a gas, namely nitrous oxide (N_2O) – a major greenhouse gas. A big driver of N_2O emissions is the level of nitrogen in the soil, which in agricultural areas, can be augmented by the application of synthetic and organic fertilisers.

To understand the impact of land management on such emissions, the JRC has developed a highly complex modelling platform to assess N_2O fluxes from the soils of the EU. The DayCent biogeochemistry model was run on soil from more than 11 000 locations that had been denoted as being under agricultural use by the European Union Statistical Office's Land Use and Coverage Area Frame Survey (LUCAS).

The results published in *PLOS One*[2] showed that current N_2O emissions from soil for the LUCAS points were around 2.27 kg N per hectare per year. When the modelled results were upscaled to the EU level, direct soil emissions of N_2O are in the range of 171-195 Tg per year of CO_2equivalent or 0.95 Mg per year of CO_2equivalent per hectare (CO_2equivalent is a term for describing different greenhouse gases in a common unit which signifies the amount of CO_2 which would have the equivalent global warming impact).

If information on management practices would be made available and model bias further reduced by N_2O flux measurement at representative LUCAS points, the combination of the land use/soil survey with a well-calibrated biogeochemistry model may become a reference tool to support agricultural, environmental and climate policies.

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2 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0176111

Soil is a non-renewable resource that requires constant monitoring to prevent its degradation and promote its sustainable management.

Measuring life in soil with LUCAS

Soil is a non-renewable resource that requires constant monitoring to prevent its degradation and promote its sustainable management. Every three years, the Statistical Office of the European Union (Eurostat) undertakes a regular survey of land use, land cover and changes over time across the European Union (EU). This programme is known as the Land Use and Coverage Area Frame Survey (LUCAS). Since 2009, a topsoil (0-20 cm) assessment, referred to as LUCAS Soil, has been included for around 22 000 locations, where the main physico-chemical properties of soil (texture, pH, organic carbon, nutrient concentrations and cation exchange capacity) have been measured[3]. Data from 2009 and 2012, together with derived outputs in the form of more than 20 maps, are available for free from the European Soil Data Centre website[4]. Samples collected during 2015 are currently being analysed, and data will be available in late 2018.

A new sampling programme will be undertaken in 2018, which will include new measurements. A fascinating new development will be an attempt to measure soil biodiversity through DNA metabarcoding to identify bacteria and archaea, fungi and eukaryotes other than fungi. In general, living organisms occupy ecotopes with specific features in terms of chemical and physical properties, for which they are adapted; likewise, different soil biological communities will tend to occupy specific ecotopes (also known as pedotopes) within the soil defined by soil properties, climate and vegetation cover. Thus, the sampling scheme should aim to capture the range of values of the soil and environmental features. Specific samples will be collected from 1 000 of the 26 014 total soil data points that are planned for 2018.

The overall aim is to develop a standard indicator for the EU that represents the range of organisms living in the soil, their spatial distribution and how they might be related to environmental features. The decision to include the assessment of soil biota in future LUCAS surveys resulted from the increasingly recognised importance of soil organisms in the provision of several soil-related ecosystem services, from nutrient cycle regulation to soil erosion control. The biodiversity module of LUCAS Soil aims to cover a broad spectrum of soil-living organisms, from microorganisms to macrofauna. Furthermore, the methodology was established by considering other projects with similar research objectives, such as continental assessment of soil biodiversity distribution in Australia and Africa.

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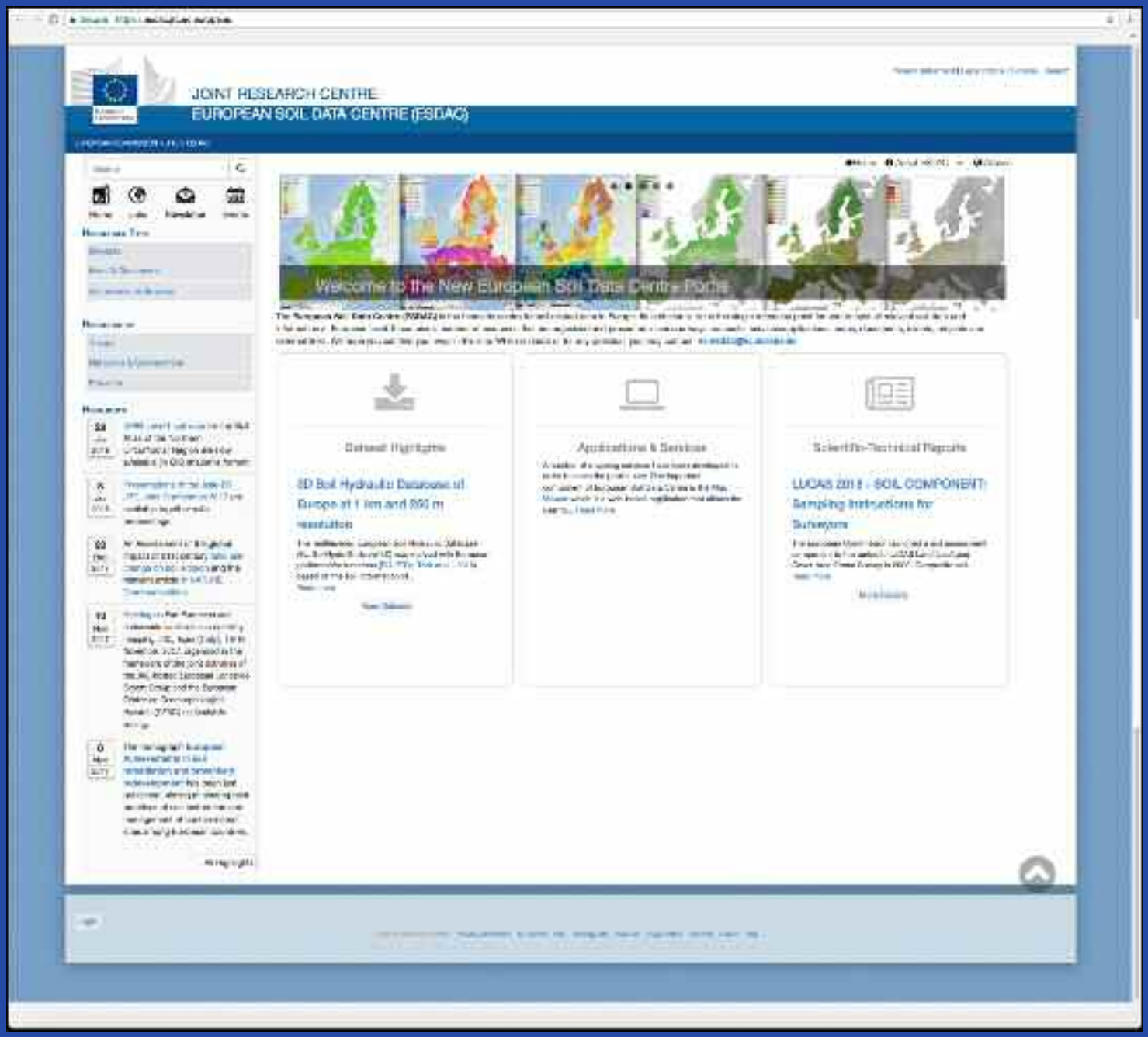
3 http://onlinelibrary.wiley.com/doi/10.1111/ejss.12499/full
4 ESDAC https://esdac.jrc.ec.europa.eu/


JOINT RESEARCH CENTRE
EUROPEAN SOIL DATA CENTRE (ESDAC)
Welcome to the New European Soil Data Centre Portal
Dataset Highlights
3D Soil Hydraulic Database of Europe at 1 km and 250 m resolution
Applications & Services
Scientific-Technical Reports
LUCAS 2018 - SOIL COMPONENT: Sampling Instructions for Surveyors

European Soil Data Centre

At the core of the soil activities of the JRC is the European Soil Data Centre, the primary soil knowledge hub for EU institutions.

Policymakers require easy access to soil data and information of various types and scales to assess the state of soils at the European level. To satisfy this need, the European Commission and the European Environment Agency (EEA) established the European Soil Data Centre (ESDAC), an online platform that is hosted at the European Commission's Joint Research Centre in Ispra, Italy.

ESDAC is the thematic centre for soil-related data for Europe. It is one of ten environmental data centres that have been established in support of environmental policy development, implementation and monitoring. Its objective is to host relevant soil data and information at the European level. The establishment and the evaluation of harmonised databases should facilitate improved soil protection measures.

ESDAC consists of two main elements: a catalogue of soil resources and a map viewer that displays soil data.

- The catalogue of soil resources is a lightweight metadata system that describes and directs to various soil resource types: datasets, services and applications, documents, events, projects and external links. The majority of the content is the result of JRC in-house research and collaborations with external organisations through EU-funded research programmes (e.g. European Soil Bureau Network, FP7, H2020). ESDAC is the home for data collected within other Commission services such as Eurostat's LUCAS Survey and the JRC's Biosoil project.
- The ESDAC Map Viewer allows users to navigate through key soil data for Europe. It provides access to the attributes of the JRC's European Soil Database and some additional data related to main soil threats as identified in the Soil Thematic Strategy. The ESDAC Map Viewer prescribes common standards to ensure interoperability and real-time integration of environmental data from around the world.

Analyses of the application of ESDAC datasets have yielded some interesting conclusions. For example, a high number of researchers use ESDAC data for modelling, research projects, PhD theses and related academic purposes (Masters dissertations, postdoctoral studies, undergraduate projects).

In parallel, ESDAC data and information are highly relevant for a number of EU policy areas and have been utilised for studies relating to agriculture, bioenergy, water protection, nature protection, development policy, health and sustainable development, land use and land use changes, and soil pollution.[5]

For more information, please visit:
https://esdac.jrc.ec.europa.eu/
or contact ec-esdac@ec.europa.eu

5 https://www.sciencedirect.com/science/article/pii/S0264837711000718

While targets have been set by some countries, no legal standards for soil quality are currently set at the EU level.

Dealing with contaminated sites

Industrialisation over the past 200 years has created much wealth and opportunities for human beings. However, this progress has been accompanied by numerous side effects, which include releases of hazardous chemicals that pollute the air, water and, in particular, soil. The emissions of dangerous substances from local sources can impact the quality of soil functions and water quality, with obvious risks to human health and the provision of ecosystem services.

The overarching policy objective for the European Union (EU) is to impede potential risk to the environment and human health caused by manmade contaminants. While existing EU legislation helps to prevent new contamination of soil (i.e. the Integrated Pollution Prevention and Control Directive, Landfill Directive, and Water Framework Directive), efforts should still be made to deal with historical soil contamination.

While targets have been set by some countries, no legal standards for soil quality are currently set at the EU level. In general, legislation aims to prevent new contamination and to set targets for the remediation of sites where environmental standards have already been exceeded.

In this context, the JRC collects data on the indicator "Progress in the Management of Contaminated Sites" which aims to assess the adverse effects caused and measures taken to satisfy environmental standards according to current legal requirements. In 2014, the indicator reported[6] that:

- There are an estimated 2.5 million potentially contaminated sites in Europe, where soil contamination is suspected and detailed investigations are needed;
- Out of the circa 115 000 contaminated sites that have already been identified in Europe, nearly half of them (46%) have already been remediated;
- Contaminated sites are mainly managed using 'traditional' techniques such as excavation and off-site disposal, which together account for about one third of management practices;
- Mining activities, metal industries and gasoline stations are the most frequently reported sources of soil and groundwater contamination. However, the range of polluting activities varies considerably from country to country;
- The most frequently occurring contaminants are mineral oils and heavy metals;
- Annual national expenditure for the management of contaminated sites is on average about €10 per capita.

The indicator will be revised in 2018.

To support the reduction of this pressure on soil, the JRC has collaborated with countries across Europe to publish a monograph[7] of success stories of best practices in the remediation of contaminated and brownfield sites. The report presents twenty-nine case studies from thirteen countries that show progress in research and innovative technologies of soil remediation, the beneficial integration of stakeholders in decision-making and fruitful progress in raising public awareness and citizen science.

A second monograph[8] has just been published containing more inspirational examples of brownfield redevelopment that supports the trend towards the objective of 'no net land take'. These include the 2012 London Olympic Park, the new residential area of Penttilänranta in Finland, and the Guggenheim Museum in Bilbao.

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6 http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/30755/1/lbna26376enn.pdf
7 http://publications.jrc.ec.europa.eu/repository/bitstream/JRC98077/lbna27530enn.pdf
8 http://publications.jrc.ec.europa.eu/repository/bitstream/JRC102681/kj0217891enn.pdf

Creating a Europea Soil Partnership

While the importance of soil seems evidently clear, it has not necessarily received the due care and attention in terms of its use and management. Part of the difficulty is a societal perception whereby soils are regarded as a renewable resource, an increasingly urban population that is losing connection with the critical ecosystem services provided by soil, and a reluctance to champion sustainable soil management approaches. As a result, there is an urgent need to raise awareness on the importance of soil, especially the need to protect soils and use them in a more sustainable manner.

The Global Soil Partnership (GSP) was established by the Food and Agriculture Organization of the United Nations (FAO) in 2012 as a mechanism to develop a strong interactive partnership and enhanced collaboration and synergy of efforts between all stakeholders. Including all relevant stakeholders, the key objectives of the GSP are to improve the governance and promote sustainable management of soils. Since its creation, the GSP has become an important forum in which global soil issues are discussed and addressed by multiple stakeholders. Recent outputs, such as the report on the State of World Soil Resources, have demonstrated that the concept fills a gap in the promotion of sustainable soil management.

A key element of the GSP is Regional Soil Partnerships (RSP), which are formed among interested and active stakeholders in the five FAO regions. In 2013, the GSP secretariat convened a workshop to launch the European Soil Partnership (ESP), whose Secretariat is hosted by the European Commission's Joint Research Centre in Ispra, Italy[9]. Given the specificities of eastern Europe

9 https://esdac.jrc.ec.europa.eu/networkcooperations/european-soil-partnership

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and Eurasian GSP members, a sub-regional soil partnership within the ESP was created covering Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, the Russian Federation, Tajikistan, Turkey, Tukmenistan, Ukraine and Uzbekistan, which is chaired by the Russian Federation.

In line with the GSP, the vision of the ESP is to improve the governance of European soil resources in order to guarantee healthy and productive soils for a food secure world, and to support other essential ecosystem services. This will be achieved by building actions that foster awareness and contribute to the development of capacities, build on best available science, and both facilitate and contribute to the exchange of knowledge and technologies among stakeholders for the sustainable management and use of soil resources. The activities of the ESP focus on five core areas:

- **Pillar 1:** Promote sustainable management of soil resources for soil protection, conservation and sustainable productivity;
- **Pillar 2:** Encourage investment, technical cooperation, policy, education, awareness and extension (advice to farmers) in soils;
- **Pillar 3:** Promote targeted soil research and development, focusing on identified gaps, priorities, and synergies with related productive, environmental and social development actions;
- **Pillar 4:** Enhance the quantity, quality and availability of soil data and information: data collection (generation), analysis, validation, modelling, reporting, monitoring and integration with other disciplines;
- **Pillar 5:** Harmonisation of methods, measurements and indicators for the sustainable management and protection of soil resources.

For additional information or if you feel that you would like to contribute to the ESP, especially in relation to the five core activities, please contact:
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