European Commission

Joint Research Centre

EUSO Annual Bulletin 2025

Broothaerts, N., Panagos, P., Arias Navarro, C., Ballabio, C., Belitrandi, D. Breure, T., Cesarini, L., De Medici, D., Fahl, F., Fendrich, A., Havenga, C., Labouyrie, M., Liakos, I., Lugato, E., Martin Jimenez, J., Orgiazzi, A., Sanchez Garcia, C., Scarpa, S., Schillaci, C., Vieira, D., van Eynde, E., van Liedekerke, M., Viskari, T., Wojda, P., Yunta, F., Jones, A.

2026

Contact information
Name: Arwyn Jones
Address: European Commission Joint Research Centre, Sustainable Resources, Via Fermi 2749, 21027 Ispra (VA), Italy
Email: Arwyn.jones@ec.europa.eu
Tel.: +39 0332 789162

The Joint Research Centre: EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC146084
EUR 40701

PDF ISBN 978-92-68-39377-2 ISSN 1831-9424 doi:10.2760/1842894 KJ-01-26-177-EN-N

Luxembourg: Publications Office of the European Union, 2026

How to cite this report: Broothaerts, N., Panagos, P., Arias Navarro, C., Ballabio, C., Belitrandi, D. et al., EUSO Annual Bulletin 2025, Publications Office of the European Union, Luxembourg, 2026, https://data.europa.eu/doi/10.2760/1842894, JRC146084.

Contents

Abstract 4

Acknowledgements 5

Executive summary 6

1. Introduction 9

1.1. The EU Soil Observatory and its policy context 9

1.2. Objectives of the EU Soil Observatory 10

2. Activities and outcome of the EU Soil Observatory 11

2.1. Policy support 11

2.1.1. Support to the Soil Monitoring and Resilience Directive 11

2.1.2. Support to the Mission Soil 12

2.1.3. Support to the Carbon Removals and Carbon Farming Regulation 13

2.1.4. Contributions to the 4 per 1000 initiative 15

2.1.5. Support to the EEA reports on Carbon Sink and Carbon Dioxide removals 16

2.1.6. New proposal for a methodology to assess land degradation and desertification 16

2.1.7. Monitoring report on progress towards the SDGs in an EU context 17

2.1.8. United Nations Environment Programme 2025 – Global Environment Outlook 17

2.1.9. Support to Enlargement 18

2.1.10. Support to the Nature Restoration Regulation 18

2.1.11. Contributions to MAES2IPBES 19

2.1.12. Support to the Zero Pollution Monitoring and Outlook 2025 report 19

2.1.13. Support to the Pact for the Mediterranean 20

2.2. EU-wide soil monitoring 20

2.2.1. Laboratory analysis related to the LUCAS Soil Module 2022 20

2.2.2. An inventory of existing international and European standards 21

2.2.3. Preparing the next LUCAS Soil Module 21

2.3. Monitoring soil health and soil policies 21

2.3.1. The EUSO Soil Degradation Dashboard 21

2.3.2. The EU Soil Strategy Action Tracker 24

2.4. Enhancing the functionality of the European Soil Data Centre 24

2.4.1. New datasets added to ESDAC 25

2.4.2. ESDAC performance in 2025 30
2.5. Supporting soil research and innovation 33
2.5.1. In-house research activities 33
2.5.2. Collaborations with Mission Soil funded projects 41
2.5.3. Collaborations with other projects 48
2.6. Supporting stakeholder interactions and soil literacy 48
2.6.1. EUSO Stakeholders Forum 48
2.6.2. European Mission Soil Week 2025 50
2.6.3. 2nd European Carbon Farming Summit 51
2.6.4. Soil literacy workshop 51
2.6.5. EUSO Monthly Newsletter 53
2.6.6. Other activities to support stakeholder interactions and citizen engagement 54
3. Working group activities 58
3.1. WG Soil erosion 58
3.2. WG Data sharing and integration 60
3.3. WG Soil pollution 60
3.4. WG Soil monitoring 61
3.5. WG Soil biodiversity 62
3.6. WG Soil organic carbon monitoring reporting and verification 63
3.7. WG Nutrients 64
4. Planned developments for the EUSO in 2026 65
4.1. Policy support 65
4.1.1. Supporting the implementation of the SMRD 65
4.1.2. Supporting the Mission Soil 65
4.2. EU-wide soil monitoring 66
4.3. Monitoring soil health and soil policies 66
4.4. Enhancing the functionality of the European Soil Data Centre 67
4.5. Supporting soil research and innovation 67
4.6. Supporting stakeholder interactions and innovation 68
5. Conclusions 69
References 70

List of abbreviations and definitions 73
List of boxes 78
List of figures 79

Abstract

Healthy soils are essential for our society and environment, as they provide many ecosystem services. However, more than 60% of the soils in the EU are currently affected by one or more soil degradation processes and thus hampering the functioning of these soils. Recent EU policy initiatives have been taken to protect and restore soils. The entry into force of the Soil Monitoring and Resilience Directive (SMRD) in December 2025 marked a major milestone. Also, the EU Soil Strategy for 2030 and the Mission Soil are important policy initiatives to safeguard and restore soils in the EU and beyond. Given this context, the EU Soil Observatory (EUSO) is the principal provider of knowledge and data on soils to underpin EU soil policy development and implementation. This report highlights the main activities and outcomes of the EUSO during 2025. In the past year, the EUSO provided support to the legislative process and the implementation of the SMRD, the Mission Soil and the Carbon Removals and Carbon Farming Regulation, and successfully oversaw the European Commission joining the 4 per 1000 initiative. Next, the EUSO Soil Degradation Dashboard and the EU Soil Strategy Actions Tracker, two of EUSO's tools to monitor respectively the state of soil degradation in the EU and the progress of the actions under the EU Soil Strategy were updated. Furthermore, the European Soil Data Centre, a key part of the EUSO, has grown significantly with 15 new datasets and over 14 000 downloaded datasets in 2025. In addition, in the past year, the EUSO published 55 scientific papers and 10 technical reports, many of which in close collaboration with Mission Soil projects. Finally, the EUSO supported stakeholder interactions and increased soil literacy among society by organising activities such as the 5th EUSO Stakeholders Forum, the Soil Literacy Workshop and several EUSO Working Group activities. Looking forward to 2026, the EUSO will continue taking up its role as the principal provider of data and knowledge to monitor, safeguard and restore soils.

Acknowledgements

The work described in this report was jointly realised by the EUSO Project under the JRC's Institutional Work Programme 2025-2027, the Administrative Agreement JRC No 36283-2022 (Implementation of the soil monitoring tasks of the Mission Soil), the Administrative Agreement JRC No 36825 (Support to the implementation of the Soil Monitoring Law), and the Administrative Agreement JRC No 36662 (Carbon Removal in Land: activities, budgets and verification) .

The EUSO is thankful to all their stakeholders for the collaborations and interactions.

Authors

Broothaerts, N., Panagos, P., Arias Navarro, C., Ballabio, C., Belitrandi, D., Breure, T., Cesarini, L., De Medici, D., Fahl, F., Fendrich, A., Havenga, C., Labouyrie, M., Liakos, L., Lugato, E. Martin Jimenez, J., Orgiazzi, A., Sánchez-García, C., Scarpa, S., Schillaci, C., Vieira, D., Van Eynde, E., Van Liedekerke, M., Viskari, T., Wojda, P., Yunta, F., Jones, A.

Executive summary

The **EU Soil Observatory (EUSO)** is the principal provider of knowledge and data on soils to underpin EU policy development and implementation. This report highlights the main activities and outcomes of the EUSO from 2025. It also presents planned activities and developments to be expected in 2026.

Policy context

Healthy soils are essential for mitigating climate change, providing healthy food and halting the loss of biodiversity. The entry into force of the **Soil Monitoring and Resilience Directive** (SMRD) in December 2025 marked a major milestone for soil protection in the EU. Furthermore, the **EU Soil Strategy for 2030** sets out a framework to ensure that soils are used sustainably by setting concrete measures to protect and restore soils. In addition, the Mission 'A Soil Deal for Europe' (**Mission Soil**) is advancing the state of knowledge and data available on soils in the EU and beyond. Moreover, healthy soils are key for **sustainable prosperity and competitiveness**, one of the European Commission's priorities for 2024-2029. Given this context, the main objective of the EUSO is to provide the European Commission and other relevant stakeholders with the knowledge and data needed to monitor, safeguard and restore soils at the EU-level.

EUSO's activities and outcomes in 2025

Through its activities in 2025, the EUSO: (1) supported a range of soil-related policies, (2) supported the development of a EU-wide soil monitoring system, (3) contributed to the monitoring of soil health and policies, (4) contributed to sharing data and knowledge on EU soils, (5) supported soil research and innovation, and (6) supported stakeholder interactions and citizen engagement regarding soils (**Figure 1**):

1. The EUSO provided **policy support** to a wide range of soil related areas. This included scientific and technical support to the legislative process and the implementation of the SMRD, the Carbon Removals and Carbon Farming Regulation, and the Mission Soil.
2. The EUSO coordinates the **LUCAS Soil Module**, currently the only EU-wide harmonised and regular provider of soil data. In 2025, the EUSO processed interim data of the LUCAS Soil Module 2022. Complete results are expected in 2026.
3. The **EUSO Soil Degradation Dashboard** was updated in 2025. It is a unique tool to monitor and report on the state of soil degradation at the EU-level, showing that ca. 60% of the soils in the EU are currently degraded. The EUSO also updated the **EU Soil Strategy Actions Tracker**, showing that 75% of the listed actions are completed.
4. The **European Soil Data Centre (ESDAC)**, a core part of the EUSO, is the leading web platform for sharing data and knowledge on EU soils. ESDAC has grown significantly in 2025, with 15 new datasets and over 14 000 downloaded datasets.
5. In **support to soil research and innovation**, the EUSO published 55 scientific papers and 10 technical reports. In addition, the EUSO was actively involved in the soil monitoring elements of the Mission Soil and worked closely with numerous Mission Soil projects.
6. In 2025, the EUSO organised and contributed to activities to **support stakeholder interactions and citizen engagement regarding soils**. Highlights include the 5th EUSO

Stakeholders Forum, the EU Mission Soil Week and the Soil Literacy Workshop. The main communication tool is the EUSO monthly newsletter, send to over 13 000 subscribers.

EUSO Working Group activities in 2025

The EUSO **Working Groups** (WGs) are a key element of the EUSO. These WGs consists of relevant experts from academia, business and policy, and aim to advance the knowledge and data on a specific aspect of EU-soils. In 2025, seven working groups were active: (1) WG Soil erosion, (2) WG Data sharing and integration, (3) WG Soil pollution, (4) WG Soil monitoring, (5) WG Soil biodiversity, (6) WG Soil organic carbon monitoring reporting and verification, and (7) WG Nutrients. Activities included advancing scientific knowledge, stimulating technical advances and integration of data, and providing policy support.

Planned developments for the EUSO in 2026

In 2026, the EUSO will continue to play its significant role in the implementation of the EU policy objectives in relation to soils. More precisely, the EUSO will continue to support the implementation of the SMRD, by providing scientific and technical support to relevant Commission Services and EU Member States. The EUSO will also continue to support the Mission Soil, the Nature Restoration Regulation, the Carbon Removals and Carbon Farming Regulation, and other soil-related policy actions at the EU-level. Secondly, related to the EU-wide soil monitoring, the EUSO will publish in 2026 the results of the laboratory analysis of the LUCAS Soil Module 2022. Thirdly, the EUSO will develop the EU Soil Health Gateway, reflecting the requirements of the SMRD. Next to updates for the EUSO Soil Degradation Dashboard and EU Soil Strategy Actions Tracker, the EUSO will also create new thematic dashboards, including the African Soil Health Dashboard, the Map Viewer for the Carbon Removals and Caron Farming Regulation and the Soil Nutrients Dashboard. Fourthly, the EUSO will take further steps to enhance the capacity and functionality of the ESDAC and to consolidate its position as the one-stop-shop for soil related data in the EU and beyond. Planned activities in this regard include the integration of the SoilWise data catalogue within ESDAC. Fifthly, the EUSO will continue to support soil research and innovation, by in-house scientific research and collaboration with Mission Soil funded projects. Finally, the EUSO will continue to engage stakeholders and citizens on soil-related topics and try to increase soil literacy. A key will be the EUSO Stakeholders Forum 2026.

Figure 1. EUSO's main activities and outcomes in 2025

Source: JRC analysis.

1. Introduction

1.1. The EU Soil Observatory and its policy context

Healthy soils are essential for our environment and society, as soils deliver crucial ecosystem services such as prevent droughts and floods, mitigate climate change and ensure food security. However, it is estimated that currently more than 60% of the soils in the EU are affected by one or more soil degradation processes and thus affecting the functioning of the soils (Panagos et al., 2024). The entry into force of the Soil Monitoring and Resilience Directive (SMRD) in December 2025 marked a major milestone for soil protection in the EU. Furthermore, the EU Soil Strategy for 2030 sets a vision and objectives to achieve healthy soil by 2050, with concrete actions due by 2030. In parallel, the Horizon Europe research programme (2021-2027), includes a mission on soils. Entitled 'EU Mission: A Soil Deal for Europe' (Mission Soil), this mission is expected to significantly advance the state of knowledge and data available on soils in the EU and beyond. These soil related strategies are aligned with the EU Strategic Agenda for 2024-2029 and the European commission's priorities for 2024-2029. Indeed, healthy soils are key for sustainable prosperity and competitiveness, as well as for sustaining our quality of life, two of the Commission's priorities for 2024-2029.

The EU Soil Observatory (EUSO) was launched in December 2020 as part of the European Green Deal. The EUSO aims to be the principal provider of soil-related data and knowledge at the EU-level and to support EU policymaking related to soils. The EUSO is hosted within the Joint Research Centre (JRC) of the European Commission, Directorate D (Sustainable resources), Unit D.1 (Land and Climate). The EUSO is an inclusive and dynamic platform that supports EU soil-related policymaking and that provides the relevant Commission Services and relevant stakeholders with the knowledge and data flows needed to monitor, safeguard and restore soils at the EU-level. Furthermore, the EUSO supports EU Research and Innovation on soils and aims to raise societal awareness of the value and importance of soils to the lives of citizens. Active for five years now, the EUSO plays a key role in supporting soil policy development, monitoring the state of soil health, supporting and interacting with research activities, supporting stakeholder interactions and raising citizens' awareness of the need for soil protection.

This report presents the activities of the EUSO that have taken place in 2025 and highlights the main messages drawn from these activities. The report also shortly discusses the planned developments and activities for the EUSO in 2026.

1.2. Objectives of the EU Soil Observatory

The main goal of the EUSO is to be the principal provider of knowledge and data on soils to underpin EU policy development and implementation. To achieve this goal, the following objectives has been defined (**Figure 2**):

1. **Supporting policymaking** related to soils.
2. Supporting the development of an operational **EU-Wide Soil Monitoring System**.
3. **Monitoring** the state of **soil health** and the **policies** in place to enhance soil protection, through a Soil Health Gateway, a Soil Degradation Dashboard and a Soil Policy Actions Tracker.
4. Consolidating and enhancing the capacity and functionality of the **European Soil Data Centre (ESDAC)**.
5. **Supporting soil research and innovation** through the implementation of Horizon Europe's Mission 'A Soil Deal for Europe'.
6. Providing an open and inclusive Forum that supports **stakeholder interactions and citizen engagement** and the drive towards a societal change in the perception of soil.

Figure 2. The main objectives of the EU Soil Observatory.

Source: JRC analysis.

2. Activities and outcome of the EU Soil Observatory

2.1. Policy support

2.1.1. Support to the Soil Monitoring and Resilience Directive

One of the main EUSO's tasks for 2025 was the support to the legislative process of the Soil Monitoring and Resilience Directive (SMRD). The SMRD entered into force on 16 December 2025.

The SMRD aims to make soil health monitoring obligatory and addresses situations where soil contamination poses unacceptable risks. Through the EUSO, the JRC was requested by the Directorate-General for the Environment (DG ENV) to support the design and impact assessment of the proposal from the Commission based on long-standing scientific and technical competencies related to soil.

The EUSO provided significant support to DG ENV to discussions during the Trialogue phase of the Polish and Danish Presidencies. Throughout the implementation of the SMRD, the EUSO has been tasked with providing Member States with a starting sample of possible monitoring sites (reflecting statistical demands of the SMRD) in addition to a series of guidance documents to help Member States.

Moreover, support for the implementation of the directive has been formalised under an Administrative Agreement (AA) in 2024 (JRC No 36825, Support to the implementation of the Soil Monitoring Law). Under this AA, the EUSO worked on several topics in 2025:

— Building the EU Digital Soil Health Data Portal: extensive discussions have taken place on the potential structure, functional and orientation of the portal, which should be a hub providing access to soil data coming from various sources, in an aggregated form. The EUSO is also exploring the broader context of communication and support needs linked to the SML through a possible interface as part of the migration of the EUSO to the Commission's Knowledge for Policy environment. In parallel, deliberations on a draft list of data to be reported and interlinkages between reporting and the Data Portal were explored.

— Provide support and guidance to Member States implementing the SMRD: together with DG ENV and the European Environmental Agency (EEA), the EUSO has been actively preparing the groundwork for a series of elements contained in the Directive. These included an indicative list of soil contaminants, elements of the monitoring framework (e.g. evidence for soil health thresholds - eventually referred to as Sustainable Target and Operational Trigger values), defining requirements for a knowledge repository for local measures and practices to increase soil resilience, preparation for first exchange with MS on key concepts and implementation, a prototype EU-wide soil laboratory ring test, towards validated transfer functions (with Mission Soil), and approaches to identify unsealed soils in urban areas and implications for starting sample.

— Preparing the next LUCAS Soil Module: during 2025, the EUSO contributed extensively to internal discussions on the future evolution of the LUCAS programme (see also section 2.2.3). Specific focus has been placed on adapting the field-sampling instructions to be fully in line with the SML framework (e.g. subsoil compaction sample, organic layer in woodlands, more representative replicate sampling) as well as budget and time constraints. In addition, a revised set of sampling locations were provided to Member States.

— Considering the need to provide informed guidance on the assessment of PFAS and other emerging contaminants, the EUSO developed a programme to assess different analytical methods for measuring PFAS in LUCAS 2022 samples. Results are expected to be published by 2026 Q3.

— Finally, the EUSO contributed to the discussions on the 4th Meeting of the EIONET Thematic Group Soil in relation to target and trigger values and the EU Digital Soil Health Data Portal.

2.1.2. Support to the Mission Soil

The Mission 'A Soil Deal for Europe' (Mission Soil) supports the EU's ambition on soil health and sustainable land management. The Mission Soil aims to establish 100 Living Labs and Lighthouses to co-create, test and pioneer innovations for soil health, next to advancing the knowledge on healthy soils. The Mission Soil is substantiated by eight specific objectives and implemented through activities under four building blocks and operational objectives, as described in the Mission Implementation Plan. 'Monitoring and indicators' is one of these four building blocks, linked to the Mission's operational objective 3 ('Develop an integrated EU soil monitoring system and track progress towards soil health'). Demonstrating that the health of European soils is improving would be a clear indicator of the success of the Mission. In this context, the EUSO is providing scientific and technical support to the Directorate-General for Agriculture and Rural Development (DG AGRI) and the Directorate-General for Research and Innovation (DG RTD) through an Administrative Agreement (2022-2026).

Key outcomes and relevant activities in 2025 of this scientific and technical support to the Mission Soil includes:

— The EUSO Soil Degradation Dashboard monitors the state of soil degradation in the EU. In 2025, the dashboard was updated with new features (see section 2.3.1).

— The EUSO contributed to the drafting of the Mission Soil Work Programme (WP) for 2025 and 2026-2027. For WP 2025, this included leading the preparation of calls for proposals on drivers and costs of land degradation, EU global footprint on soils and soil salinity. For WP 2026-2027, this includes proposals on antimicrobial resistance in soils, long-term field experiments, long-term drivers and consequences of soil degradation, and living labs to monitor and mitigate carcinogenic substances in and originating from soils.

— The latter build upon the outcomes of the JRC Exploratory Research project "Understanding the links between SOiL pollution and CancEr (SOLACE)". As part of the interservice discussions with DG RTD and AGRI, this proposal was refined and then presented to the Mission Cancer Secretariat, which agreed to match the 12 million euro budget from the Mission Soil (HORIZON-MISS-2027-06). SOLACE aimed to investigate the complex relationships between soil properties, pollution, land use and human health, providing a foundation for further research and policy development. The SOLACE project performed an ecological study across 26 EU countries, which revealed associations between the regional rates of lung cancer mortality and soil pollution with arsenic and cadmium. The SOLACE project underscores the importance of comprehensive soil monitoring to safeguard environmental and human health and emphasizes the need for continued investment in research and monitoring.

— The Mission Soil Work Programme 2026-2027 also includes the "Technical and scientific support for the development of an EU soil monitoring framework - Scientific and technical services by the Joint Research Centre " which is the request to JRC to support the Mission Soil for the period 2026-2030 under an Administrative Agreement. This is the follow-up of the current Administrative Agreement (see above).

— The EUSO supported DG AGRI in organising the European Mission Soil Week (EMSW), which included a keynote address that highlighted the role, developments and achievements of the EUSO and how the EUSO contributed to EU competitiveness. The keynote speech proposed possible market incentives that can support sustainable soil management (see also 2.6.2).

— The EUSO provided input to several ad hoc requests from the Mission Secretariat, related to soil monitoring and indicators.

— The EUSO collaborated with many Mission Soil projects, through bilateral discussions, joint research activities and participation in project events. An overview is presented in section 2.5.2.

— The EUSO also co-lead three clusters of the Mission Soil. An overview is presented in section 2.5.2.

— The EUSO worked at several deliverables of the current Administrative Agreement, including:

- A scientific publication on indicator frameworks for continental scale soil monitoring, building on a technical report on the indicator framework currently used in the EUSO.
- A technical report on the new data sources for soil monitoring and the potential integration with traditional soil monitoring efforts. The report is expected to be published in Q1 2026.
- An internal technical report on EUSO's contributions towards the good realization of the SoilWise data catalogue. The report was published in early 2026.
- A technical report describing underlying principles, potential methodology, data sources and uncertainties for an EU soil footprint calculator. The report is expected to be published in Q1 2026.
- A scientific publication and a science-for-policy report on trends in soil health in the EU, expected to be published in Q2 2026.

2.1.3. Support to the Carbon Removals and Carbon Farming Regulation

The EUSO has been supporting the Directorate-General for Climate Action (DG CLIMA) to implement the Carbon Removals and Carbon Farming Regulation (CRCF), through the Administrative Arrangement Carbon Removal on Land (AA CRL). Through this AA, the EUSO provides scientific and technical support regarding designing and testing methodologies for the quantification of carbon removals from agricultural and forest soils. The EUSO supports the Expert Working Group on CRCF and co-organises the Carbon Summits.

Following the development of the CRCF and DG CLIMA requests, the EUSO is developing advanced tools to calculate the standardised baseline of carbon fluxes from land at the EU-level. For agricultural mineral soils, two distinct approaches were designed and tested:

— EU-wide ensemble approach, in which the information comes from the soil LUCAS network (Orgiazzi et al., 2018) and the EU large-scale process-based modelling framework, with DayCent. This approach is designed to provide a first-order approximation standardised baseline using consistent and harmonised dataset across the EU, ingesting as well high-resolution spatial layer into the methodology to better represent local circumstances.

— Parcel-based Earth Observation carbon monitoring, in which the remote sensing data (Sentinel-2) at parcel level are directly assimilated into a process-based soil organic carbon (SOC) model. The application of this tool over many parcels in a homogenous region can directly provide a dynamic and high-resolution standardised baseline.

The close collaboration with DG CLIMA ensured that EUSO scientists provided robust results, enriched by interactive feedback and insights from policymakers. Those results have been shared and discussed with the CRCF Expert Group (Stakeholders and Member States representatives, policy makers and NGOs). They are also presented in the 2nd Carbon Summit, co-organised by JRC and DG CLIMA (see also section 2.6.3). In this event JRC and DG CLIMA highlighted the current policy landscape for carbon farming in Europe and explored how evolving agricultural and climate frameworks (mainly the CRCF) can support an inclusive and credible transition toward regenerative land management.

In addition, the EUSO is designing the risk assessment methodology for 'agriculture mineral soil', contained in the Delegated Acts of the CRCF. The risk assessment is an important part of the certification process, aiming at guaranteeing the integrity of the CRCF units generated by carbon farming activities. Reversals or losses of carbon due to unforeseen events require, in fact, liability mechanisms as the buffer pool. The buffer pool is a reserve of carbon units set aside to account for potential reversal, and it is proportional to the risk. Currently there is not a consolidated framework to assess the risk of SOC reversal, taking into consideration that SOC has an intrinsic resilience due to different protection mechanisms. Therefore, the methodology developed was based on the results published as a scientific publication in Nature Communications (Breure et al., 2025) adapting the Intergovernmental Panel on Climate Change (IPCC) risk framework into a SOC risk index. Under the IPCC definition, the risk is based on the interaction of three factors: hazard, exposure, and vulnerability. For SOC, these concepts are adapted as following:

— Exposure: the SOC stock in the agricultural mineral soils.

— Hazard: climate and anthropogenic-related effects on SOC that are often very difficult to be disentangled. For this reason, the rate of SOC changes in the decade preceding the beginning of the project is considered a good proxy of drivers affecting the carbon cycle in soils.

— Vulnerability: the level of carbon saturation, given by the ratio between the mineral-associated organic carbon (MAOC) over its maximum capacity that a given soil can potentially store. The MAOC is a fraction of carbon more protected but, approaching saturation, the organic carbon tends to accumulate in less protected pools and becomes more vulnerable (Georgiou et al., 2025; Lugato et al., 2021).

The combination of Hazard and Vulnerability lead to the definition of four SOC risk classes to which a buffer pool can be attributed. National or European soil inventories such as LUCAS soils, can be used to calculate SOC change (Hazard) and the saturation within pedo-climatic cluster (Vulnerability) if soil fractionations are done (see Breure et al., 2025). Moreover, the EUSO is hosting the CRCF map viewer to easily query the 'risk' indicators and download the datasets.

2.1.4. Contributions to the 4 per 1000 initiative

The International "4 per 1000" Initiative 'Soils for Food Security and Climate', was launched during the 21st COP of the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in 2015. The initiative aims to highlight the crucial role of agricultural and forest soils in promoting food security, mitigating climate change through soil organic carbon (SOC) sequestration, enhancing adaptation and resilience to the harmful effects of global climate warming, and restoring soil, land and ecosystem health, and biodiversity for better life on Earth. It sets an ambitious aspirational target of a 4 per 1000 (i.e. 0.4%) rate of annual increase in global SOC stocks, with a focus on agricultural lands where farmers would ensure the carbon stewardship of soils thus mitigating industrial emissions of greenhouse gases. The EUSO was responsible for coordinating the decision that the European Commission formally joined the 4 per 1000 initiative in May 2025.

The "SoilCarbon4Climate" Conference (11-13 September 2025) brought together a wide-ranging group of experts from across the temperate climate zone to work on a roadmap for the advancement of soil organic carbon sequestration. As part of the high-level introductory session, Bernard Magenhann (Director-General of the JRC) and the EUSO represented the Commission in its new role as a member of the 4 per 1000 Initiative. Through a keynote address outlining the work of the JRC and the EUSO in supporting EU climate and soil-related policies, the Director-General reflected on the new involvement of the Commission, highlighting synergies between the work of the Commission (and specifically that of the JRC and the EUSO) and the 4 per 1000 Initiative, while outlining future collaboration on how can the JRC help the initiative and vice versa. Specifically, these include:

- JRC and EUSO involvement in relevant policies, such as the Carbon Removals and Carbon Farming Certification Regulation, Nature Restoration Regulation, Soil Monitoring and Resilience Directive, LULUCF Regulation, SDGs, Land Degradation Neutrality (UNCCD),
- co-organizing of high-level and technical international multi-stakeholder events or conferences (involving all types of stakeholders),
- developing and providing access to relevant tools and platforms,
- coordinate and develop scientific cooperation on SOC, particularly in the context of synergies to be strengthened with the International Research Consortium on Soil Carbon (now referred to as Soil Carbon Futures).

On 13 November 2025, the EUSO chaired a meeting of Commission services to assess collaboration around the 4 per 1000 Initiative, as well as the request from the French Government to Commissioners Hansen and Zaharieva to consider financial support from the Commission to the initiative. At the meeting, the 4 per 1000 was represented by Paul Luu (Executive Secretary) and Beatrice Breton-Askar (Strategic Partnerships & Global Outreach Director), who presented the initiative's Strategic Plan and proposals for collaboration, which are targeted around five pillars: Policy advocacy, Education and awareness raising, Promotion of transdisciplinary research, Improve Monitoring, Reporting and Verifications Systems, Facilitation of stakeholder interaction and sharing of best-practices between all stakeholder groups. In addition to the JRC, the Commission was represented by DG AGRI, ENV, RTD and CLIMA. During the meeting, it was explained that the JRC provides support to all policies and instruments mentioned through the EUSO, that holds regular stakeholder forum meetings, that has a platform with data, tools and models, as well as increasing collaboration with the EIT Food.

2.1.5. Support to the EEA reports on Carbon Sink and Carbon Dioxide removals

The EU aims to reach carbon neutrality by 2050, which will require rapid and substantial emission reductions in all sectors. By that year, residual greenhouse gas (GHG) emissions will need to be balanced by carbon being removed from the atmosphere. The largest potential removals in the short- to medium term are expected to come from the land use, land use change and forestry sector (LULUCF). LULUCF currently provides a net carbon sink, counterbalancing around 6% of the EU's GHG emissions from other sectors. In line with the EU Climate Law, the EU has set its first net LULUCF removals target, to be met by 2030. Yet the LULUCF carbon sink has been declining in the last decade, and this target is at risk of not being met. Member States must act to reverse this trend, both by reducing GHG emissions and increasing removals. GHG fluxes in the LULUCF sector are impacted by human activities, mostly associated with land use, land management and land use.

In 2025, the EUSO supported the drafting of the European Environmental Agency (EAA) reports on carbon sinks (European Environment Agency, 2025) and carbon dioxide removals (European Environment Agency, 2024). The EUSO provided data on SOC sequestration. In addition, the EUSO has simulated the impact of management practices on SOC in topsoils. The potential of management practices, such as reduced tillage, cover crops, and conversion from arable land to grassland have also been quantified by the EUSO. To do so, the EUSO used the LUCAS Soil data and biochemical models to estimate the carbon stocks in EU topsoils. In addition, the EUSO performed scenario analysis to estimate the potential of the land sector for carbon sequestration based on agricultural management practices.

2.1.6. New proposal for a methodology to assess land degradation and desertification

Land degradation is a growing environmental concern in the EU, affecting soil functions, ecosystem services, agricultural productivity, and climate resilience. In response to recommendations from the European Court of Auditors Special Report 33/2018, the EUSO has developed a methodological framework to better characterise and monitor land degradation and desertification across the EU. The work contributes to the monitoring of Sustainable Development Goal (SDG) indicator 15.3.1 – “Proportion of land that is degraded over total land area”, which represents the core metric for tracking Land Degradation Neutrality under the United Nations Convention to Combat Desertification (UNCCD).

The methodology builds upon the UNCCD SDG 15.3.1 framework while addressing several limitations identified in previous EU assessments (Schillaci et al., 2023). In particular, the default global approach relies on relatively coarse datasets and simplified indicators that may underestimate degradation processes at the European scale. The EUSO framework therefore introduces a series of improvements to the three core sub-indicators used to assess land degradation: land cover change, land productivity dynamics, and soil condition. The land cover component has been enhanced by replacing the global ESA-CCI land cover dataset with the CORINE Land Cover (CLC) inventory from the Copernicus Land Monitoring Service, which provides a more detailed representation of European land cover through 44 thematic classes (Schillaci, 2026). In addition, a revised transition matrix has been developed to assess the degradational impact of land-cover transitions using a biophysically informed scoring system derived from MODIS NDVI vegetation dynamics. This approach enables the detection of degradation processes occurring within the same land-cover class, which are not captured by the standard SDG 15.3.1 methodology. The land productivity indicator is based on long-term vegetation dynamics derived from MODIS NDVI time series, allowing the identification of statistically significant vegetation degradation trends at

the pixel level (Schillaci, in press). This component provides a consistent pan-European indicator of ecosystem functioning and complements the land-cover analysis. The soil component is extended beyond the default SDG 15.3.1 indicator (changes in soil organic carbon stocks) by incorporating multiple soil degradation indicators compiled within the EUSO Soil Degradation Dashboard. This convergence-of-evidence approach integrates datasets derived from LUCAS soil surveys, pan-European modelling outputs, and thematic soil indicators (e.g., erosion, soil contamination, salinisation, and soil sealing). This allows a more comprehensive representation of soil degradation processes affecting European landscapes. The three sub-indicators are combined using the "One-Out-All-Out" principle, whereby land is classified as degraded if any of the indicators shows a negative trend. In addition, desertification processes are geographically delineated using the Aridity Index threshold (<0.65), consistent with the UNCCD definition of drylands.

This work contributes to establishing a harmonised European baseline for land degradation assessment, supporting EU reporting obligations under the UNCCD, and providing a scientific basis for monitoring progress toward Land Degradation Neutrality. The methodology also aligns with the SMRD, which will provide periodic soil physico-chemical and biological conditions across EU Member States. Within the EUSO, the methodology will support the development of an EU land degradation and desertification dashboard, providing interactive maps and indicators that allow policymakers, researchers, and stakeholders to explore spatial patterns of degradation across Europe. The framework is designed to be scalable and regularly updated as new datasets become available, ensuring that EU land degradation assessments remain scientifically robust and policy relevant.

2.1.7. Monitoring report on progress towards the SDGs in an EU context

The EUSO developed and updated the 'Estimated soil erosion by water' SDG Indicator to assess the progress towards the Sustainable Development Goal (SDG) 2 'Zero hunger' and 15 'Life on Land'. The EUSO has developed assessments of soil erosion changes and is able to provide this support to track the SDG objectives. The work of the EUSO shows the trends in soil erosion in Europe, which is improving across Europe. The analysis and the indicators have been made available to EUROSTAT and DG ENV and have been included in the Sustainable development in the European Union Flagship Report. The indicator remained unchanged compared to the 2024 edition, however, the policy context has changed with the entry into force of the SMRD.

2.1.8. United Nations Environment Programme 2025 – Global Environment Outlook

Land degradation is a global environmental and socioeconomic problem recognized by various United Nations conventions and the SDGs. SDG target 15.3 (combat desertification, restore degraded land and soil) explicitly mentions the concept of land degradation neutrality.

JRC and the EUSO provide the soil erosion estimates predicted through the Global Soil Erosion Modelling platform. This unique harmonised assessment of soil erosion at global scale is recognised by the scientific community and various global organisations (e.g. FAO, OECD, UNEP). At global scale, semi-empirical approaches are used in physical models to inform policy makers (Borrelli et al., 2020). Conservation agriculture, agroecology and regenerative agriculture –based on minimal soil disturbance, crop rotations and cover cropping – now cover an estimated 11 to 14% of agricultural land globally, or ~1.42 billion hectares. These practices could reduce global soil erosion by 7.1% (Borrelli et al., 2017). The EUSO has provided the datasets for the land degradation assessment in chapter "4.3.2 Land and soil degradation". More contributions from the EUSO are also in other chapters of the Global Environmental Outlook.

2.1.9. Support to Enlargement

The EU's enlargement policy is a cornerstone of its external relations, driving long-term security, peace, stability, and prosperity in Europe. The European Commission plays a crucial role in supporting these countries, helping them meet the necessary criteria and implement related reforms.

EUSO's work is closely aligned with the EU's accession process, particularly in the context of Chapter 27 (Environment and Climate), which sets out the EU's environmental and climate acquis. Within this framework, the EUSO has made significant contributions, with a particular focus on soil research. This effort has had a notable impact on several regions, informing policy decisions and supporting sustainable development.

Notably, in Ukraine, the EUSO played a key role in assessing the environmental and climate status, with a specific emphasis on the effects of war and its implications for the country's reconstruction. The European Commission's report, "Status of Environment and Climate in Ukraine", highlights the significant environmental challenges posed by the ongoing conflict, including deterioration of air quality, increased emissions of pollutants and greenhouse gases, deforestation, and soil degradation. The report emphasises the need for sustainable reconstruction efforts and benchmarks progress towards EU accession, particularly in the green transition and environmental policies. By contributing to the soil section of the report, the EUSO helped inform key policy recommendations that will guide Ukraine's recovery and rebuilding efforts.

In the Western Balkans, the EUSO has advanced research on soil pollution, resulting in a highly regarded scientific publication, "Addressing point source soil pollution in the Western Balkans: challenges and opportunities for European Union integration". This study reveals that industrial and mining activities are the primary sources of soil pollution in the region, whilst asbestos and nuclear energy contribute relatively less. The analysis of 118 contaminated or potentially contaminated sites highlights the need for comprehensive regional data on waste management and pollution levels, as well as effective strategies to prioritise high-risk sites and establish clear criteria for identifying pollution hotspots. The study emphasises the need for coordinated soil protection strategies to ensure sustainable land use and healthy soils in the Western Balkans. The study's findings have important implications for the region, highlighting the importance of protecting soil health and promoting sustainable land management practices. By informing policy discussions and supporting the development of effective strategies to mitigate soil pollution, EUSO's work has contributed to a better understanding of the issues and challenges in the region.

Through its work in these regions, the EUSO has demonstrated its commitment to supporting the EU's enlargement policy, using science to inform decision-making and support policy development. By leveraging its expertise in soil research and providing targeted support for Chapter 27, the EUSO has provided valuable insights and recommendations that can inform policy decisions and support sustainable development in Ukraine and the Western Balkans.

2.1.10. Support to the Nature Restoration Regulation

The Nature Restoration Regulation (NRR) aims to support the long-term and sustained recovery of ecosystems across the Member States (MS). In this context, the NRR states that MS shall achieve increasing trends for a selection of indicators until satisfactory levels (SL) identified in accordance with Art. 14(5) are reached. One of the indicators listed in the NRR is the stock of organic carbon in cropland mineral soils (Art. 11).

It is further stated that the Commission shall establish a 'guiding framework for setting the satisfactory levels' by means of implementing acts by the end of 2028. The guiding framework will present concrete and transparent methodologies to estimate thresholds to be used as SL for the selected indicators in the NRR.

The SMRD lists the SOC/clay ratio as an indicator of soil organic matter status and is thus foreseen to be quantified across the EU. Given that the SOC/clay ratio is not applicable across the EU (Chahal et al., 2024; Poeplau and Don, 2023), Member States are expected to apply corrective factors to the ratio where specific soil types or climatic conditions justify it.

The EUSO is preparing guidelines to help defining the stratification of data reported by MS, such that corrective factors can be applied, making the SOC/Clay ratio more informative. It is foreseen that the guidelines for the SMRD can be adopted in the NRR, which would reduce the administrative burden placed on MS.

2.1.11. Contributions to MAES2IPBES

The EUSO contributed to the ongoing second European Assessment on Biodiversity and Ecosystem Services (MAES2IPBES). This second European Ecosystem Assessment aims to deliver a comprehensive evaluation of the state and trends in ecosystems and their services throughout Europe. This initiative builds upon the first EU Ecosystem Assessment published in 2020 and integrates the newest data and methodologies, such as the 2022 EU-wide methodology to map and assess ecosystem condition. It will contribute to international frameworks like the Second IPBES Global Assessment Report on Biodiversity and Ecosystem Services, the Kunming-Montreal Global Biodiversity Framework, and the evaluation of the EU Strategy of Biodiversity for 2030. It analyses eight ecosystems, including soils. The ecosystem assessment will be published by the end of 2026.

2.1.12. Support to the Zero Pollution Monitoring and Outlook 2025 report

The Zero Pollution Monitoring and Outlook (ZPMO) 2025 report comprises two key components: monitoring the current state of environmental pollution in the EU and providing an outlook of the likelihood of achieving the Zero Pollution Action Plan targets by 2030. JRC staff played a crucial role in developing and drafting the outlook part while also contributing to the monitoring part, which was led by the EEA. The JRC developed and applied relevant methodologies and models to quantitatively assess the effectiveness of existing and planned pollution-reducing measures, building on peer-reviewed research and technical JRC reports.

The EUSO contributed to the soil pollution aspects of the ZPMO 2025 report. Soil pollution in the EU is poorly quantified compared to air or water pollution. Consequently, the limited research linking soil contamination to human health relies on case studies from specific local populations, tackling merely a subset of contaminants – specifically, metals and pesticides – within the broader spectrum of soil pollutants found in the EU (Vieira et al., 2024).

The JRC collaborated with the EEA to launch the ZPMO 2025 report on 3 March 2025. The report was unveiled together with the Zero Pollution Dashboard at a high-level event, the Zero Pollution Stakeholder Forum. The forum was attended by EU Commissioner for Environment, Jessika Roswall. Additionally, the report was highlighted in a European Commission press conference, accompanied by a dedicated press conference by Commissioner Roswall. Subsequently, the report featured in 66 articles, including media platforms specialised in environmental topics but also general press outlets, such as Euronews, Politico, EUreporter, El Pais, Le Monde, TAZ. Such articles reported and

commented on the findings of the ZPMO, calling for further policy measures given that many 2030 pollution targets will probably be missed. Also, websites of industry federations referred to the findings of the document. Such media coverage has substantially raised awareness of the pollution problem and the current reduction targets in the EU, as well as the likelihood of failing to meet them. This has put pressure on policymakers to intensify efforts to mitigate the problem. Moreover, heightened awareness among the general public has the potential to drive changes in consumer behaviour, ultimately contributing to a broader societal shift towards a cleaner, healthier and more sustainable future.

2.1.13. Support to the Pact for the Mediterranean

Soils are critically important for the Mediterranean region due to a combination of environmental, agricultural, and socio-economic factors. Firstly, agriculture is highly important as many communities depend on cultivating a range of crops or grazing. The Mediterranean is a major producer of olives, grapes, citrus fruits, and vegetables. Healthy soils are essential for sustaining crop yields, especially in areas with limited water resources. Secondly, Mediterranean soils support unique ecosystems and biodiversity. They regulate water cycles, store carbon, and filter pollutants—vital for maintaining ecological balance. Thirdly, soils help buffer against climate extremes such as droughts and floods. Organic-rich soils retain moisture better, which is crucial in the region's dry summers. Finally, the Mediterranean's hilly terrain and intense rainfall events make soils prone to erosion. Low vegetation cover enhances wind erosion. Maintaining soil cover and structure helps prevent land degradation and desertification. However, soil degradation threatens food security and economic stability across the region. Issues such as desertification, erosion, salinization, soil sealing, unsustainable land management and pollution are recognised challenges.

To reflect the increasing policy focus on the Mediterranean, the third part of the EUSO Stakeholder Forum 2025 focused on recent research to better quantify degradational processes and innovative solutions in the Mediterranean (see section 2.6.1.3).

In parallel, the EUSO, together with FAO's Global Soil Partnership, is reaching out to the scientific community to collaborate in the preparation of a Soil Atlas of the Mediterranean. The atlas will serve as a powerful tool, providing a comprehensive, visual, and data-rich overview of soil characteristics across the regions or countries while helping people understand how they vary with climate, geology, and vegetation. The atlas will describe the key functions played by soils while highlighting the main pressures and threats that they face as well as the importance of sustainable land use. Finally, the atlas helps inform decision makers, while being a powerful educational and research tool. Compilation of the Soil Atlas of the Mediterranean will be supported by the SOILS4MED and SHARING_MED projects (2023-2027), which are funded by the Partnership for Research and Innovation in the Mediterranean Area (PRIMA) Foundation. Publication is planned for 2028.

2.2. EU-wide soil monitoring

2.2.1. Laboratory analysis related to the LUCAS Soil Module 2022

The LUCAS Soil Module is currently the only EU-wide mechanism for collecting harmonised data on soil characteristics. It covers the entire continental territory of the EU, addressing all major land cover types simultaneously, in a single sampling period. Results of the LUCAS Soils survey are available for 2009, 2015 and 2018.

In 2022, the EUSO successfully rolled out the latest LUCAS Soil Module collection. In 2024, a call for tender for the laboratory analysis of the soil samples collected during the 2022 LUCAS Soil Survey was published. The laboratory analyses were organised in three lots: (1) analysing basic soil physical and chemical parameters including the concentrations of metals/trace elements, (2) carry out metabarcoding DNA analysis, and (3) screen soil samples for the residues of active ingredients of plant protection products and to measure their concentrations.

While interim data became available during 2025, complete results will be published in 2026 as a database and a report. The report will present an overview of the various laboratory analysis and will describe the spatial variability of soil properties by land cover class and a comparative analysis of the soil properties.

2.2.2. An inventory of existing international and European standards

The SMRD establishes a harmonised soil monitoring framework to assess soil health in the EU. A harmonised approach implies that standards become important to ensure interoperability among, and within, Member States. The SMRD prescribes reference methodologies and requires transfer functions for other methods. The SMRD also includes some standards for the monitoring and measuring of soil descriptors based on those being used through the LUCAS Soil Module from 2009 to 2022. In 2025, the EUSO worked on a technical report providing an inventory of 574 soil-related standards from international and European standard bodies including the International Organization for Standardisation (ISO) and the European Committee for Standardisation (CEN). The reports shows that there is a need for harmonisation of soil-related standards to ensure consistency and comparability of soil data and to support effective soil management and protection efforts.

2.2.3. Preparing the next LUCAS Soil Module

In 2025, the EUSO has been preparing for the next campaign of the LUCAS Soil module. This involved building and adapting the sampling methodology and instructions to surveyors to meet the requirements of the SMRD. The proposed methodology contains a number of new developments with respect to the previous LUCAS Soil campaigns: i) the radius of the sampling scheme has increase from 2 to at least 4 m to be more in line with Member States soil monitoring schemes; ii) the standard soil sample shall be a mixture of 5 subsamples; iii) bulk density samples are collected at different depths (0-10, 10-20, 20-30, 30-40 cm); iv) in forested areas, the litter and organic layers shall be sampled separately, if relevant. The thickness and weight of these layers shall be recorded.

To achieve this, the EUSO has engaged with projects like EJP-Soil and ICP Forests. Moreover, the proposed methodology was presented and discussed during a webinar organized by the EUSO in December 2025 with soil monitoring experts (see also section 3.4).

2.3. Monitoring soil health and soil policies

2.3.1. The EUSO Soil Degradation Dashboard

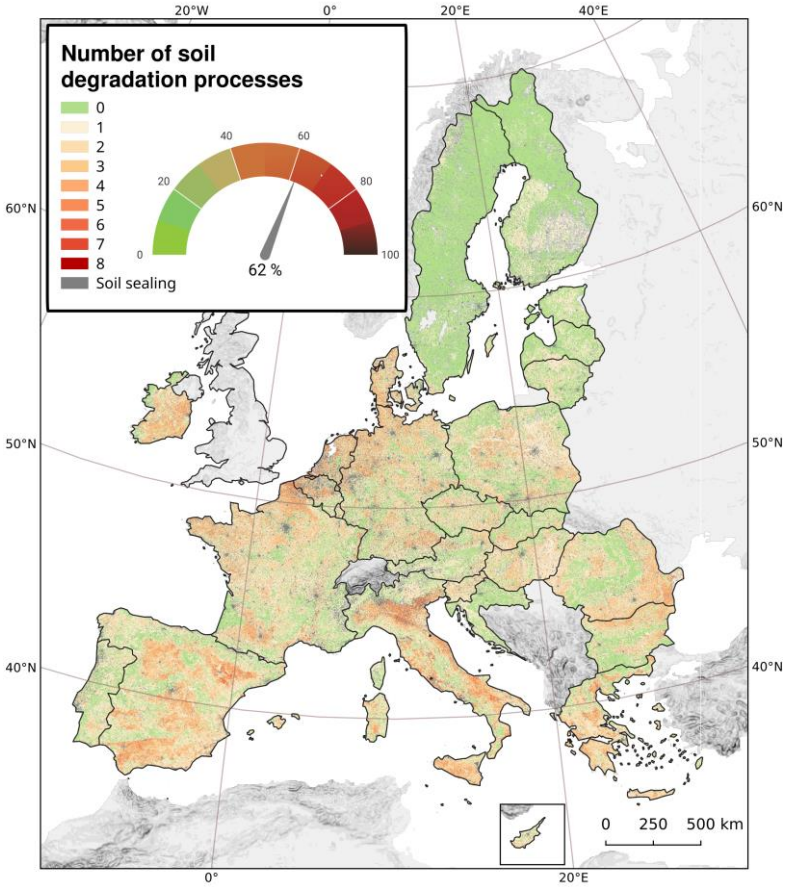
The EUSO Soil Degradation Dashboard aims to monitor and report the state of soil degradation at the EU-level. The dashboard spatially combines different datasets to highlight the intensity and location of relevant soil degradation processes. As such, the dashboard provides a spatial assessment of the location of unhealthy soils in the EU, and which degradation processes affect

them. The resulting map shows where current scientific evidence converges to indicate areas that are likely to be affected by soil degradation (**Figure 3**).

Two new features were added to the dashboard in March 2025. Firstly, a correlation matrix was added, showing the strength and direction of the relationship between two soil degradation indicators (**Figure 4**). Secondly, a graph comparing the percentages of degraded soils in Member States was added (**Figure 5**).

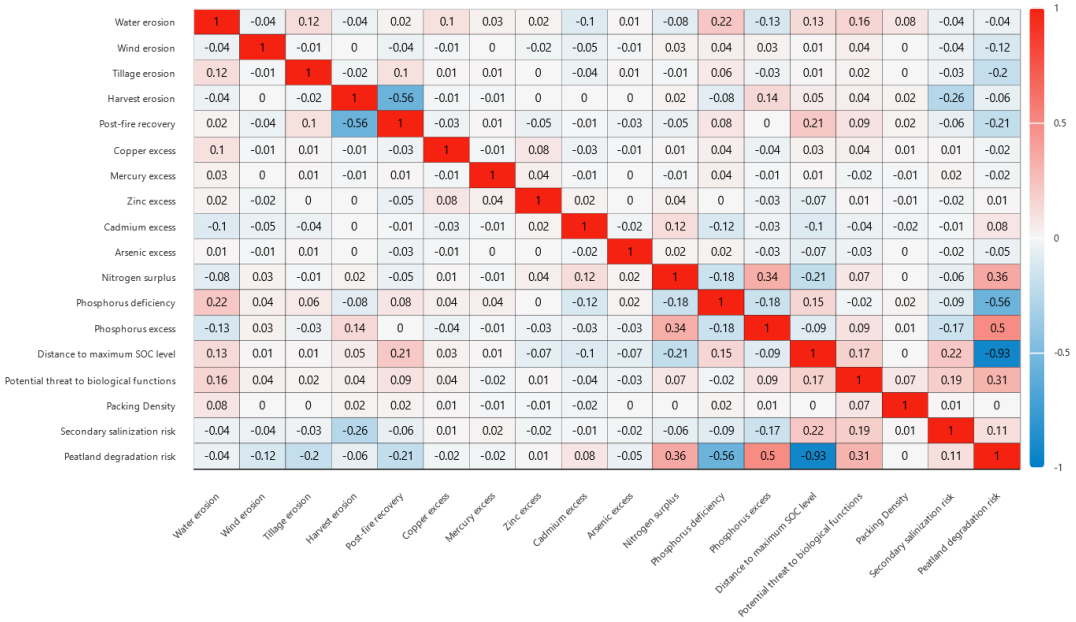
Results from the EUSO Soil Degradation Dashboard show that more than 60% of the EU soils are degraded (**Figure 3**). The dashboard also clearly shows that most unhealthy soils are subject to more than one type of soil degradation. The most prevalent types of soil degradation are the loss of soil biodiversity (33% of the EU), soil erosion by water (19% of the EU), and the loss of soil organic carbon (14% of the EU).

Figure 3. EUSO Soil Degradation Dashboard and its convergence of evidence map (indicating the number of soil degradation processes likely to be present) and speedometer (indicating the proportion of land likely to be affected by one or more soil degradation processes or by soil sealing in the EU).



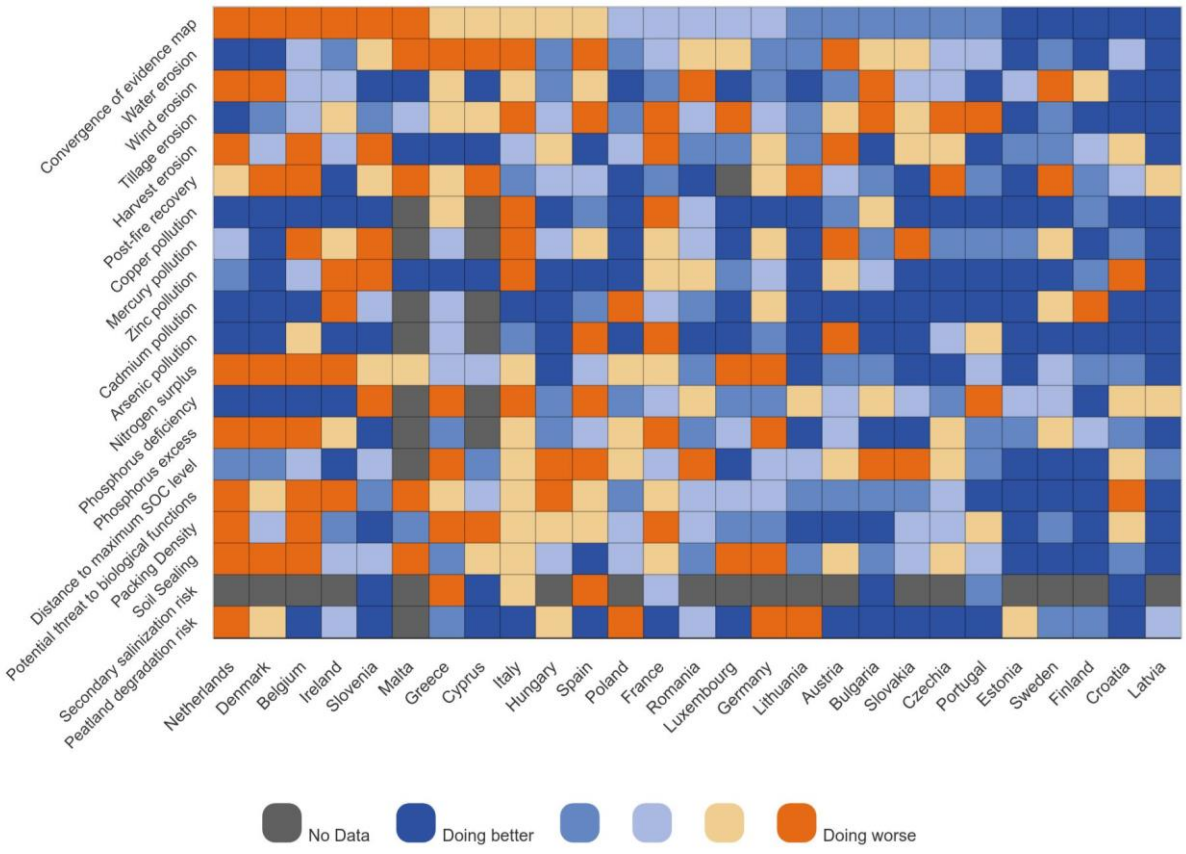
Source: Broothaerts et al. (under review)

Figure 4. Correlation matrix for the indicators in the EUSO Soil Degradation Dashboard.



Source: JRC analysis.

Figure 5. Comparison of the percentages of degraded soils in the Member States for each individual soil degradation indicator.



Source: JRC analysis.

2.3.2. The EU Soil Strategy Action Tracker

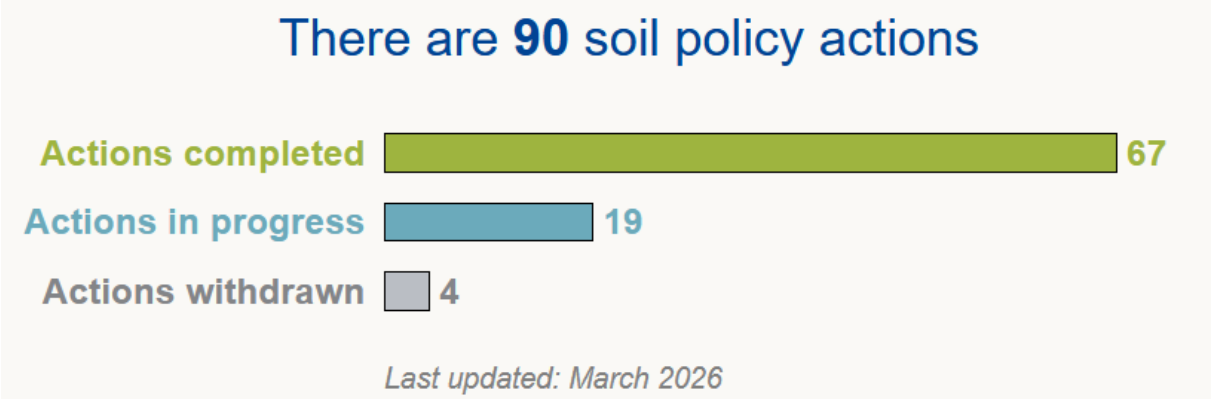
The EU Soil Strategy Action Tracker, developed by the EUSO in 2024 and updated in 2025 and early 2026, tracks the progress of policy actions in the EU Soil Strategy for 2030.

The EU Soil Strategy for 2030 sets out a framework and concrete measures to protect and restore soils and ensure that soils are used sustainably. It aims to achieve healthy soils by 2050 with concrete actions by 2030. The EU Soil Strategy Actions Tracker provides an overview on the status of the actions, information on the due date, recent updates, links to related EU policies, links to relevant sources, and the main actors responsible for implementation. As such, it is a starting point to dig deeper in the status and progress of EU soil policy actions.

The EU Soil Strategy Action Tracker shows that, currently, 67 out of 90 actions (74%) are marked as completed, 19 actions (21%) as in progress, and 4 actions (4%) as withdrawn (**Figure 6**). The Tracker provides a clear overview of the progress made by the European Commission under the EU Soil Strategy. With almost 75% of complete actions, the tracker shows that the Commission is well on track to complete most of the actions included in the EU Soil Strategy. Together with the EUSO Soil Degradation Dashboard (see section 2.3.1), it provides an informative overview on the status of EU soils and ongoing actions to preserve and restore this state. The EU Soil Strategy Actions Tracker is the first step towards an EUSO Soil Policy Actions Tracker to monitor all EU policy actions relevant to soils. An update is foreseen for 2026.

Details on the methodology used to develop the Tracker are provided in a technical report, published in 2025.

Figure 6. Summary of the status of the actions included in the EU Soil Strategy for 2030.



Source: Broothaerts and Breure et al. (2025).

2.4. Enhancing the functionality of the European Soil Data Centre

The European Soil Data Centre (ESDAC) is the leading web platform for gathering and disseminating soil related datasets, maps and knowledge in the EU (Panagos et al., 2022). ESDAC is at the core of the EUSO by providing soil data and knowledge, thus supporting policy making and awareness raising related to soils in the EU. EUSO aims to continuously enhance the capacity and functionality of ESDAC.

The ESDAC platform currently hosts 141 datasets, over 6 000 maps, over 500 scientific documents, 7 atlases, and a wide range of soil related material. The ESDAC has grown significantly in 2025, both in terms of content hosted (see 2.4.1) and number of users (see 2.4.2).

2.4.1. New datasets added to ESDAC

ESDAC has added 15 new datasets in 2025 (see **Figure 7**). All datasets were accompanied with a scientific publication. The newly added datasets are listed below. These datasets were downloaded already extensively, with some achieving more than 100 downloads in the first year of release (**Figure 8**). Especially the datasets of the Soil Carbon Risk Index (section 2.4.1.3) and the SOC index (section 2.4.1.2) had a strong interest in their first year of release (**Figure 8**).

2.4.1.1. Soil biodiversity and related ecosystem function data measured in LUCAS 2018 sites across the EU

In the LUCAS 2018 survey, soil biodiversity and related ecosystem functions have been measured in the 881 sampling sites selected for the soil biodiversity assessment across Europe. These soil functions include soil aggregates (i.e., mean width diameter and water-stable aggregates), enzyme activities, microbial respiration and biomass, and measurement of ester-linked fatty acid methyl esters (FAMEs). Data are available on ESDAC.

2.4.1.2. Observed/Typical SOC index

Observed/Typical Soil Organic Carbon (O/T SOC) index classes and associated pedoclimate zones across the EU and UK are presented in two GeoTiff files at 100 m resolution. These maps from Feeney et al. (2024) illustrate the O/T SOC index classes, derived from LUCAS 2009-18 observations, to stratify the landscape into areas suitable for benchmarking SOC concentrations. O/T SOC is less sensitive to soil texture, land-use and climate than SOC/clay, and is sensitive to changing SOC under land management over years and decades. Data are available on ESDAC.

2.4.1.3. Soil Carbon Risk Index

This dataset includes the a) Soil organic carbon risk index b) SOC fractions predicted by visible near-infrared c) the mineral associated organic carbon saturation. This dataset accompanies the Nature Communication publication of Breure et al. (2025) and can be used to access the results, data and code. Data are available on ESDAC.

2.4.1.4. Data on texture LUCAS Soil 2009/2015/2018

Textural data for all soil samples from the LUCAS SOIL campaigns. This data from the LUCAS SOIL campaigns of 2009/2012, 2015 and 2018 was assembled in a single file which includes the particle size distribution (clay, silt, sand) and the textural classification according to USDA, FAO and INTERNATIONAL. The datafile refers to 27 819 sample points. Data are available on ESDAC.

2.4.1.5. Gully erosion in the EU

Gully erosion channels were mapped across the full LUCAS 2022 survey (ca 400 000 locations). This expert-based assessment identifies the presence or absence of gully erosion forms at each LUCAS location, through in-situ and on-screen observations. The findings led to the development and validation of the LUCAS Gully Erosion Model (GE-LUCAS v1.1), a pan-European inventory of gully erosion channels comprising 3 116 locations affected by gully erosion. In addition, the gully erosion channels probability across the EU and UK is also available, as well as point data with gully occurrence and pictures. This dataset accompanies the publication of Borrelli et al. (2025). Data are available on ESDAC.

2.4.1.6. Ecological Risk of heavy metals from application of sewage sludge

A methodological approach to quantify the impact of sewage sludge application on agricultural soils in the EU and the United Kingdom. Concentrations of heavy metals (Cd, Cu, Hg, Ni, Pb and Zn) in agricultural land from LUCAS 2009 topsoil database were used as a baseline. This dataset accompanies the publications in European Journal of Soil Sciences and Environmental Science and Pollution Research. Data are available on ESDAC.

2.4.1.7. Dissolved cadmium content and oxalate-extractable iron in EU and China

Bioavailability and risks of heavy metals in agricultural soils remain one of the important obstacles to achieving global food safety and security. Evaluating heavy metals bioavailability is crucial for comprehensive soil contamination assessment but challenging at large scales due to complex and resource-intensive analytical procedures, and the amount of dissolved metal in soils represents the relative solubility and potential mobility of cadmium, which is a key factor determining bioavailability. This dataset, derived from a geochemical-integrated machine learning framework, predicts the bioavailable fraction of cadmium in European and Chinese topsoils. In addition, the total cadmium content is also available. Oxalate-extractable iron is important for Cd fixation and has been also made available in this dataset. This dataset accompanies the publication in Communications Earth & Environment. Data are available on ESDAC.

2.4.1.8. Projected Soil Organic Carbon (SOC) changes by 2070 under the RCP4.5 scenario

Loss of SOC is one of the main threats to European and global soils. The impact of climate change, especially warming, on SOC varies by regions but remains poorly understood. To address this, we used a Random Forest algorithm to model SOC in topsoil of Europe based on LUCAS data and applied Shapley Additive exPlanations values to interpret spatial patterns. This dataset includes the prediction SOC content in 2070 under the RCP4.5 scenario with changes compared to a 2018 baseline. Under the RCP4.5 scenario, projected warming over the next 50 years could lead to significant SOC loss around the southern Baltic Sea (55°N-60°N), while regions north of 65°N could experience SOC gains. This dataset accompanies the publication in Journal of Environmental Management. Data are available on ESDAC.

2.4.1.9. Global Soil Organic Carbon displaced due to erosion

Soil erosion significantly affects soil organic carbon (SOC) dynamics, impacting carbon neutrality and climate change mitigation. Global SOC loss from erosion is estimated at approximately 0.97 Pg C/year. Projections for 2070 suggest this could increase to 1.18Pg C/year under the RCP2.6 scenario and1.31 Pg C/year under the RCP8.5 scenario. This dataset combines current and future global soil erosion maps (GloSEM 1.3), containing inter-rill and rill processes, with SoilGrids 250 m data on a SOC content (in ‰ (g kg−1)) map. This dataset accompanies the publication in Advances in Agronomy. Data are available on ESDAC.

2.4.1.10. Optimising phosphorus inputs in EU agricultural soils

Excessive phosphorus (P) fertilisation has resulted in elevated soil P concentrations in some regions in the EU. Legacy soil P imposes a risk for soil functioning and may lead to P losses into the aquatic environment. We present a data & modelling framework to estimate how much and where P inputs in EU agricultural (cropland and grassland) soils can be optimized by2050. The dataset includes a) the distribution of nine P management strategies in EU agricultural land, b) optimised P inputs to reach optimal P concentrations by 2050, and c) the increase in P inputs required when the aim is to

reach at least 20mg kg^{-1} of topsoil P-OLSEN concentrations by 2050. This dataset accompanies the publication in Environmental Science & Policy. Data are available on ESDAC.

2.4.1.11.Soil erodibility point data on ESDAC

Measured soil erodibility (K-factor) point data are now available on ESDAC. This dataset contains 21 680 records from LUCAS 2009/2012, as presented in the paper in Science of The Total Environment. It includes point data, shape files and the geopackage. Data are available on ESDAC.

2.4.1.12.Fraction of Carbon in Soil Organic Matter on ESDAC

A collation of datasets and derived carbon metrics includes data on total soil carbon, soil organic carbon (SOC) and soil organic matter (SOM) for soil samples from Europe, permafrost regions and global seagrass sediments. SOC and SOM were used to calculate the fraction of SOC in SOM (foc) and SOM content was used to define mineral (<20% SOM) and organic (>20% SOM) soils. The provided dataset was used to explore foc as a national-scale soil process indicator. This dataset accompanies the publication in Global Change Biology. Data are available on ESDAC.

2.4.1.13.Aboveground biomass carbon over the Amazon for 2010-2020

The Amazon rainforest is crucial for the global carbon cycle, yet annual changes in its aboveground biomass carbon (AGC) stock remain highly uncertain due to the lack of fine-resolution and temporally consistent information. The current dataset contains reconstructed maps of annual AGC change at a~100m spatial resolution, resulting from the disaggregation of low-frequency passive L-band microwave data over 2010-2020. They show that the Amazon lost −0.37 ± 0.17 PgC, with gains by undisturbed (0.33 ± 0.13 PgC) and secondary forest growth (0.33 ± 0.05 PgC) outweighed by losses through deforestation (−0.55 ± 0.04 PgC), degradation (−0.42 ± 0.08 PgC), and agricultural areas (−0.06 ± 0.03 PgC). This dataset includes the files required to calculate the expected aboveground carbon (in MgC/ha) over the Amazon, as well as the corresponding uncertainty (e.g., confidence intervals) at a spatial resolution of 0.000888° (~100m at the Equator). This dataset accompanies the publication in Nature Communications. Data are available on ESDAC.

2.4.1.14.Inter- and Intra-laboratory replicate measurements of soil organic carbon for LUCAS

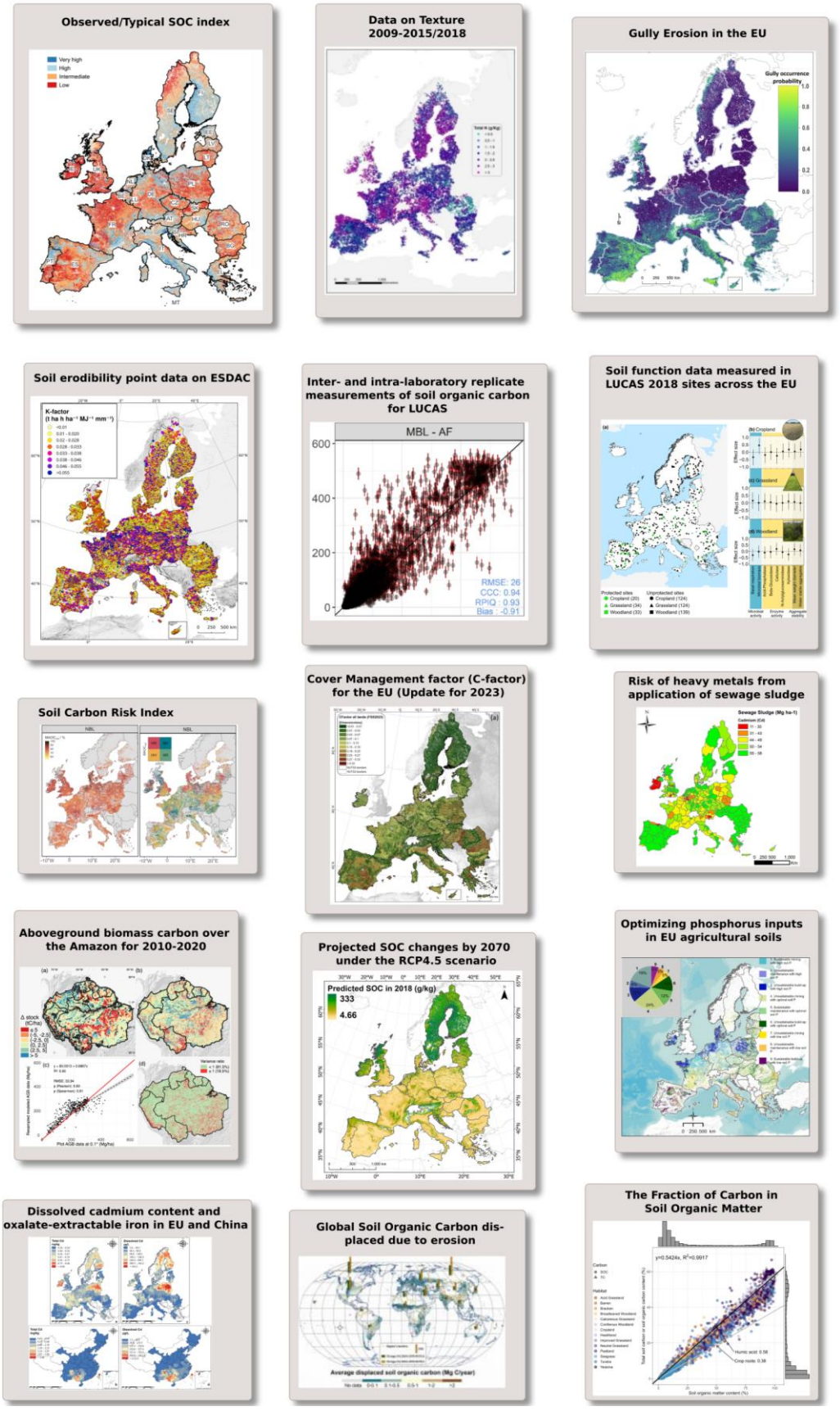
Analytical soil data from conventional methods is generally assumed to be error free. However, conventional methods also have associated errors due to different laboratory conditions, protocols, operators, instruments and random variation. These factors contribute to variation in analytical measurements from a single laboratory (the intra-laboratory error) as well as between different laboratories (inter-laboratory error). The relative differences between the intra- and inter-laboratory analytical measurement error depend on the soil property being measured and the protocols and instruments used. Therefore, any methods that seek to replace conventional analytical methods, such as visible near-infrared spectroscopy (VNIRS), need to be assessed in context of these error variances. This allows for a better quantification of the value of VNIRS predictions for subsequent analysis and decision-making. Breure et al. (2026) provided two different methods in which the intra- and inter-laboratory from LUCAS measurements can be used to interpret soil property predictions, either from VNIRS or other methods. We found that using the laboratory error changed relative differences between models compared to mean prediction metrics commonly used in the literature (e.g. RMSE, R2). This is due to that mean prediction metrics are more dependent on the

underlying data distribution and have a higher sensitivity to outliers. This dataset accompanies the publication in Geoderma. Data are available on ESDAC.

2.4.1.15.Cover Management factor (C-factor) for the EU (Update for 2023)

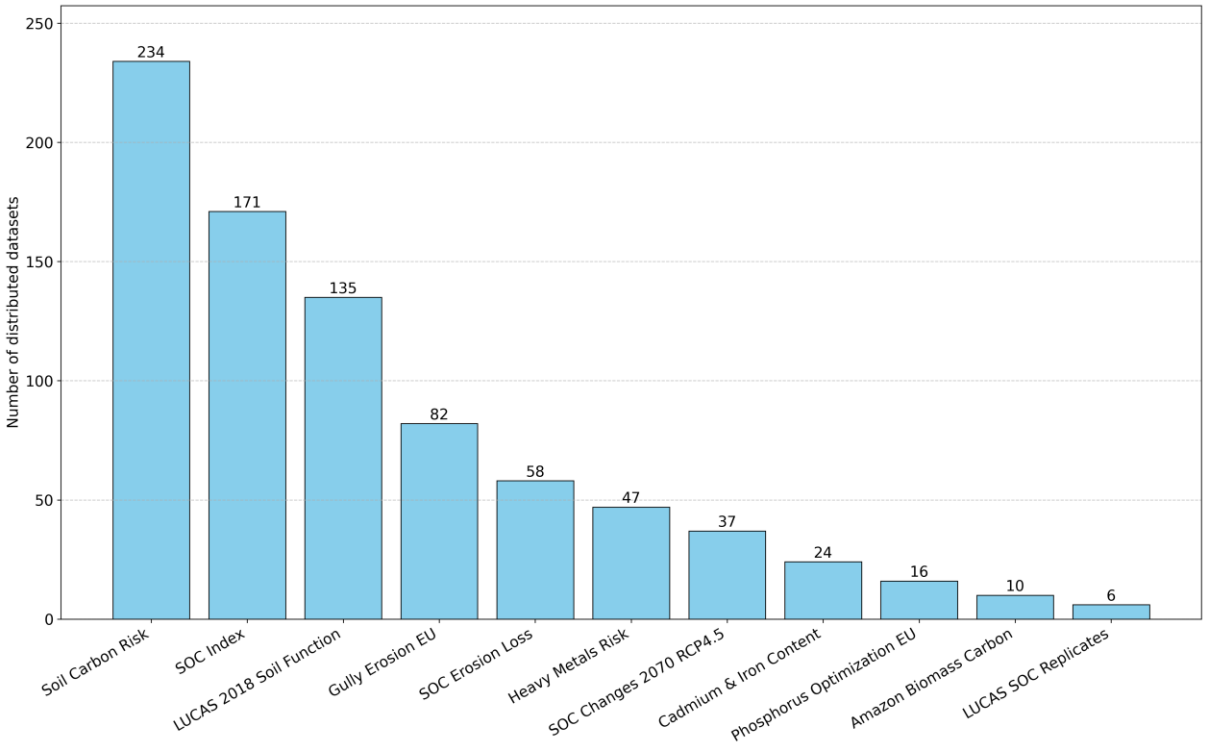
Land use and management influence the magnitude of soil loss. Among the different soil erosion risk factors, the cover-management factor (C-factor) is the one that policy makers and farmers can most readily influence to help reduce soil loss rates. The present study proposes a methodology for estimating the C-factor in the EU, using pan-European datasets (such as CORINE Land Cover), biophysical attributes derived from remote sensing, and statistical data on agricultural crops and practices. In arable lands, the C-factor was estimated using crop statistics (% of land per crop) and data on management practices such as conservation tillage, plant residues and winter crop cover. The C-factor in non-arable lands was estimated by weighting the range of literature values found according to fractional vegetation cover, which was estimated based on the remote sensing dataset Fcover. The mean C-factor in the EU is estimated to be 0.1043, with an extremely high variability; forests have the lowest mean C-factor (0.00116), and arable lands and sparsely vegetated areas the highest (0.233 and 0.2651 respectively). Conservation management practices (reduced/no tillage, use of cover crops and plant residues) reduce the C-factor by on average 19.1% in arable lands. The methodology is designed to be a tool for policy makers to assess the effect of future land use and crop rotation scenarios on soil erosion by water. The impact of land use changes (deforestation, arable land expansion) and the effect of policies (such as the Common Agricultural Policy and the drive to grow more renewable energy crops) can potentially be quantified with the proposed model. An update of the C-factor took place for the year 2023 and the results have been published in Data in Brief. This update focus in arable lands and we also made available the dataset for the pre-GAEC period (year: 2000). Data for the years 2000, 2010, 2016 and 2023 are available on ESDAC.

Figure 7. Datasets added to ESDAC in 2025.



Source: JRC analysis.

Figure 8. Number of downloads of the new datasets added to ESDAC in 2025.



Source: JRC analysis.

2.4.2. ESDAC performance in 2025

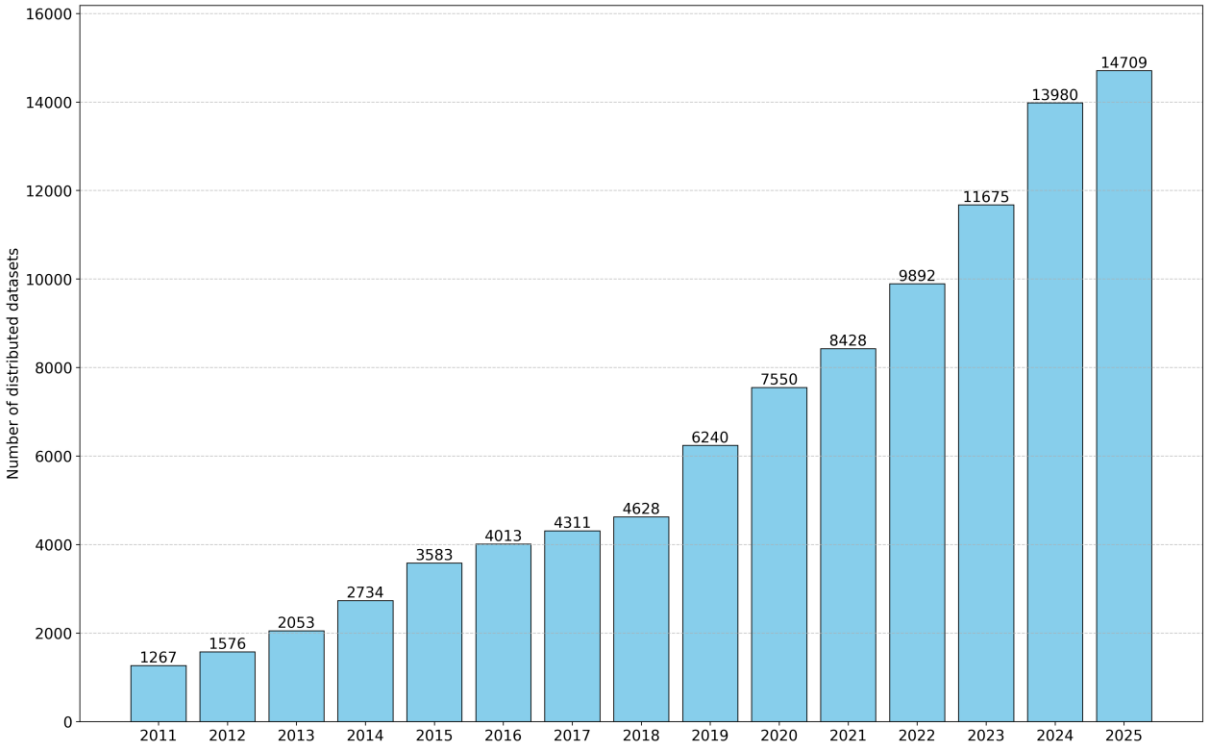
In 2025, 14 600 ESDAC datasets were downloaded, which is slightly higher than for 2024. Compared to 2020, the number of downloaded datasets is twice as high, while compared to 2011, the number of downloaded datasets increased 10-fold (**Figure 9**). Overall, the number of downloaded ESDAC datasets substantially increased over the past 15 years, reflecting sustained expansion in data sharing and user demand and increased interest in pertinent soil data over time (**Figure 9**).

Around 60% of these datasets were downloaded from an EU Member State, with most of the downloads in Italy, Germany, Spain and France. Most downloads from non-EU countries came from China, United Kingdom and India (**Figure 10**). This distribution demonstrates, although the platform has a strong user base within the EU, substantial international reach and the platform's ability to engage both regional and global audiences. Regarding the institutional type of the users, 60% of the downloads came from academia, 16% from private companies, 15% from research organisation and 4% from public administration (**Figure 11**). These shares remained constant over the past years. The most downloaded ESDAC datasets in 2025 were the LUCAS soil data of 2018, the European Soil Database v2, the European Soil Raster 1km dataset and the Global rainfall erosivity database (**Figure 12** and **Figure 13**).

The ESDAC website had over 230 000 visitors and over 700 000 page views in 2025. These numbers increase continuously over the past years and are twice as high compared to 2022.

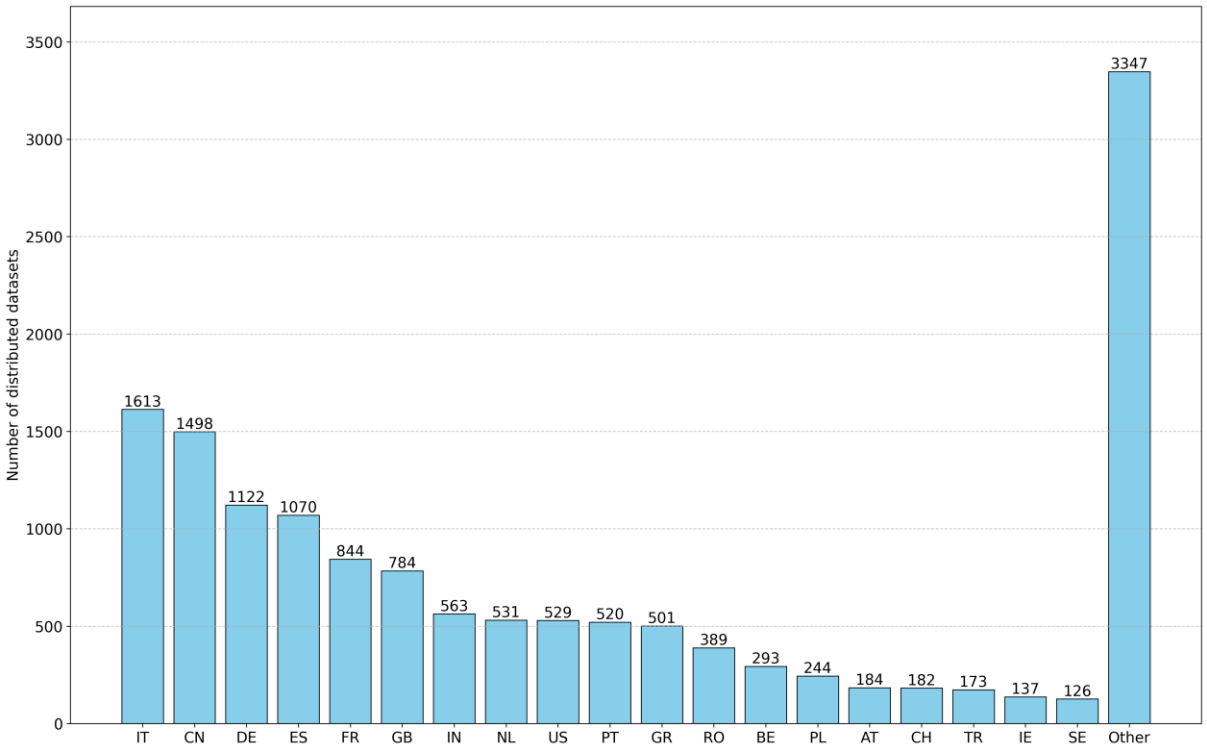
Overall, these trends underscore a robust and global focus on high-resolution spatial data of soil degradation and soil properties.

Figure 9. Number of downloaded ESDAC datasets in the period 2011-2025.



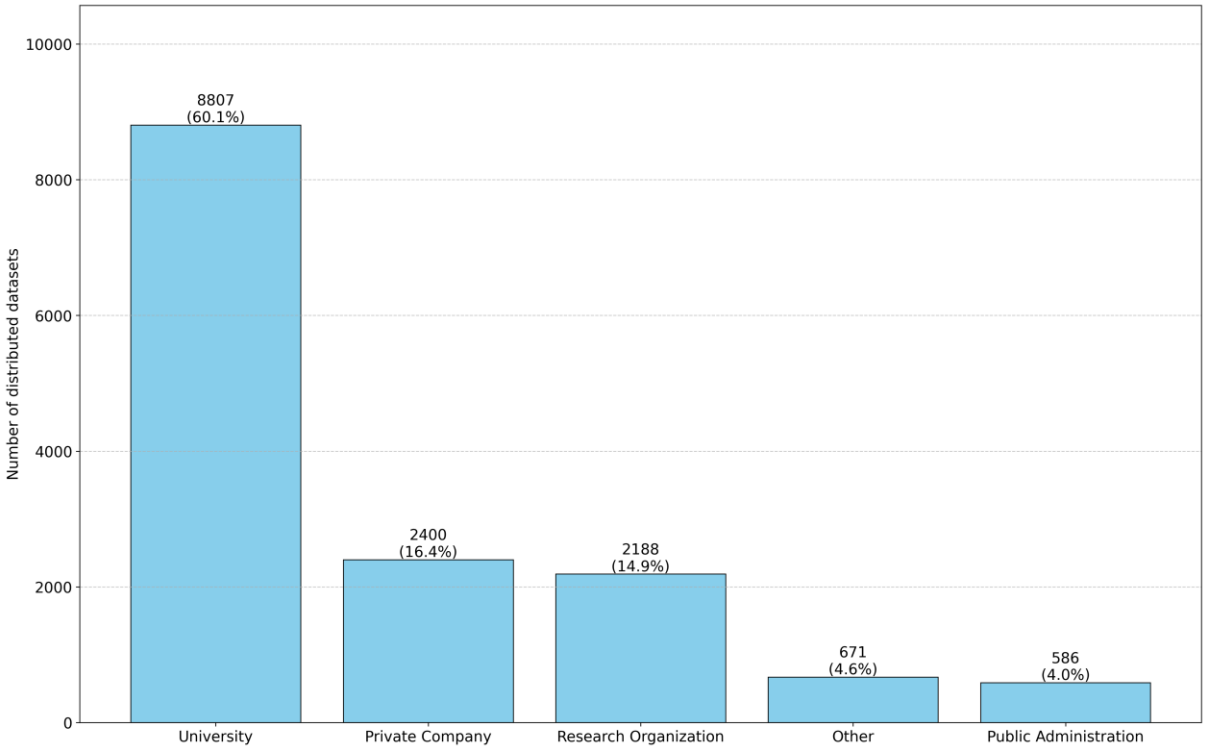
Source: JRC analysis.

Figure 10. Number of downloaded ESDAC datasets per country in 2025 (country codes can be found in the list of abbreviations).



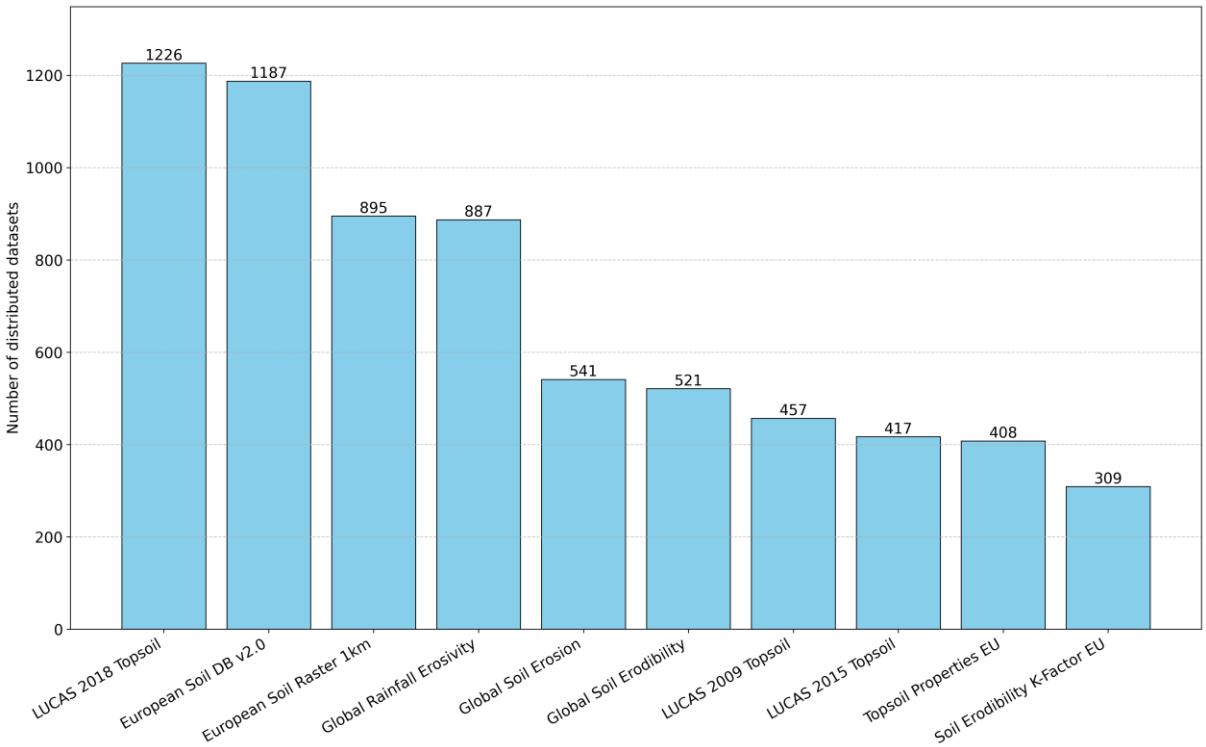
Source: JRC analysis.

Figure 11. Number of downloaded ESDAC datasets per institutional type, in 2025.



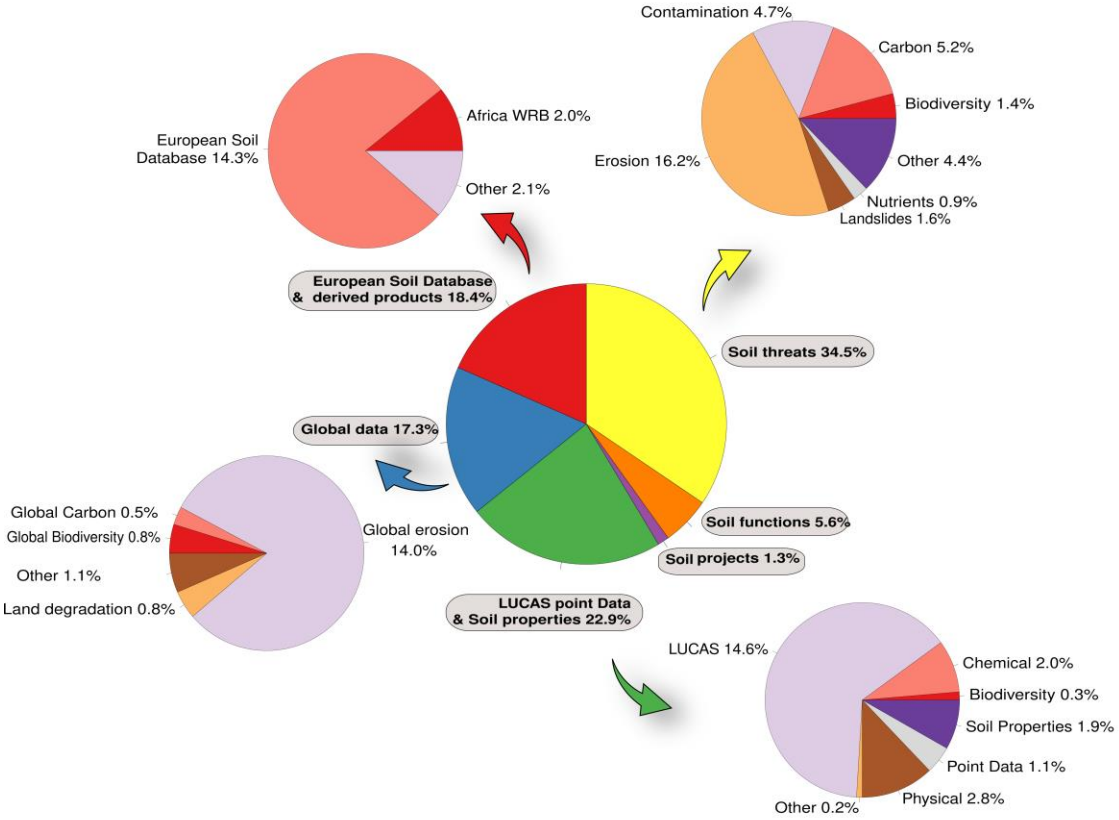
Source: JRC analysis.

Figure 12. Most downloaded ESDAC datasets in 2025.



Source: JRC analysis.

Figure 13. Share of ESDAC datasets downloads according to category.



Source: JRC analysis.

2.5. Supporting soil research and innovation

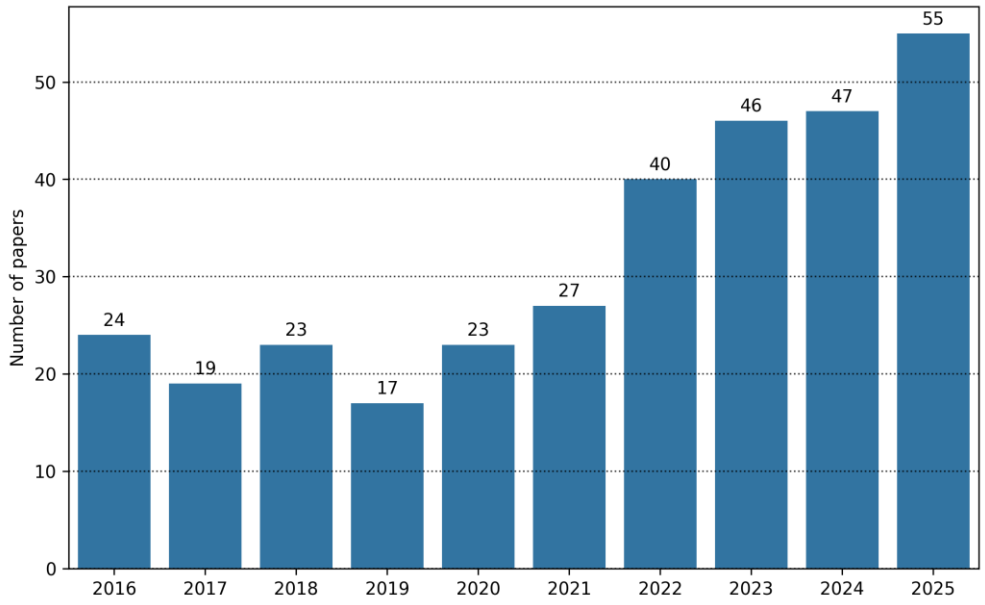
2.5.1. In-house research activities

A key objective of the EUSO is to support research and innovation, and to intensify targeted research, data and monitoring on soils. The EUSO contributes directly to advances in scientific knowledge on soils through its in-house research activities. In 2025, the EUSO team published 55 papers in Scopus-indexed journals (**Box 1**). The number of papers published in 2025 is higher comparable to the past years and is twice as high compared to five years ago (**Figure 14**). Many of these papers were published in high-impact journals, such as Nature, Nature Communications, Global Change Biology and Reviews of Geophysics (**Figure 15**). The monthly EUSO newsletter, sent to over 13 000 subscribers, highlights six recent EUSO publications (**Figure 16**).

In 2025, three EUSO team members have been listed as Highly Cited Researchers by Clarivate, highlighting researchers whose work has achieved exceptional global impact and placing them in the top 1% by citations in their respective fields.

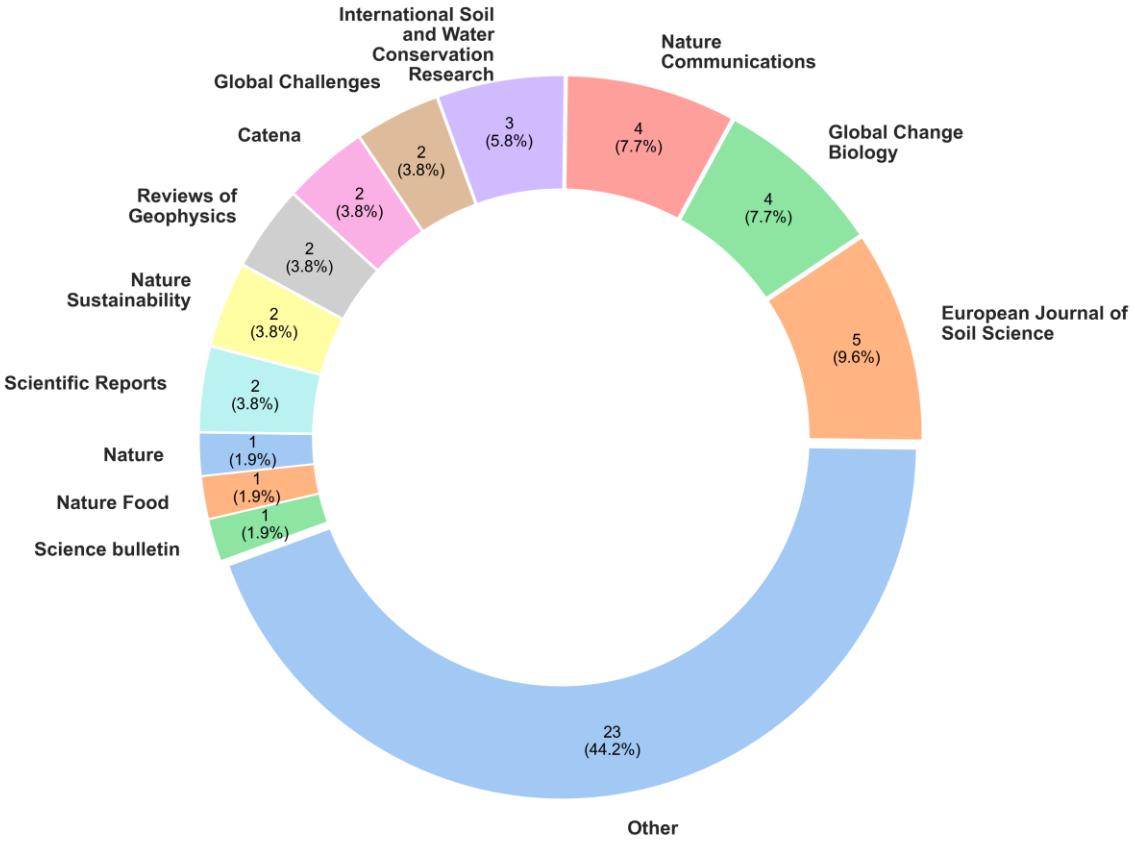
In addition, the EUSO team has published 10 JRC technical reports in 2024 (**Box 2**) and co-authored 1 science-for-policy report (**Box 3**).

Figure 14. Number of papers in Scopus-indexed journals published by EUSO per year.



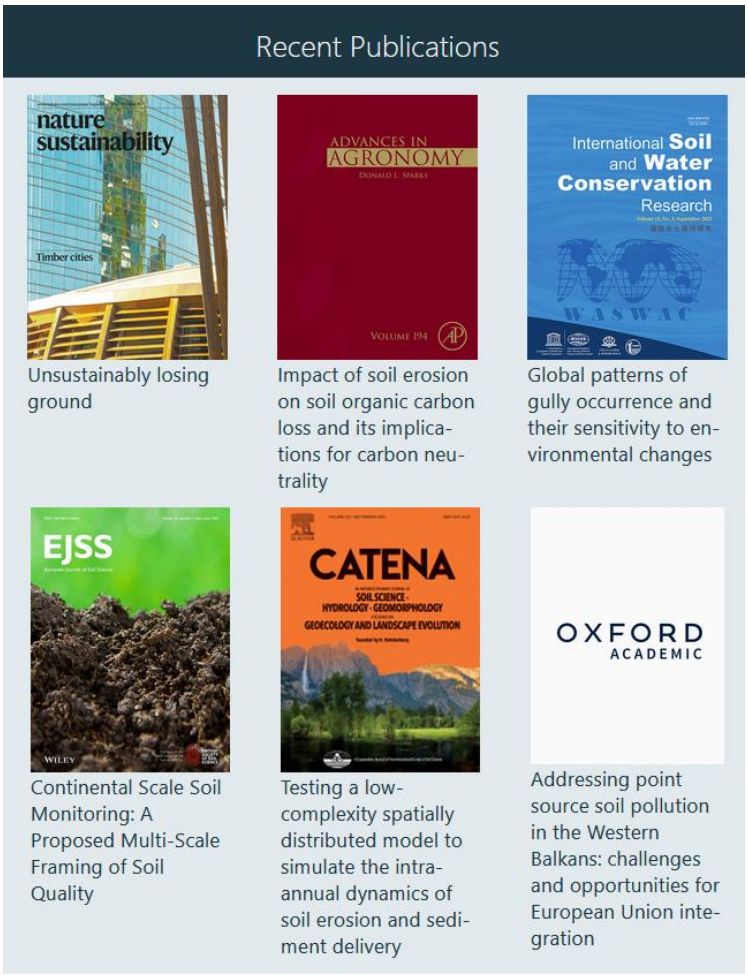
Source: JRC analysis.

Figure 15. Journals in which EUSO published in 2025, and the number and share of papers in these journals.



Source: JRC analysis.

Figure 16. Recent EUSO publications, highlighted in the EUSO monthly newsletter.



Source: JRC.

Box 1. Scopus-indexed journal papers published by the EUSO in 2025. EUSO team members are underlined.

Breure, T.S., De Rosa, D., Panagos, P., Cotrufo, M.F., Jones, A. and Lugato, E., 2025. Revisiting the soil carbon saturation concept to inform a risk index in European agricultural soils. *Nature Communications*, 16(1): 2538. https://www.nature.com/articles/s41467-025-57355-y

Fendrich, A.N, Feng, Y., Wigneron, J.P., Chave, J., Araza, A., Li, Z., Herold, M., Ometto, J., Aragão, L.E., Martinez Cano, I. and Zhu, L., 2025. Human influence on Amazon's aboveground carbon dynamics intensified over the last decade. *Nature Communications*, *16*(1): 6681. https://www.nature.com/articles/s41467-025-61856-1

Migliavacca, M., Grassi, G., Bastos, A., Ceccherini, G., Ciais, P., Janssens-Maenhout, G., Lugato, E., Mahecha, M.D., Novick, K.A., Peñuelas, J. and Pilli, R., 2025. Securing the forest carbon sink for the European Union's climate ambition. *Nature*, *643*(8074): 1203-1213. https://www.nature.com/articles/s41586-025-08967-3

Van Eynde, E., Fendrich, A.N., Yunta, F., Jones, A., Panagos, P., 2025. A data-driven impact evaluation of nutrient input reduction on wheat yields across Europe. *International Soil and Water Conservation Research,* 13(4): 733-743. https://www.sciencedirect.com/science/article/pii/S2095633925000814

Michailidis, V., Lugato, E., Panagos, P., Freund, F. Abalos, D., 2025. Impact of healthy diet shifts on soil greenhouse gas emissions across Europe. *Global Change Biology*, *31*(11): e70624. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.70624

Panagos, P., Orgiazzi, A., Lugato, E., Vandenesch, G., Thannberger, L., Neff, J.C., Reijneveld, A., Mathijs, E., Chapot, P., Guerrini, S., Štyriaková, D., Kremers, J., Martin, P., Van Der Tol, R., Burgeon, V., Kalimeri, E., Van Eynde, E. 2025. Healthy soils as a booster to EU competitiveness. *Land Use Policy*, 158:107755. https://www.sciencedirect.com/science/article/pii/S0264837725002893

Van Eynde, E., Ros, G.H., Yunta, F., Muntwyler, A., Hinsinger, P., Fendrich, A.N., Panagos, P., 2025. Opportunities for optimizing phosphorus inputs in EU agricultural soils. *Environmental Science & Policy*, 171: 104168. https://www.sciencedirect.com/science/article/pii/S1462901125001844

Panagos, P., Jones, A., Lugato, E., Ballabio, C., 2025. A Soil Monitoring Law for Europe. *Global Challenges*, *9*(3): 2400336. https://onlinelibrary.wiley.com/doi/full/10.1002/gch2.202400336

Michailidis, V., Lugato, E., Panagos, P., Grados, D., Freund, F., Jones, A., Abalos, D., 2025. How do diet shifts affect the greenhouse gas balance of agricultural soils? Denmark as a case study. *Agricultural Systems*, *224*: 104263. https://www.sciencedirect.com/science/article/pii/S0308521X25000034

Schillaci, C., Scarpa, S., Yunta, F., Lipani, A., Visconti, F., Szatmári, G., Balog, K., Koganti, T., Greve, M., Bondi, G. and Kargas, G., Panagos, P., Montanarella, L., Jones., A. 2025. Empirical estimation of saturated soil-paste electrical conductivity in the EU using pedotransfer functions and Quantile Regression Forests: A mapping approach based on LUCAS topsoil data. *Geoderma*, *454*: 117199. https://www.sciencedirect.com/science/article/pii/S0016706125000370

Yunta, F., Schillaci, C., Panagos, P., Van Eynde, E., Wojda, P., Jones, A., 2025. Quantitative analysis of the compliance of EU Sewage Sludge Directive by using the heavy metal concentrations from LUCAS topsoil database. *Environmental Science and Pollution Research*, *32*(28):16554-16569. https://link.springer.com/article/10.1007/s11356-024-31835-y

Arias-Navarro, C., Vidojević, D., Zdruli, P., Yunta Mezquita, F., Jones, A., Wojda, P., 2025. Addressing point source soil pollution in the Western Balkans: challenges and opportunities for European Union integration. *Integrated Environmental Assessment and Management*, p.vjaf104. https://academic.oup.com/ieam/advance-article/doi/10.1093/inteam/vjaf104/8222732

Zacharoudi, S., Fendrich, A., Cescatti, A., Spyroglou, G., Fotelli, M., Radoglou, K., Panagos, P., 2025. Monitoring and Modelling Soil Respiration in Deciduous and Broadleaf Evergreen Oak-Dominated Ecosystems in Greece. *European Journal of Soil Science*, *76*(6): e70254. https://bsssjournals.onlinelibrary.wiley.com/doi/full/10.1111/ejss.70254

von Jeetze, P., Weindl, I., Johnson, J.A., Borrelli, P., Panagos, P., Meyer, T., Humpenöder, F., Sauer, P., Dietrich, J.P., Lotze-Campen, H. and Popp, A., 2025. Conservation outcomes of dietary transitions across different values of nature. *Nature Sustainability*, 8: 1130-1142. https://www.nature.com/articles/s41893-025-01595-9

Borrelli, P., Matthews, F., Saggau, P., Manzaneda, A.J., Panagos, P., Kaffas, K., Alewell, C., 2025. Unsustainably losing ground. *Nature Sustainability*, *8*(9): 986-989. https://www.nature.com/articles/s41893-025-01628-3

Zhang, N., Lv, C., Li, Y., Panagos, P., Ballabio, C., Man, J., Gu, X., Zhao, F.J., Wang, P., Liu, X. and Qian, Y., 2025. Geochemical-integrated machine learning approach predicts the distribution of cadmium speciation in European and Chinese topsoils. *Communications Earth & Environment*, *6*(1): 548. https://www.nature.com/articles/s43247-025-02516-6

Borrelli, P., Matthews, F., Alewell, C., Kaffas, K., Poesen, J., Saggau, P., Prăvălie, R., Vanmaercke, M., Panagos, P., 2025. A hybrid in situ and on-screen survey to monitor gully erosion across the European Union. *Scientific Data*, *12*(1): 755. https://www.nature.com/articles/s41597-025-05074-w

Lebron, I., Feeney, C.J., Reinsch, S., Shokri, N., Afshar, M.H., Lofts, S., Griffiths, R., Fidler, D., Jones, B., Panagos, P., Sawicka, K., Keith, A., Seaton F., Robinson, D. 2025. Patterns and thresholds for soil pH across Europe in

relation to soil health and degradation. *Catena*, 260: 109454. https://www.sciencedirect.com/science/article/pii/S0341816225007568

Wang, H., Ciais, P., Yang, H., Smith, P., Grassi, G., Schwingshackl, C., Panagos, P., Bar-On, Y., Sitch, S., Chevallier, F. and Palmer, P.I., 2025. Land use-induced soil carbon loss in the dry tropics nearly offsets gains in northern lands. *Nature Communications*, *16*(1): 10008. https://www.nature.com/articles/s41467-025-64929-3

Shokri, N., Robinson, D.A., Afshar, M., Alewell, C., Aminzadeh, M., Arthur, E., Broothaerts, N., Campbell, G.A., Eklund, L., Gupta, S. harper, R., Hassani, A., Hohenegger, C., Keller, T, Kiener, M., Lebron, I., Madani, K., Marwala, T., Matthews, F., Moldrup, P., Nemes, A., Panagos, P., Prăvălie, R., Rillig, M., Saggau, P., Shokri-Kuehni, S., Smith, P., Thomas, A., Wollesen de Jonge, L., Or, D. 2025. Rethinking global soil degradation: Drivers, impacts, and solutions. *Reviews of geophysics*, *63*(4): e2025RG000883. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2025RG000883

Deng, R., Li, D., Zhao, Y., Walling, D.E., Panagos, P., Borrelli, P., Ciais, P., Huang, Y., Bai, Y., Chalov, S. and Golosov, V.N., 2025. Intensified rainfall overrides vegetation greening in driving erosion and carbon loss on the Tibetan Plateau. *Science bulletin*, *70*(22): 3698-3702. https://www.sciencedirect.com/science/article/pii/S2095927325009181

Hateffard, F., Gumbricht, T., Ranhem, T., Breure, T., Panagos, P. and Hugelius, G., 2025. Predicting Soil Properties Using Spectral Subsets of LUCAS Visible Near-Infrared Spectroscopy Data. *European Journal of Soil Science*, *76*(6): e70242. https://bsssjournals.onlinelibrary.wiley.com/doi/full/10.1111/ejss.70242

Reinsch, S., Lebron, I., de Jonge, L.W., Weber, P.L., Norgaard, T., Arthur, E., Gomes, L., Pesch, C., Konstantinos, K., Zalidis, G. Epelde, L., Romic, M., Romic, D., Zovko, M., Reljic, M., Heikkinen, J., Feeney, C., Bentley, L., Levy, P., Vanguelova, E., Panagos, P., Schneider, F., Bernhard, A., Leifeld, J., Hugelius, G., Bridget, E., Brentegani, M., Tandy, S., Thomas, A., van Soest, M., Robinson, D. 2025. The Fraction of Carbon in Soil Organic Matter as a National-Scale Soil Process Indicator. *Global Change Biology*, 31(11): e70572. https://onlinelibrary.wiley.com/doi/10.1111/gcb.70572

Matthews, F., Borrelli, P., Panagos, P., Bezak, N., 2025. Dynamic assessment of rainfall erosivity in Europe: evaluation of EURADCLIM ground-radar data. *Hydrology and Earth System Sciences*, *2025*, 29(20): 5299-5313. https://hess.copernicus.org/articles/29/5299/2025/

Cao, B., Yu, L., Li, W., Ciais, P., Panagos, P., Borrelli, P., Naipal, V., Wei, W., Jiao, Y., Xie, Y. and Fu, B., 2025. Terracing can reduce cropland water erosion in China by over 50% at present and under future climate change. *One Earth*, *8*(10): 101490. https://www.cell.com/one-earth/fulltext/S2590-3322(25)00316-1

Afshar, M.H., Hassani, A., Aminzadeh, M., Borrelli, P., Panagos, P., Robinson, D.A., Or, D. and Shokri, N., 2025. Spatial and temporal assessment of soil degradation risk in Europe. *Scientific Reports:* 15(1): 44636. https://www.nature.com/articles/s41598-025-33318-7

Zhang, Z., Gao, H., Gao, X., Huang, S., Niu, S., Lugato, E. and Xia, X., 2025. Short-term warming supports mineral-associated carbon accrual in abandoned croplands. *Nature Communications*, *16*(1): 344. https://www.nature.com/articles/s41467-024-55765-y

Siles, J.A., Vera, A., Labouyrie, M., van den Hoogen, J., Crowther, T.W., Romero, F., Tedersoo, L., García, C., Jones, A., Panagos, P., Orgiazzi, A., van Der Heijden, M.G., 2025. Land Use Interacts With Climate to Influence Microbial Diversity-To-Biomass Ratios Across Europe via Soil Organic Carbon and Nitrogen. *Molecular Ecology*, 24(20): e17806. https://onlinelibrary.wiley.com/doi/full/10.1111/mec.17806

Li, Y., Panagos, P., Yunta F. and Zhang, C., 2025. Warming could cause significant soil organic carbon loss around the southern Baltic Sea. *Journal of Environmental Management*, 391: 126488. https://www.sciencedirect.com/science/article/pii/S0301479725024648

Matthews, F., Panagos, P., Fendrich, A., Verstraeten, G., 2025. Testing a low-complexity spatially distributed model to simulate the intra-annual dynamics of soil erosion and sediment delivery. *Catena*, *257*: 109054. https://www.sciencedirect.com/science/article/pii/S034181622500356X

Gupta, S., Scheper, S., Borrelli, P., Panagos, P. and Alewell, C., 2025. Soil Erosion as a Driver of Eutrophication: An Analysis of European Lakes Using Sentinel-2 Satellite Data. *Global Change Biology*, *31*(9): e70494. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.70494

Haregeweyn, N., Tsunekawa, A., Fenta, A.A., Borrelli, P., Panagos, P., Aynekulu, E., Abe, T., Pablo, P. and West, S., 2025. A Transdisciplinary Framework to Bridge Science–Policy–Development Gaps in Global Land Management Initiatives. *Global Challenges*, *9*(8): 2400261. https://onlinelibrary.wiley.com/doi/full/10.1002/gch2.202400261

Campbell, G.A., Smith, P., Broothaerts, N., Panagos, P., Jones, A., Ballabio, C., De Rosa, D., De Jonge, L.W., Arthur, E., Gomes, L. Shokri, N., Robinson, D.A. 2025. Continental scale soil monitoring: A proposed multi-scale framing of soil quality. *European Journal of Soil Science*, *76*(4): e70174. https://bsssjournals.onlinelibrary.wiley.com/doi/full/10.1111/ejss.70174

Matthews, F., Medved, A., Borrelli, P., Liakos, L., Verstraeten, G., Panagos, P. and Bezak, N., 2025. Towards the development of bias-corrected rainfall erosivity time series for Europe. *Journal of Hydrology*, *651*, p.132460. https://www.sciencedirect.com/science/article/pii/S0022169424018560

Lutz, S., Mikryukov, V., Labouyrie, M., Bahram, M., Jones, A., Panagos, P., Delgado-Baquerizo, M., Maestre, F.T., Orgiazzi, A., Tedersoo, L. and van der Heijden, M.G., 2025. Global richness of arbuscular mycorrhizal fungi. *Fungal Ecology*, *74*: 101407. https://www.sciencedirect.com/science/article/pii/S1754504824000783

Zheng, H., Miao, C., Huntingford, C., Tarolli, P., Li, D., Panagos, P., Yue, Y., Borrelli, P. and Van Oost, K., 2025. The impacts of erosion on the carbon cycle. *Reviews of Geophysics*, *63*(1): e2023RG000829. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2023RG000829

Yoon, J.H., Jung, S.S., Kim, H.S., Park, Y., Kim, H., Mishra, U., Gautam, S., Alewell, C., Panagos, P., Kirkham, M.B. and Borrelli, P., 2025. Impact of soil erosion on soil organic carbon loss and its implications for carbon neutrality. *Advances in Agronomy*, *191*: 363-414. https://www.sciencedirect.com/science/chapter/bookseries/pii/S0065211325000203

Shirzadi, A., Shahabi, H., Rahimzad, M., Salvati, A., Jaafari, A., Kress, V., Panagos, P., 2025. Novel Deep Learning Algorithm in Soil Erodibility Factor Predicting at a Continental Scale. *International Soil and Water Conservation Research*, 2025. https://www.sciencedirect.com/science/article/pii/S2095633925001157

Alewell, C., Gupta, S., Poulenard, J., Niquille, N., Kaiser, A., Shokri, N., Scheper, S., Gross-Schmölders, M., Robinson, D.A., Campbell, G. and Kabala, C., Panagos, P., Borrelli, P. 2025. A first quantitative assessment of soil health at European scale considering soil genesis. *Journal of Plant Nutrition and Soil Science*, 2025. https://onlinelibrary.wiley.com/doi/full/10.1002/jpln.70034

Chen, Y., De Geeter, S., Poesen, J., Matthews, F., Campforts, B., Borrelli, P., Panagos, P., Vanmaercke, M., 2025. Global patterns of gully occurrence and their sensitivity to environmental changes. *International Soil and Water Conservation Research*, 2025. https://www.sciencedirect.com/science/article/pii/S209563392500111X

López i Losada, R., Hedlund, K., Haddaway, N.R., Sahlin, U., Jackson, L.E., Kätterer, T., Lugato, E., Jørgensen, H.B. and Isberg, P.E., 2025. Synergistic effects of multiple "good agricultural practices" for promoting organic carbon in soils: A systematic review of long-term experiments. *Ambio*, 54: 1715–1728. https://link.springer.com/article/10.1007/s13280-025-02188-8

Wu, M., Lugato, E., Li, P., Liu, J., Qiu, C., Wang, S., Ma, X., Hao, X., Liu, M., Shan, J. and Yan, X., 2025. Bacterial richness enhances the thermostability of soil organic matter via a long-term trade-off between molecular diversity and thermodynamic stability. *Nature Food*, 6: 1032–1041. https://www.nature.com/articles/s43016-025-01253-5

Georgiou, K., Angers, D., Champiny, R.E., Cotrufo, M.F., Craig, M.E., Doetterl, S., Grandy, A.S., Lavallee, J.M., Lin, Y., Lugato, E. and Poeplau, C., 2025. Soil carbon saturation: what do we really know?. *Global Change Biology*, *31*(5): e70197. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.70197

Galimberti, F., Bopp, S.K., Carletti, A., Catarino, R., Claverie, M., Florio, P., Ippolito, A., Jones, A., Marchetto, F., Olvedy, M. and Pistocchi, A., Vieira, D., D Adrimont, R. 2025. Development of a spatial risk indicator for monitoring residential pesticide exposure in agricultural areas. *Scientific Reports*, *15*(1), p.16785. https://www.nature.com/articles/s41598-025-96928-1

Mason, E., Cornu, S., Arrouays, D., Fantappiè, M., Jones, A., Götzinger, S., Spiegel, H., Oorts, K., Chartin, C., Borůvka, L. and Pihlap, E., 2025. Monitoring Systems of Agricultural Soils Across Europe Regarding the Upcoming European Soil Monitoring Law. *European Journal of Soil Science*, *76*(4): e70163. https://bsssjournals.onlinelibrary.wiley.com/doi/full/10.1111/ejss.70163

Del Duca, S., Tondini, E., Vitali, F., Lumini, E., Garlato, A., Vinci, I., Tagliaferri, E., Brenna, S., Motta, S., Maillet, E. and Bispo, A., Orgiazzi, A., Jones, A., Mocali, S. 2025. Comparison of LUCAS and Italian Sampling Procedures for Harmonising Physicochemical and Biological Soil Health Indicators. *European Journal of Soil Science*, *76*(3): e70108. https://bsssjournals.onlinelibrary.wiley.com/doi/full/10.1111/ejss.70108

Visca, A., Di Gregorio, L., Costanzo, M., Clagnan, E., Nolfi, L., Bernini, R., Orgiazzi, A., Jones, A., Vitali, F., Mocali, S. and Bevivino, A., 2025. Microbial bioindicators for monitoring the impact of emerging contaminants on soil health in the European framework. *Sustainability*, *17*(3), p.1093. https://www.mdpi.com/2071-1050/17/3/1093

Cogato, A. and Schillaci, C., 2025. "From data to fork" data-driven science inspired by policy initiatives for the promotion of smart agricultural technologies. *Smart Agricultural Technology*, 11: 100928. https://www.sciencedirect.com/science/article/pii/S2772375525001613

Wiersma, W., Van Eynde, E., Comans, R.N. and Groenenberg, J.E., 2025. Quantifying the Accuracy, Uncertainty, and Sensitivity of Soil Geochemical Multisurface Models. *Environmental Science & Technology*, *59*(10), pp.5172-5181. https://pubs.acs.org/doi/10.1021/acs.est.4c04812

Zhu, L., Ciais, P., Yao, Y., Goll, D., Luyssaert, S., Martínez Cano, I., Fendrich, A.N, Li, L., Yang, H., Saatchi, S. and Li, W., 2025. Spatially varying parameters improve carbon cycle modeling in the Amazon rainforest with ORCHIDEE r8849. *Geoscientific Model Development*, *18*(15): 4915-4933. https://gmd.copernicus.org/articles/18/4915/2025.

Pellegrini, A., Certini, G., García-Carmona, M. Sánchez-García, C., 2025. A bottom-up perspective on how fire changes ecosystem biogeochemistry via plant-soil interactions. *Plant Soil* 517, 1–9. https://doi.org/10.1007/s11104-025-08031-z

Doerr, S.H., Girona-García, A., Sánchez-García, C., Badía-Villas, D., Bryant, R., Dickinson, M.B., Hsieh, R., Mataix-Solera, J., Miesel, J.R., Robichaud, P.R., Stoof, C.R., Santín, C., 2025. Soil heating during wildfires and prescribed burns: a global evaluation. *International Journal of Wildland Fire* 34, WF25103. https://doi.org/10.1071/WF25103

Bahram M., Lehtovirta-Morley L., Mikryukov V., Sveen T.R., Grant A., Pent M., Hildebrand F., Labouyrie M., Koeninger J., Tedersoo L., Jones A., Panagos P., Orgiazzi A. 2025. Intensive land use enhances soil ammonia-oxidising archaea at a continental scale. *Soil Biology and Biochemistry*, Volume 213, 2026, 110024, ISSN 0038-0717. https://doi.org/10.1016/j.soilbio.2025.110024

Romero, F., Labouyrie, M., Orgiazzi, A., Ballabio C., Panagos P., Jones A., Tedersoo L., Bahram M., Eisenhauer N., Sue.nnemann M., Guerra C., Tao D., Jiao S., Mocali S., Rillig M., Lehmann A., Delgado-Baquerizo M., van der Heijden M. 2025. The soil microbiome as an indicator of ecosystem multifunctionality in European soils. *Nature Communications* 17, 705. https://doi.org/10.1038/s41467-025-67353-9

Köninger, J., Beule, L., Tsiafouli, M., Seeber, J., Blasbichler, H., Sousa, J. P., da Silva, P. M., Frouz, J., Hedlund, K., Orgiazzi, A., Iglesias Briones, M. J., & Potapov, A. (2025). Molecular and morphological identification

methods show contrasting trends in soil fauna diversity along land-use intensity gradients. *Applied Soil Ecology*, 106499. https://doi.org/10.1016/j.apsoil.2025.106499

Box 2. JRC technical reports authored by the EUSO in 2025. EUSO team members are underlined.

Broothaerts, N., Breure, T., Belitrandi, D., Havenga, C., Peeters, B., Probst, C., Barbero, M., Panagos, P., Jones, A., 2025. EU Soil Strategy Actions Tracker, Publications Office of the European Union, Luxembourg, https://data.eu-ropa.eu/doi/10.2760/9506344

Broothaerts, N., Panagos, P., Arias Navarro, C., Ballabio, C., Belitrandi, D., Breure, T., De Medici, D., Fendrich, A., Havenga, C., Liakos, L., Martin Jimenez, J., Michailidis, V., Orgiazzi, A., Scarpa, S., Schillaci, C., Vieira, D., van Eynde, E., van Liedekerke, M., Wojda, P., Yunta, F., Jones, A., 2025. EUSO annual report 2024, Publications Office of the European Union, Luxembourg, https://data.europa.eu/doi/10.2760/9304175

Belis, C.A., Petrosian, A., Turos, O., Maremuhka, T., Morhulova, V., Kona, A., Djatkov, D., Caudullo, G., Ceccherini, G., Beck, P.S.A., San-Miguel, J., Arias Navarro, C., Wojda, P., Jones, A., Hanke, G., Mariani, G. and Carravieri, A., 2025. Status of Environment and Climate in Ukraine, Publications Office of the European Union, Luxembourg, https://data.europa.eu/doi/10.2760/6292177

Yunta, F., Vieira, D., van Eynde, E., Jones, A., Bopp, S., ..., Wojda, P., 2025. Harmonizing soil pollution data and knowledge in Europe: a collaborative effort towards achieving healthy soils by 2050, Publications Office of the European Union, Luxembourg, https://data.europa.eu/doi/10.2760/440283

Yunta Mezquita, F., Bartnicka, J., Carvalho, R., Rodriguez Rasero, F., Dyba, T., Randi, G., Panagos, P., Wojda, P., Jones, A., 2025. SOLACE - Understanding the links between SOiL pollution and CancEr, Publications Office of the European Union, Luxembourg, https://data.europa.eu/doi/10.2760/2697480

Arias-Navarro, C., Vidojević, D., Zdruli, P., Islamaj, B., Scarpa, S., Yunta, F., Wojda, P., Jones, A. (2025). LUCAS Topsoil Survey for the Western Balkans: Presentation of the dataset and results - Presentation of the dataset and results, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/9105095

Wolf, M.-A., Ferrara, N., Damiani, M., Yunta, F. and Garcia Herrero, L., Environmental Footprint Initiative - Agricultural Working Group Milestone 4 - Life Cycle Inventory: modelling of water use, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/8169424.

Wolf, M.-A., Horn, R., De Laurentiis, V., Yunta, F. and Garcia Herrero, L., Environmental Footprint Initiative - Agricultural Working Group Milestone 7 - Cross-cutting issues and additional points, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/5836380.

Wolf, M.-A., Thylmann, D., De Weert, L., Salim, I., Bosco, S. Boschiero, M., Yunta, F., Garcia Herrero, L. (2025). Environmental Footprint Initiative - Agricultural Working Group Milestone 2 - Life Cycle Inventory: modelling of fertilisers, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/7525339

Marsden, M., Bouxin, A., Boschiero, M., Bosco, S., Mendez Batan, S. Wolf, M.-A, Yunta F, Garcia-Herrero, L. (2025). Environmental Footprint Initiative - Agricultural Working Group Milestone 3 - Land based farmed animals - flows/direct emissions related to feed digestion and manure management at the facility, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/8262135

Box 3. Science for policy reports, (co)-authored by the EUSO in 2025.

Marelli, L., Trane, M., Barbero Vignola, G., Gastaldi, C., Guerreiro Miguel, M. et al., 2025. Delivering the EU Green Deal – Progress towards targets, Publications Office of the European Union, https://data.europa.eu/doi/10.2760/3105205

In 2025, the EUSO made significant contributions to, or took the lead in, specific research projects. These research projects are listed below:

— **African Soil Health Project (AFSOH)**: The AFSOH project, which started in October 2024, has progressed in three lines during 2025. The first line concerns a scientific paper proposing the definition of regions with similar combinations of threats to soil health, finalized and submitted in October 2025. The second line is a paper investigating the impacts of implementing soil health policy in Africa on the global economy, which was finalized and submitted in March 2026. The two works were developed in partnership with researchers from the African Union Soil Observatory (AUSO), a Horizon-funded project that brings together African and European partners. The AUSO project was officially launched in October 2025, with a kick-off meeting held in Nairobi (Kenya), featuring a presentation by the EUSO team (see section 2.6.6.5). The third line of work in AFSOH concerns the development of an interactive soil health dashboard to be included in the future version of EUSO's Soil Health Dashboards. The AFSOH dashboard compiles global and local datasets of threats to soil health and presents other relevant information to assist policymakers. The AFSOH dashboard is expected to be launched in 2026.

— **Collaborative Doctoral Partnership** (CDP): The CDP is an initiative of the JRC to establish strategic collaboration with higher education institutes that grant doctoral degrees. In 2025, EUSO hosted and mentored the following doctoral candidates in the context of the CDP:

  - Vasilis Michailidis successfully finished the collaborative doctoral training programme and obtained the doctoral degree in November 2025 at Aarhus University, Denmark. The PhD thesis was entitled ‘Assessing the soil GHG balance of demand-driven dietary shifts across Europe: emission trade-offs and mitigation strategies’.

  - Collin Van Rooij currently works on a PhD project entitled ‘Peatland mapping on national and European scales’, a collaboration between the JRC and Aarhus university, Denmark.

2.5.2. Collaborations with Mission Soil funded projects

The Mission Soil aims to establish 100 Living Labs and Lighthouses to co-create, test and pioneer innovations for soil health, next to advancing the knowledge on healthy soils. The projects funded under the Mission Soil are available at the project hub of the Mission Soil Platform.

The EUSO is actively involved in and responsible for the soil monitoring elements of the Mission Soil and contributes to the mission annual work programme. The EUSO is also beneficiary of the research activities in the Mission Soil funded projects and works in close collaboration with most of these projects.

Collaboration between Mission Soil funded projects is structured within Mission Soil Clusters. The EUSO is part of the coordination group of three of these clusters:

— **Mission Soil Cluster on Indicators and Monitoring**. This Cluster focusses on indicator frameworks and soil monitoring at different scales. The Cluster aims to (i) improve indicators of the Mission Implementation Plan and further develop descriptors in the SMRD, (ii) provide orientation to other projects regarding indicators and monitoring, and (iii) elaborate a roadmap for the development of indicators and soil monitoring. In 2025, one online cluster meeting took place, as well as an in-presence training for living labs. This Mission Soil Living Labs Indicator Training, held on 15-17 September 2025 in Vitoria-Gasteiz, Spain, was developed in response to a concrete need identified by Mission Soil Living Labs: the practical guidance on selecting relevant soil health indicators tailored to local contexts and land-use systems. Many practitioners working on the ground face challenges in choosing indicators that are meaningful, measurable, and aligned with both local objectives and broader monitoring frameworks. The event was jointly organised by BENCHMARKS and AI4SoilHealth with the valued contribution of NEIKER, the EUSO, and the Mission Soil Platform. It also played a key role in connecting local action with broader European ambitions for healthier soils.

— **Mission Soil Cluster on Data and Knowledge Management**. This Cluster aims to achieve a better management of research data and knowledge related to soil. More precisely, it aims to deliver more structured research data management and templates for metadata for outcomes of Mission Soil funded projects. In 2025, one online cluster meetings took place, as well as an in-presence meeting. The online meeting took place in September and focused on ongoing SoilWise Catalogue developments, exchanging updates, and preparing the ground for the next in-person workshop. The in-person meeting, in December 2025, focused on four specific topics: (1) Metadata template, (2) Vocabularies and glossaries, (3) How to populate the SoilWise catalogue with data and knowledge items, and (4) Soil knowledge management.

— **Mission Soil Cluster on Soil Pollution and Remediation.** This cluster brings together EU Mission Soil-funded projects and related initiatives working on the complex challenge of soil contamination and remediation. The cluster serves as a collaborative platform where projects can explore these challenges together. By connecting researchers and practitioners working on contamination monitoring, risk assessment, and remediation across Europe, the cluster helps align efforts, identify good practices, and support evidence-based policymaking. The cluster was launched in June 2025.

Next to the interaction within the Mission Soil Clusters, the EUSO has worked in 2025 in close collaboration with some of the Mission Soil funded project on more specific topics. Some of these collaborations and the resulted outcomes are highlighted below, this list is however not exhaustive.

— AI4SoilHealth

- Signature of a collaboration agreement between AI4SoilHealth and JRC. The collaboration includes: (i) collaborating on the development and validation of indicators for soil health, (ii) the EUSO will be the scientific beneficiary of the project, which implies that the project deliverables (e.g. data, knowledge and indicators) will be delivered to the EUSO, (iii) building capacity for policy support in soil related EU policies.

- EUSO participated in a key publication of AI4SoilHealth on land degradation: Rethinking Global Soil Degradation: Drivers, Impacts, and Solutions. Soil degradation is a growing problem that threatens soil and food security, ecosystem functioning, and socio-economic activities. The article in Reviews of Geophysics looks at how soil degradation is defined and measured, the causes behind it, and how it affects people and the environment. It also explores new tools like satellite data, artificial intelligence, and big data analytics that could help us better detect and predict soil degradation. The study highlights how protecting soil health is essential to achieving UN Sustainable Development Goals. It calls for better ways to measure soil health and smarter strategies to manage land in a sustainable way.

- Continental scale soil monitoring: Selecting appropriate soil indicators across Europe is challenging due to diverse climate, topography, geology, and soil types. Therefore, establishing clear principles and criteria for soil indicator selection is essential. Thanks to a fruitful collaboration between the EUSO and AI4SoilHealth, four distinct frameworks for soil quality assessment were identified and described: 'Fitness for Purpose', 'Free from Degradation', 'External Benchmarking' and 'Value Assessment', with each possessing a unique role and application. The 'Free from Degradation' framework is particularly suitable for pan-European assessments as conducted in the EUSO Soil Degradation Dashboard. This work is published in a scientific publication.

- AI4SoilHealth and EUSO have collaborated and published the paper A First Quantitative Assessment of Soil Health at European Scale Considering Soil Genesis. In this paper, we introduce SHERPA (Soil Health Evaluation, Rating Protocol, and Assessment) as a framework for discussion and present a first quantitative soil health assessment across Europe.

- AI4SoilHealth and EUSO have collaborated and published the paper Spatial and temporal assessment of soil degradation risk in Europe. Using over 38,000 LUCAS topsoil observations and a machine learning model trained on climate, land cover, topographic, soil parent material properties, and spectral variables, we map annual SDP values between years 2000 to 2022 across Europe. Results show soil degradation risk is highest in southern Europe, especially in intensively managed and sparsely vegetated landscapes.

- AI4SoilHealth and EUSO have collaborated and published the paper Soil Erosion as a Driver of Eutrophication: An Analysis of European Lakes Using Sentinel-2 Satellite Data. This study examines the impact of soil erosion on eutrophication, considering other covariates such as slope, elevation, phosphorus, nitrogen, flow accumulation and temperature, by analyzing zones of varying sizes around lakes in six different countries of Europe covering an area of 1596 km2: Austria (81 lakes), France (310), Germany (266), Hungary (73), Poland (465), and the United Kingdom (316).

- AI4SoilHealth and EUSO have collaborated and published the paper Patterns and thresholds for soil pH across Europe in relation to soil health and degradation. In this research we analysed the European topsoil pH data (LUCAS) in combination with other soil properties from the LUCAS survey, to identify thresholds and spatial patterns of soil pH across Europe in relation to soil health and degradation.

- AI4SoilHealth and EUSO have collaborated and published the paper The Fraction of Carbon in Soil Organic Matter as a National-Scale Soil Process Indicator. In this paper, we show an intriguingly tight relationship between the fraction of SOC in SOM, habitat and soil physical properties, as well as SOC stored in POM and MAOM. This opens new ways to predict spatial variations in the distribution of POC and MAOC using more widely available fraction data as a covariate.

- AI4SoilHealth and EUSO have collaborated and published the paper Predicting Soil Properties Using Spectral Subsets of LUCAS Visible Near-Infrared Spectroscopy Data. This study explores the predictive potential of selected spectral subsets from the full visible and near-infrared (VIS–NIR) range, using various machine learning algorithms (MLAs), as a theoretical exercise to support the design of practical soil sensing tools.

- On 2-3 October 2025, the EUSO hosted a delegation of Ai4SoilHealth to develop a roadmap and enhance collaboration in utilizing soil health information through AI technology, in relation to the project's deliverables and in support of the Mission Soil and the EUSO. Discussions focused on indicators for soil degradation, erosion, soil biodiversity, soil organic carbon, water retention, porosity, salinity, and spectroscopy.

— BENCHMARKS

- A key contribution towards standardised soil health monitoring in Europe has been achieved with the release of three comprehensive soil sampling protocols developed under the Mission Soil-funded project BENCHMARKS. The protocols, tailored to urban, agricultural and forest land uses, are being used to update the protocols of the LUCAS Soil Module in line with the needs of the SMRD.

— BENCHMARKS and AI4SoilHealth and the EUSO co-organised the Mission Soil Living Lab Indicator Training Course (15-17 September 2025). Living Labs from across Europe came together to share their unique contexts and co-develop monitoring plans tailored to landscapes, soil types, and challenges. The Living Labs were trained in soil health monitoring and management specific to their context.

— SOIL O-LIVE

- Co-author of a scientific article in Nature Sustainability "Unsustainably losing ground". The article presents how Mediterranean olive groves – symbols of culture, tradition, and livelihoods – are increasingly threatened by unsustainable soil loss. The pronounced climatic sensitivity of olive groves, combined with the complexity of the interactions among land, atmosphere, water and human systems, positions these ecosystems as a highly policy-relevant case study.

- Signature of the collaboration agreement between SOIL O-LIVE and JRC. The collaboration includes: (i) developing models and data for monitoring soil health in olive plantations; (ii) transferring project data, knowledge and indicators to the EUSO; (iii) building capacity for policy support in soil-related EU policies and (iv) scientific synergies as joint publications, workshops, seminars and exchange of data and knowledge.

— ECHO

- The EUSO and ECHO Developed a first database on citizen-science projects related to soil health. Such citizen science projects have gained significant interest driven by the prominence of soil within public policy agendas. The database includes initiatives and projects on citizen science, engaging citizens to monitor soil.

- The EUSO and ECHO co-drafted the report: A review of existing tools for citizen science research on soil health. In this work, over 60 citizen science projects on soil health were reviewed. Citizen science projects were collected based on literature review, expert interviews, suggestions from project partners and suggestions from the European Network for Soil Awareness (ENSA) and the EUSO stakeholders. All projects were screened regarding geographic coverage, duration, scientific factors (e.g. soil properties considered, fieldwork), technological factors (e.g. applications used) and their citizen engagement (e.g. target groups). Two-thirds of the reviewed studies were based in Europe and mostly conducted at regional- or national scales. Main recommendation is to align the citizen science methodology with the desired level of participation. Also, a need was identified for the development of standardised, user-friendly and cost-effective methodologies to generate soil data.

— SoilWise

- Development of the SoilWise catalogue for data and knowledge sharing within the Mission Soil. The support provided by the EUSO to the SoilWise team is founded on 4 pillars that would allow the integration of the repository in the existing EUSO ecosystem and in future endeavors regarding soil science, as well as reflecting the values of the European Commission. These 4 pillars include (1) spotlight on the mission soil projects, (2) open access, (3) deliver an intuitive, user-friendly experience, and (4) integration with current EUSO ecosystem.

- Throughout the coordination meetings, following the abovementioned pillars, more than one hundred requirements were discussed and submitted to the project. The long list of requirements, once consolidated, can be grouped into categories that turned into fundamental requirements, which led to a roadmap highlighting the key points the project should follow, to guarantee a successful implementation of the repository. The categories include: (i) A Metadata template should be developed; (ii) Highlights and priority, but not exclusive, should be given to Mission Soil projects as data providers; (iii) Every part of the catalogue must be open source; (iv) Front end and back end are to be developed according to JRC indications. Frond end is also vital regarding to the implementation of the repository inside the EUSO environment; (v) A coherent manual, in plain language, should be developed; (vi) Besides automatic harvesting, manual metadata insertion should be made available; (vii) Integrating of the knowledge management part of the projects.

- On 29 April 2025, the EUSO participated in the first public demonstration event of the prototype of the SoilWise data catalogue. The meeting was an opportunity to present the data catalogue and to explain how it can provide links to the outcomes of Mission Soil projects. The EUSO is steering the developments and facilitating its eventual implementation within the EUSO platforms. The meeting was also an opportunity to describe use cases, addressing both a data/knowledge (re)user and a data/knowledge provider perspective. Support for data/knowledge persistence, quality measures, metadata, validations and licenses were also discussed.

— SoilWise, ISLANDR, EDAPHOS, ARAGORN, and BENCHMARKS

- Harmonizing soil pollution data and knowledge in Europe: a collaborative effort towards achieving healthy soils by 2050. This report addresses soil pollution in the EU, supporting the implementation of the SMRD and Zero Pollution Action Plan. This document presents the outcomes of workshop with several Mission Soil projects on soil pollution, including SoilWise, ISLANDR, EDAPHOS, ARAGORN, and BENCHMARKS. The report provides a comprehensive approach to harmonisation and standardisation of soil pollution data, essential for effective policymaking and decision-support. The report also provides information on the development of new policy measures, such as the SMRD. This report hopes to serve ongoing and future Mission Soil projects with data harmonisation for a higher dissemination and policy impact.

— ISLANDR

- On 23-24 January 2025, the EUSO hosted the Mission Soil project ISLANDR. On the first day, scientists from BRGM Deltares Centre for Research & Technology Hellas evaluated a new spatial data interpolation algorithm on soil pollution data from the LUCAS Soil Module. The objective of this algorithm is to facilitate the detection of soil pollutant concentration anomalies (hot spots) to prioritise remedial action. During the second day of the visit additional ISLANDR colleagues attended the meeting, from the Geological Survey of Finland and the Finnish Environment Institute, to discuss the ISLANDR metadata catalogue dedicated to local and diffuse soil contamination in Europe.

— SOLO

- EUSO staff members contributed to the SOLO's preliminary assessments on the knowledge gaps, including Outlook on the knowledge gaps to reduce soil erosion; Outlook on the knowledge gaps to improve nature conservation of soil biodiversity; Outlook on the knowledge gaps the EU global footprint on soils; and Outlook on the knowledge gaps to reduce land degradation in Europe.

— SoilValues

- SoilValues participated in and provided keynote speech at the 5th EUSO Stakeholder Forum on "How can healthy soils increase EU competitiveness?". Moreover, the Mission Soil project contributed to the joint study on Healthy soils as a booster to EU competitiveness. The study presents soil health related business models addressing most of the challenges posed by soil degradation, climate change, and biodiversity loss, while promoting sustainable agriculture practices and improving ecosystem functioning.

— SOB4ES

- Co-analysing soil spectra from LUCAS Soil Survey 2018 and developing correlations with soil biodiversity indicators.
- SOB4ES supported the EUSO in the preparations of the European Soil Biodiversity Monitoring Symposium (February 2026, see also section 3.5).

— MARVIC – MRV4SOC

- Workshops on the development of “Baseline approaches for monitoring soil carbon removals” and intercomparison of models to improve the European baseline for carbon removals. Co-organised a session at the 2nd Carbon Farming Summit. This session reflected on the different options to calculate standardised baselines and to reflect on what the public sector can provide and what private sectors need related to their experiences in practice. Through open dialogue, the session aimed to identify differences in EUSO’s methodologies, and to find collaborative solutions. Additionally, this session highlighted the importance of regional contexts and the role of pedo-climatic and regulatory circumstances in establishing accurate and reliable baselines. Main outputs from the session.

— CREDIBLE

- Support to the organization of the 2nd Carbon summit (Dublin, 2025).
- Contribution to the Credible Focus Group 3.4, with the outcomes of this collaboration published in the report "Unlocking data for MRV: Data sharing for effective carbon farming"

— MONALISA

- MONALISA has contributed to the development and update (2023) of Cover-Management (C-factor) doine by EUSO. This update is drafted in the data paper: A data-driven indicator for assessing the evolving impact of the EU Common Agricultural Policy on soil erosion mitigation. This developement included C-factor updates of C-factor using LANDUM model for 2000, 2010, 2016 and 2013 and are available in ESDAC.
- Development of a methodology for assessing desertification at EU scale (ongoing).

— SOILL

- EUSO staff has been a keynote speaker in the SOILL highlight event 'Shaping the Future of Soil Health Living Labs and Lighthouses in Europe'. This was a policy-oriented conference to connect EU-level expectations with on-the-ground evidence from the first and second waves of Mission Soil Living Labs.

— HuMus, Prepsoil, LOESS, SOLO, SOILTRIBES, SOILSCAPE, CURIOSOIL and ECHO participated actively in the Soil Literacy workshop 13-14 March 2025. The meeting was an opportunity to share and explore best practices from a range of diverse perspectives and targeted stakeholders, as well as reflections towards a future roadmap of possible actions (see section 2.6.4).

— LivingSoil, ECHO, AI4SoilHealth, EDAPHOS, SPIN-FERT, BENCHMARKS, SOILSCAPE, NBSOIL, SUS-SOIL, Sol O-live, SoilWise, Humus, and SOILRES presented their achievements and main scientific outputs during the 5th EUSO Stakeholder Forum “*Cutting edge developments with the EU Mission Soil*”, Seville during EUROSOIL2025 conference (see section 2.6.1.2).

— The EUSO gave presentations at kick-off meetings of Mission Soil projects, including NEMESIS, NITROSCOPE, EUROSION, MONALISA, AUSO, SoilRES, Lila4Soils, Tribes, and URSOILL.

2.5.3. Collaborations with other projects

The CUP4SOIL Project is a follow up to the European Space Agency's WORLDSOILS initiative to develop a series of potential Copernicus downstream services to support national and European institutions for reporting on soil health. The project was funded under the Framework Partnership Agreement on Copernicus User Uptake (FPCUP). The project is executed by DLR (the German Aerospace Center) and ISRIC (World Soil Information) with close cooperation with other EU soil related projects and initiatives (e.g. EJP SOIL, Soil Mission, ...). The EUSO was a member of the project's Advisory Board. The final project meeting was held on September 23, where EUSO representatives contributed to a panel discussion on the value of the outcomes from the project and provided a closing presentation on the role of earth observation in the Soil Monitoring Law and other soil-related EU policies. A highlight of the meeting was the launch of the SoilSuite Europe package – a set of remotely sensed derived soil products, together with use cases on MRV, modelling cropland SOC stocks, monitoring regenerative agriculture and the mapping of soil erosion. The SoilSuite products are based on Sentinel-2 data and include (i) soil reflectance composites, (ii) cover frequency of soils, and (iii) vegetation dynamics on a high spatial resolution (20 m). In addition, a series of physical soil parameters (e.g. texture, pH, total nitrogen, bulk density (oven dry), coarse fragments (volumetric) & soil inorganic carbon content, etc.) have been developed using digital soil modelling approaches. SoilSuite EO layers and SoilSuite digital soil mapping layers are available through the respective links. Data layers can be viewed through the ISRIC viewer

2.6. Supporting stakeholder interactions and soil literacy

2.6.1. EUSO Stakeholders Forum

The EUSO Stakeholders Forum is an annual event bringing together soil scientists, policy makers, regional and national representatives, land managers and interested citizens. It also aims to support citizen engagement and the drive towards a societal change in the perception of soils. The EUSO Stakeholders Forum of 2025 took place in three parts.

2.6.1.1. Part1: How healthy soils contribute to EU competitiveness

Part 1 was held online on 12 June 2025 and focused on the contribution of healthy soils to EU competitiveness (**Figure 17**). In this Forum, stakeholders presented and discussed a set of examples on how soil-related business models increase EU competitiveness. As the EU moves towards a more sustainable, resilient, and strategic future, soil health has evolved from being solely an environmental concern to a multifaceted issue with economic, climate, and geopolitical implications. Some highlights:

- Acceleration is needed, as the current progress in soil health and sustainability is not sufficient to meet the challenges posed by food security, climate change, soil degradation and biodiversity loss.
- Carbon farming is a business model with high economic potential (almost 13 billion euros), involving many actors, and potentially attractive for farmers, certificating authorities, auditors and the Soil Carbon Industry Alliance.
- Regenerative agriculture has the potential to transform the agricultural sector and to contribute to a more sustainable food system.

— Farmers' profit is very important. However, social benefits and sustainability also need to be addressed.

— Regarding biotechnology, microorganisms have the potential to produce a wide range of molecules with pharmaceutical applications.

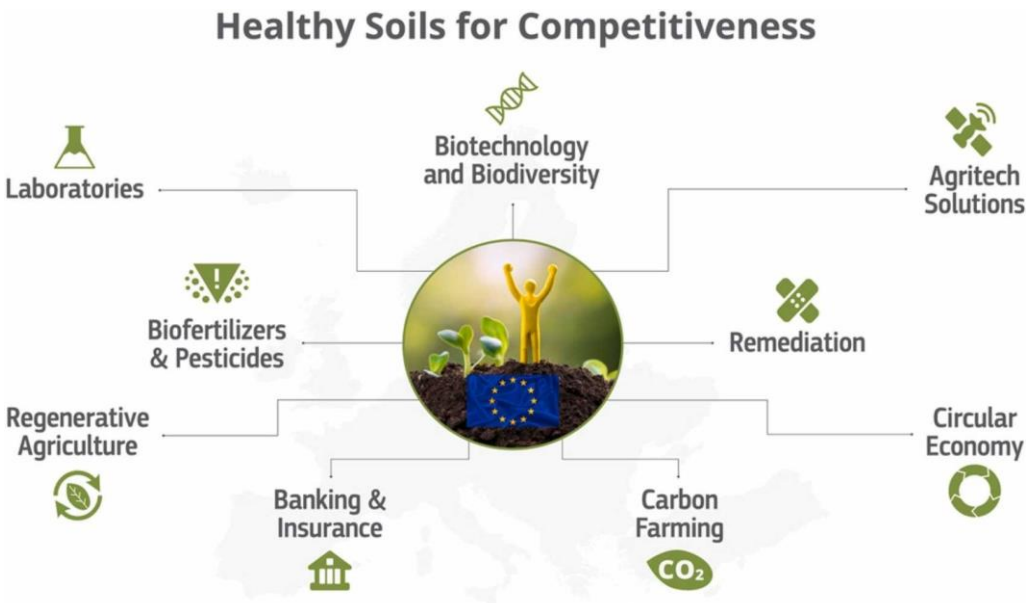
— A clear and simplified policy framework is essential for promoting sustainable agriculture practices and soil health.

— The banking sector should incentivise, with lower interest rates, farmers investing in soil health.

— Innovation, artificial intelligence, data analytics, and modelling approaches are essential for promoting sustainable agriculture practices and soil health.

With 590 registered subscribers and 440 colleagues attending various sessions, the event drew significant interest. Recordings and presentations are available on the EUSO website. Besides the event, the outputs have been summarised in an opinion paper ("Healthy soils as a booster to EU competitiveness" (Panagos et al., 2025)).

Figure 17. Part 1 of the EUSO Stakeholders Forum 2025, focussing on the contribution of healthy soils to EU competitiveness.



Source: Panagos et al. (2025).

2.6.1.2. Part 2: in-person meeting at the EUROSOIL Conference 2025

Part 2 was held in-person on 9 September 2025 in Seville, Spain, in conjunction with the EUROSOIL Conference 2025 (**Figure 18**). This part brought together Mission Soil projects to present and discuss cutting edge developments within the Mission Soil. The Forum hosted new developments from several Mission Soil projects, namely LivingSoiLL, ECHO, AI4SoilHealth, SPIN-FERT EU, EDAPHOS, BENCHMARKS, SOILSCAPE, NBSOIL, SUS-SOIL, Soil O-live, SoilWise, HuMUS and SOILRES. Presentations are available on the EUSO website.

Other milestones of the EUSO presence at the EUROSOIL Conference 2025 included:

— EUSO members gave a keynote and opening speech at the Conference, entitled 'Improving Soil Health in Europe: Emerging Challenges and Opportunities for Soil Science and Policy'.

— The EUSO had a prominent stand at the EUROSOIL Conference, where 200 soil atlases, 300 copies of The state of soils in Europe report, and 250 copies of the EUSO annual report 2024 were distributed.

— The EUSO chaired the session 'Soils at the Crossroads'.

— EUSO members took part of the panel discussion entitled 'Status of Soils Worldwide: State of the Art and Future Prospects'.

Figure 18. Part 2 of the EUSO Stakeholders Forum 2025, held in Seville during EUROSOIL 2025 conference.

Source: JRC.

2.6.1.3. Part 3: soils in the Mediterranean area

Part 3 was held in-person on 9 October 2025 in Rome Italy, focussing on challenges and solutions for soils in the Mediterranean area.

To reflect the increasing policy focus on the Mediterranean (see section 2.1.13), the third part of the Stakeholder Forum provided the opportunity to reflect on recent research to better quantify degradational processes and innovative solutions that focus on sustainability, resilience, and adapting to climate and landscape challenges. This was a hybrid workshop, in collaboration with the FAO. Participants had the opportunity to reflect on recent research to better quantify soil degradation and innovative solutions that focused on sustainability, resilience, and adapting to climate and landscape challenges. Presentations are available on the EUSO website.

2.6.2. European Mission Soil Week 2025

The European Mission Soil Week 2025 (EMSW) was held on 5-6 November 2025 in Aarhus, Denmark. The EMSW is an annual event aimed at promoting the Mission Soil, with many different stakeholders, raising awareness and triggering action. Stakeholders include researchers, policymakers, private sector, farmers and landowners. The 2025 edition was co-organised by

European Commission and the Danish Presidency. The event was followed by 300 participants in presence and 500+ participants online. This year, the EMSW focussed on new business and investment models for soil health, as well as on healthy soils as part of sustainable multifunctional landscapes. The first day focused on scaling soil health through new business and investment models. Highlighting the role of the Mission Soil in advancing sustainable land management and bringing together policymakers, researchers, practitioners, businesses, investors, and stakeholders committed to healthy soils. The second day focused on the role of healthy soils as part of sustainable multifunctional landscapes and highlighted Denmark as an inspirational example for the green transition through initiatives related to climate change mitigation, biodiversity and reduced environmental impact from agriculture, using the recent 'tripartite agreement' as a common thread. Deputy JRC.D Director and HoU of JRC.D.1 Greet Maenhout gave a keynote talk during the second day. The presentation highlighted the role of the EUSO and the JRC within the Mission Soil and presented the outcomes of the EUSO Stakeholders Forum on 'Healthy soils as a booster to EU competitiveness' (see section 2.6.1.1).

2.6.3. 2nd European Carbon Farming Summit

The second European Carbon Farming Summit took place on 4-6 March 2025 in Dublin, with more than 600 participants who joined both in presence and online. This remarkable turnout highlights the topic's significance and a broad community engagement. The event was relevant for scientists, both also for stakeholders from industry, policy and agribusiness.

The Summit aimed at strengthening the support for the development of robust carbon farming markets and policies. It provided a space for sharing knowledge and experience, up-scaling solutions and enabling the multiplication of climate action across the EU. The EUSO co-organised a session on standardised baselines and presented the framework for better modelling and monitoring soil organic carbon and carbon removals from agricultural soils and forestry.

Participants stressed the need for a harmonised approach in Europe to foster trust in carbon credits, given the disparate certification methods hindering a robust market. In addition, carbon farming extends beyond mere carbon sequestration. Carbon farming also drives the transition of agriculture towards resilience amidst climate change and biodiversity loss. Therefore, aspects related to climate adaptation and risk or reversal of carbon removals were discussed during the conference.

The summit was an important opportunity to disseminate the work of the JRC and get informed on recent developments in Earth observation and modelling that can serve the CRCF regulation (EU/2024/3012). The proposed solutions for the Standardised Baseline methodology for Carbon farming were well received by the stakeholders (researchers, private sector, farmers, agri-consultants, etc) and the policy makers.

2.6.4. Soil literacy workshop

On 13 and 14 March 2025, EUSO organised a full-immersion workshop on Soil Literacy. Several major players of this sector took part in the event, such as representatives of DG AGRI, UNESCO, FAO, EU-funded project partners (CURIOSOIL, SOILSCAPE, SOLO, ...), as well as industry agents, among others (**Figure 19**).

Both the EU Soil Strategy 2030 and the Mission Soil have increasing soil awareness as key objectives: in conjunction with the European Network on Soil Awareness, the workshop aimed to explore how the EU Soil Strategy and the Mission Soil can really drive a revolution in soil awareness by taking soil literacy and citizen engagement to a new level. The meeting was both an opportunity

to share and explore best practices from a range of diverse perspectives and targeted stakeholders, as well as reflections towards a future roadmap of possible actions.

On day 1, the EUSO kicked off the meeting highlighting the importance of soils and the rather scarce attention that is normally attributed to the matter: while included with topics such as curing cancer, ocean well-being and climate change in the group of Horizon Europe Missions, soil lacks the same visibility or consciousness. Political inaction reflects this lack of interest by society. Even now, after the Green Deal, policy documents still emerge with a focus only on air and water yet healthy soils underpin our very fabric. Though soils in Europe, as it emerged from the participants' presentations, are gaining momentum: in four years, the Horizon Europe Mission alone has already invested more in soil-related projects for a total of 435.5 million euro, that is 22% more than Horizon 2020 in 7 years. A virtuous example of that in the framework of Mission Soil are the Living Labs, a network of 100 Living Labs and Lighthouses in rural and urban areas to be created by 2030 to support the transition towards healthy soils.

On day 2, the presentations round continued, with a focus on best practices on how to raise awareness in a broader and differentiated audience. For instance, the CURIOSOIL project aims to awake soil curiosity and advance in soil literacy through collaborative efforts in education, by also establishing Communities of Practice: a tangible example of collaborative networks where people can experience soils first hand. Whereas Soils for Europe, or SOLO, aims to create a knowledge hub for soil health research and innovation that will last beyond the project's lifespan by establishing strategic partnerships and implementing a participatory process. At the conference's closing, it was regarded as a solid foundation to come forward and many of the participants involved expressed their wish for meeting again and expanding the stakeholder base.

Figure 19. Participants at the soil literacy workshop at the JRC.

Source: JRC.

2.6.5. EUSO Monthly Newsletter

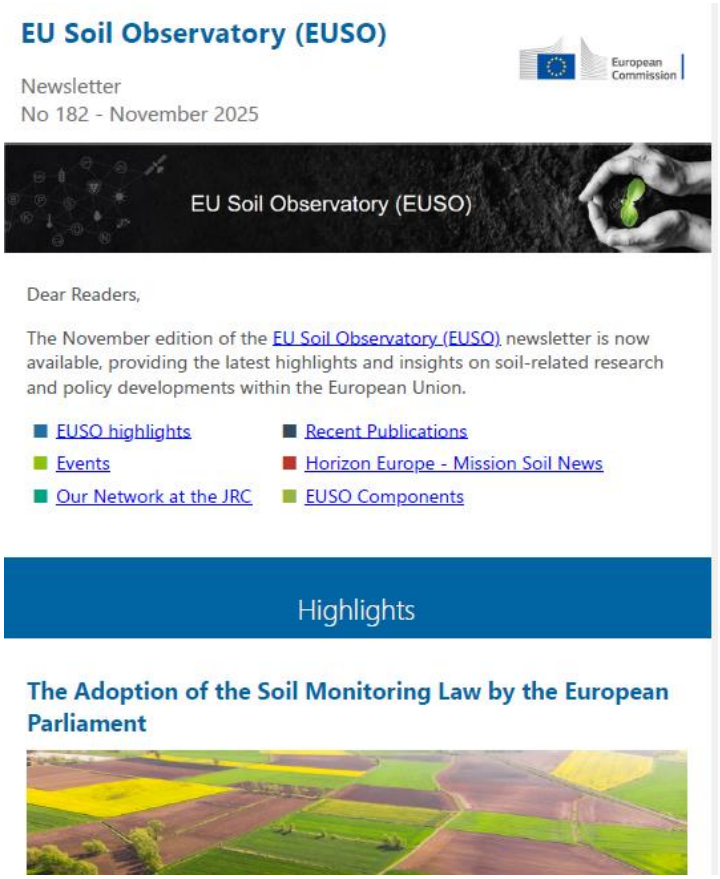
The EUSO publishes every month a newsletter highlighting new datasets, calls for data, publications, events and vacancies. The tradition of monthly newsletters of EUSO and ESDAC started in 2009. Since then, more than 180 newsletters have been sent. Currently, the newsletter has more than 13 000 subscribers, including stakeholders from academia, business and policy, as well as interested citizens.

In 2025, the newsletters were made according to the new JRC corporate style (**Figure 20**). This new formatted newsletter includes six main sections:

1. Highlights, including new datasets, calls for data and vacancies,
2. Recent publications, highlighting recent scientific papers (co-)authored by EUSO members,
3. Events, related to soil science, soil policy and soil literacy,
4. Mission Soil News, highlighting news from the Mission Soil and from Mission Soil projects,
5. EUSO's network at the JRC, providing links to newsletters and websites of EUSO's partners at the JRC, and
6. EUSO components, providing links to the webpages of the EUSO.

Archive of the newsletters and subscription form are available through the respective links.

Figure 20. Example of the EUSO monthly newsletter.



Source: JRC.

2.6.6. Other activities to support stakeholder interactions and citizen engagement

2.6.6.1. Participation at the event 'Shaping the Future of Soil Health: Living Labs and Lighthouses in Europe'

The Mission Soil Living Labs are driving bottom-up innovation for soil health. The Living Labs are fostering innovation, sustainable solutions, and management practices to restore and improve soil health. The EUSO participated, and delivered a keynote presentation, at the event: "Shaping the Future of Soil Health: Living Labs and Lighthouses in Europe" in Brussels on 3 December 2025. Key messages of the EUSO at the event included: (i) Living Labs can contribute to the EU's efforts to enhance soil monitoring and data collection by integrating their insights and management practices, (ii) Living Labs will generate new knowledge and data through a bottom-up mapping approach, directly supporting EU policies such as the SMRD, CRCF, and the Nature Restoration Law, and (iii) the EUSO promotes open access to soil-related data and is developing a comprehensive ESDAC to centralize and share knowledge across the continent.

2.6.6.2. 13th Global Soil Partnership Plenary Assembly

The Global Soil Partnership (GSP) is a mechanism, established in 2012, to position soils in the Global Agenda and to promote sustainable soil management. The Partnership, hosted by the UN Food and Agriculture Organization (FAO), works to improve soil governance to ensure healthy soils that deliver food security, climate change adaptation and mitigation, while meeting sustainable development goals. The Plenary Assembly is the decision-making body of the GSP. It embraces all the GSP partners in a yearly meeting to review and prioritize GSP actions while facilitating a balanced regional decision-making process.

The 13th Plenary Assembly was held in Rome from 3 to 5 June 2025. DG ENV and JRC represented the EU partner. The meeting was an opportunity to engage with FAO colleagues, together with representatives of the global soil science and policy community, many of which are long-term collaborators with the JRC.

Considering the forthcoming 80th anniversary of the founding of FAO, Alessandra Zampieri (Director of Directorate D of the JRC) participated in a high-level panel discussion within the formal opening. Her presentation focused on the close and strategic collaboration between FAO and the JRC on the topic of soil over the past 30 years, highlighting JRC's contribution to the Harmonised World Soil Database (a key layer in several global assessments) as well as the JRC's key role in the establishment, subsequent implementation, and ongoing work, of both the Global and European Soil Partnerships.

In parallel, EUSO members acted as the EU Delegate to the plenary, participated in a panel event on data and technology, and presented the work of the EUSO on assessing soil degradation and future developments in improving soil and land data information.

The meeting was an opportunity strengthened links with FAO, with high public awareness, while showcasing JRC's and EUSO's work to a global audience and learning from others. The work of the JRC and EUSO was highly visible and often referenced by other speakers. The EUSO is seen as a model for developing global systems on soil health.

The FAO GSP also co-hosted with the EUSO a workshop on soil issues in the Mediterranean as part of the 2025 EUSO Stakeholder Forum (see section 2.6.1.3).

2.6.6.3. SoilN-DATACUBE

On 3 and 4 April 2025, the workshop 'SoilN-DATACUBE: Bridging Soil Nitrogen Cycle GHG Emissions Modelling and LCA for Sustainable Agriculture' took place. Organised by the JRC, EUSO and the University of Basilicata, the workshop focused on topics at the crossroads between soil science and life cycle assessment (LCA): specifically, they aimed at exploring how the measurement and modelling of greenhouse gas (GHG) emissions from the soil nitrogen cycle can be integrated in the LCA of agricultural products, thus enhancing the overall environmental impact evaluation in agriculture.

Up until now, the GHG emissions from agricultural soils are in fact predominantly based on Tier 1 approaches. These tiers of data are based on the system used by the International Panel for Climate Change (IPCC) and are the standard reference for GHG emission assessment, with Tier 1 being larger modelled data with little or no local data available (lower quality) and Tier 3 being the highest quality.

During the workshop, the experts delved into the intricacies of IPCC Tier 2 and Tier 3 modelling approaches, and highlighted the importance of addressing data requirements, refining emission factors, and tackling the challenges of integrating complex process-based models and accounting for all nitrogen pathways.

The EUSO scientists contributed to the high-level discourse, underscoring the significant contribution of agriculture to GHG emissions and the challenges in quantifying non-CO_2 emissions, especially the spatially and temporally variable N_2O. The underlying idea is to use the outcomes of nitrogen modelling as input for a better life cycle assessment in the field of agriculture.

The relevance to policy could not be more apparent: with increasing regulatory pressures of the measures entailed in the EU's "Fit for 55" package — which aims to reduce GHG emissions by 55% by 2030 — the agricultural sector faces significant challenges. Particularly, during the workshop they explored the implications of the SMRD, the Common Agricultural Policy, and the CRCF. Compliance with these regulations requires accurate reporting of GHG emissions, particularly Scope 3 emissions associated with the supply chain.

2.6.6.4. A Soil Information System for Africa

Africa Soil Information System

On Monday 19 May 2025, the EU Horizon 2020 Soils4Africa project officially launched the continental Africa Soil Information System (SIS). The continental SIS was built based on an impressive effort of more than 1 500 people that were trained to visit more than 15 000 agricultural fields across the continent to collect field observations and soil samples. The EUSO was a full partner in the Project, supporting the development of the sampling framework and field protocols. In addition, the JRC developed a set of indicators relating to soil fertility based on the data contained in the SIS. To assure its sustainability and impact on the ground, the SIS was officially handed over to the African Union and the Forum for Agricultural Research in Africa (FARA).

Keynote speeches were given by Commissioner Moses Vilakati (Commissioner for Agriculture, Rural Development, Blue Economy, and Sustainable Environment) who was represented by Dr. Janet Edema (Acting Head of Agriculture & Food Security Division from the AUC), Prof. Eyasu Elias (State Minister of Agriculture in Ethiopia), Madam Bongiwe Njobe (Chair of the FARA board. A keynote was also addressed by the EUSO, outlining the development of LUCAS Soil and its role in providing unique characterisations of soil condition across the EU, and beyond. All speakers emphasized the

importance of the SIS to support sustainable agriculture, food and nutritional security as well as soil health in Africa: priorities embedded in the EU-AU partnership and AU policies (Agenda 2063, Nairobi Declaration, the Soil Initiative for Africa and the African Fertilizer and Soil Health Action Plan).

SOILS4AFRICA

The SOILS4Africa Project was the result of a call for proposals for the development of a soil information system for Africa under the EU-Africa Research & Innovation Partnership's action on Food and Nutrition Security and Sustainable Agriculture. The project should collect and analyse chemical and physical properties in at least 20 000 soil samples collected from agricultural land across Africa. The process should be based on the LUCAS Soil Module that was developed by the JRC for assessing soil conditions across the EU. Presentation of data and results should be provided in an open data and map viewer. In this regard, the SOILS4AFRICA Project can be regarded as a demonstration of JRC 'technology transfer' to support soil-related policies for Africa.

2.6.6.5. Launch of the AU Soil Observatory

The African Union Soil Observatory (AUSO) Project was officially launched on 6 October 2025 in Nairobi, Kenya, in a high-level event bringing together African and European partners, policymakers, scientists, and development stakeholders.

The three-day launch and inception meeting marked the start of a five-year Mission Soil project designed to generate robust, harmonized soil data and strengthen soil health management across the continent. Coordinated by the Forum for Agricultural Research in Africa (FARA), the AUSO will establish a continental soil observatory, based on the EUSO, comprising the African Soil Data Centre (ASDAC) and an interactive Soil Health Dashboard. The platform will support continuous soil health monitoring, evidence-based policymaking, and targeted land management interventions across Africa.

The Government of Kenya was represented by Dr. Paul Kipronoh Ronoh, Principal Secretary at the State Department of Agriculture and Mr. Mongo Chimwaga, Secretary of Administration at the Department of Environment, Climate and Forestry. Speakers from the African Union Commission, European Commission (including the EUSO), Mission Soil, FARA, Kenya Agricultural and Livestock Research Organisation, ISRIC, and other key partners underscored the strategic importance of the AUSO Project. Across the board, they challenged partners to work towards open data, interoperability, and usability of soil information to support evidence-based policies and sustainable land management.

The AUSO consortium brings together 21 African and European partners, including national agricultural research systems, universities, international research centres, and advisory services. Implementation will take place across 12 target countries—Cameroon, Cabo Verde, Central African Republic, Ethiopia, Ghana, Kenya, Malawi, Madagascar, Senegal, Zambia, Zimbabwe, and Morocco—with additional engagement across the continent.

Through a co-development approach, AUSO will:

- Build on the Soils4Africa Soil Information System and lessons from the EUSO,
- Develop scalable frameworks for soil health data collection,
- Support countries to formulate national soil health strategies, and

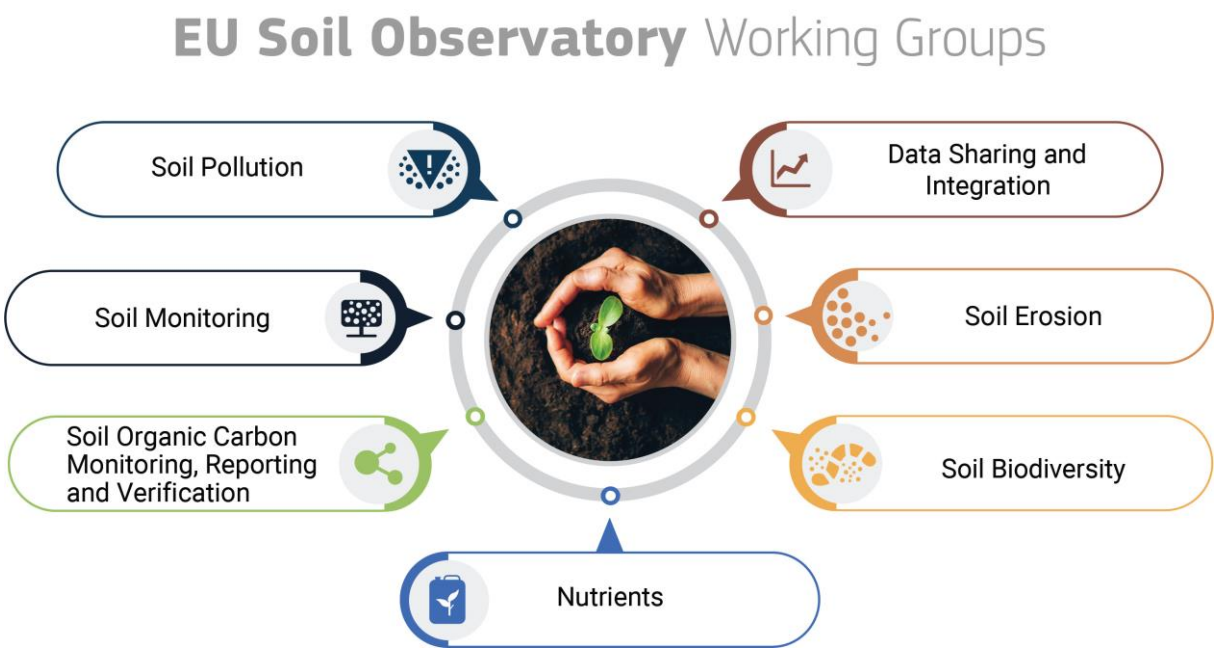
— Enhance soil literacy among stakeholders and the public.

As part of the meeting, EUSO representatives described the work carried out under the Antoine Royer Award to develop a novel Soil Health Dashboard for Africa (see also section 2.5.1).

3. Working group activities

The EUSO Working Groups (WG) are a key element of the EUSO. These WGs aim to advance the knowledge and data on specific aspects of EU-soils. The WGs are composed of relevant experts from academia, businesses or policy, and are co-chaired by EUSO staff and external partners. In 2025, seven WGs were active (**Figure 21**): (1) WG Soil erosion, (2) WG Data sharing and integration, (3) WG Soil pollution, (4) WG Soil monitoring, (5) WG Soil biodiversity, (6) WG Soil organic carbon monitoring reporting and verification, and (7) WG Nutrients.

Figure 21. EUSO Working Groups.



Source: JRC.

3.1. WG Soil erosion

The EUSO Working Group on Soil Erosion organised a one-day webinar on gully erosion on 25 June 2025 (**Figure 22**). This webinar highlighted ongoing research on gully erosion at local, European, and global scales. Three gully erosion experts gave their latest insights into gully erosion processes, monitoring, and modelling. Prof. Javier Casali and Inigo Barberena (University of Navarra, Spain) presented the field experiments at local scale. Prof. Pasquale Borrelli (UniRoma3, Italy) presented a monitoring approach for gully erosion at European scale. Prof. Matthias Vanmaercke (KU Leuven, Belgium) gave an overview of global issues addressing gully erosion. With 160 registered subscribers and 100 colleagues attending the webinar, the event drew significant interest. Recordings, presentations and the main conclusions are available on the EUSO website.

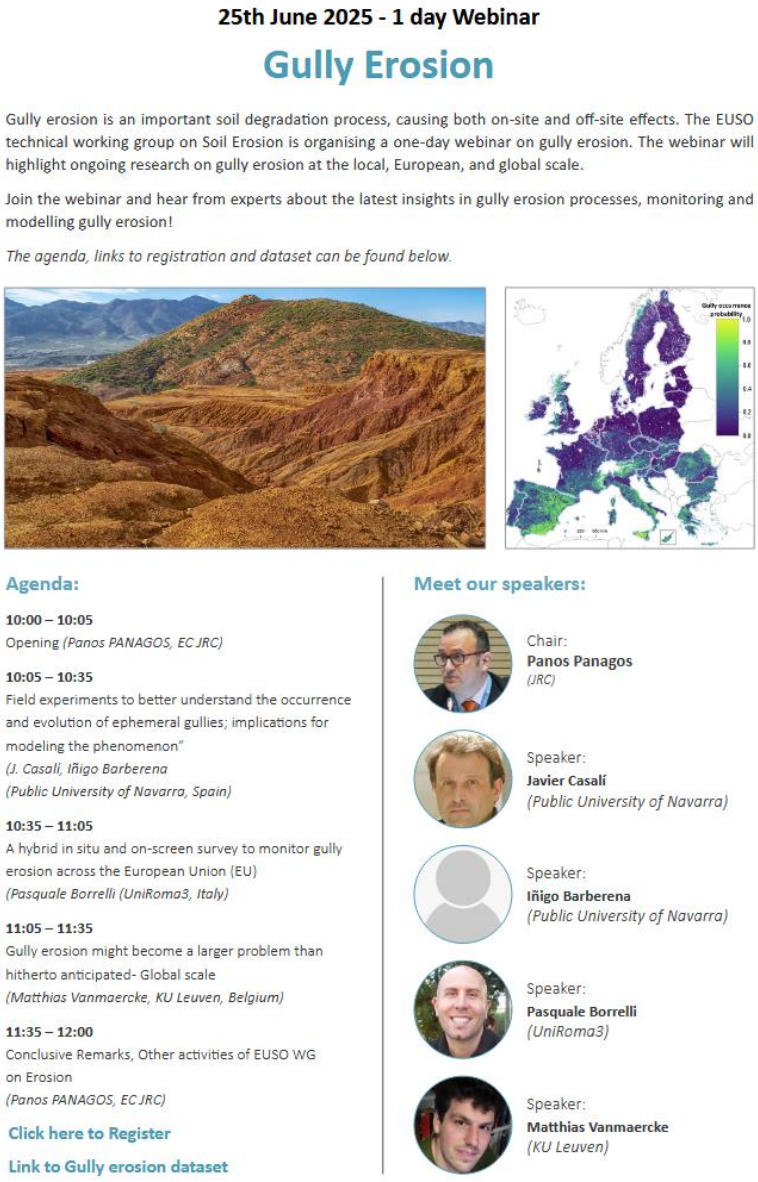
Some conclusive remarks of the webinar:

- There is a need for experimental data from fields as well as new data streams (e.g. drones and remote sensing) to better understand gully erosion.
- Recommendation for combined modelling approaches: physically based models for research and simplified predictive tools for practical land management.

— Stratified random sampling was proposed as a more effective approach compared to a regular monitoring network for gully detection.

— To achieve more effective soil conservation practices per region, gully erosion data should be integrated in the analyses.

Figure 22. Agenda and highlights of the gully erosion webinar, on 25 June 2025.



Source: JRC analysis.

In addition, the EUSO participated and delivered a keynote speech in the session on Soil Hydrology & Erosion organised during the EUROSOIL 2025 conference.

In 2025, the WG Soil erosion released three flagship, pan-European soil-erosion datasets that build on the EUSO 's long-term monitoring and research activities: (i) the update of Cover Management (C-factor) for the EU (see section 2.4.1.15), (ii) the 'Gully erosion in the EU' dataset (see section 2.4.1.5), and (iii) the measured soil erodibility (K-factor) point data (see section 2.4.1.11). These

datasets are freely downloadable from ESDAC and are already being used by researchers, policy-makers and land managers across Europe. In addition to the datasets, relevant soil erosion publications have been produced within EUSO in collaboration with members of the WG (see section 2.5.1).

3.2. WG Data sharing and integration

The purpose of this working group is to help EUSO achieve its vision of being a central hub for EU-scale soil data, where anyone can freely access and utilize soil-related datasets and supporting documentation, making EUSO and ESDAC the go-to reference point for soil data at the EU level.

In 2025, the activities of the WG were strongly intertwined with the activities of the Data and knowledge management cluster of the Mission Soil. The WG coordinates this cluster together with the Mission Soil funded project SoilWise. The cluster aims at bringing together the whole soil health community, promoting the best approach to manage the diverse data and knowledge outputs generated by the community at large, with a special focus on the Mission Soil projects. To foster the collaboration and exchange between the experts, two meetings were organized: one virtual on 22 September 2025, and one in-person in Brussels on 2 December 2025.

The virtual cluster meeting played an important role in framing the topics more relevant to the community. Indeed, while a part of the meeting was dedicated to presentation and discussion of two specific topics, namely the definition of knowledge and the presentation of the SoilWise catalogue, the meeting also focused on interactively collecting feedback and responses from the attendees regarding urgent topics that the cluster should address. The cluster members indicated that specific trainings on data and knowledge management practices, the adoption of a metadata template, and a shared and centralised vocabulary are among the top priorities for data managers and technical partners for their work with data and knowledge management.

The topics identified during the virtual meeting shaped the agenda for the in-person meeting held in Brussels, focusing on four specific topics: (1) Metadata template, (2) Vocabularies and glossaries, (3) How to populate the SoilWise catalogue with data and knowledge items, and (4) Soil knowledge management. With 72 participants coming from 38 different Mission Soil projects, the turnout can be considered satisfactory, with the plenary sessions being the focus of discussion and interaction between research projects and the policy DG. The presence of colleagues from DG AGRI, DG ENV, and the REA provided a bridge between research and policy, laying the foundation for possible collaboration aimed for specific policy (e.g., the SMRD).

The outcomes of the activities of the WG were also the foundation to discuss the scheduling of the webinars and activities of the cluster for 2026.

3.3. WG Soil pollution

Supporting the Mission Soil Cluster on Soil Pollution and Remediation

The EUSO WG on soil pollution supported the creation of the Mission Soil cluster on soil pollution and remediation, in collaboration with the Mission Soil Secretariat, to centralize research efforts and foster direct synergies between ongoing projects, with additional contributions from experts and scientific networks. The cluster serves as a strategic platform where projects voluntarily align their work, allowing the group to identify the current state-of-the-art and address the most pressing concerns in the field. By bringing these researchers together, a more cohesive approach was

facilitated to soil pollution and remediation, ensuring that project outputs are integrated rather than isolated.

RemTech Europe Conference

Over the past five years, the EUSO WG on soil pollution organised the opening session of the RemTech Europe Conference, a prestigious event that bridges policy and research focusing on critical issues of soil pollution and remediation (15-19 September 2025). The first two days of the conference were fully digital. The other three days filled with scientific sessions and discussions were hybrid. In 2025 the Opening Sesson focused on aligning European soil policies with technical strategies for managing soil contamination, highlighting the SMRD and the Zero Pollution 2025 report. Key discussions emphasize the urgent need to address PFAS, prioritize emerging contaminants, and establish international standardization (CEN/TC 444) for monitoring and remediation efforts. Multiple institutions presented their views, notably: JRC, DG ENV, DG AGRI, EEA, FAO, Environmental Protection Agency of the Republic of Serbia, University of Tübingen, ISLANDR (Mission Soil Project) and the Program manager Deltares, Chairman of CEN/TC 444. This forum has served as a platform to highlight the EU Soil Strategy for 2030, facilitate discussions on the SMRD, and foster high-level and operational-level engagement with industry stakeholders, addressing both challenges and innovative solutions. More information on the event can be found on the official Remtech Europe website.

Indicative list of substances

The WG on soil pollution has been collaborating with DG ENV and the EEA to develop a prioritization strategy for soil contaminants to be selected by Member States under the SMRD. The development of this indicative list of substances began through exchanges with the NORMAN Network, as well as with scientists working on the Water Framework Directive, and later with experts involved in Horizon Europe and Mission Soil projects.

In the first stage, substances with potential pathways to soil were identified. This was followed by the application of a prioritization procedure, and subsequently by a validation step to assess the robustness and relevance of the resulting list. Prioritisation considered criteria related to environmental relevance, including potential risk, exposure pathways to soil, feasibility of monitoring, and the availability of analytical determination methods. The validation stage involved expert consultation and comparison with existing monitoring initiatives and regulatory frameworks.

Harmonisation on soil pollution data

Following previous interactions, the WG soil pollution published a report on the harmonisation of soil pollution data. This report summarizes the results of several soil-pollution initiatives and Mission Soil projects, namely SoilWise, ISLANDR, EDAPHOS, ARAGORN, and BENCHMARKS. The report concludes that harmonising and standardising data are essential for effective soil-pollution management. It also stresses that a comprehensive, coordinated approach is needed to tackle the complex problem of soil pollution across Europe.

3.4. WG Soil monitoring

The Working Group on soil monitoring aims to contribute to an integrated soil monitoring system at EU-level to assess the impact of the EU Soil Strategy for 2030, the Mission Soil, and related soil-policies.

On 10 December 2025, the WG on soil monitoring organised a webinar on the updated in-situ soil sampling protocol for the next LUCAS Soil survey. This webinar was organised in the light of the SMRD. More precisely, Recital 45 of the SMRD states that the Commission should assist and support Member States at their request in monitoring their soil health by continuing to carry out and enhancing regular in-situ soil sampling as part of the LUCAS Soil survey. For that purpose, LUCAS Soil is to be upgraded to fully align with the requirements of the SMRD. The scope of this webinar was to discuss with stakeholders the technical specificities of the proposed sampling protocol for the next LUCAS Soil survey that meets the requirements set by SMRD. Attendees provided feedback on the proposed sampling protocol. This feedback was used to update the sampling protocol for the nest LUCAS Soil survey. Presentation and recordings of the webinar, as well as the updated sampling protocol for the next LUCAS Soil survey, are available on the EUSO website.

3.5. WG Soil biodiversity

In 2025, the Working Group on Soil biodiversity co-authored eight peer-reviewed publications, including high-impact journals, through collaborations with EU and Swiss institutions. The WG research advanced understanding of soil health indicators, microbial biodiversity, and emerging contaminants.

A first study, by Del Duca et al. (2025), compared LUCAS Soil sampling protocols with Italian regional methods to assess harmonisation of physicochemical and biological indicators. Analysing 58 sites in northern Italy, microbial community structure was found correlating well between protocols, fungal diversity showed higher variability than bacteria, and land cover strongly influenced results, suggesting it should be accounted for when merging datasets. The findings supported data integration for most parameters but highlighted the need for further standardisation, particularly for fungal diversity and select physicochemical traits.

Two additional studies explored microbial indicators for soil health monitoring. Visca et al. (2025) investigated antibiotic resistance (AR) and microplastics (MPs) – a WHO-prioritised global health threat – across 885 LUCAS Soil Biodiversity samples. They identified four bacterial genera strongly linked to both MP degradation and AR pathways, proposing them as potential bioindicators for early detection of pollution-driven AR risks. Meanwhile, Romero et al. (2025) examined the soil microbiome's role in ecosystem multifunctionality (e.g., structure, biochemistry, productivity) across 484 European soils. Results showed that multifunctionality arises from interactions between abiotic soil traits and microbial communities, with two bacterial phyla and one fungal genus emerging as strong predictors, showing promise as bioindicators for multifunctionality monitoring.

Other research focused on modelling soil biodiversity patterns. Bahram et al. (2026) revealed that land-use intensification increases archaeal abundance while shifting communities from adaptive forest microbes to specialised, ammonia-oxidising groups in fertilised croplands, suggesting lower resilience and potential impacts on soil fertility and greenhouse gas emissions. Separately, Lutz et al. (2025) conducted a global mapping of arbuscular mycorrhizal fungi, uncovering unprecedented taxonomic diversity and reshaping understanding of their ecological importance. Furthermore, Siles et al. (2025) combined DNA metabarcoding and biomass data to assess microbial diversity-to-biomass ratios across Europe, warning that climate change and land-use shifts could destabilise microbial balance, with implications for soil health and ecosystem resilience.

Finally, a paper led by former JRC CDP student, Julia Köninger, investigated differences in detecting soil biodiversity by means of eDNA-based and morphological methods (Köninger et al., 2025). The analysis of Köninger at al. (2025) may be of interest when developing guidelines for the

implementation of the SMRD in terms of selection of descriptors for soil biodiversity assessment/monitoring.

The Soil Biodiversity WG also actively contributed to the organisation of the first part of 5th EUSO Stakeholders Forum "How can healthy soils increase EU competitiveness?" on 12th June 2025 (see section 2.6.1). In particular, Generare, a French start-up working on translating the complexity of soil microbial DNA into a scalable platform for transforming drug discovery, was among the invited participants. As a result of online discussions, a perspective paper on the importance of soils for boosting EU competitiveness was published (Panagos et al., 2025).

Beyond scientific publication, the WG submitted a CAS proposal (MICRO-CLEANERs) to investigate microbial genes degrading pollutants (e.g., pesticides, PFAS, microplastics) and their potential for bioremediation. They also contributed to revising the next LUCAS soil biodiversity protocols, proposing adjustments for woodland sampling, and provided expert recommendations to EU soil living labs (LILA4SOILS, LIVINGSOILL) and projects like AI4SoilHealth.

A major milestone was organising the first European Soil Biodiversity Monitoring Symposium (2–3 February 2026), which aimed to bring together 40+ experts to discuss monitoring standards and long-term targets under the SMRD. The event featured contributions from major Horizon and Soil Mission projects (e.g., SOB4ES, BENCHMARKS, BIOservicES, AI4SoilHealth, SOILGUARD, HoliSoils, EJP-SOIL [MINOTAUR]), fostering alignment on soil biodiversity monitoring and descriptors.

3.6. WG Soil organic carbon monitoring reporting and verification

From 4 to 6 March 2025, the 2nd European Carbon Summit united diverse practitioners and organisations in carbon farming, soil management and certification, with more than 600 participants in Dublin and online. The EUSO and the WG organised a session on standardised baselines and presented the framework for better modelling and monitoring soil organic carbon (SOC) and carbon removals from agricultural soils and forestry. Proper monitoring is essential to ensure the validity of carbon credits.

The EUSO and the WG plays an important role in the development of the Carbon Removals and Carbon Farming (CRCF) Regulation. The CRCF regulation seeks to establish the first EU-wide voluntary framework for certifying carbon removals, fostering investment in innovative carbon removal technologies and sustainable carbon farming solutions. The EUSO provides technical support to DG CLIMA for the definition and evaluation of methodologies. The EUSO is developing innovative Monitoring Reporting and Verification schemes which are tested both at regional and parcel scale. In particular, the EUSO, building on datasets such as LUCAS, remote sensing products and inhouse modelling tools, developing hybrid methodologies to calculate standardised baselines.

Next to that, the WG organised a workshop titled “Tools for the Standardised Baseline Methodology for Carbon Removals” on 13 –14 November 2025 at the JRC in Ispra. The event brought together 20 modellers and scientists from five Soil Mission Projects: MRV4SOC, MARVIC, CAFAMORE, OGCR, and LilaSoils Living Lab, as well as 25 online participants. Representatives from the Carbon Alliance Industry also attended, as well as DG CLIMA and the Mission Soil Secretariat (DG AGRI and DG RTD). The workshop was important for advancing the Delegated Act of the CRCF Regulation. During the workshop, EUSO members presented progress on developing a European standardised baseline methodology for the CRCF. The five Soil Mission Projects shared regional approaches based on their model developments, which are used to validate European-level assessments. A dedicated session also explored quality criteria for qualifying models under the CRCF framework. A follow-up session is planned during the European Carbon Farming Summit in Padova, Italy, on 17–19 March 2026.

3.7. WG Nutrients

The WG on nutrients aims to engage with stakeholders dealing with soil nutrients to address knowledge gaps, knowledge needs and provide support for EU policies. On 14 April 2025, the WG organised a webinar to present the existing knowledge on soil phosphorus status, phosphorus balances and losses, data, modelling and mapping, to support EU policy decisions.

In a first presentation, Cristiano Ballabio (EUSO) presented the EUSO's mapping of soil phosphorus, based on 20 000 soil samples analysed in 2009 in the framework of the LUCAS Soil. Soil phosphorus was mapped based on satellite, meteorological and landcover information, to give estimated on soil P by 100 (total P) – 250 (Olsen P) m square resolution across Europe.

In the second presentation, Panos Panagos (EUSO) presented an empirical equation to calculate soil phosphorus budgets, using estimates for crop and crop residue production and their phosphorus content, fertiliser and manure application, atmospheric P deposition and release from base rock (weathering), and estimates of P losses by water erosion. Results suggest that on average 3.5 kgP ha^{-1} $year^{-1}$ is accumulating in soil, but with wide variations by country and region, with some regions showing soil depletion and others high soil P accumulation. These studies are summarised in ESPP eNews no. 83 and no. 73.

Thirdly, Anna Muntwyler (ETH Zurich) presented a process-based approach to estimate phosphorus fluxes in EU agricultural land at a $1km^2$ resolution. This approach, including the total P budget, uses a model previously calibrated for carbon and nitrogen. The phosphorus sub-model was calibrated using data from long-term field trials in Italy and Switzerland and showed to provide good estimates for average soil P budgets and soil P pools (best estimates obtained for total P rather than available P). Scenario calculations show, for example, that nitrogen-fixing cover crops can decrease the P balance by increasing P export, whereas non-N-fixing cover crops can reduce crop productivity (by competing for nutrients) thereby decreasing P export and increasing the P balance. Implementing a 20% reduction in P-fertilisation, as per the Green Deal target, targeting areas with available P > 22 mg P kg^{-1} results in lower crop productivity (on average) and a negative P balance. However, a more refined scenario approach could mitigate these effects.

Fourthly, Julian Helfenstein (Wageningen University and Research) underlined the need for a better understanding of P availability and high-resolution spatial data across Europe, to support modelling and decrease uncertainties. It was shown that spatial autocorrelation between soil P is small, as anthropogenic inputs are the main driver that vary between fields. Recommendations for future work were given, namely (1) to use process-based measurements of soil P and (2) to map soil P differently for agricultural and non-agricultural soils and with process-based models for mapping soil P and (3) to always include clear communication on map uncertainties.

4. Planned developments for the EUSO in 2026

4.1. Policy support

4.1.1. Supporting the implementation of the SMRD

The EUSO will continue to support the implementation of the SMRD, by providing scientific and technical support to DG ENV and EU Member States. Planned outcomes and relevant activities in 2026 include:

- Publication of a prototype and continued evolution of the SMRD web platform (EU Soil Health Gateway) and support to the implementing act on reporting data,
- Support to Member States in relation to Article 4 (soil districts and soil units) and Article 9 (measurements and methodologies),
- Support to the development of possible sustainable target values and operational trigger values,
- Initial establishment of the indicative list of soil contaminants, in cooperation with Member States (Article 8)
- Support for the soil health monitoring (for instance, provision of relevant data for determining the number and location of sampling points, assessment of Member States needs and soil samples archiving) (Article 9.1-2, 9.11), and
- Preparing and implementing the next LUCAS Soil Module.

4.1.2. Supporting the Mission Soil

The EUSO will continue to provide scientific and technical support to DG AGRI and DG RTD through an Administrative Agreement (AA). In Q3 2026, the current AA will be followed up by a new AA, which will be operational until 2030. Planned outcomes and relevant activities in 2026 of this scientific and technical support to the Mission Soil includes, among others:

- Report on new data sources for soil monitoring, discussing new data sources for soil monitoring, the potential integration with traditional soil monitoring efforts, and examples of how these data sources can be integrated and used within the EUSO.
- Report on the EU soil use calculator, discussing methodologies to track and measure the impact of EU consumer demands on global soils and soil health.
- Scientific paper on trends in soil degradation indicators over the past decades.
- Science-for-policy report on trends in soil health in the EU, including changes in soil data availability, changes in soil monitoring, changes in EU soil policies, and quantitative changes in soil degradation indicators.
- Monitoring and assessing the progress and outcomes of Mission Soil projects relevant for the Mission Soil building block 'Monitoring and Indicators'.
- Support and work together with the Mission Soil Platform in designing and creating a Mission Knowledge Hub.

— Providing guidance for the Mission Soil Living Labs, regarding monitoring and reporting on soil health at the local scale.

4.2. EU-wide soil monitoring

In 2026, the EUSO will process the results of the laboratory analysis of the LUCAS Soil Module 2022. The EUSO will prepare a report presenting an overview of the various laboratory analysis and describing the spatial variability of soil properties by land cover class and presenting a comparative analysis of the soil properties. The EUSO will also finalise the programme to assess different analytical methods for measuring PFAS in LUCAS 2022 samples.

Moreover, the EUSO will prepare and implement the next LUCAS Soil Module, building and adapting the sampling methodology and instructions to surveyors to meet the requirements of the SMRD.

4.3. Monitoring soil health and soil policies

Further developments of the **EUSO Soil Degradation Dashboard** are planned in 2026. First, temporal datasets for more indicators will be included, in line with the scientific publication on trends in soil degradation indicators in the EU (Broothaerts et al., under review). Next, new indicators will be added to complete the assessment of the state of soil degradation in the EU, according to the availability of new data (e.g. output of Mission Soil funded projects). For this, the EUSO will work in close collaboration with the Mission Soil funded projects. Finally, new functionalities will be added, for a better visualisation of the state of soil degradation processes in the EU and a better user experience.

The **EU Soil Strategy Actions Tracker** will be updated regularly, to reflect progress in policy implementation. Moreover, this Tracker is a first step towards a more complete EUSO Soil Policy Actions Tracker, monitoring all EU policy actions relevant to soils and not exclusively focussing on the EU Soil Strategy for 2030.

Next to the existing EUSO Soil Degradation Dashboard and EU Soil Strategy Actions Tracker, the EUSO will also create other, thematic dashboards. In 2026, the EUSO will work on the following tools:

— **CRCF Map Viewer**: Under the EU Carbon Removals and Carbon Farming Regulation (CRCF), a carbon farming (CF) activity should provide a net carbon removal or soil emission reduction benefit to be computed against a baseline. To account for the risk of reversal after the CF activity has taken place, the Delegated Act from the CRCF requires operators to carry out a risk assessment. The risk assessment of the CF activity needs to be done before the start of the activity period. The planned CRCF Map Viewer will provide a beta-version of the spatially continuous layers resampled at 5 km relevant to the risk assessment for mineral soils under agriculture.

— **Soil Nutrients Dashboard**: Building further on previous EUSO work, trends in nutrient budgets will be established and linked to actual soil nutrient status and trends based on the different LUCAS soil campaigns.

— **Soil Pollution Dashboard and Watch List**: Development of the first fully dedicated Soil Pollution dashboard featuring the most up to date indicators on diffuse soil pollution and ecotoxicological risk, as well as the inclusion of potentially contaminated sites.

— **EU land degradation and desertification dashboard**: Providing interactive maps and indicators to explore spatial patterns of degradation across Europe.

— **African Soil Health Dashboard**: The public launch of the new African Soil Health Dashboard (AFSOH) is planned in 2026. The AFSOH dashboard compiles global and local datasets of threats to soil health and presents other relevant information to assist policymakers.

Finally, in 2026, the **EU Soil Health Gateway** will be created. This platform will support the implementation of the Soil Monitoring and Resilience Directive (see also section 4.1.1).

4.4. Enhancing the functionality of the European Soil Data Centre

Also in 2026, EUSO will enhance the capacity and functionality of ESDAC and consolidate ESDAC as the single-stop-shop for soil related data in the EU. A key activity in this regard will be the integration of the SoilWise data catalogue within ESDAC. The SoilWise data catalogue will be a centralised catalogue where data and knowledge concerning soil are collected at EU level. To guarantee a long-term future for the catalogue that extends beyond the duration of the SoilWise project, an integration within ESDAC is foreseen in 2026.

Next to that, further steps will be taken to evolve towards ESDAC 3.0 to integrate existing and future data from Member States, the LUCAS Soil Module and research projects into the EU Digital Soil Health Data Portal, in compliance with the SMRD. ESDAC 3.0 would include data from Member States, relevant results from Mission Soil funded projects, as well as data from remote sensing, spectroscopy, sensors for precision agriculture and citizen science.

4.5. Supporting soil research and innovation

The EUSO will continue to support soil research and innovation. This will include collaboration with Mission Soil funded projects, through bilateral meetings with the projects, joined activities and events, and collaboration withing the Mission Soil Clusters.

Next, the EUSO plans also in-house research in 2026. This includes, among others:

— Advanced modelling on soil organic carbon cycles,

— Changes in soil health in the EU over the past decades,

— Mapping and assessing soil biodiversity in the EU,

— Emerging pollutants,

— Importance of soil nutritional properties (micro-nutrients) of crops,

— Spectroscopy and innovative remote sensing-based techniques for soil monitoring,

— Prototype of transfer functions to harmonise Member States data collected under the SMRD,

— Standards and methods to be followed for Member States sampling within the SMRD,

— Integration of citizen science actions in EUSO tools,

— Development of an EU soil use calculator,

— LUCAS Western Balkans soil health assessments,

— Operational data flows for soil monitoring at the EU-scale,

— Land suitability for renewal energy,

— Analysing LUCAS Soil Module 2022.

In addition, the EUSO will also start two new Collaborative Doctoral Partnerships (CDP), together with the University of Basel. The first PhD project will investigate how artificial intelligence can support the achievement of healthy soils by 2050 through EU policy implementation. It will develop AI tools to map and predict soil health across space and time, accelerate literature reviews, extract best management practices from long-term experiments, and design methods to evaluate soil health. The project will also explore translating Mission Soil Living Labs outcomes into policy recommendations and conducting policy-relevant scenario analyses. The second PhD project will develop integrated and reproducible approaches to quantify and reduce soil- and sediment-driven nutrient pollution in European catchments. It will assess the role of soil erosion and land management in phosphorus transport and eutrophication, using monitoring data from the EU Water Framework Directive to calibrate and validate advanced sediment routing and modelling approaches. The research will also design a European-scale turbidity and sediment monitoring framework combining in situ observations and satellite remote sensing.

4.6. Supporting stakeholder interactions and innovation

The EUSO will continue to engage stakeholders and citizens on soil-related topics and try to increase soil literacy. To do so, the EUSO will (co-)organise several activities to engage soil awareness among citizens and to bring together stakeholders. Highlights for 2026 include the EUSO Stakeholders Forum, which will take place in different parts, and the fourth European Mission Soil Week, which will take place in Dublin (Ireland). Efforts to support the implementation of the SMRD will feature prominantly.

Another highlight will be the JRC Summer School 2026 on the evaluation of air, soil and water protection. This summer school aims to strengthen green skills for a more sustainable and resource-efficient society, in line with the objectives of the EU Enlargement policy. It contributes to regional economic growth within the framework of the dual green and digital transitions. It is organised in partnership with Goce Delcev University (North Macedonia) a strategic regional and European partner in research, innovation and academic excellence.

Soil-related conferences in which the EUSO will participate in 2026 include:

— European Carbon Farming Summit in Padova (Italy),

— EGU General Assembly 2026 in Vienna (Austria),

— 23rd World Congress of Soil Sciences in Nanjing (China),

— Mission Soil Investment Forum in Brussels (Belgium),

— Soils for Europe Conference 2026 in Coimbra (Portugal).

5. Conclusions

This report highlights the main activities and outcomes of the EUSO in 2025. Through its activities in 2025, the EUSO provided policy support to a wide range of policy areas, including the Soil Monitoring and Resilience Directive, the Mission Soil, and the EU Soil Strategy for 2030. Next, the EUSO has been monitoring EU soils, through the LUCAS Soil Module and the EUSO Soil Degradation Dashboard. The latter was updated in 2025 with new functionalities for a better user experience. Furthermore, the EUSO has been contributing to sharing data and knowledge on EU soils by enhancing the functionality and capacity of ESDAC. This resulted in 15 new datasets in ESDAC and over 14 000 downloaded datasets in 2025. EUSO also supported soil research and innovation in 2025, by collaborating with Mission Soil projects and (co-)authoring 55 scientific papers and 10 technical reports. And finally, EUSO supported stakeholder interactions and soil literacy among society, through events such as the fifth edition of the EUOS Stakeholders Forum and the Soil Literacy Workshop.

Overall, in 2025, the EUSO has achieved its operational objectives and has successfully taken up its role to be the principal provider of soil related data and policy support at the EU-level. Also in 2026, the EUSO will further support EU soil-related policy initiatives. Together with its stakeholders, the EUSO will provide data, tools and knowledge to monitor, safeguard and restore EU-soils.

References

Bahram, M., Lehtovirta-Morley, L., Mikryukov, V., Sveen, T.R., Grant, A., Pent, M., Hildebrand, F., Labouyrie, M., Köninger, J., Tedersoo, L., Jones, A., Panagos, P., Orgiazzi, A., 2026. Intensive land use enhances soil ammonia-oxidising archaea at a continental scale. Soil Biol. Biochem. 213, 110024. https://doi.org/10.1016/j.soilbio.2025.110024

Borrelli, P., Matthews, F., Alewell, C., Kaffas, K., Poesen, J., Saggau, P., Prăvălie, R., Vanmaercke, M., Panagos, P., 2025. A hybrid in situ and on-screen survey to monitor gully erosion across the European Union. Sci. Data 12, 755. https://doi.org/10.1038/s41597-025-05074-w

Borrelli, P., Robinson, D.A., Fleischer, L.R., Lugato, E., Ballabio, C., Alewell, C., Meusburger, K., Modugno, S., Schütt, B., Ferro, V., Bagarello, V., Oost, K.V., Montanarella, L., Panagos, P., 2017. An assessment of the global impact of 21st century land use change on soil erosion. Nat. Commun. 8, 2013. https://doi.org/10.1038/s41467-017-02142-7

Breure, T.S., De Rosa, D., Panagos, P., Cotrufo, M.F., Jones, A., Lugato, E., 2025. Revisiting the soil carbon saturation concept to inform a risk index in European agricultural soils. Nat. Commun. 16, 2538. https://doi.org/10.1038/s41467-025-57355-y

Breure, T.S., Jones, A., Panagos, P., 2026. Evaluating visible near-infrared spectroscopy in context of a repeated sampling survey across the European Union. Geoderma 465, 117647. https://doi.org/10.1016/j.geoderma.2025.117647

Broothaerts, N., Breure, T., Belitrandi, D., Havenga, C., Peeters, B., Probst, C., Barbero, M., Panagos, P., Jones, A., 2025. EU soil strategy actions tracker: a tool to track the actions listed in the EU soil strategy for 2030. Publications Office of the European Union.

Broothaerts, N., Fendrich, A.N., Van Eynde, E., Yunta, F., De Rosa, D., Borrelli, P., Jones, A., Panagos, P., under review. Trends in soil health in the European Union. Eur. J. Soil Sci.

Chahal, I., Amsili, J.P., Saurette, D.D., Bower, J.A., Gillespie, A.W., van Es, H.M., Van Eerd, L.L., 2024. Soil organic carbon to clay ratio in different pedoclimatic and agronomic conditions in northeastern North America. Geoderma Reg. 39, e00893. https://doi.org/10.1016/j.geodrs.2024.e00893

Del Duca, S., Tondini, E., Vitali, F., Lumini, E., Garlato, A., Vinci, I., Tagliaferri, E., Brenna, S., Motta, S., Maillet, E., Bispo, A., Orgiazzi, A., Jones, A., Mocali, S., Fantappiè, M., 2025. Comparison of LUCAS and Italian Sampling Procedures for Harmonising Physicochemical and Biological Soil Health Indicators. Eur. J. Soil Sci. 76, e70108. https://doi.org/10.1111/ejss.70108

European Environment Agency, 2025. Enhancing Europe's land carbon sink: status and prospects. Publications Office of the European Union.

European Environment Agency, 2024. Scaling up carbon dioxide removals: recommendations for navigating opportunities and risks in the EU. Publications Office of the European Union.

Georgiou, K., Angers, D., Champiny, R.E., Cotrufo, M.F., Craig, M.E., Doetterl, S., Grandy, A.S., Lavallee, J.M., Lin, Y., Lugato, E., Poeplau, C., Rocci, K.S., Schweizer, S.A., Six, J., Wieder, W.R., 2025. Soil Carbon Saturation: What Do We Really Know? Glob. Change Biol. 31, e70197. https://doi.org/10.1111/gcb.70197

Köninger, J., Beule, L., Tsiafouli, M., Seeber, J., Blasbichler, H., Sousa, J.P., Martins da Silva, P., Frouz, J., Hedlund, K., Orgiazzi, A., Briones, M.J.I., Potapov, A., 2025. Molecular and morphological

identification methods show contrasting trends in soil fauna diversity along land-use intensity gradients. Appl. Soil Ecol. 216, 106499. https://doi.org/10.1016/j.apsoil.2025.106499

Lugato, E., Lavallee, J.M., Haddix, M.L., Panagos, P., Cotrufo, M.F., 2021. Different climate sensitivity of particulate and mineral-associated soil organic matter. Nat. Geosci. 14, 295–300. https://doi.org/10.1038/s41561-021-00744-x

Lutz, S., Mikryukov, V., Labouyrie, M., Bahram, M., Jones, A., Panagos, P., Delgado-Baquerizo, M., Maestre, F.T., Orgiazzi, A., Tedersoo, L., van der Heijden, M.G.A., 2025. Global richness of arbuscular mycorrhizal fungi. Fungal Ecol. 74, 101407. https://doi.org/10.1016/j.funeco.2024.101407

Orgiazzi, A., Ballabio, C., Panagos, P., Jones, A., Fernández-Ugalde, O., 2018. LUCAS Soil, the largest expandable soil dataset for Europe: a review. Eur. J. Soil Sci. 69, 140–153.

Panagos, P., Broothaerts, N., Ballabio, C., Orgiazzi, A., De Rosa, D., Borrelli, P., Liakos, L., Vieira, D., Van Eynde, E., Arias Navarro, C., others, 2024. How the EU Soil Observatory is providing solid science for healthy soils. Eur. J. Soil Sci. 75, e13507.

Panagos, P., Orgiazzi, A., Lugato, E., Vandenesch, G., Thannberger, L., Neff, J.C., Reijneveld, A., Mathijs, E., Chapot, P., Guerrini, S., Štyriaková, D., Kremers, J., Martin, P., Van Der Tol, R., Burgeon, V., Kalimeri, E., Van Eynde, E., 2025. Healthy soils as a booster to EU competitiveness. Land Use Policy 158, 107755. https://doi.org/10.1016/j.landusepol.2025.107755

Panagos, P., Van Liedekerke, M., Borrelli, P., Köninger, J., Ballabio, C., Orgiazzi, A., Lugato, E., Liakos, L., Hervas, J., Jones, A., others, 2022. European Soil Data Centre 2.0: Soil data and knowledge in support of the EU policies. Eur. J. Soil Sci. 73, e13315.

Poeplau, C., Don, A., 2023. A simple soil organic carbon level metric beyond the organic carbon-to-clay ratio. Soil Use Manag. 39, 1057–1067. https://doi.org/10.1111/sum.12921

Romero, F., Labouyrie, M., Orgiazzi, A., Ballabio, C., Panagos, P., Jones, A., Tedersoo, L., Bahram, M., Eisenhauer, N., Sünnemann, M., Guerra, C.A., Tao, D., Rog, I., Jiao, S., Mocali, S., Rillig, M.C., Lehmann, A., Delgado-Baquerizo, M., van der Heijden, M.G.A., 2025. The soil microbiome as an indicator of ecosystem multifunctionality in European soils. Nat. Commun. 17, 705. https://doi.org/10.1038/s41467-025-67353-9

Schillaci, C., 2026. Enhancing the SDG 15.3.1 Land-Cover Transition Matrix Using Multidecadal Vegetation Indicators. J. Land Use Sci.

Schillaci, C., in press. Land productivity trends and climate corrections for the SDG 15.3.1 land degradation indicator assessment at EU scale, in: Handbook of Land Degradation. Routledge.

Schillaci, C., Jones, A., Vieira, D., Munafò, M., Montanarella, L., 2023. Evaluation of the United Nations Sustainable Development Goal 15.3.1 indicator of land degradation in the European Union. Land Degrad. Dev. 34, 250–268. https://doi.org/10.1002/ldr.4457

Siles, J.A., Vera, A., Labouyrie, M., van den Hoogen, J., Crowther, T.W., Romero, F., Tedersoo, L., García, C., Jones, A., Panagos, P., van der Heijden, M.G.A., Orgiazzi, A., Bastida, F., 2025. Land Use Interacts With Climate to Influence Microbial Diversity-To-Biomass Ratios Across Europe via Soil Organic Carbon and Nitrogen. Mol. Ecol. 34, e17806. https://doi.org/10.1111/mec.17806

Vieira, D.C.S., Yunta, F., Baragaño, D., Evrard, O., Reiff, T., Silva, V., de la Torre, A., Zhang, C., Panagos, P., Jones, A., Wojda, P., 2024. Soil pollution in the European Union – An outlook. Environ. Sci. Policy 161, 103876. https://doi.org/10.1016/j.envsci.2024.103876

Visca, A., Gregorio, L.D., Costanzo, M., Clagnan, E., Nolfi, L., Bernini, R., Orgiazzi, A., Jones, A., Vitali, F., Mocali, S., Bevivino, A., 2025. Microbial Bioindicators for Monitoring the Impact of Emerging Contaminants on Soil Health in the European Framework. Sustainability 17. https://doi.org/10.3390/su17031093

List of abbreviations and definitions

Abbreviations	Definitions
AA	Administrative Agreement
AFSOH	African Soil Health Project
AGC	aboveground biomass carbon
AR	antibiotic resistance
ASDAC	African Soil Data Centre
AT	Austria
AUSO	African Union Soil Observatory
BE	Belgium
C-factor	cover-management factor
CDP	Collaborative Doctoral Partnership
CEN	European Committee for Standardisation
CEN/TC	European Committee for Standardization Technical Committees
CN	China
CH	Switzerland
CLC	CORINE Land Cover
CO_2	Carbon dioxide
COP	Conference of the parties
CRCF	Carbon Removals and Carbon Farming
CRL	Carbon Removal on Land
DE	Germany

Abbreviations	Definitions
DG AGRI	Directorate-General for Agriculture and Rural Development
DG CLIMA	Directorate-General for Climate Action
DG ENV	Directorate-General for the Environment
DG RTD	Directorate-General for Research and Innovation
DNA	Deoxyribonucleic acid
EEA	European Environmental Agency
eDNA	Environmental DNA
EGU	European Geoscience Union
EIT	European Institute of Innovation and Technology
EJP	European Joint Programme
EMSW	European Mission Soil Week
ENSA	European Network for Soil Awareness
ES	Spain
ESA	European Space Agency
ESDAC	European Soil Data Centre
EU	European Union
EUSO	EU Soil Observatory
FAO	Food and Agriculture Organization
FARA	Forum for Agricultural Research in Africa
foc	fraction of SOC in SOM
FR	France
GAEC	Good agricultural and environmental conditions

Abbreviations	Definitions
GB	United Kingdom
GHG	Greenhouse gas
GR	Greece
GSP	Global Soil Partnership
IACS	Integrated Administration and Control System
ICP Forests	International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests
IPCC	International Panel for Climate Change
IE	Ireland
IN	India
ISO	International Organization for Standardisation
IT	Italy
JRC	Joint Research Centre
K	soil erodibility
LUCAS	Land Use/Cover Frame area Survey
LULUCF	Land use, land use change and forestry
MAES2IPBES	European Assessment on Biodiversity and Ecosystem Services
MAOC	mineral-associated organic carbon
MP	microplastics
MRV	Monitoring, reporting and verification
MS	Member States
NGO	non-governmental organization

Abbreviations	Definitions
NL	Netherlands
NRR	Nature Restoration Regulation
OECD	Organisation for Economic Co-operation and Development
O/T SOC	observed/typical soil organic carbon
P	phosphorus
PFAS	Per- and polyfluoroalkyl substances
PL	Poland
PT	Portugal
REA	European Research Executive Agency
RO	Romania
SAIS	Spatial Agricultural Information System
SDG	Sustainable Development Goals
SE	Sweden
SIS	Soil Information System
SMRD	Soil Monitoring and Resilience Directive
SOC	Soil organic carbon
SOM	soil organic matter
t	tonne
TR	Republic of Türkiye
UNCCD	United Nations Convention to Combat Desertification
USDA	United States Department of Agriculture
UNEP	United Nations Environment Programme

Abbreviations	Definitions
UNFCCC	United Nations Framework Convention on Climate Change
UK	United Kingdom
UN	United Nations
US	United States of America
VNIRS	visible near-infrared spectroscopy
WG	Working Group
WHO	World Health Organization
WP	Work programme
yr	year
ZPMO	Zero Pollution Monitoring and Outlook

List of boxes

Box 1. Scopus-indexed journal papers published by the EUSO in 2025. EUSO team members are underlined..... 35

Box 2. JRC technical reports (co-)authored by the EUSO in 2025. EUSO team members are underlined..... 40

Box 3. Science for policy reports, (co)-authored by the EUSO in 2025..... 40

List of figures

Figure 1. EUSO's main activities and outcomes in 2025 8

Figure 2. The main objectives of the EU Soil Observatory. 10

Figure 3. EUSO Soil Degradation Dashboard and its convergence of evidence map (indicating the number of soil degradation processes likely to be present) and speedometer (indicating the proportion of land likely to be affected by one or more soil degradation processes or by soil sealing in the EU). 22

Figure 4. Correlation matrix for the indicators in the EUSO Soil Degradation Dashboard. 23

Figure 5. Comparison of the percentages of degraded soils in the Member States for each individual soil degradation indicator. 23

Figure 6. Summary of the status of the actions included in the EU Soil Strategy for 2030. 24

Figure 7. Datasets added to ESDAC in 2025. 29

Figure 8. Number of downloads of the new datasets added to ESDAC in 2025. 30

Figure 9. Number of downloaded ESDAC datasets in the period 2011-2025. 31

Figure 10. Number of downloaded ESDAC datasets per country in 2025 (country codes can be found in the list of abbreviations). 31

Figure 11. Number of downloaded ESDAC datasets per institutional type, in 2025. 32

Figure 12. Most downloaded ESDAC datasets in 2025. 32

Figure 13. Share of ESDAC datasets downloads according to category. 33

Figure 14. Number of papers in Scopus-indexed journals published by EUSO per year. 34

Figure 15. Journals in which EUSO published in 2025, and the number and share of papers in these journals. 34

Figure 16. Recent EUSO publications, highlighted in the EUSO monthly newsletter. 35

Figure 17. Part 1 of the EUSO Stakeholders Forum 2025, focussing on the contribution of healthy soils to EU competitiveness. 49

Figure 18. Part 2 of the EUSO Stakeholders Forum 2025, held in Seville during EUROSOIL 2025 conference. 50

Figure 19. Participants at the soil literacy workshop at the JRC. 52

Figure 20. Example of the EUSO monthly newsletter. 53

Figure 21. EUSO Working Groups. 58

Figure 22. Agenda and highlights of the gully erosion webinar, on 25 June 2025. 59

Getting in touch with the EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),
— at the following standard number: +32 22999696,
— via the following form: european-union.europa.eu/contact-eu/write-us_en.

Finding information about the EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

Science for policy

The Joint Research Centre (JRC) provides independent, evidence-based knowledge and science, supporting EU policies to positively impact society

Scan the QR code to visit:

The Joint Research Centre: EU Science Hub

https://joint-research-centre.ec.europa.eu

Publications Office
of the European Union