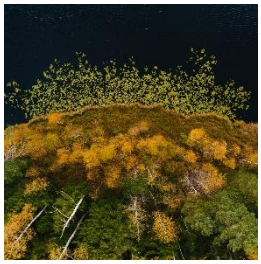
ORCaSa
Because soil carbon matters



Is there a place for international research on soil carbon?

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SUMMARY

Soils are the foundations of food security, ecosystem stability, and climate resilience. Beyond their essential role in agriculture and biodiversity, soils hold immense potential to contribute to carbon neutrality by sequestering atmospheric carbon. Recognized as a critical climate change mitigation strategy [1], soil carbon sequestration reduces greenhouse gas emissions (GHGs) while enhancing agricultural productivity and sustainable land use. However, integrating carbon sequestration into international research cooperation remains fragmented and insufficiently prioritized. Consequently, the global response remains disjointed and overly theoretical. Research initiatives could benefit from a stronger coordination to deliver the actionable solutions urgently needed to address the climate change crisis. Considering the limited financial resources, and the collective environmental and production challenges, synergies are urgently needed to face the emergency of adaptation to and mitigating climate change and to translate research findings into concrete actions.

- Ambitious initiatives support soil research at the national, regional, international levels.
- The scientific community is more and more structured and collaborative at the national and international levels.
- Several technical barriers remain to improve soil health and respond to climate change challenges

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INTRODUCTION

Soil carbon sequestration has the potential to mitigate greenhouse gas emissions, provided that more research on technologies can fill the knowledge gaps in quantification and verification [2,3]. At COP21, the French government launched the '4 per 1000 Initiative [4]: Soils for Food Security and Climate' targeting a global increase of 0.4% per year (or 4 per 1000) in soil carbon stock. This target is a sound and indispensable attempt to use soil-based solution to fight climate change, except that more research may be needed to ensure successful implementation at a large-scale level [5].

Over the last decade, numerous national and international research programmes have been launched on soils, including large-scale initiatives (Tables 1-2). At the national level, fitting the purpose of carbon sequestration, **"Bonares"** can be seen as a light-house German project funded by **BMBF** in the national programme "nationale Bioökonomiestrategie" for Germany (Table 2). Furthermore, **the Federal Humus Programme** was launched in 2019 to support model and demonstration projects. These initiatives have the advantage of directly involving farmers, enabling the adoption of humus-building methods as standard best practices. Additionally, research and development projects that explore biochar's use and potential benefits are also being supported. Similarly, the French government has funded through FairCarboN an ambitious fundamental research initiative on carbon and a continuum of research projects on soil carbon for 10 years. From methods to the deployment of measurements [6] and modeling [7], these projects have made it possible to better understand and simulate the effects of changes in land use, practices and production systems, on soil carbon stocks and flows, with applications and development towards decision-making tools at different scales from the plot to the territory, up to prospective approaches.

Also, in the last 10 years, European and international research programmes have been launched on soils including large scale initiatives such as the **European Joint Programme SOIL** [9] and the **MISSION SOIL** [10] targeting research on soil health in Europe (Table 1). At the international level, FAO promotes collaborative efforts to generate the regional action plans for sustainable management of soil resources. The **Global Soil Partnership** [11] hosted by the FAO promotes the development of sustainable soil management and represents a platform where multiple stakeholders discuss soil issues.

This policy brief revisits the role of soil carbon research in contributing to soil health and increasing climate change mitigation while reaching the Sustainable Development Goals.

METHODS: SURVEY OF INTERNATIONAL CALLS FOR PROPOSALS

We surveyed 45 calls for proposals related to soils and having an European or transnational dimension (the web pages for these call texts are provided in Table 1). We analyzed scopes and expected impacts to better highlight and compare the importance of the research topics targeting soil carbon and the disciplines involved.

RESULTS

- Many calls for proposals were funded in Europe in the last 10 years on soils for an overall budget above **450 M€** (Table 1).
- The European Joint Programme SOIL and the SOIL MISSION target **healthier soils** and attempt to involve **all stakeholders** (Tables 3 and 4).
- An emphasis on carbon storage and carbon sequestration has recently emerged (Figure 1). Several programmes have dedicated a significant budget to research soil carbon, health, and climate change. For example, **EJP SOIL** external calls dedicated about **9.2M€** to projects considering **carbon cycle** or **carbon sequestration** (35.5% of the external calls budget).
- Soil carbon is also often relegated to **secondary agendas** focused on broader **soil health or land management** issues, rather than being treated as the central focus it deserves. Soil studies often include several dimensions: topics about soils are embedded in more global topics such as agroecology, soil functioning and ecosystem services. Our analysis of topics covered by 45 international calls highlights **soil management as a major research theme** (Figure 1).
- Soil carbon, soil health and climate change are more and more interconnected in calls:

  - to analyse how changing climate patterns, affect soil properties and functions

  - to understand the role of healthy soils in adapting to and mitigating climate change impacts.

  - to understand how soil carbon sequestration can contribute to climate change mitigation (expected impacts of the EJP SOIL)

Table 1. Budget of calls in soil sciences and part dedicated to carbon cycle or carbon sequestration in transnational or European initiatives

Programme	Web page of the calls	All funded projects		Projects with some focus on carbon		
		Number of projects	Budget (million euros)	Number of funded projects	Budget (million euros)	% of the total budget
EJP SOIL 2020-2025	https://ejpsoil.eu	26	80	11	25.979	32.5%
EJP SOIL external calls 2021 and 2022	https://anr.fr/en/call-for-proposals-details/call/european-joint-programme-soil-1st-external-call-ejp-soil-1/?no_cache=1	18	25.9	8	9.185	35.5%
Belmont forum 2019	https://www.belmontforum.org/cras#soils2020	5	4.53	2	1.377	30.4%
BIODIVERSA SOIL 2015-2019	https://www.biodiversa.eu/wp-content/uploads/2022/12/biodiversa_2015-2016_cofund_call.pdf	8	12.6	2	4.109	32.6%
SOIL MISSION 2021	https://mission-soil-platform.ec.europa.eu/project-hub/funded-projects-under-mission-soil	11	63.470	0	0	0
MISSION SOIL 2022		18	93.113	3	17.061	18.3%
MISSION SOIL 2023		21	174.706	1	11.6	6.6%
TOTAL		107	454.3	27	69.311	15.3%

Figure 1. World cloud of research themes covered by 45 recent transnational funding calls related to soil sciences. Each theme was counted once per call text. The size of each word represents its relative importance based on its frequency across all call texts. The figure was drawn with the worldcloud2 package in R environment [12].

CONCLUSION

The role of soil in climate change, biodiversity, and desertification has transitioned from being a peripheral issue to a significant focus of discussion in all three (Biodiversity, Desertification and Climate) COPs since 2023. The sequestration of soil organic carbon is now recognized as a global issue, but climate does not receive the same attention in all research initiatives research projects. Research on soil organic carbon is still fragmented, which delays the implementation of scalable solutions. Given the national funds allocated locally to soil research, countries and institutions would benefit from meaningful synergies to adapt solutions to local needs. The absence of targeted calls for soil carbon research is a significant barrier to progress. Research on carbon sequestration is often placed under broader topics, which weakens its impact.

RECOMMENDATIONS

It is time for action. Each delay in aligning soil carbon research with actionable, real-world applications brings us closer to irreversible ecological and socio-economic consequences. Soil carbon sequestration is not a peripheral issue, but a frontline solution in the battle against climate change. The question is not whether we have the resources to act, but the collective determination to take decisive steps now. Without decisive and immediate action, the opportunity to leverage soil carbon as a global climate solution may soon slip beyond our reach.

Therefore, we recommend to:

- **Join the ORCaSa [13] Knowledge Hub dedicated to brainstorming about cooperation needs in the area of soil research with a specific focus on soil carbon sequestration:**
  - Participate in our meetings to discuss the research needs, shared *vs* local priorities, transferability across countries, and common goals to increase scientific cooperation and knowledge transfer
  - Meet scientific partners for our future research projects
  - Share your research needs with the funding bodies
- **Strengthen international cooperation:**
  - Avoid duplication of projects and create synergies
  - Speed the knowledge transfer across countries aiming at similar targets but facing different issues
  - Reach greater coordination among international funding bodies
  - Move from research to actions
  - Ensure research is scalable and relevant to diverse contexts
- **Align soil national research programmes** to:
  - Respond better to the global issues of climate change
  - Accelerate the translation of fundamental research into concrete actions
  - Carefully allocate financial resources dedicated to soil research
- **Prioritize international research on soil carbon**:
  - Launch calls focusing on soil carbon research while considering soil health and its indicators
  - Ensure resources are allocated to high-impact, actionable projects
  - Strengthen the connection between soil carbon research and other key aspects targeting healthier soils, including soil-subsoil interactions, the balance between organic and inorganic carbon, relationships with biodiversity, and the interconnection of all ecosystemic services provided by soils
  - Develop clear accountability metrics that link research to measurable outcomes in soil carbon sequestration and climate adaptation

ANNEXES

Table 2: Examples of national initiatives including soil research

Country	Initiative	Description	Budget	Reference or website
African countries	Soil Initiative for Africa (SIA)	The continental long-term framework for managing Africa's soil for agricultural productivity and effective ecosystem services. The SIA framework prioritises actions to halt soil degradation and improve soil health. The SIA is implemented through the 10-year Africa Fertilizer and Soil Health Action Plan.		https://faraafrica.org/soil-initiative-for-africa/
Australia	**SCaRP (2009-2012**	The Soil Carbon Research Programme is the largest and most extensive soil sampling and analysis program undertaken in Australia to measure soil carbon stock. Over 20,000 samples were taken from various soil types and farming operations across more than 4000 locations in selected farming regions.		https://csiropedia.csiro.au/wp-content/uploads/2016/06/SAF-SCaRP-methods.pdf
Australia	**National Soil Monitoring Program**	The NSMP is a key deliverable of the National Soil Action Plan. Priority 1 of the Action Plan includes the development of an 'agreed national framework to support the measurement, monitoring, mapping, reporting and sharing of soil state and trend information, to inform best practice management, decision making and future investment in soil'. The NSMP also supports the National Soil Strategy (2021) goal 3, to 'strengthen soil knowledge and capability'. The purpose of the NSMP is to monitor agreed physical, chemical and biological soil properties and to use the data to help understand soil conditions and trends.	**$21,599 million**	https://www.agriculture.gov.au/agriculture-land/farm-food-drought/natural-resources/soils/national-soil-monitoring-program https://research.csiro.au/nsmp/
Australia	**National Soil Carbon Innovation Challenge**	The National Soil Carbon Innovation Challenge aims to fast-track low-cost, accurate technological solutions for measuring soil carbon. The Soil Carbon Data Program aims to improve data in low-cost alternatives for measuring soil carbon. The program includes : -Engaging CSIRO and their state-based partners under the Soil Organic Carbon Monitoring Project (SOC-M). The SOC-M project will access and collect new data from 300 original Soil Carbon Research Program (SCaRP) sites to fast-track data collection that can support estimates of changes in soil carbon over time. -Making improvements to modelling soil carbon, including in rangelands ecosystems, in Australia's Full Carbon Accounting Model.	**$40 million**	https://www.dcceew.gov.au/climate-change/emissions-reduction/agricultural-land-sectors/soil-carbon-storage-measurement#toc_1
Brazil	**CCARBON/ USP**	The Center for Carbon Research in Tropical Agriculture at the University of São Paulo conduct research, innovation, and dissemination activities to promote low-carbon agriculture		https://ccarbon.usp.br/welcome-to-the-center-for-carbon-research-in-tropical-agriculture-at-the-university-of-sao-paulo-ccarbon-usp/
Brazil	**Brazilian national soil programme, PronaSolos**	Expands knowledge of Brazilian soils	**740 MB reais ($225M) for the first 10 years**	https://www.embrapa.br/pronasolos/sobre-o-programa

Canada	**NSERC Programme on Alliance Missions: Anthropogenic greenhouse gas research**	• Promotes interdisciplinary collaboration among researchers and policymakers to increase the scientific information available to support government decision-making to achieve net-zero GHG emissions targets • Builds on scientific capacity in earth system climate science, atmospheric monitoring/modelling and socio-economic analysis to understand anthropogenic GHG emissions at regional and national scales or by sector to inform ambitious GHG mitigation opportunities and to improve understanding of how GHG emissions are changing over time • Advances Canadian knowledge and tools to inform decision-making processes for the achievement of net-zero GHG emissions by 2050 through the investigation of anthropogenic GHG emissions and their changes over time	**3M CAD$** allocated to research on soil health and carbon sequestration in 2022 call	https://www.nserc-crsng.gc.ca/Innovate-Innover/AllianceMissions-MissionsAlliance/CFP-ADP/AGGR-RGESA/index_eng.asp
France	**FairCarboN**	FairCarboN is an exploratory project with priority research programme and infrastructure (PEPR) funding. It aims to harness the efforts of all French researchers studying carbon dynamics in continental ecosystems. With a six-year budget of €40 million, FairCarboN is clarifying how continental ecosystems can help mitigate the effects of climate change. This work is key in helping attain the Paris Agreement objectives	**40 M€**	https://www.peprfaircarbon.fr/eng
Germany	**Soil Systems**	Systems ecology of soils – energy discharge modulated by microbiome and boundary conditions		https://soilsystems.net/
Germany	**German Agricultural Soil Inventory (BZE-LW)**	The German Agricultural Soil Inventory (BZE-LW) is the first nationwide, uniform inventory of agricultural soils. On behalf of the Federal Ministry of Food and Agriculture, the organic carbon stocks down to a depth of one meter in agricultural soils throughout Germany were recorded for the first time between 2011 and 2018. The influence of site and management factors was assessed on soil organic carbon (SOC) stocks in a grid of 8 x 8 km. The initial BZE-LW was based on the voluntary participation of 3,104 farmers. Its primary purpose was the scientific validation and further development of Germany's greenhouse gas emission reporting within the framework of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol.		https://www.thuenen.de/en/institutes/climate-smart-agriculture/projects/agricultural-soil-inventory-bze-lw
Germany	**BonaRes**	**BonaRes** is short for "Soil as a sustainable resource for the bioeconomy". In this funding initiative of the German Federal Ministry for Education and Research (BMBF) the focus is on the sustainable use of soils as a limited resource. The ultimate goal of interdisciplinary research is to extend the scientific understanding of soil ecosystems and improve the productivity of soils and other soil functions while developing new strategies for sustainable use and management. As major products of the coordinating BonaRes Center, data repositories and model tools have been developed to assess and predict the impact of soil management measures on soil fertility and other critical soil functions.	**108 M €**	https://www.bonares.de/
Germany	**Rhizo4Bio**	The main goal is the investigation of the interplay between plant roots and their local environment, the rhizosphere. The research focuses on processes in structured soils and/or agricultural ecosystems covering the entire scale from microscopic to open fields. The insights improve soil productivity, resistance to pests, and resilience to abiotic stress and reduce agrochemical use.	**20 M€**	https://www.bonares.de/service-portal/projects
Germany	**Federal Humus Program 2025**	The German Federal Government's 2030 Climate Action Program stipulates that the carbon storage potential of agricultural soils should be increasingly activated. As part of the Federal Humus Program, the Federal Ministry of Food and Agriculture (BMEL) is implementing various measures to	**8.20 M€**	https://www.ble.de/DE/Projektfoerderung/Foerderungen-Auftraege/Bundes

		generate knowledge about humus-enhancing and humus-preserving agriculture and disseminate this knowledge as widely as possible in agricultural practice.	programm_Humus/Humus_node.html
Lebanon	**national grant research program (GRP) of CNRS**	the programme targets soil as a component of an agro-eco-system, focusing on the environment and agricultural development.	

Table 3. Mission SOIL-specific objectives (https://mission-soil-platform.ec.europa.eu/about/mission-soil)

1.	Reduce land degradation relating to desertification
2.	Conserve and increase soil organic carbon stocks
3.	No net soil sealing and increase reuse of urban soils
4.	Reduce soil pollution and enhance restoration
5.	Prevent erosion and rehabilitate degraded areas
6.	Improve soil structure to enhance soil habitat quality for soil biodata and crops
7.	Reduce the EU global footprint on soils
8.	Increase soil literacy in society across Member States

Table 4. The six expected impacts of EJP SOIL (https://ejpsoil.eu/**)**

1.	Fostering an understanding of soil management and its influence on climate change mitigation and adaptation, sustainable agricultural production and environment
2.	Understanding how soil-carbon sequestration can contribute to climate change mitigation at the regional level and accounting for carbon
3.	Strengthening scientific capacities and cooperation across Europe including training young soil scientists
4.	Supporting harmonized European soil information, including international reporting
5.	Fostering the uptake of soil management practices conducive to climate change adaptation and mitigation
6.	Develop and demonstrate region- and context-specific fertilization practices (soil, water and pedoclimatic conditions)

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1. Conclusions

The objective of the task 3.2 about the Knowledge Hub is reached. The Knowledge Hub goes beyond knowledge sharing and aims at identifying tangible actions to increase soil organic carbon and thereby contribute to attenuation of greenhouse gas emission. The workshops were organized around four actions chosen by the Hub members:

- Mapping international soil carbon priorities
- Observation accessibility
- Transfer of practices
- The long-term perspective

The production of at least one Policy Brief was achieved and there is some potential to write some others after the end of the project. It would be relevant to write a series of policy briefs that recipients (the funders) would receive periodically as a kind reminder of challenges in soil research and its funding. It could become a habit to receive news of soil science research funding from our Knowledge Hub. In these policy briefs, we could discuss the calls for proposals under several angles: content of the calls, research needs and gaps, funding instruments… Two themes of interest suggested by the Knowledge Hub members are: the soil ontology used in the calls for proposals and the concrete set up of transdiciplinarity in soil research projects.

Next, to keep this community active after the project, we have included the animation activities in the service 3 of the Soil Carbon Futures international consortium "international research collaboration and alignment". These activities aim to keep this community active and attractive. They offer:

✓ Access to a Hub different from other Knowledge Hubs
    It involves representatives from funding agencies
    It integrates diverse disciplines within each group to address barriers to soil carbon sequestration
✓ Stimulate connections with other communities
    It involves researchers from several European projects and the Global Soil Partnership
✓ Monthly scientific webinars
✓ Biannual workshops which go beyond scientific conferences by preparing policy briefs and discussing how the actions can be translated and applied across the countries
✓ Coordination of article writing (policy briefs and opinion papers) and dissemination of one publication per workshop