ORCaSa
Because soil carbon matters

ORCaSa

Operationalising International Research Cooperation on Soil carbon

Deliverable D3.2

Knowledge Hub Policy Brief 2024

Due date of deliverable: M34

Actual submission date: M34

Start date of the project: September 1st, 2022 **Duration:** 36 months

Organisation name of lead contractor: ANR

Funded by
the European Union

Document Information

Grant agreement n°101059863	
Project title	Operationalising the International Research Cooperation on Soil Carbon
Project acronym	**ORCaSa**
Project duration	36 months (01/09/2022 – 31/08/2025)
Coordinator	Suzanne Reynders - INRAE
Related work package(s)	WP 3
Related task(s)	T 3.2
Lead organisation	ANR
Contributing partner(s)	INRAE
Due date	**30/06/2025**
Submission date	17/04/2026
Dissemination level	PU

History

Date	Version	Submitted by	Reviewed by
27/06/2025	N°1	Nathalie Pavy and Ines Soltani	Mathieu Nogues
8/04/2026	N°2	Nathalie Pavy	Heather McKhann
13/04/2026	N°3	Nathalie Pavy	Suzanne Reynders et Cloe Paul-Victor

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1. Summary

Objectives:

The objectives were to bring key messages about soil carbon research to the attention of funders, identify knowledge gaps in soil science and feed the Strategic Research and Innovation Agenda developed in WP2.

Rationale:

We have set up a Knowledge Hub, that is a network of international experts interested in soils and working in several disciplines. This hub was set up by the ANR in collaboration with international funding agencies and met throughout the project to discuss barriers to carbon sequestration. The ANR designed and organized several webinars and workshops to brainstorm more particularly on the key messages for funders. Therefore the policy brief produced was oriented towards research policy. To produce this deliverable, several contributors of the Knowledge Hub worked on a draft about funding of soil research. Its objective is to promote carbon research and to highlight opportunities for international collaboration by providing an overview of European and national funding. Beyond research policy, the Knowledge Hub members provided several recommendations regarding broader policy needs.

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Partners involved:

ANR, INRAE

2. Introduction

Definition of a Knowledge Hub :
We define Knowledge hubs as thematic networks consisting of selected research groups within a defined area. Aims are the to:

- ✓ Increase and facilitate cooperation.
- ✓ Integrate and share knowledge, infrastructures, data, modelling tools, key lessons, etc.
- ✓ Train and perform capacity building.
- ✓ Provide scientific support for strategic and political decision making.

Scope, membership logic, governance/light-touch modus operandi
The scope is soil carbon, as determined through the brainstorming with international researchers about research priorities on soil cabon and deliver key messages to research funding agencies.
Members are nominated by national funders and contributions are made on a voluntary basis. The activities of the Knowledge Hub have been fully conceived and managed by the ANR. In particular, the content of the workshops was designed by the ANR following a consultation of a number of French experts. The ANR also managed the workshops and their outputs (Policy Brief, reports).

Complementarity and interfaces with other ORCaSa/Soil Carbon Futures assets (e.g., platform/tools, SRIA-related outputs, workshop series)
This Knowledge Hub is a community of experts interested in brainstorming about soil sciences, soil health, research needs to improve the fight against climate change. It completely differs from Impact4soil (developed in the WP4) which is an informatic platform serving as a knowledge repository including data about research results and research projects. The discussions on research needs and international cooperation needs have been linked to the work on the Strategic Research & Innovation Agenda (SRIA) developed in WP2. Logically, several ORCaSa partners from WP2, WP4 and WP5 have been involved and contributed to the workshops.

3. Results

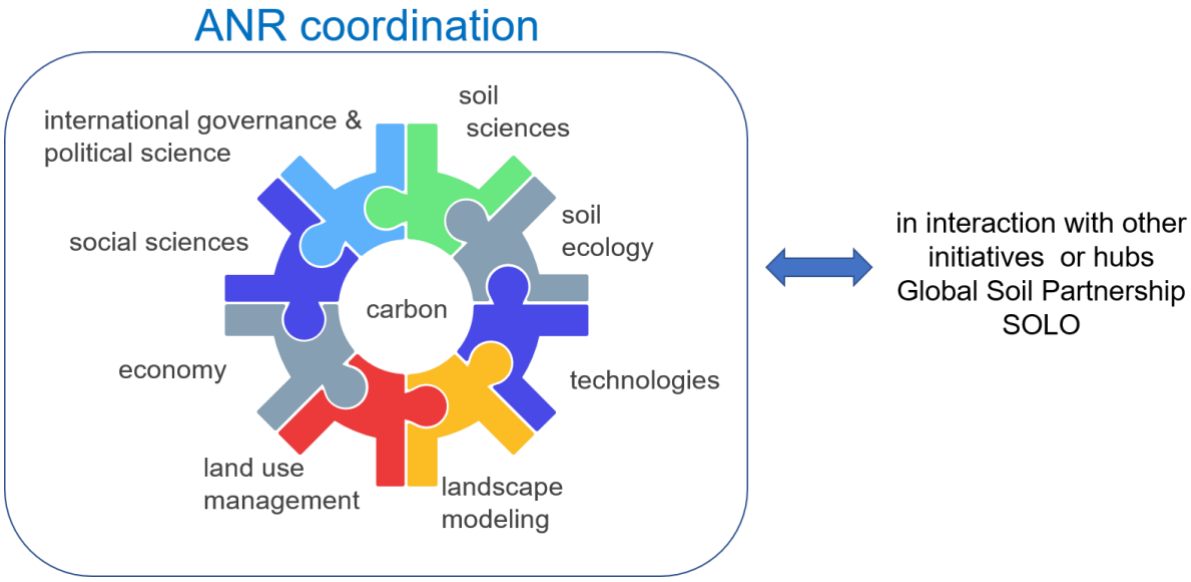
Implementation of the Knowledge Hub

In July 2023, ANR organized two workshops to introduce the Knowledge Hub and TAP actions to all its partners involved in funding environmental science. The INRAE partners presented the ORCaSa project on this occasion.These upstream discussions relied on scientific presentations to overview the goals, some work already achieved to build international research consortia on soil carbon and reports from previous similar initiatives undertaken by the Facce-JPI and the Water JPI. They were followed by discussions about the steps needed to launch similar activities about soil carbon. In total, 50 participants attended the workshops, representing 11 countries from Europe, 9 countries from Africa, 5 countries from Asia and 5 countries from the Americas and Australia. ANR organized several meetings with institutions unable to attend these two first workshops. Then, the ANR asked the participants to appoint scientific experts to build the ORCaSa Knowledge Hub. The ANR circulated a survey among funders to ask for their contributions to identify highly qualified experts, both junior and experienced researchers, from diverse institutions and working in any field consistent with carbon sequestration. The funders chose to include the following disciplines in the hub: soil sciences, ecology and biodiversity, biogeochemistry, technologies and artificial intelligence, soil landscape modelling, digital soil mapping, remote and proximal sensing, history and sociology, international governance, economy, agricultural and food policies. The objective is to foster meetings among researchers having the

same preoccupation but not collaborating with each other or not knowing each other. In accordance with ORCaSa objectives:

- Experts know challenges posed by a variety of soils and ecosystems: agroecosystems, peatlands, urban soils, oasis, tundra and boreal, forests, mangroves, savana, afro-alpine wetlands.
- The INRAE task leader of the ORCaSa Strategic Research Innovation Agenda was included in the Knowledge Hub

Figure 1: Organization of the ORCaSa Knowledge Hub. The figure illustrates the research disciplines converging towards soils and covered by the Hub as well as the interactions in place with the Global Soil Partnerhip (group coordinated by the FAO) and the SOLO project (Horizon Europe Coordination and Support Action on soil health)



Preparation of the workshops

To frame the work asked to these experts, the ANR organized preparatory meetings with a core group (Table 1). The meetings aim to delineate the Knowledge Hub objectives, methods, targeted policy briefs. During the first workshop, ANR presented the initiative and experts introduced themselves and proposed links with other teams. During the second workshop, members agreed on the objectives and operating methods. During the third workshop, themes of interest to develop a position paper or a policy brief were discussed. During this phase, the Knowledge Hub grew progressively involving experts not knowing each other. Two webinars were organized to enable participants to introduce their ongoing research projects and discuss themes that could be developed during the workshops.

Table 1: Preparatory workshops and webinars to set up an international Knowledge Hub

date	Objective of the meeting	Number of participants	Number of organizations
15/11/2023	Discussion about the structure and functioning of the Hub	11	9
18/01/2024	Discussion about the structure and functioning of the Hub	5	4

6/02/2024	Webinar by Christian Hartman, Green test results from the GLOSOLAN Global Soil Laboratory Network, Global Soil Partnership (GSP) FAO	10	8
5/03/2024	Webinar by Laure Manach, Les promesses de la séquestration du carbone dans les sols, Centre Alexandre Koyé, CNRS	5	3
17/05/2024	Workshop on the agenda of the series of international workshops	3	2

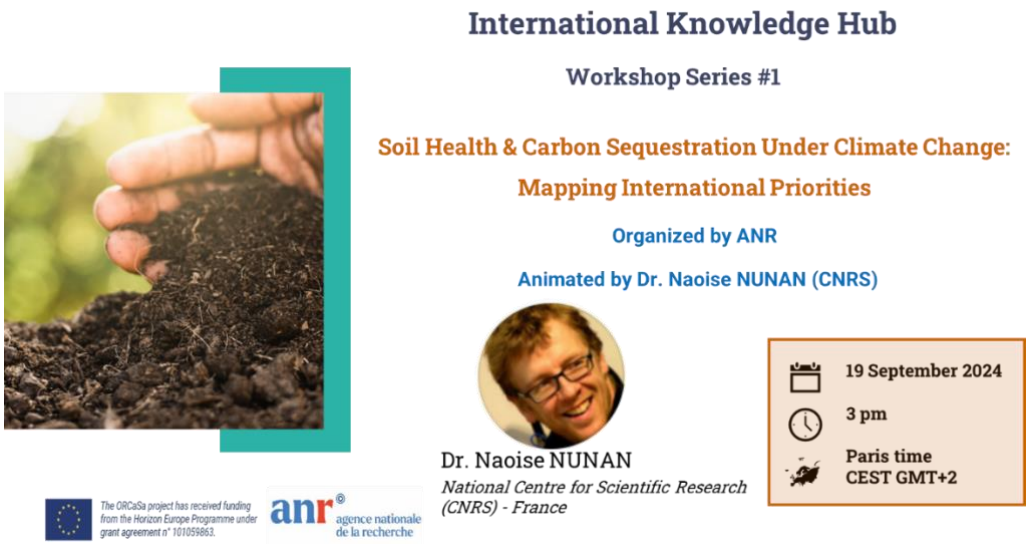
The main outcomes of these preparatory workshops were to:

- Identify clear and realistic objectives
- Differenciate the Hub from other existing hubs on soils
- Prepare a strong basis to attract international experts and ensure credibility

We have decided to organize a series of international workshops divided in four sessions around four themes (Figure 2).

- Session 1: Mapping international soil health & carbon sequestration priorities
- Session 2: Observation accessibility - Harmonizing observations for climate resilience
- Session 3: Transfer of practices
- Session 4: The long-term perspective

Figure 2: Posters announcing the four international workshops



International Knowledge Hub

Workshop Series #2

Observation accessibility

Harmonizing observations for climate resilience

Organized by ANR

Animated by Dr. Manuel MARTIN (INRAE)

Dr. Pierre Barré
CNRS/ENS and FairCarboN – France
Dr. Ahmad Al Bitar
CNRS/CESBIO and ORCASA – France
Dr. Fenny Van Egmond
ISRIC, The Netherlands
Prof. Budiman Minasny
U. of Sydney, Australia
Dr. Macoumba Loum
INP, Senegal

11 October 2024
9 am
Paris time
CEST GMT+2

The ORCaSa project has received funding from the Horizon Europe Programme under grant agreement n° 101059863.

please write us at orcasa@anr.fr if you would like to join

International Knowledge Hub

Workshop Series #3

Transfer of practices

Organized by ANR

Animated by Dr. Beata MADARI (EMBRAPA)

Prof. Joann Whalen, McGill University – Canada
Prof. Axel Don, The Institute of Climate-Smart Agriculture - Germany
Dr. Edvaldo Sagrilo, EMBRAPA - Brazil
Dr. Maria De La Luz Mora Gil, University de la Frontera - Chile
Prof. Mohamed Moussa, IRA - Tunisia

29 October 2024
3 pm
Paris time
CEST GMT+2

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International Knowledge Hub

Workshop Series #4

The long term perspective

Organized by ANR

Animated by Dr. Silvia POBLADOR (U. of Barcelona)

Dr. Leigh Ann Winowiecki
CIFOR-ICRAF - Kenya
Dr. Ebagnerin Jérôme Tondoh
University Nangui Abrogoua – Ivory Coast
Prof. Hans Jörg Vogel
Helmholtz Centre for Environmental Research – Germany
Prof. Felix Ngetich, Jaramogi Oginga Odinga University - Kenya

7 November 2024
3 pm
Paris time
CEST GMT+2

The ORCaSa project has received funding from the Horizon Europe Programme under grant agreement n° 101059863.

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Contributions of the ORCaSa partners

Several ORCaSa partners contributed to the workshops:

- Dr. Delphine Derrien from INRAE participated actively since she is also ORCaSa task leader coordinating the Strategic Research and Innovation Agenda (WP2).
- Dr. Ahmad Al Bitar (CNRS) and Dr. Fenny van Egmond (ISRIC) both members of the ORCaSa project and contributors of WP4 also actively participated in discussions about measures (Workshop session 2).
- Dr. Abigael Fallot from CIRAD gave a talk about the social science dimension in soil science research (Workshop session 4).
- Dr. Beata Madari from EMBRAPA (Brazil) moderated the workshop session 3. These workshops were also opportunities to present the Soil Carbon IRC. Mathieu Nogues and Dr. Suzanne Reynders presented twice the progress to set up the IRC and eventually enroll new members.

Participations to the Knowledge Hub

In total, 86 persons participated to the international workshops of the Knowledge Hub.

- There were 67 researchers from 23 countries: Australia (1), Belgium (2), Brazil (3), Cameroon (3), Canada (1), Finland (2), France (15), Ghana (10), Senegal (5), Kenya (4), Morocco (4), Ivory Coast (3). Germany (2), Switzerland (2), Tunisia (2), Irland (1), Lebanon (1), Nigeria (1), The Netherlands (1), Portugal (1), South Africa (1), Spain (1), USA (1).
- There were 16 representatives from funding institutions from Argentina (INTA), Brazil (EMBRAPA and FAPESP), France (ANR and Ministry of Research), Germany (BLE), Ivory Coast (FONSTI), Kenya (NRF), South Africa (NRF).
- There were also 3 representatives of the FAO or Global Soil Partnership.

The participation was strong at each session:

- Session 1- 19/09/2024: 63 participants representing Europe, Africa, Latin America, and the Middle East
- Session 2- 11/10/2024: over 50 participants from public agencies, research institutions, and NGOs across four continents
- Session 3 - 29/10/2024: 50+ participants from four continents
- Session 4 - 7/11/2024: 50+ participants from Africa, Europe, Latin America, and the Mediterranean

Programme of the session 1 and main results: Mapping international soil health & carbon sequestration priorities

The programme of the first session was designed by the ANR and the session was prepared with Dr. Naoise Nunan (CNRS, France).

International Knowledge Hub:

Workshop on **Mapping international soil health & carbon sequestration priorities** – Session1

19 September 2024 from 03:00 - 5:00 PM Paris Time CEST GMT+2

Opening, Welcome remarks	
03:00 - 03:10	**Overview and introduction** **Dr. Nathalie PAVY,** *The French National Research Agency (ANR) - France*
Mapping international soil health & carbon sequestration priorities Facilitator: **Dr. Naoise NUNAN**, *The French National Centre for Scientific Research (CNRS) - France*	
03:10 - 03:50	◎ **Soil Health Under Climate Change: Assessment and Improvement** **Dr. Abad CHABBI,** *French National Institute for Agriculture, Food, and Environment (INRAE) – France* ◎ **Challenges and Perspectives for Carbon Sequestration and Sustainable Soil Health** **Dr. Talal DARWISH,** *National Council for Scientific Research (CNRS-L) - Lebanon*
Roundtable discussion	
03:50 - 04:50	◎ **Dr. Delphine DERRIEN,** *French National Institute for Agriculture, Food, and Environment (INRAE) – France* ◎ **Dr. Carlos António Guerra,** Soil for Europe (SOLO) coordination, University of Coimbra –Portugal ◎ **Dr. Edward YEBOAH,** *the Council for Scientific and Industrial Research-Soil Research Institute (CSIR-KUMASI) – Ghana* ◎ **Dr. Karl RICHARDS,** *TEAGASC-The Agriculture and Food Development Authority – Ireland*
Closure of the meeting	
04:50 - 05:00	Recapitulation of key points discussed during the workshop Workshop closure

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Dr Naoise NUNAN, research director at *the French National Centre for Scientific Research (CNRS) – France*, is a soil ecologist, specializing in soil ecology, focusing on soil water, microbial population biology, spatial ecology, and geostatistics. His research integrates soil science with environmental chemistry, focusing on soil carbon dynamics, microbial community distribution, and soil structure. Recent work highlights soil organic carbon sequestration and decomposition complexities, enhancing the understanding of soil health and ecosystem sustainability.

Dr Abad CHABBI, Research Director at the *French National Institute for Agriculture, Food, and Environment (INRAE) – France*, is a plant ecologist and soil biogeochemist. He has worked at Louisiana State University (USA), the Faculty of Environmental Science in Cottbus (Germany), and the University of Pierre & Marie Curie (France). Since 2009, he has led the National Observatory for Environmental Research. His research focuses on biogeochemical cycles in the context of climate and land use changes. Dr. Chabbi coordinates major international projects, including those funded by the European Commission, and chairs a Working Group at the FAO/IAEA Division. He is an adjunct professor at Nanjing University (China), Universidade Federal do Rio Grande do Sul (Brazil), and Universidad de La Frontera (Chile). With over 165 published papers, he has supervised 25 PhD students and postdocs.

Dr Talal DARWISH, is a soil scientist with extensive experience at the *National Council for Scientific Research (CNRS-L) – Lebanon*, where he served as Director of Research and Director of the National Center for Remote Sensing until 2014. His research spans soil mapping, soil and land degradation, and soil contamination. Dr. Darwish has supervised over fifty Master's and PhD students and has published more than 150 papers. He has led projects such as the detailed soil map of Lebanon and provided crucial data for various national and international initiatives. He has served on numerous committees, including the Intergovernmental Technical Panel on Soils (ITPS) and the FAO-GSP, and is currently Deputy Director of the Academic Committee of the China-Lebanon Joint Laboratory of Modern Agriculture and Water Management.

Dr. Edward YEBOAH is a Chief Research Scientist at *the Council for Scientific and Industrial Research-Soil Research Institute in Kumasi – Ghana.* His research focuses on nutrient and soil organic dynamics in tropical agroecosystems. Dr. Yeboah collaborates with farmer groups, input suppliers, and Community Based Organizations to develop innovations and enhance soil fertility practices. He currently leads a consortium in Ghana under the AGRA-USAID Partnership for Inclusive Agricultural Transformation (PIATA) initiative and coordinates grants from organizations including the African Plant Nutrition Institute (APNI) and FAO RECSOIL. He serves as President of the Soil Science Society of Ghana, Focal Person for the Global Soil Partnership (GSP) in Ghana, and is a member of the International Union of Soil Sciences (IUSS) Presidential Election Committee and the Soil Organic Carbon Community of Practice of the Africa Climate Action Partnership (AfCAP).

Dr Delphine DERRIEN, is a research scientist at at the *French National Institute for Agriculture, Food, and Environment (INRAE) – France*, pecializing in the processes that control soil organic carbon dynamics, particularly in forest soils. Her expertise spans soil science, forestry, environmental science, and geochemistry. Delphine is actively involved in the EU research program ORCaSa, where she leads efforts to identify research and innovation needs related to soil organic carbon. Her work aims to develop a region-specific Strategic Research and Innovation Agenda.

Dr. Karl RICHARDS is a Principal Research Officer and Head of the Environment Soils and Land-Use Department at *Teagasc Johnstown Castle – Ireland*. His research focuses on nitrate leaching, nitrous oxide emissions, environmental microbiology, and sustainable agricultural practices. Since joining Teagasc in 2002, he has led significant research on nitrogen cycling and emissions reduction and has published over 125 peer-reviewed scientific papers. As Head of the Teagasc Climate Centre, he has advanced initiatives such as the National Agricultural Sustainability Research and Innovation Centre (NASRIC) and the National Soil Greenhouse Gas Testing Facility. His current work includes developing the Strategic Research and Innovation Agenda for the Climate Centre, addressing climate and biodiversity challenges in agriculture.

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Dr. Carlos A. Guerra is a researcher at the *University of Coimbra – Portugal* and coordinator of the "*Soils for Europe (SOLO)*" project, which focuses on advancing soil health and sustainability across Europe. His research spans environmental dynamics, soil ecosystem conservation, and large-scale ecological assessments. Dr. Guerra has led key initiatives, including the "*Global Soil Biodiversity Observation Network (SoilBON)*" and "*Ecossistemas do Solo no Século XXI: pressões, conservação e cenários futuros.*" He has contributed extensively to projects on biodiversity monitoring, environmental risk management, and geospatial analysis. With over 50 publications in international journals and books, his work integrates natural and social sciences to provide evidence-based solutions for global environmental challenges, supporting sustainable development and informed policymaking.

Main results of session 1:

The focus of this session was about the regional priorities which can be summarized as follows:

Region	Strategic Emphases
Western Europe	Soil-climate modelling, monitoring system innovation, policy alignment (EU)
Ireland	Peatland rehabilitation, SOC vs GHG flux paradoxes, national thresholds
France	Linking research to legislative frameworks, supporting Soil Health Law and cross-sectoral action plans
Ghana / West Africa	Farmer-centered fertility strategies, digital soil mapping, limited access to lab equipment
North Africa / NENA	Salinity, soil erosion, rapid land-use changes, need for national soil policies

Strategic Barriers and recommendations

Challenge	Recommended Response
Fragmented data and non-harmonized protocols	Invest in interoperable, multi-level monitoring systems with clear metadata and common vocabularies
Functional indicators are research-heavy and policy-weak	Create hybrid indicators: scientifically sound, but simple, scalable, and policy-friendly
Disconnect between soil research and farmer realities	Mainstream co-creation of knowledge and tools with agricultural communities and extension agents
North–South asymmetry in access to labs, funding, and standards	Build long-term partnerships, support regional soil hubs, include infrastructure in funding requirements
Soil health underrepresented in climate/biodiversity legislation	Elevate soil as a core asset in national and international environmental strategies

- Soil health assessments must evolve from static, descriptive metrics (e.g. SOC content, pH) toward a functional understanding of how soils support ecosystems and human needs.
- Promote collaborative prototyping of functional indicators with both scientists and end-users, ensuring indicators are scalable, repeatable, and meaningful across contexts.
- Develop regionally calibrated SOC thresholds and combine them with GHG flux assessments for a holistic view of soil-climate interactions.
- Co-design a tiered monitoring architecture—a harmonized core indicator set (SOC, pH, respiration, infiltration), with region-specific modules as needed.
- Expand long-term trials and cost-benefit studies across diverse agroecological zones, especially in the Global South.

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- Develop open-source tools and low-cost protocols
- Launch North-South twinning schemes for lab capacity and data analysis
- Include capacity building as a formal KPI in all relevant calls
- Prioritize equity in soil research programming and empower under-resourced regions with locally adaptable technologies.

Programme of the session 2 and main results: Observation accessibility - Harmonizing observations for climate resilience

This session was prepared with Dr. Christian Walter and Dr. Manuel Martin (INRAE). It involves several ORCaSa partners : Mathieu Nogues (WP1), Dr. Fenny van Egmond and Dr. Ahmad Al Bitar (WP5).

International Knowledge Hub: Workshop on **Harmonizing Observations for Soil Carbon and Climate Resilience** – Session2

11 October 2024 from 09:00 - 11:00 AM Paris Time CEST GMT+2

Opening, Welcome remarks	
09:00 - 09:10	**Introduction** Dr. Inès Soltani, *The French National Research Agency (ANR) - France* **Launch and progress of the Soil Carbon International Research Consortium** Mr. Mathieu Nogues, *French National Institute for Agriculture, Food, and Environment (INRAE) - France*
Observation Accessibility: Harmonizing Observations for Soil Carbon and Climate Resilience Facilitator: **Dr. Manuel Martin**, *The French National Institute for Agriculture, Food, and Environment (INRAE) – France*	
09:10 - 09:50	◎ **The need for a task force to provide validated models simulating changes in soil organic carbon stocks** Dr. Pierre Barré, *French National Centre for Scientific Research (CNRS)/ ENS and FairCarboN coordinator – France* ◎ **An innovative hybrid approach for the Monitoring Reporting and Verification of Soil Carbon Farming** Dr. Ahmad Al Bitar, *French National Centre for Scientific Research (CNRS)/ CESBIO – France* ◎ **Running SOC dynamics models for large areas, the uncertainties of using readily available data and the effect of spatial aggregation** Prof. Bas van Wesemael, *Université catholique de Louvain (UCLouvain) and* MRV4SOC p*roject – Belgium*
Roundtable discussion	
09:50 - 10:50	◎ **Dr. Fenny Van Egmond,** *Wageningen Environmental Research (WENR) and ISRIC – The Netherlands* ◎ **Prof. Budiman Minasny,** *University of Sydney – Australia* ◎ **Dr. Macoumba Loum,** *Research Scientist, INP – Senegal*
Closure of the meeting	
10:50 - 11:00	Recapitulation of key points discussed during the workshop Workshop closure

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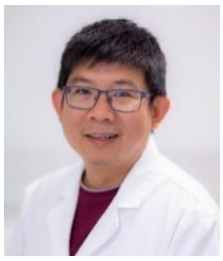
Dr. Manuel Martin is a Research Engineer at The French National Institute for Agriculture, Food, and Environment (INRAE), specializing in soil organic carbon monitoring and digital soil mapping. With a PhD in Spatial Ecology and over 20 years of experience, he employs a combination of statistical, dynamical, and sampling design-based approaches to assess soil carbon changes from regional to national scales. Dr. Martin is actively involved in several European projects, including H2020 Landmark, JPI-FACCE Comet Mondial, and CIRCASA. Recently, he coordinated a project aimed at improving France's greenhouse gas emission inventories for the Land Use, Land Use Change, and Forestry (LULUCF) sector. Additionally, he contributes to the production of soil digital maps as part of the GlobalSoilMap initiative and oversees the estimation of Available Water Content in French soils.

Dr. Pierre Barré is a soil biogeochemist and carbon specialist whose research spans micro-scale mechanisms of organic matter stabilization to the regional quantification of carbon stock changes. He is a Research Scientist at CNRS, affiliated with the Laboratoire de Géologie at the École Normale Supérieure (France). Dr. Barré investigates the influence of soil mineralogy on essential ecosystem processes, particularly focusing on carbon stabilization and nutrient cycling. By integrating concepts from biogeochemistry and ecology, he evaluates the resilience of stable soil carbon fractions and their vulnerability to global change. Additionally, he co-directs the FairCarboN program, an exploratory research initiative aimed at advancing our understanding of the carbon cycle and identifying strategies for achieving carbon neutrality in the context of climate change.

Dr. Ahmad Al Bitar is the Head of Development for the AgriCaron-EO MRV and an Expert in Earth Observation at CESBIO in Toulouse, France. He earned his PhD in Earth Sciences from INPT and his MS from INSA-Lyon. Dr. Al Bitar was a visiting scientist at Princeton, IISc Bangalore, and Neuchâtel University. His research addresses the integration of Earth observation into physical modeling using assimilation and machine learning to answer climate change mitigation and sustainable development challenges. He has published over 120 research papers (h-index 44) and was part of expert teams for space agencies (CNES, NASA, ESA, and ISRO). Additionally, he engages in private-public partnerships with organizations focusing on integrating hybrid solutions for carbon farming.

Prof. Bas van Wesemael is an emeritus professor of physical geography at the Earth and Life Institute of the Université catholique de Louvain (Belgium). His research focuses on soil property dynamics at landscape and regional scales, exploring the drivers of spatial patterns and their impacts on carbon and water cycles. He develops VNIR-SWIR reflectance spectroscopy techniques to improve soil property monitoring. Currently, Currently, he is involved in the EU-funded MRV4SOC project, which aims to monitor carbon farming through standardization, reporting, and verification, addressing challenges such as soil organic carbon accumulation due to climate change. Over the past two decades, he has led around 40 projects and contributed to initiatives on greenhouse gas emissions and soil organic carbon dynamics, publishing extensively in the field and serving as associate editor for the European Journal of Soil Science.

Dr. Fenny Van Egmond is a Soil Sensing and Soil Information Specialist at ISRIC – World Soil Information (The Netherlands). She specializes in soil data exchange standards and the standardization of soil sensing techniques. She actively participates in and leads several European projects, including EJP SOIL, SoilWise, and BENCHMARKS, while also engaging in initiatives like the IUSS Soil Information Systems Working Group and the Global Soil Partnership (GSP). Dr. Van Egmond holds Master's degrees in Soil Inventory and Land Evaluation and Geo-Information and Remote Sensing from Wageningen University. Prior to her current role, she worked with The Soil Company and Medusa Explorations, applying proximal soil sensing techniques for local mapping in agriculture, archaeology, and environmental assessments.



Prof. Budiman Minasny is a Professor of soil-landscape modeling at the University of Sydney (Australia), leading the Soil, Carbon, and Water theme at the Sydney Institute of Agriculture. He has published over 160 articles in international journals and was recognized as a Highly Cited Researcher in 2019. His research emphasizes soil dynamics and employs innovative methodologies, including mechanistic and machine learning models. As a leader in digital soil mapping, Prof. Minasny has contributed to initiatives like GlobalSoilMap, addressing food security and climate change challenges. He is also a member of the Scientific and Technical Committee (STC) for the International "4 per 1000" initiative, aimed at increasing soil carbon sequestration. In 2022, he was awarded the Richard Webster Medal by the International Union of Soil Sciences (IUSS) for his significant contributions to the field.

Dr Macoumba LOUM is a researcher at the National Institute of Soil Science of Senegal (Institut National de Pédologie, INP/Senegal). The research's area of interest of Dr LOUM revolve around Digital Soil Mapping, modeling of organic carbon dynamic on the soil which includes applications of GIS and remote sensing tools. The publications of Dr LOUM focused on soil fertility mapping, near infrared spectroscopy of soil and sustainable land management options related to climate change. Head of the Division of Research Development and Innovation of INP until august 2024, Dr LOUM is presently the Head of the Division of the Soil Mapping and Cadastre of Agricultural Land of INP.

Main results of session 2:

The second session reaffirmed the collective commitment to making soil carbon monitoring fit for purpose—scientifically credible, regionally responsive, and policy-relevant. This session reinforced the need for pragmatic harmonization—combining scientific rigor with operational feasibility. It highlighted

i) the importance of collaborative design, regional calibration, and policy-oriented communication.
ii) The need of clarity, transparency, and scientific interoperability in model development.

The strategic Barriers and recommendations are :

Barrier	Recommendation
High monitoring costs and infrastructure gaps	Fund regional labs and deploy low-cost, scalable tools
Disconnection between models and local needs	Engage end-users in model co-development and feedback
Technical data inaccessible to decision-makers	Simplify outputs through visuals and storytelling
Fragmented validation efforts	Build cross-border calibration networks and reference sites
Structural North–South inequality	Launch twinning programs and equitable funding criteria

- Design a multi-level monitoring framework that combines universal indicators (e.g., SOC, pH) with region-specific extensions to maintain both comparability and relevance.
- Establish regional calibration networks and long-term reference datasets to support model transparency and reproducibility.
- Make equity and affordability core design principles by promoting low-cost, scalable methods and requiring co-financing and capacity-building in all relevant initiatives.
- Co-create visual and narrative tools to express uncertainty and enable informed trade-offs, tailored for policy, farmer, and funder audiences.

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Programme of the session 3 and main results: Transfer of practices

This session was prepared with Dr. Beata Madari (EMBRAPA, WP4) who animated the session and introduced by Dr. Suzanne Reynders (INRAE, coordinator of ORCaSa).

International Knowledge Hub: Workshop on Transfer of Practices – **Agricultural and Forestry Practices for Enhancing Soil Health & Carbon Sequestration**

29 October 2024 from 03:00 - 05:00 PM Paris Time (UTC +1)

Opening, Welcome remarks	
15:00 - 15:10	**Introduction** **Launch and progress of the Soil Carbon International Research Consortium** Dr Suzanne REYNDERS, *ORCaSa coordinator, French National Institute for Agriculture, Food, and Environment (INRAE) - France*
Transfer of practices: Agricultural and forestry practices for enhancing soil health & carbon sequestration Facilitator: **Dr. Beata MADARI**, *EMBRAPA– Brazil*	
15:10 - 15:50	◎ **Agricultural practices supporting soil health and carbon sequestration in semi-arid regions of North America and Africa** Prof. Joann WHALEN, *McGill University – Canada* ◎ **Potential of different agricultural measures to enhance soil C and soil health at European scale** Prof Axel DON, *Institute of Climate-Smart Agriculture – Germany* ◎ **Challenges to improve soil health and resilience in Brazilian Northeast** Dr. Edvaldo SAGRILO, *EMBRAPA – Brazil*
Roundtable discussion	
15:50 - 16:50	◎ **Dr. Maria De La Luz MORA GIL,** *University de la FRONTERA – Chile* ◎ **Prof. Mohamed MOUSSA,** *Institut des Régions Arides – Tunisia* ◎ **Speakers**
Closure of the meeting	
16:50 - 17:00	Recapitulation of key points discussed during the workshop Workshop closure

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Dr. Beata Emoke Madari is a soil scientist at the Embrapa National Research Center for Rice and Beans and is a professor in post-graduate training at the Federal University of Goiás, Brazil. Previously, she worked as a researcher at the National Soil Research Center of Embrapa from 2002 to 2005. Dr. Madari has led the Embrapa Research Network on Greenhouse Gas Emissions from Grain Crop Production Systems and currently serves on the Executive Committee of Embrapa's Climate Change Portfolio. Her expertise includes carbon and nitrogen cycling in tropical acid soils and integrated crop-livestock-forestry systems, with experience in soil carbon determination methods. She is a Fellow Scientist of CNPq and has contributed to the IPCC on soil and wetland assessments, as well as the 4 per 1000 Initiative.

Dr. Suzanne Reynders is an expert in agricultural economics, environmental science, and agronomy. She serves as a Senior Advisor at INRAE, specializing in soil organic carbon and environmental strategies. Dr. Reynders leads INRAE's European climate initiatives and represents the institute in Climate KIC, focusing on climate adaptation and resilience in agriculture and forestry under the EU Green Deal and Horizon Europe. She coordinates the ORCaSa consortium, driving collaborative efforts in soil carbon sequestration and climate resilience. With over 12 years of experience at INRAE, she has directed numerous national and international projects to advance sustainable environmental practices across Europe.

Prof. Joann K. Whalen is the Executive Director of the Global Phosphorus Institute and a James McGill Professor at McGill University, as well as an Affiliate Professor at Mohammed VI Polytechnic University in Morocco. She earned her B.Sc. (Agr.) from Dalhousie University, an M.Sc. from McGill University, and a Ph.D. from Ohio State University (USA). A professional agronomist in Quebec, Canada, she is a Past President of the American Society of Agronomy. Prof. Whalen's research focuses on soil biology, soil health, and agricultural nutrient management. She has supervised or co-supervised 80 graduate students and postdoctoral researchers and published over 270 peer-reviewed articles. She serves as Editor-in-Chief for Soil Biology and Biochemistry and as a Review Editor for PNAS Nexus. Additionally, she is a Fellow of the Soil Science Society of America and the Canadian Society of Soil Science.

Prof. Dr. Axel Don is a soil scientist and Deputy Director at the Thünen Institute of Climate-Smart Agriculture, as well as a professor at the Technical University of Braunschweig, Germany. With over 15 years of expertise in soil carbon management, he leads a research unit focused on soil organic matter and coordinates various national and international projects. His collaborative work with farmers seeks to identify innovative strategies and address challenges related to carbon sequestration. Prof. Don has published over 80 peer-reviewed articles, achieving an H-index of 54. He is an active member of the European Geophysical Union and the German Soil Science Society and serves as a topical editor for the Open Access Journal SOIL. His contributions are vital to advancing sustainable soil management practices.

Dr. Edvaldo Sagrilo is a Brazilian agronomist and researcher at EMBRAPA Mid-North, focusing on sustainable crop production and soil management practices. He earned his B.Sc. in Agronomy in 1998 and his M.Sc. in Plant Production in 2001 from Maringá University, Brazil. Dr. Sagrilo completed his Ph.D. in Soil Biology and Biological Soil Quality at Wageningen University in December 2014, with funding from EMBRAPA. His major research areas include soil chemical and biological quality, crop physiology and management, and agro-ecological systems, and he is linked to the Terra Preta program.

Dr. María de la Luz Mora is the Director of the SmartC-BIOREN Project at Universidad de La Frontera, Chile. She holds a degree in Chemistry from Universidad de La Frontera and a Ph.D. in Chemistry from Universidad de Santiago de Chile, complemented by postdoctoral training at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia. Dr. Mora leads an interdisciplinary research group focused on soil physicochemistry, soil-plant interactions, and plant nutrition, significantly contributing to improved plant production, particularly in cereals, meat, and milk. She has authored over 50 scientific publications in the past five years and has directed numerous FONDECYT projects. Her current research aims to enhance phosphorus use efficiency and aluminum detoxification in acid volcanic soils while investigating environmental factors that influence blueberry quality.

Prof. Mohamed Moussa is the Director of the Laboratory for Erémology and Desertification Control at the Institute of Arid Regions in Tunisia. He is an expert in soil and water management with over 30 years of experience in scientific research, particularly in arid and semi-arid regions. Specializing in soil and water conservation, he has published numerous research papers in prestigious international journals focusing on improving soil properties. Prof. Moussa has supervised 12 doctoral theses and several master's theses, primarily in soil and water harvesting. He also serves as the national coordinator for multiple international cooperation projects aimed at sustainable water and soil management and has conducted various studies to enhance soil and water harvesting practices for development projects.

Main results of session 3:

This third session of the ORCaSa Knowledge Hub confirmed that effective practice transfer requires scientific rigor, local adaptation, and enabling conditions. The value of real-world cases from Brazil, Canada, Germany, Tunisia, and Chile underscored the diversity of challenges and solutions.

The workshop advanced:

- Peer learning across agroecological zones
- A shared vocabulary for assessing SOC-enhancing practices
- A broader understanding of practice feasibility under real-world constraints

These outcomes will feed into the development of:

- A compendium of practice-based evidence
- Recommendations for regionally adapted incentive schemes
- Contributions to the ORCaSa implementation plan and SRIA

The table below summarizes the most pressing barriers to practice adoption discussed during the session, along with corresponding recommendations

Identified Barrier	Recommendation
Limited adoption capacity among farmers in economically fragile regions	Provide economic incentives and policy support for innovation uptake
Uncertain long-term stability of SOC gains	Establish long-term monitoring integrated with farming practices
Unclear local relevance of technologies such as SAPs	Promote participatory trials and co-innovation tailored to dryland needs
Site-specific constraints (e.g., volcanic soils, phosphorus deficiency)	Develop locally adapted technical solutions
High energy demand and sustainability of biochar production	Evaluate net environmental and energy impacts before broad implementation
Lack of harmonized indicators for evaluating SOC practices across contexts	Support comparative research to build robust, shared but adaptable monitoring frameworks
Disconnect between science and policy implementation	Bridge grassroots innovations with strategic policy and funding mechanisms
Undervalued role of women and need for inclusive knowledge exchange	Enhance visibility, co-learning opportunities, and capacity building with gender-sensitive approaches
Inconsistent success of interregional practice transfer	Prioritize context-sensitive adaptation while maintaining global dialogue and exchange
Limited international collaboration infrastructure	Strengthen data-sharing and coordination across global soil carbon initiatives (e.g., FAO, 4p1000, ORCaSa)

Programme of the session 4 and main results: The long-term perspective
This session was prepared with Dr. Silvia Poblador (U. of Barcelona).

International Knowledge Hub: Workshop on **Sustainable Soil Health & Carbon Sequestration: A Long-Term Perspective** – Session4

7 November 2024 from 03:00 - 05:00 PM Paris Time

Opening, Welcome remarks	
15:00 - 15:10	**Introduction** Dr. Inès Soltani, *The French National Research Agency (ANR) – France* **Soil carbon sequestration via enhanced silicate weathering: co-benefits for agriculture?** Dr. Silvia Poblador Ibañez, *University of Barcelona – Spain*
Sustainable approaches to maintain soil health & carbon sequestration Facilitator: **Dr. Silvia Poblador Ibañez**, *University of Barcelona – Spain*	
15:10 - 15:50	◎ **Advancements in soil and land health monitoring** Dr. Leigh Ann Winowiecki, *The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) – Kenya* ◎ **Promoting soil health to restore degraded agroecosystems and build up resilient agricultural landscapes in Côte d'Ivoire** Dr. Ebagnerin Jérôme Tondoh, *Université Nangui Abrogoua – Ivory Coast* ◎ **Socio-economic challenges of carbon sequestration** Dr. Abigaïl Fallot, *The French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions (CIRAD) – France*
	Roundtable discussion
15:50 - 16:50	◎ **Prof. Hans-Jörg Vogel,** *the Helmholtz centre for Environmental research – Germany* ◎ **Prof. NGETICH Felix,** *Jaramogi Oginga Odinga University of Science and Technology – Kenya* ◎ **Speakers**

	• Identifying and Implementing Sustainable Practices for Long-Term Soil Health Improvement in the Context of Climate Change • Evaluating the Long-Term Sustainability and Effectiveness of Carbon Sequestration and Soil Health Practices • Exploring the Long-Term Implications of Carbon Sequestration on Soil Resilience and Climate Adaptation • Navigating Socio-Economic and Institutional Challenges to Adopting Sustainable Soil Management Practices
Closure of the meeting	
16:50 - 17:00	Recapitulation of key points discussed during the workshop Workshop closure

Dr. Sílvia Poblador Ibáñez is an accomplished soil biogeochemist specializing in nitrogen and carbon cycling within soils and studying greenhouse gas emissions across diverse ecosystems. She completed her PhD in Ecology, Environmental Science, and Plant Physiology at the University of Barcelona, Spain with the highest honors. Currently, she is a postdoctoral researcher at the same institution, focusing on greenhouse gas emissions from various wetland types. Dr. Poblador's recent research investigates enhanced silicate weathering techniques to improve soil carbon sequestration and reduce N_2O emissions, targeting agricultural and urban soils. Starting in the spring, she will join CREAF-UAB under a prestigious MSCA grant, where she will explore the potential of enhanced weathering to enhance carbon storage in rice paddies. With previous postdoctoral experience at the University of Antwerp, she brings expertise in nature-based climate solutions and innovative agricultural practices for carbon management

Dr. Leigh Ann Winowiecki is the Global Research Lead for Soil and Land Health at CIFOR-ICRAF, based in Nairobi, Kenya. A soil scientist, her research focuses on scaling farmer-centered landscape restoration and understanding the drivers of land degradation, while quantifying the impacts of land management on soil health. Since 2009, she has co-developed the Land Degradation Surveillance Framework (LDSF), a methodology used in over 40 countries across the tropics to assess soil health, track land degradation, and monitor restoration efforts. Dr. Winowiecki has published extensively on soil organic carbon, ecosystem services, and land degradation in sub-Saharan Africa and the tropics. She co-founded the Coalition of Action 4 Soil Health (CA4SH) within the UN Food Systems Summit, which aims to catalyze investments in soil health for climate, human well-being, and nature. Dr. Winowiecki also co-leads the CIFOR-ICRAF Landscape Restoration Transformative Partnership Platform and serves on the Scientific and Monitoring Task Forces for the UN Decade on Ecosystem Restoration. She is a founding Board Member of the International Union of Agroforestry (IUAF) and serves on the Board of Directors of the International Fertilizer Development Center (IFDC).

Dr. Jérôme TONDOH is a Senior Agroecologist and Soil Scientist with over 23 years of experience in ecology and sustainable land management. He graduated from Sorbonne University and currently holds the position of Associate Professor at Nangui Abrogoua University in Abidjan, Côte d'Ivoire. In addition to his academic role, he works as a Seconded Land Health Scientist at CIFOR-ICRAF, focusing on the sustainable management of tree-based cash crops, such as cocoa and cashew. Dr. Tondoh has chaired the Scientific Committee for the 15th Conference of Parties to the UN Convention to Combat Desertification, where he contributed to the "Abidjan Legacy Program," aimed at restoring degraded land and enhancing food security in Côte d'Ivoire. He has published over 50 peer-reviewed articles, accumulating more than 3,500 citations in leading scientific journals. His research emphasizes evidence-based approaches to address environmental challenges, promote agro-ecological intensification, and conserve biodiversity. Dr. Tondoh collaborates with various stakeholders to implement projects that tackle climate change and sustainable agricultural practices in West and Central Africa, significantly impacting the livelihoods of rural communities.

Dr. Abigail Fallot is a distinguished researcher at CIRAD (the French agricultural research and international cooperation organization working for the sustainable development of tropical and Mediterranean regions), in the research unit SENS (Knowledge, Environment and Societies). With a background in Economics (PhD from the Ecole des Hautes Etudes en Sciences Sociales and London School of Economics), she has been developing transdisciplinary research on several responses to climate change both in terms of mitigation and adaptation. From a top-down perspective she analyses climate policies, the concepts they rely on and the instruments of their implementation. From a bottom-up perspective with local stakeholders, she investigates social-ecological dynamics at the landscape level so as to discern and assess alternative development pathways for mitigation and adaptation. Currently based in Montpellier, France, she has been working in several countries of Latin America and Africa and coordinates research projects on soil carbon sequestration (DSCATT) and on territorial adaptation (Change-UP).

Prof. Dr. Hans-Jörg Vogel is the Head of the Soil System Science Department at the Helmholtz Centre for Environmental Research – UFZ in Halle, Germany, and a Professor of Soil Physics at Martin Luther University Halle-Wittenberg. With a career spanning over three decades, he has held positions at prestigious institutions, including the University of Hohenheim and INRA in France, focusing on soil physics and the interactions between physical and biological processes in soil. His research emphasizes the quantification and modeling of water flow and solute transport in heterogeneous soil materials, bridging scales from pore to field. Prof. Vogel has contributed significantly to understanding soil structure-function relationships, developing methodologies for measuring soil hydraulic properties, and addressing scaling issues in soil process characterization. He has received numerous accolades, including the Emil-Ramann Medal and the Don and Betty Kirkham Soil Physics Award in 2022. As an active member of the scientific community, he serves as an associate editor for several journals and leads initiatives such as the long-term BonaRes project, aimed at sustainable soil resource management.

Prof. Felix Ngetich is an Associate Professor of Soil Science at Jaramogi Oginga Odinga University of Science and Technology (JOOUST) in Kenya, bringing over 17 years of research, outreach, and teaching experience. He founded the Directorate of Research and Extension at the University of Embu in 2015 and has successfully supervised over 30 postgraduate students. Felix excels in securing research funding through proposal writing and has led several multidisciplinary projects supported by various donors, including the Swiss National Science Foundation and the World Bank. In addition to his academic pursuits, he serves as an active consultant in agro-ecosystem sustainability, collaborating with notable organizations such as AGRA and FAO. Through his not-for-profit organization, the Research Centre for Smallholder Farmers (RCFSF), he works closely with smallholder farmers, providing soil and water testing services and fertility advisory. His efforts are aimed at enhancing agricultural practices and improving the livelihoods of farmers in the region. Felix's commitment to research and community engagement highlights his significant contributions to sustainable agriculture in Kenya.

Main results of session 4:

The table below summarizes strategic barriers and recommendations :

Identified barrier	Recommendation
Disconnect between farmer priorities and research outputs	Co-design research agendas with local stakeholders
Unstable gains from soil carbon initiatives	Prioritize practices that support long-term stabilization
Overemphasis on carbon metrics	Broaden focus to multifunctional soil health
Low adoption of agroecological practices	Link practices to income gains and reduced risk
Knowledge asymmetry in modeling tools	Use participatory models as negotiation tools
Lack of tailored incentives and policy coherence	Adapt subsidy and funding schemes to site-specific realities
Misuse of irrigation and resource inputs	Integrate GHG monitoring with practical management advice
Fragmented collaboration across disciplines	Promote living labs and transdisciplinary platforms

This final workshop in the ORCaSa Knowledge Hub confirmed that long-term soil health and carbon sequestration require:

- Context-sensitive, participatory, and transdisciplinary strategies
- Alignment of science, policy, and community needs
- Reform of funding and incentive mechanisms to reward sustainability
- Better communication across stakeholders and disciplines

Key messages included:

- The need for predictive, site-specific models to inform policy
- The importance of integrating economic logic into sustainability transitions
- The value of living labs, co-design, and practical knowledge translation

The session concluded with a collective call for continuity, collaboration, and courage in addressing the long-term challenges of soil degradation and climate resilience. These reflections will contribute to the final ORCaSa recommendations and upcoming strategic research and innovation agendas (SRIA).

Strategy to develop the deliverable

The deliverable of this task of the ORCaSa project was a policy brief. We have focused on research policy highlighting the possibilities to strengthen research on carbon sequestration and international cooperation on this topic since significant national funding was already allocated in several countries. It is oriented towards action in the context of calls for proposals and included recommendations. To this purpose we analyzed the research topics and funding per topics in past calls for proposals and collected data about soil research worldwide. The targeted audience are all the funding agencies, ministries, the decision makers of self-funded research institutions in relationship with the ANR.

The format is also an important aspect of the publication strategy. Decision-makers do not read long documents. To be the most convincing, we have tried to deliver a succinct (2 pages of text) note, presented in simple language, limited to the specific aspects of a problem and to the information that really interests the recipient.

Thus, the policy brief provided below promotes research on soil carbon sequestration. The overview of the national and European calls describes the numerous research opportunities in place over the past decade about soil health and/or soil carbon. This analysis of the call texts and of the allocated budgets argues in favour of a greater alignment of national research initiatives. It was shared with all participants of the

Knowledge Hub, all ANR partners involved in national or transnational funding. It was also distributed by Artik through its contribution in WP6 and ORCaSa communication activities.

Is there a place for international research on soil carbon?

Inès Soltani[1], Joann Whalen[2], Talal Darwish[3], Silvia Poblador Ibañez[4], Andrews Opoku[5], Edward Yeboah[6], Ulrike Ziegler[7], Melanie Herker[8], Ngonidzashe Chirinda[9], Macoumba Loum[10], Oluwole A. Fatunbi[11], Miriam Buitrago[12], Sylvain Rullier[12], Jackline Muyalo[13], Allassane Ouattara[14], Suzanne Reynders[15], Nathalie Pavy[1]

[1] French National Research Agency/Agence Nationale de la Recherche (ANR), Paris, France
[2] McGill University, Department of Natural Resource Sciences, Montreal, Canada- Center for Sustainable Soil Science (C3S), Mohammed VI Polytechnic University (UM6P), Ben Guerir, Morocco
[3] National Council for Scientific Research, Center for Remote Sensing, Beirut, Lebanon
[4] University of Barcelona, Centro de Investigacion Ecologica y Applicaciones Forestales, Spain
[5] CSIR-Soil Research Institute, Department of Soil Microbiology, Kumasi, Ghana
[6] Department of Crop and Soil Sciences Kwame University of Science and Technology, Kumasi Ghana
[7] Forschungszentrum Jülich GmbH, Jülich, Germany
[8] Federal Office of Agriculture and Food, Bonn, Germany
[9] Mohammed VI Polytechnic University (UM6P), College of Agriculture and Environmental Sciences, Ben Guerir, Morocco
[10] National Institute of Pedology (INP), Dakar, Senegal
[11] Forum for Agricultural Research in Africa (FARA), Accra, Ghana
[12] Agence de l'Environnement et de la Maîtrise de l'Énergie, Angers, France
[13] National Research Fund, Nairobi, Kenya
[14] Laboratory of Environmental and Aquatic Biology, Nangui Abrogoua University, Ivory Coast
[15] National Research Institute for Agriculture, food and Environment, Paris, France

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

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.

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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

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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/Alliance_Missions-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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4. 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

Funded by the European Union