

The impact of biodiversity on carbon related ecosystem services provided by soils of managed forests

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Task force components, competence and diversity

The task force will bridge forestry institutions from Europe, Asia, Africa and America, covering temperate, subtropical land, tropical regions of the globe, and a broad geographical and ethnic diversity while effectively targeting a vast region very rich in forest ecosystems. Most partners from Europe and some from Asia have been working on the subtopic of microbial diversity and soil carbon (C) cycle in the ongoing EU funded projects (incl. HoliSoils, Benchmarks), and have therefore already relevant experience and network.

On the subtopic of mixed species forests, there are relevant efforts already ongoing in SLU and LUKE. Padua University members are experienced in soil communities functional and taxonomic analyses.

External partners

Most members not in IUFRO, KTH (Sweden), B3C (Spain), Berkeley lab (USA), and CNRS (France), have been a very important part of the HoliSoils activity on C cycling and biodiversity. Also Yonsei University (South Korea) will join the effort, bringing in relevant expertises about forest biogeochemical cycles controls.

The task force relies also on the involvement of Wondo Genet College of Forestry and Natural resources, Hawassa University (Ethiopia) which is a pending IUFRO member and can provide expertises about the potential drivers of diversification (as ongoing land use changes).

Main aims:

- Connecting current research projects around the globe exploring the impact of biodiversity on C-related ecosystem services from forests and exploring synergies.
- Identify knowledge gap in the current process-based understanding linking soil biodiversity and C-related processes in soil

- Identify conceptual gaps in soil monitoring tools and definitions for soil biodiversity

Secondary aims:

- Combine the knowledge of the teams participating in the task force to obtain an overview of the state of the art of the knowledge available on the task force theme.
- Establish a network for future developments and research projects.

Background and rationale

The importance of C related ecosystem services from commercial forestry emerged sharply in the last decades. With the attention on greenhouse gas emissions, forests are nowadays not just expected to provide sustainable products but also to minimise human footprint by capturing and storing C. The C balance of a stand results from inputs (plant growth) and outputs (products and decomposition). With recent attention towards climate-smart forestry increased the focus towards biodiversity, its impact on these two components of the stand C balance has become a crucial question.

Possible change drivers: shift in management practices

Even-aged forest monocultures, by far the dominant approach until now, are losing support in favour of much more diverse systems (in terms of age, but also species composition). A more diverse stand is more resilient towards stressors such as insect outbreaks, drought or storms, which are all predicted to increase in the near future; but it is also changing the way the stand allocates C, for example towards less soil C stocks and higher above ground C stocks due to reduced mortality.

Among other changes, diversity of plant communities could also affect the decomposition process more directly by influencing microbial communities (Spohn et al., 2023). All these alterations, which are foreseeable in the near future, could alter soil ecological communities and this could have profound consequences on all C-related ecosystem services provided by soils because of a change in C-related processes. Still, this is a change we are not able to foresee because of our limited understanding of the involvement of microbial communities in the decomposition process, since communities have largely been treated as a lumped term in current SOC models and their interactions largely neglected.

What a change in soil communities might mean

The main process related to the C biogeochemical cycle in soils is decomposition, and decomposition kinetics and their interactions with climate and, to a lesser extent, edaphic properties like clay minerals. So far models including soil microbial communities, or micro- and mesofauna, are rare. Decomposition kinetics have been traditionally considered constant: the more material the more decomposition, with rate depending on the quality of the material, with the microbial C pump mechanism and the non-equilibrium state of the soil C cycle considered as the main factors and forces responsible for the organic matter formation in soil. However, the most recent research shows that rates might be not an inherent property of organic matter but an emergent ecosystem property resulting from interactions among all ecosystem components. As such, it is not necessarily constant and might for example vary across an ecological transition.

One of such interactions might be specifically at the soil ecological community level. Recent literature suggests that decomposition rates are influenced by the composition and metabolic activity of microbial communities (Handa et al., 2014, Khurana et al., 2023), as

well as biodiversity when soils approach the lower boundaries of diversity (Feng et al., 2024). There is evidence that microbial diversity could increase the efficiency of decomposition, and some key microbial species might play key roles (Lindahl et al., 2012), as well as mesofauna. But community effects tend to be nonlinear and with many interactions, and the magnitude of this effect is uncertain. Do communities matter, and if so in which cases do they, why and most importantly how?

Capturing community effects is especially difficult in particular, because, especially in soil, it is a highly multidimensional problem. The decomposition of organic matter is a process involving many metabolic pathways that are in some cases redundant and in some crucial, and the interactions of microbial communities are a very complex network. Reducing the complexity of this network to one single dimension (for example a biodiversity indicator based on species presence) means losing most of this information. This is why it would be important given the current state of research to work on the conceptual definition of biodiversity first, determining how to define it when related to soil. The task force will work first on such a definition, considering diversity first of all in a functional way related to all soil C ecosystem services. From that definition, we will proceed on understanding its potential impact on such ecosystem services, targeting the relationship of microbial communities with soil carbon kinetics in forests.

Why does this matter?

A modification in the kinetics of the organic matter decomposition process affects directly the amount of SOC stocks of global soils by modifying the equilibrium. In case of community effects partially driving such a process, the community changes caused by changes in management might generate a cascade effect impacting the biogeochemical cycles of C that we might not yet be able to account for. This might mean that current models might either under- or overestimate C stocks changes following a management change.

How does the task force leverage current ongoing projects?

Participants to the task force have in many cases ongoing projects on the topic. In particular the currently ongoing Holisoils project (<https://holisoils.eu/>) is one of the largest in this sense and will run until the end of 2025, and has already produced a vast amount of results and data. The dataset produced by the project, connecting high resolution mineralization measurements with biodiversity indicators (micro-, and mesofauna), will represent one of the initial capitals of the task force and once released publicly (beginning of 2026) can constitute the foundation for future works within this task force.

During the first two years of the project, the task force will organise webinars chaired in turns by one of the participating institutions, where we will disseminate internally to the task force the most recent results of ongoing projects. This internal dissemination will, besides sharing the current knowledge, connect participants in the interpretations of the results.

Plan and timeline:

Network building and coordination (whole duration of the task force)

Coordination will be centralised with one main task coordinator and some local vice-coordinators to facilitate local networking.

- Main coordinator: Lorenzo Menichetti

- Asia vice-coordinator: Nobuhiko Shigyo (Forestry and Forest Products Research Institute, Japan) nshigyo@ffpri.affrc.go.jp
- Europe vice-coordinator: Jorge Curiel-Juste (Basque Center for Climate Change Research), jorge.curriel@bc3research.org
- Africa Vice-Coordinator: Leigh Ann Winowiecki (ICRAF), l.a.winowiecki@cifor-icraf.org

The responsibilities of the main coordinator will fall onto the two vice coordinators if this is unavailable.

Collaboration phase I: Dissemination of current ongoing work (2025, 2026, 2027)

During the first two years of the task force duration we will organise regular webinars for results dissemination and discussion between all the members of the task force. The first one-two webinars will be chaired by LUKE and will be about results from the Holisoils project (which will be ready by then), but future webinars will be organised and chaired in turns by every participating institution. The webinars will include a long discussion session.

Collaboration Phase II: Identification of current knowledge gaps (2027, 2028, 2029)

During the last three years of the task force duration the participants will focus on identifying current knowledge and conceptual gaps, assembling then the review results in a consistent form. This includes not only knowledge gaps in the modeling community, but also bridging modeling and field observations/laboratory experiments to better understand soil biodiversity impacts and to define biodiversity in a functional way that can be linked with objective measurements related to precise ecosystem services. This collaboration will promote the establishment of a global standard for monitoring soil biodiversity for C-related ecosystem services.

This will be done by splitting the work into smaller sections, where each section will include a small team chosen within the task force based on respective interests. One or more coordinators (either the task force coordinator alone or with the help of vice-coordinators) will organise a consistent framework for the sections, with the aim of compiling a consistent review document.

The organisation of this phase will require at least 1 or 2 plenary meeting sessions in 2027, followed by smaller meetings or other coordination tools during each year. Annually we will hold a checkpoint, in the form of a remote workshop, to monitor the ongoing activity.

Dissemination of the task force outcomes (2029)

Results from the work from the task force will be used to write a report. Eventually, if findings will be enough, we will write a manuscript for peer-reviewed journals. This activity will be supervised by the project coordinator and the vice-coordinators, which will allocate tasks and coordinate the activities. In the report we will analyse the practical implication of our findings for forest management.

In-person meetings (optional, during the whole task force duration but more likely towards the end)

The organisation of in-person meetings will be preferred to online activity, and in that case the form will be longer workshops (1-2 days), but this will depend on the resources that locally we will be able to find for organising them, as well as the travel money available. Ideally the task force will hold at least one gathering, and possibly more local gatherings

(open to everyone, but of course easier to access for the institutions geographically closer).

Deliverables

1. Policy report including the results of the publication in a more popular form, with a particular focus on relevance and policy indications

Deliverables (optional)

2. If findings will be enough, a manuscript with all the results to be submitted to peer-reviewed journals.

Meetings implementations:

The first collaboration phase (approximately two years) will be about knowledge exchange, and will take the form of regular webinars among the participants to share results. At the end of each meeting, we will define the chair for the next one.

The second collaboration phase (approximately three years) will require a more structured approach. We will start with one plenary session in 2027 where we will build a structure of topics (which will ideally become paragraphs of a final work), and each topic will group together some of the participants in subgroups. Each subgroup will elect a coordinator that will lead a smaller series of 2-3 meetings during the year to develop the topic as well as the work towards the final deliverable (a few paragraphs, ideally 1-2 pages of length, about each topic). After approximately one year, the topics will be presented in another plenary session for a restructuring of the common document. Crucial task for each plenary session will be working on the connections between the topics, assembling them in a consistent framework (this can be done by setting up tasks for each subgroup to be executed during the following year).

This process will be iterated two more times, refining the topics and the common structure.

Leading:

The task force coordinator leads the plenary meetings and ensures that the agenda is followed. Particular attention will be given to the plenary session of 2027, where topics (each representing one deliverable) will be defined as well as the associated subgroups and coordinators.

Subgroups organization will be more agile given that different groups might face different needs, and will be left to the elected subgroup coordinator that will have the responsibility of communicating with the task force coordinator informing about planned deadlines and deliverables.

Final document responsibilities:

Each member is responsible for each own topic, and the subgroup coordinator is responsible for assembling each topic. Writing the final document by connecting together all the topics is a shared responsibility during the plenary sessions of the second collaboration phase, but the final assembly and formatting will be executed either by some member elected in a plenary session or of the coordinator (whoever does it will be main author of an eventual manuscript). Responsibilities of an eventual failure in compiling the shared final document will be shared as well, as it will mostly depend on the work of each subgroup.

Defining the topics and the subgroups

This will be done during the first plenary meeting of the second collaboration phase, in two steps. We will first collect a list of topics (approximately 1 hour discussion), each topic defining a

subgroup, and then each person will voluntarily subscribe to one of the subgroups.

Defining the agenda for the meetings

The meeting agenda for the first collaboration phase will be defined by each chair.

The meeting agenda for each plenary session of the second collaboration phase will be defined top down by the coordinator but at every meeting we will have an eventual agenda restructuring as first step.

Conflict management:

If conflicts arise about something not specifically in the scope of this proposal (in which case they will be solved by adhering to it), they will be dealt with in a collaborative way. The first step will be a mediation attempt by the task coordinators. If this fails, the conflict will be dealt with in the following plenary session (or if time constraints demand it a special plenary session will be called) and after a public discussion the conflict will be resolved by clear voting.

Budget

The task force will leverage on several (EU scale) projects, Holisoils (ongoing, closing in 2025), BENCHMARKS and NextGenCarbon (upcoming, 2024-2025). Holisoils in particular (<https://holisoils.eu/>), with its holistic perspective on forest soils, focuses on biodiversity and community effects on soil C and produced some very relevant knowledge on the topic, while NextGenCarbon is aimed more generally at improving and monitoring C related services from forests across Europe. Leveraging these projects will cover the coordination activities.

Padua University: H2020 'EARTHONE' will start in January 2025. This project might bring synergies within the task force but these have yet to be explored.

The task force will coordinate and work online for the most part. Any additional resource which we will find on the way will allow us to organize events for a tighter collaboration, in particular hosting local in person meetings, but the activity can proceed even otherwise

Contribution to implementation of the IUFRO Strategy;

The topic is multidisciplinary in its nature and directly bridges two IUFRO divisions, Silviculture (1) (uneven-aged and mixed forests) and Forest Environment (8) (biodiversity, ecosystem functions), extending towards Forest Operations Engineering and Management (3) (sustainable forest operation) and potentially Forest Assessment, Modeling and Management (4).

As such it aligns with the three goals of IUFRO post 2020 strategy (research excellence, network cooperation, and Enhancing visibility and outreach of forest research). More specifically:

Research excellence: the task force will examine current results about biodiversity impacts on biogeochemical C cycles and evidentiare current research gaps. In particular, the increased pressure on forestry globally is pushing for a transformation of management approaches in the direction of more diverse systems, for their increased values in terms of resilience, recreational value and even services related to productivity. Examining critically

which of these ecosystem services relates to biodiversity, how and how much, or otherwise which research gaps there are that might prevent us from drawing robust conclusions.

Network cooperation: the task force is focused on network building, connecting some of the world excellences in the proposed research topic. By sharing results and opinions the network will develop and deepen, and the participating member will gain a clear picture of how to efficiently distribute tasks based on the respective knowledge base. Each member brings in a valuable network to be integrated that will likely involve institutions still outside IUFRO, building a valuable platform for future research on the topic and possibly increasing the IUFRO reach.

GOALS

How this TF pursues them

	<i>Promoting the utilization of a still unused large dataset together with other data from the participants</i>
<i>Strengthen research</i>	<i>Creating working definitions of biological diversity to use quantitatively, and assess its impacts on C related ecosystem services</i>
<i>Expand strategic partnership and cooperations</i>	<i>Create a global partnership between multiple institutions focused on the topic (that can also serve as platform for future efforts)</i>
<i>Enhance the communication with the scientific community</i>	<i>Establishing a working network between scientists and institutions</i>
	<i>Sharing results among participants</i>
<i>Enhance the communication with policy makers</i>	<i>Spreading the final policy report</i>
	<i>Results dissemination leveraging on the network of each participant</i>

Synergies with other ongoing projects?

Padua University: H2020 'EARTHONE'

LUKE: H2020 Holisoils, HE BENCHMARK, HE NextGenCarbon (starting 2024/2025)

ATLANTIS: Excellence project funded by the Ministry of Science of the Government of Spain

Visibility and outreach:

All participants to the task force are already involved in projects on the task force topic, and it is therefore likely they will participate in events where their results fit and where the task force would be advertised.

The final document (the policy report), compiled with the results from the activity of the task force, will be advertised in all institutions involved, through the informal network of each participant and (in its draft form) at public events before the conclusion of the task force, and later in its final form. Many participants are also involved at the level of policymaking and will rely on their network for maximising the impact of the task force results.

How will the Task Force address interdisciplinary science-policy initiatives

Results of the work of the task force will impact the current discussion about alternative forest management, C sequestration as well as biodiversity preservation. Biodiversity is a very important topic in the current public discourse, but already its definition and measurement is fuzzy. Conventional diversity indicators, such as Species Richness, Shannon index and similar, are a very coarse linearization of a multidimensional complexity and often fail to capture the relationships and processes ongoing at the ecosystem scale. This is particularly true for soils, where organisms tend to be highly redundant and diversity is very high, but there might be crucial functional groups whose importance might be lost when using aggregated indicators. While biodiversity is something clear and measurable for communities of macro-organisms like plants and mammals (and even soil meso- and macrofauna), in soils it becomes much harder (DNA based methods) and depending on the definition might or might not matter for certain ecosystem processes. Defining first the ecosystem processes we are interested in, and from there proceeding towards identification of relevant taxons/genes and developing definitions of biodiversity that are linked to them, would be a necessary step for a quantitative exploration of biodiversity effects on soil functions. By improving our definitions in this sense, the task force will provide more solid grounds for political communication.

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