NATURAL RESOURCES
INSTITUTE FINLAND

Soil health, preparation of soil monitoring law, and forest climate change mitigation potential

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Life on Earth depends on healthy soils

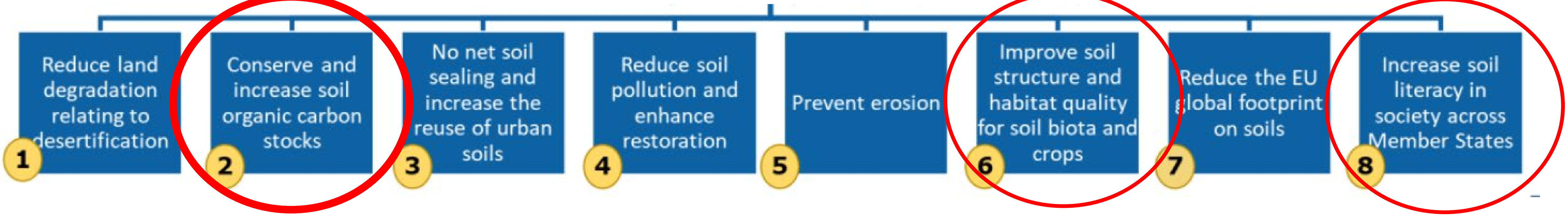
Soil mission aims at putting Europe on a trajectory towards sustainable soil management and restoration.

If soils are healthy and are managed sustainably, they provide essential environmental, economic, and social benefits for society.

Ecosystem services provided by soils include

- producing adequate quantities of **safe and nutritious food**, feed, fibre and other biomass. About 95% of our food comes from terrestrial sources[i];
- **storing and purifying water, regulating flows, recharging aquifers**, and reducing the impact of droughts and floods thereby helping adaptation to climate change;
- **capturing carbon** from the atmosphere and reducing emission of greenhouse gases from soils, thereby contributing to climate mitigation; more carbon resides in soil than in the atmosphere and all plant life combined[ii];
- **nutrient cycling** supporting crop productivity and **reducing contamination**;
- preserving and protecting **biodiversity** by preserving habitats above and within the soil;
- supporting the quality of our **landscapes, preserving our cultural heritage** and **greening of our towns and cities**.

Specific objectives of Soil Mission



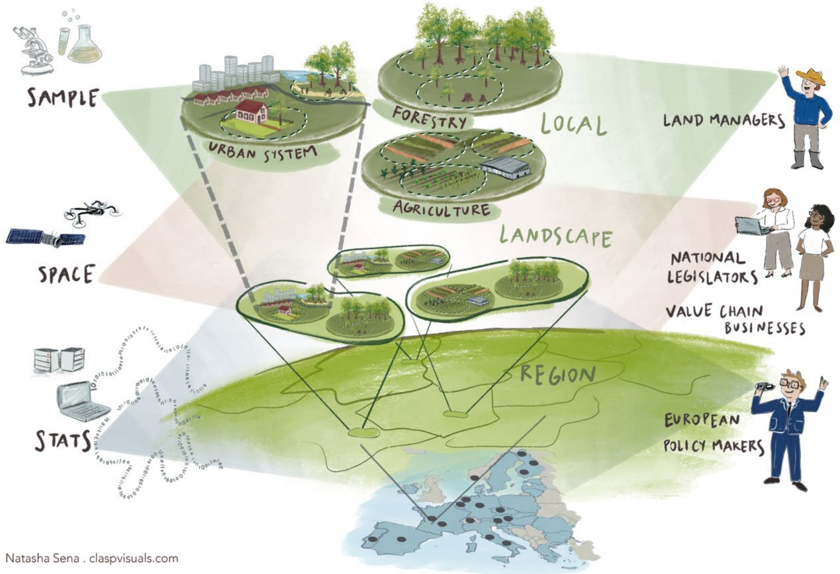
EU soil strategy for 2030

- Set a vision: By 2050 all EU soil ecosystems are in healthy condition and are thus more resilient.
- Sets out a framework and concrete measures to protect and restore soils, and ensure that they are used sustainably.
- Announces a new Soil Monitoring Law, which is
  - putting in place a solid and coherent **monitoring framework** for all soils across the EU so Member States can take measures to regenerate degraded soils
  - making sustainable soil management the norm in the EU. Member States will have to define which practices should be implemented by soil managers and which should be banned because they cause soil degradation
  - requesting Member States to identify potentially contaminated sites, investigate these sites and address unacceptable risks for human health and the environment, thereby contributing to a toxic-free environment by 2050.
- Soil Monitoring Law Proposal for a Directive on Soil Monitoring and Resilience - European Commission (europa.eu) with proposed soil health indicators is under discussion in the EU parliament

Research project BENCHMARKS initiated testing and development of the soil indicators and arranged workshops for stakeholder engagement

- BENCHMARKS (2023-2027): Building a European Network for the Characterisation and Harmonisation of Monitoring Approaches for Research and Knowledge on Soils
- Workshops arranged in 24 case studies in Europe
  - Land use: Agriculture, forest, urban
- Main aims of the workshops:
  - Build trust and partnerships with different stakeholder group
  - Gain insights and knowledge on soil health objectives and practices among stakeholders

Anonymous feedback: "The event was inspiring and open to non-passionate reflecting."



BENCHMARKS is working across scales and land uses.

Soil health – Definition

Scientific definition:

The ability of a soil, at a specified point in time, to function as a vital living system, within natural or managed ecosystem boundaries and land-use boundaries, **to sustain plant and animal productivity and health, maintain or enhance water and air quality and to further provide ecosystem services in the long-term** without (increased) trade-offs between ecosystem services.

Political definition:

The physical, chemical and biological condition of the soil determining its **capacity to function as a vital living system and to provide ecosystem services**.

Source: https://soilhealthbenchmarks.eu/glossary/4036/

Evaluation of the proposed soil health criterias

Assessment of soil health **at EU level** consider salinization, soil erosion, loss of organic carbon, subsoil compaction, and

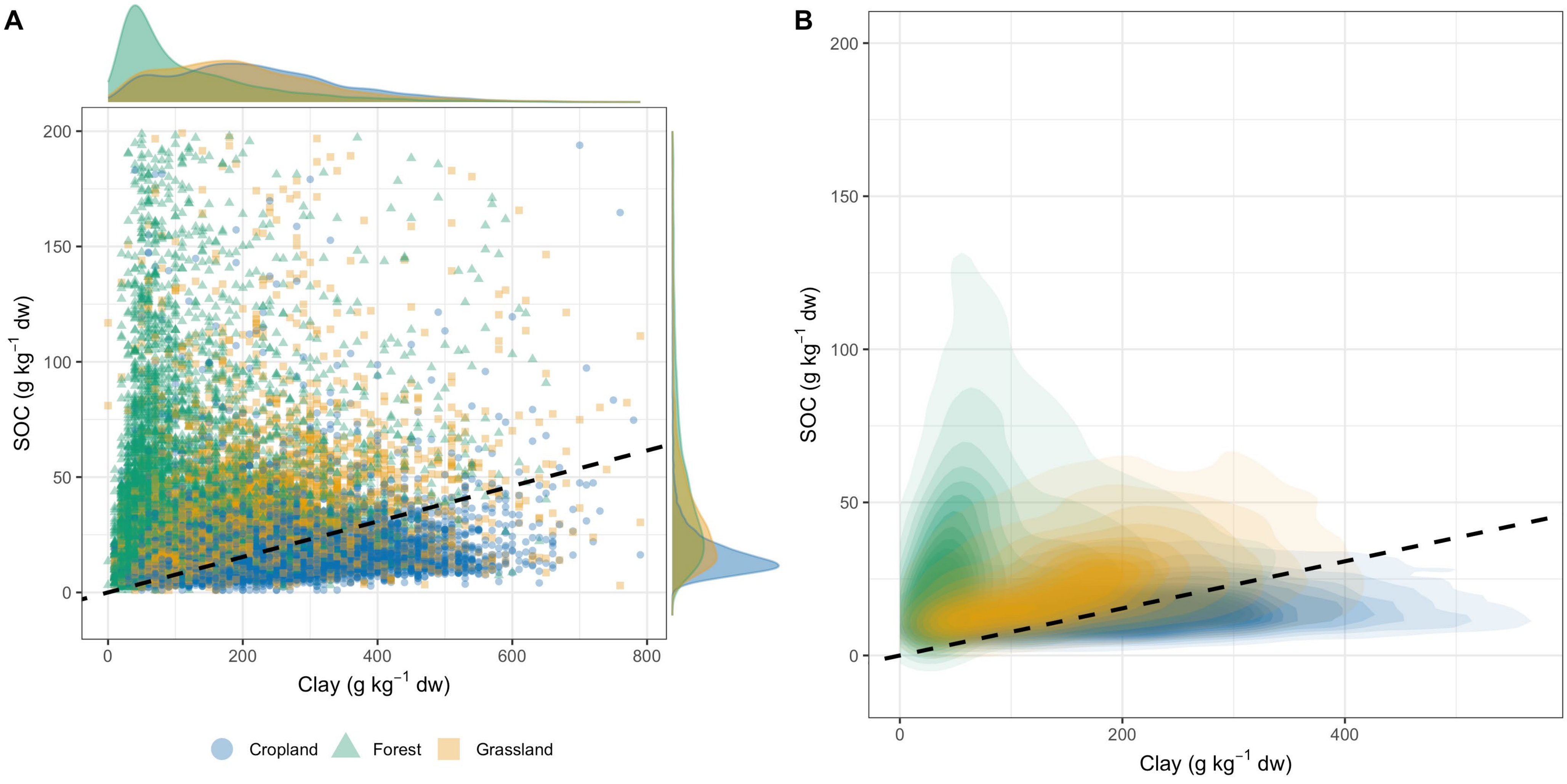
at member states level, excess phosphorus and nitrogen content in soil, soil contamination, Reduction of soil water retention capacity, acidification, topsoil compaction, loss of biodiversity.

We evaluated performance of the soil C loss criteria by

appling a $\frac{1}{13}$ threshold on $\frac{SOC}{Clay}$ relationship for detecting "non-healthy" soils to LUCAS 2009 soil data (preliminary results)

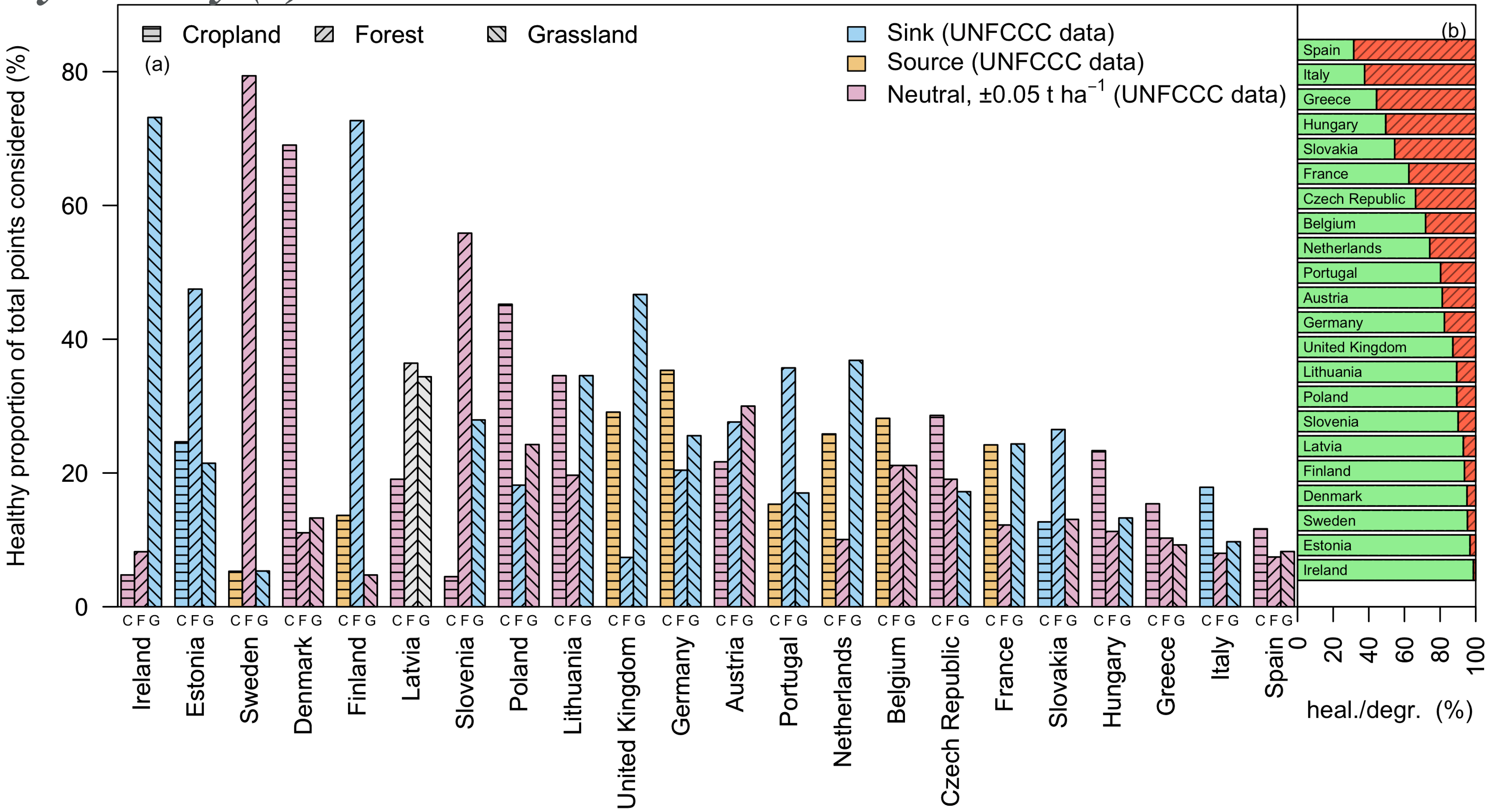
Mäkipää, Raisa and Menichetti, Lorenzo and Martínez-García, Eduardo and Törmänen, Tiina and Lehtonen, Aleksi, Is the Organic Carbon-to-Clay Ratio a Reliable Indicator of Soil Health?. Manuscript submitted and pre-print available at SSRN: https://ssrn.com/abstract=4681574 or http://dx.doi.org/10.2139/ssrn.4681574

Distribution of the soil organic carbon (SOC) and clay content for different land uses (cropland, forest, and grassland)



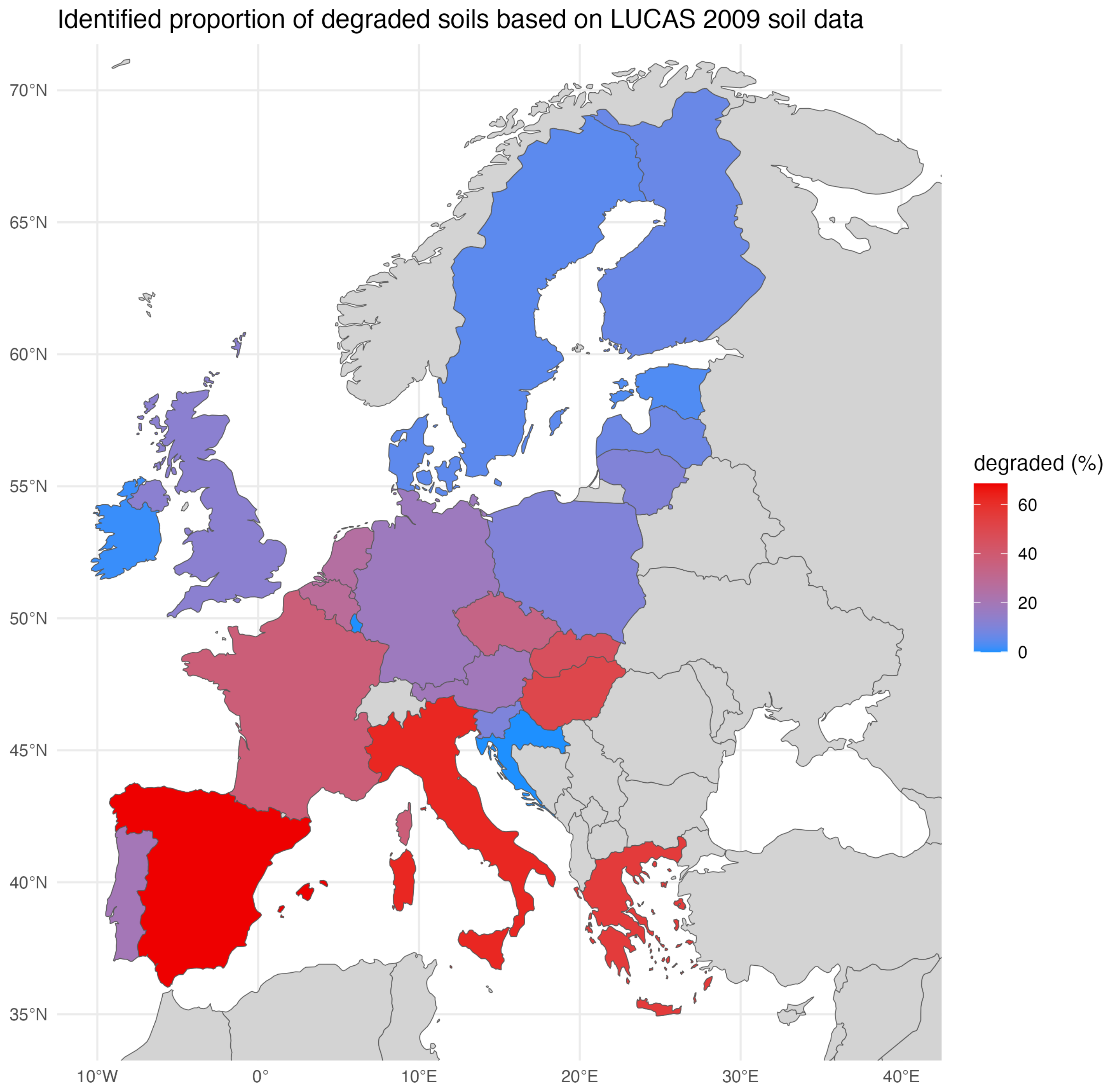
Density plots of SOC and clay contents for each land use are shown in panel a). Panel b) shows the 2-dimension density distribution of the data points in the same space. Dashed line represents the SOC:Clay threshold of 1:13. Less represented land-use classes are not plotted for readability and SOC contents above 200 g kg^{-1} dry weight (dw) were excluded.

Proportions of non-degraded (healthy) mineral soils by the three major land use classes and country included in the 2009 LUCAS soil survey (a) and the proportion of total degraded soils by country (b)



The colors in panel (a) shows the carbon stock change for each land use based on GHG reporting (UNFCCC, 2000-2020) for mineral soils. Blue = sink, orange = source. Pink = "neutral" (±0.5 t C ha^{-1} change). White = missing data.

The small labels under each bar denote the land uses cropland (C), forest (F), and grassland (G). The colors in panel (b) correspond to degraded (red, shaded) and healthy (green) soils.



Proportions of non-degraded (healthy) mineral soils by country in EU

The map is a representation of the same data showed in Fig. 2, panel b. Colors are associated to the proportion (on the total number of sampled points) of degraded soils detected in each country.

Challeging to find a single indicator for soil C loss

- Soil carbon loss indicator proposed by the European Commission for the Soil Monitoring Law cannot adequately monitor the loss of soil carbon.
- A single indicator such as SOC:Clay ratio, with one threshold value for all soils across various land covers, management practices, and climatic conditions, is unable to respond to the variety of soils, climates and uses across Europe, and is thus inappropriate for monitoring soil carbon loss.
- We observed discrepancies between the soil carbon stock changes reported by the national GHG inventories and the proportions of degraded soils identified by using the soil health indicator.

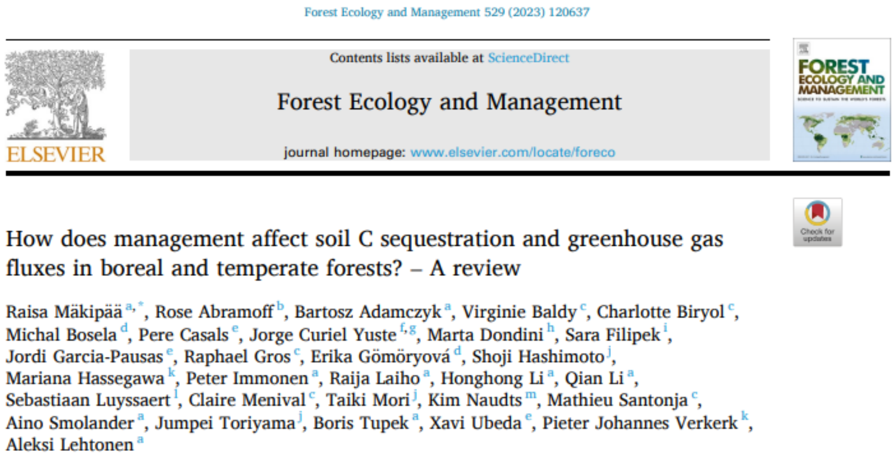
https://holisoils.eu/holisoils-finds-proposed-soil-health-indicator-lacking/

Forest soil climate change mitigation potential

How does forest management affect soil C sequestration and GHG fluxes – A review

HoliSoils
Working together for forest soils

Forest soils can increase climate change mitigation with targeted management


Forest Ecology and Management 529 (2023) 120637

Contents lists available at ScienceDirect

Forest Ecology and Management

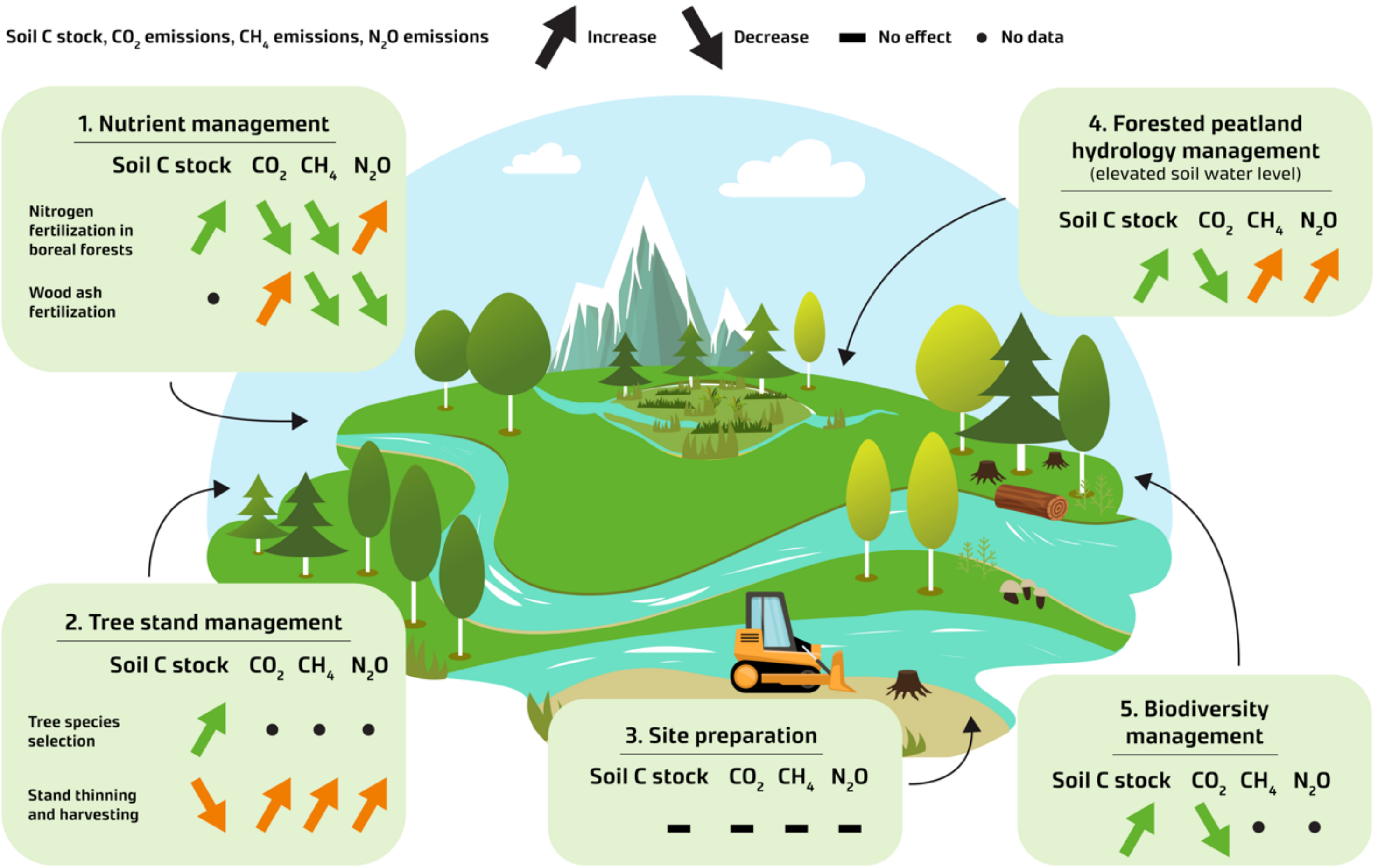
journal homepage: www.elsevier.com/locate/foreco

How does management affect soil C sequestration and greenhouse gas fluxes in boreal and temperate forests? – A review

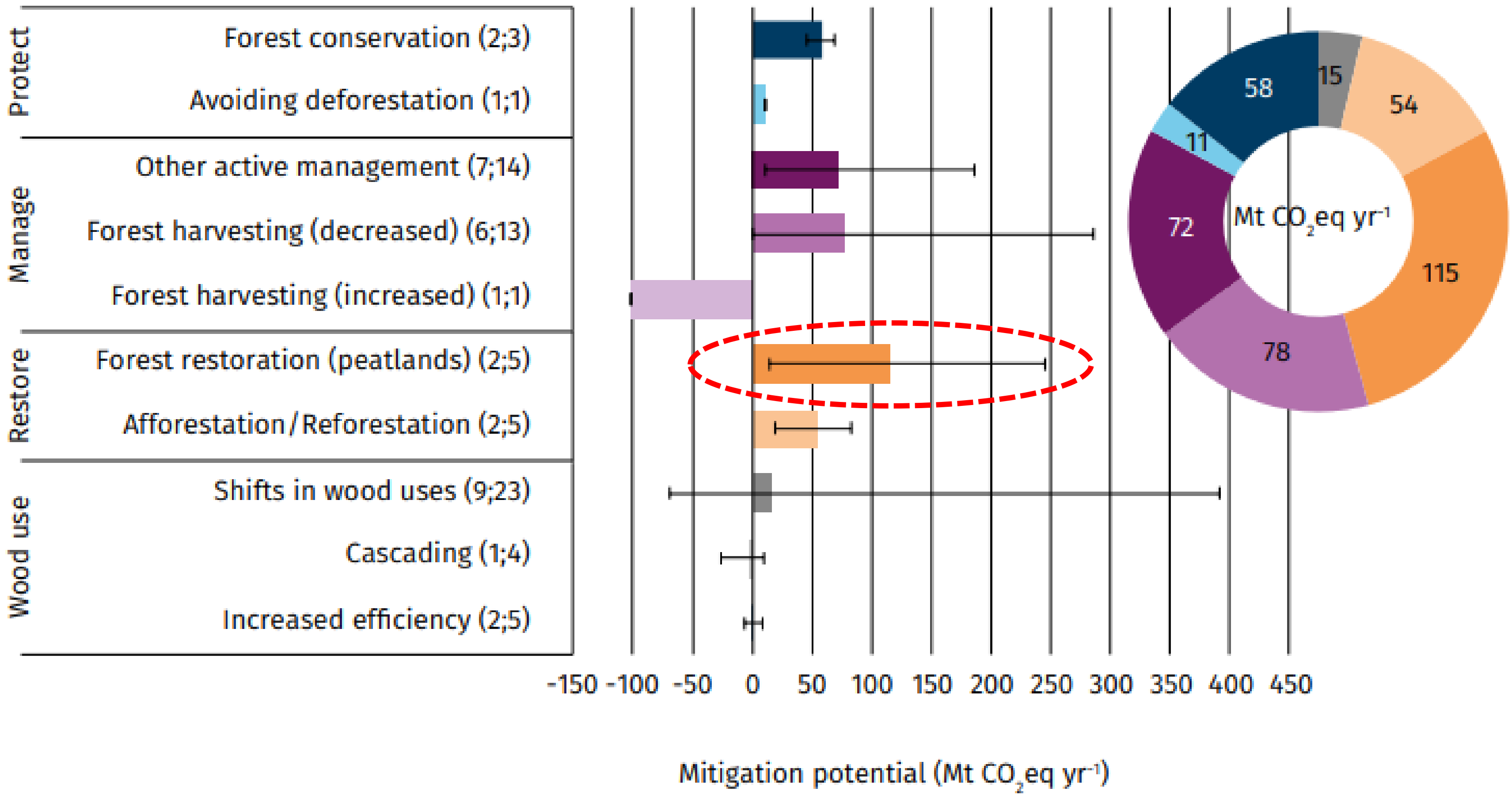
Raisa Mäkipää[a,*], Rose Abramoff[b], Bartosz Adamczyk[a], Virginie Baldy[c], Charlotte Biryol[c], Michal Bosela[d], Pere Casals[e], Jorge Curiel Yuste[f,g], Marta Dondini[h], Sara Filipek[i], Jordi Garcia-Pausas[e], Raphael Gros[c], Erika Gömöryová[d], Shoji Hashimoto[j], Mariana Hassegawa[k], Peter Immonen[a], Raija Laiho[a], Honghong Li[a], Qian Li[a], Sebastiaan Luyssaert[l], Claire Menival[c], Taiki Mori[j], Kim Naudts[m], Mathieu Santonja[c], Aino Smolander[a], Jumpei Toriyama[j], Boris Tupek[a], Xavi Ubeda[e], Pieter Johannes Verkerk[k], Aleksi Lehtonen[a]

www.holisoils.eu

Management practice



Forest-based climate change mitigation potential is 136-155 $MtCO_2eq/yr$ by 2050 (EU-27, Norway, Switzerland and UK)



Challenging to achieve the EU's climate targets for the LULUCF sector 170 $MtCO_2eq$/year by 2050.

Source: Verkerk et al. 2022. Forest-based climate change mitigation and adaptation in Europe. From Science to Policy 14. European Forest Institute. https://doi.org/10.36333/fs14

Holistic management practices, modelling & monitoring for European Forest Soils (www.holisoils.eu)

The HoliSoils project has eight study sites to examine different management practices.

Experimental data will also be used in the modelling i.e. we are developing soil models that account drivers of the soil C and GHG fluxes (incl diversity of soil microbiota).

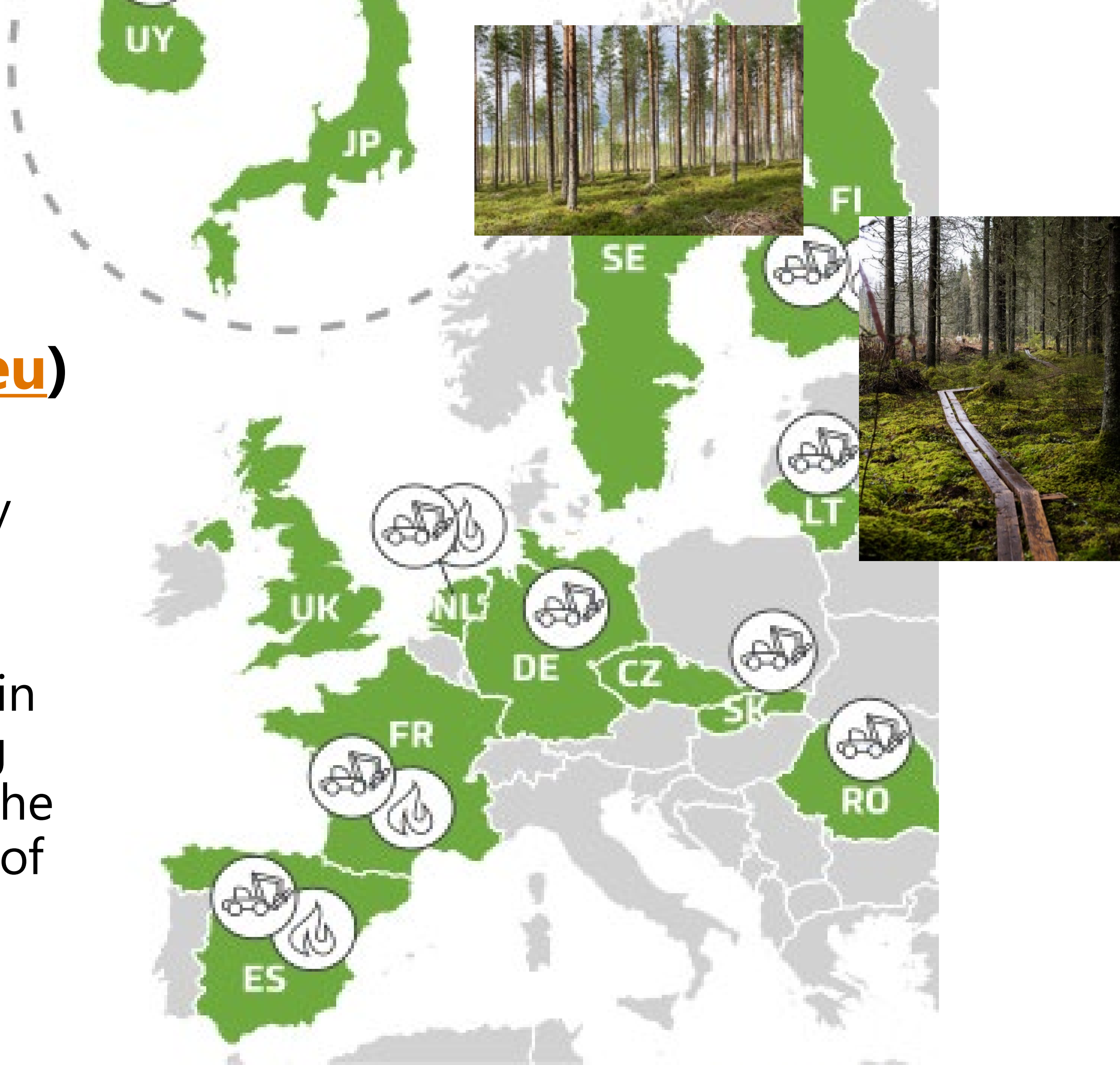


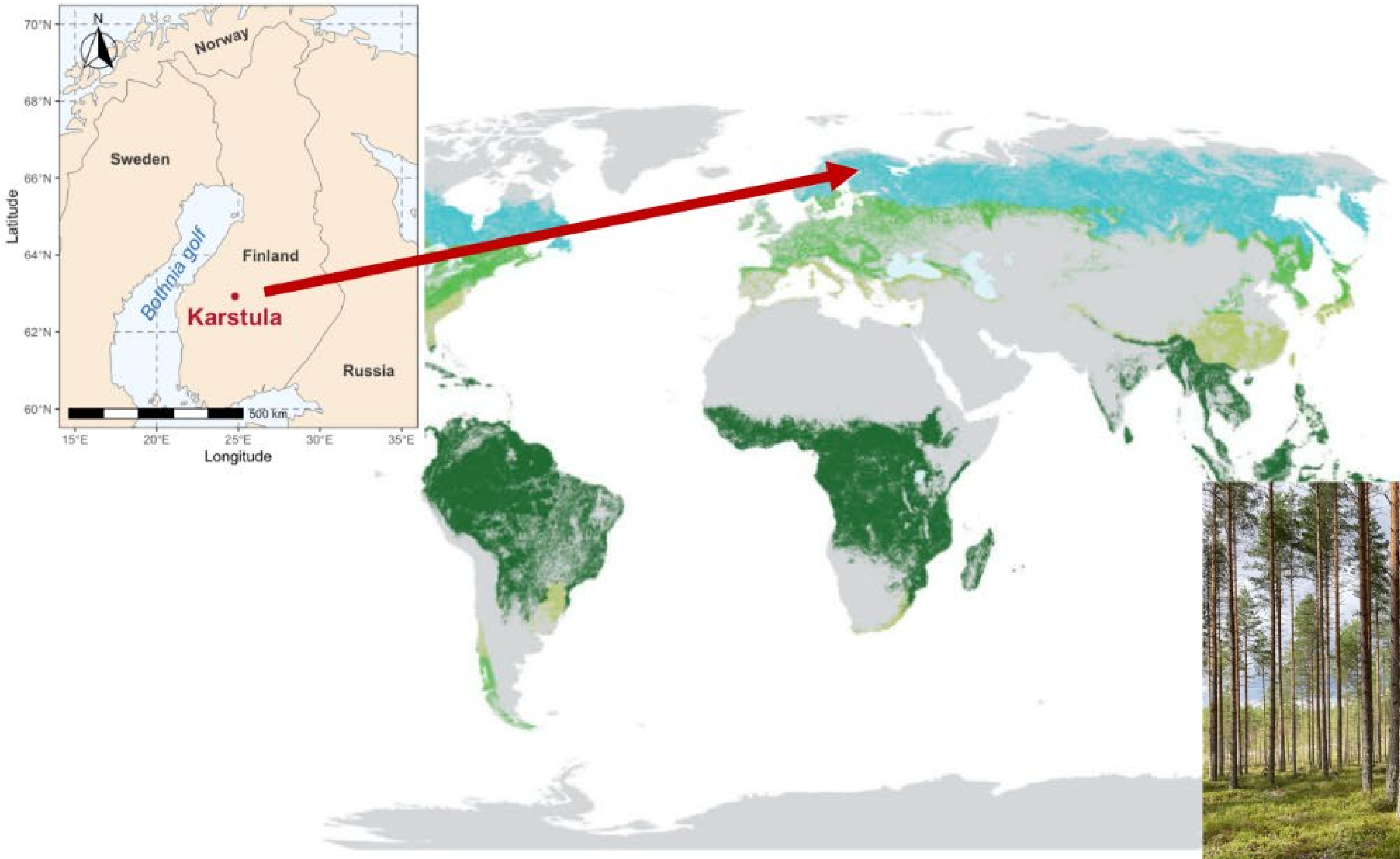
Figure 1.3.b. Geographical distribution of ***HoliSoils'***

Does fertilization stimulate decomposition and limit C accumulation? Experiment in boreal forest

Location of study site

HoliSoils
Working together for forest soils

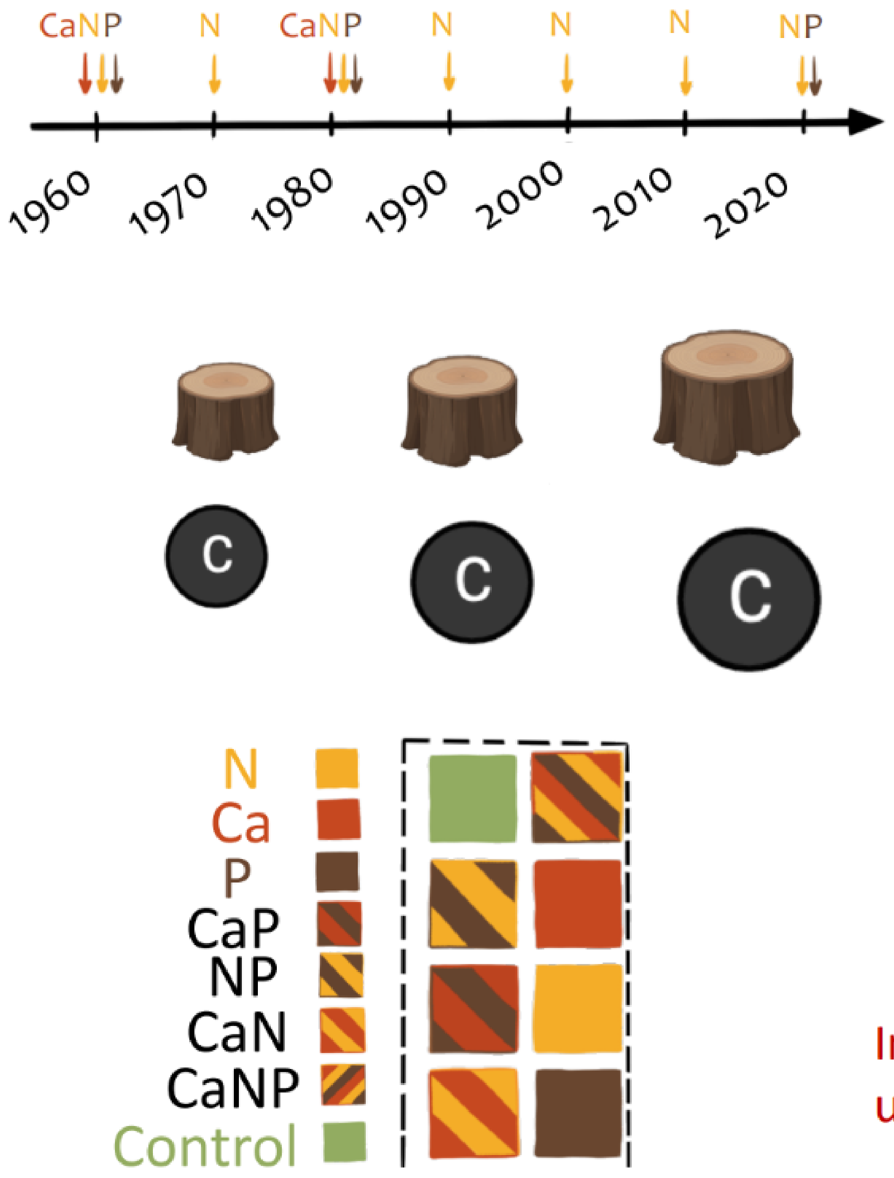
by Etienne Richy, Petr Baldrian et al. Manuscript in prep.

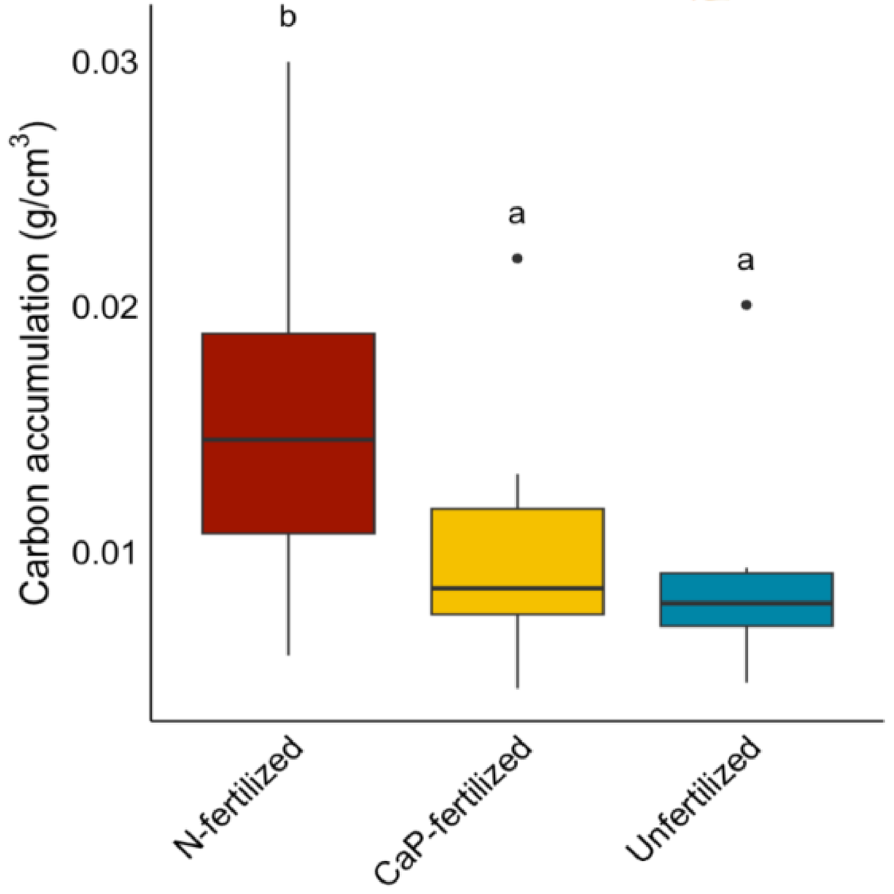


Karstula forest, Finland

Modified from Global Forest Resources Assessment (2020)

Mixed effect models and post hoc pairwise comparisons, $p < 0.02$



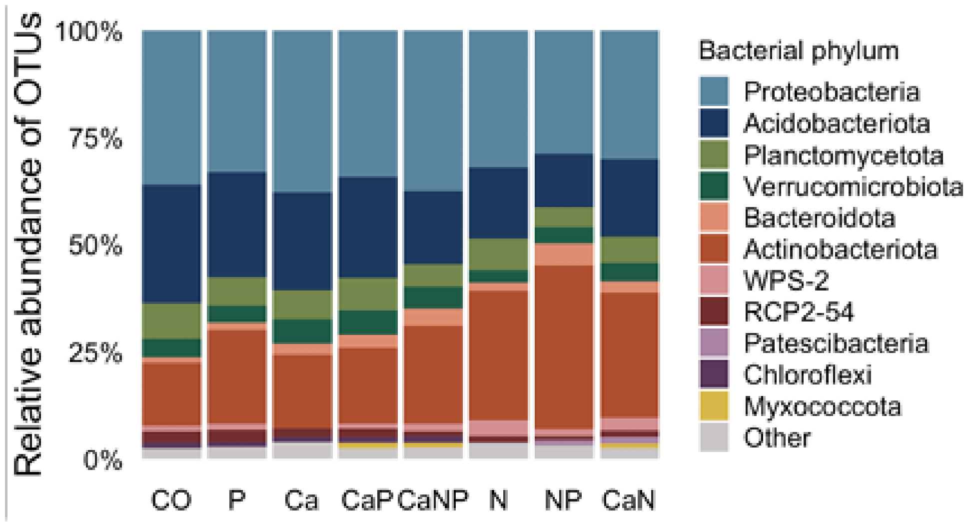


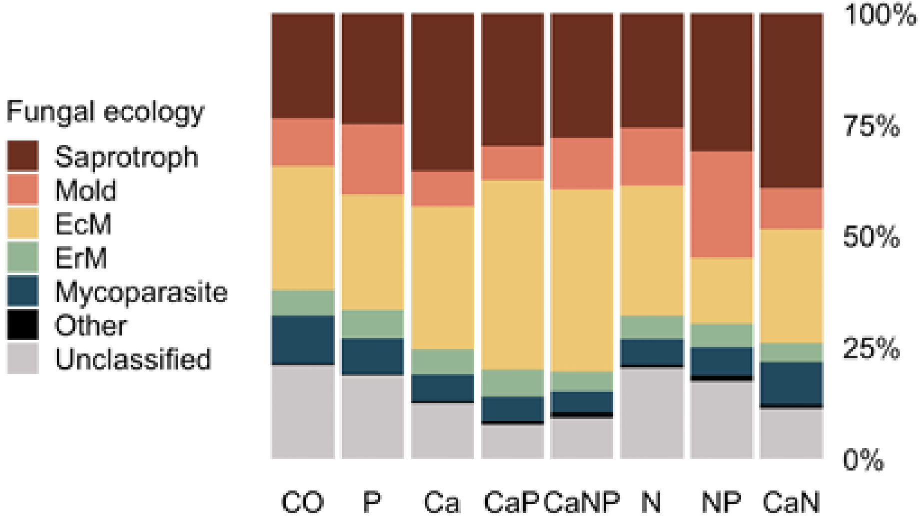
Increased soil carbon storage by 65% compared to unfertilized plots

Increased tree biomass by 50% between 1980 to 2015

by Etienne Richy, Petr Baldrian et al. Manuscript in prep.

Does microbial composition influence carbon accumulation processes?





by Etienne Richy, Petr Baldrian et al. Manuscript in prep.

How to explain C storage in CaN plots?

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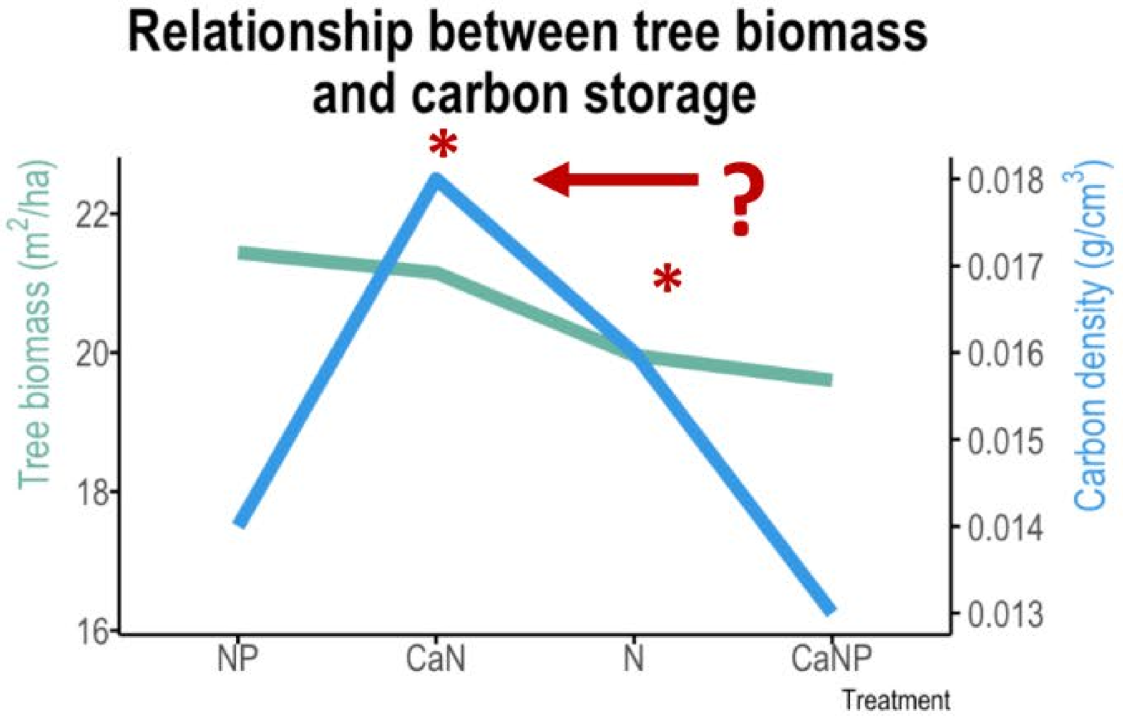
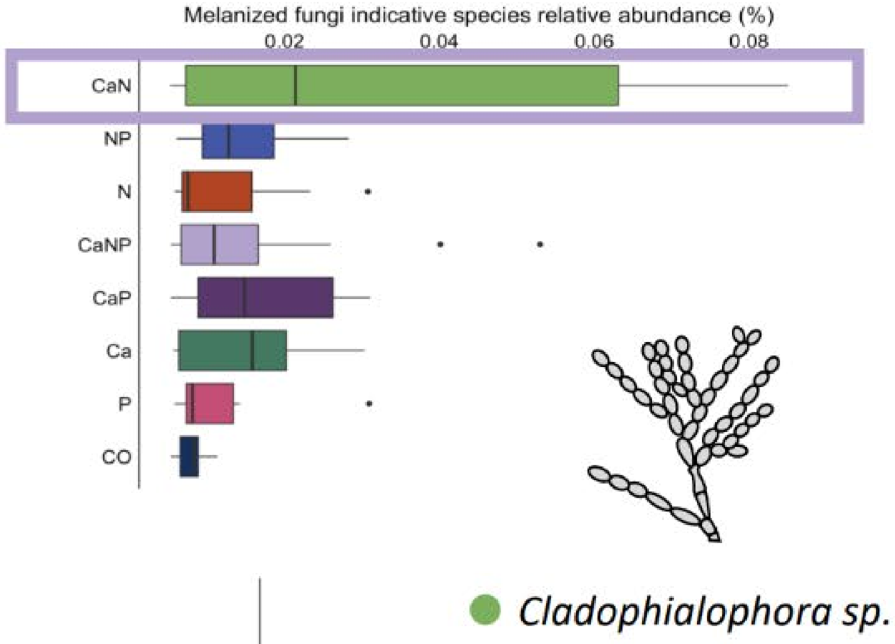
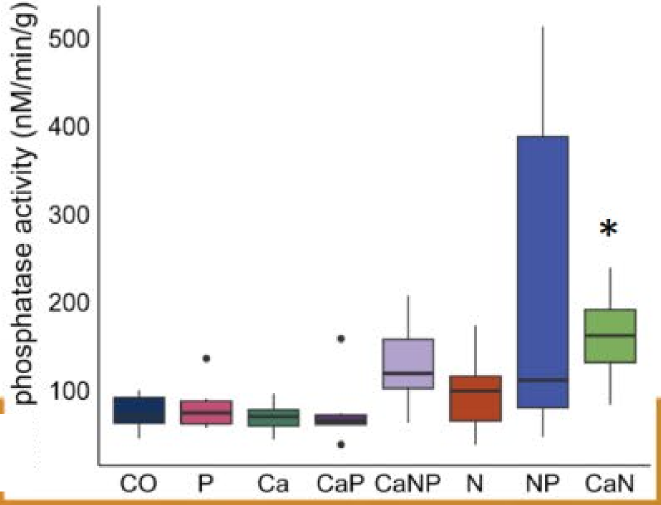


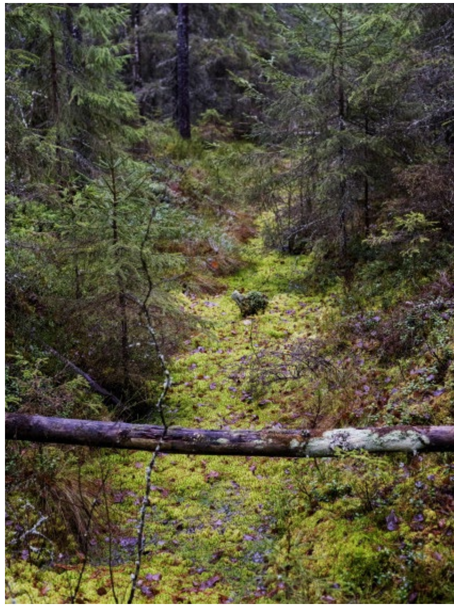




Phosphorus forage and saprotrophic melanized fungi emerged as the key factors for long-term carbon storage

by Etienne Richy, Petr Baldrian et al. Manuscript in prep.

Drivers of the peatland soil GHG fluxes



Peatland water level affects soil GHG emissions

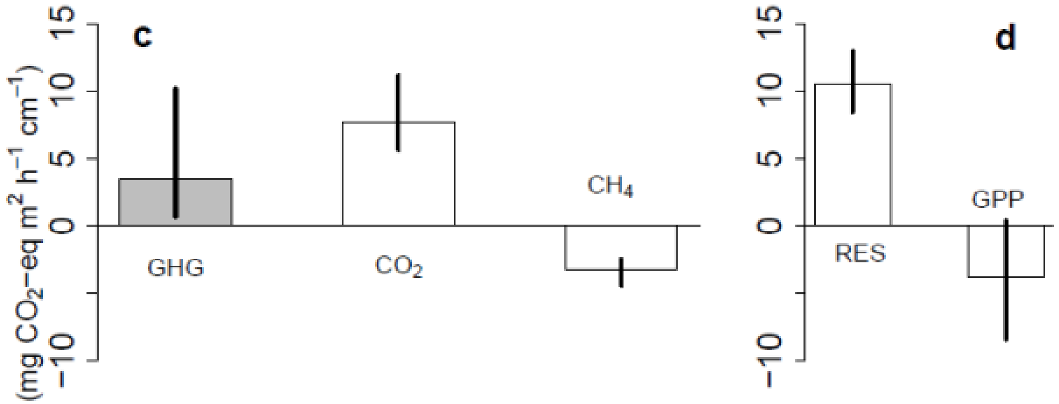
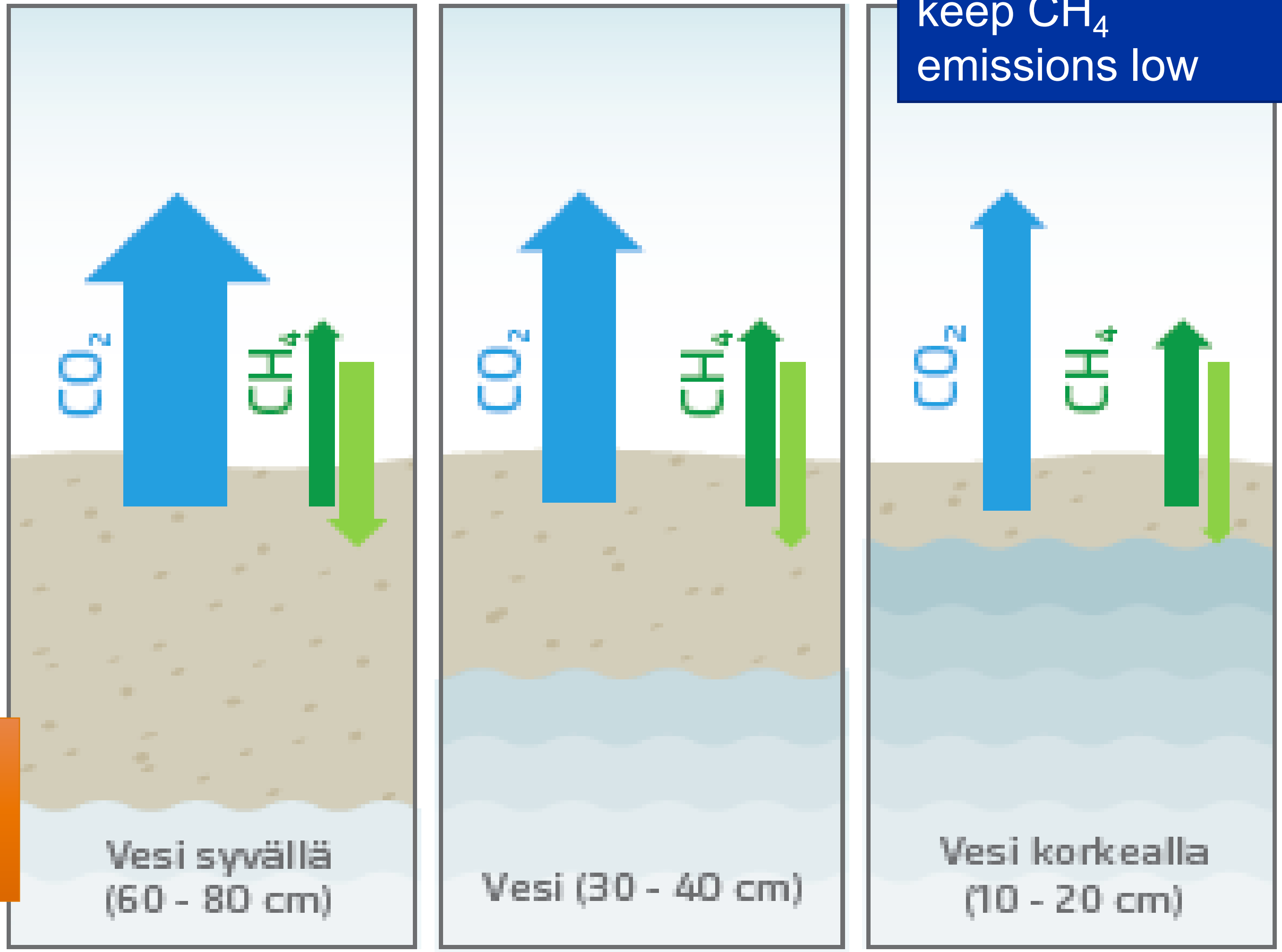


Fig. Sensitivity of peatland carbon emissions per 1 cm water level drawdown.

Meta-analyses by Huang et al. 2021 Nat. Clim. Chang. 11, 618–622 https://doi.org/10.1038/s41558-021-01059-w

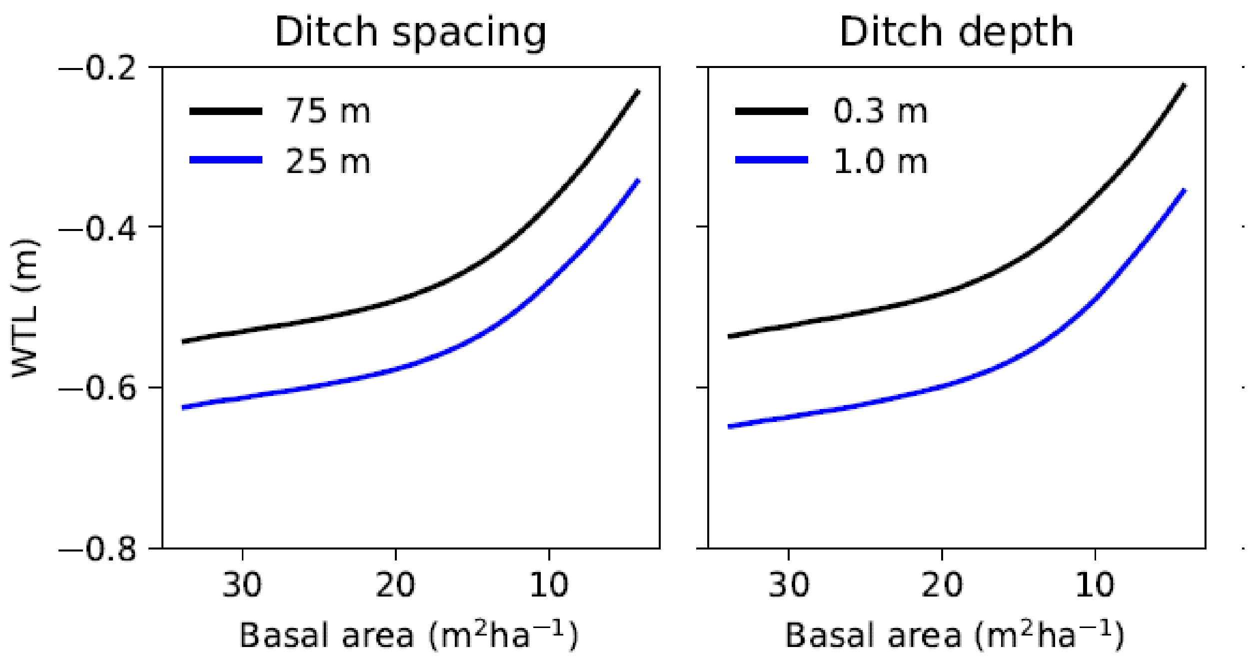
Low water table: peat decomposes and high CO_2 emissions

Avoid flooding to keep CH_4 emissions low



Living trees control the water level in peatland forests

No need for ditch maintenance if stand is not clear cut

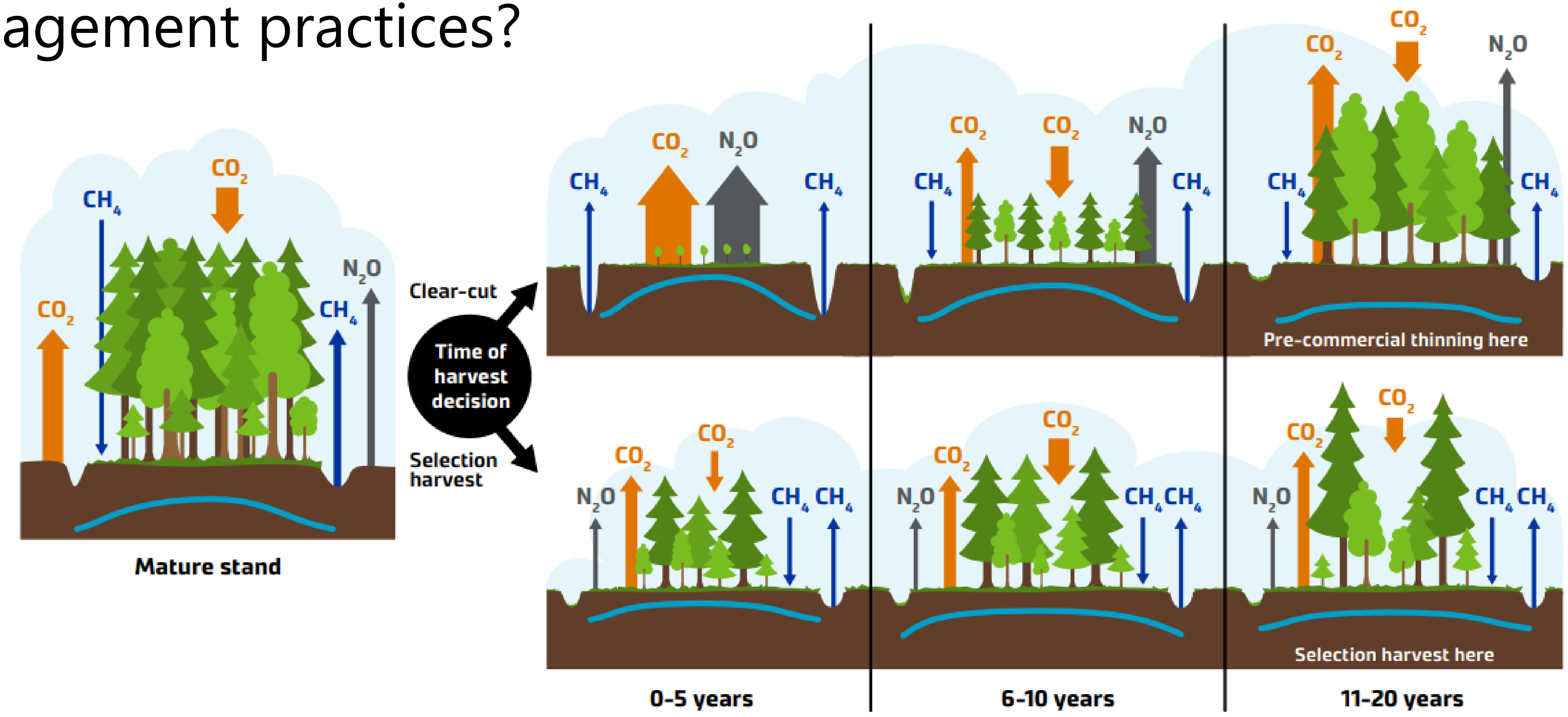


Leppä et al., Selection Cuttings as a Tool to Control Water Table Level in Boreal Drained Peatland Forests (2020) Front. Earth Sci., 09 Oct 2020. https://doi.org/10.3389/feart.2020.576510

https://github.com/LukeEcomod/SpaFHy-Peat

Management regime affects GHG emissions

Clear-cut or selection harvesting? Can we find sustainable peatland management practices?



What we know about GHG dynamics in peat?

Science of The Total Environment
Volume 901, 25 November 2023, 165421

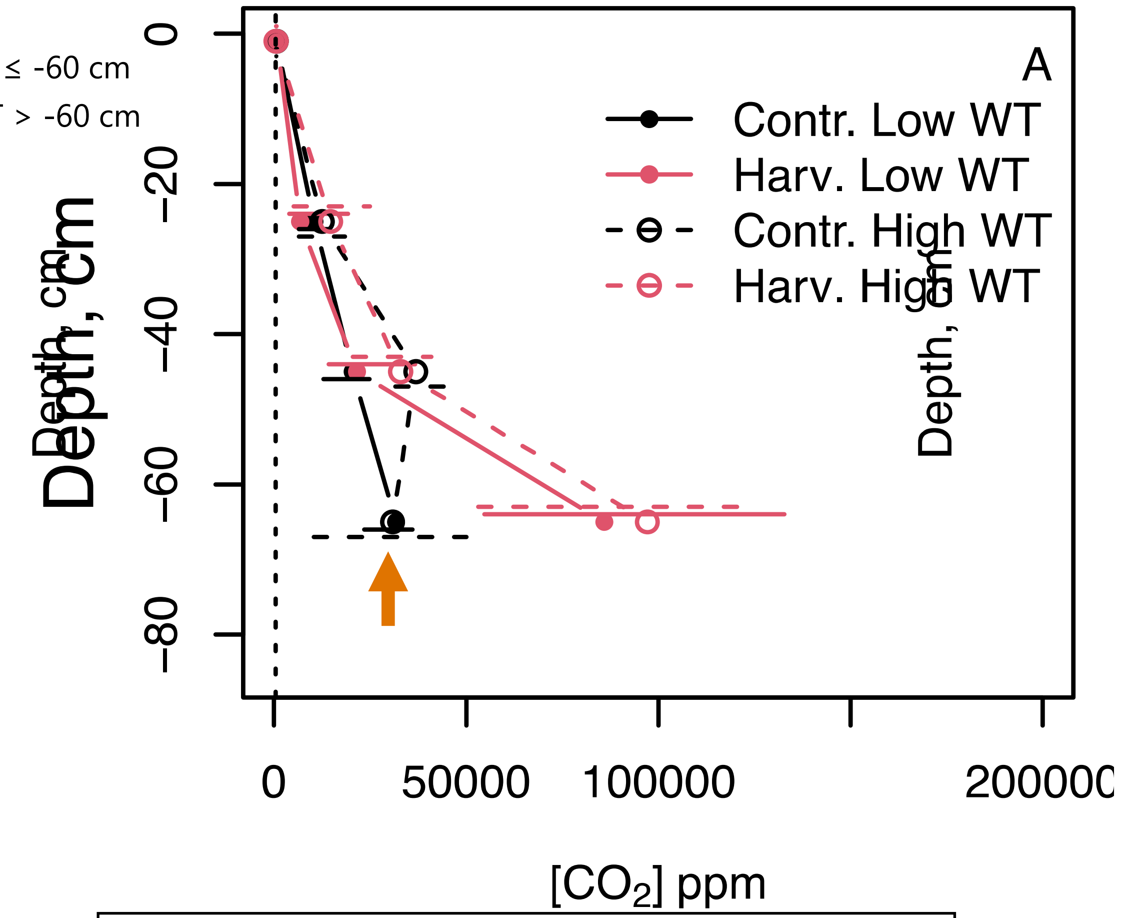
Soil GHG dynamics after water level rise – Impacts of selection harvesting in peatland forests

Mikko Peltoniemi [a], Qian Li [a], Pauliina Turunen [a b], Boris Tupek [a], Päivi Mäkiranta [a], Kersti Leppä [a], Mitro Müller [a], Antti J. Rissanen [a c], Raija Laiho [a], Jani Anttila [a], Jyrki Jauhiainen [a], Markku Koskinen [b], Aleksi Lehtonen [a], Paavo Ojanen [a], Mari Pihlatie [b], Sakari Sarkkola [a], Elisa Vainio [b], Raisa Mäkipää [a]

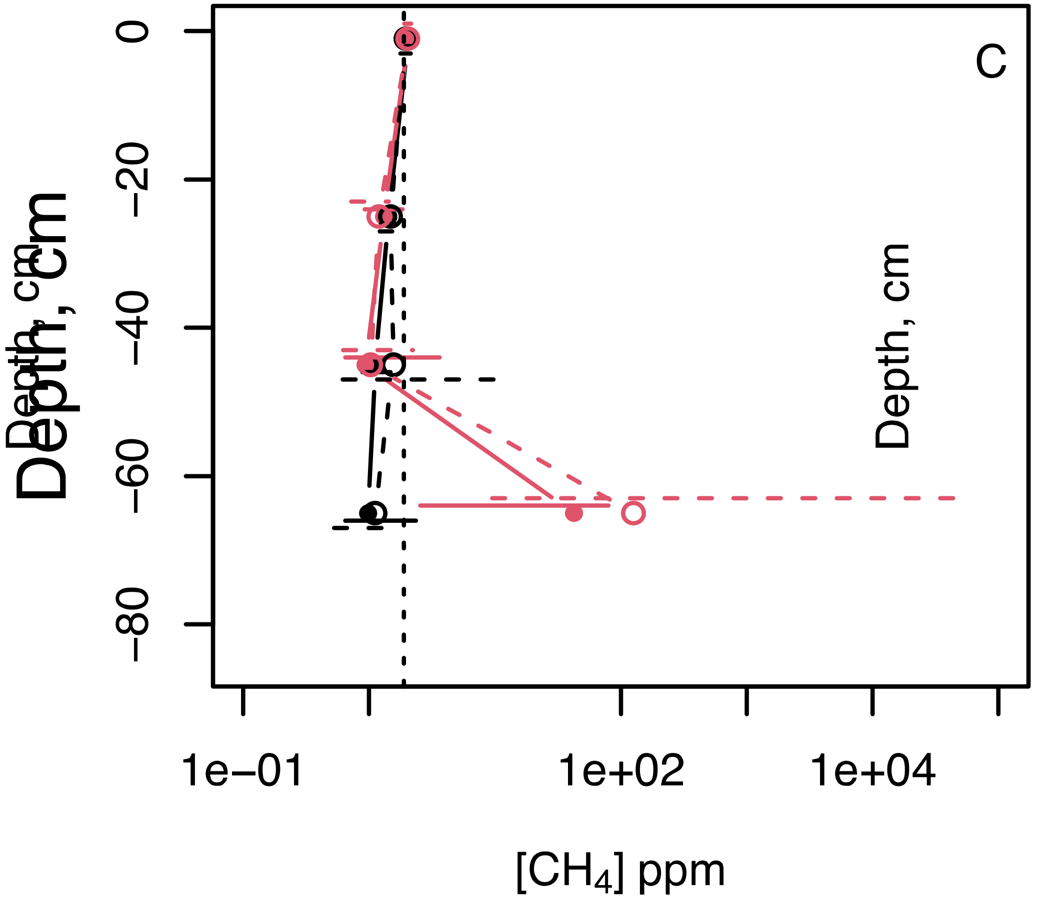
https://doi.org/10.1016/j.scitotenv.2023.165421

Observed CO_2 and CH_4 concentrations in soil, in pore air

Low WT ≤ -60 cm
High WT > -60 cm



Deep soil CO2 concentrations were higher when soil is wet (high WT, selection harvest)



CH_4: High consentrations in deep soil when it is wet
Sub-atmospheric concentrations in middle horizons & when dry

What is role of ditches?

Ditched are CH_4 sources, but are there differences between ditches

frontiers | Frontiers in Environmental Science

TYPE Original Research
PUBLISHED 05 April 2023
DOI 10.3389/fenvs.2023.1121969

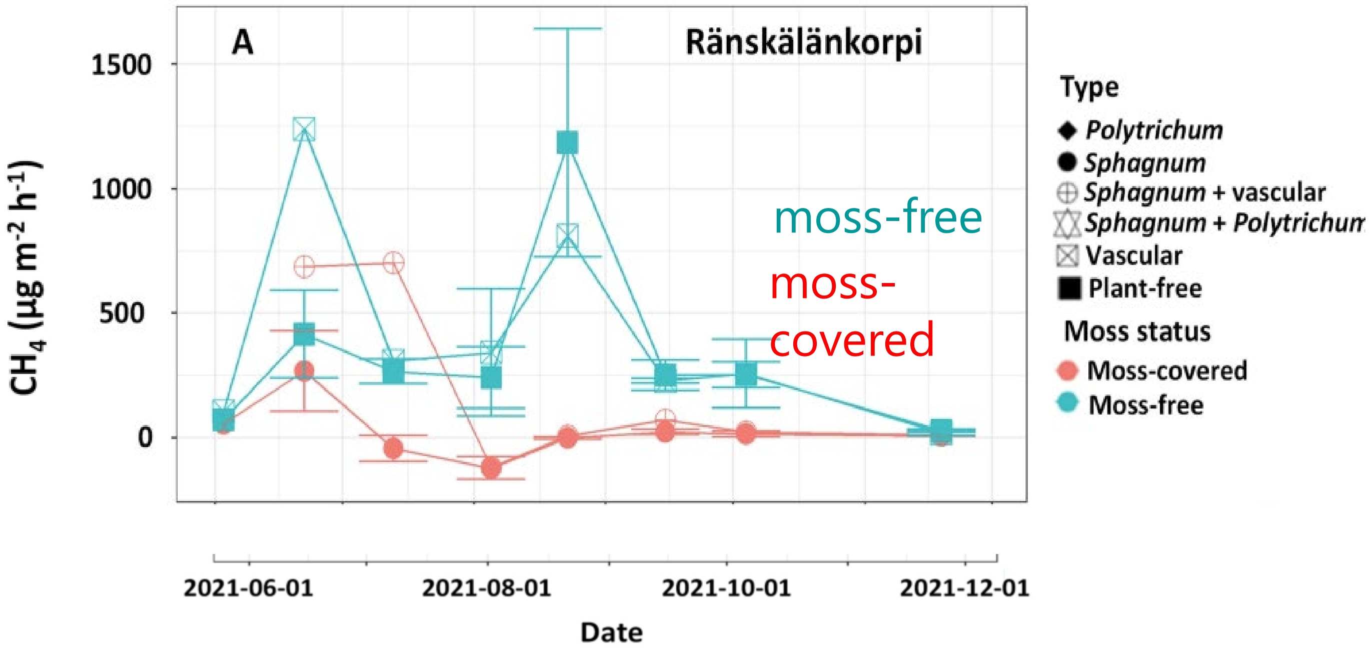
Vegetation impacts ditch methane emissions from boreal forestry-drained peatlands—Moss-free ditches have an order-of-magnitude higher emissions than moss-covered ditches

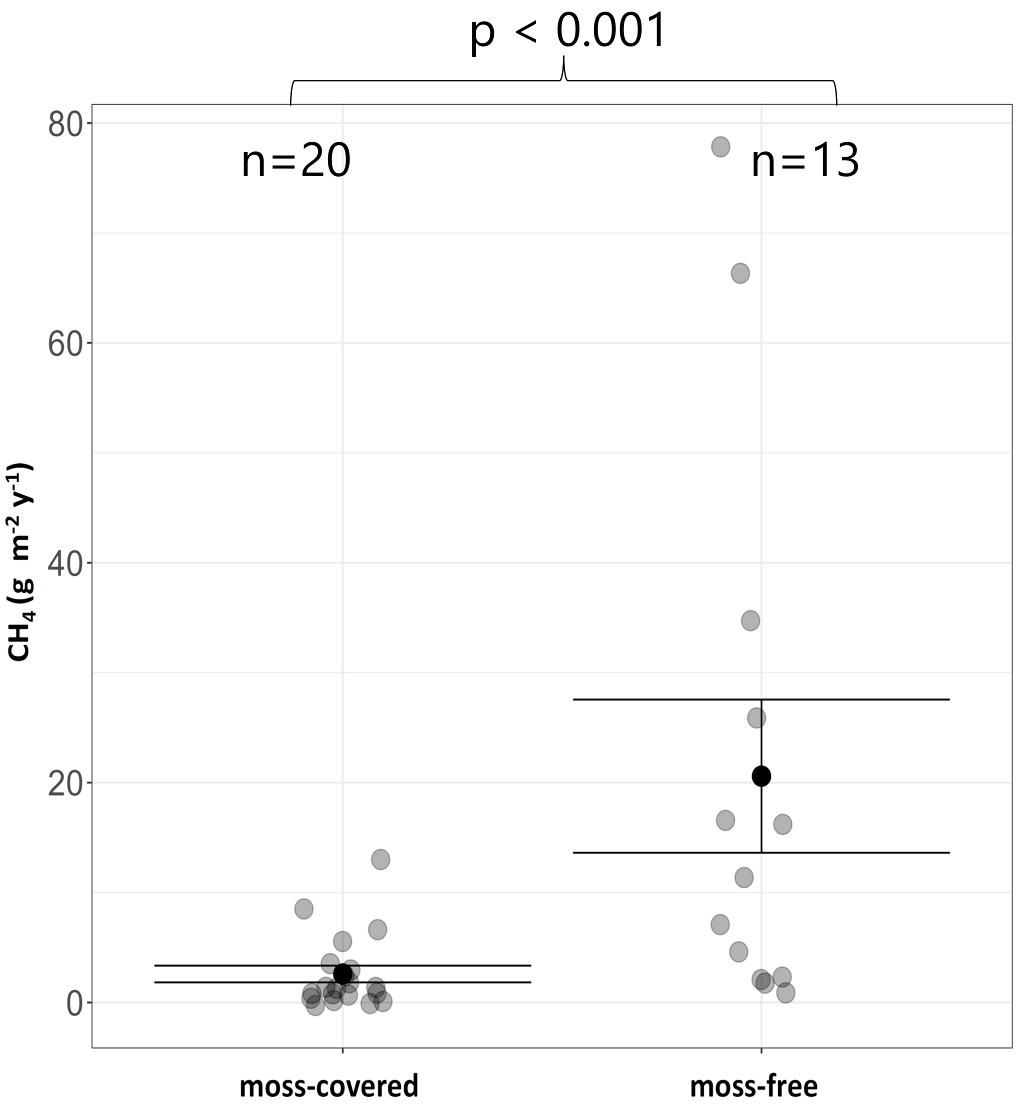
Antti J. Rissanen[1,2]*, Paavo Ojanen[1,3], Leena Stenberg[1], Tuula Larmola[1], Jani Anttila[1], Sakari Tuominen[1], Kari Minkkinen[3], Markku Koskinen[4,5] and Raisa Mäkipää[1]

Photo by Sarkkola, Luke

Ditch CH_4 emissions lower in moss covered ditches

Seasonal CH_4 emissions (µg m^{-2} h^{-1}) in ditches of Ränskälänkorpi (2021)





Role of Sphagnum mosses in ditches

- Mean seasonal CH_4 emissions from moss dominated ditches ~90% lower than from open water surfaces
- Moss layer - in addition to surface sediment - filters efficiently CH_4 emissions from ditches
- CH_4 flux from moss cover to the atmosphere enriched in ^{13}C compared to ditch water - Indicate CH4 oxidation (preferentially consuming 12C) within the moss layer
- 10-28% of carbon in ditch *Sphagnum* mosses potentially originated from oxidized CH_4.

Now we are working on linkages between peatland GHG fluxes, microbial processes and microbial community

Summary

1. Soil carbon accumulation is increased by N fertilization due to increased tree biomass, increased fungal biomass and changed in microbial community.
2. Peatland GHG emissions can be mitigated by avoiding clear-cuttings and opening of the ditches. Major part of the emissions are produces in the topmost peat layer.
3. Effects of climate wise management practises are not fully accounted in the national greenhouse gas (GHG) inventories: inventory methods have to be updated and further developed.
4. Further measurement are needed - especially soil responses to clear-cutting are not well known.
5. EU Soil Mission will enhance understanding on soil properties and processes, and it creates networks for communication between research and stakeholders.

Thank you!

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