Title: Collaboration on forest soil monitoring in support of policy and sustainable forest management – harmonizing current national programs to do better - together

Network title: Integrating Soil Monitoring in Nordic Forests – data harmonization, future designs and studies to examine soil function at different scales (NorForSoil)

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Preamble:
Thousands of years with cool and moist climates have resulted in large contemporary soil carbon stocks in Nordic and Baltic forests; forests that are actively managed to help feed global needs for wood products. Several national soil monitoring programs are in place to follow trends in soil characteristics but often observations are too few to attain the statistical certainty necessary for robust conclusions. The annual SNS network NorForSoil explored the potential of merging national Nordic and Baltic monitoring data on forest soil quality and carbon to enable robust cross-border analyses and broadly applicable results facilitating policy development, mandatory environmental reporting and sustainable forest management. NorForSoil included all Nordic and Baltic countries, partnering also with Canada and Germany.

Forest soil monitoring programs
National forest soil monitoring programs track the development in soil health indicators and carbon content by regular sampling of forest soils in a way that represents the forest soil of a whole country. After drying, sieving, weighing and chemically analysing the soil samples, soil carbon stores and other metrics are calculated to document soil conditions over time. Such data maps the variation around a level or trend to provide baselines of soil conditions, under the present biophysical, economic and societal conditions. Such baselines are critical for detecting changes.

Regional synergy by merging data is challenging
Forest soil inventories have been carried out in most of the Nordic and Baltic countries, with programs emerging at different times in response to national priorities. As a result, methodologies differ among countries at least in some respects. These differences - though not unexpected or incorrect - prevents the immediate data merging, analysis, and comparison across countries. This is a challenge for the reporting under international agreements, such as to the EU and UNFCCC, which increasingly move towards using comparable data across nations. A recent example is the newly proposed EU soil monitoring law where consistent and large amounts of data are needed to define criteria and indicators of soil health as well as to perform the reporting on compliance. Further, carbon trading schemes increasingly request methods to document forest soils, methods that can only be developed with large amounts of consistent data. Despite the many similarities in forests of

Nordic-Baltic countries, systematic attempts to harmonize monitoring methods and data are scarce and requires cross-national collaborations.

Addressing the challenge – with limited means
NorForSoil addressed these challenges in three ways: ***First, by conducting a survey*** among national forest soil monitoring programs in the Nordic-Baltic region and beyond for an overview of similarities and differences. ***Second, collaborated on a specific case*** to harmonize a small subset of existing data to study the development of soil carbon stocks following clear cut harvest. ***Third, by gathering researchers, monitoring team members and stakeholders*** we facilitated numerous discussions on methodologies – current and future - and data usage with the intention to ease knowledge transfer and collaboration.

The survey allowed for the comparison of funding and implementing bodies, statistical design, and methodologies for field sampling, laboratory work and calculations. It also collected information on existing and potential future data. One country in the NorForSoil network monitors soil biodiversity indicators routinely, but the survey indicated the interest in several of the other countries. Recent scientific insights on the importance of microbial communities for soil functioning supports the relevance of such monitoring. The value of forest soil monitoring data increases when combined with National Forest Inventories (NFIs), that monitor forest resources and vegetation, such as timber volumes, tree biomass and forest health. The extent to which national forest soil monitoring are or could be integrated with NFIs were also part of the survey. The survey provides basic information on methodologies at all levels and the context in which targeted harmonization could take place.

The case performed data harmonisation in a subset of available data and focused on the potential effect of clear-cut harvest on forest floor and mineral soil carbon. Harmonization enabled the meaningful merging of national datasets, making it easier to reach the critical amount of data needed for statistical detection of effects, and thereby enhancing the value of individual national datasets. Such large-scale datasets help clarify the broader applicability of findings from detailed but spatially limited field experiments. Additionally, these expanded datasets can reveal patterns detectable only at larger spatial scales, encompassing wider ranges of conditions related to climate, forest- and soil types. Results from the study is reported in a PhD-thesis (University of Copenhagen, 2024).

The gatherings were numerous – physical and online - and reflect, that the NorForSoil engagement with stakeholders and fellow researchers has increased awareness of the benefits in harmonizing and merging national forest soil monitoring datasets. Benefits that include an efficient use of resources by leveraging existing national systems leading to potentially more robust conclusions and harmonizing or standardizing for easier use internationally without compromising the value of these systems for national needs. The many discussions on how to monitor soil health and the role of monitoring microbial communities have offered a basis for countries wishing to expand their monitoring into this field but also, they indicate that Nordic-Baltic collaboration on this aspect is needed. On the practical level, the participation in common field training sessions, knowledge exchange on field excursions and a low threshold for contacting colleagues for help and inspiration indicates the potential for collaboration at all steps in the monitoring process.

We believe the activities of the NorForSoil network have created meaningful progress towards guiding policy and forest management on forest soil issues in the Nordic-Baltic region. NorForSoil has facilitated the efficient use of the knowledge and invested data in a region subject to climatic changes, supplying a significant part of the global timber needs and thus carrying the potential burdens of negative management effects in our forest ecosystems and. Further, the network has worked to ensure that our forest soils are represented in an accurate and meaningful way in international reporting. Case studies were limited to soil carbon; however, the recent emergence of the EU soil monitoring law makes it apparent that soil carbon is just one among many indicators of soil function and health for which national data sets should be used jointly.