SITUATIONAL ANALYSIS

on Natured-based Carbon Offsets

The possibilities of nature-based carbon offsets in Central Finland

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Central Finland (FINLAND)

2024

This Situational Study has been prepared by the Regional Council of Central Finland on behalf of Central Finland region in the framework of Interreg Europe programme project Nature-based Carbon Offsets (NACAO). The Nature-based Carbon Offsets (NACAO) project receives financial support from the European Union (Interreg Europe/ERDF). This publication reflects the author's views only and the Interreg Europe programme authorities are not liable for any use that may be made of the information contained therein.

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1. Introduction

Climate change is one of the greatest challenges requiring urgent policy action. The climate crisis is dire. The compensation of GHG emissions is, in general, a topic underdeveloped by the public administration and, when developed, only limited and traditional measures are entered into force.

To improve this, NACAO (Nature-based Carbon Offsets) project aims at being an accelerator for regional governments with competencies on climate change throughout Europe actively approaching carbon sequestration, in this case by developing nature-based solutions and policies.

Central Finland's regional strategy is based on the goal of overall sustainability, and the strategy sets the goal of achieving carbon neutrality and stopping the biodiversity loss by 2030. In particular, the Roadmap for Carbon Neutral Central Finland 2030 includes measures related to carbon sequestration in the thematic area Agriculture and Forests.

The majority of Central Finland is covered by forests. These forests are especially important for carbon sequestration, as growing vegetation absorbs carbon dioxide through photosynthesis, while mature, old-growth forests serve as significant carbon reservoirs and hotspots of biodiversity. Currently, logging levels in Central Finland are high, leading to a reduction in carbon storage. In managed forests, carbon is most efficiently sequestered in forests during their rapid growth phase. Once the forest reaches middle age or maturity, the rate of carbon sequestration slows down but does not cease. The intensity of forest management affects the potential for carbon sequestration, particularly in clear-cut based forestry, as after logging and possible terrain treatment, the area can act as a carbon source for years, whereas forests beyond maturity serve as carbon reservoirs and sinks.

In addition to forestry, the potential for carbon sequestration in forests is influenced by possible land-use changes, particularly deforestation resulting from construction activities. In Central Finland, there are significant pressures for renewable energy construction, and redirecting these pressures to areas other than forests would help preserve forest carbon sinks and storage.

Object and scope of Situational Studies

The report provides a general assessment of the carbon sequestration potential of the region's natural areas, evaluates future changes and potential for change from a biodiversity perspective, and presents visions for nature-based carbon sequestration solutions in Central Finland. Among other things, the study identifies which habitats in Central Finland act as effective carbon sinks for vegetation and soils, where these areas exist, and what combinations of measures could be implemented in the region to enhance the potential for nature-based carbon sequestration. Land ecosystems, such as peatlands and forests, and their associated human-induced activities will be considered.

2. Methods

2.1 Spatial data analysis

The spatial data review used a variety of data describing forest and peatland characteristics from the Central Finland region. Forest structure was examined based on the 16 m x 16 m gridded data on stand age and stand length from the multi-source National Forest Inventory (MVMI) of the Natural Resources Institute of Finland (LUKE). The analysis of peatlands was based on the peatlands in the cadastral database of the Finnish Land Survey (MML) and the peatland drainage status data from the Finnish Environment Institute (Syke). There is some overlap between the forest area of the MVMI and the peatlands of the MIS, i.e. peatland forests may naturally overlap with drained peatlands in these analyses. The unprotected sites in the status report of the Supplementary Proposal for Mire Protection (Aapala et al. 2021) were compared to the drainage status of the sites. The area of peatland fields was determined using fields from the terrain database and soil and topsoil data from the Geological Survey of Finland (GTK) soil map (1:200 000) on peat layers.

In addition, various other data, such as forest areas of biodiversity importance (Mikkonen et al. 2018), were used to visually examine the projected climate change in the area based on the heat sum change rate data produced by the Finnish Meteorological Institute (Aalto 2023).

The potential for nature-based carbon sequestration in different areas should be compared with the situation where the habitat type under consideration is as undisturbed (natural) as possible. This will allow an assessment of how human activities, in this case in particular the conversion of forests and peatlands to economic use, have influenced the natural carbon cycle in the habitats and how the carbon cycle in modified areas will evolve in the future. The analysis compared the carbon sequestration potential of forests and peatlands on protected and non-protected lands. Approximately 542 square kilometres of Central Finland's land area is under protection, which corresponds to about 3.4% of Central Finland's land area excluding inland waters. The total area of Central Finland is 19 950 square kilometres and the land area is 16 075 square kilometres. In the spatial data analyses, nature conservation areas included state and private nature reserves, other state protected areas, Forestry Agency (Metsähallitus) properties for nature conservation purposes, and Natura 2000 network areas.

The Global Forest Watch (GFW) data, based on the interpretation of changes in Landsat satellite data, effectively identifies large areas of clear-cutting. The GFW data were used to estimate the loss of canopy cover caused by clear-cutting or possible large-scale natural disturbances in Central Finland between 2000 and 2022. The resolution of the data was changed to match the MVMI data and these stand levels were considered overlapping, and the average annual canopy cover loss was estimated. This reduction is mostly due to clear-cutting and was estimated to be slightly above 1% each year during the current millennium.

The forests were classified by age and height into four maturity classes representing the different stages of carbon sequestration. As the MVMI data describe the situation in 2021, the stand age was increased by three years to correspond to the current situation in 2024. After the change, the stand age of forest land in Central Finland varied between 3 and 165 years. The data were classified into five categories based on the carbon sequestration potential of the stand age (Repo et al. 2021).

A second classification was also produced for the forest area of Central Finland based on the length of the stand. The length reflects the carbon sequestered in the stand and its growth stage. A young forest can be expected to increase in height and thus act as a carbon sink in the coming years, while tall trees can be expected to have reached their growth maximum and thus carbon sequestration to have slowed down. In Central Finland, the stand length varied between about 0 and 30 m. The average stand length data were classified into six categories (0-5), roughly representing the stages of stand growth from a post-open-felling seedling towards a mature, mature forest.

The classified stand age and height levels were summed to a single stand maturity level. At this level, the values ranged from 1 to 10. The lowest values were found in areas where the tree was less than 2 m tall and less than 15 years old. The highest scores were in areas where the forest was relatively old and tall. This sum score was classified into four categories to describe the carbon sequestration potential of forests in Central Finland (Table 2.1).

TABLE 2.1 MATURITY VALUE CLASSIFIED ON THE BASIS OF MEAN AGE AND HEIGHT OF THE STAND.

Sum of the age and height levels of the classified stand	**Carbon sequestration potential of the tree stand**	**Category in the forest land coarseness grid level**
0–2	Seedling stand, the tree population has not reached the age of rapid growth and is low. The area of forest after clear-cutting can be a carbon source for up to 15 years, depending on the site, among others.	1
3–5	A fast-growing forest, the trees are young and growing rapidly while sequestering carbon efficiently.	2
5–8	Medium-aged forest, the stand continues to grow and mature. Carbon sequestration is still efficient, but the phase of fastest growth has passed.	3
9–10	Mature forest, trees approaching or past maturity for felling. It is relatively old and close to its maximum length. The carbon sequestration of mature forest is slowing down, but it is a valuable carbon store.	4

The condition of the mires was examined using the drainage data produced by Syke based on the swamp data in the terrain database. The material distinguishes between undrained and drained peatlands as well as peat production sites. The majority of mires in Finland have been converted to forestry through drainage. This may have had different effects on their carbon sequestration depending on the type of mire. As natural, undrained mires are the most important carbon sinks and carbon stocks in Finland, and as there is already a voluntary programme to supplement the protection of mires, this study examined the remaining undrained, unprotected sites under the Supplementary Proposal for the Protection of Wetlands (SSTE). The SSTE sites were examined in overlap with the protected areas and drainage data.

The area of peatlands was calculated by overlaying the field data from the terrain database with the Geological Survey of Finland surface and subsoil data at 1:200 000 on the soil map. Areas with thick or thin peat layers on the subsoil (>1 m) or topsoil (<1 m) were selected from the soil map. The total area of arable land in Central Finland was approximately 1016 square kilometres, of which approximately 84.2 square kilometres, or about 8%, was on peatland. As the starting point for the analysis was the fields in the cadastral database, these areas do not overlap with peatlands, i.e. the data on the drainage status of peatlands and peatland fields do not overlap in this analysis.

2.1.1 Sources of error in spatial data analysis

The drainage data produced by Syke is based on the 2008 terrain database delineations of marshes and streams and an analysis based on the 2006 Corine land cover classification. The drainage status may therefore be out of date in some areas, as drainage or restoration of drained marshes, if any, since these data sets are not reflected in the results.

The fields in the geodatabase were overlaid on the 1:200 000 soil map. Soil data at this scale is a generalisation, which should be considered when examining results and targeting carbon sequestration measures.

2.2 Literature review

The literature review collected and systematically reviewed publications and materials from research projects on the topic. The review covered measures related to nature conservation, forestry, agriculture, peat production and their potential impacts. Land use and construction were also discussed, with particular reference to combating deforestation.

2.3 Stakeholder workshop

The spatial data analysis and literature review of the study was supplemented with qualitative data based on a multidisciplinary stakeholder workshop in Jyväskylä on 11 March 2024.The aim of the workshop was to enrich the study's data with local insight and to generate understanding of what kind of nature-based carbon sequestration solutions could work best in the region and how they should be promoted. A total of 12 people attended the workshop. The participants represented the following organisations.

The workshop applied the method of futures research, where the potential of nature-based carbon sequestration was explored through three different combinations of measures. The alternative combinations of measures were developed on the basis of a literature review and include carbon sequestration measures for forestry, agriculture, conservation and land use and construction.

3. Potential sites for carbon sequestration in Central Finland

3.1 Carbon sequestration potential in forests

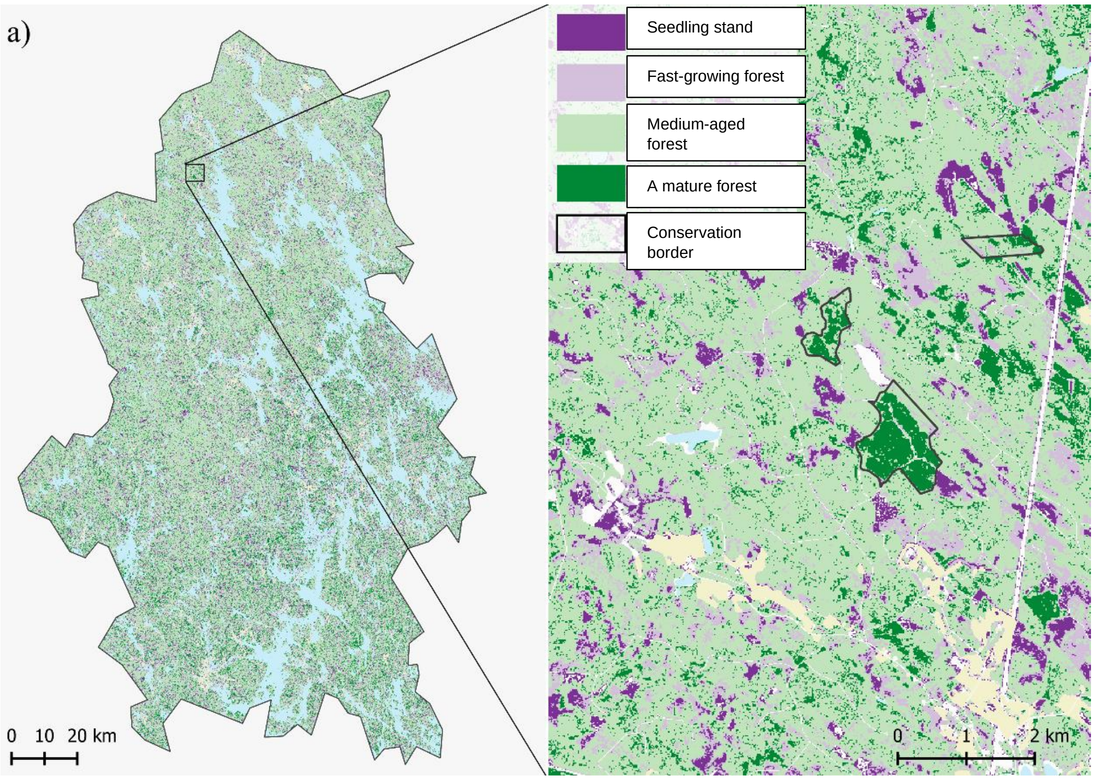
Forests were classified into four categories based on their age and height, which roughly describe the development of tree carbon sequestration in a forested boreal landscape. The creation of the maturity level and the data are described in chapter 2.1.

TABLE 3.1 AREAS OF STAND MATURITY CLASSES AND THEIR SHARE OF THE FOREST AREA IN CENTRAL FINLAND.

	Seedling stand	Fast-growing forest	Medium-aged forest	A mature forest	Total forest area (according to MVMI 2021 data)
Forest area (km^2)	1 015	2 206.5	8 664.4	1 888.3	13 774.2
Share of forest area (%)	7.4	16	62.9	13.7	
Forest area in protected sites (km^2)	16.8	55.7	276.1	106.1	454.7
Share of protected forest area (%)	3.7	12.2	60.7	23.3	

Most of the forest area in Central Finland in 2024 is approaching middle age, i.e. harvesting maturity on forestry land. The second largest category in Central Finland is fast-growing forest. In total, slightly less than 80 % of the forest area in Central Finland is currently a potential carbon sink (Table 3.1). Just under 14 % of the stand has reached or is reaching peak growth, i.e. their carbon sequestration is slowing down and their role is changing from sink to potential storage, while about 7 % is a potential carbon source.

The structure of non-forestry sites, i.e. protected forest, differs from the rest of the forest land, especially in the proportion of mature forest and stands. The age structure of protected forests is clearly older and the proportion of mature forest in these areas is over 23 %, which is about 10 percentage points higher than the average for forests in Central Finland. This difference can be easily seen when looking more closely at the regional classification of the stands according to carbon sequestration potential (Figure 3.1). The largest concentrations of mature forest are often found in conservation areas, although smaller patches can also be found outside conservation. When allowed to develop into old and mature stands, forests provide not only an important carbon storage, but also valuable habitats for many endangered species that require structural features of old-growth forests, such as decaying wood and mature trees.



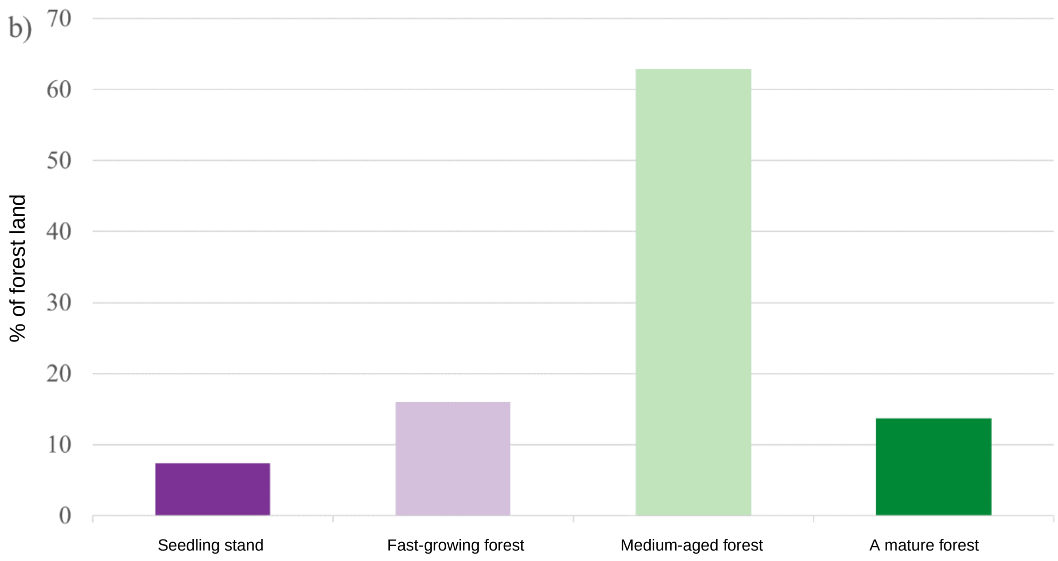


FIGURE 3.1 CLASSIFICATION OF FORESTS BY STAND CARBON SEQUESTRATION POTENTIAL IN CENTRAL FINLAND. A) SPATIALLY B) HISTOGRAM OF CATEGORIES.

3.2 Carbon sequestration potential in mires

Almost 2 457 square kilometres, that is, about 87%, of Central Finland's mires are drained or otherwise used by humans, e.g. as peat production areas (Table 3.2). The area of undrained mires in Central Finland is about 373.5 square kilometres, i.e. about 13% of the mire area. Of this undrained part, about 36.5% is under conservation, i.e. the majority of the still undrained mires are not protected. The data also indicate that some drained peatlands are protected.

TABLE 3.2 DRAINAGE STATUS, AREA UNDER CONSERVATION AND AREA OF VALUABLE PEATLANDS IDENTIFIED IN THE SUPPLEMENTARY PROPOSAL FOR THE PROTECTION OF WETLANDS (SSTE) IN CENTRAL FINLAND THAT ARE STILL UNPROTECTED.

	Undrained	**Drained**	**Total**
Area (km^2)	373.5	2 457	2 830.5
Share of mire area (%)	13.2	86.8	100
Protected (km^2)	136.5		
At SSTE sites without protection (km^2)	14.9		

The conservation status of mires could be significantly improved, for example by encouraging voluntary conservation action at sites identified in the Supplementary Proposal for the Protection of Wetlands, which have not been modified, but are not yet protected. These sites represent about 7% of the unprotected and undrained peatland area in Central Finland (Figure 3.2).

Although only just over a third of the undrained mires are protected, they constitute the largest remaining area of continuous undisturbed wetlands. The unprotected undrained mires occur in small areas and the land use of the surrounding areas is most likely to affect the hydrology of these mires and thus the dynamics of carbon sequestration and storage. The hydrology of peatlands and potential restoration activities should be planned at the watershed scale so that contiguous areas of carbon and methane sequestration benefit from potential natural enhancement activities. Particularly important are the areas crossed by the main river basins. In these areas, mires play an important role in filtering nutrient loads from the environment and thus buffering water pollution.

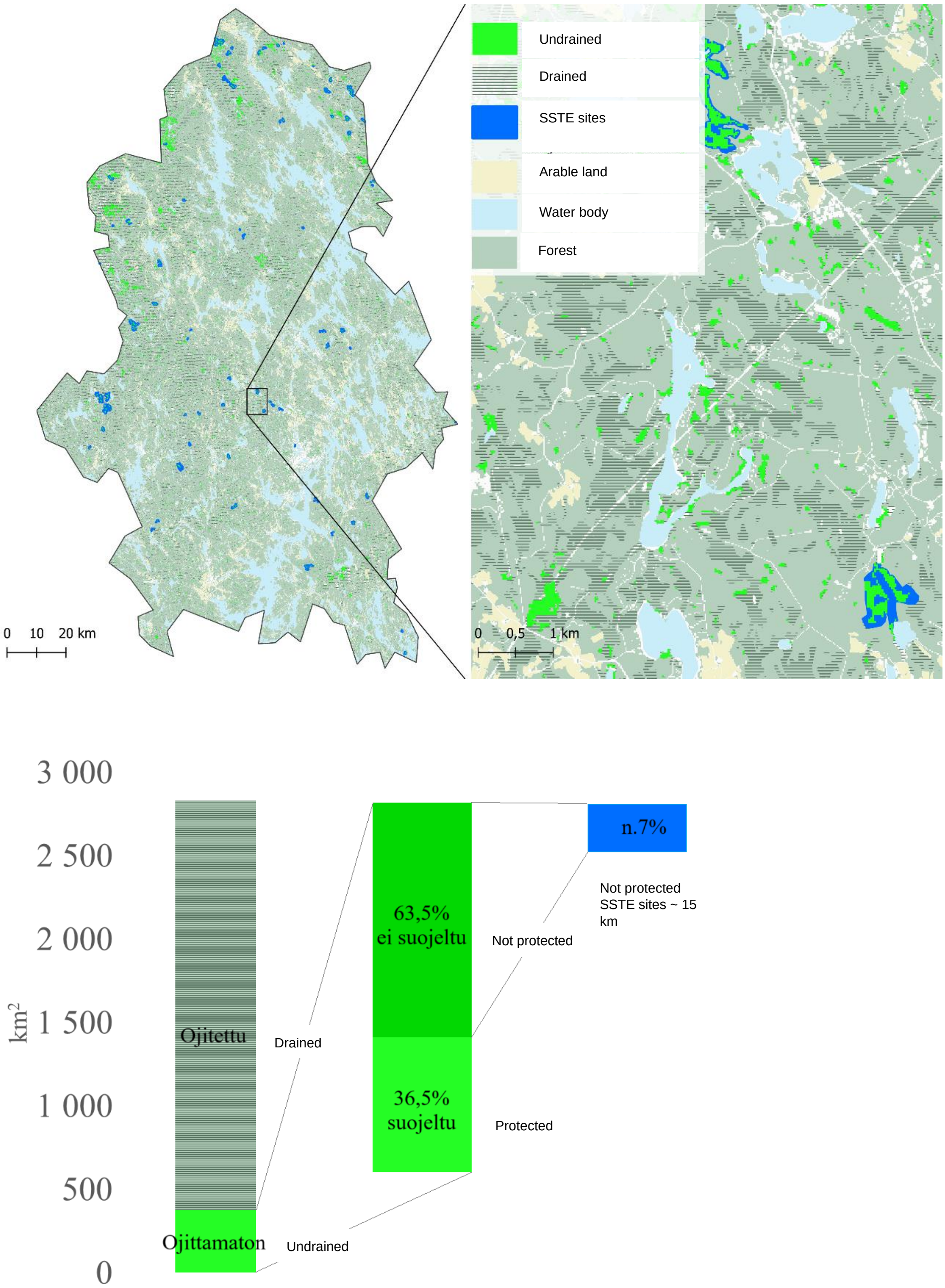


FIGURE 3.2 DRAINAGE STATUS OF PEATLANDS IN CENTRAL FINLAND AND LOCATION OF UNPROTECTED UNDRAINED SSTE SITES.

3.2.1. Peatland fields in Central Finland

The total area of arable land in Central Finland was about 1016 square kilometres, of which about 84.2 square kilometres, or about 8%, is peatland soil (Figure 3.3). Peatland fields are evenly distributed in Central Finland, but the proportion of peatland in fields varies. The largest concentrations of agriculture are in the northern parts of the region. Peatland fields need to be considered in this study because they produce a significant amount of carbon dioxide emissions when peat decomposes.

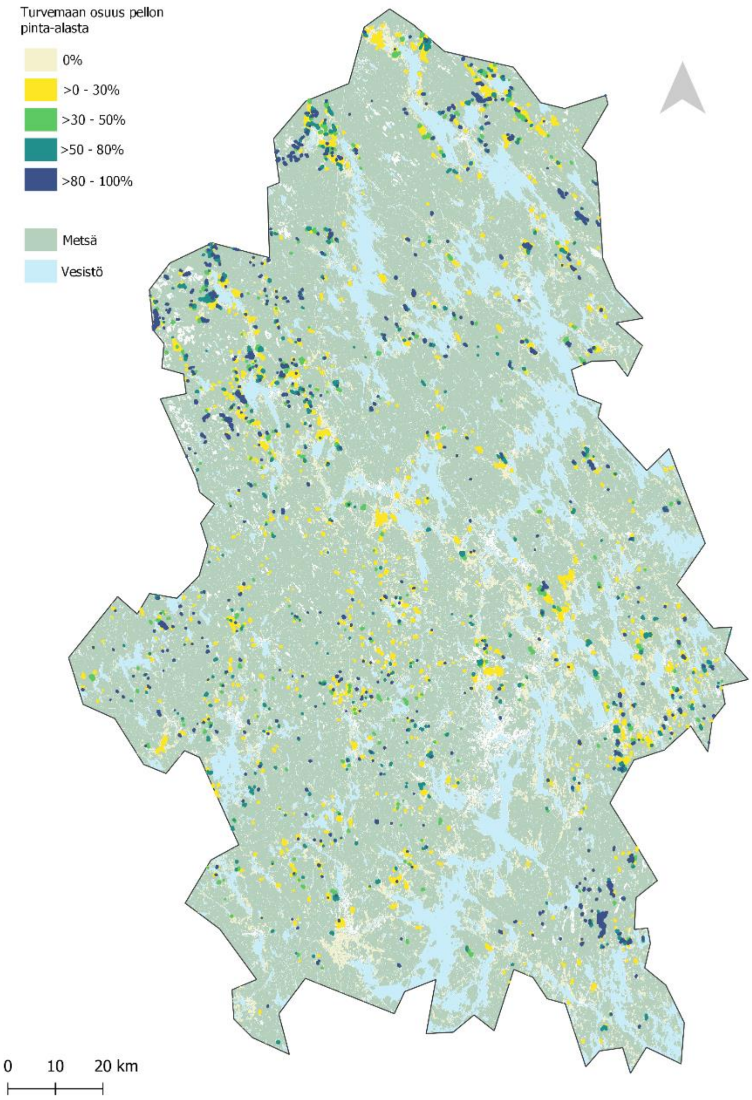


FIGURE 3.3 SHARE OF PEATLAND SOILS IN THE AREA OF ARABLE LAND IN CENTRAL FINLAND. THE AREA OF FIELDS CONTAINING PEATLAND HAS BEEN ENLARGED FOR READABILITY.

4. Assessment of carbon sequestration potential and appropriate measures

Central Finland's total calculated annual emissions are approximately 8.7 million tonnes of carbon dioxide equivalent (CO2eq.a-1). Of total emissions, carbon sinks account for 75%, so the neutrality gap is 25%. The net emissions in Central Finland are 2.2 Mt CO2eq.a-1 (Holmberg et al. 2023). Table 4.1 provides a breakdown of carbon stocks and stocks in Central Finland for different land use categories.

TABLE 4.1. CARBON FLUXES IN CENTRAL FINLAND (HOLMBERG ET AL. 2023).

Land use category	**Area km^2**	**Emissions TgCO2eq a-1**	**Sinks TgCO2eq a-1**	**Net emissions TgCO2eq a-1**
Forests, drained peatland	1 726	0,7	-0,6	0,19
Forests on mineral land	11 697	5,0	-6,0	-0,97
Forests together	13 423	5,7	-6,6	-0,8
Agricultural land	907	0,44		0,44
Surface waters	2 937	0,8		0,8
Wetlands	442	0,23	0,19	0,04
Built environment	483	1,521		

A summary of the measures is presented in Table 4.2, presenting also the habitats they affect, the land uses to which they relate and, in the case of forests, whether the forests grow on mineral soil or peatland.

Three different combinations of nature-based carbon sequestration measures have been compiled: 1. Business as usual, 2. Multifunctional carbon measures and 3. Strong carbon measures. The categories indicate the policy options discussed in the stakeholder workshop. The first combination of measures, *Business as usual,* describes a situation where nature-based carbon sequestration solutions are moderate, carbon sinks are decreasing and the land protection level remains at the current level. The second combination of measures, *Diversified carbon measures*, provides more diversified solutions, increases carbon sinks and slightly higher levels of protection. The third set of measures, *Strong carbon measures*, illustrates a situation where solutions and conservation targets are the most ambitious compared to Business as usual. The three policy lines are illustrated in figure 4.1.

TABLE 4.2 LIST OF CARBON SEQUESTRATION AND MITIGATION MEASURES FOR THE REGION OF CENTRAL FINLAND.

Measure	Habitat	Form of land use
Avoiding logging	Forests on mineral land	Forestry
Reducing soil preparation	Forests on mineral land	Forestry
Selecting the best forest management practices in terms of forest damage risks	Forests on mineral land	Forestry
Avoiding reduction of forest area	Forests on mineral land	Forestry
Extending the growing season and avoiding felling	Forests on mineral land	Forestry
Use of processed planting material for regeneration	Forests on mineral land	Forestry
Ensure rapid regrowth of the end harvested forest	Forests on mineral land	Forestry
Fertilisers for plant breeding	Forests on mineral land	Forestry
Afforestation of arable and built land	Forests on mineral land	Forestry
Restoration to mire or wetland	Peatland forests	Forestry
Continuous covered growing	Peatland forests	Forestry
Avoiding efficient drainage: means-testing strict assessment of the need for re-drainage	Peatland forests	Forestry
Avoid intensive drainage: dig shallower ditches	Peatland forests	Forestry
Low-yield areas out of forestry use	Peatland forests	Forestry
Avoiding land use changes	Peatland forests	Forestry
Ash fertilisation (especially on sites with thick peat)	Peatland forests	Forestry
Afforestation of swamp fields and swamp bottoms	Peatland forests	Agriculture
Afforestation of abandoned or underused fields	Peatland forests	Agriculture
Restoration of abandoned or underused peatland fields to wetlands	Peatland forests	Agriculture
Afforestation or reforestation as an aftercare measure on suitable areas withdrawn from peat production	Peatland forests	Peat production
Targeting construction to areas outside the best carbon sinks and carbon sequestration sites	All forests	Land use and construction
Forestry	Built land	Land use and construction

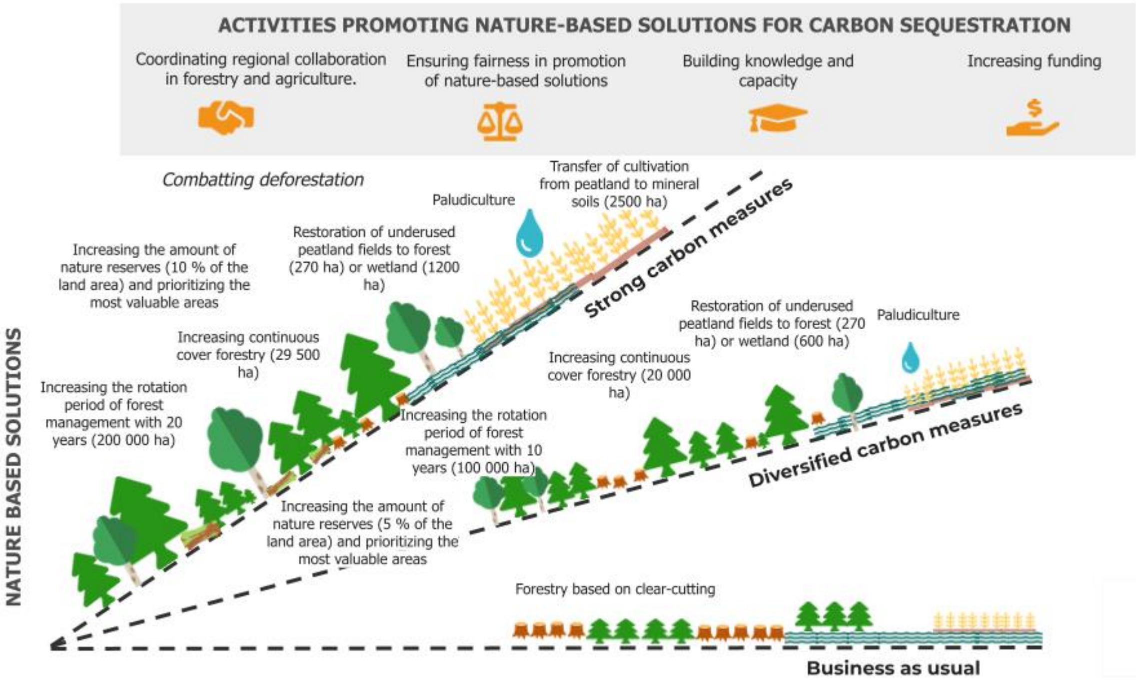


FIGURE 4.1. MEASURES ADVANCING NATURE-BASED CARBON SEQUESTRATION IN THREE COMBINATIONS: BUSINESS AS USUAL, MULTIFUNCTIONAL CARBON MEASURES AND STRONG CARBON MEASURES.

5. Conclusions and recommendations

Drainage and conversion of peatlands for forestry and agriculture cause significant carbon dioxide emissions from the soil. Peat decomposes as the water level drops, releasing carbon dioxide into the atmosphere. Emissions from heavily fertilized drained peatlands can be particularly high. Although the draining of new areas has nearly ceased, the forestry sector still carries out restoration drainage, which has received government support until very recently. In forestry, soil emissions can be addressed by avoiding unnecessarily intensive drainage and by switching to continuous cover forestry, in which case restoration drainage may not be necessary. Over the long term, restoration of low-yielding areas has emission reduction and carbon sequestration effects.

Extending the average growth period of forests and reducing logging is the quickest way to increase carbon sinks. Extending rotation periods by twenty years from current recommendations increases carbon stored in spruce stands by 0.5 tC/ha/a and in pine stands by 0.3 tC/ha/a. In the long term, increasing forest area is an effective measure. Furthermore, switching to continuous cover forestry in drained areas could increase carbon sinks by -0.4 Tg carbon dioxide equivalent per hectare by 2035.

Emissions from drained peatlands are the most significant source of emissions in agriculture. Although peatlands represent only about a tenth of all agricultural land in

Finland, they account for over half of all agricultural greenhouse gas emissions. In Central Finland, peatlands cover about 8% of the arable land, most of which are fields with a deep peat layer in intensive use with significant emission reduction potential. In agriculture, emissions from peatlands can be reduced by transitioning to continuous vegetative cover on fields with a thin peat layer and by shifting cultivation from fields with a deep peat layer to mineral soils as well as using controlled drainage. A rough estimate is that emissions from peatland fields in Central Finland could be reduced by about half if effective measures are taken on peat fields, taking into account the thickness of the peat layer and the type of use of the field.

Carbon dioxide emissions will continue in old peat extraction areas unless post-harvest measures are taken. If keeping the peatland dry does not require continuous action, the area can be afforested using, for example, downy birch, turning it into a carbon sink over time. If the area requires drainage, it is advisable to restore it as a wetland.

To promote nature-based carbon sequestration in Central Finland, the stakeholder workshop identified the following as particularly important: enhancing collaboration and knowledge dissemination, ensuring fairness and securing financing, improving the quality of nature protection, prioritizing and targeting the most important areas, and decentralizing energy production.

Based on the findings of this study, we recommend the following impactful and concrete measures to promote carbon sequestration and reduce carbon emissions in natural environments:

- Strive to increase the area of nature reserves to preserve carbon stocks and protect the most biodiverse areas. These include areas proposed for conservation by the complementary mire conservation programme as well as the most valuable old-growth forest sites.
- Extend forest management rotation periods to increase forest carbon storage as trees mature.
- Shifting to continuous cover forestry, especially in nutrient-rich peatland forests.
- Shift low-yield peatlands to other uses (e.g., afforestation, wetland restoration).
- Move cultivation from peatlands to mineral soils, rewet peatlands which are in agricultural use, and practice paludiculture. Use controlled drainage where applicable.
- Avoid clearing forests for agriculture or construction. Place wind turbines on already built-up areas, such as industrial zones, whenever possible. Identify other local energy production opportunities that can utilize existing built environments.

To implement the above concrete measures, landowners need incentives such as:

- Coordinating regional cooperation in forestry and agriculture.
- Increasing knowledge and developing skills in new or alternative production methods.
- Ensuring fairness in promoting nature-based solutions.
- Increasing funding and exploring different financing options (e.g., international carbon trading).

6. Bibliographic references

Aalto, J. 2023. Climate data from "Fine-grained climate velocities reveal vulnerability of protected areas to climate change" by Heikkinen et al. 2020. Ilmatieteen laitos. Saatavilla: https://doi.org/10.23728/FMI-B2SHARE.414565C6E993426DBDF4F05FCE8FC28F

Aapala, K., Kartano, L., Määttänen, A. M. & Alanen, A. 2021. Soidensuojelun täydennysehdotus: Tilannekatsaus 2015-2020.

Holmberg, M., Junttila, V., Schulz, T., Grönroos, J., Paunu, V.-V., Savolahti, M., Minunno, F., Ojanen, P., Akujärvi, A., Karvosenoja, N., Kortelainen, P., Mäkelä, A., Peltoniemi, M., Petäjä, J., Vanhala, P. & Forsius, M. 2023. Role of land cover in Finland's greenhouse gas emissions. Ambio 52, 1697–1715. Saatavilla: https://doi.org/10.1007/s13280-023-01910-8

Mikkonen, N., Leikola, N., Lahtinen, A., Lehtomäki, J., & Halme, P. 2018. Monimuotoisuudelle tärkeät metsäalueet Suomessa - Puustoisten elinympäristöjen monimuotoisuusarvojen Zonation-analyysien loppuraportti.

Repo, A., Rajala, T., Henttonen, H. M., Lehtonen, A., Peltoniemi, M., & Heikkinen, J. 2021. Age-dependence of stand biomass in managed boreal forests based on the Finnish National Forest Inventory data. Forest Ecology and Management, 498, 119507.