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Towards sustainable forest management: Strategies for soil carbon sequestration and GHG mitigation

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Forest-based mitigation potential by 2050



EU-27, Norway, Switzerland, and the UK

Protect	Forest conservation (2;3)	
	Avoiding deforestation (1;1)	
Manage	Other active management (7;14)	
	Forest harvesting (decreased) (6;13)	
	Forest harvesting (increased) (1;1)	
Restore	Forest restoration (peatlands) (2;5)	
	Afforestation/Reforestation (2;5)	
Wood use	Shifts in wood uses (9;23)	
	Cascading (1;4)	
	Increased efficiency (2;5)	
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Mitigation potential (Mt CO₂eq yr⁻¹)

- European forests and wood products can provide a significant contribution to achieve climate neutrality by 2050
- Need for implementation of sustainable soil & forest stand management

Forest soils can increase climate change mitigation with targeted management

A comprehensive understanding of the soil carbon sequestration potential and GHG emissions to help design climate change mitigation strategies.

24 Test Sites

WP4 Test sites: 1,2&4

- + Conversion from monocultures to mixed stands
- + Managing forests to mitigate forest fires



and harvesting

Soil C stock, CO, emissions, CH, emissions, N,O emissions





4. Forested peatland hydrology management

(elevated soil water level)

Soil C stock CO, CH, N,O

5. Biodiversity

management

Soil C stock CO, CH, N,O

🔭 Increase 🕒 Decrease 📼 No net impact 🔹 No data

N fertilization has positive impacts on boreal forest mineral soils



(A) Increase in tree productivity

(B) Increase in soil C stock

Increase in Rh **(C)**, but Rh/SOC **(D)** did not differ significantly between plots



+ Modest raise in N₂O emissions

+ Increases fungi biomass and enzyme activities

Selection harvest as tool to mitigate clear-cut related GHG emissions in drained peatland forests





Traditional (CC) management

- More water table variability
- Higher GHG emissions

Alternative (CCF) management

- Economic savings
- Reduced nutrient exports
- Lower GHG emissions

- Extensive peatland areas drained for forestry purposes in the Nordic countries (4.7 Mha in Finland)
- Reaching maturity \rightarrow imminent harvest

Selection harvest as tool to mitigate clear-cut related GHG emissions in drained peatland forests









(B) Higher WTL increase at the CC site

(C) Similar CO_2 emissions at C and CCF sites. Increasing trend at CC site

(D) CH_4 uptake is lost after CC

(E) Harvesting triggers N_2O emissions

* Manual chambers

Source: Martínez-García et al. In preparation

Source: Deliverable 4.4. Empirical analysis on the impact of CSF management on soil properties and GHG exchange

Selection harvest as tool to mitigate clear-cut related GHG emissions in drained peatland forests





2022 (first post-harvest year)



Results:

(A) Annual budgets in 2022:

- CO₂: 23.3 t CO₂-eq ha⁻¹ yr⁻¹ (82.5%)
- N₂O: 4.8 t CO₂-eq ha⁻¹ yr⁻¹ (17.1%)
- CH₄: 0.1 t CO₂-eq ha⁻¹ yr⁻¹ (0.4%)

(B) Significant decrease in CO_2 and N_2O emissions in consecutive years

* Eddy covariance

WORK

IN PROGRESS

Thinning + slash burning enhances tree growth and drought resistance

Results (A):

- Higher tree growth
- Higher resistance to wildfire
- Higher resilience to drought

Results (B):

- Lower forest-floor organic C stocks (~ -50%)
- Higher stability (lower basal SR) in mineral layer





Source: Vilá-Vilardell et al. (2023) Forest Ecology and Management, 527, 120602. https://doi.org/10.1016/j.foreco.2022.120602 Source: Tudela-Haberland et al. Submitted



Forest soil challenges in Europe: Solutions through sustainable forest management and monitoring

Summary of the messages

- Further measurements and sharing of soil data, models, and expertise are needed to reduce uncertainty in carbon stock changes in GHG inventories.
- Enhancing soil carbon sequestration on mineral soils and reducing emissions on peatlands can help meet LULUCF climate targets in the EU.
- Reducing harvests, increasing stocking density and extending rotation length, as well as sustainable post fire management practices, can increase soil carbon stock.
- Partial peatiand hydrology restoration and emission reduction in drained peatland forests can be combined with timber production through continuous cover forestry, avoiding further ditching.
- Forest restoration to more resilient mixed and broadleaf dominated stands enhances adaptation to climate change.
- Readily available methods for assessing soil biodiversity, functional redundancy, and community resilience facilitate implementation of the proposed Soil Monitoring Law.

WP4 Key messages



- Forest management practices have remarkable impact on soil C sequestration and GHG mitigation.
- Most of the results of HoliSoils' WP4 have been implemented in the elaboration of the Policy Brief 2025.

More information:

https://holisoils.eu/



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Thank you for your attention



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