LIVING LAB OF ESTONIA

Restoration for the future WETLANDS
www.alfawetlands.eu

UNIVERSITY OF TARTU 1632

Estonia's Living Lab compares natural, drained and restored wetlands to assess changes in greenhouse-gas balance, ecosystem recovery and water quality



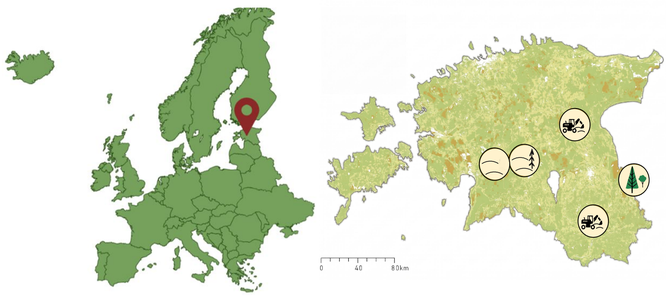




Rewetting can reestablish the natural sink potential of drained and managed sites that provide both ecological and social benefits

1 OUR LIVING LAB

WHERE?



WETLAND TYPES

- Natural peatland, Kuresoo (reference site)
  Natural peatland, Valgeraba (reference site)
- Drained peatland forest, Agali II
- Rewetted drained peatland (initially drained for forestry), Kuresoo
  Restored forestry drained peatland, Valgeraba
- Rewetted peat-extraction area, Ess-soo
  Rewetted peat-extraction area, Laiuse

THE CHALLENGE

Nearly half of Estonia's peatlands have been drained, covering about 0.4 million hectares. The Estonian Living Lab addressed two main restoration challenges:

- In drained peatland forests, it was unclear how rewetting would affect the long-term GHG balance across nutrient-rich and low-fertility sites.
- In former peat extraction areas, natural revegetation can take 20-30 years and remains unpredictable. Restoration needs to re-establish wetland vegetation while limiting CH_4 and N_2O emissions.



Agali drained peatland forest

FIELD VISIT AND KNOWLEDGE EXCHANGE



Joint field excursion to Kuresoo site during the consortium meeting, June 2025

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2 WHAT WE DID

ACTIONS

Rewetting drained peatlands and restoring former extraction sites by raising the groundwater level and mechanised sowing of peat moss to accelerate plant revegetation

Development of a harmonised metadata database linking geographic and continuous tabular records of GHG fluxes, soil properties, biodiversity and microbial data from the project's Living Labs

Monitoring GHG exchange using eddy covariance, transparent and dark closed chamber techniques, along with continuous measurement of environmental parameters

Analyses of soil properties, soil-water chemistry and soil microbial communities

Surveying plant species distribution and vegetation cover across rewetted and restored peatlands

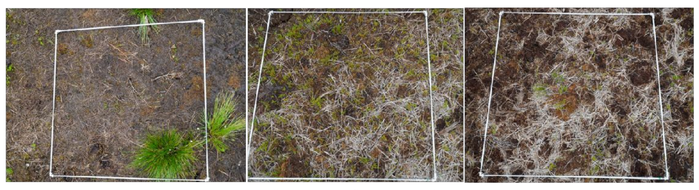
Modelling annual net ecosystem exchange (NEE), CH_4 and N_2O fluxes in both natural and restored peatlands



Laiuse, peat extracted area



Ess-soo peat extracted area



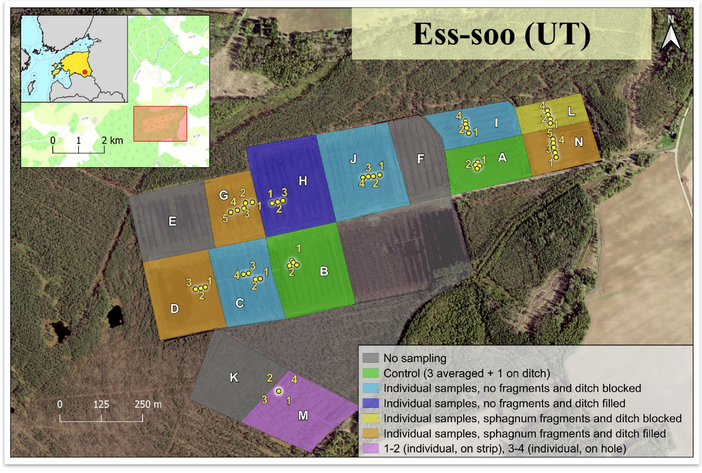
Peat moss cover before and after establishment and restoration



Drained and restored peatlands, Kuresoo



Geochemical and microbial analysis



ALFAwetlands Site ID system example for linkage of GIS and tabular data

3 RESULTS & LEGACY

KEY FINDINGS

The observed GHG balance varied among sites and years, and CO_2, CH_4 and N_2O sometimes changed in opposite directions.

PEATLAND FORESTS

- ✔ At Agali, the nutrient-rich drained peatland forest was a net GHG sink during the first four study years.
- ✔ In 2025, a higher water table coincided with the loss of net CO_2 uptake and greater CH_4 emissions. Lower N_2O emissions did not prevent the site from becoming a net GHG source.
- ✔ Five to six years after rewetting, restored and natural reference forests had similar net CO_2 exchange. Over the available study period, both released more CO_2 than they absorbed.
- ✔ Year-to-year weather variation strongly affected the forest CO_2 balance, mainly through changes in photosynthetic uptake.
- ✔ Vegetation changes after rewetting were associated with higher CH_4 emissions, consistent with increased transport through plants.

FORMER PEAT EXTRACTION AREA

- ✔ Within about five years after rewetting, the growing-season CO_2 balance changed from a net source to a net sink.
- ✔ CO_2 exchange followed strong seasonal temperature patterns. The drained area showed a summer emission peak, while the restored area showed stronger growing-season uptake.
- ✔ Recovering vegetation controlled NEE from spring to autumn and explained more variation in net CO_2 uptake than soil moisture.

MICROBIAL RESPONSE ACROSS ALL LL SITES

- ✔ Across 33 European wetlands, rewetted sites were about twice as similar to unmanaged wetlands as other managed systems. Rewetting also supported the recovery of methanogenesis and methanotrophy.
- ✔ Microbial community composition and interaction networks provided clearer evidence of restoration response than microbial diversity alone.
- ✔ Fungal communities responded less strongly to management and soil depth than bacterial and archaeal communities.

BENEFITS & TRADE-OFFS

Climate mitigation	++
Biodiversity	+
Water quality	+
Production	Not assessed
Management costs	Not assessed
Stakeholder acceptance	+–

++ strong positive
+ positive
+/– mixed
– negative / trade-off

LESSONS

What worked: Comparing natural, drained and restored sites within the same monitoring framework.
What was difficult: Weather variation and different site histories made short-term restoration effects difficult to interpret.
What others can apply: Use suitable reference sites and monitor CO_2, CH_4 and N2O for several years after rewetting.

LEGACY AND NEXT STEPS

- ❖ Long-term monitoring is needed to distinguish restoration effects from year-to-year weather variation. Harmonised site descriptions and metadata will support future cross-site analyses and data publication.
- ❖ Metadata catalogue to persist after project completion as a standing resource for partner institutions' ongoing and future research.

KNOWLEDGE GAPS

When does rewetting deliver a lasting net climate benefit when CO_2, CH_4 and N_2O are considered together?

Which water-table conditions support peatland recovery while limiting long-term CH_4 and N_2O emissions?

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