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The Care-Peat impact within De Wieden

REPORT

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Introduction

The pilot is realised in the Dutch nature reserve area called "De Wieden", located in Steenwijkerland municipality in the province of Overijssel (see **Figure 1**). The nature area encompasses the Wieden and adjoining Weerribben Ramsar sites, to 'form the largest peat swamp of its kind in Western Europe' (RSIS 2022; https://rsis.ramsar.org/). The site is characterised by peat pits, fens, lakes, reed lands, marshes, shrubs, forests, quaking bogs, transitional and terrestrialising fens, and supports vital flora and fauna, such as the European otter, and the greater white-fronted goose. In addition, the reserve contains a legacy of canals, which until the 1920s supported the extraction of peat.

While the site, which is currently owned by Natura 2000 and managed by Natuurmonumenten (NM), provides a vital haven for wildlife, challenges such as agricultural water abstraction, general drainage, and pollution remain (RSIS 2022; https://rsis.ramsar.org/). The aim of the "De Wieden" pilot site is therefore to further the potential of existing site conditions, for improved sequestration and storage of carbon in soil. This was carried out via activities for the **Peat pits** and the **Foreshore** (see **Figure 1**).

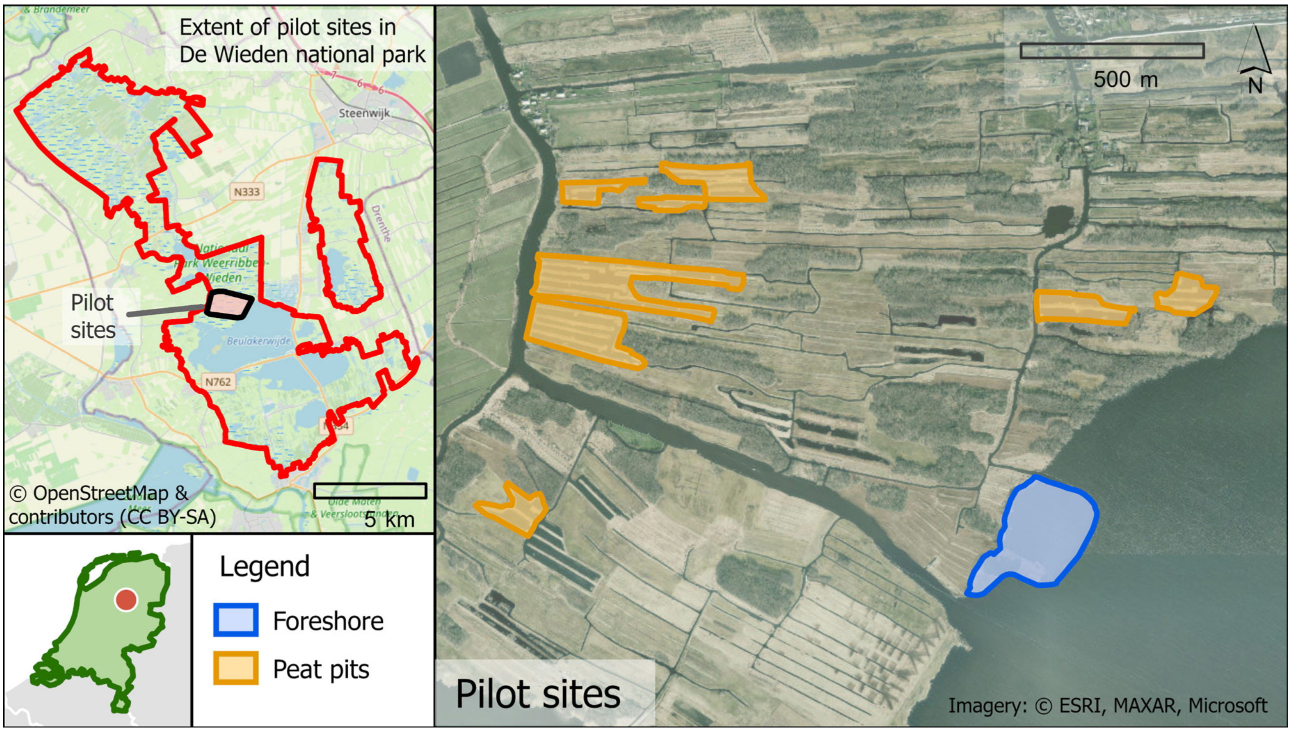

Figure 1: Location and layout of De Wieden pilot site

Aims of restoration

The primary aim of restoration is to increase carbon sequestration and storage, through an overall increase in the coverage of peat soils and beneficial habitats within the reserve. A secondary aim is to provide an improvement in biodiversity, through encouragement of habitat conditions that benefit important plant and animal species. The entire restoration process is easily visualised in **Figure 2**.

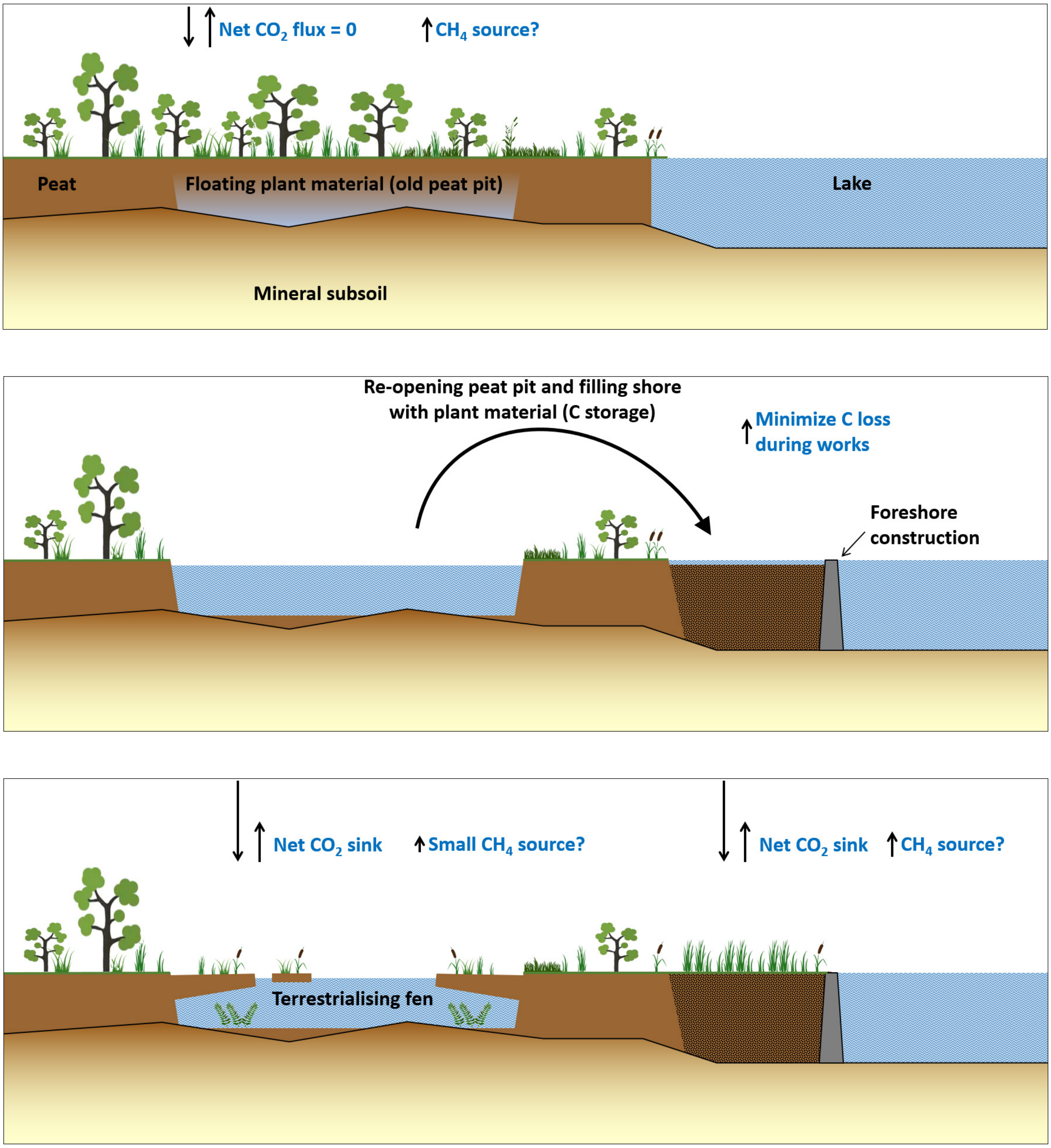

Figure 2: Visualisation of the before (top), during (middle) and after (bottom) of Care-Peat restoration activities in De Wieden

Peat pits
Activities for peat pit areas included the excavation of new turf ponds, or more precisely the re-excavation of historic peat pits. The main aim here was to restart the process of terrestrialisation and to create new layers of moss (floating mats and *Sphagnum*-dominated reedbeds, H7140) which are necessary to maintain succession in later stages (Province of Overijssel 2017a). This process of ecological succession will gradually convert the water-based environment back to peat soils, and therefore benefit the long-term storage of carbon on-site. Carbon losses in the extracted peat soils were minimised during this process, with the soil used elsewhere in the Foreshore to encourage expansion in peatland area.

Benefits to local biodiversity should also develop after restoration activities. An aim of excavation is to expand the geographic range of aquatic and semi-aquatic habitat types such as waters rich in *Characeae* (H3140), lakes containing Water Soldier (*Stratiotes Aloides*), Pondweeds (H3150) and Swamp Sawgrass marshes (H7210). Excavation activities will also encourage the development of specific habitat conditions, on the immediate banks of turf ponds, that are beneficial for the Large Copper Butterfly.

Foreshore
The aim of the foreshore was to make good use of the excavated peat soils from turf ponds in the peat pits, by creating an underwater storage area within the nearby Beulakerwijde lake. The foreshore effectively encloses a section of open water, allowing the deposition and retention of peat soil carbon within permanently wet conditions. The underwater application enables carbon dioxide emissions that are usually released when excavating turf ponds and processing excavated materials (for instance, into garden soil) to be avoided or curtailed. In this way, the creation of the foreshore also contributes to climate change mitigation, which again indirectly plays an active part in the Natura 2000 targets.

As an additional benefit, the foreshore should provide robust protection to the enclosed lake shore, which is currently undergoing erosion. This is causing existing nature, such as reed lands and marshy woodlands to gradually convert to open water. As the bank continues to erode, the surrounding water becomes turbid with peat particles that either float or sink, and then move again, under the influence of strong wind. Wave erosion on the Beulakerwijde lake is a serious threat to not only the banks, but the hinterland, the turf ponds, and ultimately the habitats and habitat types present within them.

In addition to buffering waves, the foreshore will also aim to dampen dynamics in lake water movement. This offers space and possibilities for the development of marsh vegetation that form a habitat for marsh birds, such as the Natura 2000 varieties the Bittern and Sedge Warbler. The expansion of marsh bird habitats is a component of the Natura 2000 management plan, and while the foreshore is not formally included in the marsh development process, it should provide an indirect benefit overall.

Restoration activity

Activities on site began in April 2020, and concluded in April 2021 (**Figure 3**). The first stage involved the construction of the foreshore. Here a demarcation was placed in the lake, by fixing a geotextile screen to poles positioned in the lake-bed along the foreshore line. Sand and sludge dug from around the foreshore was then pushed through the demarcation from the side of the lake. Additional sand was piled up against the inside of the screen to build up back pressure, and thus strengthen the base. The sand body was then covered with cloth canvas and then topped with stone chunks. The completed barrier was designated suitably robust to ensure peat deposited in the foreshore stays under water, and therefore does not shift into the surrounding lake.

The final stage of foreshore preparation involved the installation of willow screens (wiepen). These screens help to conduct water flow and thus prevent water turbidity caused by the discharging of process water in the lake. Local professional fishermen emptied the foreshore of fish prior to deposition of excavated peat. The foreshore was completed by August 2020, which enabled the start of work within the Peat Pits.

Demarcation posts placed in lake-bed

Stone chunks placed upon sand body

Completed barrier

Willow screens in foreshore

Figure 3: Construction of the Foreshore

Turf ponds in the peat pits were excavated using mechanical diggers (**Figure 4**).

Care was however required to protect layers during excavation, and to maintain natural and associated cultural historic values. This was ultimately achieved via strict regulations on the size of each pond. The width of ponds was constructed to between 15 and 30 metres, while the length of ponds ranged between 30 and 100 metres. The target for pond depth below the water line varied from approximately 0.5 metres at the perimeter to 1 metre in depth below towards the centre.

Peat extracted from each pond was transported to the foreshore water via geo-tubes. The tubes provided an air-tight environment, which limited soil carbon losses during the transportation process. The tubes also mitigated the need for heavy loading trucks, which could have damaged both restoration areas and surrounding habitats if they had been used. Peat material built up rapidly within the foreshore and should quickly develop into a bog over the coming years.

This stage was completed in April 2021, allowing the start of on-site monitoring works.

Loading of excavated peat into geo-tubes

Digging of turf ponds and formation of pond banks

Figure 4: Construction of Peat pits

Monitoring and Restoration Outcomes

3.1 Post-restoration

Currently the pilot site is fully developed as planned, and while continued monitoring is required in the coming years to fully assess the benefits of restoration, initial on the ground developments indicate some success towards achieving the aims of the pilot site (**Figure 5-8**). Notably bare patches of soil have begun to develop vegetation with the occurrence of *Myrica gale* (Wild Gale), *Viola palustris* (Marsh Violet), *Dactylorhiza praetermissa* (Marsh Orchid) etcetera. The emergence of species associated with an early-terrestrialisation phase – e.g. *Stratiotes, Potamogeton, Hydrocharis, Typha* – and the expansion of reed in the peat pits is a promising development.

Water quality is also improving and is projected to continue to do so in the upcoming years. This is indicated by the positive development of reeds on-site, owing to suitable provision of space and growing conditions. In parts of the foreshore the initial vegetation development has already led to the formation of a rootzone with some carrying capacity. This indicates a development towards a more stable substrate for further succession. In other parts the foreshore soil is still soft without a tied rootzone, although vegetation development has started here.

Ultimately the entire restoration has increased the space for development of peat and associated habitats, which was the primary aim of the pilot site. While it is too early to confirm definite benefits in terms in of GHG sequestration, the balance between CO_2 and CH_4 is projected to change in the coming years.

Figure 5: Post-restoration developments - Juncus effusus and reed development within Peat pits (August 2021)

Figure 6: Post-restoration developments - (Semi-)aquatic plant species development within peat pits (Augus 2021 and September 2022)

Figure 7: Post-restoration developments - (Semi-)aquatic plant species development within peat pits (Augus 2021 and September 2022)

Figure 8: Post-restoration developments - Flora and fauna behind foreshore barrier

3.2 GHG monitoring

Approach

In situ monitoring began in August 2021 and was carried out over the course of six field campaigns, centred around the months of August and November in the years 2021 and 2022 respectively, along with February and April in 2023. All restoration works in the pilot area were completed by April 2021, therefore the monitoring exercise indicates changes in GHG emissions during the initial post-restoration period. In total, three monitoring areas were designated, to examine the effect of different restoration works (**Figure 9**). The first area was located within the Foreshore (FS), with measurements undertaken on water and peat areas to contrast the current habitat areas created by restoration. Unfortunately, during the monitoring period the peat in general was unsafe to walk on. Therefore, sampling plots were designated within safe-to-access areas, that included an area next to the foreshore, and an area of floating peat accessible by boat.

The second and third areas, labelled T1 and T5 respectively, were located within the Peat pits, where peat had been previously extracted to form the foreshore. Again, measurements were undertaken to compare different restoration habitats, and included areas of water created through peat extraction, and dikes composed of crushed tree and peat residues. An additional measurement area within T1 was centred on an area adjacent to restoration works, where soil had been stripped out prior to the Care-Peat project. Measurements here, conducted on water only, provided a proxy control area to examine the future evolution of local GHG emissions after the end of the project. All measurement areas are visualised in **Figure 9**.

Figure 9: Monitoring areas within the De Wieden pilot site.

As collars could not be installed on the soil due to low compaction, measurement points were located on areas of vegetation. The foreshore (FS) area is mainly composed of *Juncus effusus* and some *Carex* species. Vegetation in the T1 and T5 areas are disturbed through mowing activities, and therefore change during the year. The main vegetation species found here include *Juncus spp.*, reeds and *Carex spp.* Due to continuing vegetation development within sample areas, small adjustments in the location of collars was required to obtain reliable measurements.

Outcomes

In situ monitoring began in August 2021 and was carried out over the course of six field campaigns, In the field, three fluxes were measured:

1. Ecosystem Respiration or RECO,
2. Net Ecosystem Exchange or NEE (at varying radiation intensities, using nets),
3. CH_4 flux from the balance between methanogenesis and methanotrophy or FCH_4.

RECO and NEE were used to calculate the Gross Primary Production (GPP) term of the balance flux NEE (NEE = RECO – GPP). The following figures visualise averaged flux values per measurement area for given measurement month. Ecosystem respiration (RECO) was measured on non-water plots only (**Figure 10**). As evident during all six field campaigns, RECO values are lower for the foreshore than the respective peat pit areas T1 and T5. This may be explained by higher levels of organic matter degradation by aerobic organisms, due to generally lower soil saturation in the peat pit areas.

Temporal patterns in RECO values also differ between the areas. RECO for the foreshore area was generally consistent between August and November, with slightly higher values recorded in the warmer months. August 2022 is an outlier here, as is also the case for area T1 (T5 measurements not available) due to the period of high temperatures and drought during this field campaign, which appears to have caused a serious increase in RECO irrespective of restoration works. With the exclusion of the August 2022 outlier, RECO appears to generally decline from the first to last measurement campaign for area T1. While this could indicate that restoration habitat development in T1 may be depressing RECO, the November 2022 measurement record significant variation in values, indicating some instability in this temporal pattern.

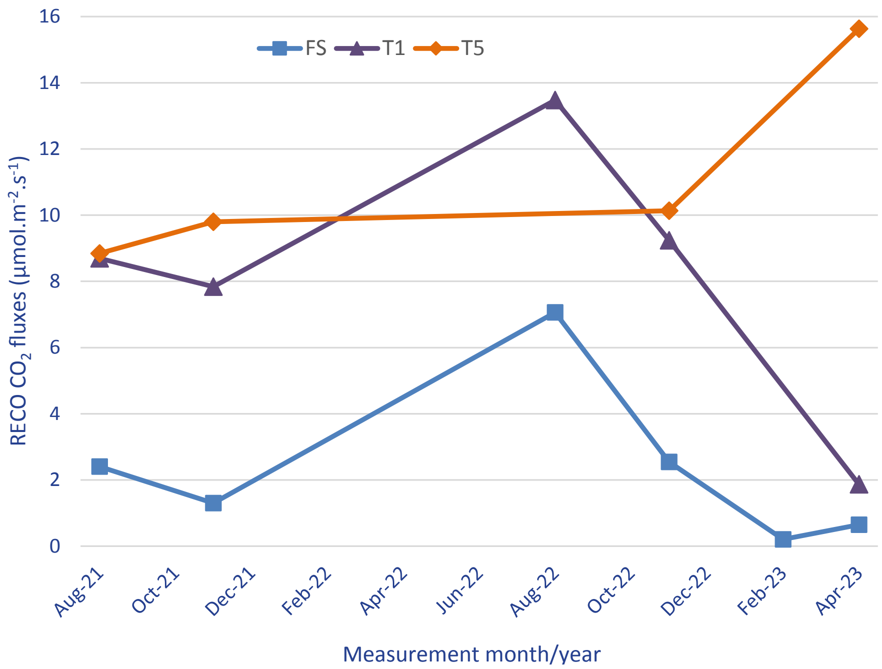

Figure 10: Mean RECO CO_2 flux values for non-water plots

All water plots demonstrate movement towards, or stability around NEE net neutrality over the measurement campaigns (**Figure 11**). In contrast, patterns for the soil monitoring plots vary according to vegetation patterns (**Figure 12**). The foreshore soil plot (FS) records generally neutral NEE values for 2021, with an improvement towards wholly negative NEE values for 2022 and 2023, which corresponds to vegetation growth recorded on this plot for these years.

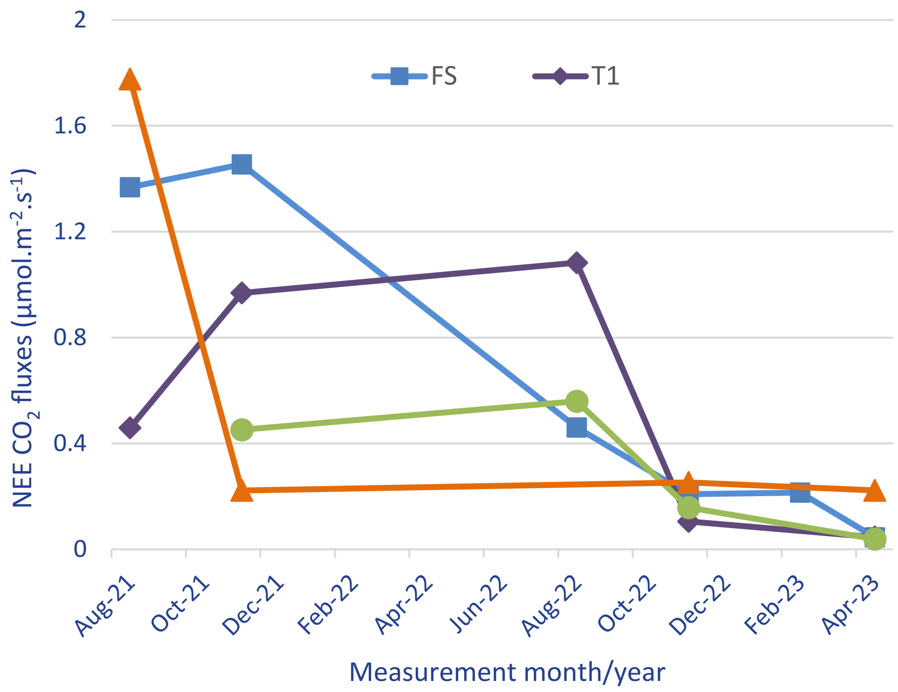

Figure 11: Mean NEE CO_2 flux values for water plots

In contrast, NEE values for the soil plots T1 and T5 in the Peat pits are generally positive. In correlation with the foreshore area, these areas recorded growth in reeds vegetation in 2022 and 2023, after low recorded cover in 2021. Unfortunately, the available chambers were too small to measure fluxes from this species type, therefore measurements were conducted on low vegetation soil and some *Carex* species.

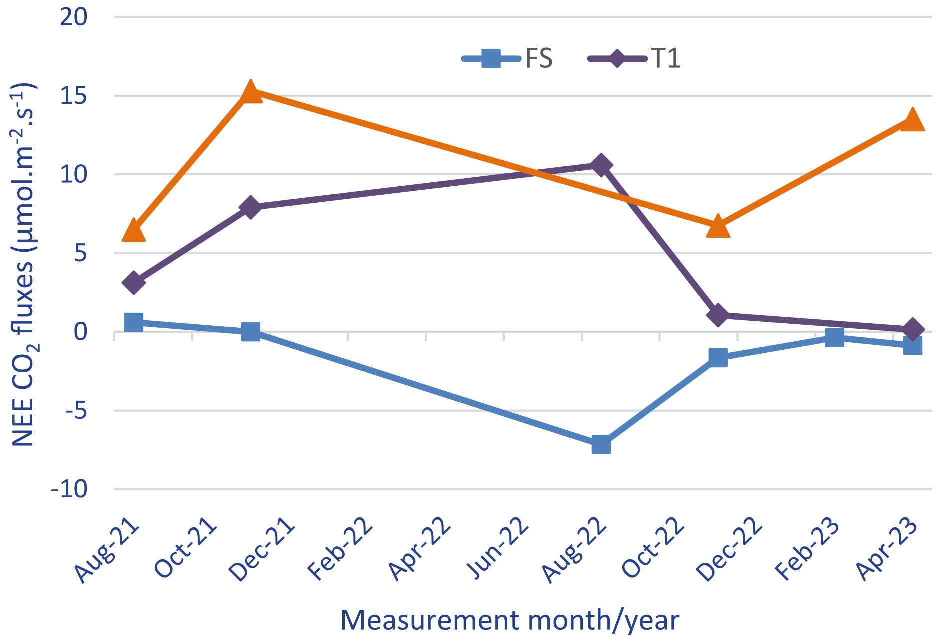

Figure 12: Mean NEE CO_2 flux values for non-water plots

Recorded NEE values for the T1 and T5 may therefore be an over-estimate of actual on-site flux conditions. Overall, the evidence of negative NEE values for all soil plots during the initial post-restoration phase demonstrate net carbon storage functions are viable for the peat restoration works, and thus provide a general NEE improvement to surrounding water-based habitats. Future monitoring efforts will be beneficial to measure NEE changes according to projected improvements in restoration habitats. Except for the first field campaign, all FS, T5 areas and water plots demonstrate movement towards, or stability around methane neutrality over the measurement campaigns (**Figure 13**). The soil plot T1 exhibits variation in methane emissions, depending upon the soil moisture saw visually in the field.

The chamber method allows measurement of diffusive fluxes only. Methane emission by ebullition have been observed but not recorded.

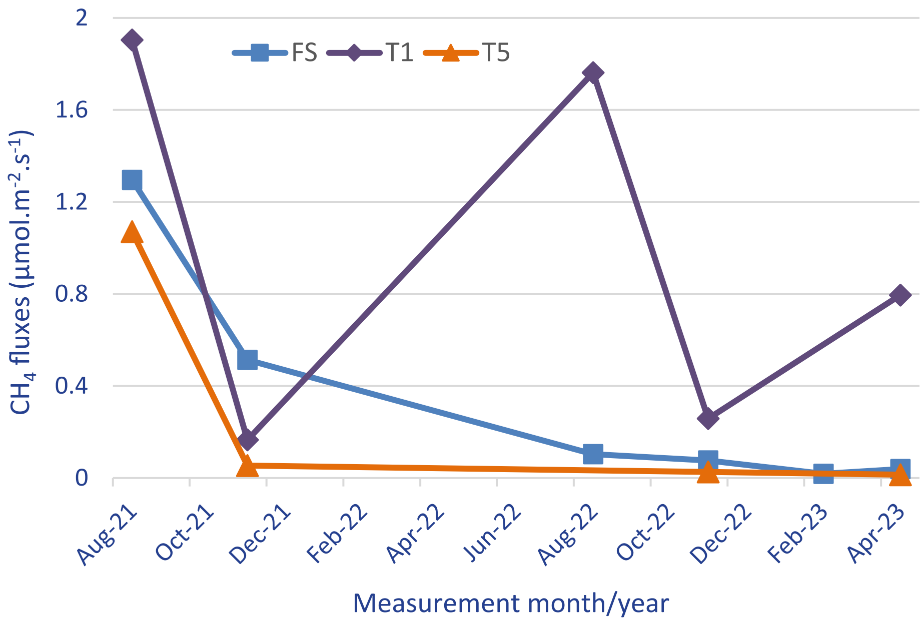

Figure 13: Mean CH_4 flux values for non-water (top) and water (bottom) plots

3.3 Earth Observation analysis

Earth observation analysis was undertaken for the De Wieden pilot site, to investigate the benefits of remotely sensed optical satellite imagery to monitor environmental change from peatland restoration. Initial observations were generated from time series (April 2018 – July 2023) Sentinel-2 image data (European Space Agency, Copernicus programme) for sample points located across turf pond sidings and water surfaces within the Peat pits, Foreshore and adjacent lake. To provide a consistent time lag for further analysis, extracted index values were aggregated to quarterly averages.

For the turf pond sidings within T1, T5 and other peat pit areas there is a clear upwards post-restoration (April 2021 onwards) trend in vegetation and moisture indices (**Figure 14**). The upwards trend in Normalised Difference Moisture index (NDMI) and Normalised Soil moisture index (NSMI) may indicate increasing water content in vegetation and soil. Trends for both indices are highly correlated with vegetation indices the Normalised difference vegetation index (NDVI) and Enhanced vegetation index (EVI) which coincides with vegetation growth on bare peat, and the development of favourable species within these areas. Further monitoring will be beneficial to examine more advanced soil moisture indices to specific terrestrialisation processes.

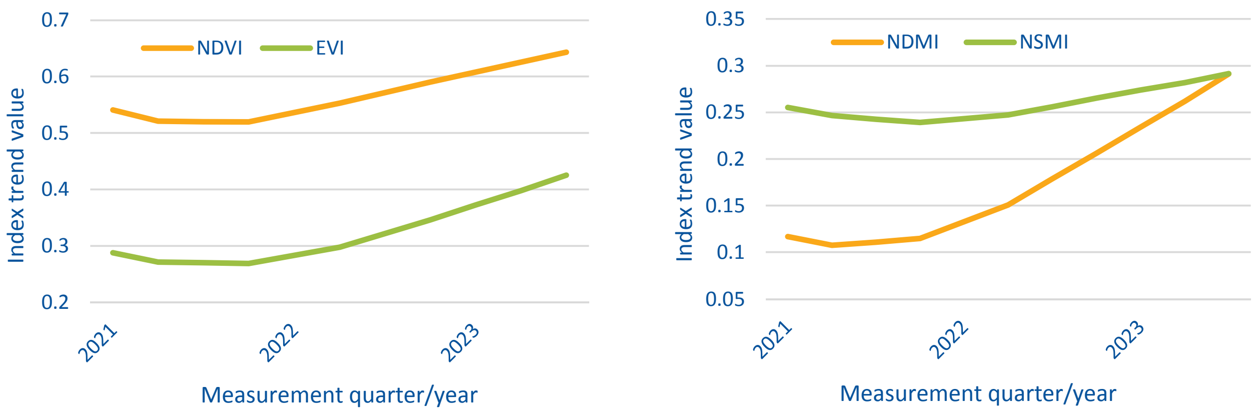

Figure 14: Trends in index values aggregated for turf pond sidings. Vegetation indices (left) include the Normalised difference vegetation index (NDVI) and Enhanced vegetation index (EVI). Moisture indices (right) include the Normalised difference moisture index (NDMI) and Normalised soil moisture index (NSMI).

In contrast, earth observation measurements for water plots indicate less turbid conditions for foreshore water than the surrounding lake water. As shown in **Figure 15**, normalised difference turbidity index (NDTI) values decline post restoration, indicating a trend towards clearer water than the adjacent lake, which records generally consistent NDTI values over the same period. This is consistent with values for the Water turbidity index (WTI), visualised in **Figure 16** which further indicates benefits from the installation of willow screens to provide favourable water flow conditions. Unfortunately, reliable measurements for water areas in the peat pits proved difficult to acquire due to the resolution of the Sentinel 2 data. However, as demonstrated by analysis in the other De Wieden monitoring areas, the acquisition of higher resolution optical imagery may prove beneficial in monitoring terrestrialisation processes for these water areas.

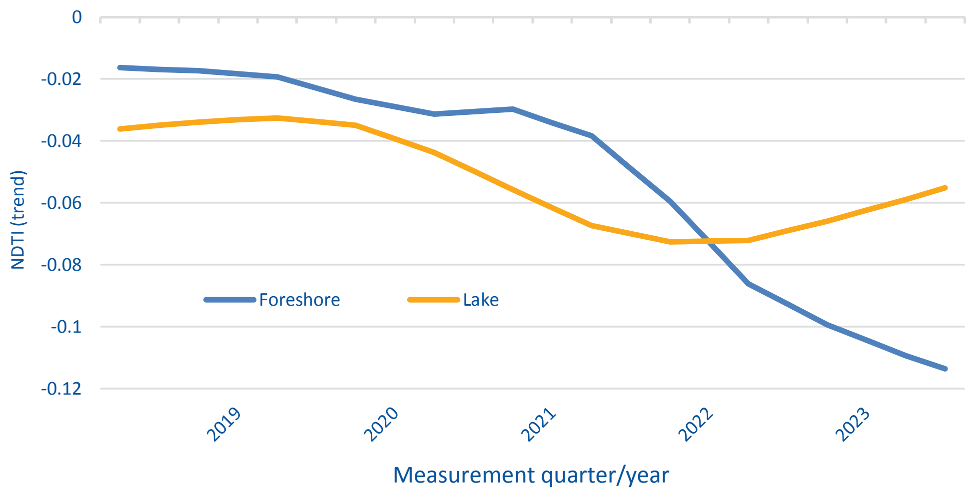

Figure 15: Trends in NDTI between foreshore and adjacent lake water

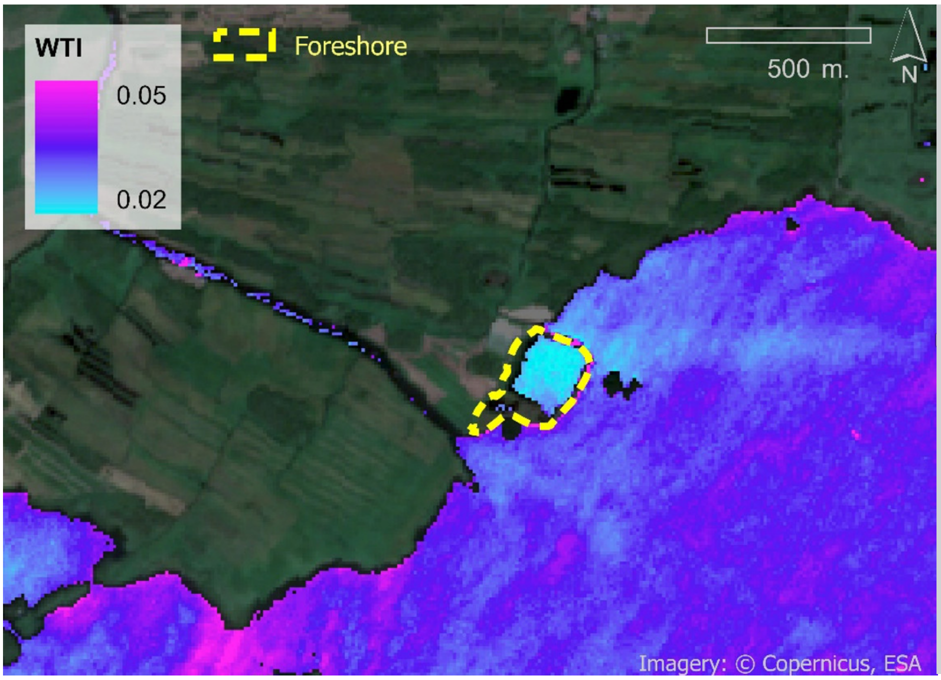

Figure 16: Patterns in WTI (imagery acquired 11.07.2023) between foreshore and wider lake water

Stakeholder involvement

Natuurmonumenten (NM) organised and led three regional platform meetings with a wide number of stakeholders interested in carbon storage. NGOs, private land-owners and regional governments were involved (**Table 1**).

Table 1: Principal organisations included in regional platform meetings

Organisation/stakeholder	Description
Herman Spans (person)	Dairy farmer
Waterschap Drents Overijsselse Delta	Water authority
Natuur en Milieu Federatie Overijssel	Environment federation in the province of Overijssel
Natuurmonumenten	Private nature conservation organisation

The case for GHG storage in soil was keenly discussed, and the outcome of the meetings was positive, with universal agreement amongst all participants on moving further GHG storage towards practical action. General discussions following this focused on the business case to make this happen. The meetings developed in the vane of project organisation towards a robust proposal to apply for Carbon Credits. This proposal is approved January 2023.

An application for actual credits was processed through this regional platform in December 2022, and is the first such application in the province of Overijssel. It was agreed that the application should be made on behalf of a Natuurmonumenten tenant. The parties will now discuss the continuation of this platform. Natuurmonumenten is thinking of replicate this format in similar areas where Natuurmonumenten operates. NM will also present the results of this platform to Eurosite, so Eurosite can use this best practice for other European organisations.

Figure 17: Presentation during regional platform meeting

Conclusion

Restoration works

The restoration works in De Wieden were carried out as planned. Historic peat pits were re-excavated, the released peaty material was transported in closed tubes to a newly created foreshore and stored there underwater. The aim was to create space to improve biodiversity whilst also creating accommodation space for the sequestration of carbon (CO_2). The latter is targeted for both the new peat pits, through the re-start of the terrestrialisation process, and the new shore, through storage of peaty material and increased space for new peat formation.

Post-restoration development

The vegetation development of the peat pits and the shore in the first years after the restoration works is promising and moving in the desired direction. Within the peat pits plant species associated with early- phase terrestrialisation were established soon after the restoration works. On the new shore vegetation growth started soon as well, including the development of a rootzone with carrying capacity in several areas. In the coming years the developments should be monitored further.

Greenhouse gas balance

The greenhouse gas (GHG) balance has been studied through on-site measurements.
Ecosystem respiration (RECO) on non-water plots was higher in the peat pit areas than in the foreshore. This might by related to dryer conditions, and thus higher degradation rates in the peat pit areas than in the foreshore. RECO seems to decline, when considering mean values, although a significant variability in the peat pit areas is observed, indicating relative instability in RECO measurements for this area. RECO on water plots has not been measured.

Net ecosystem exchange (NEE) on non-water plots vary according to vegetation patterns. NEE values in the foreshore are generally neutral for 2021, with an improvement towards wholly negative NEE values for 2022 and 2023, which corresponds to vegetation growth recorded on this plot for these years.
NEE values on non-water plots in the peat pit areas are generally positive. However, reed growth, which could contribute to a more neutral NEE, has not been taken into account in the measurements because the flux chambers were not designed for this tall species. Therefore, NEE might be overestimated in the peat pit areas. NEE on water plots show a trend towards net neutrality.

Overall, the evidence of negative NEE values for all soil plots during the initial post-restoration phase demonstrate net carbon storage functions are viable for the peat restoration works, and thus provide a general NEE improvement to surrounding water-based habitats. Future monitoring efforts will be beneficial to measure NEE changes according to projected improvements in restoration habitats.

Except for the first field campaign the foreshore, T5 peat pit areas and water plots demonstrate movement towards, or stability around CH_4 neutrality. The non-water plots in the T1 peat pit area show variation in CH_4 emissions, depending upon the soil moisture saw visually in the field.

Stakeholder involvement

Many organisations were informed about the project, with numerous stakeholder meetings organised to discuss Carbon Credits. The meetings developed in the vane of project organisation towards a robust proposal to apply for Carbon Credits, with this proposal approved in January 2023.

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