LIFE Multi Peat

LIFE20 CCM/DE/001802

Mid-term Monitoring Report (Action D.2)

(September 2021 - December 2024)

Co-funded by the European Union

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1 Introduction

The LIFE Multi Peat project aims to reduce greenhouse gas emissions and promote biodiversity through peatland management measures which involve raising peatland water levels. To make progress and the achievement of these goals measurable, scientific monitoring is being carried out. This involves the measuring of ecological parameters, as well as direct measurements of greenhouse gas emissions.

The first monitoring report of action D.2 (Project sites monitoring) was merged with the deliverables of actions A.2 (Initial surveys of the project sites) and D.1 (Monitoring of Project Performance and Socio-economic impacts) as "Joint report on the Common Documentation of Initial Surveys, Baseline Monitoring report, and Annual Monitoring Report 1" (LIFE Multi Peat, 2023). The hydrogeomorphological setting of each monitoring site, as well as the current hydrological situation, a description of the current vegetation, below ground carbon stocks, as well as a baseline estimation of greenhouse gas emissions based on the greenhouse gas emission site types "GEST" (Couwenberg, 2011) can be found in here.

The second monitoring report (LIFE Multi Peat, 2024) is part of the second annual monitoring report of Action D.1 and covers the period 01/01/2023-31/12/2023. It gives a refined calculation of the carbon stocks, including the above ground biomass, further a pre-rewetting analysis of the site hydrological site conditions using drone or satellite imagery and finally shows the first set of data gained from the monitoring of hydrology and environmental parameters, which will later be used for the modelling of GHG-balances (soil temperature, soil moisture, PAR).

This Mid-term Monitoring Report, which is also the Third Monitoring Report, will show the updated records of the monitored parameters, as well as first GHG-fluxes for those sites that have the measurements running for at least one year (Germany, Ireland, Netherlands and Poland). Additionally, Belgium, Germany, Netherlands and Poland, will show the results of the first vegetation monitoring.

2 Belgium

2.1 Project Site

The Belgium project site is situated in the Valley of the Grote Beek (Figure 1).

Figure 1: Map of the Belgium project site in the Grote Beek and the Kleine Beek creek valleys

The largest part of the nature reserve consists of alder swamp forest. Within the valley 230 hectares are under nature management. Spread over 3 cities: Beringen, Ham and Leopoldsburg (Limburg, Belgium). The valley actually consists out of 2 creek valleys: the Grote Beek (Northern part) and the Kleine Beek (Southern part) and is situated close to the valley of the Zwarte Beek (the largest peatland in Flanders (Southeast on the map)). Within this nature reserve a peat layer is present of up to 3m thick. It is heavily degraded in parts of the area and is currently drying out throughout the valley. Peatland restoration within LIFE Multi Peat will restore the carbon storing capacities of this very important and sensitive ecosystem.

2.2 Current State

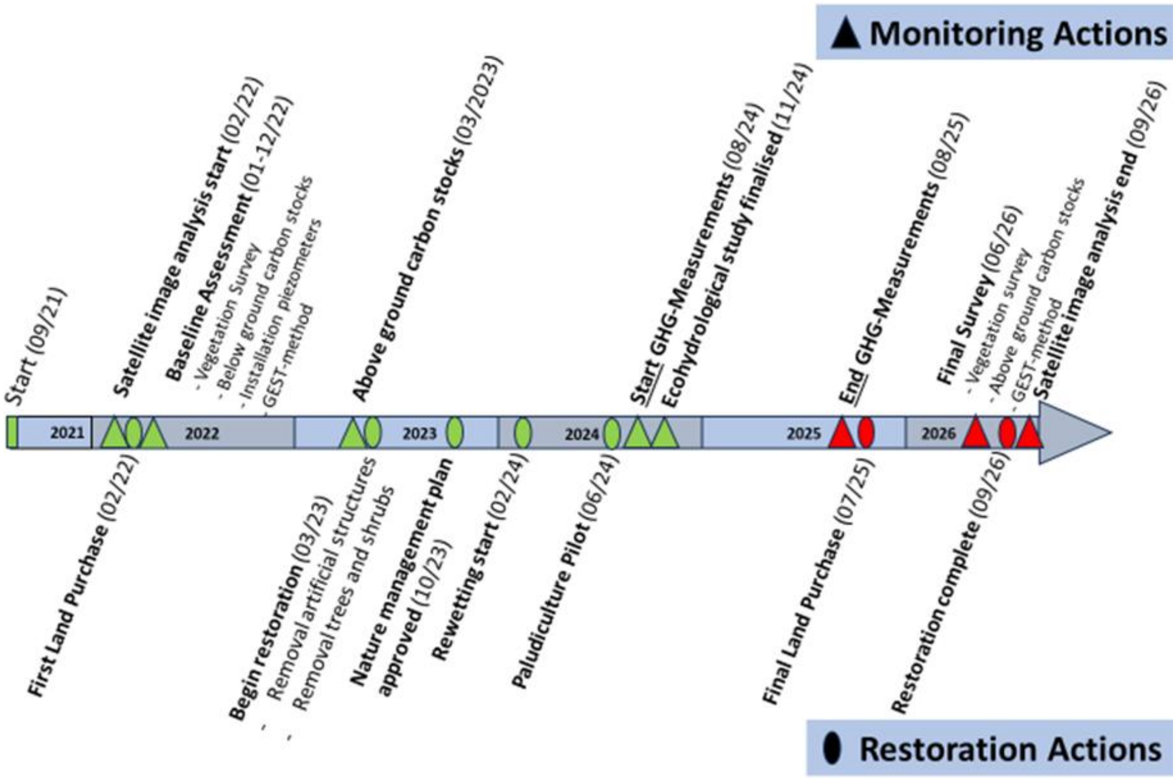

Figure 2: Timeline showing restoration- and monitoring progress for Belgium

2.3 Results

2.3.1 Hydrological Monitoring

The ecohydrological study is finalised and the report is made (EcAsCo & Paludosa research (2024)). In general, they found that water quality in the different creeks is rather bad, there is a huge silt layer which would ideally need to be removed. The biggest threat to the peatland however is the deep drainage of ground- and seep water by the extensive network of drains and ditches. Most creeks are over dimensioned and should thus be relevelled for peatland restoration. The result of this study will be of utmost importance for the restoration works.

Apart from that, our network of water level loggers is maintained and results of rewetting are monitored this way. A more extensive report on the results of hydrological restoration will be made in the final monitoring report.

2.3.2 Environmental Parameters

Environmental parameters are still monitored by a local weather station, with hourly data of temperature, wind speed, wind direction, air pressure, precipitation and relative humidity. In the nearby Valley of the Zwarte Beek there is another weather station, which will normally stay there until after the GHG measurements

On top of these parameters, extra sensors were installed at the GHG measurement plots (see Figure 3). At the restoration site we now monitor soil temperature, soil moisture and electrical conductivity at 5cm below ground level, air temperature, relative air humidity, atmospheric pressure and PAR. At the reference (rewetted 10 years ago) and control site we only monitor soil temperature, since this is the most determining parameter for greenhouse gas emissions. Other parameters are expected to be similar to the restoration site.

Figure 3: Sensors at the GHG measurement restoration site

2.3.3 GHG-Measurements

The greenhouse gas measurements have started in August 2024 and will be carried out until the end of July 2025 (see Figure 4). Each month we measure greenhouse gasses at 3 sites, with each 3 plots (see also LIFE Multi Peat 2024, chapter 2.2). Carbon dioxide is analysed using a Gas-analyser, Methane and Nitrous oxide is sampled in vacuum tubes and analysed by the University of Gent.

First results of the fluxes are not available yet.

Figure 4: GHG measurements: left: collar on which the closed chamber is placed for measuring. right: the GHG measurement site, with board walks to avoid impact on soil by moving around

2.3.4 Vegetation Monitoring

In May 2023 permanent vegetation plots were monitored. In total 13 plots were measured. 12 in the Valley of the Grote Beek and 1 at the reference site nearby where the GHG measurement take place (not on the map below). Within each plot all species and their abundances (in categories) were noted down according to the Flemish standard for the obligatory vegetation monitoring in nature reserves (see Table 1). The plots measure 20*20m and vegetation is divided into the following abundance categories:

Table 1: Categories of Flemish vegetation mapping standard

Code	Name	Density	Coverage
S	Scarce	1-10 individuals	<< 5%
WT	Few	11-100 individuals	<<5%
T	Many	> 100 individuals	<5%
B	Covering	Irrelevant	5-25%
KB	Quarter covering	Irrelevant	25-50%
HB	Half covering	Irrelevant	50-75%
D	Dominant	Irrelevant	≥ 75%

In total 110 plant species were found within these plots. The most species rich plot is situated in the upstream area of the Grote Beek (see Figure 5). Alder swamp forest are more species rich than the more open parts (which are more impacted by degradation). At the end of the project, the same plots will be measured again and differences between species and abundance will be evaluated.

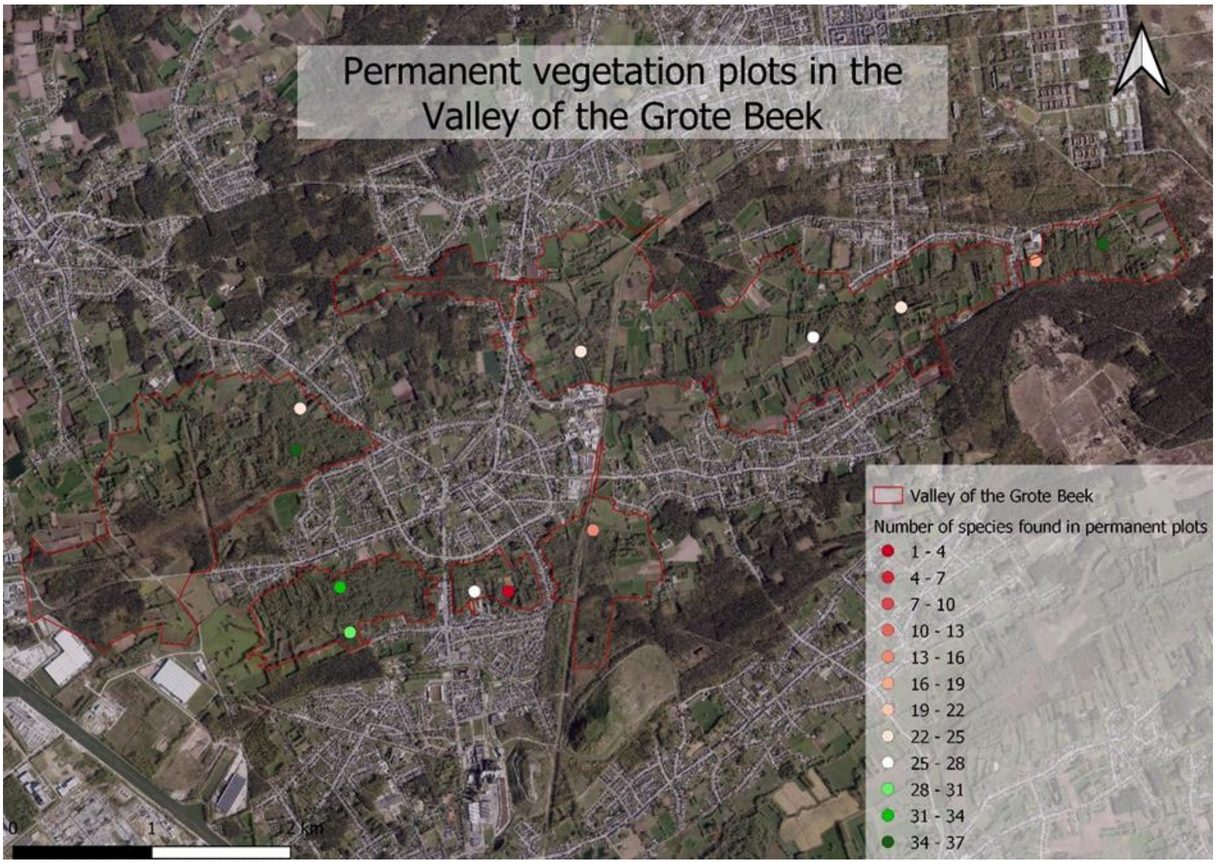

Figure 5: locations and number of species of the permanent vegetation plots

2.4 Discussion and Challenges

See also challenges identified in the 2nd annual monitoring report (LIFE Multi Peat (2024))

The greenhouse gas measurements are up and running, so this problem was resolved.

Maintaining the hydrological network is challenging. Water wells within creeks are often damaged by branches of trees getting stuck around them, adding to much pressure to the pipes. Or raising the water table next to the pipes, resulting is wrong measurements of the actual water level. Some water level pipes are damaged again by vandalism. This year, one pipe was pulled out of the ground and left on site, another pipe was also pulled out of the ground, but disappeared. It is unclear who is vandalising our loggers. They are often far from public paths, in difficult terrain (alder swamp, or even 2m high nettles and brambles), … places where no one should come or would even want to come.

The results of the hydrological study give interesting insights in the area and need for restoration. These will not be discussed here, but the comprehensive report including summaries and conclusions is made available (LIFE Multi Peat (2023)).

3 Germany

3.1 Project Site

The German project site, the Häsener Luch, is situated in the north-eastern part of Germany (see Figure 6a) and part of a long-stretched depression embedded in undulating ground moraine terrain of the Weichselian glaciation. The complex of around 120 ha is a terrestrialisation fen with reed and sedge peat overlying calcareous gyttja. The project site (see Figure 6b) covers approximately 60 ha, of which 53 ha have the conservation status "Naturschutzgebiet". Nevertheless, about 60% of the project site is used as grassland, mainly as pastures and to produce forage. Therefore, the Häsener Luch is drained by a system of drainage ditches directing the water into the upper reaches of the artificial water body Welsengraben. Summer water level lies between 80-100 cm below surface. As a consequence, the topsoil peat is highly degraded and moorshified. It has to be assumed that peat layers were much thicker before human alterations of the site started. Peatland drainage started as early as 1650 by Dutch colonists, to be used as grassland. The very intense drainage was conducted during the time of the GDR, which was accompanied by high resolution soil mapping. A comparison of peat thickness between 1969 and today shows that the ongoing oxidation of peat has already led to a vertical loss of around 65 cm of peat.

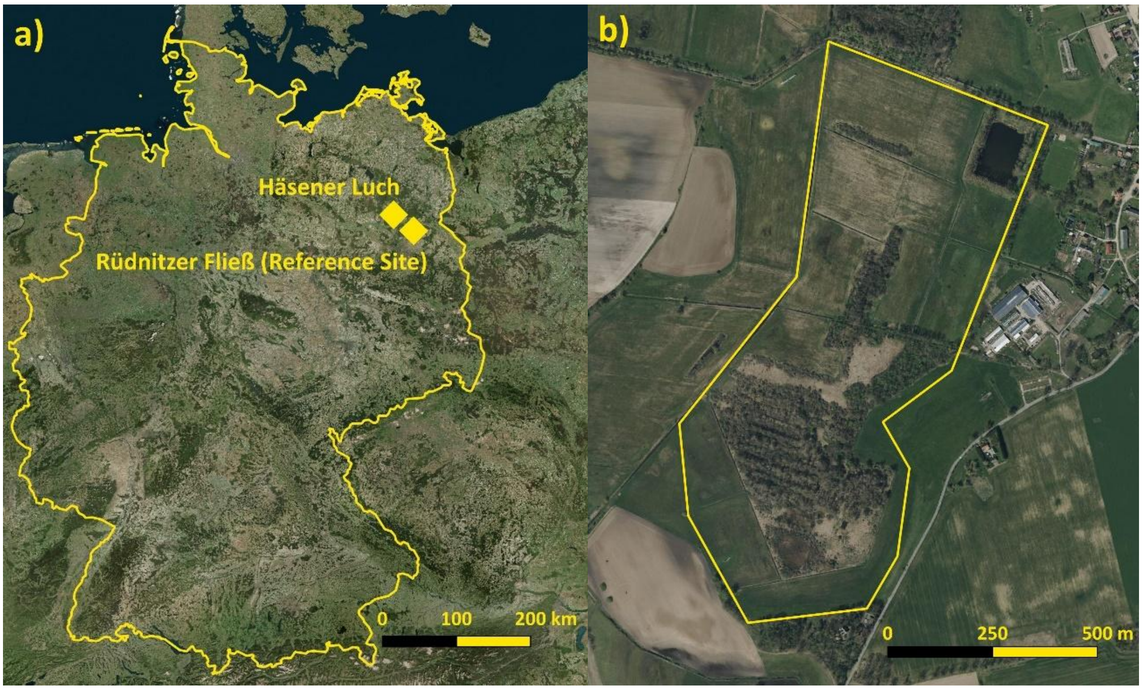

Figure 6: a) Map of Germany showing the situation of the "Häsener Luch" and the reference site "Rüdnitzer Fließ"; b) Project site "Häsener Luch" within the yellow boundary

The reference site, the Rüdnitzer Fließ (see Figure 6a), is a fen site at a distance of 35 km. It was successfully rewetted some 10 years ago and is now mainly covered with reeds (*Phragmites australis*).

3.2 *Current State*

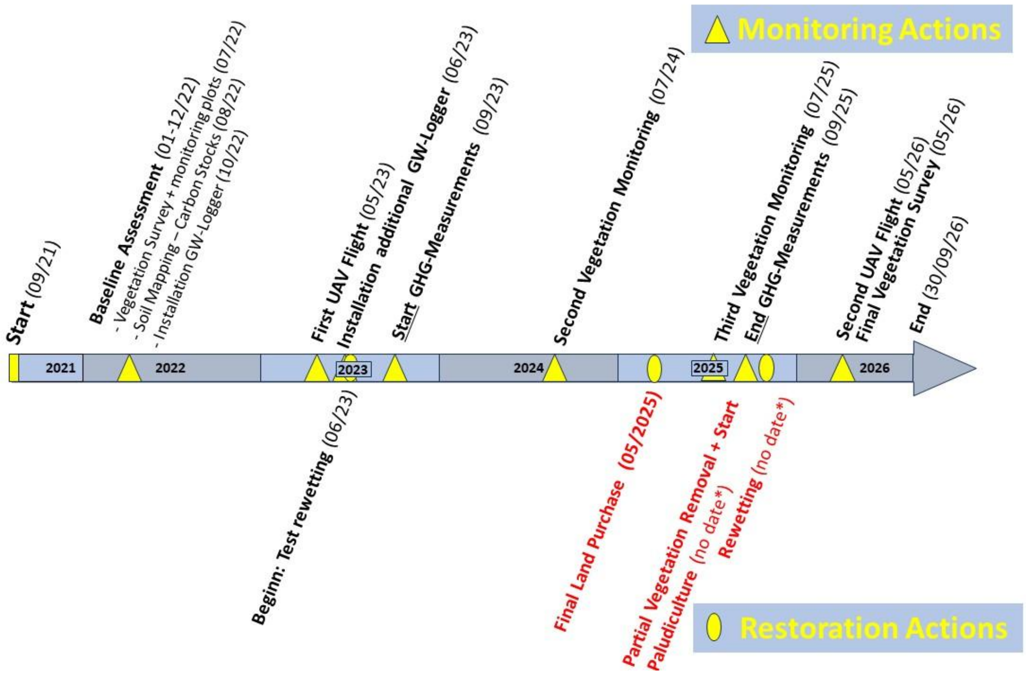

Figure 7 Timeline showing restoration- and monitoring progress for Germany. In red actions whose dates have changed. With asterisk actions whose implementation date cannot be estimated (see chapter 3.4)

The monitoring activities are conducted so far as planned. The implementation of the restoration activities will probably face problems due to the outbreak of the African Swine Fever (see chapter 3.4).

3.3 Results

3.3.1 Hydrological Monitoring

Hydrological equipment was installed at the monitoring site at two different points of time. Five water loggers (Device: Meter "Hydros 21") HL_01 to HL_05 were installed in October 2022 (see Figure 8). Six more sensors working with wireless data transmission (Device: MMM-tech "RKL-01-5") PSSS01 to PSSS03 and PSGW01 to PSGW03 were installed in June and July 2023 to monitor the "test rewetting" (Figure 9). The test rewetting refers to the reactivation of three old weir facilities to prove their effectiveness and build trust with local farmers. It started in June 2023 and is ongoing. The sensors named PSSS are directly implemented in the weirs and the sensors named PSGW were installed in the field in position, which supposedly are affected by a rise of the water levels in the respective ditches (see Figure 10).

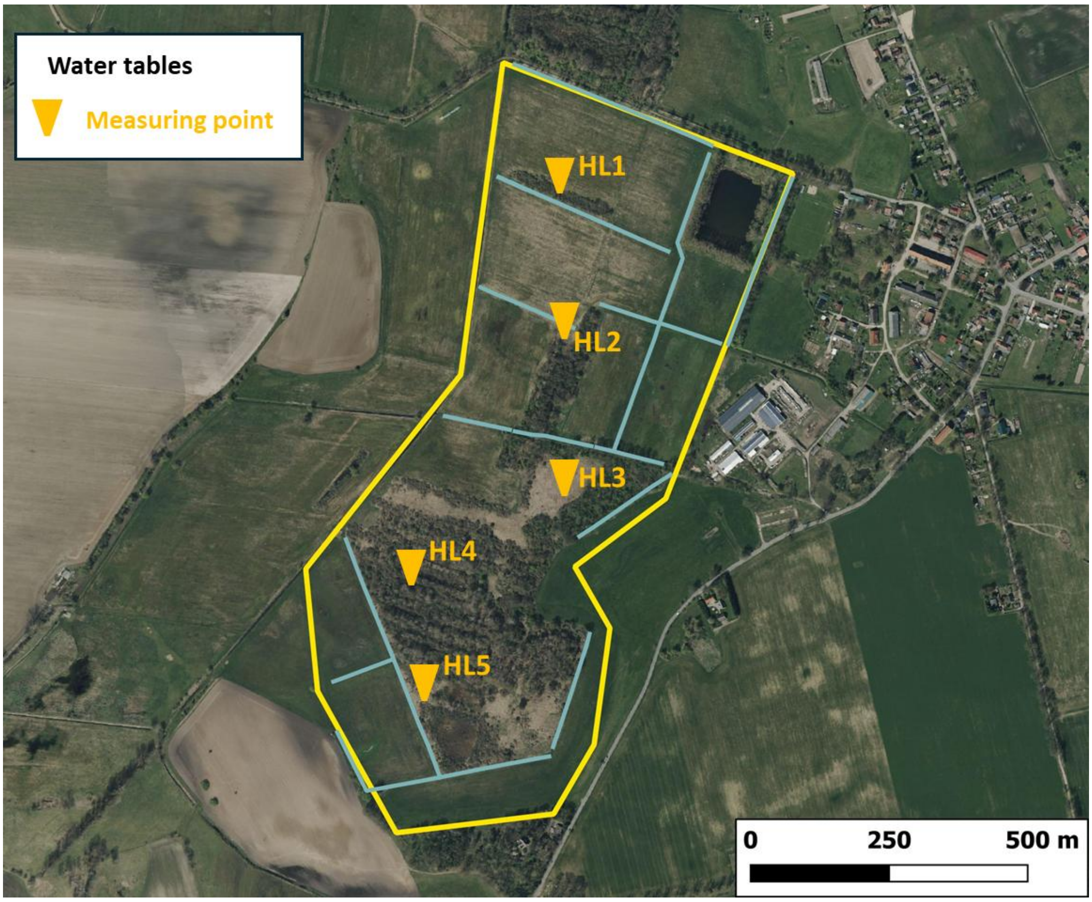

Figure 8: Positions of the water loggers at the project site in October 2022

The first set of water loggers covers a time span of more than two years (Figure 11). Unfortunately, HL01 and HL04 have some bigger data gaps, due to battery issues and damage by rodents. From the remaining loggers, HL_03 had slightly higher water levels in 2024 (mean of 53 cm below ground) than in 2023 (mean of 57 cm below ground). Also, HL_05 had slightly higher water levels in 2024 (89 cm below ground) than in 2023 (81 cm below ground). As the precipitation was lower in 2024 (650 mm) than in 2023 (757 mm), some first effects of the test rewetting might be seen here.

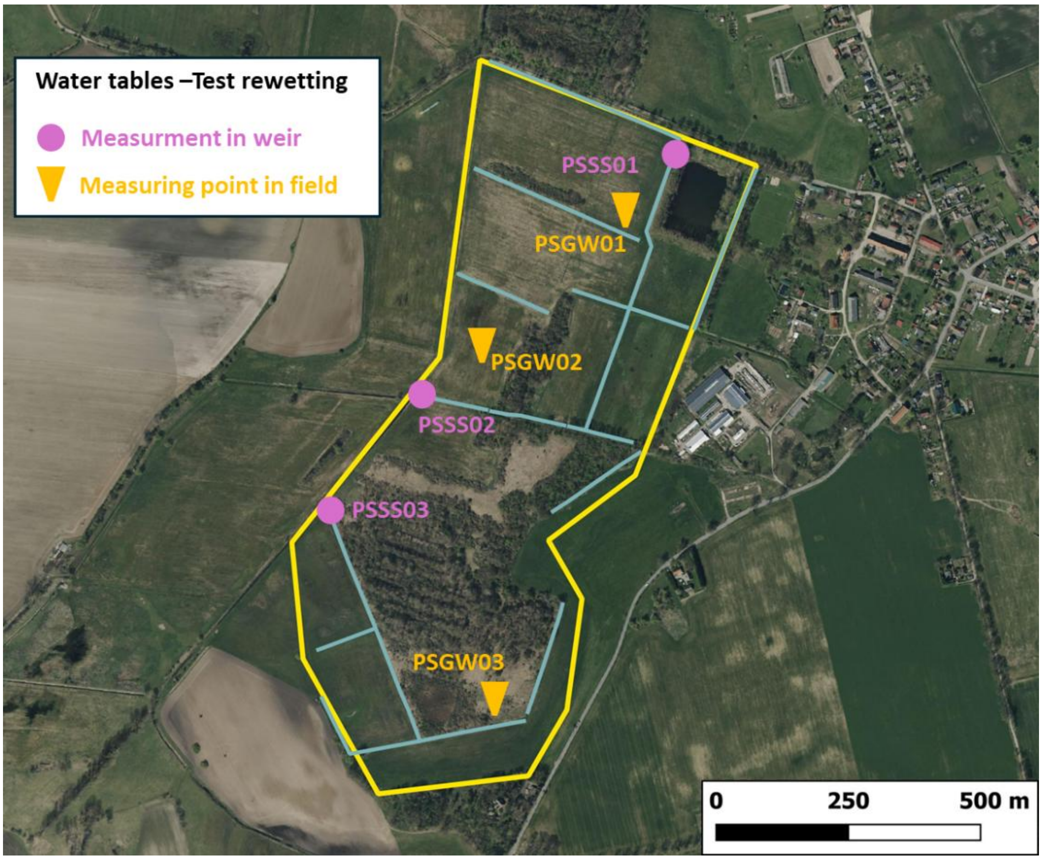

Figure 9: Positions of water loggers to monitor the test rewetting at the project site

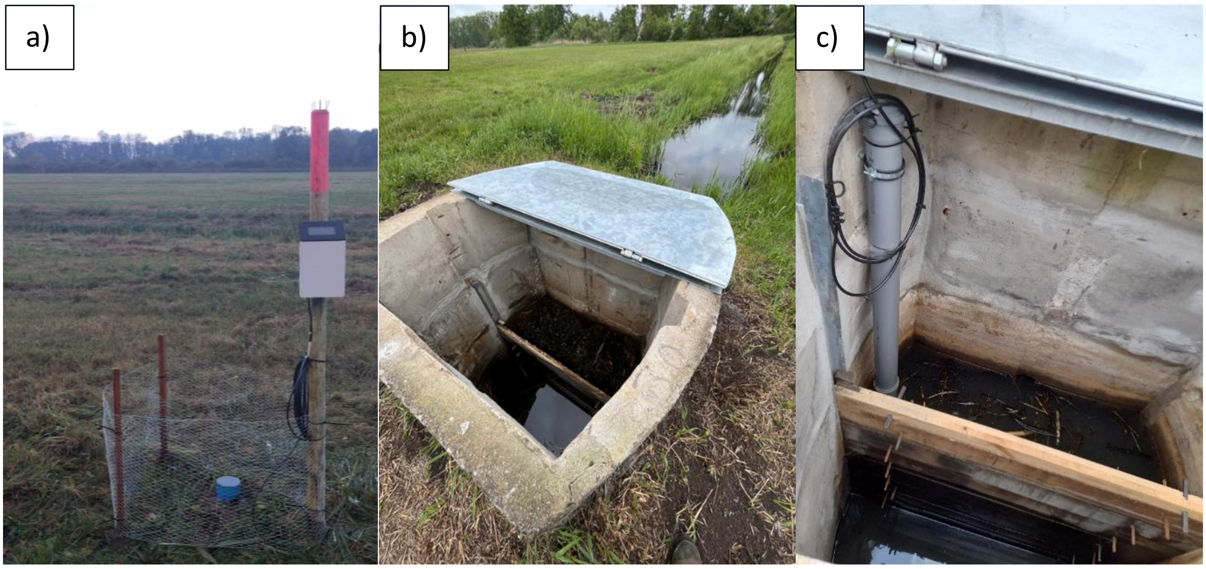

Figure 10: a) Installation of waterlevel measuring point in the field; b) ditch blocking facility; c) installation of water level sensor in ditch blocking facility. Photos by: Andreas Herrmann

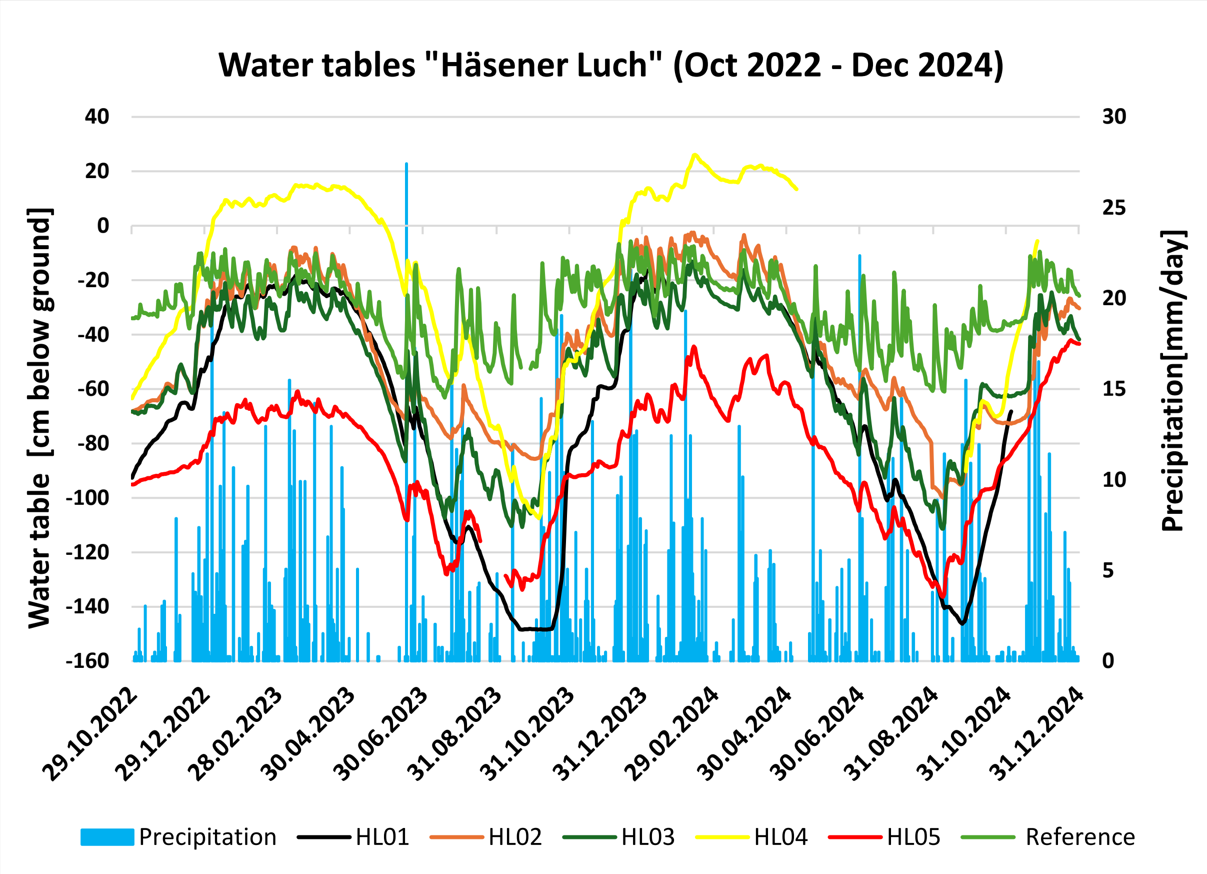

Figure 11: Water levels of the five sensors installed in October 2022

The recorded water levels of those water sensors monitoring the test rewetting (Figure 12) are partly encouraging. The weir PSSS01 had very stable water levels throughout the whole winter and springtime. The rise in March 2024 is due to the addition of another wooden plank, which was approved by that time by the lower water authority. Nevertheless, during summer water levels dropped and the course of the respective sensor in the field, PSGW01, doesn't seem to be affected at all, by the raised water levels in ditch blocked by PSSS01. The water tables of weir PSSS02 have been quite stable throughout the measurement period. The rise in December 2024 is due to the addition to another wooden plank, approved by the lower water authority. The respective sensor in the field, PSGW02, doesn't seem to affected by the rise of PSSS02 either. The water levels at the third weir, PSSS03, didn't reach stability throughout the measurement period. The hight of the water in the ditch is basically determined by the water level in the main receiving water body, the Welsengraben. Either the weir is leaking or water is lost in the ditch through mineral (sandy) parts. In summary, two of three weirs worked well, and proved to be cost effective and adjustable water regulation devices. The independent water levels at the measurement points in the field PSGW01, PSGW02, PSGW03, show, that rewetting success won't be achieved easy. According to the water monitoring results and former soil descriptions, we assume the hydrologic properties of the degraded peat soil little favourable for rewetting. Probably, many ditch blockings, or even better a complete filling of the ditches, will be necessary for the proper rewetting of the site. A blocking of the main receiving water body Welsengraben would be a very favourable, but at present almost impossible to get the consent of stakeholders and permissions by the lower water authority.

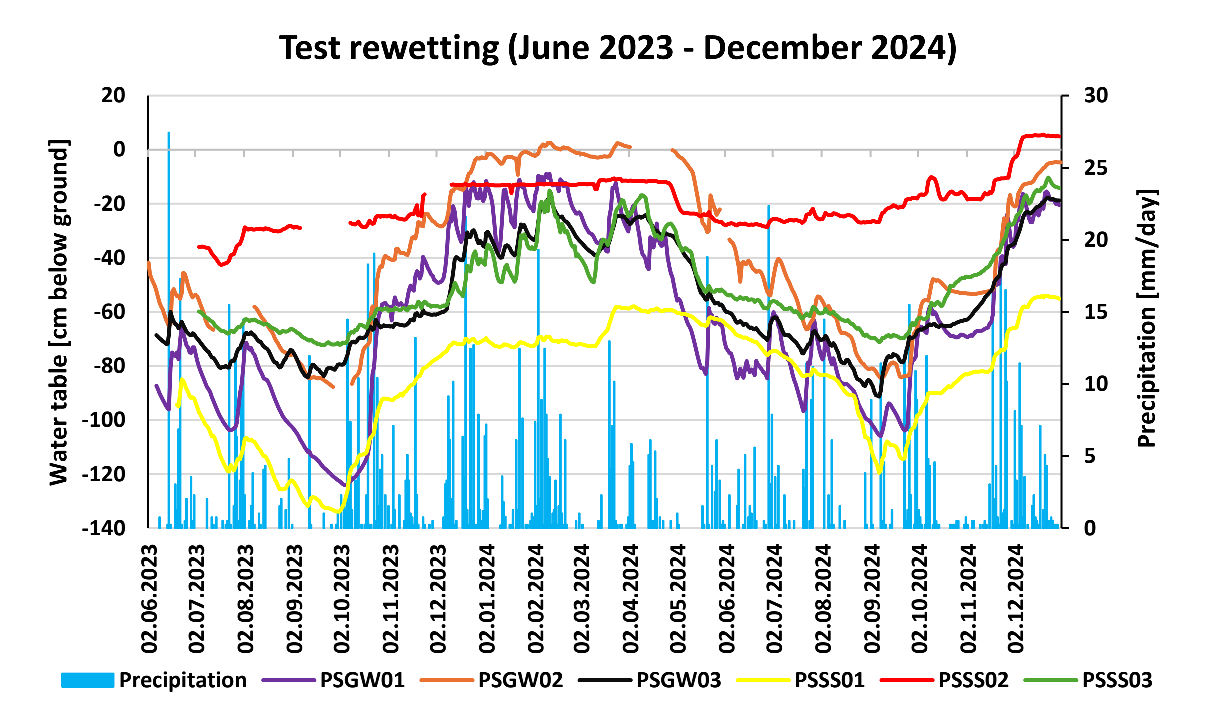

Figure 12: Water levels of the sensors installed in June 2023, monitoring the test rewetting

3.3.2 Environmental Parameters

At the sites, where greenhouse gases are measured (named HL01, HL02, and RF), the following environmental parameters are measured: Air temperature [°C] (Device: Meter “Atmos 14 Gen 2”), water temperature [°C] (Device: Meter “Hydros 21”), soil temperature [°C] and soil water content [m³/m³] (Device: Meter “Teros 11”) in 5-10 cm. Also, the photosynthetically active radiation (PAR) was measured. The results are shown in Figure 13, Figure 14 and Figure 15. With respect to soil temperature, air temperature and PAR, all three sites are similar. HL01 has a mean annual soil temperature of 10,8°C, HL02 10,0°C and RF also 10.0°C. Mean annual air temperature are at HL01 10.5 °C, HL02 10.9 °C and RF 11.0°C. The PAR values are quite similar, except of HL01, which had a period of malfunction.

The big difference between the three sites lies in the water tables. Mean water table at site HL01 is 86 cm below ground, at site HL02 55 cm below ground and at stie RF 30,5 cm below ground

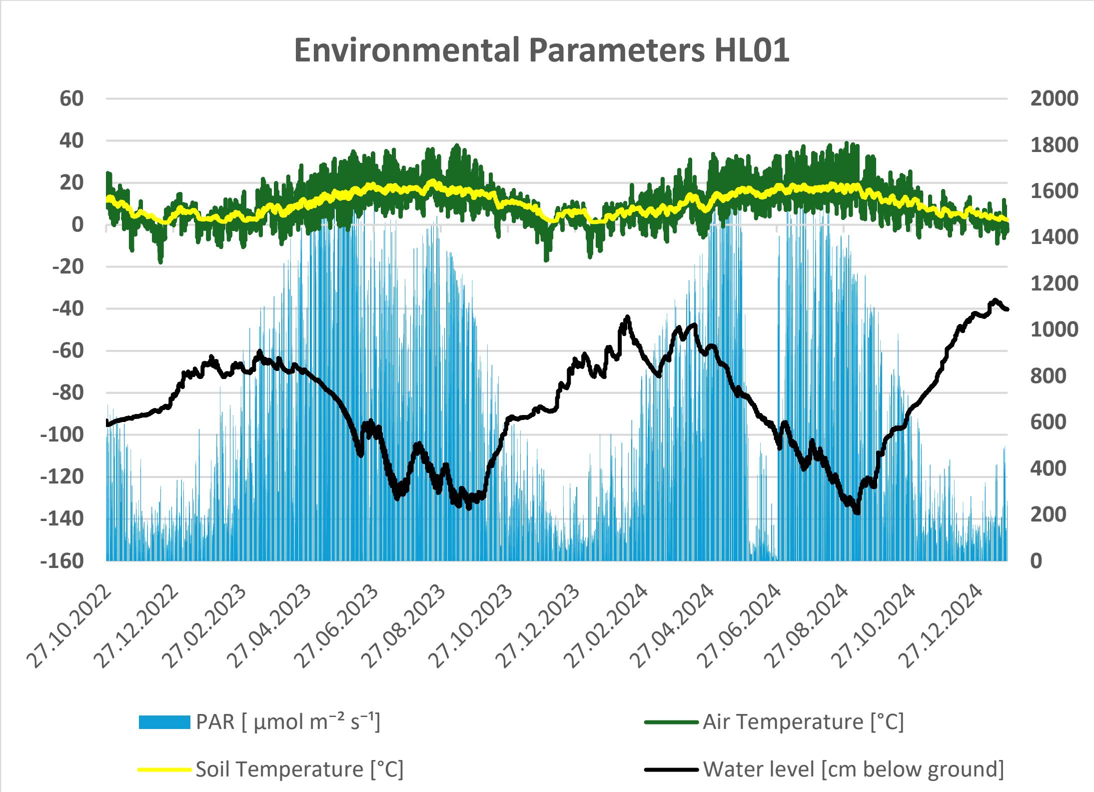

Figure 13: Environmental parameters from GHG-monitoring site HL01. PAR, soil temperature and air temperature correspond to the left y-axis; water level to right right y-axis

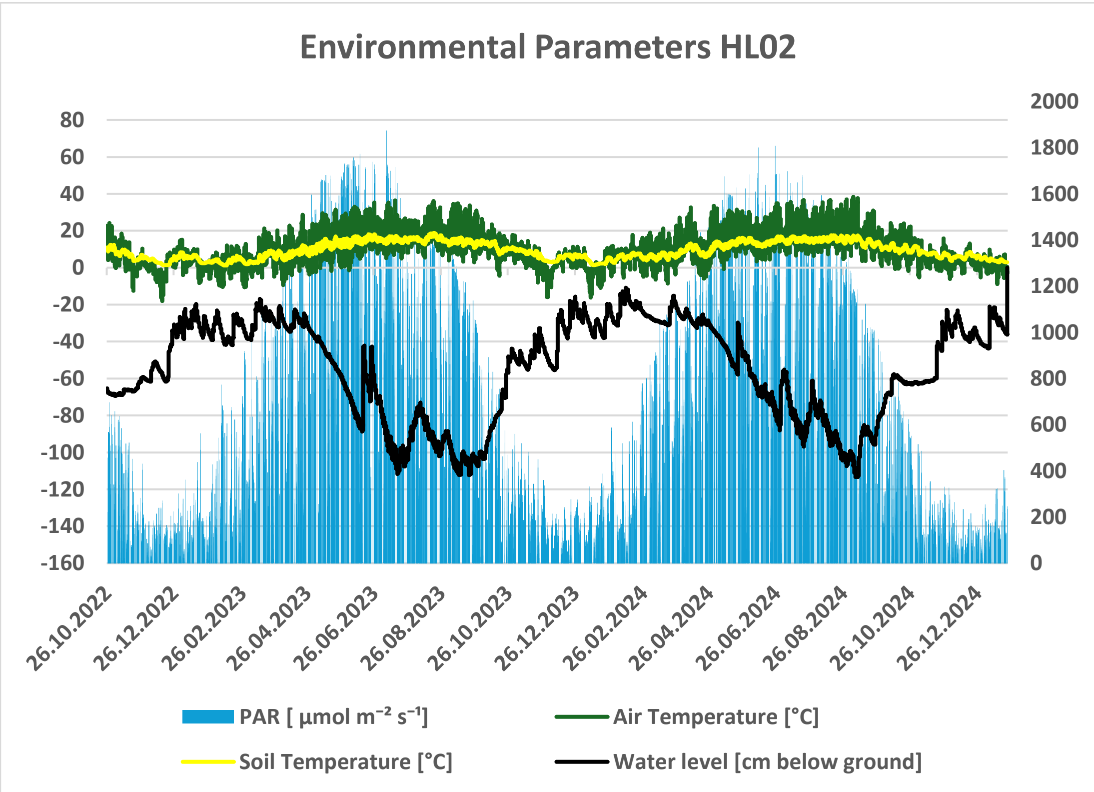

Figure 14. Environmental parameters from GHG-monitoring site HL02. PAR, soil temperature and air temperature correspond to the left y-axis; water level to right right y-axis

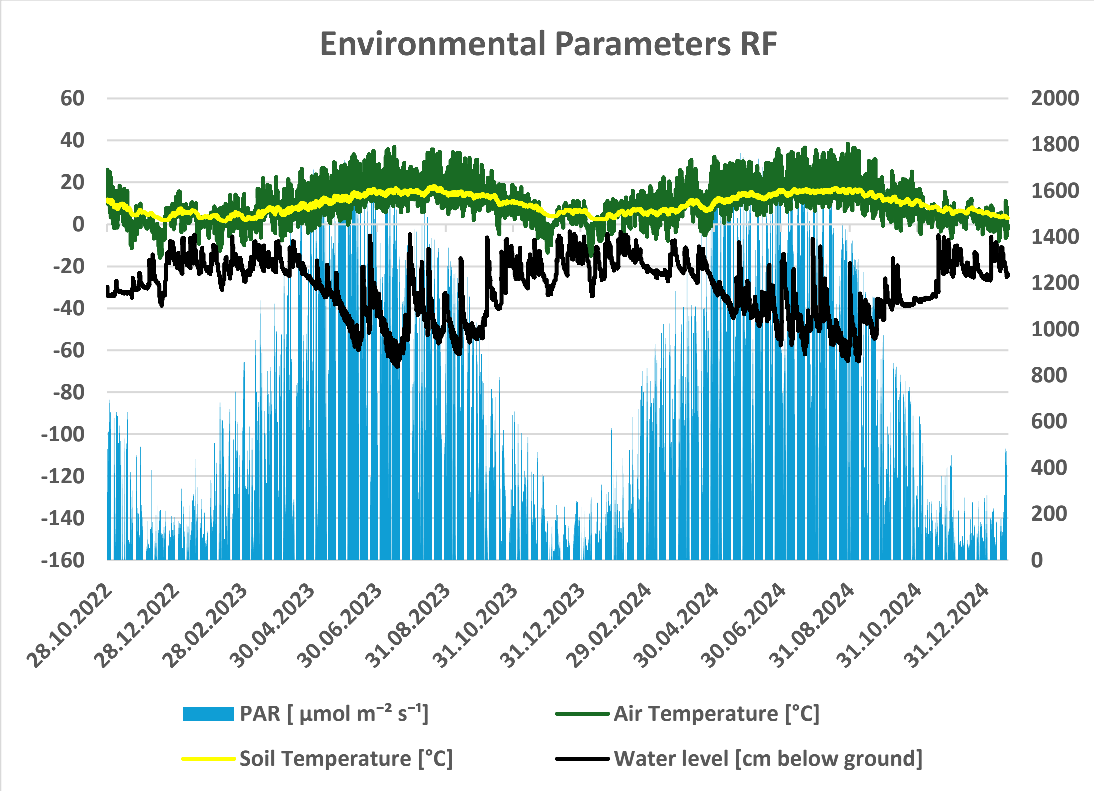

Figure 15. Environmental parameters from GHG-monitoring site RF. PAR, soil temperature and air temperature correspond to the left y-axis; water level to right right y-axis.

3.3.3 GHG-Measurements

The GHG-measurements started in September 2023 in will be conducted at three until August 2025. Two of these sites (HL01 and HL02) are at the Life Multi Peat site "Häsener Luch" (see Figure 16a). HL01 lies in a *Phragmites australis* stand located on a little mound, so it will not be affected substantially by the planned rewetting measures. Site HL02 is also situated in a *Phragmites australis* stand and will be affected directly by rewetting measures. The reference site "Rüdnitzer Fließ" was rewetted 10 years ago. The GHG-measuring equipment is also situated in a *Phragmites australis* stand (see Figure 16b).

For a more detailed description of the methods see 2nd Monitoring Report (LIFE Multi Peat, 2024, chapter 2.2). CO_2 and CH_4 fluxes are directly measured in the field with a LiCOR 7810 trace gas analyser. N_2O will be sampled from the second year on every three months in sample flask, to be later analysed in the laboratory. The measured PAR values at site HL1 are subject to errors in summer 2024 (see Figure 13), because climbing hops plants (*Humulus lupulus)* covered the sensor. As HL01 and HL02 lie in a distance of only 450 meters, the PAR values of HL02 will be used for the modelling of the GPP.

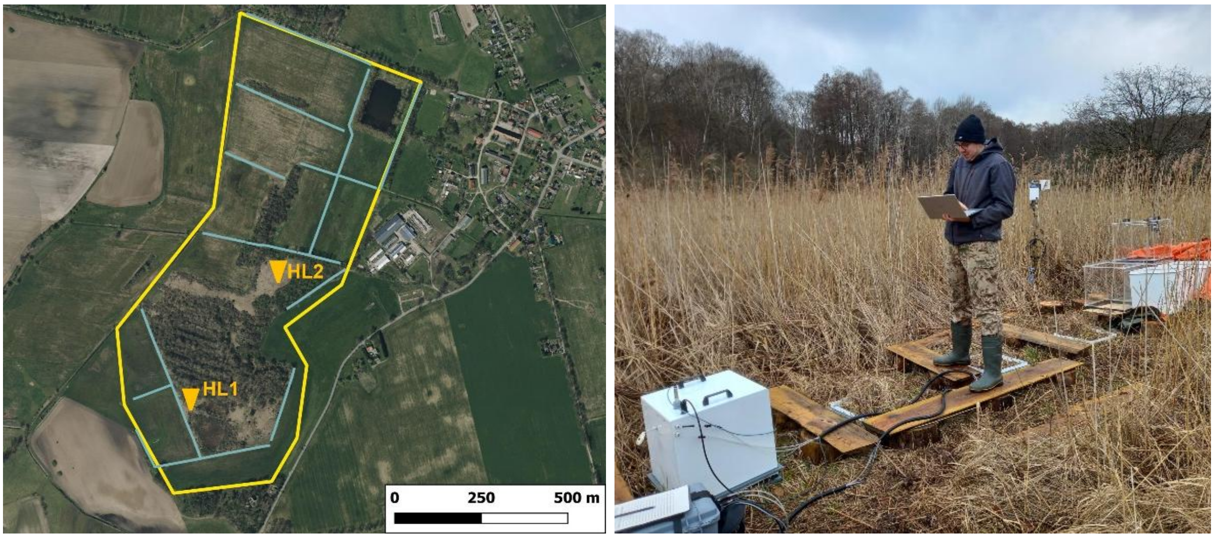

Figure 16: a) Positions of GHG-measuring sites at the Häsener Luch; b) Monitoring plots with wooden boardwalks in a Phragmites australis stand

Currently, the data of the first measuring year is processed and ecosystem respiration (RECO), gross primary product (GPP) and net ecosystem exchange (NEE) are modelled. As an example, Figure 17 shows preliminary results for site HL1. As the model parameters still need a better fit, the data is only preliminary and will be refined until the end of the project.

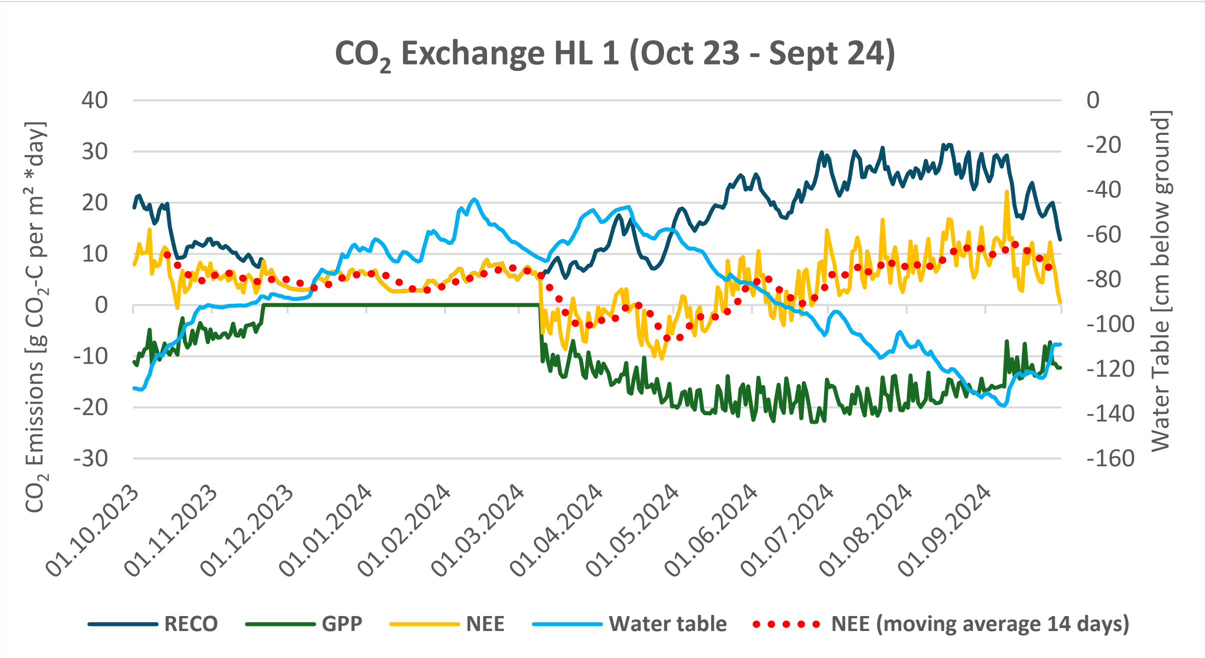

Figure 17: Preliminary results for the first measuring year at site HL1 [not to be used for citation]. GPP (dark green) is modelled only for the vegetation period

3.3.4 Vegetation Monitoring

In June 2022, 20 vegetation monitoring plots were installed at different places and vegetation types of the project area (Figure 18). Each plot measures 5x5 meters and on the managed grassland they were marked with magnets in the ground, for finding them again. The vegetation description follows the rules of Braun-Blanquet (1964). In June 2024 the first repetition of the vegetation monitoring was conducted.

Figure 18: Positions of the 20 monitoring plots inside of the project site

So far, no changes in soil moisture classes have been registered on any of the vegetation plot. This was expected, as the test rewetting was in place in only three weirs, of which only one (PSSS02) elevated water levels in the drainage ditch (see chapter 3.3.1). Even this successfully raised ditch water level has limited effects in the surrounding areas, that none of the vegetation plots lies close enough to be affected. The number of species in general, as well as the number of peatland related species was higher in 2024. We did not attribute this effect to an improvement of the site, but rather to the fact that the pastures were freshly mowed in 2022, and it was therefore difficult to determine the grass species without inflorescence.

Table 2: Changes in species composition between 2022 and 2024 at each plot

Vegetation plot	Number of species		Number of species typical for peatlands		Number of endagered species	
	2022	2024	2022	2024	2022	2024
01	11	21 (+)	6	7 (+)	1	1
02	12	15 (+)	-	1 (+)	-	1 (+)
03	16	22 (+)	3	7 (+)	-	-
04	7	5	6	3	-	-
05	9	10 (+)	6	7 (+)	-	1 (+)
06	13	11	4	3	-	-
07	10	10	3	3	1	2 (+)
08	5	10 (+)	3	4 (+)	-	-
09	9	14 (+)	2	3 (+)	-	-
10	8	14 (+)	3	4 (+)	-	-
11	6	7 (+)	1	2 (+)	-	-
12	14	24 (+)	3	4 (+)	-	1 (+)
13	15	14	2	2	-	-
14	15	22 (+)	2	4 (+)	-	-
15	11	18 (+)	4	7 (+)	1	1
16	10	17 (+)	-	-	-	-
17	6	20 (+)	-	2 (+)	-	-
18	12	13 (+)	-	-	-	-
19	10	17 (+)	-	-	-	-
20	10	13 (+)	6	7 (+)	-	-

3.4 Discussion and Challenges

The implementation of the rewetting measures is further delayed by complicated land purchase negotiations. In addition, further complications arose by the occurrence of the African Swine Fever Virus (ASFV) close by. In November 2024, a dead wild boar has been found 5 km north of the Häsener Luch. It was confirmed that his death was caused by the ASFV. The project site lies now within a 15 km restriction zone around the cadaver, and agricultural and forestry activities are prohibited. Probably, these restrictions will be lifted after one year. If more ASFV cases come up, it will be prolongated. The biomass and shrub removal must therefore be postponed, as well as the construction works for the rewetting.

The GHG-monitoring will likely be permitted to continue. The third vegetation monitoring in summer 2025 might be permitted as well, but it is still unclear.

Also, increasing beaver activities in and around the project area might be good for some surprises in future.

Further, there were some problems with the hydrological monitoring equipment. Caused by battery problems, damage by rodents and still unknown malfunctions, some data was lost and could not be recovered.

The test rewetting was not as successful as hoped (see chapter 3.3.1). This will have implications on the technical design of the proper rewetting.

4 Ireland

4.1 *Project Site*

The project area is located in the West of Ireland approximately six km southwest of the town of Oughterard in County Galway. The project site lies within the Cloosh Valley Windfarm managed by SSE. The project consists of two sites: Doire Fhada (~178ha), which is the northernmost site, and Fionnán (~62ha) which is the southernmost site.

Elevation at Doire Fhada decreases from south to north with an elevation change of approximately 200m within the site. The site is situated at an elevation of approximately 100m to 300m. There is no evidence of peat harvesting within the site, however, ground works in preparation for tree planting have taken place in the past and has resulted in numerous furrows along areas of blanket bog (Figure 19). Most of the site consists of blanket bog with varying peat depths. Part of the site is planted with a conifer plantation, with other sections of the site drained, but not planted.

Figure 19 Photos from Doire Fhada, which shows the steeply sloping ground onsite, and past tree planting (lower)

There is very little elevation change within Fionnán, which is located at a lower elevation ranging from approximately 100-110m.

There are three monitoring stations located at Doire Fhada in three different Ecotopes: Blanket Bog (BB), Sitka Spruce (SS), and Open Forestry (OF). There are two monitoring stations at Fionnán: Blanket Bog (FBB), and Sitka Spruce (FSS).

4.2 Current State

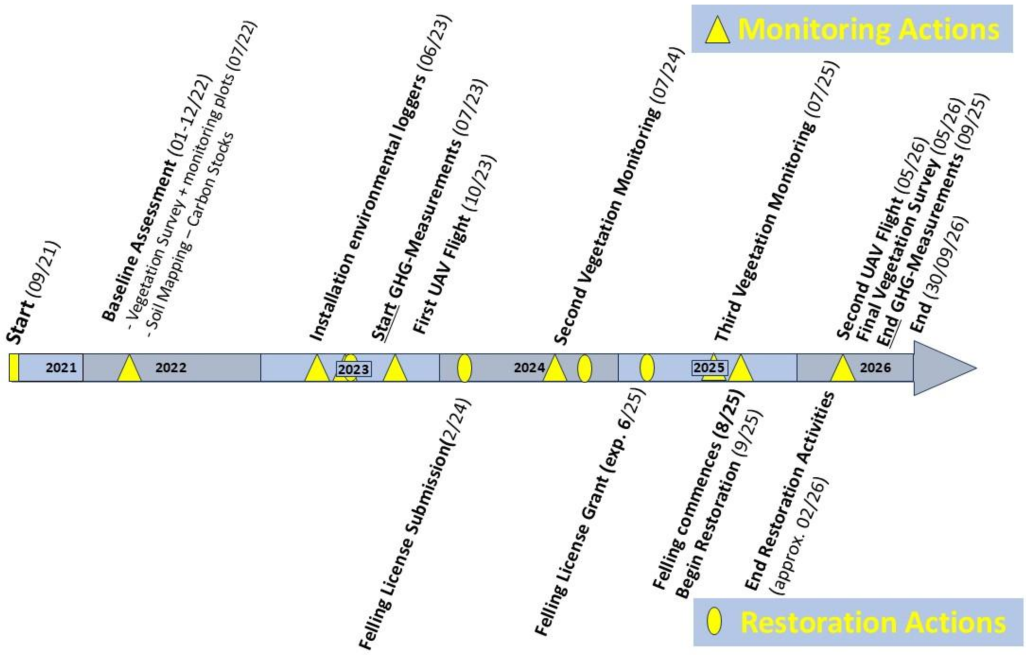

Figure 20: Timeline showing restoration- and monitoring progress for Ireland

4.3 Results

4.3.1 Hydrological Monitoring

The project area was surveyed using LiDAR in October and December 2024. The data was used to accurately map current drainage onsite in forested areas, and on open bog (see Figure 21 & Figure 22). After the LiDAR survey, ground surveys were conducted to confirm the accuracy of the LiDAR Data. This information will be used to inform the restoration plan, which will include the installation of several dams across the drainage network.

Ground water is currently being recorded at each of the greenhouse gas monitoring stations using Z6 Zentra Loggers (5 stations). These stations represent the main Ecotypes onsite. In addition, 5 additional ground water wells have been installed at Doire Fhada (see Figure 23).

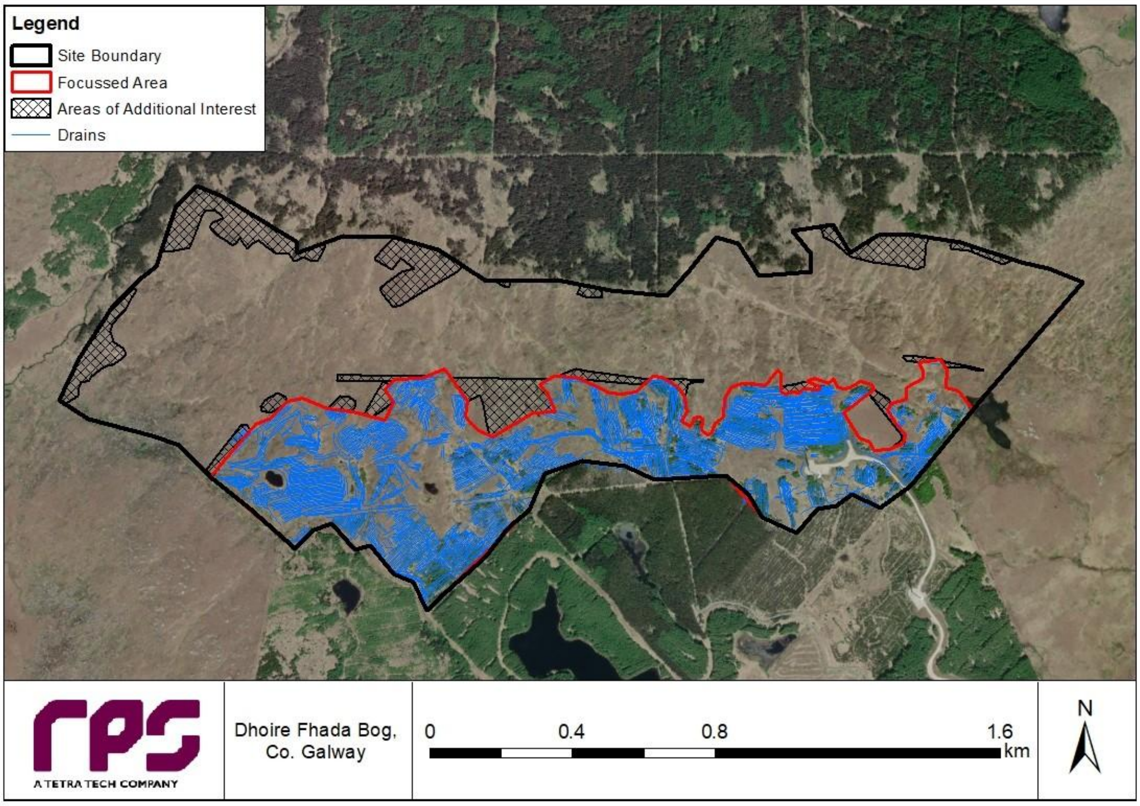

Figure 21: Drainage network on Doire Fhada as mapped by LiDAR survey

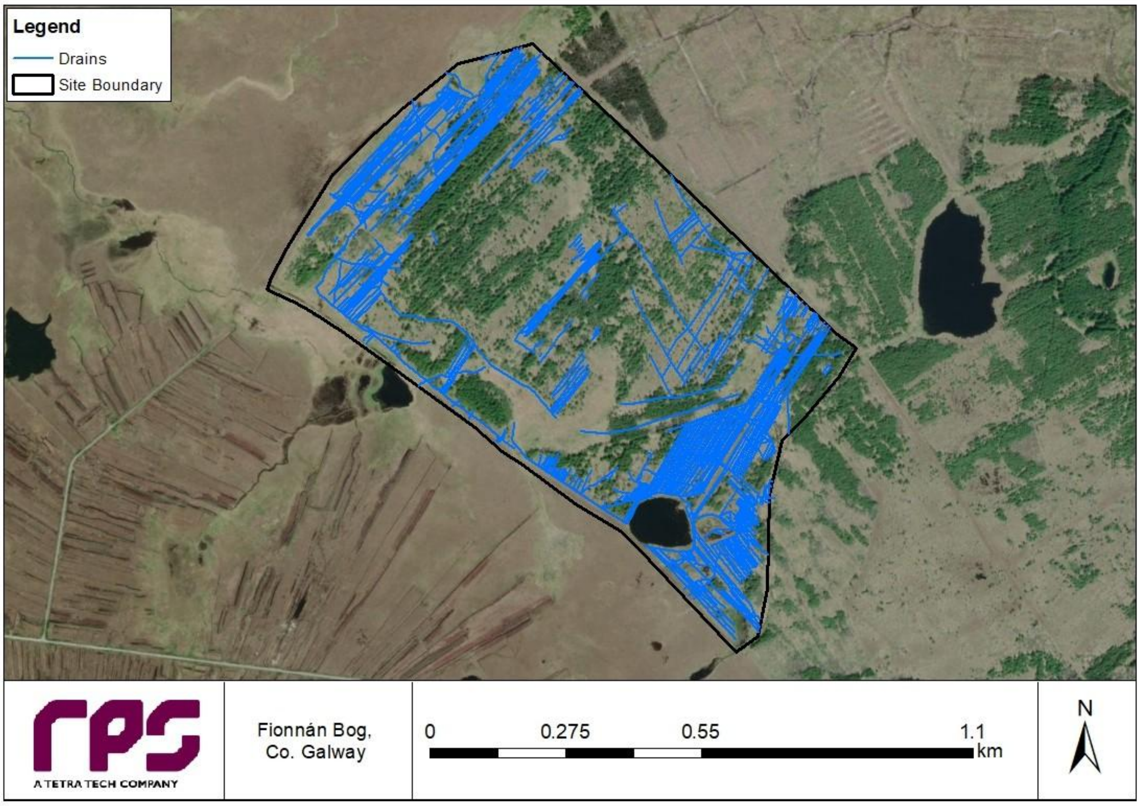

Figure 22: Drainage network on Fionnán as mapped by LiDAR survey

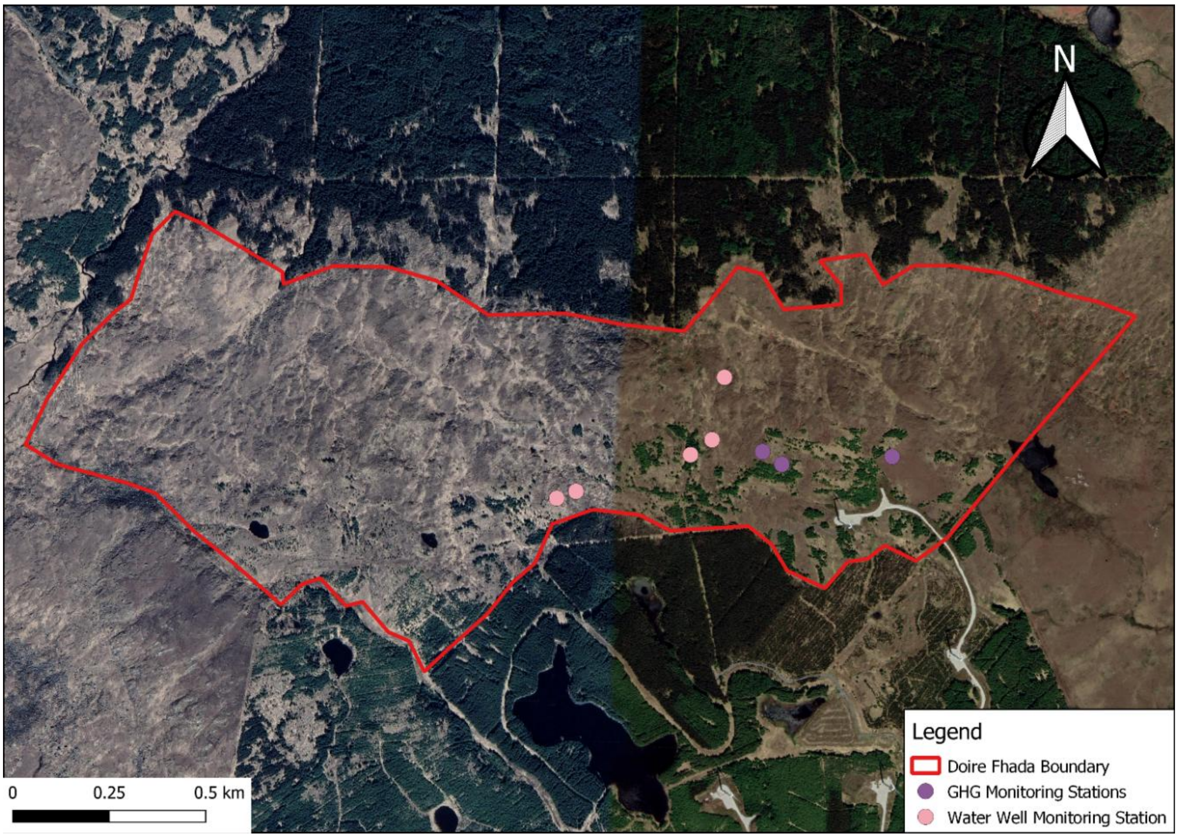

Figure 23: Environmental monitoring stations at Doire Fhada

Waterlevel onsite corresponds with drainage levels. BB is an intact ecoptope with no drainage, and water level at this station is at or near to the surface, apart from during the dryest summer months when water level drops to (-10cm).

SS and OF are areas which were extensively drained, and in comparison to BB waterlevel at these sites is consistently much lower (-20cm).

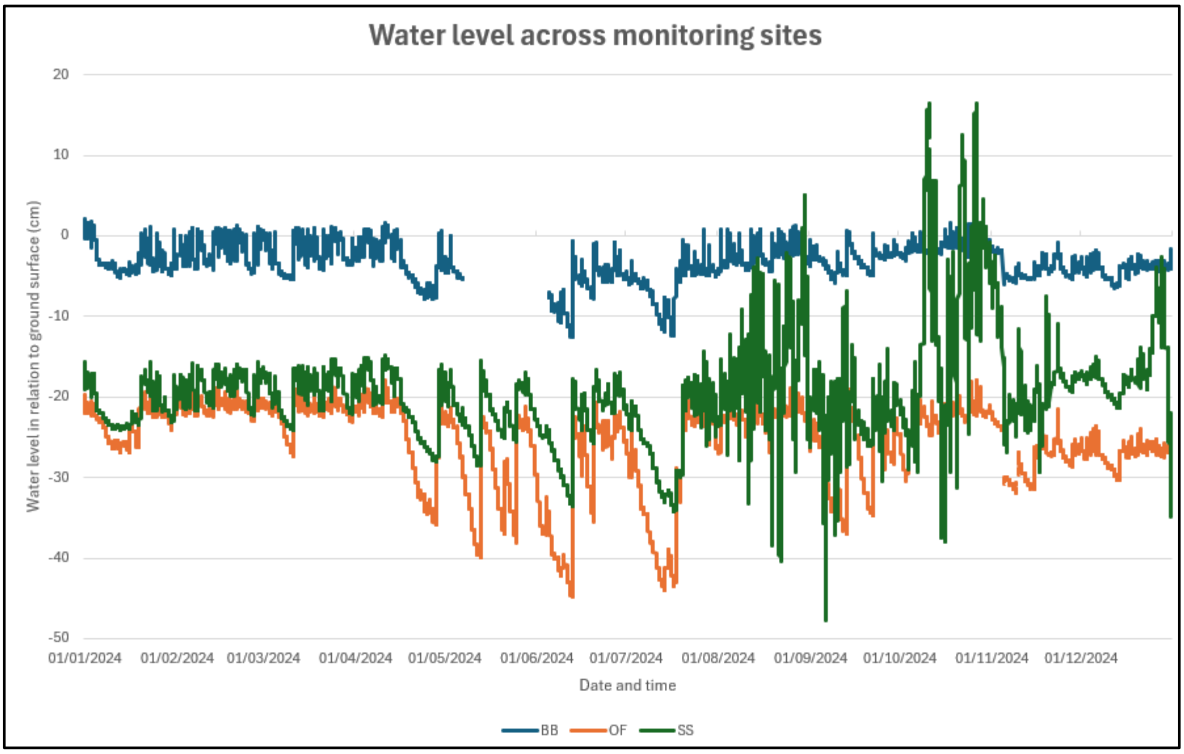

Figure 24: Waterlevel in relation to ground level at Blanket Bog (BB), Open Forestry (OF) and Sitka Spruce (SS) ecotopes

4.3.2 Environmental Parameters

There are three monitoring stations located at Doire Fhada in three different Ecotopes: Blanket Bog (BB), Sitka Spruce (SS), and Open Forestry (OF). There are two monitoring stations at Fionnán: Blanket Bog (FBB), and Sitka Spruce (FSS).

Each monitoring station was chosen to represent the most common habitats within each site. Each of these stations is monitored by Zentra (Z6) data loggers (see Figure 27), which record environmental data every 15 minutes. Each station monitors soil moisture, soil temperature, water level, and water temperature.

In addition, light intensity is currently measured at SS, OF (see Figure 25 and Figure 26). Initially, light intensity was measured at BB, but the sensor was moved to OF as this is area will include some felling and we want to monitor potential changes in light intensity post felling. Sensor cables were damaged by grazers early in the year, and there are therefore some gaps in data. Cables have since been placed in protective hosing. Light intensity fluctuates a lot at OF both seasonally and daily. This is an exposed site that is hit directly by the sun for most of the day. There is very little variation at SS as this site is heavily shaded by the trees in the conifer plantation. Similarly OF experiences wide daily fluctuations while SS shows very little change between day and night.

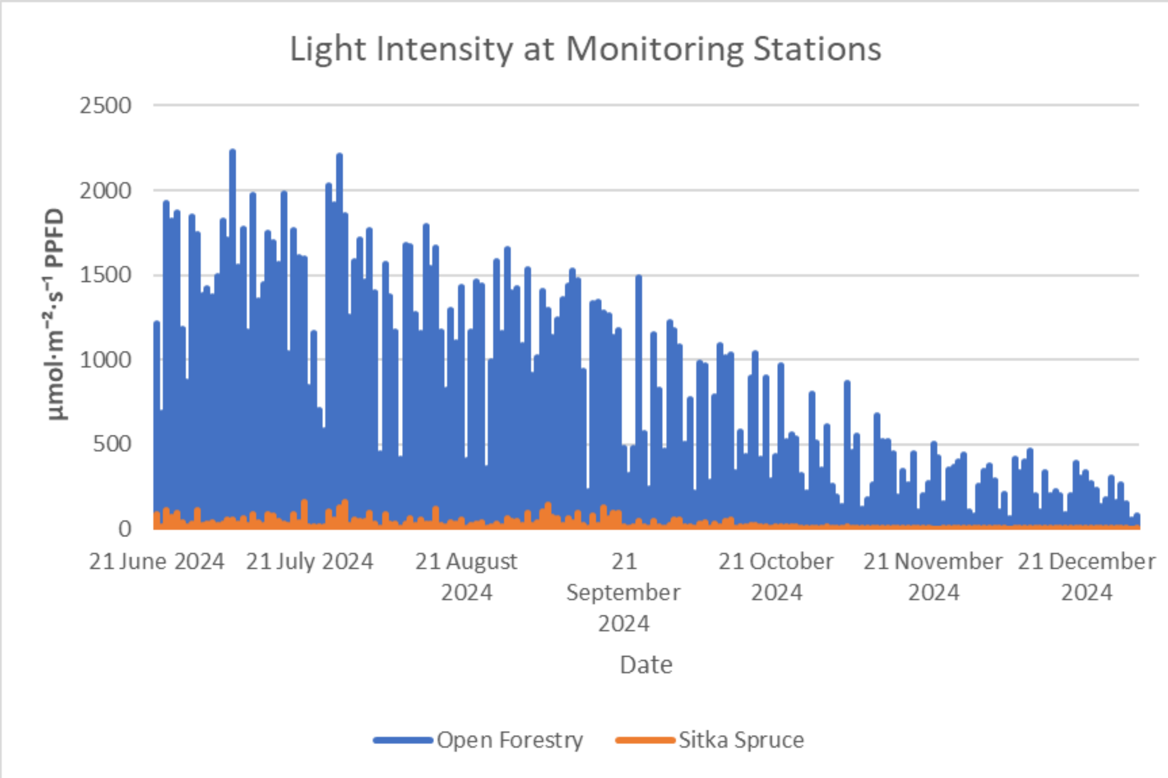

Figure 25: Light intensity across at Open Forestry and Sitka Spruce monitoring stations (June-Dec 2024)

Figure 26: Light intensity across at Open Forestry and Sitka Spruce monitoring stations (1-3rd July 2024)

Figure 27: Zentra Z6 Data logger recording soil temperature, soil moisture, water level at BB

UAV Flights

UAV flights took place at Doire Fhada and at Fionnán in October 2023 (see Figure 28 and Figure 30). This imagery was used to generate Digital Elevation Models and Vegetation Indices of the project areas. Results of these surveys were reported in the last monitoring report.

A second flight was conducted on the 14/08/2024 and 21/01/2025. The aim was to generate NDVI maps of Doire Fhada and Fionnán to compare seasonal changes within the site. The site at Fionnán was fully mapped (see Figure 29) on both occasions. Due to the high elevation at Doire Fhada, winds and precipitation is higher and a second flight at Doire Fhada has not been achieved to date.

Figure 28: NDVI map of Fionnán (06/10/2023)

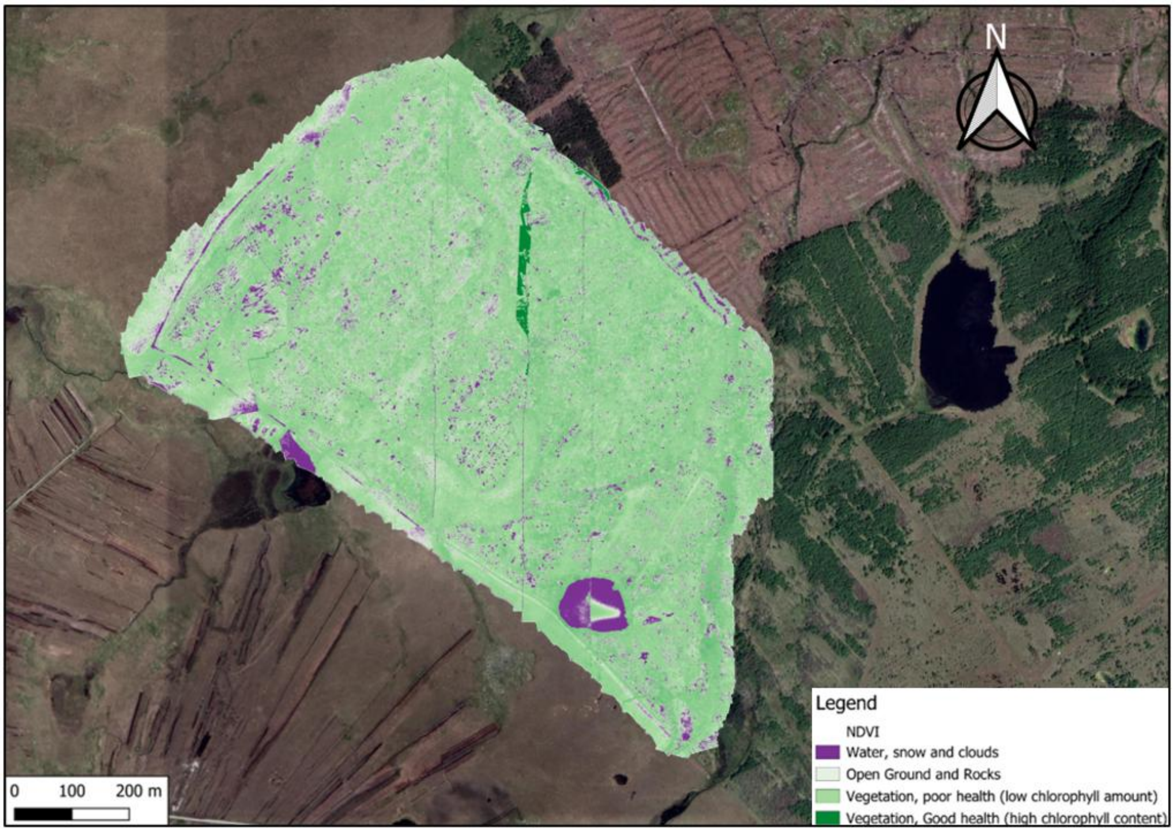

Figure 29: NDVI map of Fionnán 14/08/2024

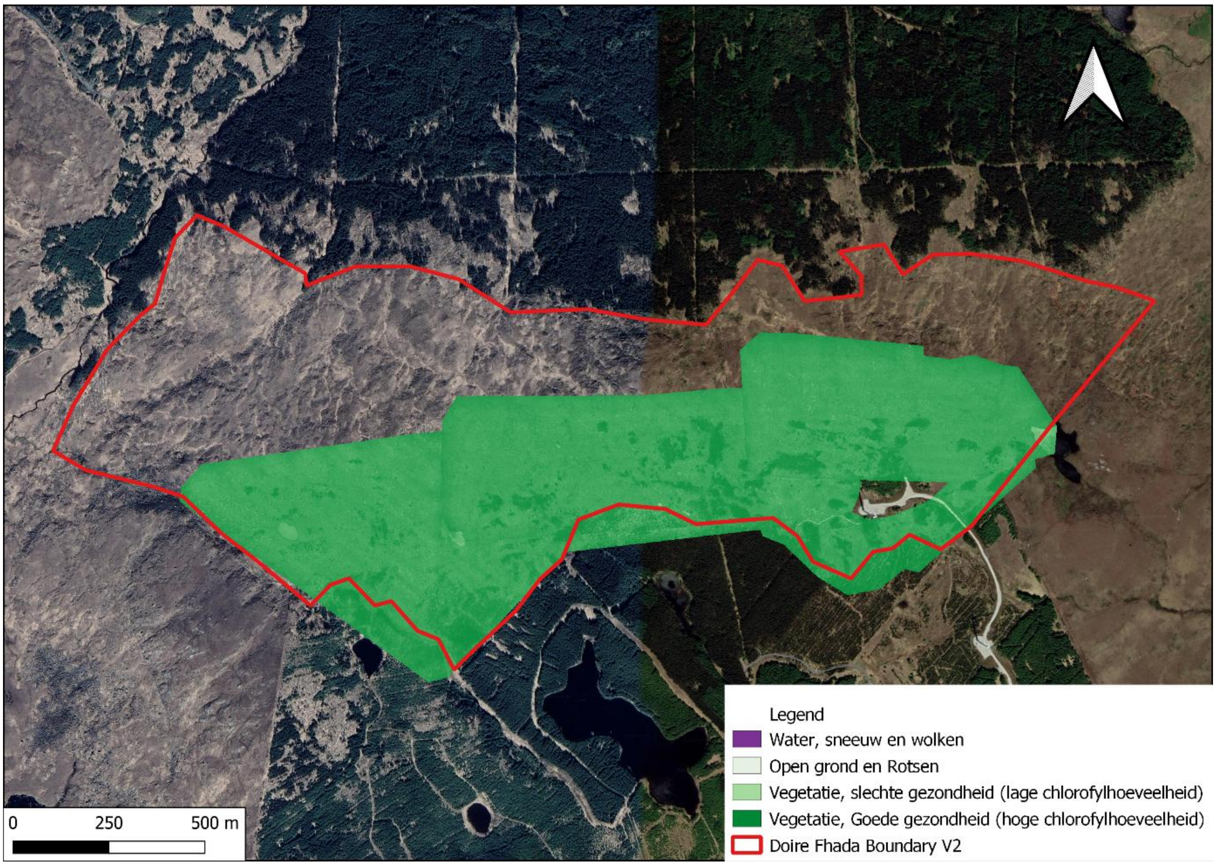

Figure 30: NDVI map of Doire Fhada 07/10/2023

4.3.3 GHG-Measurements

Each monitoring station is fitted with three permanent collars (Figure 31, Figure 32 and Figure 33) from which Carbon and Methane emissions are measured monthly using the closed-chamber method. Emissions are recorded using a Los Gatos Analyser. Emissions for each collar is measured for three minutes at full light conditions, dark conditions, and in half-light if possible.

For each three-minute recording, soil temperature, soil moisture, air temperature and light intensity is recorded. This will allow us to calculate more accurate fluxes at a later date.

Figure 31: Collars at site BB (blanked bog)

Figure 32: Collars at site OF (open forestry)

Figure 33: Collars at stie SS (Sitka Spruces)

At the time of reporting, 12 months of measurements have been completed at Doire Fhada (BB, OF, SS), as well as 3 months of measurements at Fionnán (FSS and FBB). GHG monitoring is ongoing on a monthly basis.

The graphs below (Figures 34-37) illustrate CO_2 emissions from each ecotope within Doire Fhada during light conditions (NEE) and dark conditions (NER). These results will be refined at a later date to give an estimate of annual flux from each ecotope, based on light conditions and environmental parameters.

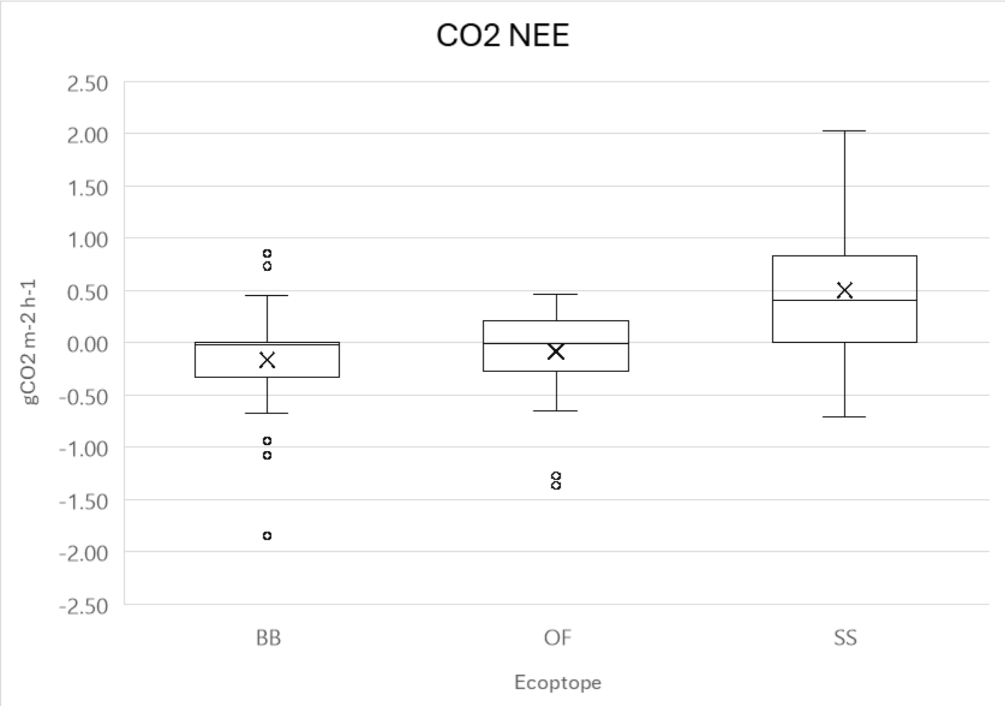

Figure 34: CO_2 emissions from each ecotope under natural light conditions (Sept 2023-Aug 2024)

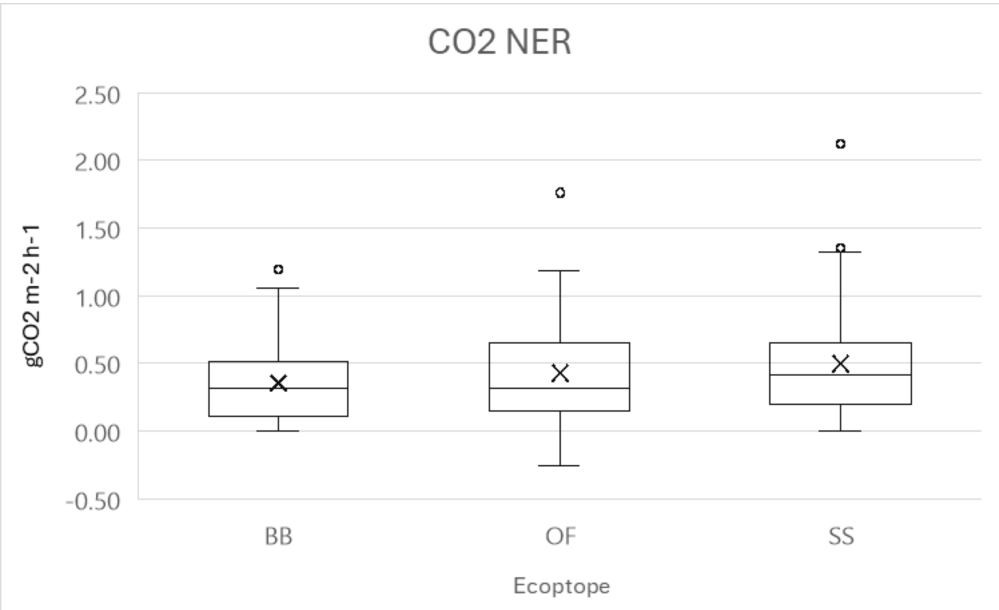

Figure 35: CO_2 emissions from each ecotope under dark conditions (Sept 2023 – Aug 2024)

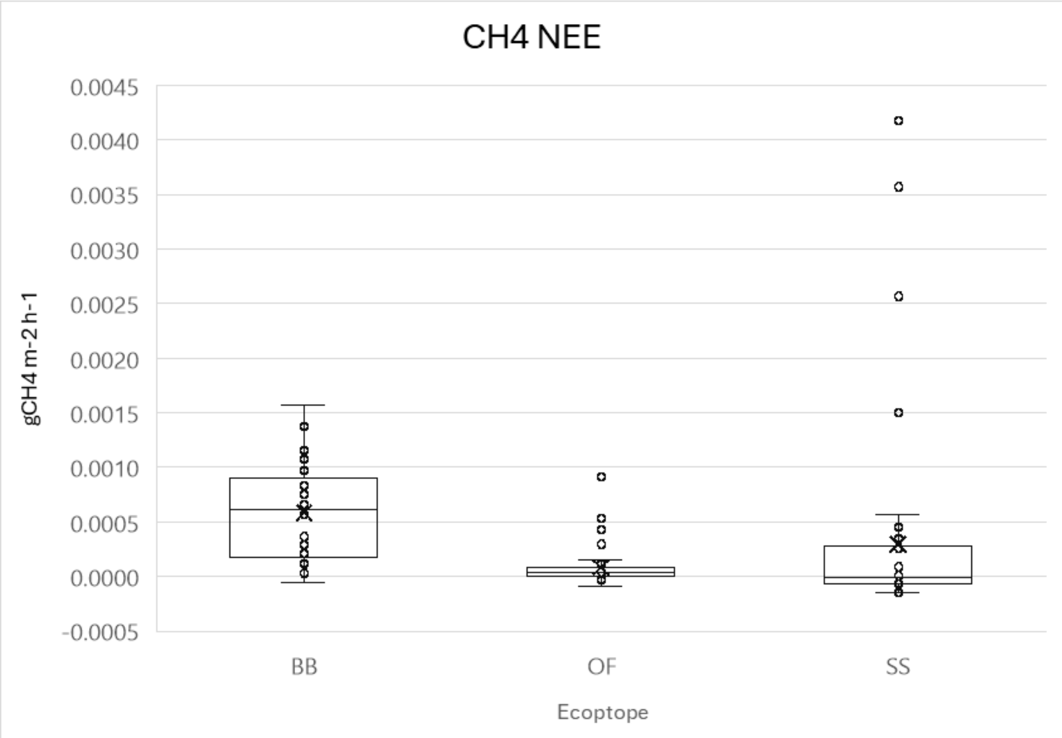

Figure 36: CH_4 emissions from each ecotope under natural light conditions (Sept 2023-Aug 2024)

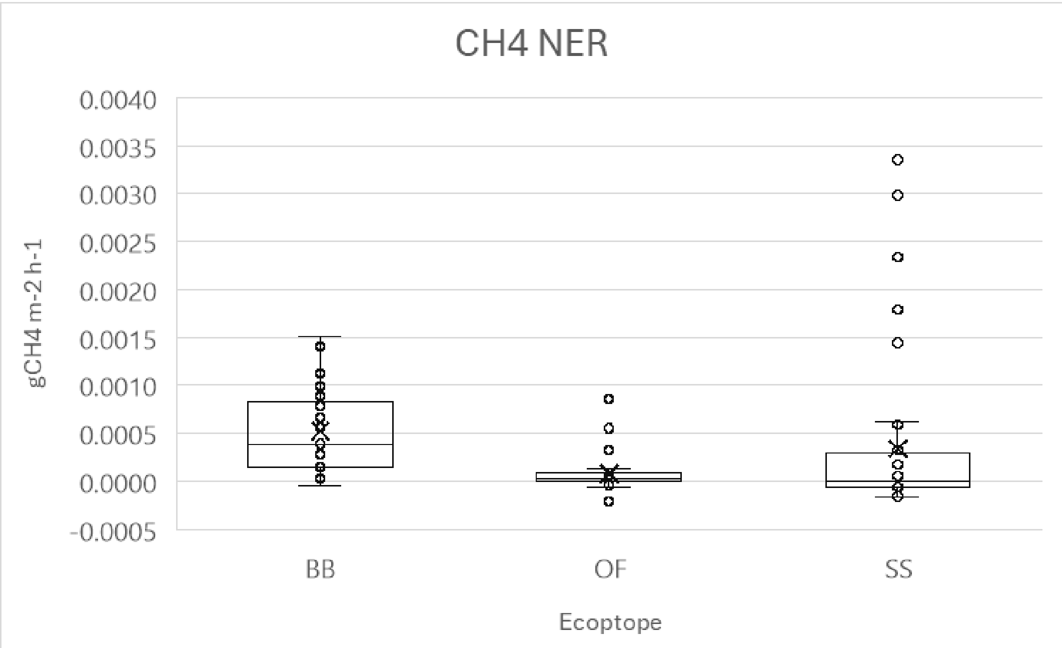

Figure 37: CH_4 emissions from each ecotope under dark conditions (Sept 2023-Aug 2024)

4.4 *Discussion and Challenges*

The onset of restoration activities has been delayed substantially at this site for several reasons beyond our control. While the site is managed by our partner Cloosh Valley Wind Farm/SSE, it is owned by the state forestry company. Thus, any activity at the project site requires consent of both the managing and owning organisations. Initial delays were a result of these negotiations and existing regulations in place that prevent the felling of trees without replanting. Our site partners have negotiated a derogation of the planting and have consent to perform the restoration. This process took 1.5 years to negotiate, approximately six months longer than expected.

The second delay is a result of a change in planning consent with the local county council. A change in land-use had been part of the windfarm activities and thus planning permission was expected to fall within the existing permissions. At a planning meeting in 2024, the council considered the restoration as new activities and thus subject to a new and separate planning application. SSE and the University of Galway, working with private consultants, have been able to procure a new application in short time and we are assured that restoration can begin immediately after the time limits in place for Natura 2000 designated areas (currently March –August) this year.

Onsite monitoring has been generally progressing smoothly, with some small issues with some data loss due severed cables from animal ingestion. We will have a four-month lapse in GHG monitoring in the next annual report, from October-January 2024, as the analyser was sent to the UK for annual calibration and was caught up in customs for three months. The University of Galway is working to eliminate the need to send items to the UK to avoid these types of delays.

5 Netherlands

5.1 *Project Site*

In the preparation of the project an extensive eco-hydrological system analysis has been established. This analysis describes the geology, geomorphology, hydrology etcetera. In the present Mid-term Monitoring Report we will only give a short summary. Full details are available in Dutch (Bell & van ‘t Hullenaar, 2018).

The Witte Veen is a Natura2000 reserve in the east of The Netherlands at the border with Germany (Figure 38). The area is located between two main brooks: the Hege Beek in the north and the Buurser Beek in the south. The main study site in the Witte Veen is the peat bog in the northeast. This peat bog was formed in a lower area in a late Pleistocene sand dune landscape on top of clayloams which originate from the glacial period. During the Holocene the peat bog grew and spread over the landscape. However, since Medieval times human influence started and after drainage, peat cutting and exploitation only a small remnant was left.

The geomorphological setting and the upper geological layers are illustrated in the cross section in Figure 39. In the above mentioned eco-hydrological analysis several of these cross sections are available.

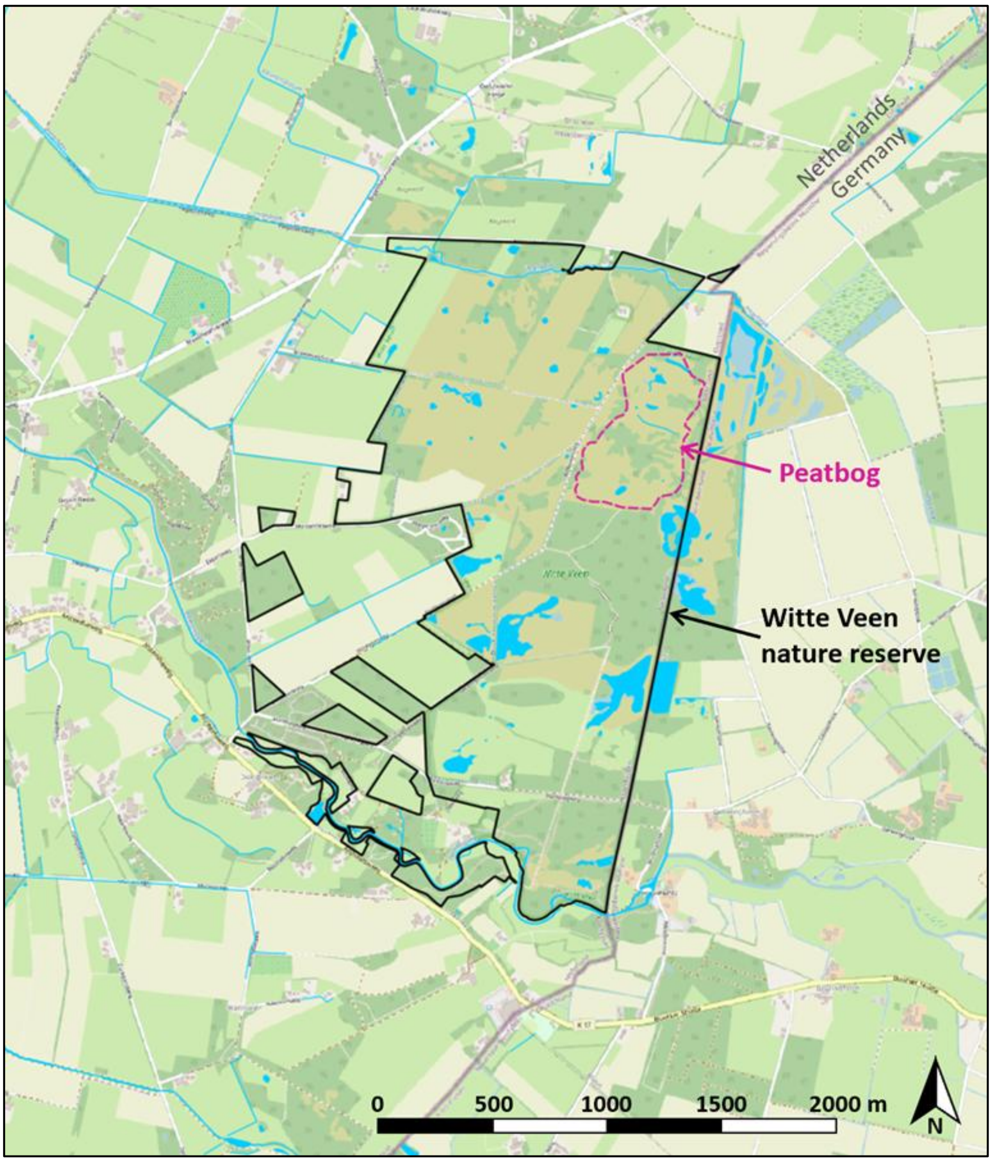

Figure 38: The Witte Veen nature reserve and the location of the peat bog

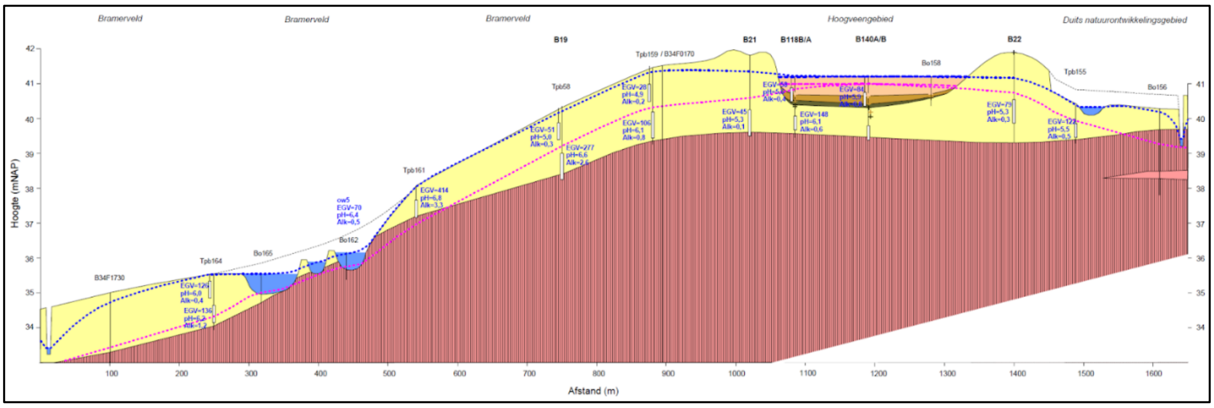

Figure 39 West-east cross section illustrating the geomorphological setting

In the Netherlands a nation-wide DEM is available on both a 0.5 meter and 5 meter resolution. By the end of 2022 the most recent version of that DEM has become available for the Witte Veen (AHN version 4). On the German side of the border we do not have a recent DEM on a fine resolution. Since the project is carried out in The Netherlands the German DEM is only needed for visualisation purposes and does not require a high level of accuracy.

The DEM for the Witte Veen and its surroundings is shown in Figure 40. The elevation decreases from east to west. The peat bog - depicted with the dotted white line - is located on the higher part of the nature area. The valley of the Buurser Beek in the south is clearly visible.

In Figure 41 the DEM of the peat bog is shown in more detail. The late Pleistocene sand dunes are visible as higher parts in the landscape, surrounding the somewhat lower peat bog.

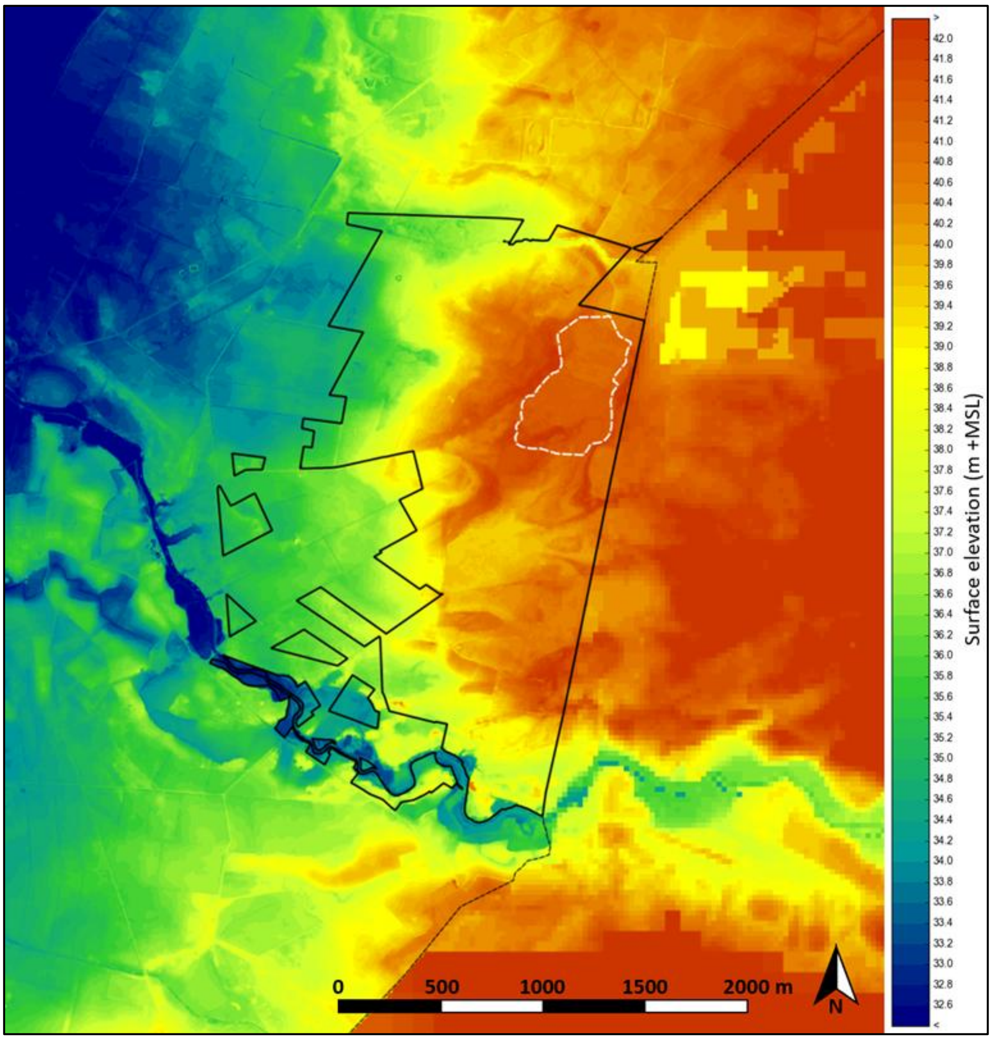

Figure 40: DEM (5x5 meter resolution) of the Witte Veen and its surroundings

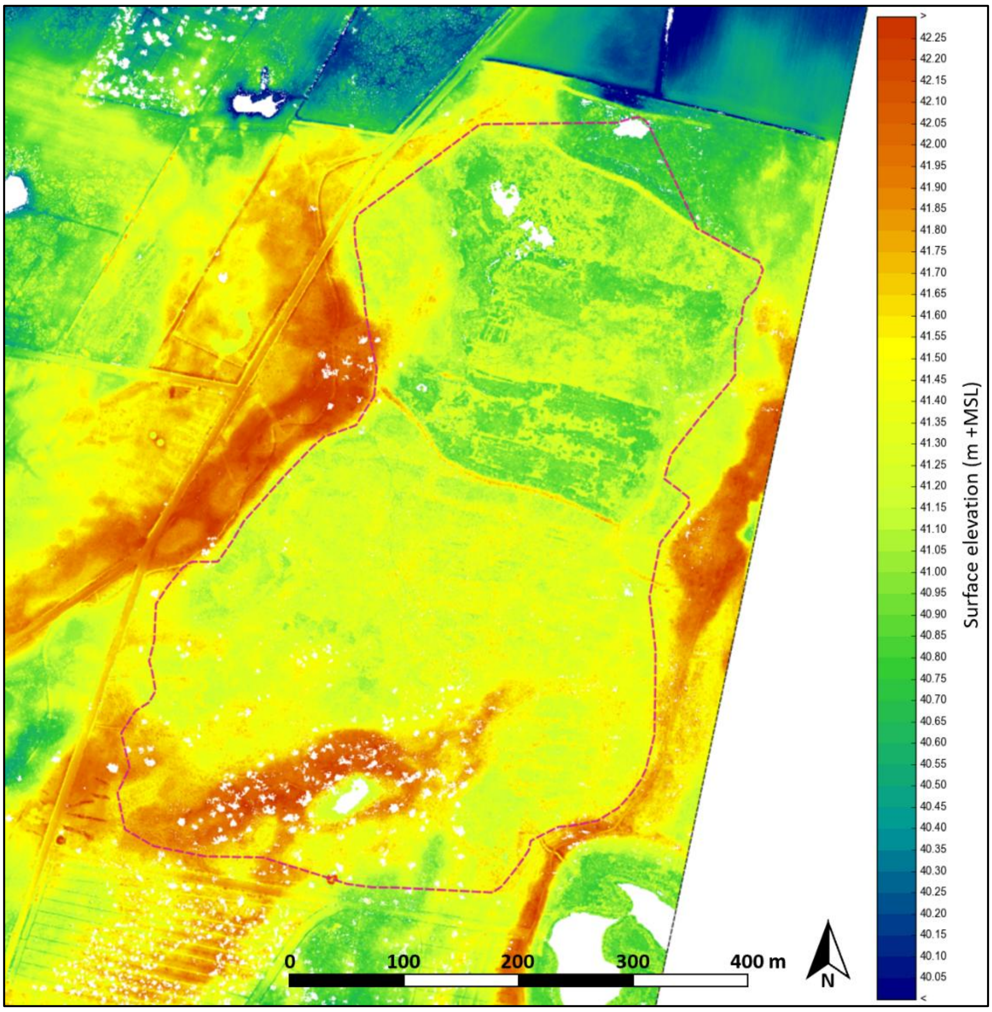

Figure 41: DEM (0.5x0.5 meter resolution) of the peat bog within Witte Veen

Within the peat bog there are no ditches or other streams present. Surface (runoff) and sub-surface water flow from south to north within the peat bog, leaving the bog through a ditch just outside the nature reserve. Water from this ditch flows to the west and north towards the Hege Beek brook in the north. In the nature area outside the bog several (shallow) ditches are present, transporting water to the surroundings in several - mainly westward - directions. These ditches cause water losses from the peat bog area and will therefore be removed in the project. The regional groundwater flow is oriented from the higher parts towards the west.

Reference site

Together with the research partner GEMCE – which measures the GHG fluxes – we have decided that the Engbertsdijksveen in the Netherlands (managed by SBB, the state forestry organization) is the most suitable reference site (see Figure 42). In this peat bog restoration works have been postponed, which give us the possibility to measure at a non-restored site for the entire duration of the LIFE project.

Figure 42: Location of Witte Veen and reference site Engbertsdijksveen in The Netherlands

5.2 Current State

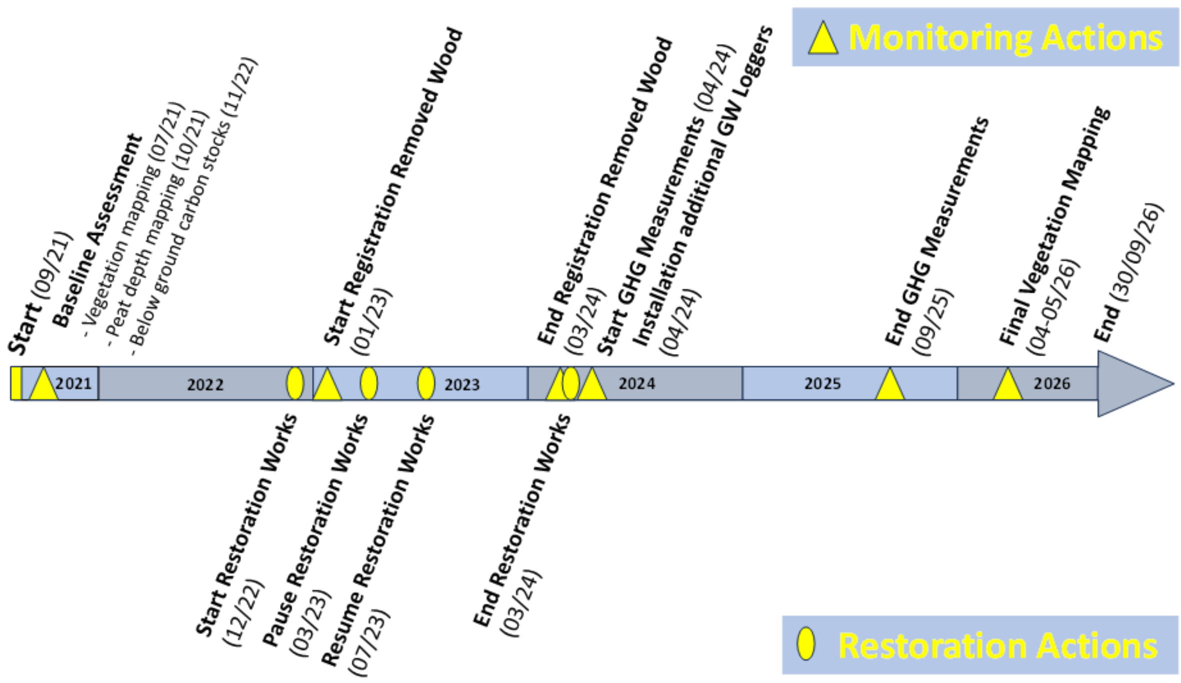

Figure 43: Timeline showing restoration- and monitoring progress for the Netherlands

5.3 Results

5.3.1 Hydrological Monitoring

Monitoring of groundwater and surface water is continued in 2024 at the locations shown in Figure 44. Additional piezometers were installed at the GHG measurement locations. Figure 45 shows an example timeseries, including a timeseries model (modeled with the Pastas timeseries modeling code). The modeled long-term linear trend is negative. The recent wet period is visible in higher groundwater levels. It is however too early to filter out the rewetting effect of the restoration measures.

In Figure 46 the responses of 2 piezometers are shown. This is an example illustrating a relatively normal to quick response (B021 on the left side) and a slower – and somewhat delayed – response (B116 on the right side). The latter is located outside the peat bog area and is likely reflecting a thicker unsaturated zone, i.e. a drier location.

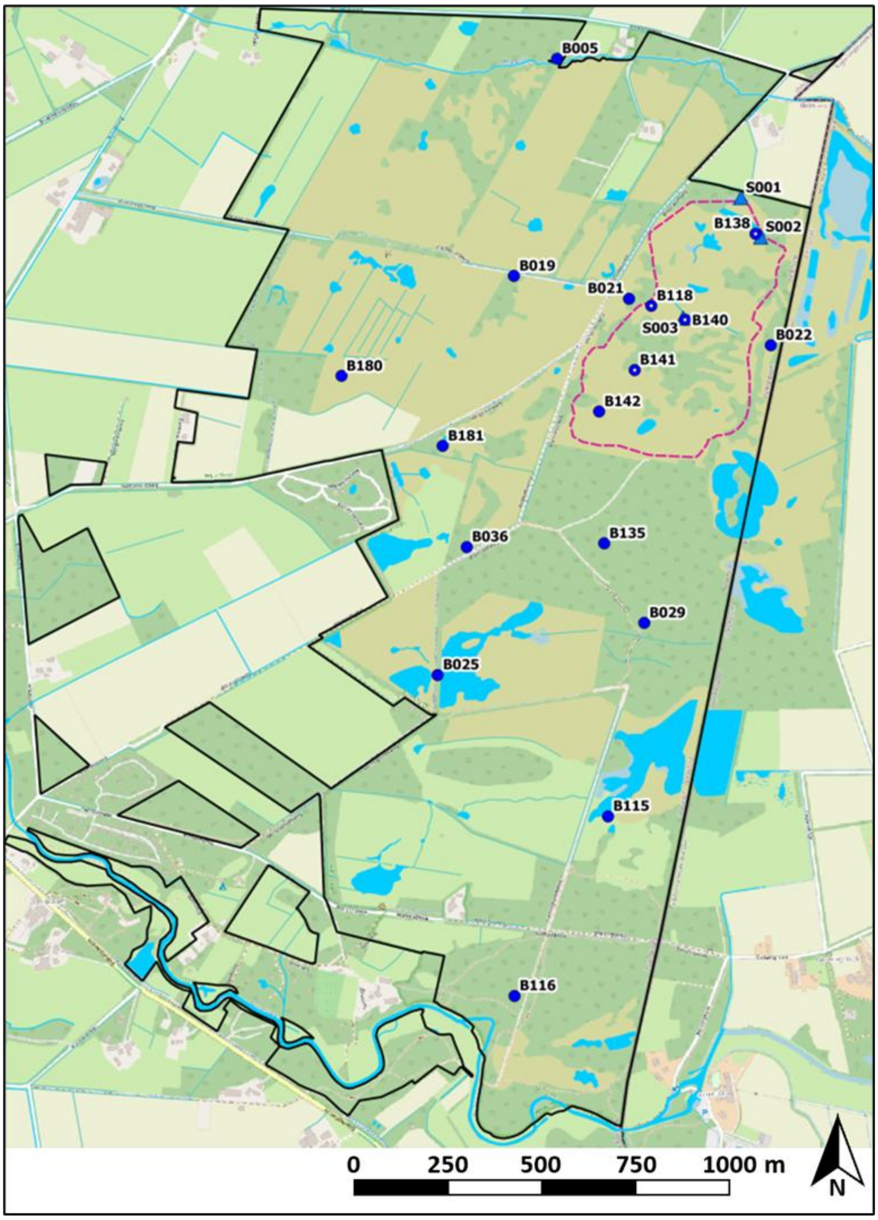

Figure 44: Location of the piezometers in the Witte Veen

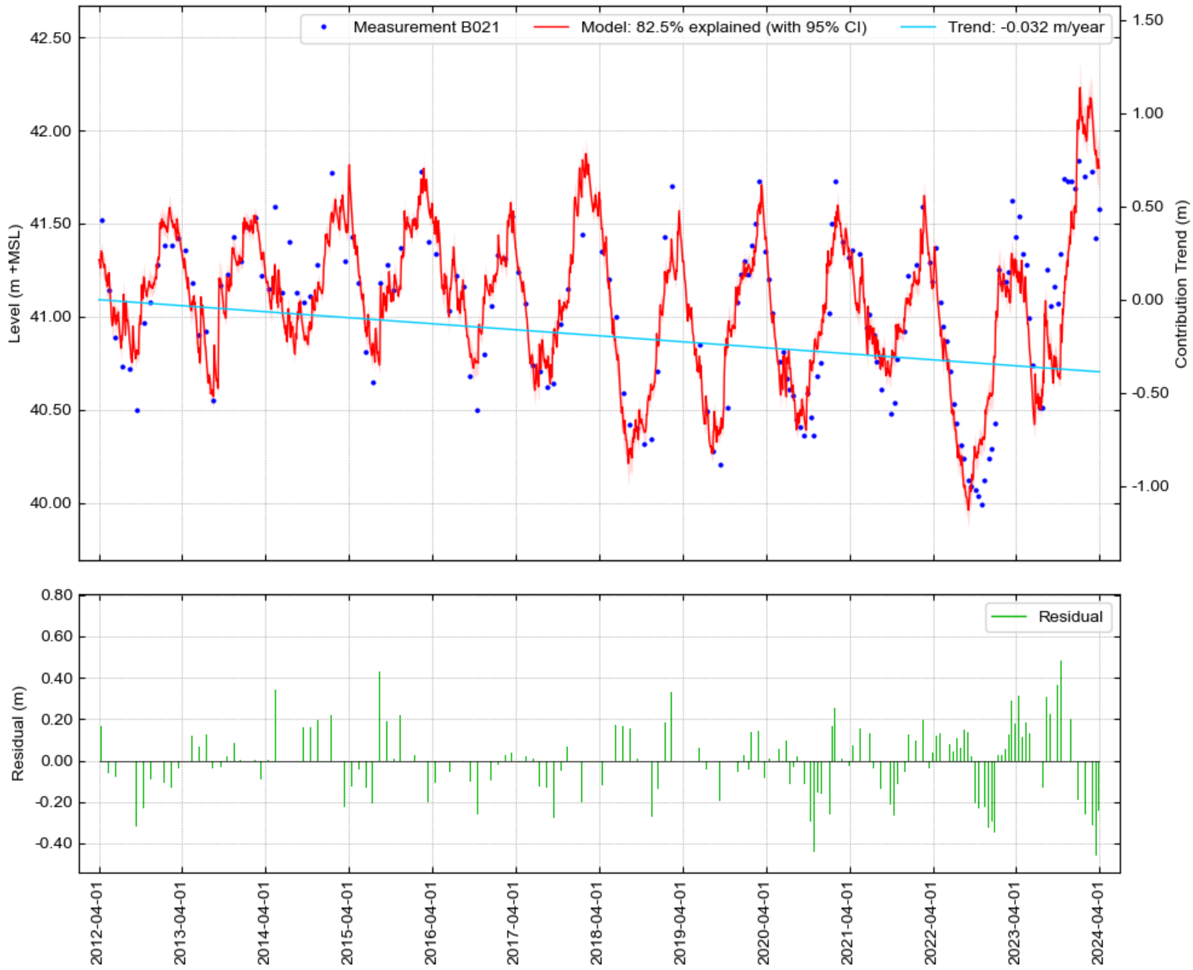

Figure 45: Groundwater timeseries of piezometer B021: measurements (blue), timeseries model (red) and residuals (green). The light blue line is the modeled linear trend

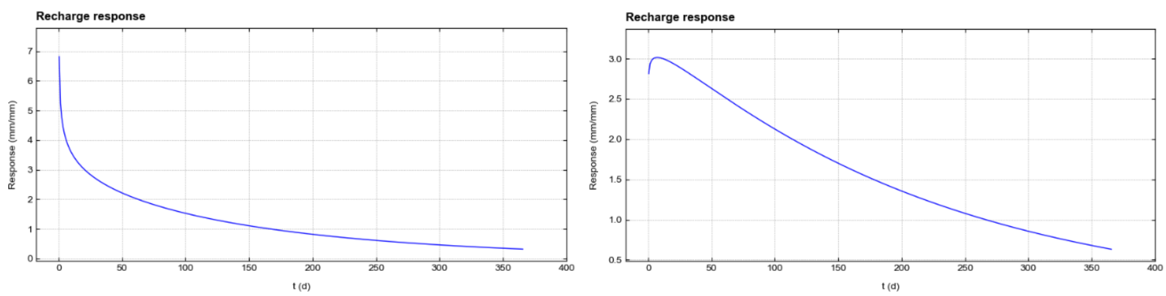

Figure 46: Modeled response to recharge (precipitation excess) of piezometers B021 en B116

5.3.2 Environmental Parameters

Meteo data are derived from nearby weather stations of the Royal Dutch Meteorological Survey (KNMI) (see Figure 47). The bottom figure clearly shows the wet period from the autumn of 2023 to the end of the summer of 2024: a high cumulative precipitation excess in the winter, followed by a low (to negative) cumulative shortage in the summer.

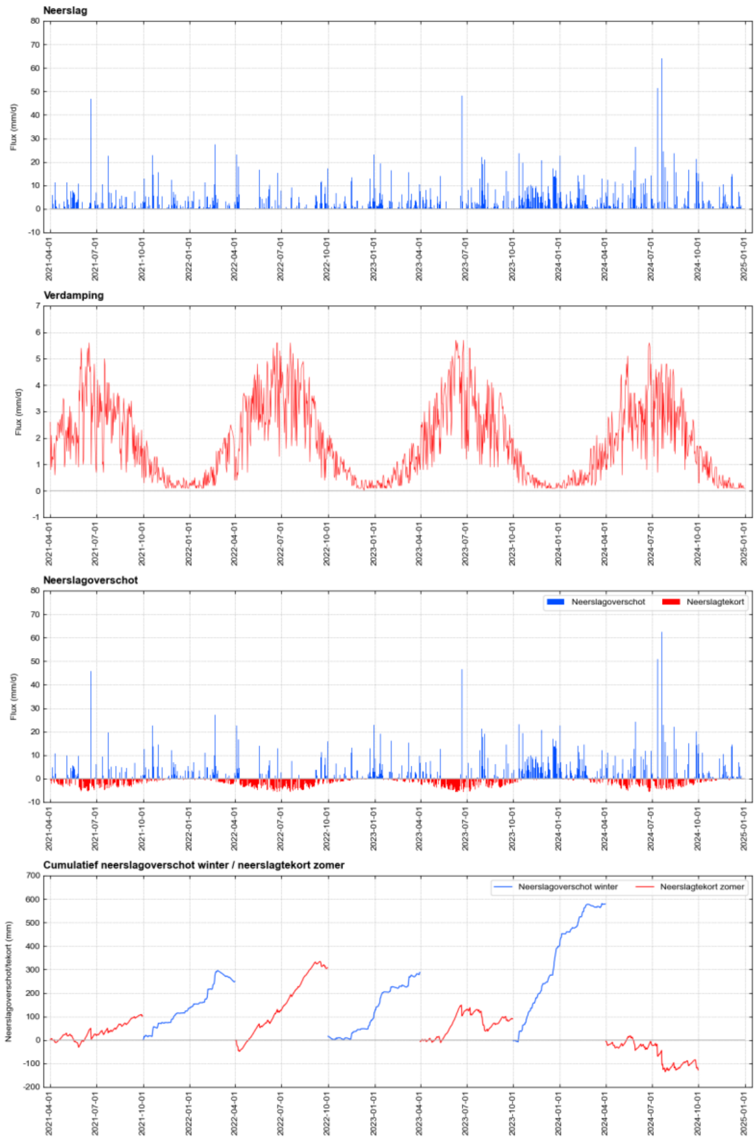

Figure 47: Meteo data for the Witte Veen in period 2021-04-01 to 2024-12-31. Precipitation, evapotranspiration (reference), precipitation excess/shortage and cumulative winter excess and summer shortage

5.3.3 GHG-Measurements

GHG measurements started in April 2024 in both the Witte Veen and the reference site Engbertsdijksveen (see Figure 48) and are done by the contractor GEMCE (B-WARE and Radboud University).

Measurements were done in 11 plots in the Witte Veen and in 10 plots in the Engbertsdijksveen (see Table 3). The plots were chosen on a dry to wet gradient and in various vegetation types (see Figure 49). A full description of the plots will be given in the end report.

In the period April-December 2024 there were 8 rounds of measurements in each site (all plots). CO_2 and CH_4 fluxes were measured in light and dark conditions, including a light-response curve.

Measurements will be continued in 2025. The results are expected to become available by the end of 2025.

Figure 48: Location of the GHG measurements (center of the plots) within the two sites

Figure 49: Impression of the measurement locations in Witte Veen (left) and Engbertsdijksveen (right)

Table 3: Overview of the GHG measurement plots

Location	Plot	Plant community characterisation
Witte Veen	1	Molinia, Erica
Witte Veen	2	Erica, Sphagnum
Witte Veen	3	Erica, Sphagnum
Witte Veen	4	Molinia, Erica
Witte Veen	5	Molinia, Sphagnum
Witte Veen	6	Molinia, Sphagnum
Witte Veen	7	Molinia
Witte Veen	8	Molinia
Witte Veen	9	Sphagnum
Witte Veen	10	Sphagnum
Witte Veen	11	Open water
Engbertsdijksveen	1	Molinia, Erica
Engbertsdijksveen	2	Molinia
Engbertsdijksveen	3	Molinia, Erica
Engbertsdijksveen	4	Molinia
Engbertsdijksveen	5	Molinia
Engbertsdijksveen	6	Molinia, Erica
Engbertsdijksveen	7	Molinia
Engbertsdijksveen	8	Molinia, Erica
Engbertsdijksveen	9	Sphagnum
Engbertsdijksveen	10	Sphagnum

5.3.4 Vegetation Monitoring

Vegetation was mapped in 2021 just prior to the start of the project. The vegetation map - shown in Figure 50 - did not cover the whole of the Natura2000 area, but included the peat bog. A more detailed picture of the vegetation map for the peat bog is given in Figure 51. The Dutch vegetation classification has not yet been translated in English, but this will be done later in the project. In addition to the 'normal' vegetation mapping the distribution and abundance of Sphagnum species was mapped, specifically with the LIFE project goals in mind.

The next vegetation mapping will be carried out in 2025 (results to be analysed in 2026).

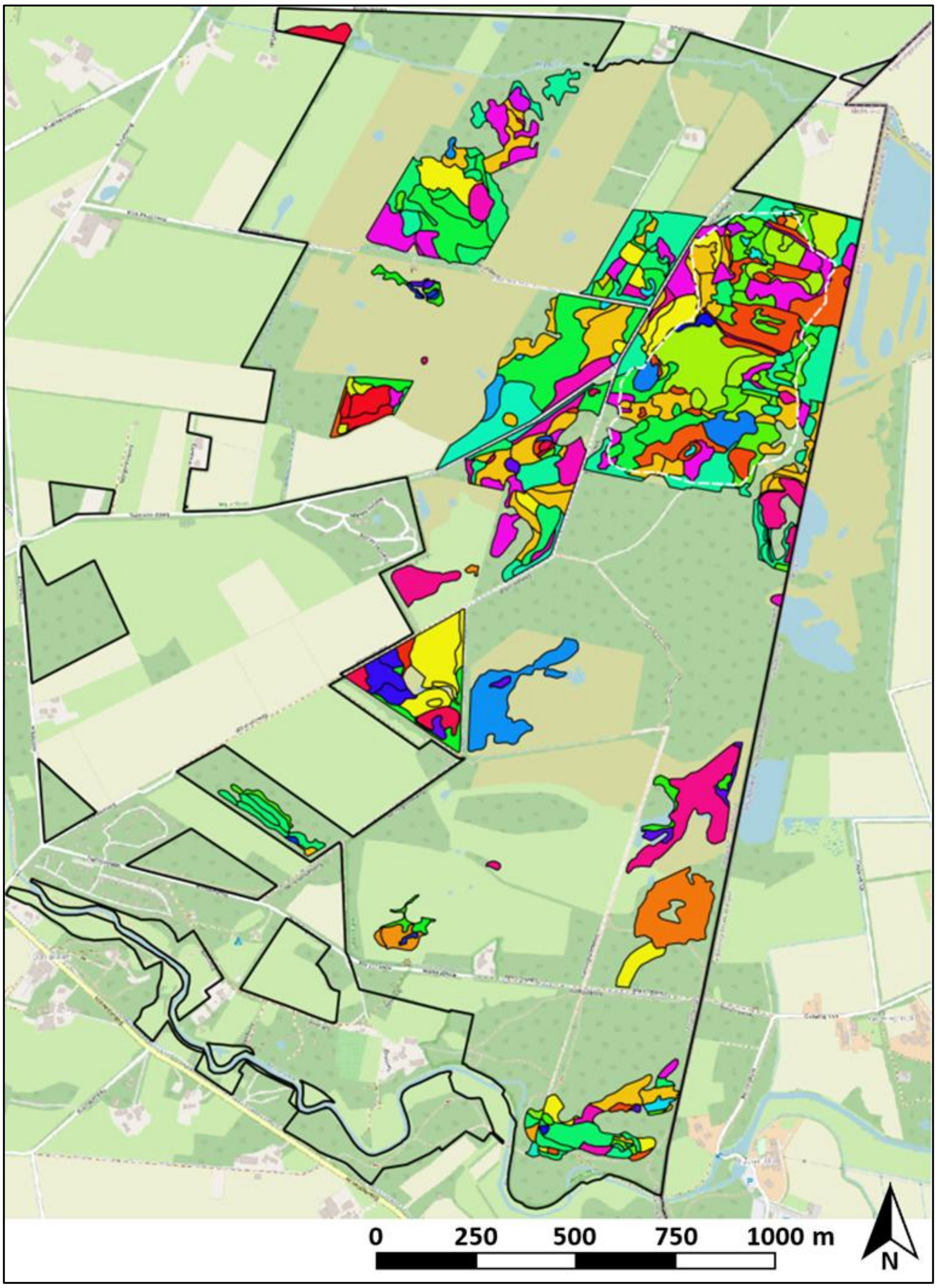

Figure 50: Vegetation mapped in 2021 in the Witte Veen

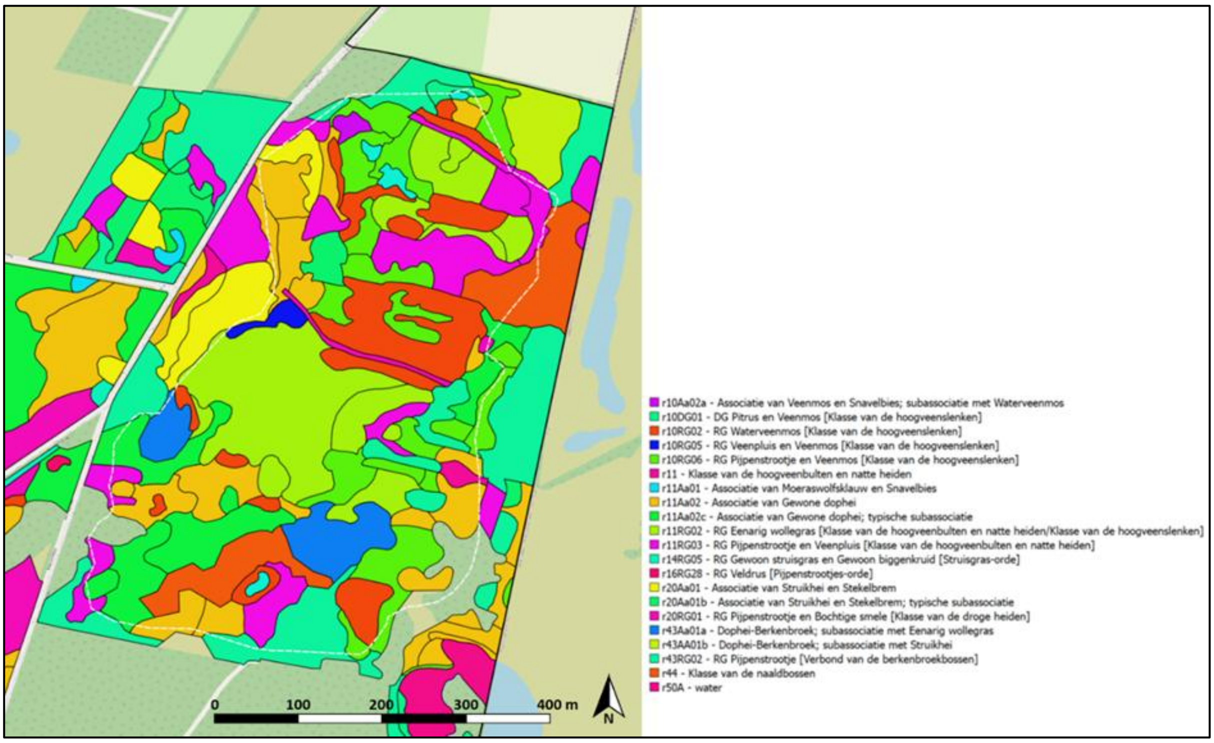

Figure 51: Vegetation map (2021), zoomed in on the peat bog in the Witte Veen

5.4 <u>Discussion and Challenges</u>

In recent years the Netherlands faced various dry spring and/or summer periods, while the autumn of 2023 and the first half of 2024 were relatively wet. This meteorological variation interferes with the hydrological effect of the restoration works.

Thus, to quantify the effect of the restoration works – which mainly took place in 2023 and was finished in march 2024 – a timeseries analysis on the groundwater measurements is needed to filter out meteorological effects. We think that this is possible after a few years. Thus, not before the last year of the LIFE project the main results in terms of hydrological and climate impact of the restoration works will become available.

6 Poland

6.1 Project Site

Project site is located within Natura 2000 site Torfowiska Orawsko-Nowotarskie (Orawa-Nowy Targ Peat Bogs) PLC120003. The area is situated in southern Poland, in Carpathian Mountains (see Figure 52). It is a part of a mid-mountain basin with a flat terrain relief, where, due to unique geological, geomorphological, hydrographic and climatic conditions, raised peat bogs started to form after the last glaciation. Nowadays they occur here in a mosaic with bog woodlands and meadows, shaping a unique landscape of the region for this part of the Carpathians. The peat bogs, elevated in the form of domes a few metres above the surrounding terrain, are built mainly by mosses *Sphagnum* spp. and dwarf shrubs of the family Ericaceae. They are also partly wooded by pines *Pinus* spp. In the past, the peat bogs were cut by a network of ditches and drained, and their area was also significantly reduced as a result of peat exploitation. These destructive activities are no longer carried out today, but their effects (drying, peat degradation, vegetation changes, tree expansion) are still visible today. Project activities are being carried out on two of the peat bogs still preserved today.

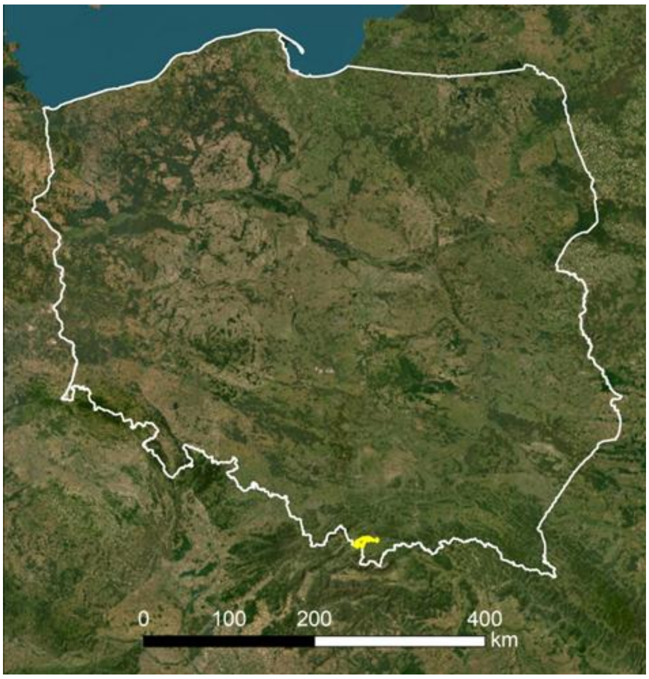

Figure 52: Map of Poland showing the location of the Torfowiska Orawsko-Nowotarskie PLC120003 Natura 2000 site (yellow polygon)

The first is Baligówka (Figure 53, left), one of the largest peat bogs in the region, with an area of ca. 200 ha, and the second is Bór za Lasem Kaczmarka (Figure 53, right), which, as a result of exploitation, has been divided into two parts, currently covering about 40 ha. Both sites are protected inside Natura 2000. A reference function is served by the peat bog Bór na Czerwonem, located in the same Natura 2000 site, which has been protected as a nature reserve since 1925.

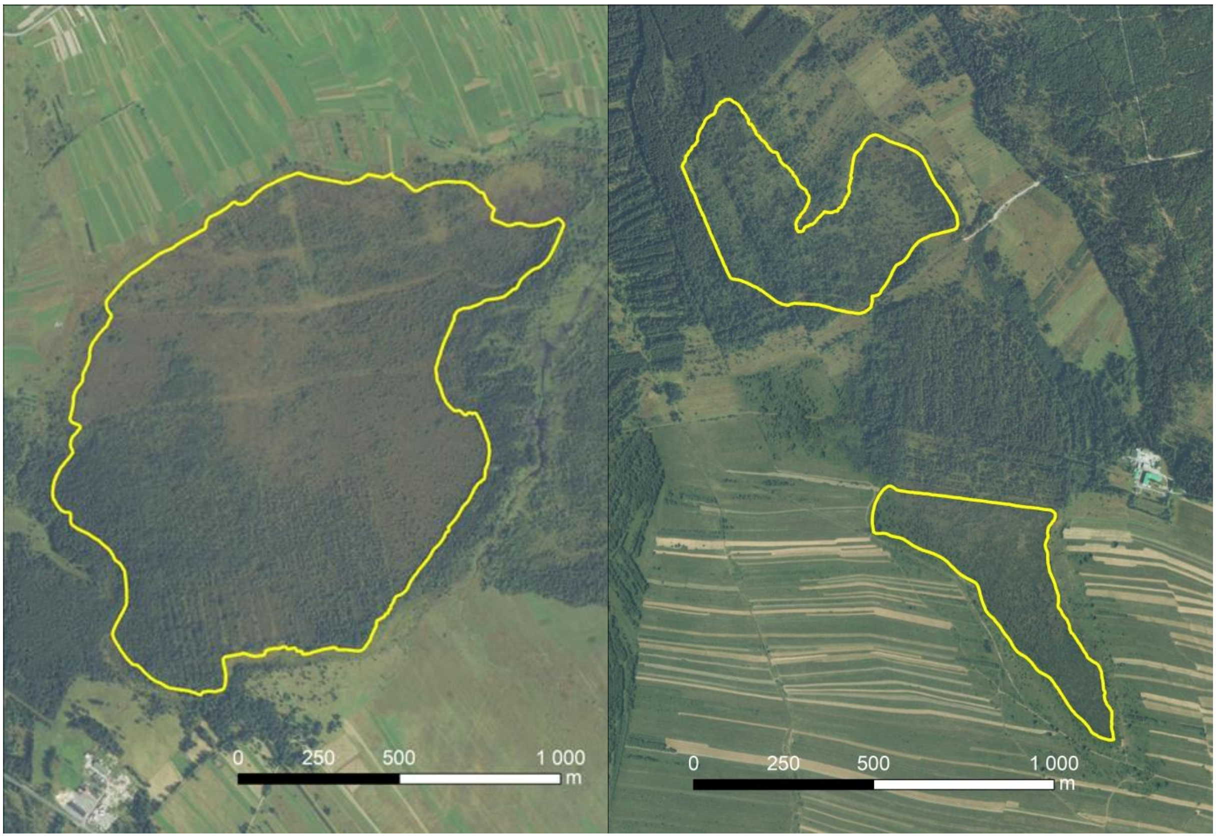

Figure 53: Map showing two project sites: Baligówka (left panel) and Bór za Lasem Kaczmarka (right panel), located within the Torfowiska Orawsko-Nowotarskie PLC120003 Natura 2000 site

6.2 Current State

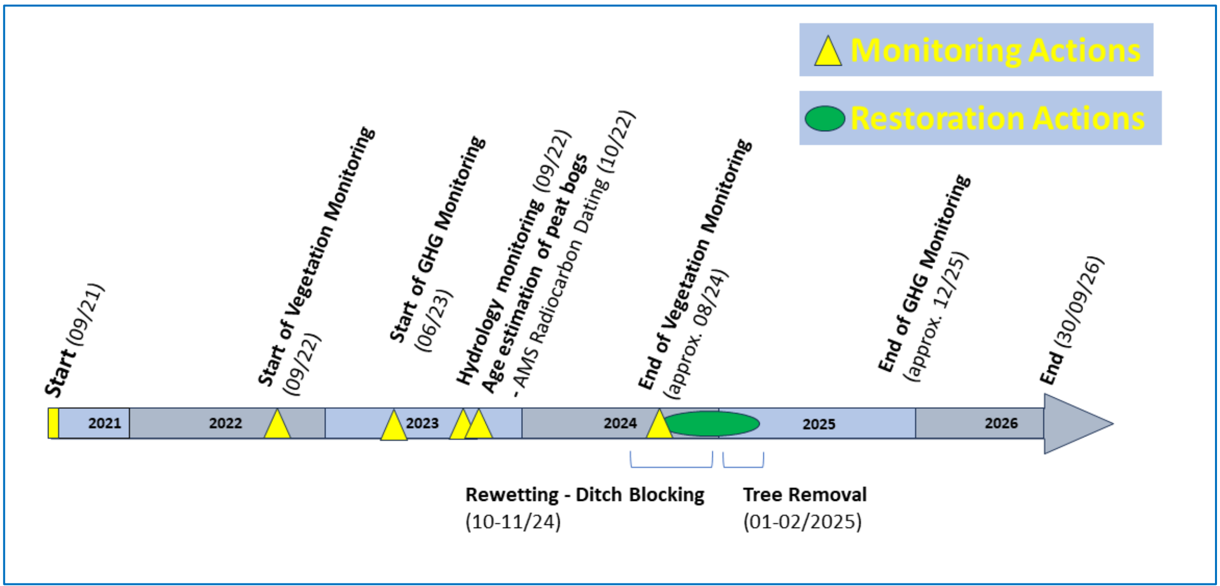

Figure 54: Timeline showing restoration- and monitoring progress for Poland

6.3 Results

6.3.1 Hydrological Monitoring

The water level in the peat has been monitored since autumn 2023 using automatic recorders in piezometers. The data for the hydrological year 2024 suggest that the water regime of these bogs is somewhat different from the typical water regime of raised bogs in the lowlands - in the well-preserved parts the water level is very stable, not showing the seasonal variability typical of bogs in the lowlands. The effects of ditch drainage are expressed in breaches of this stability and periodic drops in water levels. The response to precipitation varies in different parts of the peatland. Permanent drainage affects the marginal parts of peatlands, especially at edges shaped by peat extraction from the banks. Detailed results are graphically shown below (Figure 55, Figure 56, Figure 57):

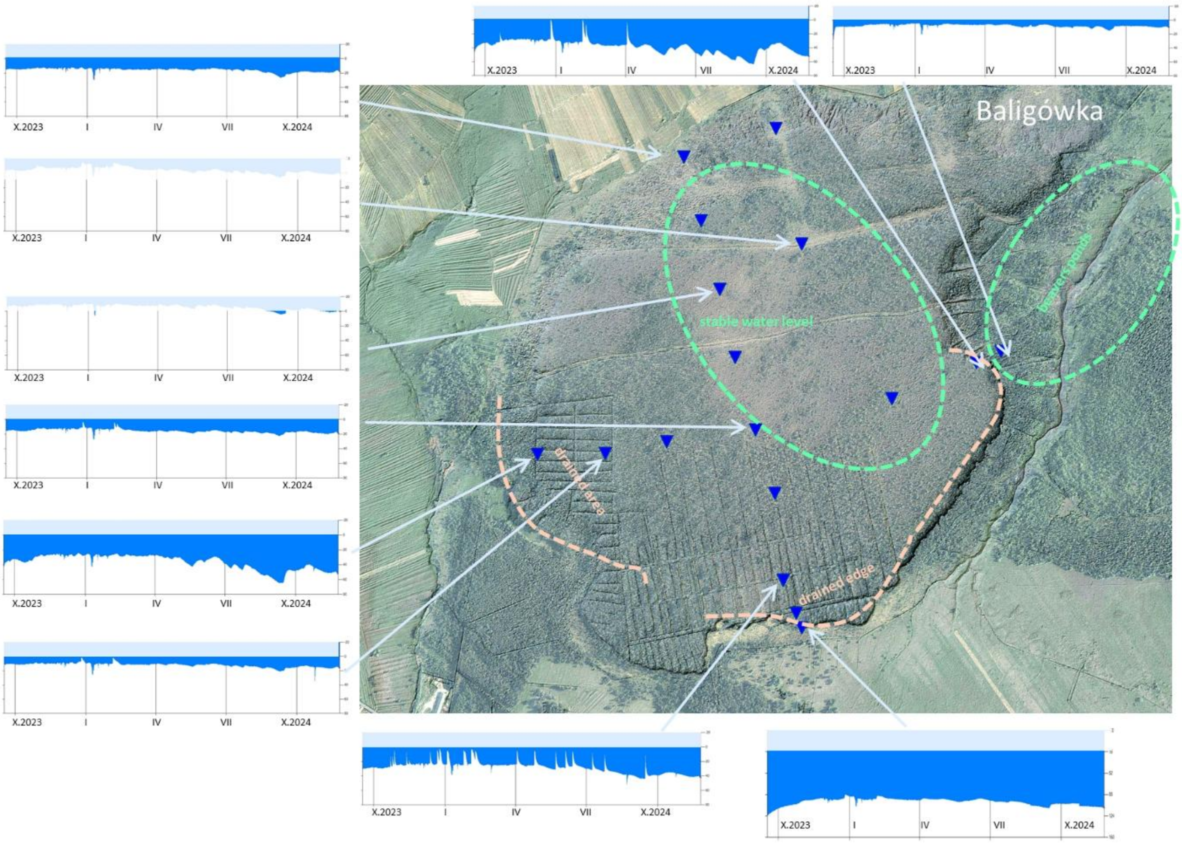

Figure 55: Hydrological measurements: Baligówka peatland

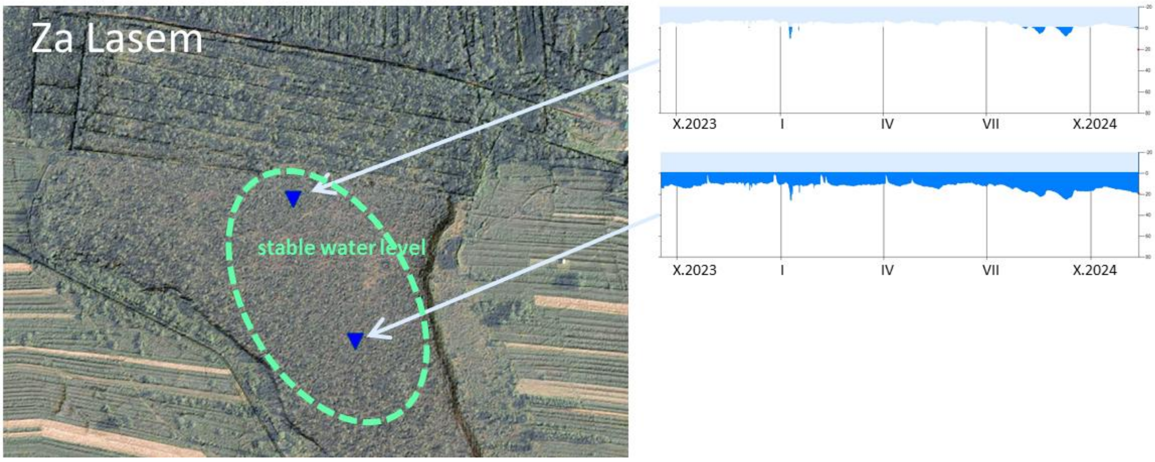

Figure 56: Hydrological measurements: Bór za Lasem peatland

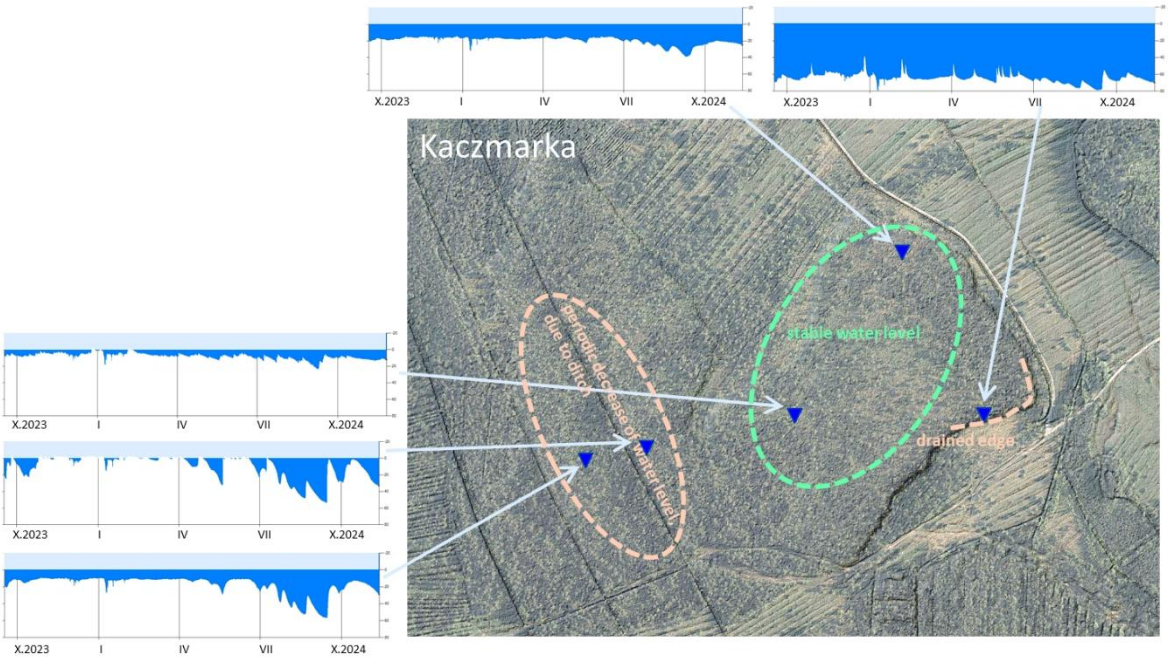

Figure 57: Hydrological measurements: Las Kaczmarka peatland

6.3.2 Environmental Parameters

At the three sites, where the GHG-measurements were conducted, the following environmental parameters were measured: Air temperature [°C] (Device: Meter "Atmos 14 Gen 2"), water temperature [°C] (Device: Meter "Hydros 21"), soil temperature [°C] and soil water content [m³/m³] (Device: Meter "Teros 11") in 5-10 cm. Also, the photosynthetically active radiation (PAR) is measured at all sites, but is not included in this report, as this parameter is to be interpreted together with the GHG-measurements, which will be part of the 3rd Monitoring Report. Environmental indices are showing similar patterns of changes throughout the time at all three sites. Also mean values of measured parameters are similar across all sites. All environmental factors will be analysed in detail at later stages of project implementation, when long-term GHG data will be available.

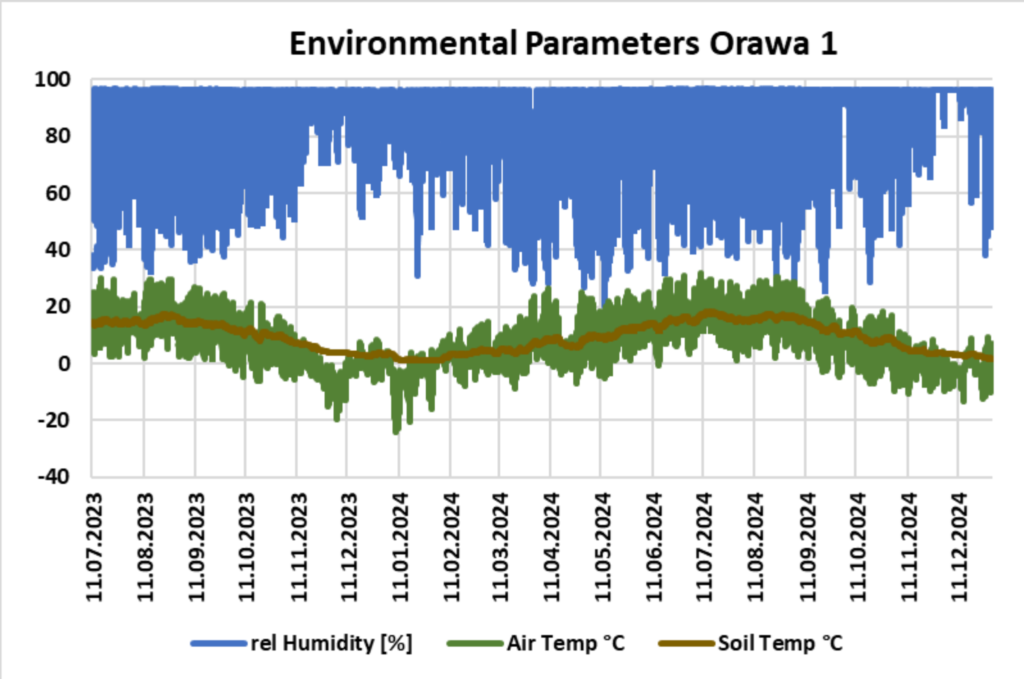

Figure 58: Environmental parameters measured in Baligówka (Orawa 1)

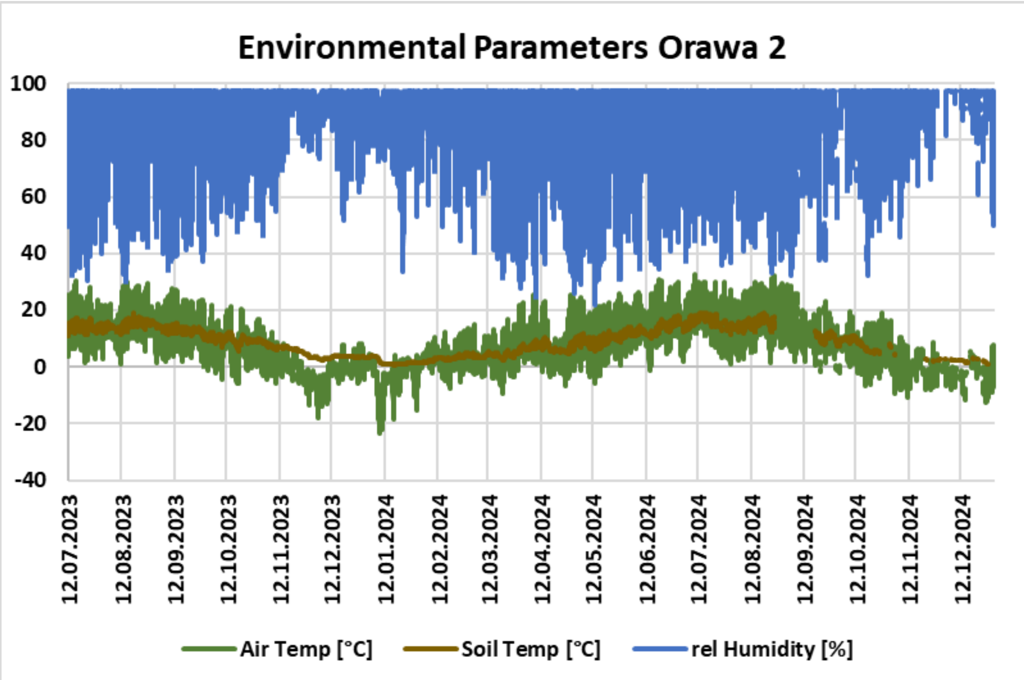

Figure 59: Environmental parameters measured in Puścizna Mała (Orawa 2)

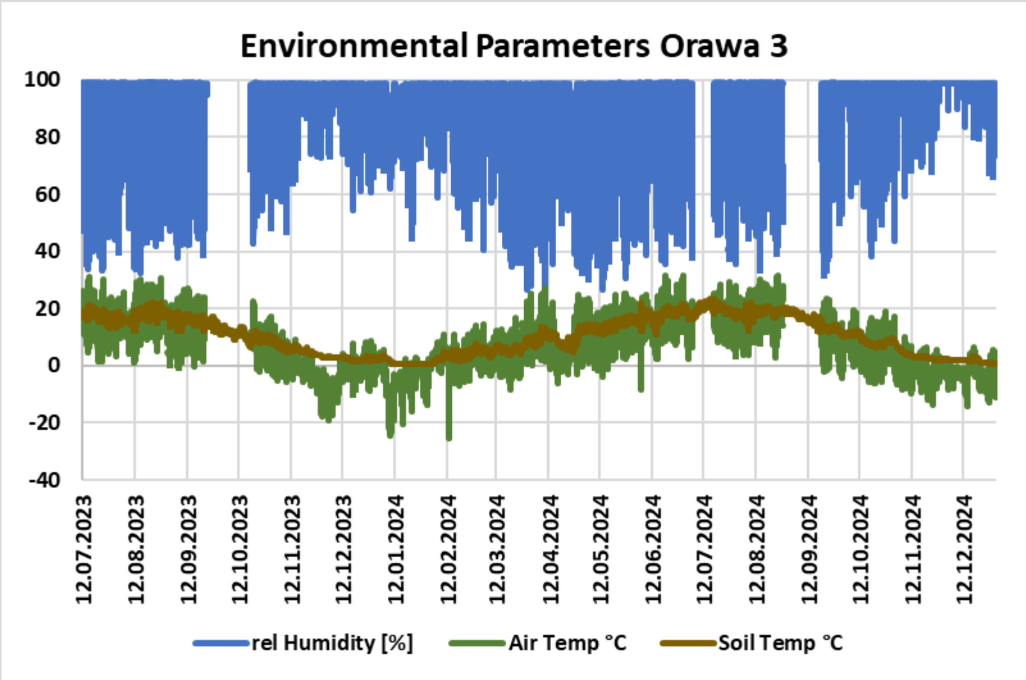

Figure 60: Environmental parameters measured in Bór na Czerwonem (Orawa 3)

6.3.3 GHG-Measurements

Greenhouse gas measurements has been started in June 2023 and are continued to be performed with the same methodology and at the same locations. They are conducted at three monitoring sites, all of them located in the Natura 2000 site Torfowiska Orawsko-Nowotarskie (see Figure 61). Site Orawa1 (Baligówka) is located in the middle of the large raised-bog dome. The vegetation on monitoring plot consists mainly of *Sphagnum* sp., *Vaccinium* sp., *Rhododendron tomentosum* (see also Figure 63). This dome was also covered by the Scots pines *Pinus sylvestris,* but they have been largely removed in 2023, as a part of restoration measures in another project. This raised-bog has been intensively drained in the past. During autumn 2024 (October-November) the Baligówka dome, including the surroundings of the Orawa1 measurement site, was restored by extensive rewetting measures (151 dams on draining ditches, blocking water outflow) implemented within LIFE MultiPeat project. Site Orawa2 (Puścizna Mała) is located on a nearby, smaller raised-bog dome. This plot serves as a ‘natural state’ reference site, as it has not been subject to intensive drainage (though some ditches and peat digging were implemented nearby). The vegetation structure is similar to the Orawa1 plot, with some scattered Scots pines. Orawa3 (Bór na Czerwonem) site is located at the nature reserve. It serves as a ‘restored in the past’ reference site, because it has been partly re-wetted around 10 years ago. The vegetation structure is similar to the Orawa1 and Orawa2 plots, with *Sphagnum* sp., and *Vaccinium* sp., as dominant species, but with lower coverage of Scots pines. At the beginning of 2024 restoration measures has been performed at Bór na Czerwonem reserve (as a part of another project), with tree removal and ditch blocking actions implemented, which may have impact on the GHG results from that site.

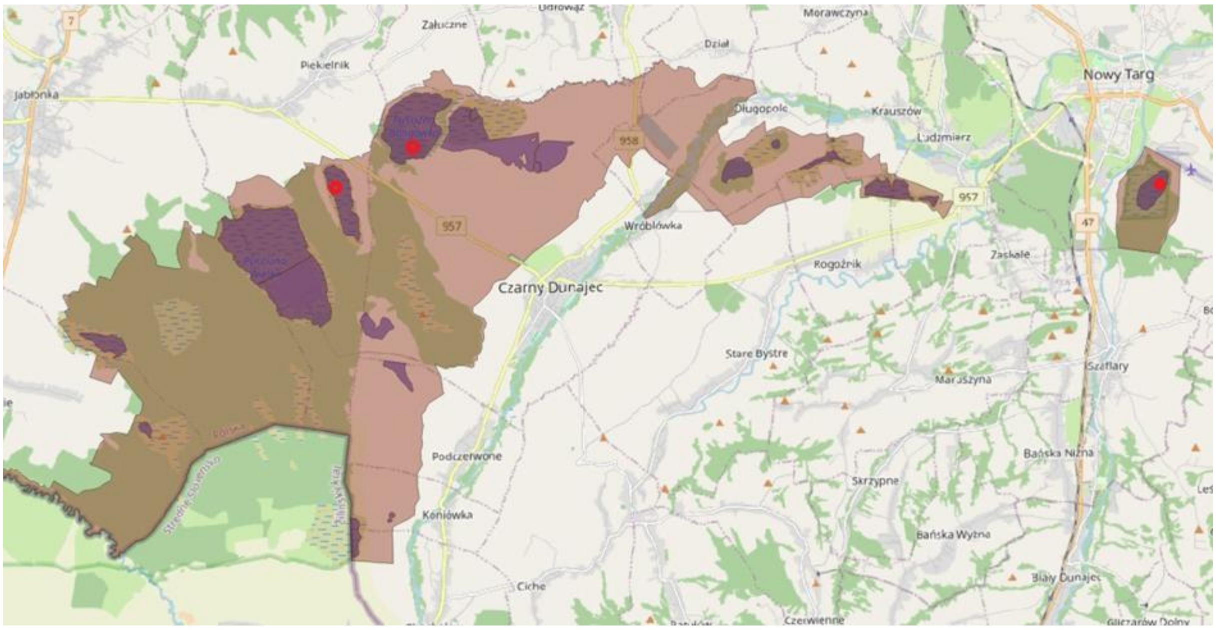

Figure 61: Location of three GHG monitoring plots (red dots: middle – Orawa 1, left – Orawa 2, right – Orawa 3) in polish project site. Pinkish area shows boundaries of Natura 2000 site, and violet polygons show raised bogs domes

Figure 62: GHG measurement at Puscizna Mała (Orawa 2) site, June 2024

Figure 63: Changes in vegetation structure inside one of the frames in which GHG monitoring is performed: Baligówka (Orawa1) site: photos are from March, July, October 2024

Currently, the data of the first measuring year is processed and ecosystem respiration (RECO), gross primary product (GPP) and net ecosystem exchange (NEE) are modelled. For a more detailed description of the methods used, see LIFE Multi Peat (2024). As an example,

Figure 64 shows preliminary results for site Orawa 1. As the model parameters still need a better fit, the data is only preliminary and will be refined until the end of the project.

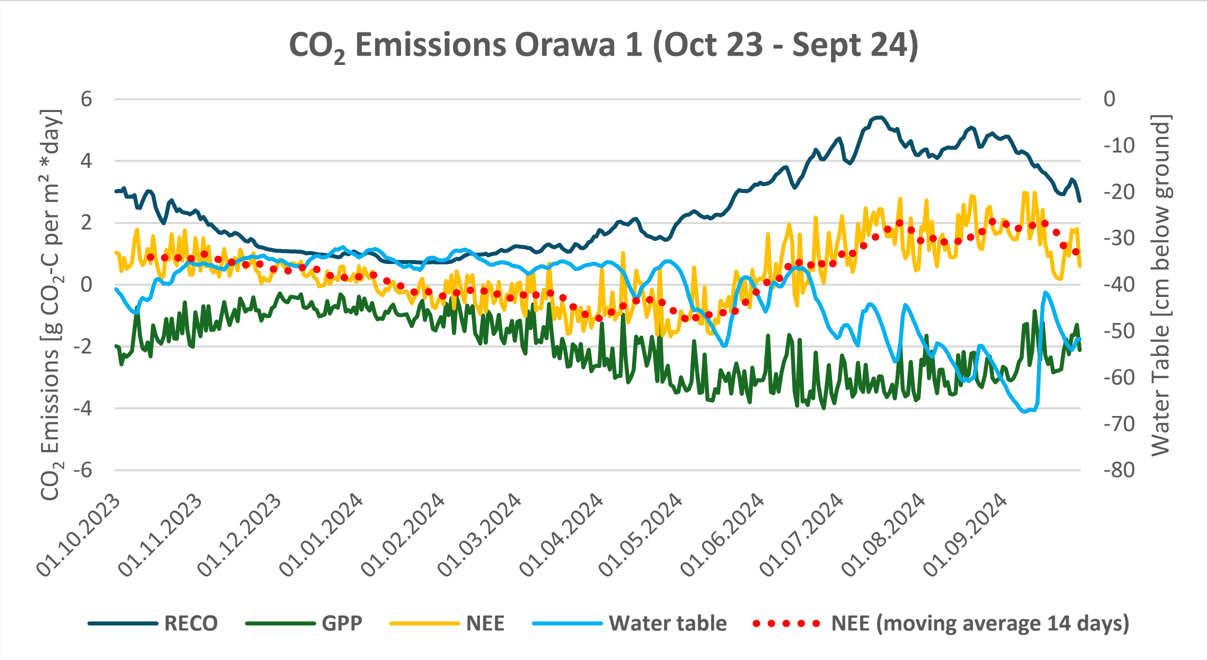

Figure 64: Preliminary results for CO_2 in the first measuring year at Orawa 1 (Baligówka). [not to be used for citation]

6.3.4 <u>Vegetation Monitoring</u>

In 2024 all 43 vegetation monitoring plots surveyed at the begining of the project on Baligówka bog, were re-surveyed again. The results however do not track yet the impact of any project interventions, as first conservation measurements were implemented in October 2024, after completing 2024 vegetation monitoring. However, the results show impact of removing trees from Baligówka bog, implemented by 2023 by regional nature conservation authority (within another project). Examples of changes are presented by photos (Figure 65):

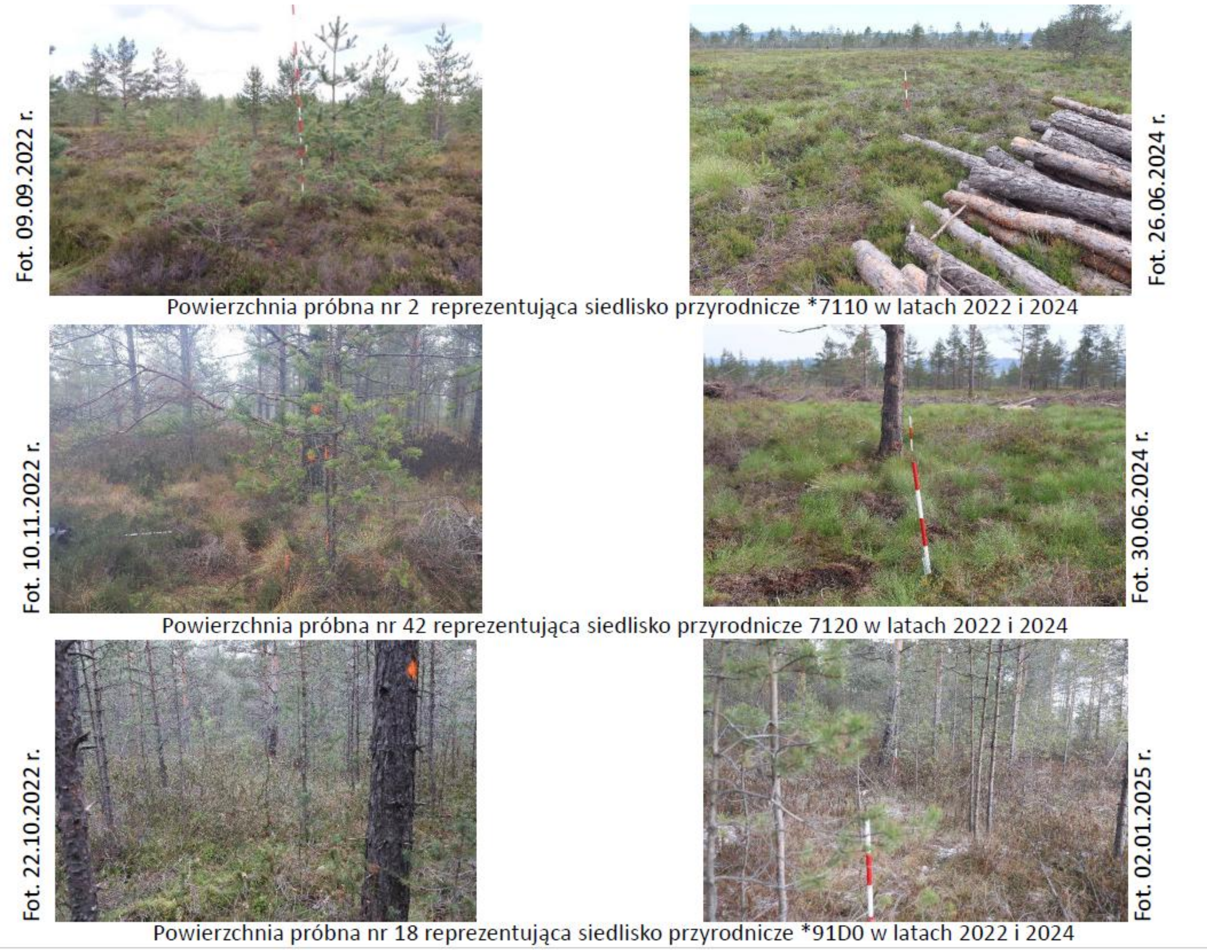

Figure 65: Changes in vegetation structure at Baligówka peatland in 2022 (left pictures) and 2024 (right), showing the impact of tree removal (performed by Regional Directorate for Environmental Protection within another project) on the vegetation

Despite intentional trees removal, coverage of “a” layer (trees) remained stable (7110 habitat) or increased (7120, 91D0 habitats). Coverage of ”b” layer (shrubs) decreased. Coverage of herb layer remained stable in habitat 7110, slightly increased in habitat 7120, but decreased in habitat 91D0. Moss layer increased (slightly in 7110, 91D0, more significantly in 7120).

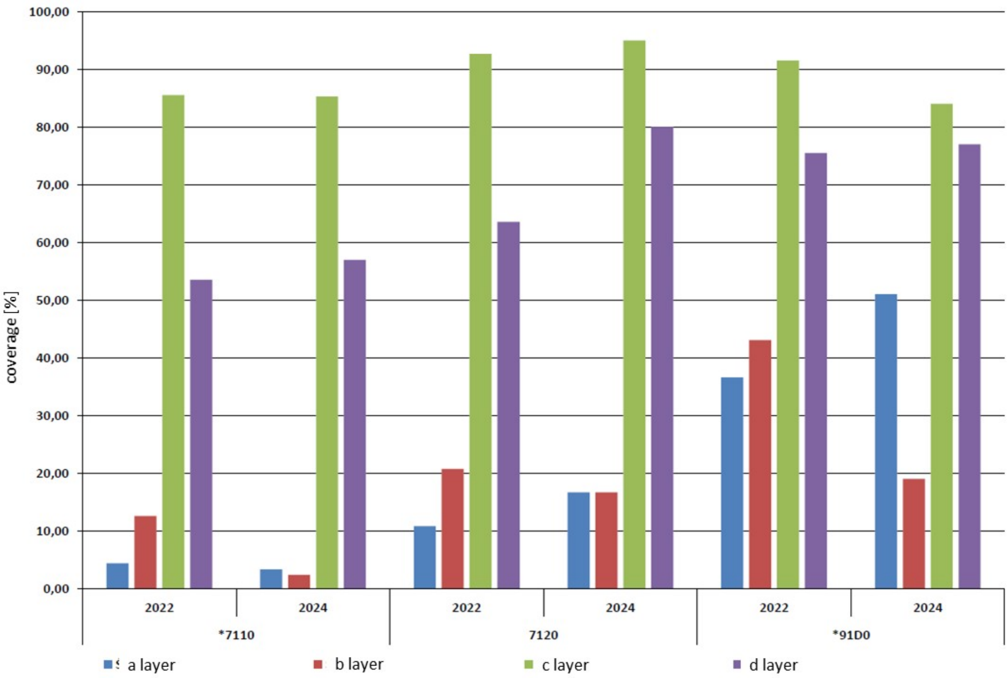

Figure 66 Changes in different types of vegetation layers coverage at Baligówka peatland in 2022 and 2024. A – trees, B – shrubs, C – herbs, D – mosses

Detailed changes concerning particular species are shown below:

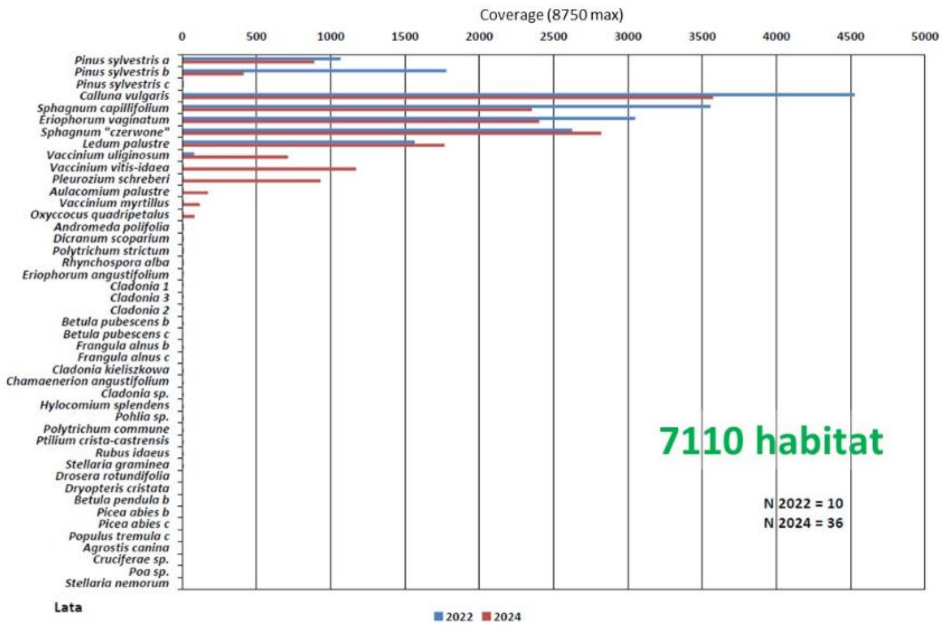

Figure 67: Changes in the coverage of particular species at monitored sites for the 7110 habitat. Blue bars: 2022, red bars: 2024

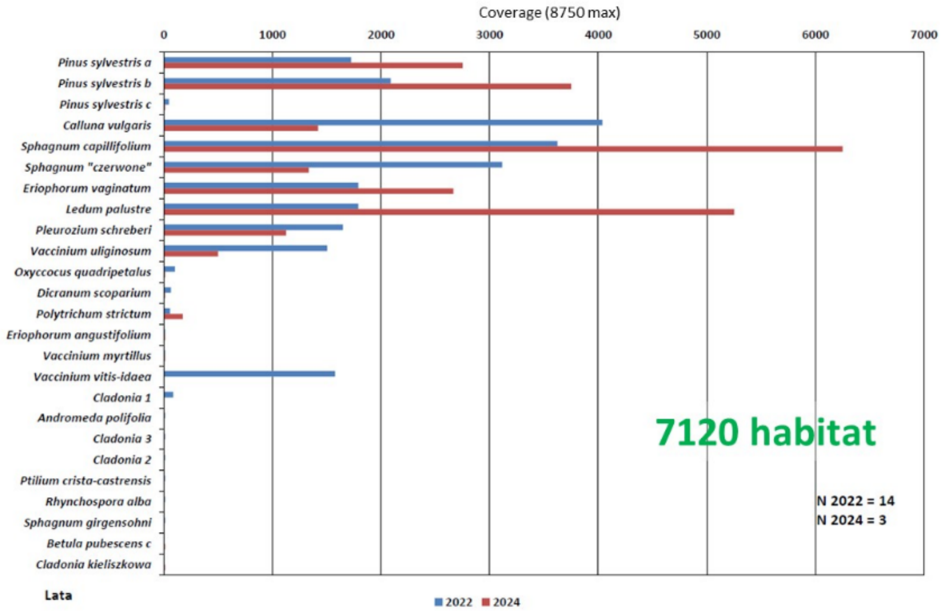

Figure 68: Changes in the coverage of particular species at monitored sites for the 7120 habitat. Blue bars: 2022, red bars: 2024

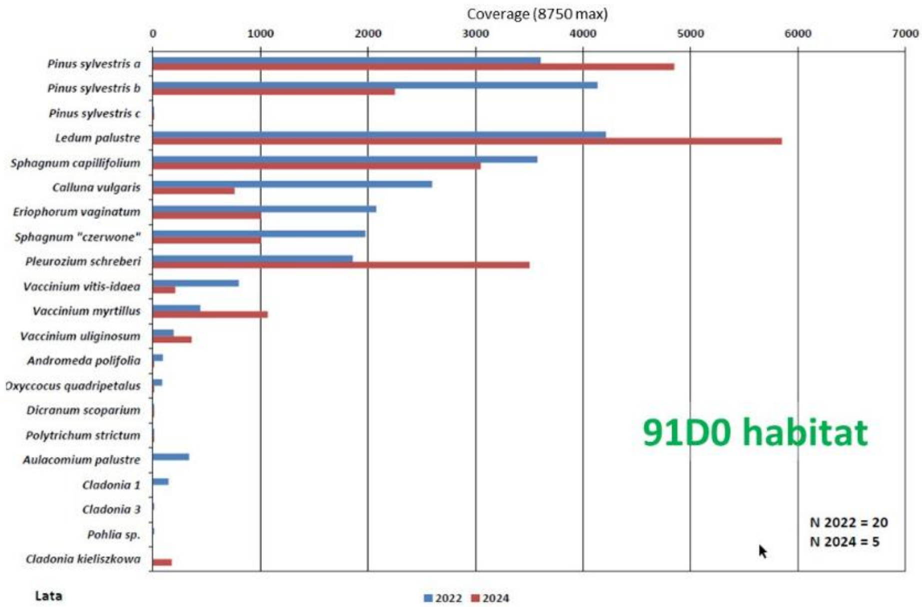

Figure 69: Changes in the coverage of particular species at monitored sites for the 91D0 habitat. Blue bars: 2022, red bars: 2024

Generally, *Ledum palustre, Vaccinium myrtillus, Vaccinium uliginosum* and *Pleurosium schreberi* are the winners, whereas the coverage of *Pinus sylvestris* and *Calluna vulgaris*, but also *Sphagnum capilifolium* and “red” *Sphagnum* group decreased.

6.4 *Discussion and Challenges*

So far, no major problems or methodological challenges have been encountered during the monitoring activities at polish project site. The data collected in 2022, 2023 and 2024 constitute part of the baseline monitoring information. All planned restoration measures have been implemented in 2024/25: ditch blocking in Oct-Nov 24, and tree removal in Dec 24-Jan25. Therefore, continuing monitoring in 2025-2026 will allow to assess the impact of restoration measures on the environmental parameters of peatlands at project sites.

7 References

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