LIFE Multi Peat

LIFE20 CCM/DE/001802

(January 2023 – December 2023)

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Content

1 Introduction

The LIFE Multi Peat project aims to reduce greenhouse gas emissions and promote biodiversity through peatland management measures that 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 second monitoring report covers the period 01.01.2023-31.12.2023. The following chapter (Methods) describes the general approaches for monitoring the respective metric. In the respective sub-chapter of each country, any deviations from the general approach are described and justified, the progress made in implementing the continuous and spot measurements is presented and the preliminary measurement results are shown.

2 Methods

This section presents methods that are used to monitor the project areas and were not included in the first annual monitoring report.

2.1 Carbon Stocks

The determination of carbon stocks is crucial for the subsequent evaluation of the monitoring results. The below ground carbon stocks are the maximum quantity of carbon that could be depleted, i.e. oxidised to CO_2 and emitted to the atmosphere. The above ground carbon stock, as a reference date, serves as a benchmark for comparisons to derive (potential) carbon sequestration rates of the biomass or to calculate losses due to the removal of woody species.

The total Carbon content of will be calculated as the sum of below ground carbon and above ground carbon.

$$\boldsymbol{C_t = C_b + C_a}$$

C_t = Total Carbon
C_b = Carbon below ground (soil)
C_a = Carbon above ground (biomass/trees)

2.1.1 Carbon stocks (below ground)

For the methods for the calculation of the below ground carbon stock, please see *Annual Monitoring Report 1 (Life Multi Peat, 2023)*.

2.1.2 Carbon stock and sequestration (above ground)

The above ground carbon stocks will be calculated for afforested areas, using formulas according to IPCC (2003). Therefore, monitoring plots will be installed at each site. Every monitoring plot has 10 x 10 m (100 m²). In total, at least three of those plots will be set up. They are marked with poles and the exact GPS-coordinates must be noted.

In the case of different forest types (e.g. one area dominated by pines and a second area by alders) three of those reference plots will be installed in each forest type. The area covered by each forest type must be considered and the total biomass calculated separately.

Sum of Carbon stocks of areas with different forest types

$$\sum_{i}^{n} Ca_i = Ca_1 + Ca_2 + \cdots + Ca_n$$

Ca_i = Sum of carbon stock of all areas with different forest types

Ca_1 = Carbon stock of area 1 (forest type 1)

Ca_2 = Carbon stock of area 2 (forest type 2)

These characteristics are enough to estimate the total biomass and when measured at different points of time, enough to estimate the change in above ground carbon stock. Aboveground dead wood and herbal species will not be considered.

<u>Total Carbon Stock</u>

$$\boldsymbol{C = [VxDxBEF]x\,(1 + R)xCF}$$

C = total carbon in biomass
V = merchantable volume, $m^3\ ha^{-1}$
D = basic wood density, tons m^{-3} merchantable volume
BEF = biomass expansion factor for conversion of merchantable volume to aboveground tree biomass, dimensionless.
R = root-to-shoot ratio, dimensionless
CF = carbon fraction of dry matter (default = 0.5), tons C

<u>The merchantable volume</u> *V* will be approximated using the *Denzin*-formula:

$$\boldsymbol{V = \left(\frac{Dbh^2}{1000}\right) + \left(\frac{Dbh^2}{1000}\right) \times (h - NH) \times Volumecorrectionpercent}$$

Dbh = Diameter at breast height
h = height of the tree
NH = Normal height
(source: https://www.forst-rast.de/pflrechner05.html)

<u>Change in Carbon Stock above Ground</u>

This is an optional monitoring action, as a possibility to set up a longterm monitoring of the woody vegetation, but it is not compulsory. In representative tree stands, permanent circular monitoring plots can be installed, with a wooden stake marking the middlepoint. Every tree inside a circle with the radius of 12,62 m monitoring plot (500 m²), with a diameter at breast height (=130 cm above ground) of more than 7 cm will be measured and marked with permanent chalk. Every tree gets a number and the corresponding species name, height and Dbh will be noted. The repetition of the measurement will be realized every five years.

$$\Delta CFF_{LB} = \frac{(C_{t_2} - C_{t_1})}{(t_2 - t_1)} * 20$$

ΔCFF_{LB} = annual change in carbon stocks in living biomass (includes above- and belowground biomass in forest land remaining forest land, tons C ha^{-1} yr^{-1}

Ct_2 = total carbon in biomass calculated at time t_2, tons C

Ct_1 = total carbon in biomass calculated at time t_1, tons C

2.2 GHG-Measurements

As part of the GHG Monitoring and within the project duration we agreed to follow a hydro-sequence-like approach with three sites per partner country representing different initial or development states: 1.) Reference site, 2.) Rewetted site and 3.) Restored site. All sites should have similar site conditions and vegetation inventories. The reference site refers to drained conditions with no rewetting, the rewetted site illustrate the effect of the rewetting activities and the restored site, which have at least for 5 to 10 years higher water levels, demonstrate the future conditions in the next years. All three sites together help to understand the GHG-dynamic at least for the most important habitats and to assess the effect of our rewetting activities.

In all partner countries we use the closed chamber method to measure the GHG fluxes. In general, the setup consists of a collar or frame, inserted in the soil permanently before the measurements start, and a chamber, equipped at least with a fan, a temperature sensor and sample ports for capture the chamber air. For estimating the annual budgets of each site, we use different chambers and modes: 1.) transparent chambers for measuring the net ecosystem exchange (NEE), 2.) opaque chambers for measuring the ecosystem respiration (RECO) and 3.) transparent chambers with two shading levels (25% and 50% reduction of full light) to simulate different radiation conditions. The chambers are usually connected to an Infrared Gas Analyzer, recording the CO_2 – concentration and partly the methane concentration. In some cases, the concentrations of methane and nitrous oxide will be measured in the laboratory by a gas chromatograph. The closure time of each chamber depends on the site and the season but will be minimized for optimal results. The dimensions and additional features of the chambers will be described in the national subchapters.

For future modelling applications we also install additional loggers close to the measurement sites to record important environmental parameters like air temperature and precipitation, photosynthetic active radiation, soil moisture and soil temperature and water level.

Results of the GHG-measurements are not part of the 2nd Monitoring Report, because of missing or sufficient validated flux data for at least a full year.

2.3 Remote Sensing (UAV or Satellite Imagery)

Remote sensing is realised once before starting the restoration actions and once after having implemented all restoration actions, as a control. Preferably drone images, if not possible satellite images, will therefore be analysed. To see, if restoration actions successfully match with the hydrological and botanical aims, the type and condition of the vegetation can be taken as an indicator. Those methods, commonly used in precision agriculture, are typically based on the calculation of near-infrared (NIR) and short-wave infrared (SWIR) spectral bands. Five indices (see below) can be applied if appropriate, with the NDVI as minimum standard, the others optional. The actual calculation of the indices is realised using the software QGIS.

1. **NDVI**: Normalized Difference Vegetation Index (plant activity)

    (NIR-RED) / (NIR+RED)

    NDVI is a measure of the state of plant health based on how the plant reflects light at certain frequencies (some waves are absorbed, and others are reflected). Chlorophyll (a health indicator) strongly absorbs visible light, and the cellular structure of the leaves strongly reflects near-infrared light. When the plant becomes dehydrated, sick, afflicted with disease, etc., the spongy layer deteriorates, and the plant absorbs more of the near-infrared light, rather than reflecting it. Thus, observing how NIR changes compared to red light provides an accurate indication of the presence of chlorophyll, which correlates with plant health.

2. **NDMI**: Normalized Difference Moisture Index (plant water stress)

    (SWIR1610 – NIR) / (SWIR1610 + NIR)

    Highlights differences in water content of leaves.

3. **NDWI**: Normalized Difference Water Index (locates changes in water content of water bodies)

    (Green - NIR) / (Green + NIR)

    Used to highlight open water features in a satellite image, allowing a water body to "stand out" against the soil and vegetation. The NDWI index effectively measures moisture content and allows to detect subtle changes in water content of the water bodies.

4. **MNDWI**: Modified Normalized Difference Water Index (searches water bodies, useful to see waterlogging, presence/absence of surface water)

    (Green - SWIR1610) / (Green + SWIR1610)

    Used to enhance open water features while efficiently suppressing and even removing built-up land noise as well as vegetation and soil noise. MNDWI is more suitable for enhancing and extracting water information for a water region with a background dominated by built-up land areas.

5. **NMDI**: Normalized multi-band drought index (locates water content within plants)

    (NIR - (SWIR1610 - SWIR2190) / (NIR + (SWIR1610 - SWIR2190))

    Used for monitoring soil and vegetation moisture.

Further, high-resolution orthophotos and high-resolution digital elevation models can be additional products of the drone method.

3 Belgium

3.1 Project Site

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

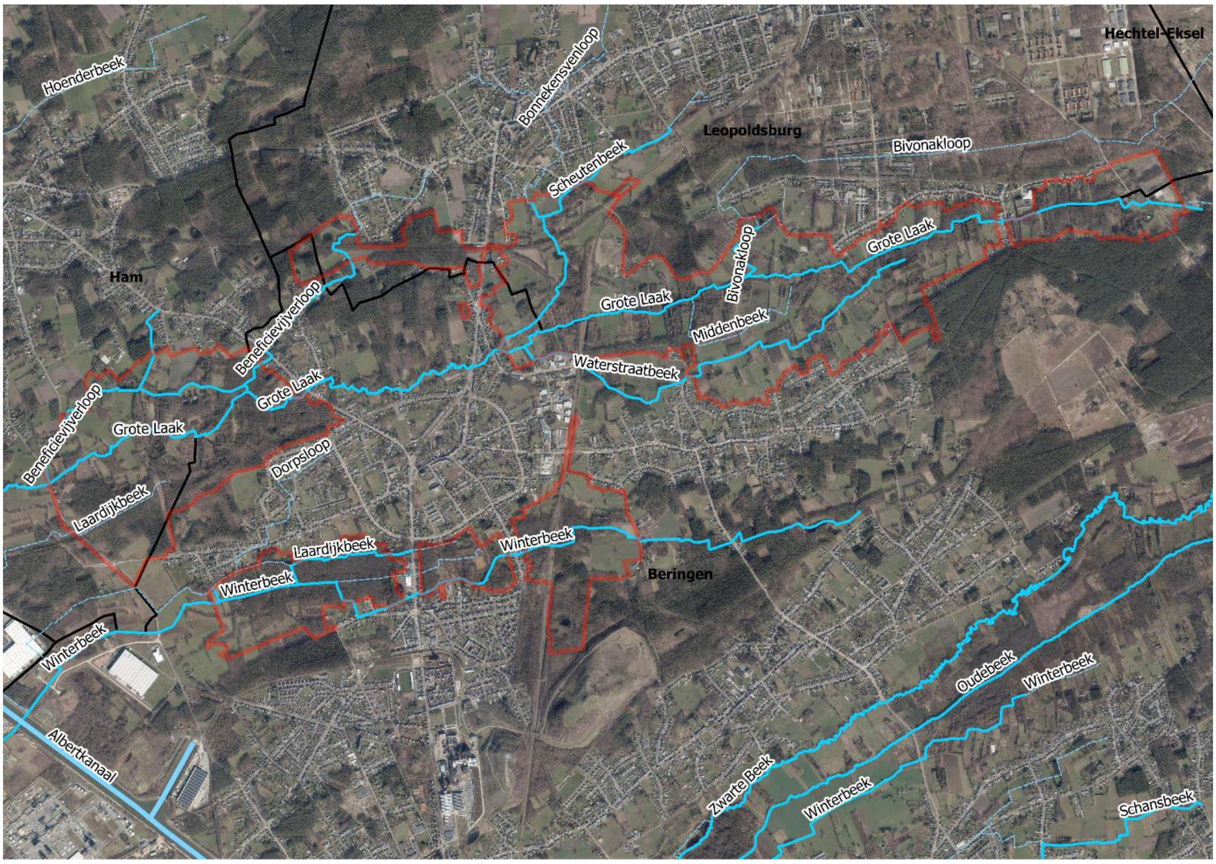

Figure 1: Map of the Belgium project site in the Grote Beek and the Kleine Beek creek valleys.

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.

3.2 Methods-Adaptations

UAV: A monthly timeseries of satellite images will be used, instead of drone imagery, because it is impossible to fly with drones over the area, due to restrictions by the adjacent military area. For more information, see the Joint monitoring report (LIFE Multi Peat, 2023).

GHG: Closed chamber measurements will only take place during one year of measurements instead of three. For more information, see the Joint monitoring report (LIFE Multi Peat, 2023).

Carbon stocks: changes in carbon stock will not be estimated.

3.3 Current State

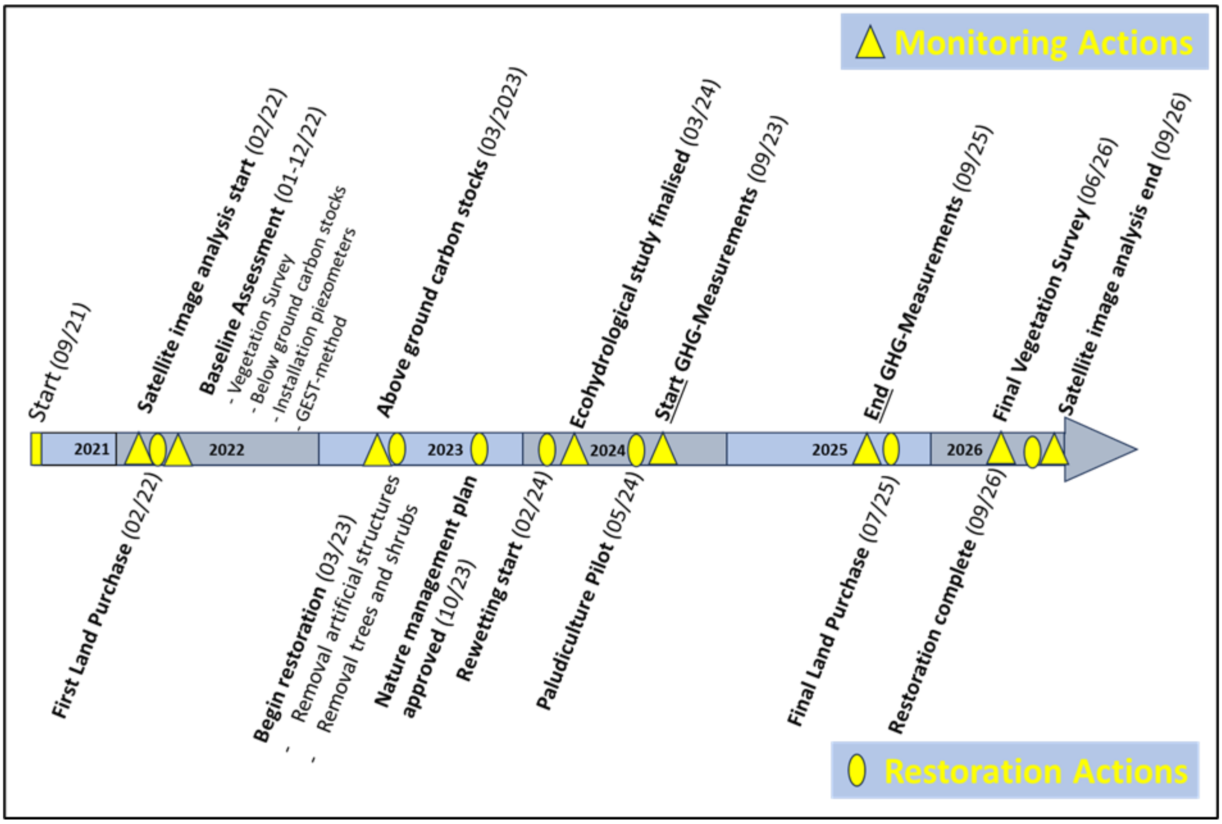

Figure 2: Timeline showing restoration- and monitoring progress for Belgium.

3.4 Results

3.4.1 Carbon Stocks

The total carbon stocks of the project site sum up to 141.119 tons. The below ground carbon stock is the major one.

For below ground carbon stocks, see the Joint monitoring report (Life Multi Peat, 2023). We finetuned our results with some adapted bulk densities and carbon fractions which are more applicable for the area. With a bulk density of 0.32 g/cm³ and a carbon fraction of 34.8% we estimated a total carbon content of 119.028 tC within the peat layer.

Above ground carbon stocks were estimated in March 2023. In total 30 plots of 10*10m were measured according to the methods explained in chapter 2.1.2. Tree heights were measured with a laser and diameters at breast height were calculated form the circumferences at breast height. The numbers we obtained were finetuned and aligned with the calculations used by other partners so that these results are comparable. Tree species consisted of (in decreasing order of occurrence): *Alnus, Quercus, Populus; Salix, Pinus, Betula, Platanus, Prunus, Sambucus, Picea, Carpinus, Sorbus and Corylus*. Species like *Prunus (serotine), Picea* and partly *Pinus* will be removed during the project, since these are non-natural or even invasive.

For the Valley of the Grote Beek we estimated 22.091 tons of carbon stored within trees (Table 1). This is far less than the below ground carbon stocks, but still a significant amount of carbon. Whilst the area is mainly consisting out of forest (alder swamp), it is the peat layer itself that has the most potential for carbon storage.

Table 1: Above ground carbon stocks in different forest types in the valley of Grote Beek.

Forest type	Average Above ground carbon stock (t C/ha)	Surface (ha)	Carbon (t)
Type 1	231,15	11,45	2646,12
Type 2	73,78	20,34	1500,41
Type 3	200,01	3,69	738,59
Type 4	0,82	8,71	7,18
Type 5	237,69	27,23	6472,75
Type 6	221,39	14,16	3135,99
Type 7	84,52	21,01	1775,92
Type 8	121,89	27,77	3385,01
Type 9	0,79	2,61	2,06
Type 10	111,76	1,61	179,57
Type 11	129,45	6,89	892,31
Type 12	32,68	5,64	184,28
Type 13	109,13	10,73	1170,82
Total	**136,50**	**161,84**	**22091,01**

The total amount of carbon stored aboveground is estimated per forest type, as to be seen in Figure 3.

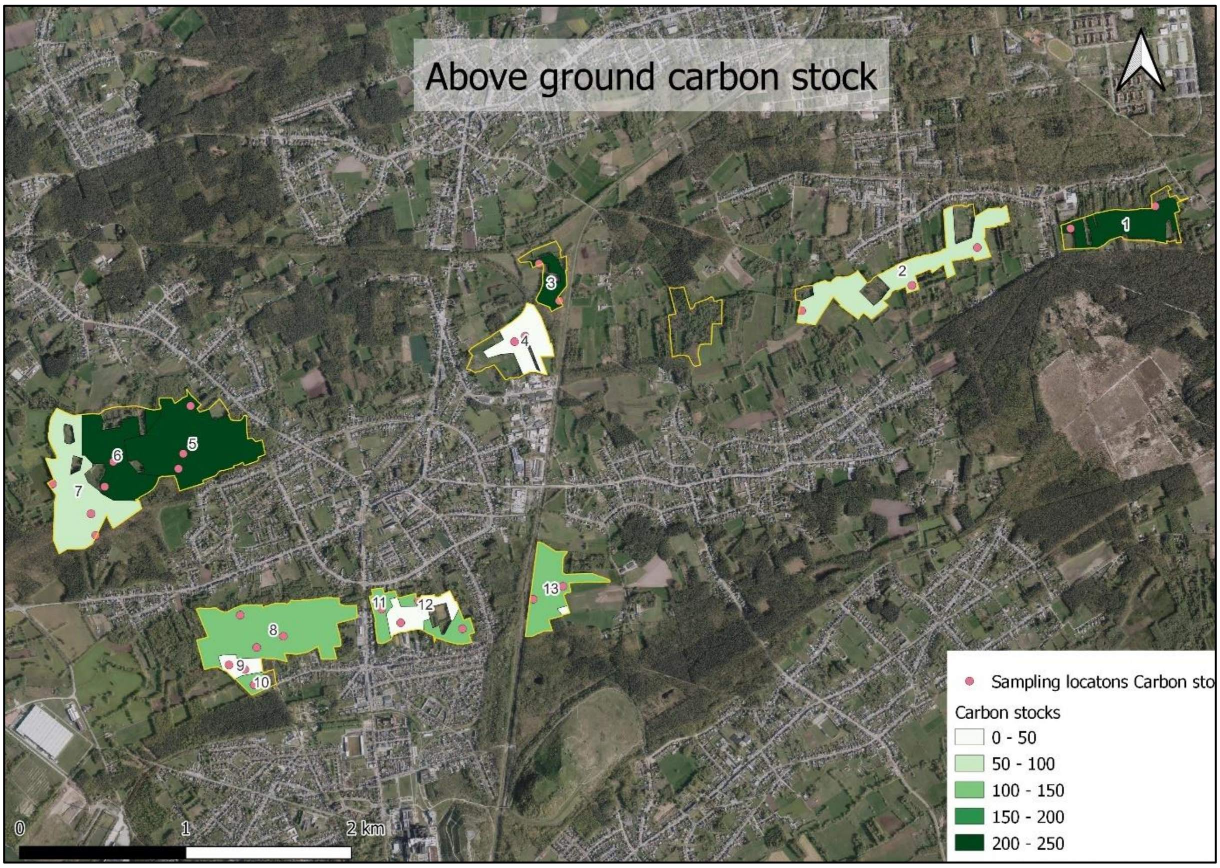

Figure 3: Forest types in the Valley of the Grote Beek, coloured by the total above ground carbon stock (in ton/ha)

3.4.2 Hydrological Monitoring

We have one full year of data, which allows us to have a first exploration of the water level within the valley. A detailed study on this is being made, but will be discussed during the next monitoring report. Some first graphs on the groundwater levels and the water levels within the different creeks are available now (Figure 4, Figure 5), as well as a hydrological comparison of our different GHG measurement locations (Figure 6).

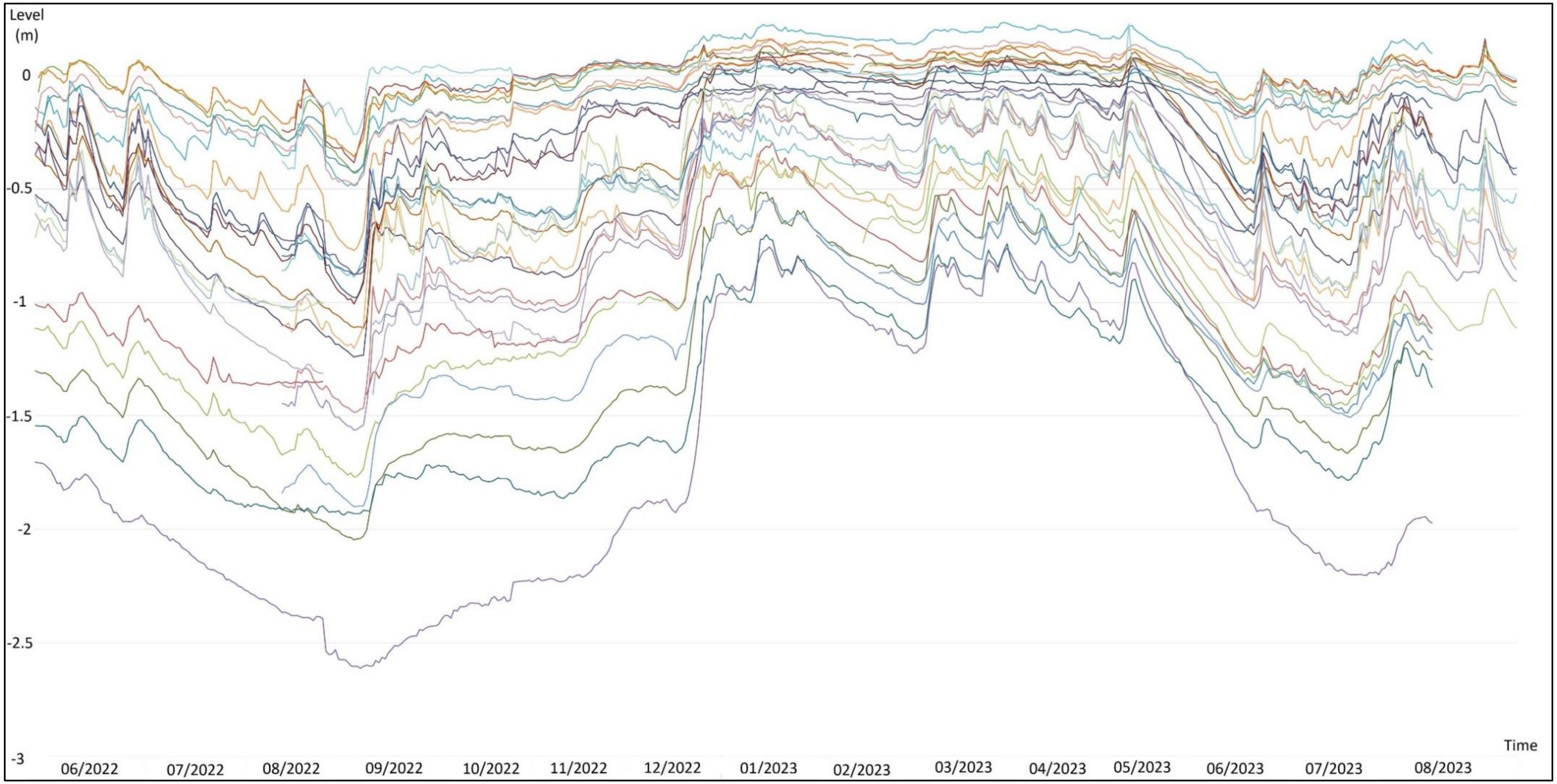

Figure 4: This graph shows the measurements of groundwater level throughout the valley over time.

It is clear that the patterns are the same for all locations, but some locations are drained really deep (up to 2.5m for the lowest purple line). Some lines are near or just above ground level.

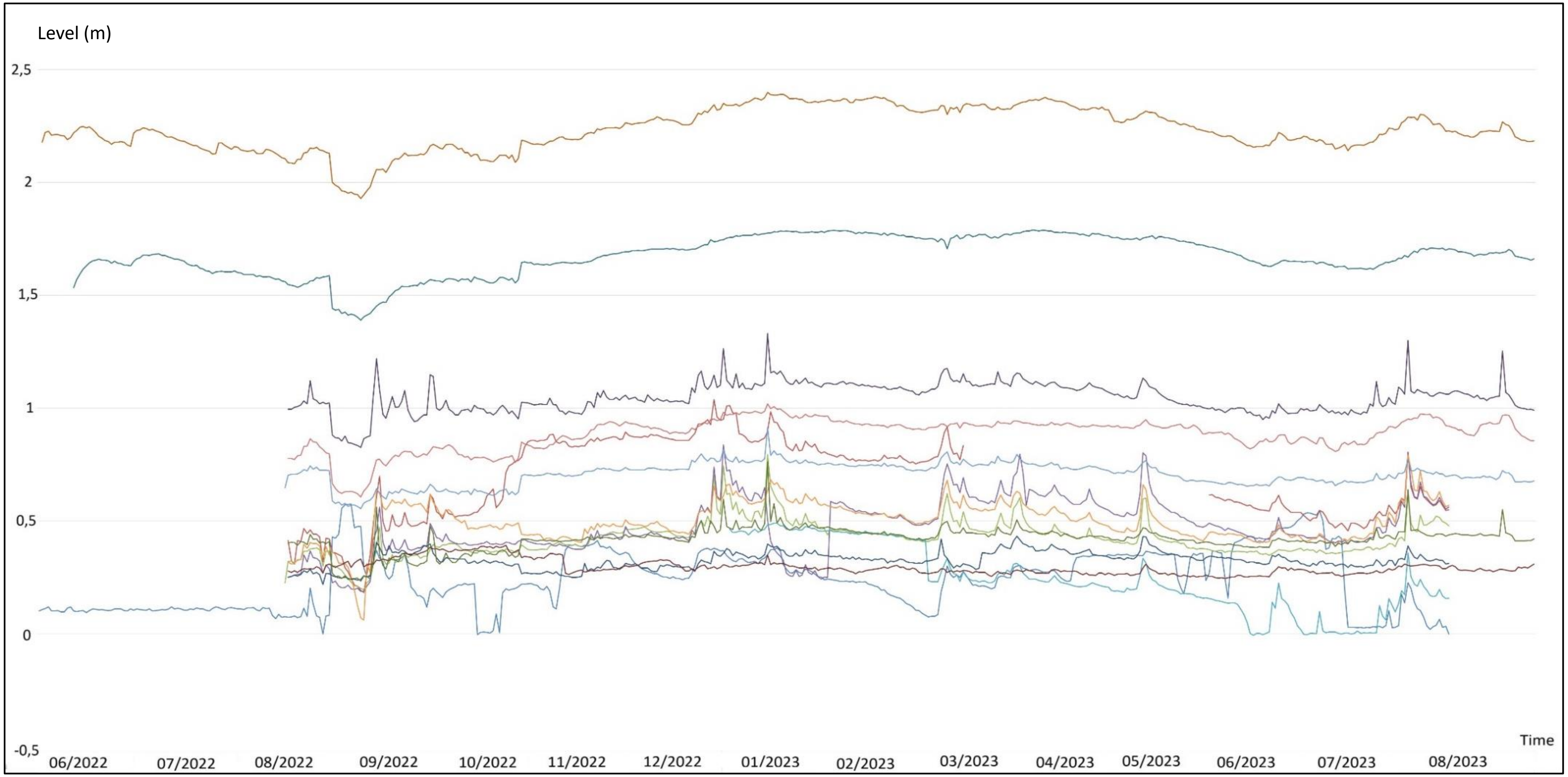

Figure 5: On this graph the water level measurements within the different creeks are visualised over time. The lower line (0) indicates when the creeks are falling dry.

We see that creeks can contain up to 2,5m of water (although some are much deeper than this) and are often rather stable in water level (less than 50cm fluctuations throughout the year.

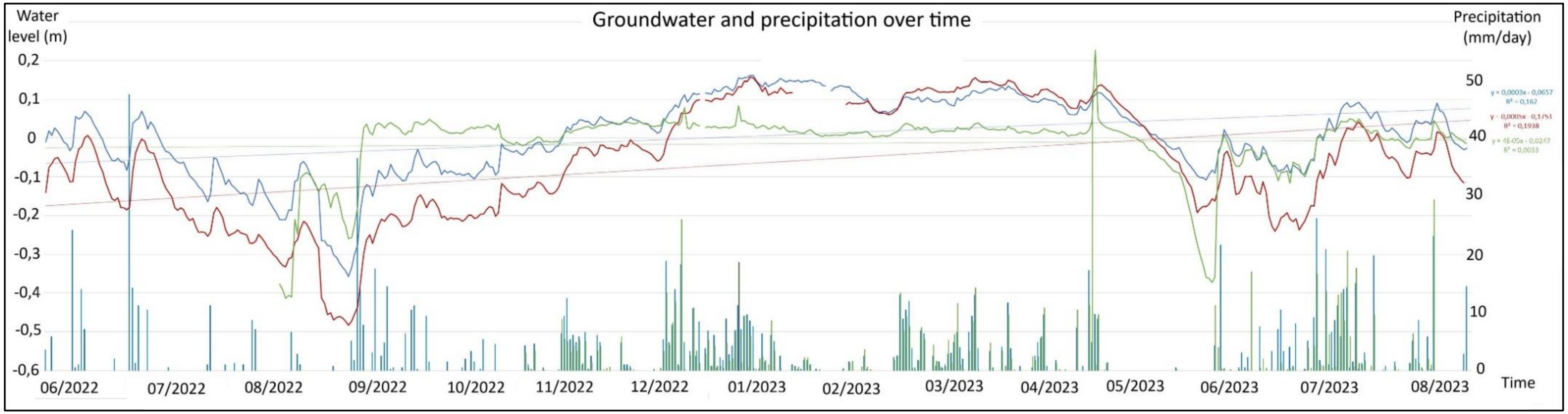

Figure 6: This graph shows the water level of the three selected GHG monitoring locations over time.

The blue line represents the area we will restore, the red line is the control where nothing will happen. For both these lines precipitation data is shown by the blue bars. The green line is our reference plot that has been restored about 15 years ago within the valley of the Zwarte Beek. For this location we have data from another weather station (although it is only 8km away). The precipitation here is shown by the green bars. We see one outlier in the green bar and line. This was a very local storm with a huge amount of rain. It is still unclear why there is a very big drop in the green line after the huge rainfall. In general, we see that the green line is more stable (as expected) compared to the red and blue lines. Once restoration measures are implemented, the blue line should become more stable as well.

3.4.3 GHG-Measurements

Will be started up in Summer 2024, see discussion and challenges.

3.4.4 Environmental Parameters

Environmental parameters are monitored by a local weather station. Here, we have 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 (at least for now). This shows rather similar data as in the Grote Beek (as expected) except from one extreme outlier in precipitation. Temperature is in general 0,5°C warmer in the Grote Beek compared to the Zwarte Beek, this is probably the difference from one weather station in the middle of the peatland (Zwarte Beek) vs the other one in the local village. A more detailed comparison can be made later.

3.4.5 UAV/Satellite Image Monitoring

Each month a satellite image is analysed following the methodology described in chapter 2. These monthly analyses will help us understand yearly variations, as well as effects of restoration. By comparing moments of similar dry-/wetness we over time, we can see the effects of the restoration works itself. The biggest problem with the valley of the Grote Beek as a peatland is that the water fluctuates too much. In winter the water level is perfect, but this is drained during summer creating really dry conditions. Monthly analyses will help us understand and monitor these huge variations within each year.

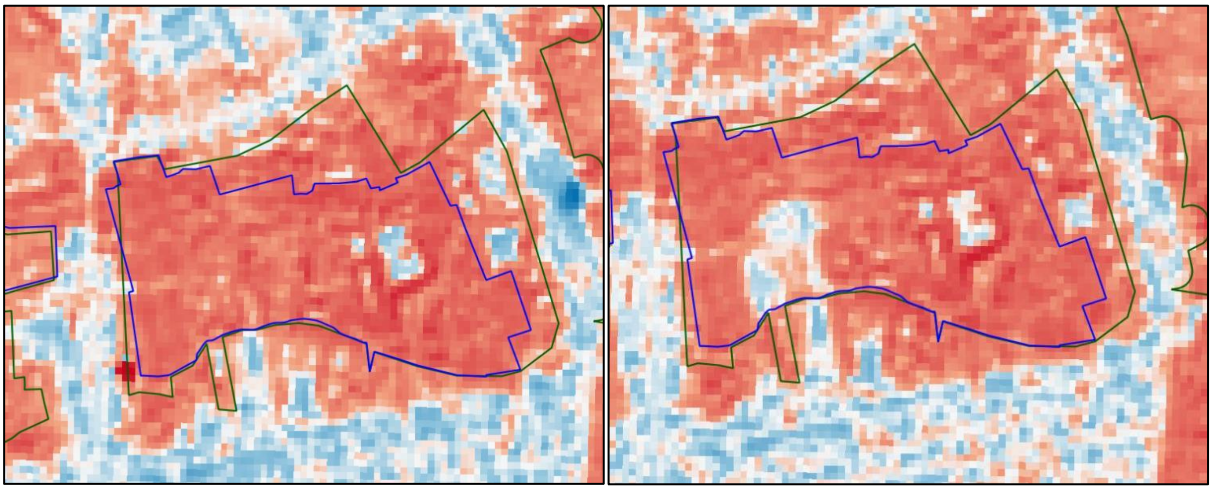

Figure 7:NDMI of the Valley of the Grote Beek: Left (September 2022), Right (September 2023)

In 2023 first restoration works have started on this subsite of the Valley of the Grote Beek. These two satellite images showing the NDMI in September (Figure 7) already show our effects on the area. While the surrounding area is coloured more or less the same, we clearly see a blue spot in the selected area indicating this small area is now wet instead of dry. When restoration works advance, larger areas should colour blue.

3.5 Discussion and Challenges

Greenhouse gas measurements are planned in collaboration with a master thesis at Ghent University. A successful measurement campaign in the Valley of the Grote Beek is thus dependent on a student actually choosing this topic and his/her availability during the summer months. But we are confident that this is a really interesting topic, covering both fundamental research, applicability and within a hot topic.
In order to have 1 full year of data we might need to do some extra measurements in summer (a master thesis period runs from July-April) so the months June and may would be missing. Another timing issue is with the equipment, which would only be available from September onwards. We are trying to solve this issue so we can actually get one full year of data.

Managing the network of 46 piezometers is quite challenging. It takes 2 full days of work to get to all these water level loggers. In order to be efficient, we want to go as less as possible. On the other hand, 4 water level pipes were already vandalised/damaged somehow. Furthermore, our 13 pipes measuring water level within creeks are constantly gathering branches that get stuck, increasing the pressure on these pipes until they break. It's a constant struggle to keep these in place and avoid an impounding effect resulting in wrong measures. In the framework of the hydrological study these piezometers were checked and data was collected 5 times in one year, while in the end we want to reduce this to 2 times.

For the environmental data we rely on a weather station in the local village and a weather station form Antwerp university in the Valley of the Zwarte Beek (ref site). Weather patterns vary significantly between those 2 regions, so hope that both weather stations will be collecting data throughout the whole project. For the weather station in Ham we have no indication this will not be the case, but the weather station in the Zwarte Beek was part of a project that has ended now. It is still unclear if the station will stay in place or be removed.

We had an extremely wet winter (maybe even the most wet ever measured), so remote sensing data of this would be really interesting. However, these huge rainfalls only happen because there were a lot of dense clouds for a long period, obscuring satellite images from this period. We thus have no images from November and December and hope January will have at least one cloud free image.

Within the ecohydrological study, below ground carbon stocks were recalculated. These result in much bigger carbon stocks than we estimated. Our estimation was cautious, so we know that we are certainly not overestimating it. Once the hydrological study is finalised, we can compare these numbers and decide which one seems most accurate or take an average between both.

3.6 Communication indicators

Belgium							
	Indicators						
	Direct			Indirect			
Units	Economic contribution	Ecosystem regulating services (GHG emissions)	Awareness raising	Ecosystem supporting services (habitat for species)	Ecosystem provisioning services (raw materials, freshwater)	Ecosystem regulating services (Fire/flood prevention)	Ecosystem cultural services (recreation, aesthetic appreciation, and inspiration)
Stakeholder and Duty holder engagement [1]	1		26				
Information boards/panels [2]			3				
Employment (Individuals/companies hired by the project) [3]	2						
Amount spent (€) [4]	184 030.11						
Number of jobs [5] (FTE and PTE)	9 PTE						
Number of events	14		14				

[1] *12 different organisations were reached within the first stakeholder meeting (including our co-financing government), during the paludiculture workshop we engaged 14 additional stakeholders, bringing the total to 26.*

[2] *3 Information panels were installed throughout the project site, explaining the project and the importance of peatland restoration.*

[3] *2 companies were hired to carry out the ecohydrological study (Paludosa research and EcAsCo (ecological assessment & consultancy)*

[4] The sum of costs from external assistance, consumables, travels, other costs Until 31/12/2023

[5] *9 persons are working on the project, not all of them are full time. These persons comprise a field team (2 persons) for the restoration works, 1 coordinator for the execution of the restoration and the field team, 1 national project coordinator, 2 persons doing administration and finances of LIFE projects, 1 person responsible for all projects within Natuurpunt and 2 persons offering technical assistance for nature management and restoration, only the first 4 persons are working part time or more on LIFE Multi Peat.*

organised or participated [6]							
Number of participants in events organised by the beneficiary [7]			84				
Number of hectares restored [8]		2,2761 ha		2,2761 ha		2,2761 ha	2.2761 ha
GWP reduction[9] (tons of CO_2-eq/ha/y)		3,4 t CO_2-eq/y (=1.5t CO_2-es/ha/y)					
Number of Print media [10]			5.100 (leaflets)				
Number of Publications/Reports, promotional material produced [11]			12				
Media coverage (newspaper articles, press releases, radio, podcast) [12]			12				

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[6] *We participated in or organised 14 events: Veldwerkplaats Bargerveen 03/2022, Ireland conference organised by Interreg Care-Peat 06/2022, Peat day Black Creek 06/2022, Demerdag 09/2022, Paludiculture workshop 10/2022, Start event Multi Peat 11/2022, Carbon farming Study day Antwerp 02/2023, European projects info day 02/2023, Info walk local inhabitants 03/2023, LIFE peat platform Berlin 04/2023, Demerdag 09/2023, Power to the peatlands 09/2023, Carbon farming discussion forum 12/2023, 01/2024 intermediate results hydrological study.*

[7] *Paludiculture workshop (10/2022): 30 participants, Start event (11/2022): 38 participants, Info walk local inhabitants (03/2023): 16 participants*

[8] *On 2.2ha trees were removed in preparation of the closing of ditches, tree removal already made the parcel more wet.*

[9] *Based on the GEST method, the 2,2ha that was opened up is estimated to reduce annual emissions by 3,4 t* CO_2*-eq.*

[10] *5100 leaflets were printed and disseminated to the local inhabitants, by posting them in the neighbourhood, placing them at visitor centres and spreading through events.*

[11] *As promotional materials, leaflets and billboard were made, furthermore we have published 10 project updates on the website*

[12] *2 press releases were made and picked up by several newspapers resulting in 7 Newspaper articles, 2 television items and 1 radio interview.*

Website – visits[13]			444				
Climate Performance (tons/year CO_2) [14]		2.483					
Climate Performance (tons/year CH_4) [15]		5,32					
Environmental Performance – resilience to flooding (ha) [16]						Not computable	
Baseflow contribution of receiving water (m3/s) by percentage [17]		NA				NA	
Average lowest groundwater level on the whole project site (cm below ground level) [18]		81.1 cm					
Sustainable land use, agriculture, and forestry (hectares of agricultural land under sustainable					0 ha		

[13] *Until 31/12/2023*

[14] *Current emission of the total project area according to the GEST method.*

[15] *Current emission of the total project area according to the GEST method.*

[16] *Due to the complex hydrological interactions occurring in our Creek valley fens, combined with a history of mining causing subsidence and the influence of the immense drainage network in the broad area; it is impossible to compute any meaningful numbers of flood resilience. This again would then be depending on where floods occur, how big the floods are, when they would occur and what part of the floods are influenced by our 1 part of the valley system. Our environmental performance is thus fully assessed by the climate performance.*

[17] *Baseflow calculations need at least 3 years of detailed water level data before restoration and 3 years after. Especially within our complex lowland peatlands and with no weirs measuring discharge,. It will thus be impossible to calculate a baseflow contribution at the end of the project.*

[18] *This is the average lowest groundwater level for the period 08/2022 to 08/2023 as baseline before restoration. Calculated by taking the average water level over the dry season (1/07-31/09). This value is calculated for each water well and then the average of these (45) different value was taken to achieve an estimate for the average lowest groundwater level of the whole areas.*

management) [19]							
Habitats positively affected (ha) and change in percent cover of indicator species associated with their respective target habitat [20]				NA			NA

[19] *Only applicable to our paludiculture pilot site, establishment is planned in 2024*

[20] *Only assessed at the end of the project*

4 Germany

4.1 Project Site

The Häsener Luch, situated in the north-eastern part of Germany, is 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 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 lie between 80-100 cm below surface. As a consequence, the topsoil peat is highly degraded and moorshified. Furthermore, the ongoing oxidation of peat has already lead to a vertical loss of around 65 cm of peat, since 1969.

The reference site Rüdnitzer Fließ is a fen site at a distance of 35 km. It was successfully rewetted some 10 years ago is now mainly covered with reeds (*Phragmitis australis*).

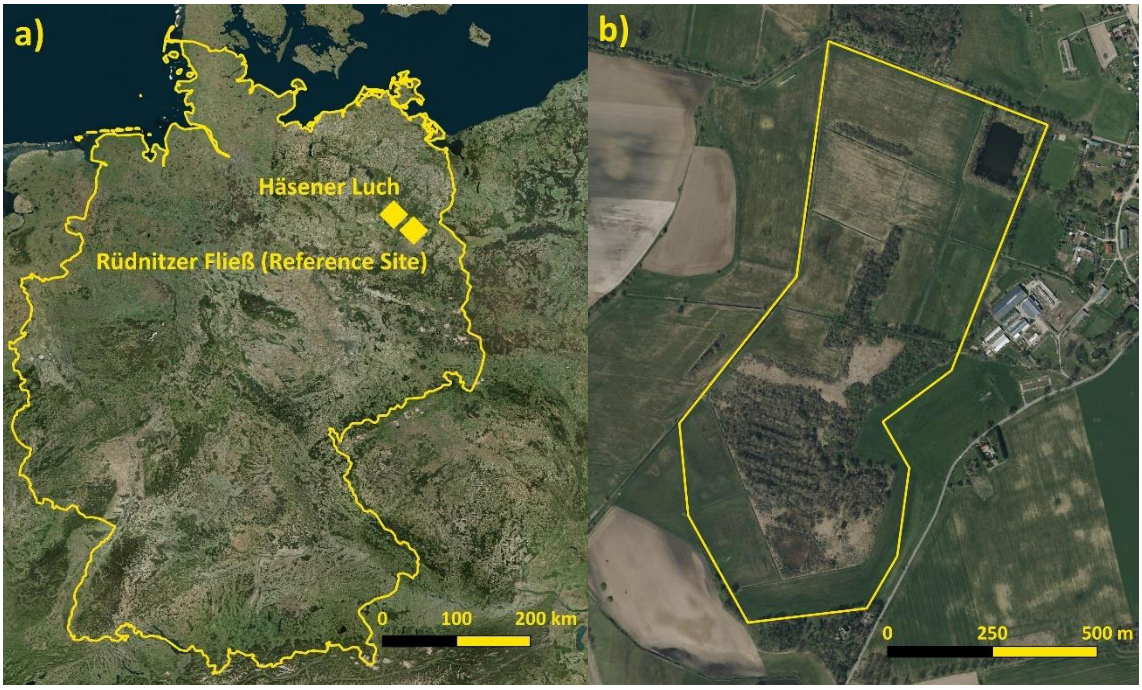


Figure 8: a) Map of Germany showing the situation of the "Häsener Luch" and the reference site "Rüdnitzer Fließ"; b) Project site "Häsener Luch" within the yellow boundary.

4.2 *Methods-Adaptations*

Change in above ground carbon stocks won't be monitored at this point of time. The GHG-measurements will be realized at five spots (frames) at each monitoring site, instead of three. Otherwise, all methods are used as described in chapter 2.

4.3 *Current State*

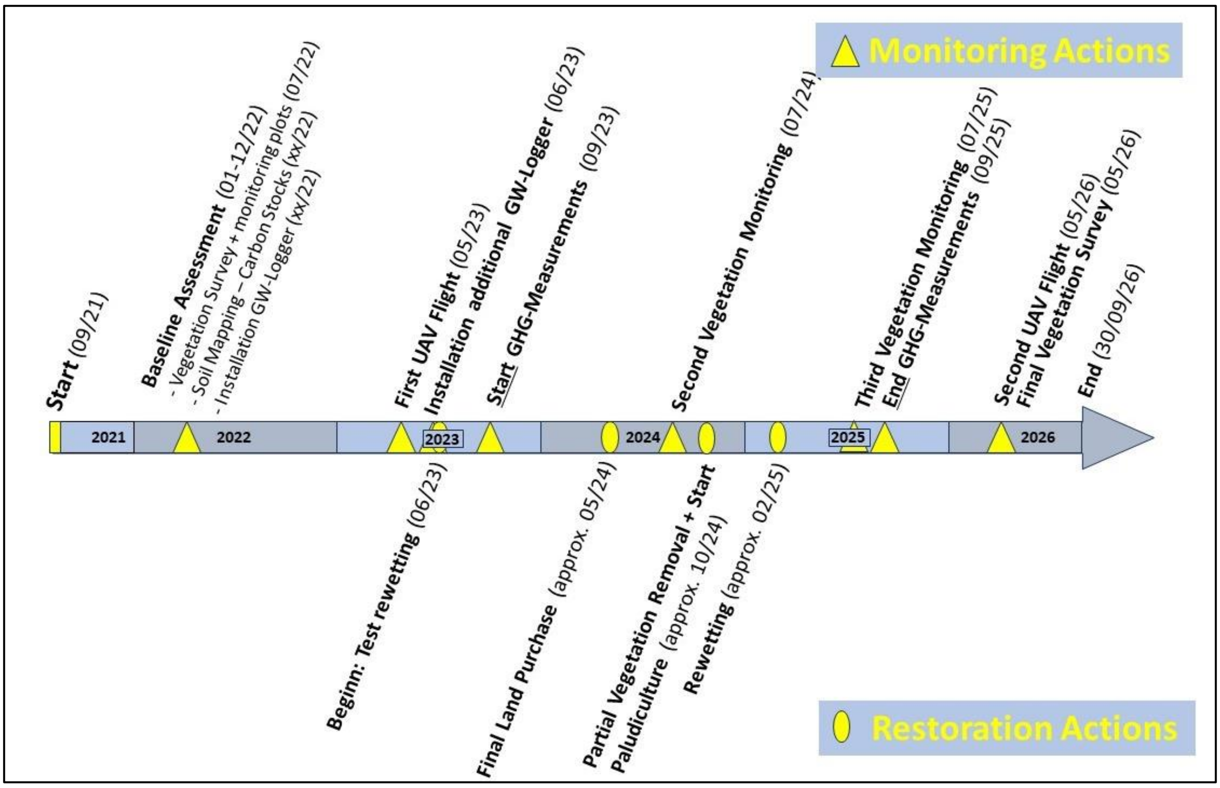


Figure 9: Timeline showing restoration- and monitoring progress for Germany

4.4 *Results*

4.4.1 *Carbon Stocks*

The total amount of carbon stored in the project site Häsener Luch sums up to about 55.771 tons, which is equivalent to 204.679 tons of CO_2. In this sum, also the organic carbon stored in gyttja horizons (lake sediments) underlying the peat soil horizons is included. Without the gyttja horizons, the amount of organic carbon stored in peat and woody biomass sums up to 44.786 tons, which is equivalent to 164.366 tons.

The **below ground carbon storage**, which appeared in the 1st Monitoring Report (Life Multi Peat, 2023) as a calculation based on (dummy) values for C-org and bulk density taken from the Peatland Archive of the Humboldt-Universität zu Berlin (Moorarchiv), has been recalculated. In the 2023 seventeen additional soil descriptions were realized in the field.

Bulk density and carbon content samples were also taken for many horizons and later analysed in the laboratory.

In a first step, the area shares for each peat thickness class (see Figure 10) have been recalculated. For each peat thickness classes, mean values of carbon content were derived, using the profile descriptions.

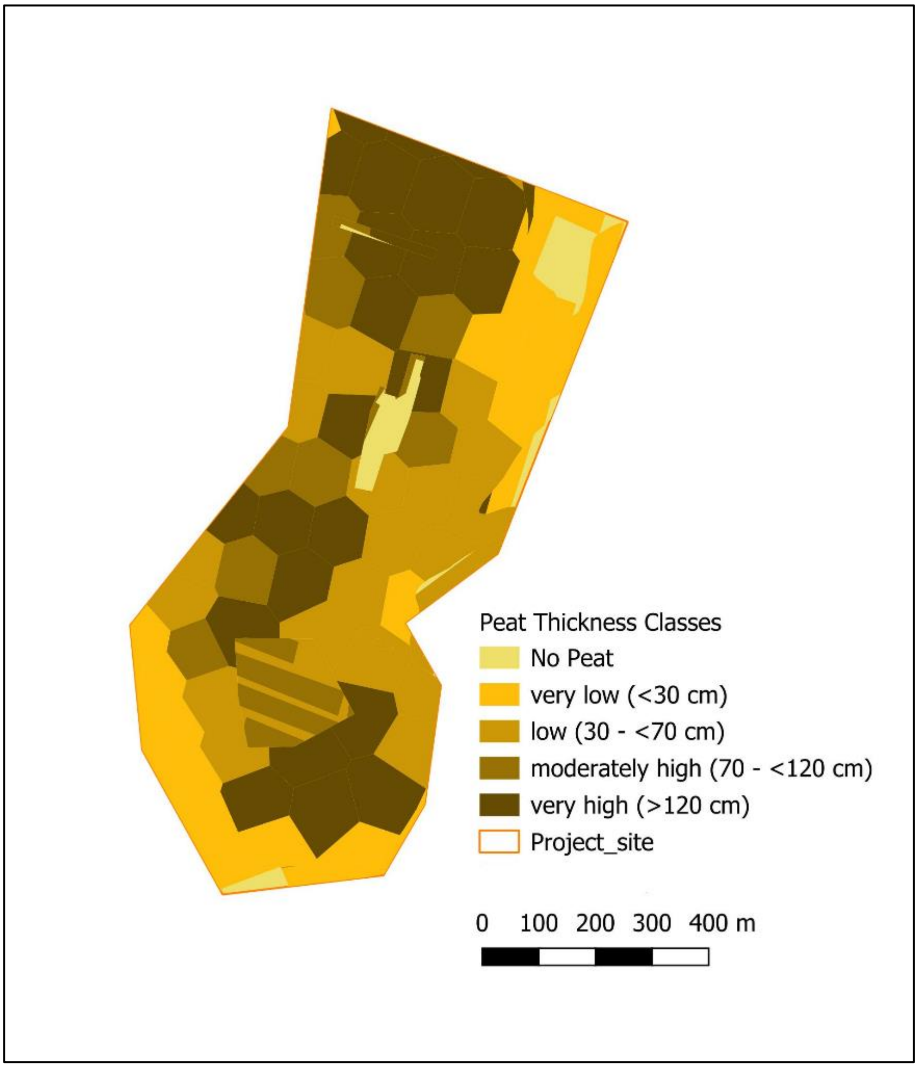


Figure 10: Recalculated Peat Thickness Classes of the Häsener Luch (2023)

In a second calculation, the contents of organic carbon comprised in the gyttjas underlying the peat were included. In this case, the blow ground carbon stocks sums up to 52.588 tons, which is equivalent to 192.999 tons of CO_2. Considering, that under aerobic conditions also organic carbon of gyttjas can become oxidized, 52.588 tons is the more correct value to use, as the maximum amount of carbon that can be released from the soil to the atmosphere.

The carbon content of each horizon was calculated. Was no value for carbon content or bulk density determined in the laboratory in 2023, mean values were taken from horizons of the same type and substrate characteristics. If no mean value for horizons of the same type was available from the 2023 analysis, a mean value for the same horizon type was taken from the Peatland Archive. In this way, the carbon content and bulk density values used to calculate the below ground carbon stocks, were as original as possible. The total of organic carbon stored in only the peat of the Häsener Luch sums up to 41.380 tons, which is equivalent to 151.864 tons of CO_2.

Table 2: Carbon stocks of below ground organic carbon, including gyttja horizons

Soil Depth Class	Area [ha]	Average C-stock [t/ha]	C per area [t]	CO_2 per area [t]
0-30	12,9	287	3.688	13.534
30-70	17,3	358	6.182	22.687
70-120	9,1	889	8.133	29.848
>120	20,7	1673	34.586	126.930
Total Area	**60,0**	**Total C [t]**	**52.588**	**192.999**

For the determination of the **carbon stock in the above ground biomass,** 16 plots 10x10 m^2 were distributed over the woody areas (approx. 21 ha) of the project site. Every vegetation unit had at least on plot. The calculated carbon stocks were averaged for every vegetation unit (see Figure 11).According to chapter 2.1.2, carbon stocks in tons were calculated for each vegetation unit according to its area share (Table 3). In total, 3.183 tons of carbon, are fixed in the woody biomass of the Häsener Luch, equivalent to 11.681 tons of CO_2.

Table 3: Carbon stocks of above ground woody biomass according to vegetation units

Vegetation units (woody)	Average C-storage [tC/ha]	Area [ha]	C [t] per Vegetation unit	CO_2 [t] per Vegetation unit
A	171,3	1,9	317	1.163
B	242,2	3,2	765	2.808
C	421,0	3,1	1.288	4.728
D	504,2	0,3	146	537
E	114,7	1,2	137	502
F	10,7	1,5	16	58
G	10,7	3,1	33	121
H	14,9	4,0	60	220
J	179,5	1,8	322	1.180
R	75,6	1,3	99	363
Total amount of C [t] in woody vegetation		**21,3**	**3183**	**11.681**

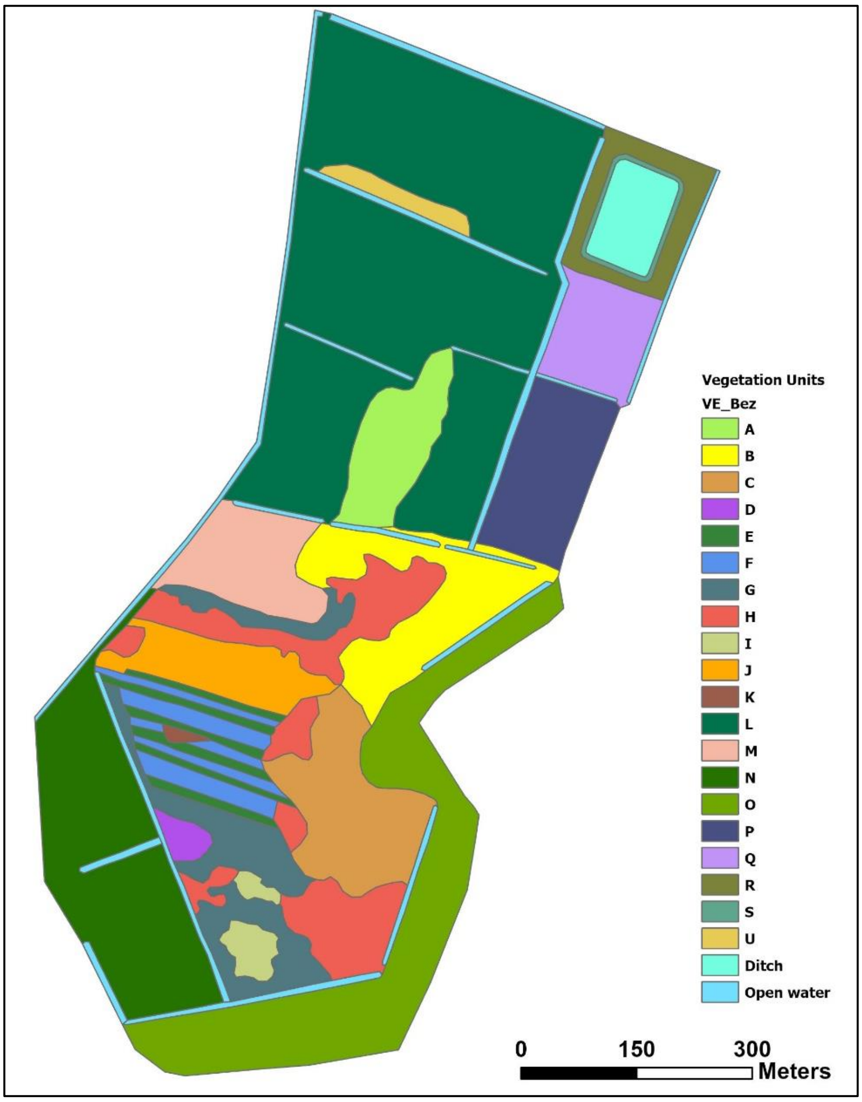


Figure 11: Map of vegetation units in the "Häsener Luch"

4.4.2 Hydrological Monitoring

Hydrological equipment was installed at the monitoring site (see Figure 13) at two different points of time. Five water loggers (Device: Meter "Hydros 21") HL_01 to HL_05 were already installed in October 2022 (see Figure 12a and Figure 14). Six more sensors (Device: MMM-tech "RKL-01-5") working with wireless data transmission were installed in June and July 2023 to monitor the "test rewetting" (PSSS01 to PSSS03 and PSGW01 to PSGW03). The sensors named PSSS are directly implemented in the ditch blockings (see Figure 12b, c).

a) b) c)

Figure 12: 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

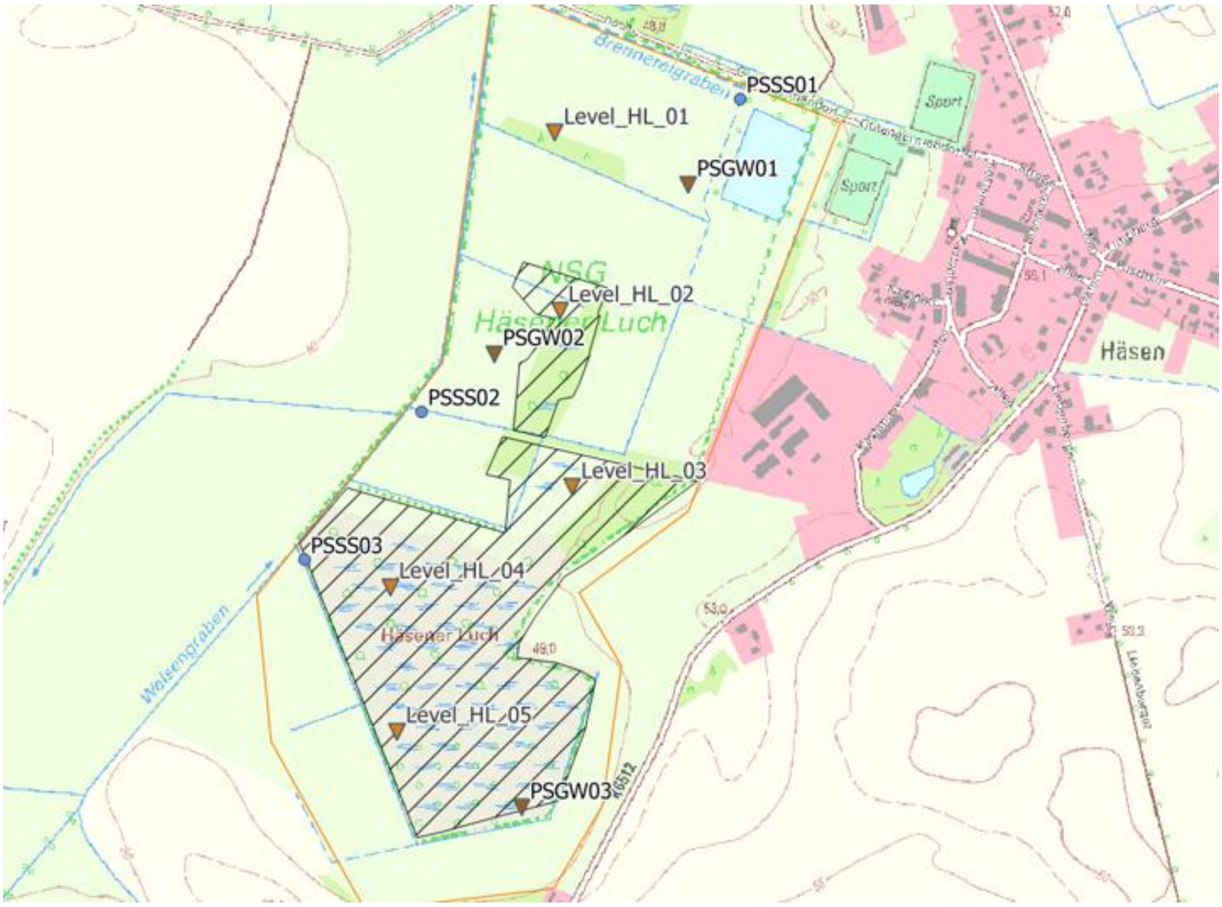


Figure 13: Map of the „Häsener Luch" showing the positions of the water level measurement points.

Results of water level measuring points installed in October 2022 show considerable fluctuations of the water tables related to the seasons (see Figure 14). Closest to the northern “water outlet” of the fluctuation is greatest with almost 130 cm. The reference site (green line) shows a distinctly smaller fluctuation, showing what also should be achieved through restoration measures at the current project site.

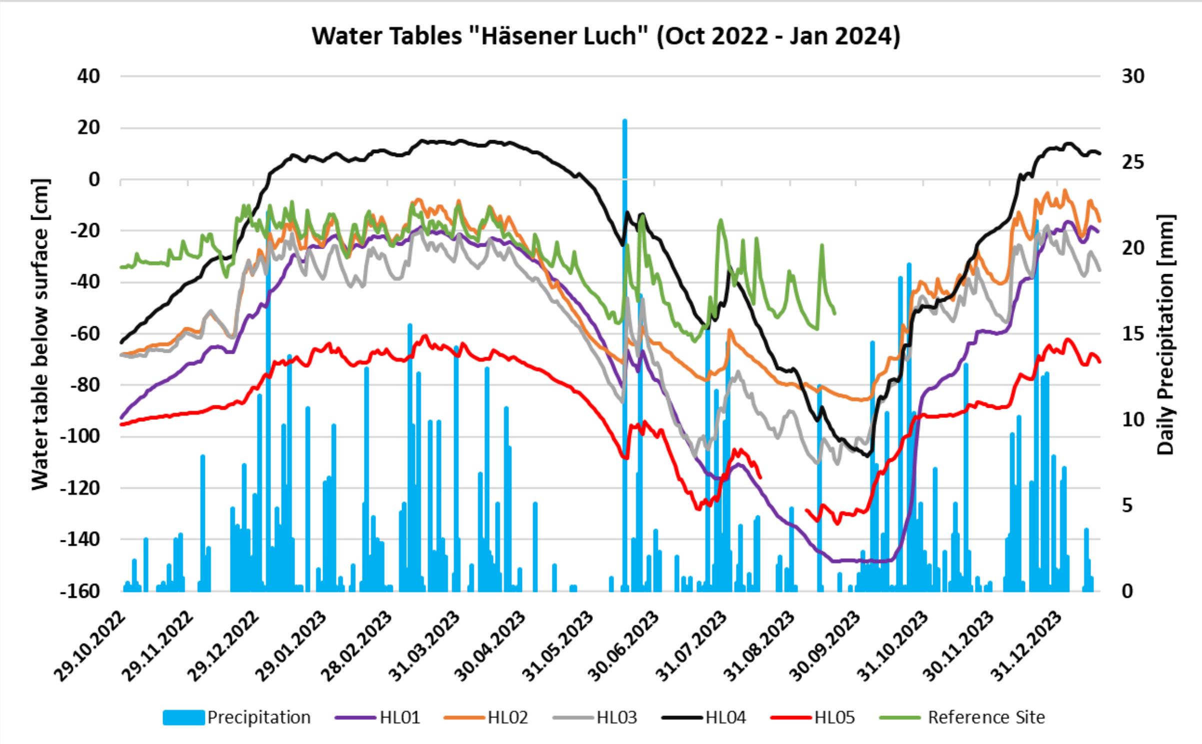


Figure 14: Water tables between Oktober 2022 and December 2023 for the first five water loggers and at the reference site.

The water levels of the measurements related to the test-rewetting are shown in Figure 15. Unfortunately, the measurements as some measurement points suffered from battery errors, as the batteries delivered with the new devices were partly discharged (gaps in PSGW02 and PSSS02). From mid-October 2023 water levels rise with over-average precipitation in November and December. By the end of December PSSS02 reached a steady water level, being the only ditch blocking facility were by that time the aimed water levels were reached. The effectiveness of the test-rewetting will have to proof itself by the end of spring, and show if the water retention of the site is enhanced, when the climatic water deficit is increasing.

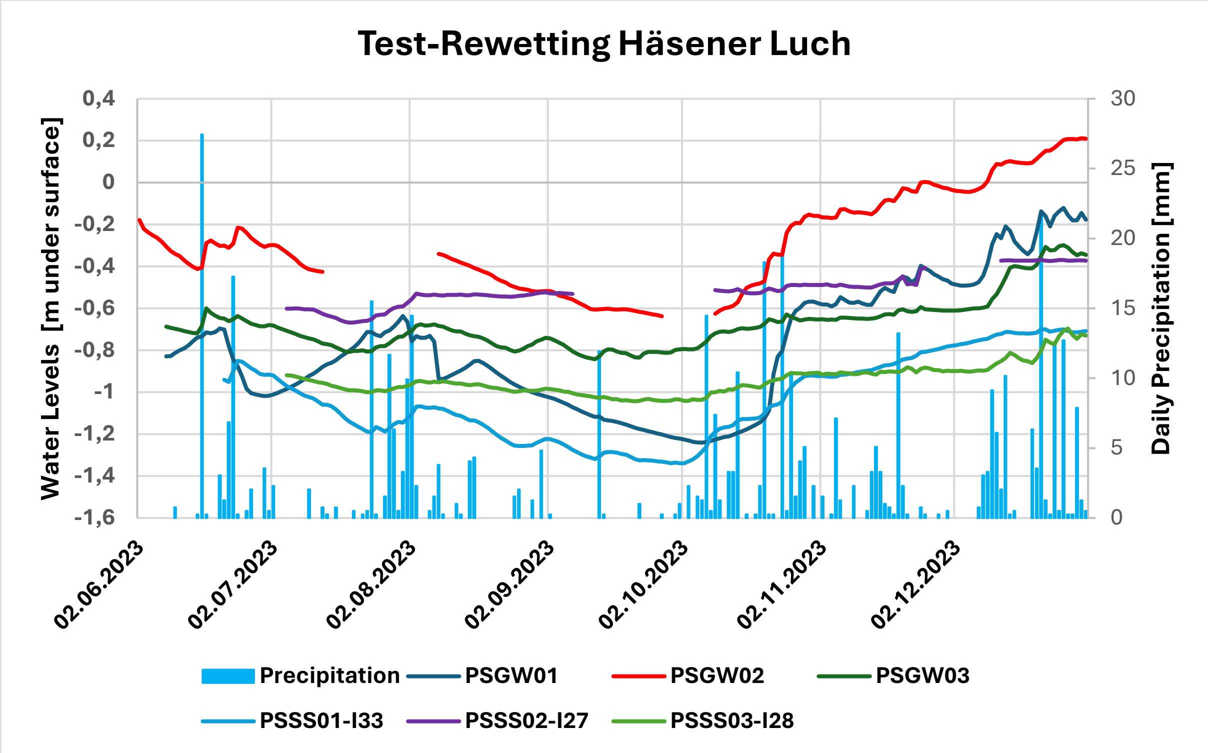


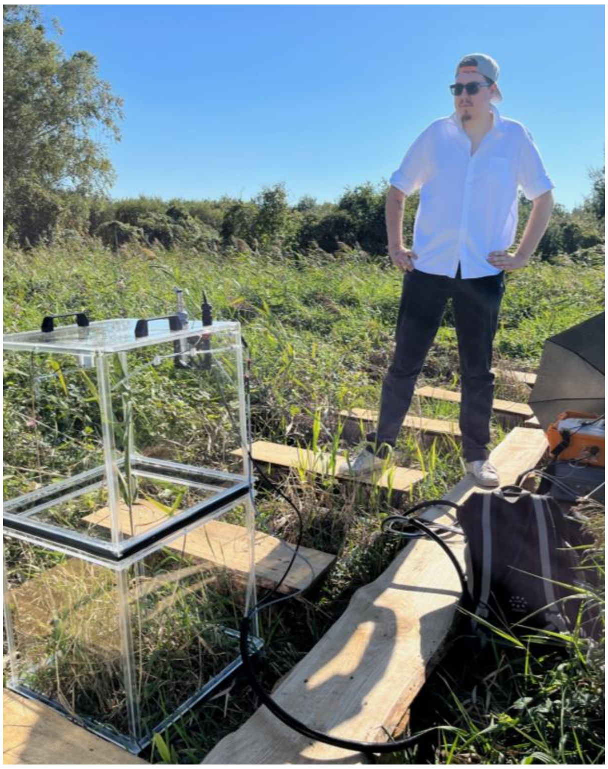
Figure 15: Water tables at measurement points related to the "test-rewetting" between June 2023 and December 2023.

4.4.3 GHG-Measurements

Monthly greenhouse gas measurements are conducted at three monitoring sites. As indicated in chapter 4.3, starting point was September 2023 and the end of the measurement campaign will be August 2025. CO_2 and CH_4 fluxes are directly measured in the field with a LiCOR 7810 trace gas analyser. N_2O is to be sampled every three months in sample flask, to be later analysed in the laboratory.

Two of these sites (HL01 and HL02) are at the Life Multi Peat site "Häsener Luch" (Figure 16). Site HL01 is situated in a *Phragmitis australis* stand (see Figure 17) and will be affected directly by rewetting measures. HL02 is lies in a *Phragmitis australis* stand as well, but is located on a little mound, so will not be affected substantially by the planned rewetting measures. The reference site "Rüdnitzer Fließ" was rewetted 10 years ago. The GHG-measuring equipment is also situated in a *Phragmitis australis* stand (see Figure 17).

Figure 16: Location of the two GHG-Monitoring Site at the project site Häsener Luch



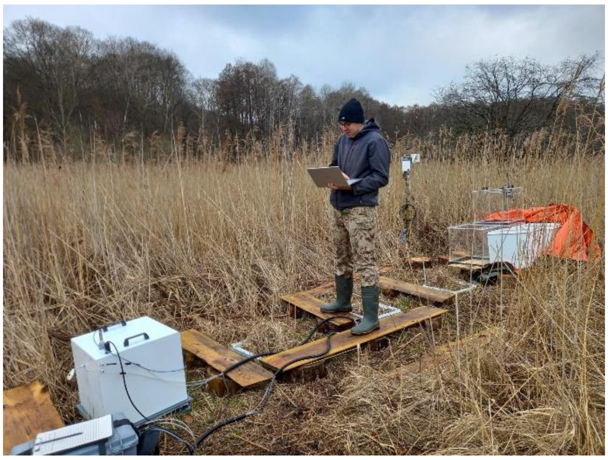
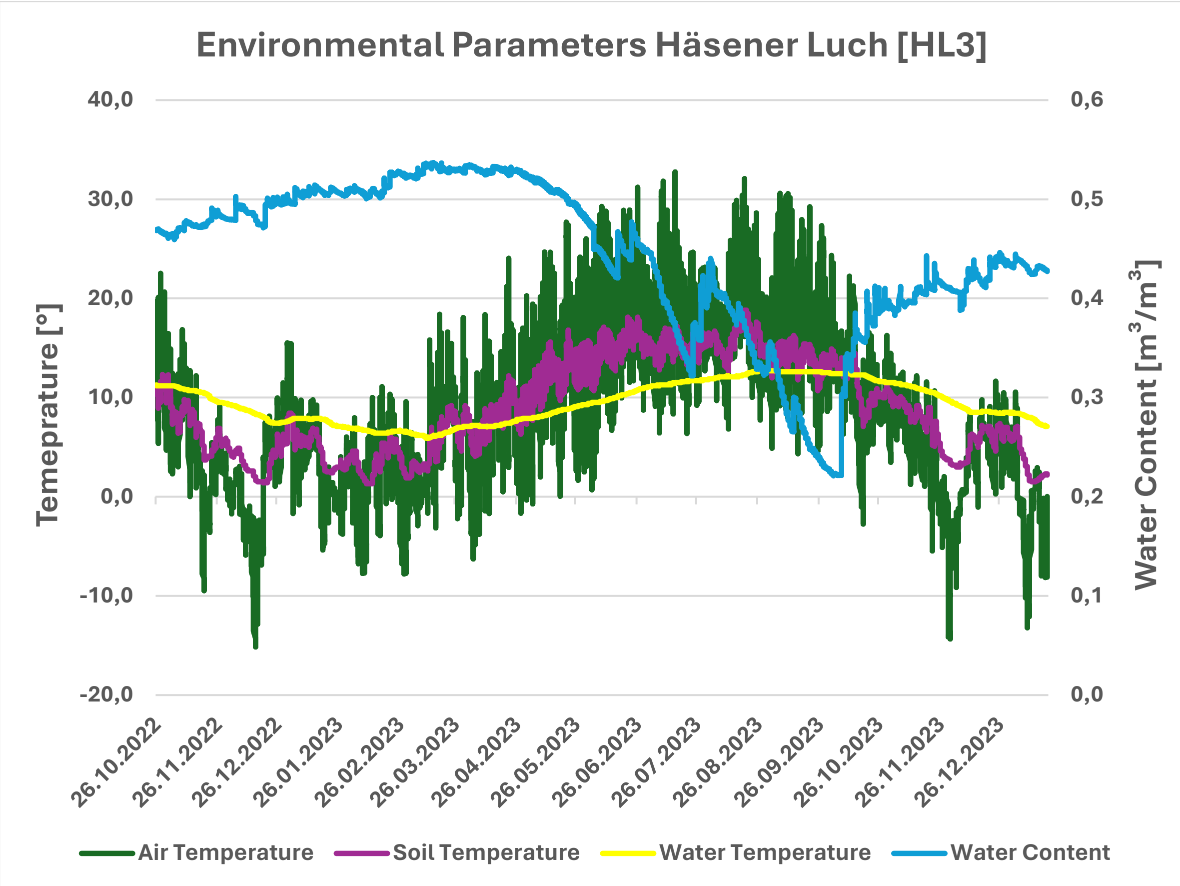


Figure 17: Boardwalk and set-up of GHG-measurements at project site "Häsener Luch" (HL01) (left), and at the reference site "Rüdnitzer Fließ" (right).

4.4.4 Environmental Parameters

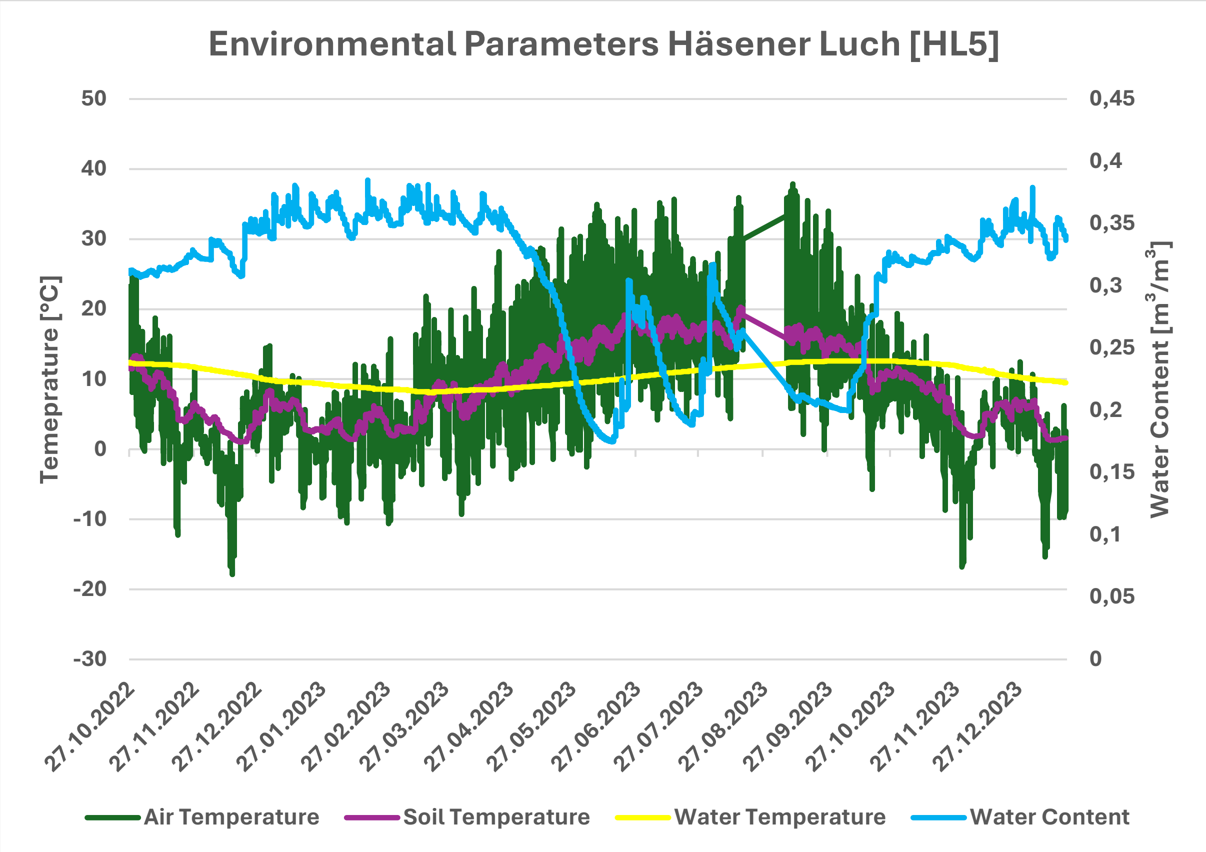
At the two sites HL3 and HL5, where the GHG-measurements are conducted, the following environmental parameters are measured: Air temperature [°C] (Device: Meter “Atmos 14 Gen 2”), water temperature [°C] (Device: Meter “Hydros 21”), soil temperature [°C] and soil water content [m³/m³] (Device: Meter “Teros 11”) in 5-10 cm. Also, the photosynthetically active radiation (PAR) was measured at both 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.



Both sites (HL03 and HL05) show the same pattern. Mean annual air temperature is 9,9°C (HL03) and 10,0 °C (HL05). Air temperature has the highest daily fluctuation and also total fluctuation. Water temperature has the lowest total fluctuation and lies around the yearly mean air temperature of around 10 °C.

Comparing the two sites to each other, one can see the difference of the groundwater tables reflected in the measurements. Mean soil water content in 5-10 cm depth at site HL03 is 0,47 m³/m³ and at site HL05 0,35 m³/m³. The soil water content in 5-10 cm is generally higher at site HL03, where due to the higher water levels also more water is around the sensors due to capillary action. The water temperature has a lower fluctuation at site HL05, where the water table is deeper and hence less influenced by the atmospheric temperature.

The relatively low water content at both sites during winter and springtime give evidence of the degradation of the peat, as capillary rise is little developed, typical for moorshified peat.



4.4.5 UAV/Satellite Image Monitoring

The drone flight was conducted on the 7th of July 2023 with a "M300RTK" drone using a "Parrot Sequoia Multi spectral camera". In total, 6605 pictures, with a resolution of 1-2 cm, were taken and stitched together. An orthophoto showing the visible light spectrum can be seen in Figure 18. The white square in the central southern part of the project site is blanked out, due to a restriction of unknown origin.

The NDVI (Figure 19) shows healthy vegetation in red colour, lightly stressed vegetation in orange and very stressed and dry/dead vegetation in yellow and green, respectively. One can see that the vegetation of the arboreous part of the project site was in very good and healthy condition, whereas the pastures in the northern and south eastern part show a specific stripe pattern. The stripe pattern are lines of hay, so grass which was mowed one or two days before the images were taken.

Figure 18: Orthophoto of the "Häsener Luch"

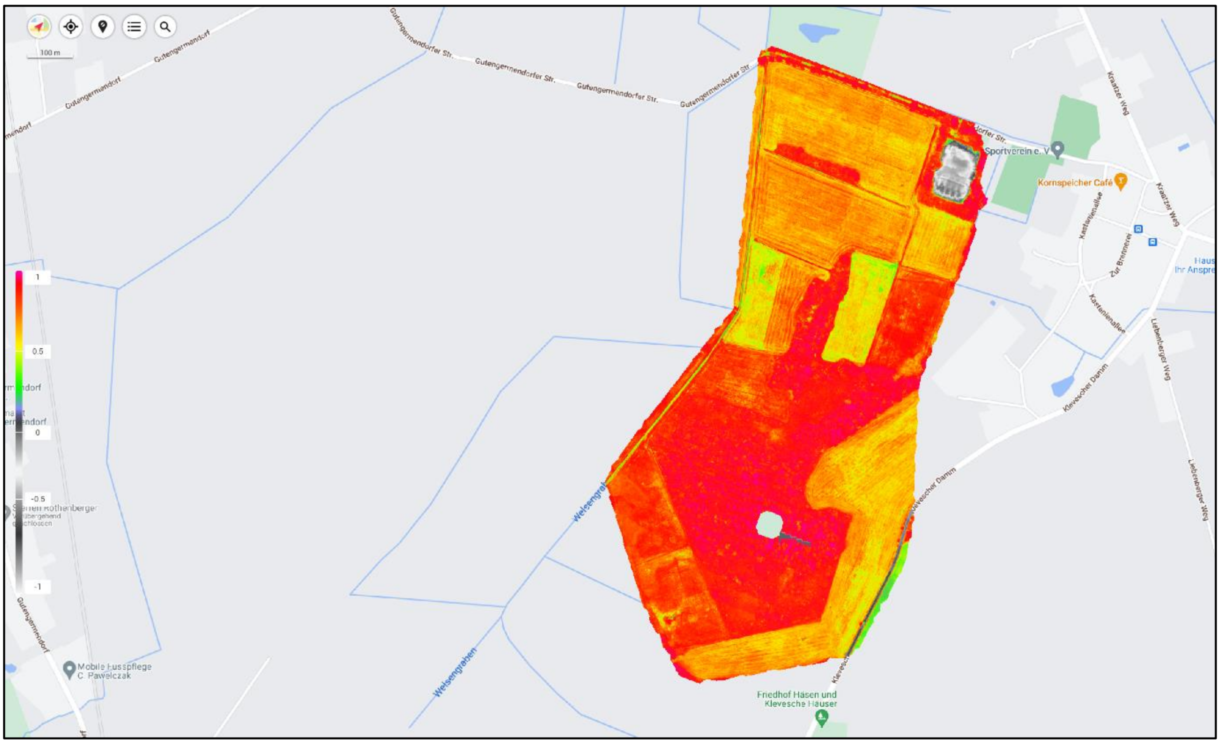


Figure 19: NVDI for the German Site "Häsener Luch"

4.5 Discussion and Challenges

During 2023 it is not expected to see many effects of restoration measures in the monitoring data. The only implemented actions were the three test rewettings (see 0). The expected effects of these test rewettings are anticipated to be seen in the monitoring data by early summer 2024, when the evapotranspiration will be increasing and landscape water budget decreases. If the test rewettings work successfully, the amount of water hold back in the adjacent peatland areas should be greater than in the areas not affected by the test rewetting. Also, water tables of the affected areas should be higher than the year before. Based on the analysis of the monitoring data, it will be possible to evaluate if the peat soil is susceptible for rewetting or not and which rewetting measures will be necessary to guarantee restoration success but opting for the most cost-effective solutions.

Some challenges arose from the used technical devices, especially battery issues at some water table measuring points using MMM-tech "RKL-01-5". Batteries, which came with the new devices, were not supposed to be replaced for about a year. Unfortunately they were discharged after only several weeks or months. As the "RKL-01-5" uses remote data transmission and has no internal storage, the data which was not recorded couldn't be recovered.

Another issue which unfortunately compromises the interpretation of the UAV method, is the hay mowing that took place on great parts of the project site, only days before the flights were executed. Therefore, the health of the vegetation cannot be used as a proxy for the hydrological situation on the whole site. There are inherent difficulties related to the timing of the conduction of this method, as the day must be cloud free and weather can only be forecasted, and neither be planned nor guaranteed. Further, both the drone enterprise and the farmers are included. Agreements with farmers of not mowing grass have their timely limits, because they run an agricultural enterprise and environmental protection is not their number one priority. The conduction of the first drone flight didn't work out at the desired date and we have the unfortunate situation of having it realised after mowing. For the second UAV flight at the end of the project we will have a quandary. We might either conduct it with the same conditions, to get the best comparison of the before and after rewetting situation. Or we might try to time the second UAV flight before mowing and get better information on the hydrological situation, using the health of the vegetation as indicator in all parts.

4.6 *Communication indicators*

GERMANY							
	INDICATORS						
	DIRECT			INDIRECT			
Units	**Economic contribut-ion**	**Ecosystem regulating services** (GHG emissions)	**Awareness raising**	**Ecosystem support-ing services** (habitat for species)	**Ecosystem provision-ing services** (raw materials, freshwater)	**Ecosystem regulating services** (Fire/flood prevention)	**Ecosystem cultural services** (recreation, aesthetic apprecia-tion, and inspiration)
Stakeholder and Duty holder engagement			9				
Information boards/panels			0				
Employment (Individuals/companies hired by the project)	5						
Amount spent (€)[21]	38448,75 €						
Number of jobs (FTE and PTE)	9						
Number of events organised or participated	3		3				
Number of participants in events organised by the beneficiary			~25				
Number of hectares restored		10 ha		0 ha		0 ha	0 ha
GWP reduction[22] (tons of GWP CO_2-eq/ha/yr)		n.a.					
Number of Print media			1				
Number of Publications/ Reports, promotional			1				

[21] The sum of costs from external assistance, consumables, travels, other costs from project start to December 31, 2022
[22] Reduction by tons CO2-eq/ha/yr

material produced							
Media coverage (newspaper articles, press releases, radio, podcast) [23]			2				
Website – visits[24]			614				
Climate Performance (tons/year CO_2)		1200					
Climate Performance (tons/year CH_4)		3,2					
Environ-mental Per-formance – resilience to flooding (ha)		10 ha				0 ha	
Baseflow contribution of receiving water (m3/s) by percentage		n.a.				0 %	
Average lowest groundwater level on the whole project site (cm below ground level)		91 cm (HL_05)					
Sustainable land use, agriculture, and forestry (hectares of agricultural land under sustainable management)					0 ha		

[23] Press release World's Wetland Day 2022, interview in LIFE podcast 'LIFE in a warming climate' published on January 2023 https://open.spotify.com/episode/5YmRgysudtjWynGugPpTky?si=XwOJtFMOScWqqzUZ3yf9Pg

[24] Since the setup until 31 December 2022. The figure refers to the German and English webpages – https://www.nabu.de/natur-und-landschaft/moore/weltweit/life-multi-peat.html and https://en.nabu.de/topics/ecosystems/life-multi-peat.html

Habitats positively affected (ha) and change in percent cover of indicator species associated with their respective target habitat				0% 0 ha			0% 0 ha

5 Ireland

5.1 *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 (5ha), 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 20). Some sections of the site have been planted with conifer trees, however most of the site consists of blanket bog.

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

Figure 20: Photos from within Doire Fhada, which shows the steeply sloping ground onsite (top) and past tree planting (lower).

5.2 *Methods-Adaptations*

All methods outlined in Chapter 2 are employed at the two restoration sites.

5.3 *Current State*

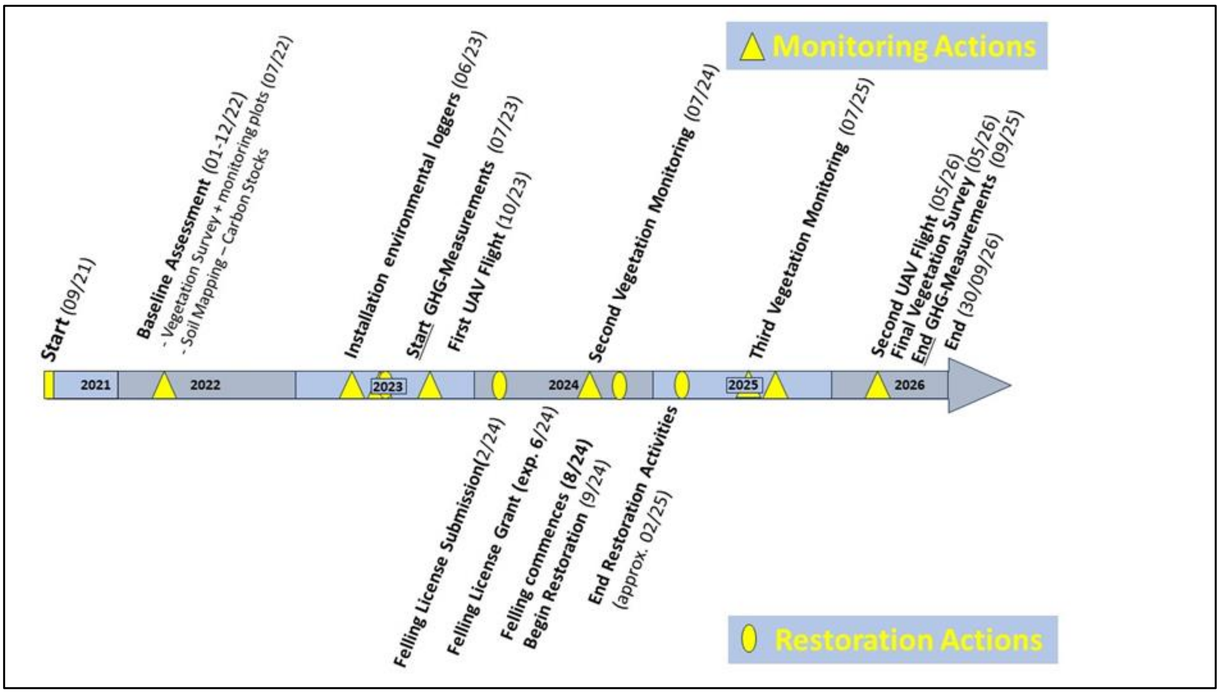


Figure 21: Timeline showing restoration- and monitoring progress for Ireland.

5.4 *Results*

5.4.1 *Carbon Stocks*

Above ground carbon stocks were estimated for the last monitoring report based on aerial photography and ground surveys, and included areas of plantation which were damaged by fire in 2010. Since then, we have completed drone flights for the forested sections of both sites (October 2023), and refined our estimates for above ground biomass of forested areas to exclude these areas of deadwood. Using Drone Imagery, forested areas were re-mapped and areas of live forestry were calculated containing 16.46ha Doire Fhada, and 34.06 ha at Fionnán. Within the forested sections we sampled nine no. 10x10m plots within the sites to estimate woody density. Plots of different densities were chosen for sampling, and we upscaled results based on drone imagery and ground surveys.

Within each plot, we measured DBH, height and stand density. Stem volume was then calculated as if it were a cylinder. Wood density per species (0,38 tonnes d.m. m^3) was taken from relevant Irish literature (Green et al., 2007). Wood density was multiplied by volume/hectare of the stand of which 50% is carbon.

Above ground biomass within the plots ranged from 122,57C/ha in the least dense forests to 1798,183C/ha in the densest sections of forestry.

The total estimate of above ground carbon stock based on these calculations is therefore: 58.247.4t (14.306,05 t at Doire Fhada and 43.941.4t at Fionnán).

For the calculation of the **below ground carbon stocks**, sampling stations within the project area based on representative habitats within the site as a whole, were selected prior to fieldwork. The selected stations correlate with the GHG/environmental monitoring stations described in section 5.4.3. Four sampling stations were selected at Doire Fhada (Figure 22): Control site, Blanket Bog, Open Forestry and Sitka Spruce. The Control Site represents an area of intact/ undisturbed Blanket Bog. Three sampling stations were selected for Fionnán (Figure 23): Blanket bog, Sitka spruce and Open Forestry.

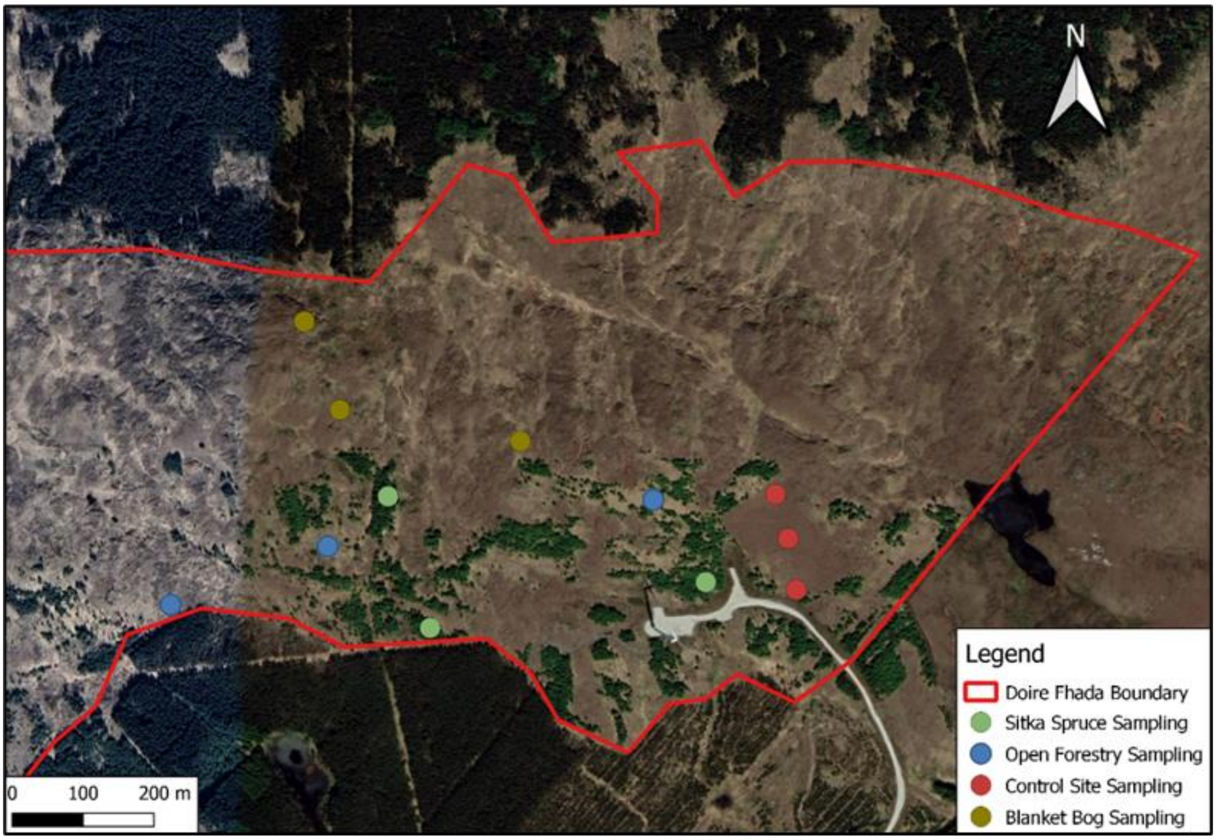


Figure 22: Sampling Stations at Doire Fhada

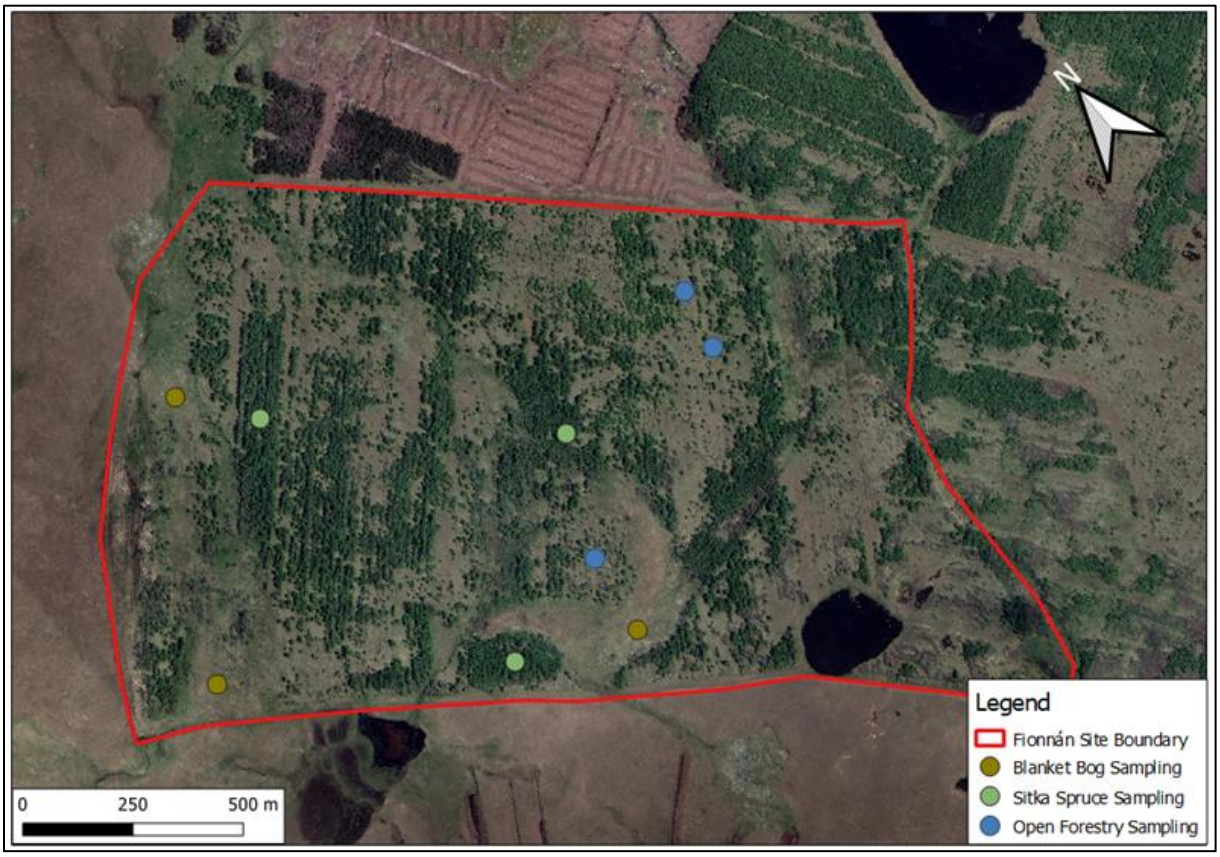


Figure 23: Sampling Stations at Fionnán

Sampling Methodology

Sampling was carried out following the Interreg Care PEAT Protocol for homogenous soil carbon stock measurements. The top layer of vegetation was removed, and cores were taken with a Russian Auger which can sample a depth of 50cm at a time. The entire peat profile was sampled from bedrock to peat surface. There are no mineral soils present within the project area. Each core was divided into 10cm sections, which were stored in airtight, individually labelled plastic bags and brought to the lab for analysis.

In total, 30 peat profiles were taken at Doire Fhada ranging from a depth of 0,30m-4,10m. No cores have been taken at Fionnán as of this annual report. However, this is anticipated to be completed by May 2024. At the time of writing, only one core has been fully processed. This core was taken at the Control Site in Doire Fhada (Figure 24), and the calculations for bulk density and carbon concentrations are based on this core alone. Results will be refined in early 2024 as more cores are processed.

Figure 24: Core taken at Control Site in Doire Fhada

Figure 25: Sampling stations at Doire Fhada 1) Open Forestry 2) Blanket Bog 3) Sitka Spruce 4) Control Site

Bulk Density

To calculate bulk density, we weighed peat samples after sample collection. They were then placed in an oven at 60 degrees Celsius for 3-5 days until all moisture had evaporated, and then reweighed after removal from the oven. Soil bulk density has been calculated by dividing the dried mass of each sample by its volume.

Carbon concentrations

The Loss on Ignition (LOI) method was used to determine soil carbon concentrations. At the time of writing only one core has been fully processed and therefore total carbon concentrations for the project area are not available yet.

Samples were first homogenised using a mortar and pestle and passed through a sieve. A small amount of the sample (c. 0,5g) was weighed and placed into crucibles of a known weight, and incinerated at 550°C for four hours. The samples were then reweighed to determine organic carbon and carbon stock calculations.

The soil carbon content for each depth interval was calculated as follows: $Soil\ carbon\ (t\ ha^{-1}) = OC\ (\%) * SBD\ (g\ cm^{-3}) * depth\ interval\ (cm)$.

For Core no. 1 at the Control Site a depth of 4,1m was recorded and from this, a carbon stock of 3108 t/ha was calculated.

Carbon stock

253 peat depths (211 at Doire Fhada and 42 at Fionnán) were taken throughout the project area and was reported on in last years monitoring report.

Carbon stock for each of the 253 depths were estimated based on a processed peat core at the Control Site. Below ground Carbon Stock for the entire project area is estimated at 217.177 tonnes – 78.159 tonnes at Doire Fhada (Figure 26), and 139.017,8 tonnes at Fionnán (Figure 27). Given that these estimates are based off of a core taken at the control site, which represents intact well preserved peatland, actual carbon stock is likely to be lower.

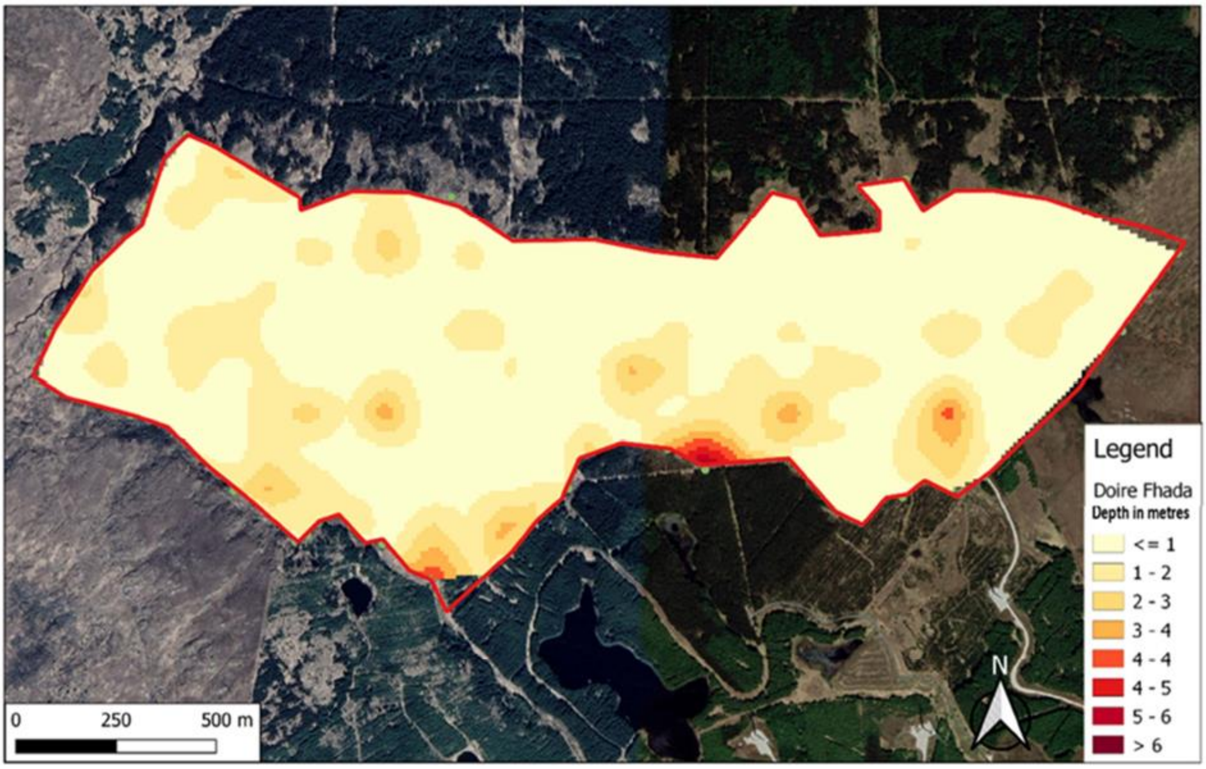


Figure 26: Peat depth map produced for Doire Fhada for last years annual monitoring report

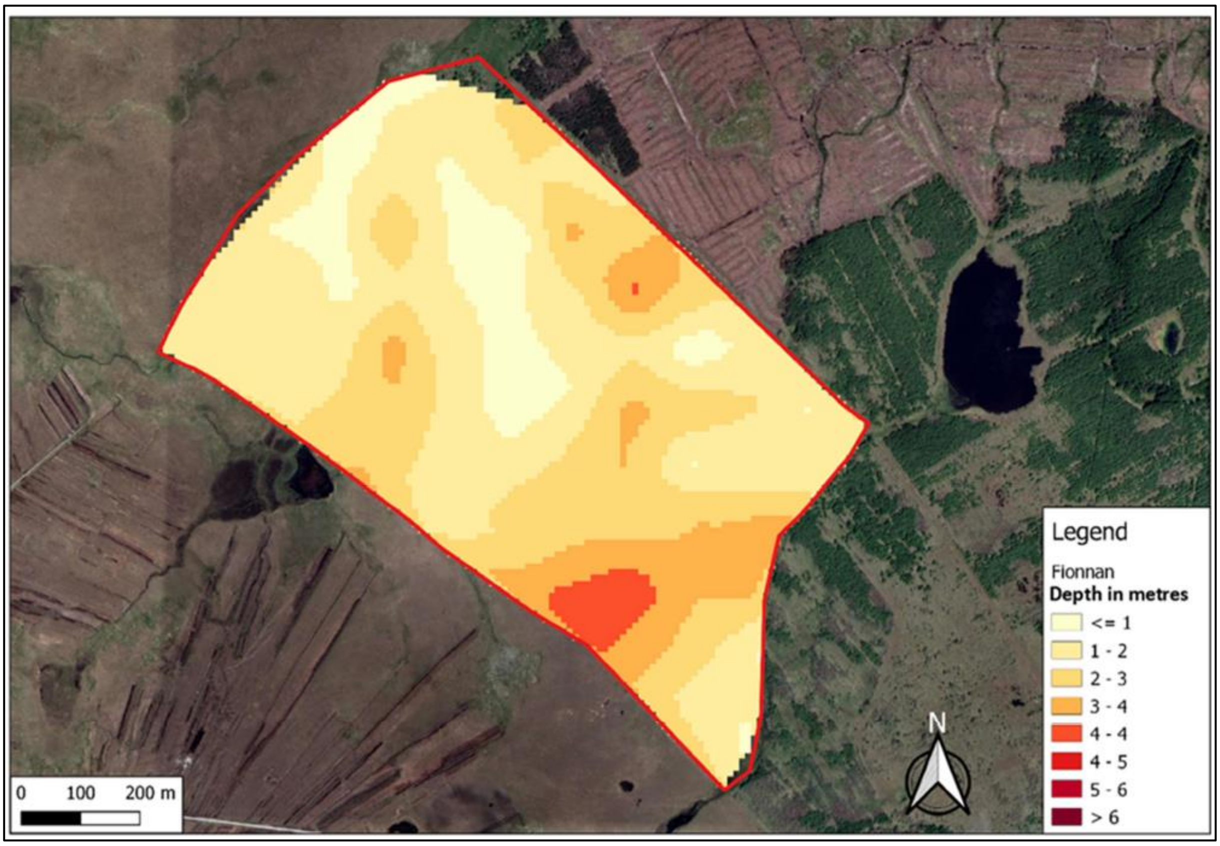


Figure 27: Peat depth map for Fionnán site.

5.4.2 *Hydrological Monitoring*

Surface water

Doire Fhada is located within the Corrib Catchment area. It is drained by six natural watercourses which flow from south to north. These water courses flow both aboveground and underground. This is clearly visible in the westernmost stream mapped in Figure 28, which is shown in three segments. The gaps in the mapped stream show where the stream disappears underground. The easternmost stream mapped in Doire Fhada has its source at the lake located along the eastern boundary of the site and flows southwards through Doire Fhada. Given the steep landscape within the site, water flow is fast within these streams.

Fionnán is located within the Galway Bay North catchment area. It has fewer watercourses, and similarly has sections of streams that flow both above and below ground, with thick Molinia and scattered Phragmites australis growing on the banks of the stream. Streams flowing within the site follow a westerly direction, eventually joining together just outside the northwest corner of the site. Given the more even topography at Fionnán, stream flow is slower than at Doire Fhada.

Figure 28: A & B: Watercourse within Doire Fhada flowing from south to north. C: Watercourse exiting the western boundary of Fionnán. D: Lake towards the southern boundary of Fionnán.

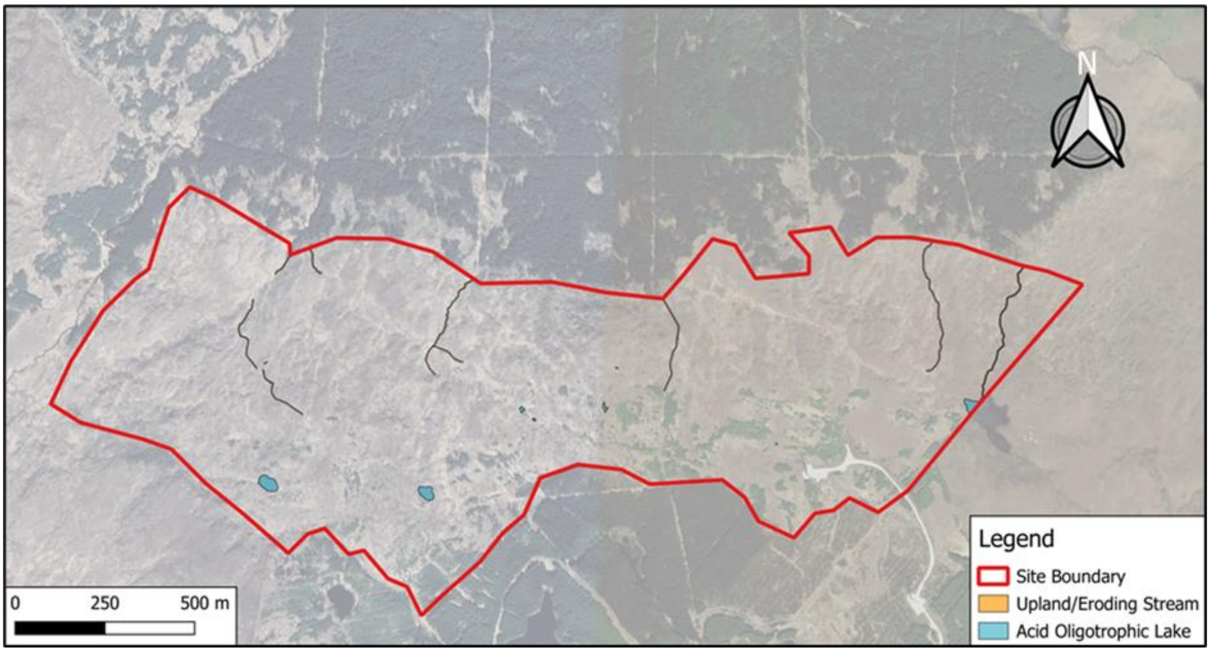


Figure 29: Streams and lakes within Doire Fhada. Stream flow is from a south to north direction.

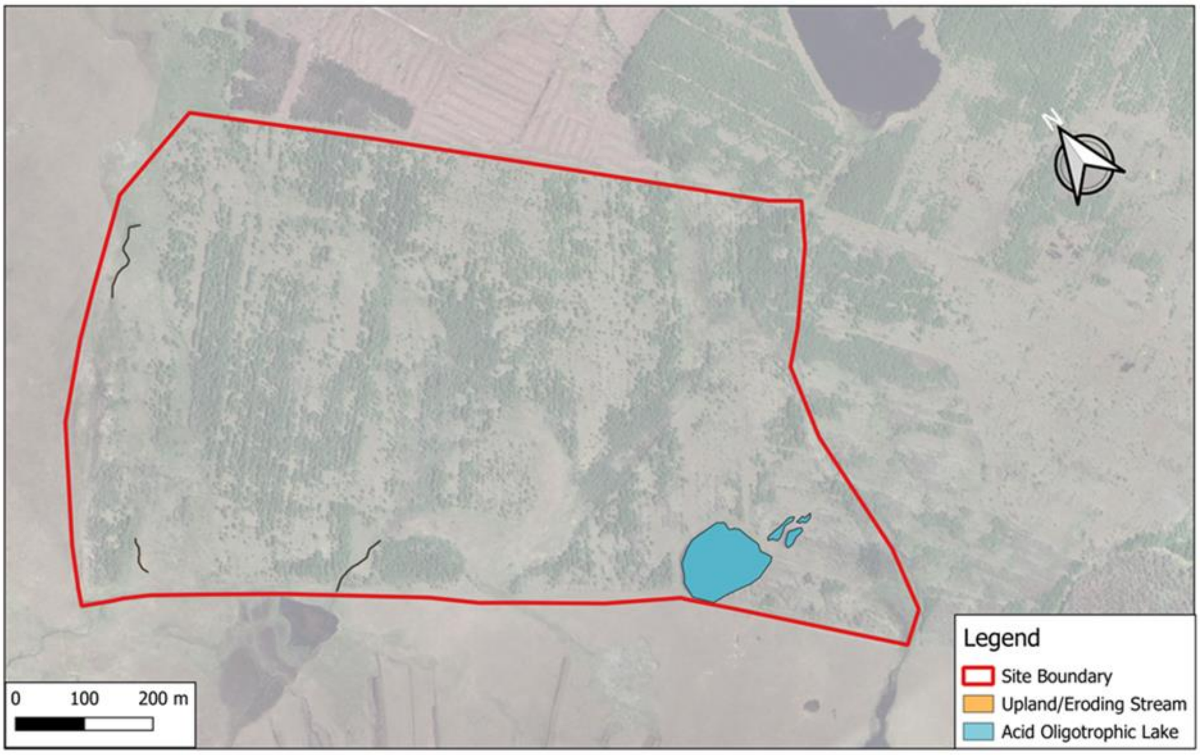


Figure 30: Streams and lakes within Fionnán, with stream flow in a westerly direction

Groundwater monitoring

Groundwater water levels are monitored by Zentra Dataloggers at five different locations throughout the project area. Three are located at Doire Fhada, directly adjacent to GHG monitoring stations – Blanket Bog (Control Site), Sitka Spruce Plantation, and Open Forestry. The Control Site is an intact section of blanket bog which has never been drained. Both Sitka

Spruce and Open Forestry have had their hydrology altered by drainage works to facilitate tree planting onsite.

Two additional dataloggers are located at Fionnán on Blanket Bog and in a Sitka Spruce Plantation. At Fionnán, the area of Blanket Bog is adjacent to drainage ditches, and therefore the water levels here fluctuate much more than at the Control Site.

Groundwater (and all environmental parameters) are measured at 15minute intervals. Data collected by the loggers are uploaded to a cloud at least once a day. Groundwater levels within the project area clearly affected by land management. At Doire Fhada (Figure 31), the control site, which is an intact area of blanket bog, has its water table at or near ground level. At Sitka Spruce Plantation and Open Forestry water levels are well below ground levels with more significant fluctuations that at Control Site.

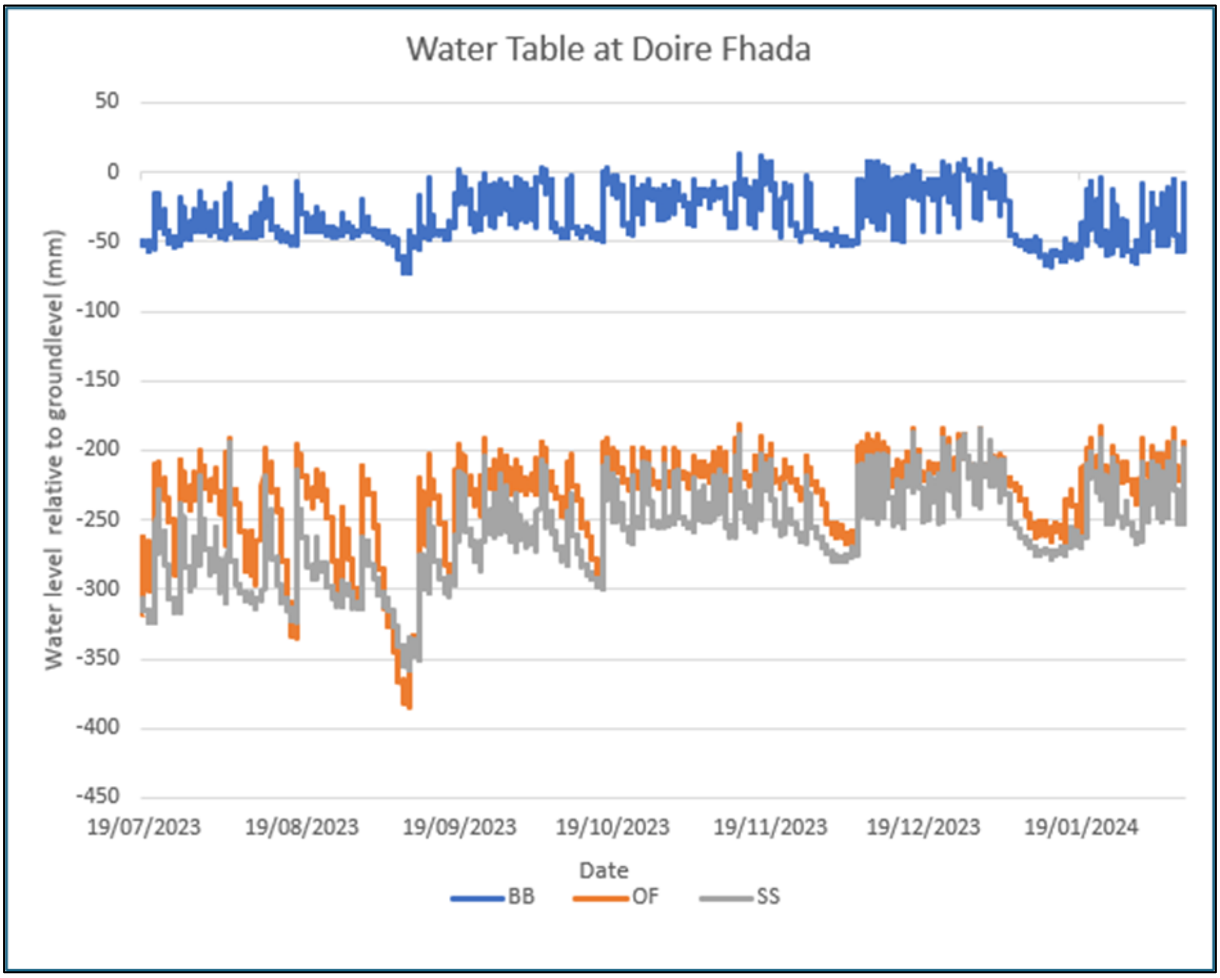


Figure 31: Relative groundwater levels at Dhore Fhada since July 2023.

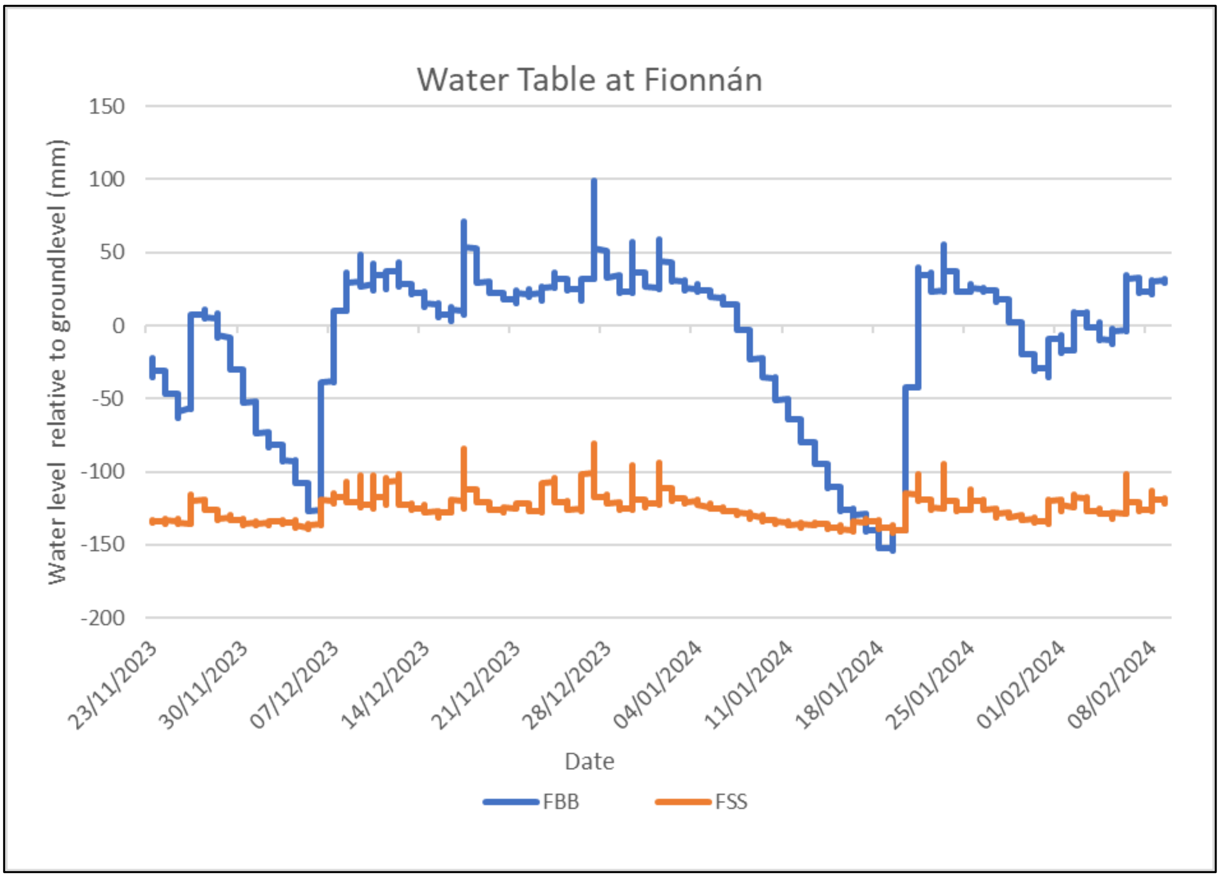


Figure 32: Relative groundwater levels at Fionnan since November 2023.

5.4.3 GHG-Measurements

Greenhouse gas measurements at Doire Fhada started in August 2023. Three stations were selected based on land type – Blanket Bog (Control Site), Open Forestry, Sitka Spruce. They were chosen as they are the most dominant habitats onsite. GHG measurements from these stations will therefore be used to upscale and calculate emissions from the site as a whole.

Each station consists of three circular 40cm diameter collars where GHG emissions are measured monthly. Measurements are made under light and dark conditions.

More detailed descriptions of each station are included below. Each station is also equipped with data loggers which continuously monitor light intensity, soil moisture, soil pH and groundwater waterlevels. Additionally, we have a stationary NDVI camera that can be moved to each station to compare with the aerial (UAV data).

1) Blanket Bog Control (BB)

This station represents intact blanket bog onsite (Figure 33). As drainage/cutting has not taken place within this station, it is used as a control site. GHG measurements from the site are expected to represent that of “natural” peatlands within the project area.

Figure 33: GHG monitoring station on Blanket Bog at Doire Fhada. The station also records environmental conditions onsite.

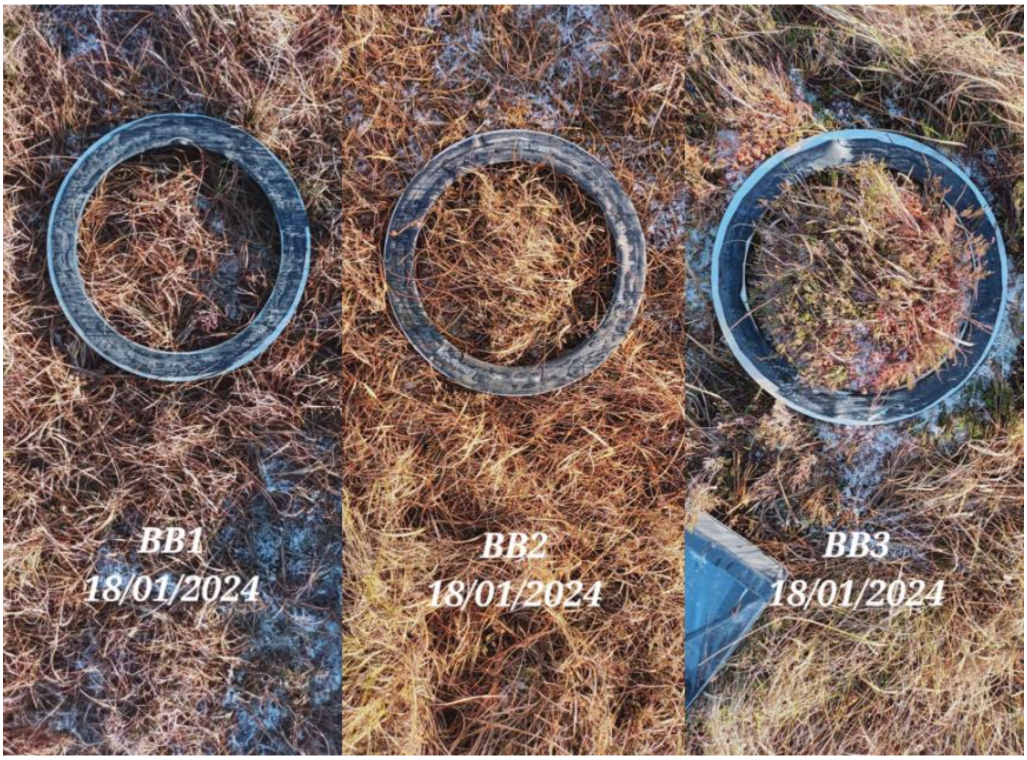


Figure 34: Three representative collars located within BB Control at Doire Fhada.

2) Open Forestry (OF)

This station represents areas of land which were drained for the planting of commercial conifer trees (Figure 35). Sections of the site in Doire Fhada were burnt in 2010, and many of the trees within this station were also burnt. No replanting occurred after the fire. The land remains drained.

Figure 35: Three representative collars located within OF at Doire Fhada.

3) Sitka Spruce (SS)

This station represents the forested sections of the site (Figure 36). The site has been drained and has mature stands of Sitka Spruce plantation.

Figure 36: Three representative collars located within SS at Doire Fhada.

5.4.4 Environmental Parameters

Doire Fhada

At Doire Fhada, each GHG monitoring station is situated next to Zentra data loggers which record Environmental Parameters from sensors installed onsite. Each of these stations record Soil Moisture, Soil pH and Groundwater Level. They record and log the data every 15minutes, and the data is then uploaded to a cloud service, and thus can be monitored remotely.

In addition to the environmental parameters listed above, the stations at BB Control and SS also record light intensity adjacent to the GHG collars. The BB Control Station also records NDVI.

Fionnán

At Fionnán 2 environmental parameter stations have been installed which monitor Soil Moisture, Soil pH and Water level.

Figure 37 Environmental monitoring station at Fionnán Blanket Bog.:

Two light sensors are installed onsite, one at the Blanket Bog (Control Site) and one in the Sitka Spruce plantation. Light levels are much lower within the forest plantation than on the open blanket bog as is demonstrated below.

Figure 38: Environmental monitoring station at Fionnán Blanket Bog.

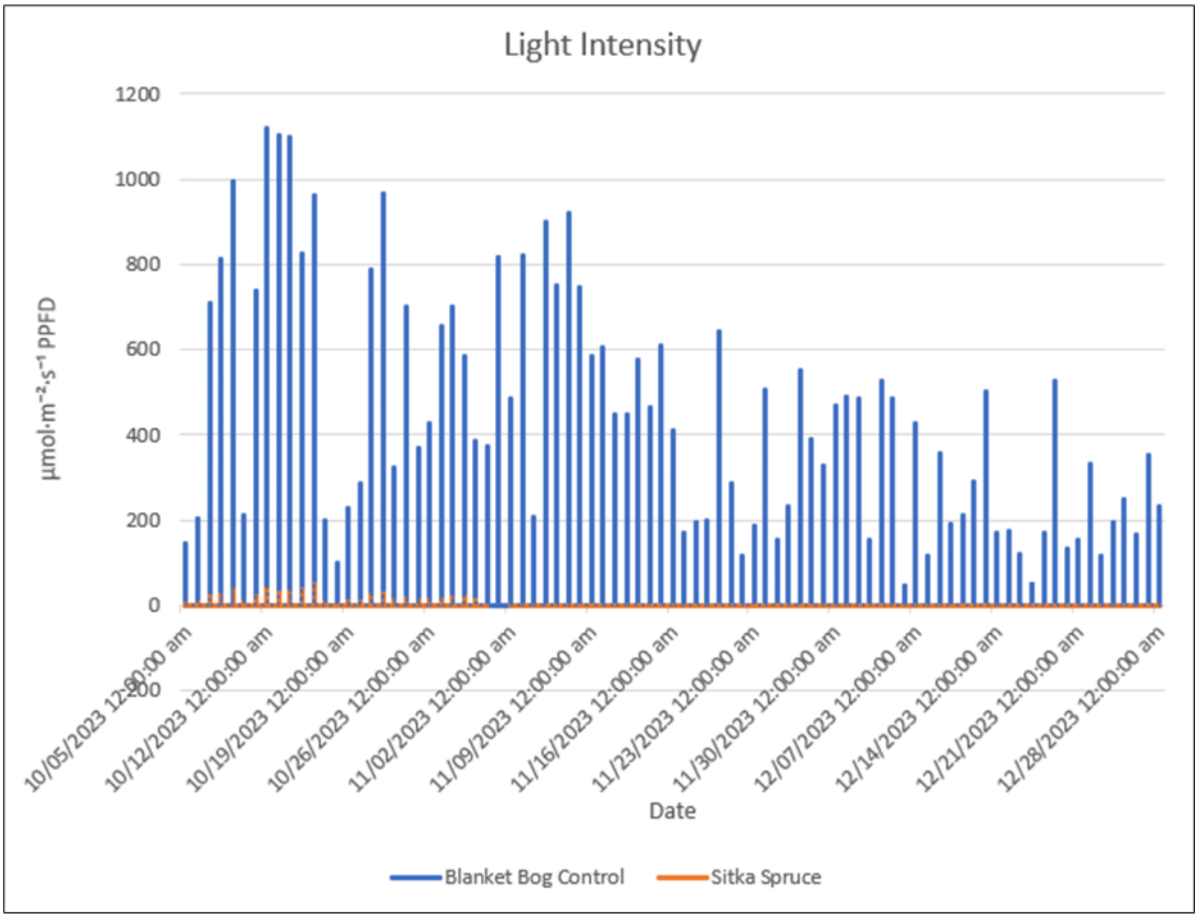


Figure 39: Representative light (PAR) intensity levels in the open bog (blue) and sitka spruce (orange) areas from October to November 2023.

5.4.5 UAV/Satellite Image Monitoring

Drone flights took place at Doire Fhada and Fionnán on 7th October 2023. Drone imagery was processed using the photogrammetry software Pix4D, to provide a more detailed and accurate DEM model to that provided in the previous monitoring report. Given the large area of Doire Fhada (178.68ha), the site was only partially mapped. The area covered by the flight was chosen to correlate with the area where restoration works are expected to take place. Fionnán was mapped in its entirety. From these flights we processed Digital Elevation Map profiles (DEM) (Figure 40 & Figure 41). Vegetation and other indices such as Normalised Difference Vegetation Index (NDVI) and wetness indices (NDWI) are currently being processed and we will provide these results in the 3rd Annual Monitoring Report.

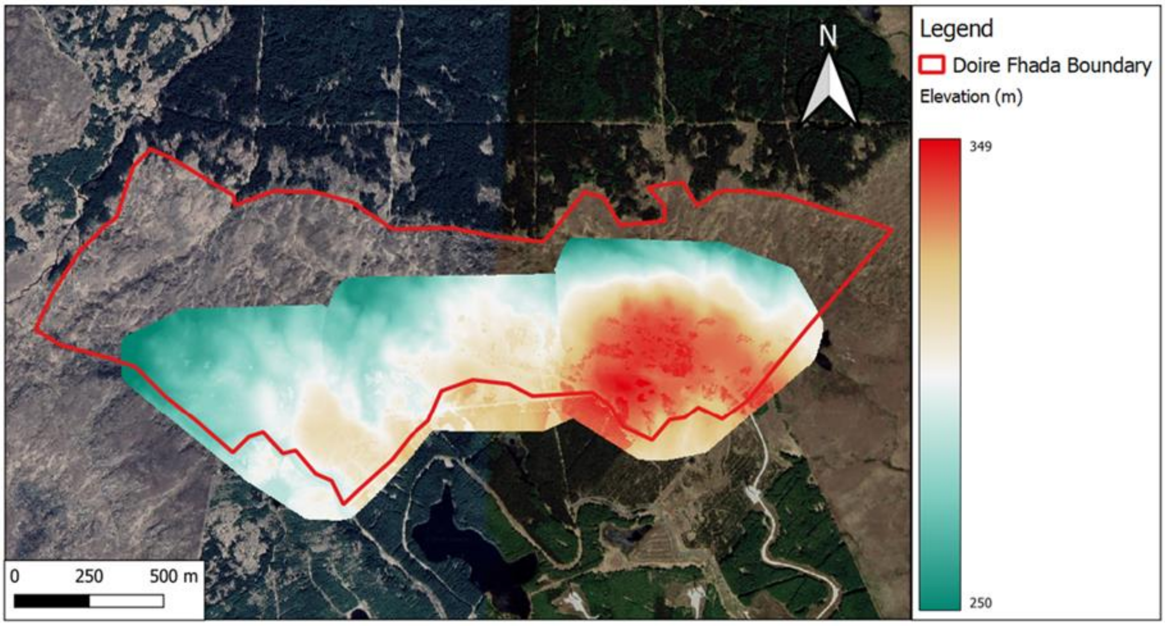


Figure 40: DEM created from drone flights at Doire Fhada October 2023.

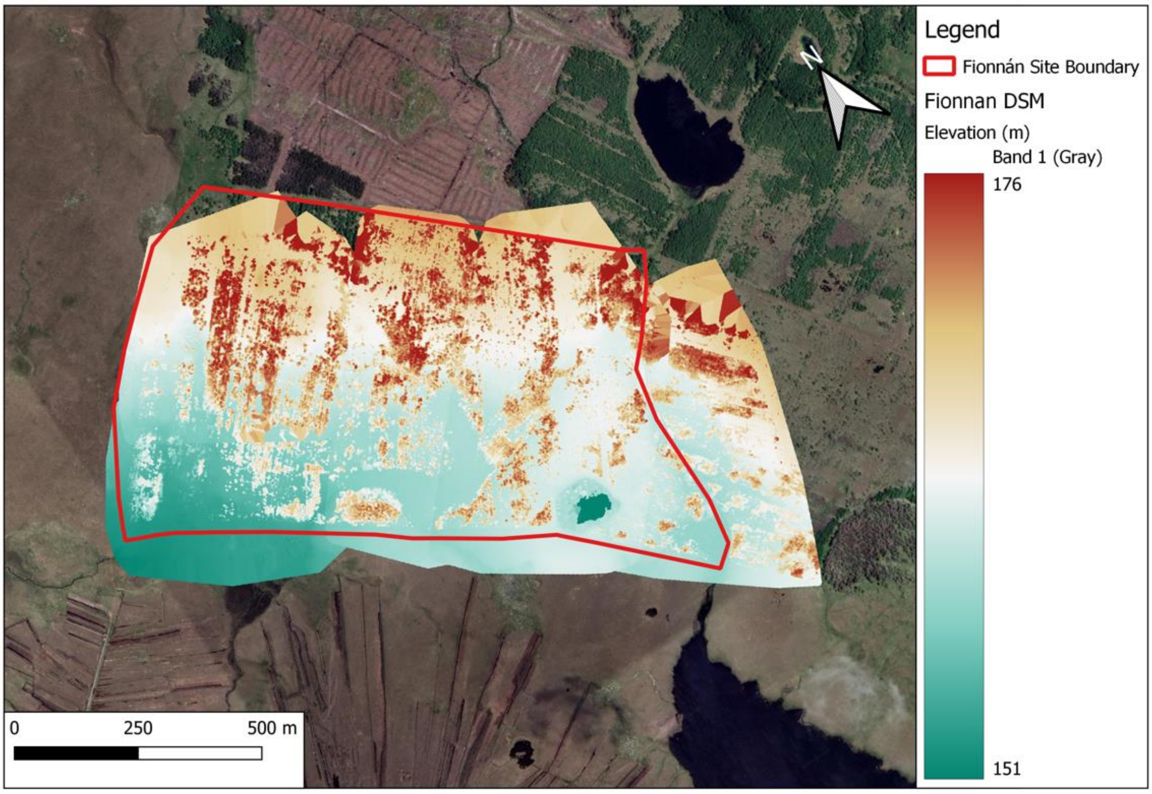


Figure 41: DEM created from drone flights at Fionnán in October 2023.

5.5 Discussion and Challenges

Site works

The project site lies under the management of the Cloosh Valley Wind Farm yet ownership belongs to a semi-state authority (Coillte). This adds additional administrative and oversight layers to project planning and coordination of activities. As a result, planning permission and applications for preliminary activities such as deploying environmental monitoring (sensors), felling licenses and many project activities have been delayed with these administrative activities. However, we've recently made substantial progress in this regard, and we anticipate substantial progress and restoration activities to begin in 2024.

Environmental Monitoring

In the west of Ireland, the weather is very unsettled and it is difficult to find a day with consistent light conditions for GHG measurements and Earth Observation data (cloudless skies). Light consistency can be a challenge for the three-minute intervals at each collar, but also between GHG stations throughout the day. These conditions result in delays in field deployment and often cancellation during measurements, but it has not resulted in missing a monthly monitoring attempt.

5.6 *Communication indicators*

Ireland							
Units	INDICATORS						
	DIRECT			INDIRECT			
	Economic contribution	**Ecosystem regulating services** (GHG emissions)	**Awareness raising**	**Ecosystem supporting services** (habitat for species)	**Ecosystem provisioning services** (raw materials, freshwater)	**Ecosystem regulating services** (Fire/flood prevention)	**Ecosystem cultural services** (recreation, aesthetic appreciation, and inspiration)
Stakeholder and Duty holder engagement			6				
Information boards/panels			2				
Employment (Individuals/ companies hired by the project)	6						
Amount spent (€)[1]	142,593						
Number of jobs[2] (FTE and PTE)	1 (FTE) 5 (PTE)						
Number of events organised or participated			6				
Number of participants in events organised by the beneficiary			925				
Number of hectares restored		0					
GWP reduction[3] (tons of CO_2-eq/ha/y)		TBD					
Number of Print media			1				
Number of Publications/Reports, promotional material produced			0				
Media coverage (newspaper articles, press releases, radio, podcast)			5				
Website – visits[4]							
Climate Performance (tons/year CO2)		TBD					

Climate Performance (tons/year CH4)		TBD						
Environmental Performance – resilience to flooding (ha)		0						
Baseflow contribution of receiving water (m3/s) by percentage		TBD						
Average lowest groundwater level on the whole project site (cm below ground level)		-40*						
Sustainable land use, agriculture, and forestry (hectares of agricultural land under sustainable management)		NA						
Habitats positively affected (ha) and change in percent cover of indicator species associated with their respective target habitat		0						

*= GW levels since July 2023.

TBD: to be determined after annual monitoring

Event participants: P2P (600); KC Irish fest (200); Ecoshow (40); Ardnacalla (60); VT(15); Rewilding (5); Insight(5)

[1] The sum of costs from external assistance, consumables, travels, other costs
[2] persons, not all actually working part time. Officialy the work of these persons is divided in the project.
[3] Reduction by tons CO2-eq/ha/yr
[4] Due to the recent EU Data Protection Law (GDDR), which allows visitors the option to block statistical tracking of the website traffic; it is assumed the figures may be higher.

6 Netherlands

6.1 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 Annual Monitoring Report we will only give a short summary. Full details are available in Dutch.

The Witte Veen is a Natura2000 reserve in the east of The Netherlands at the border with Germany (Figure 42). 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 43. In the above mentioned eco-hydrological analysis several of these cross sections are available.

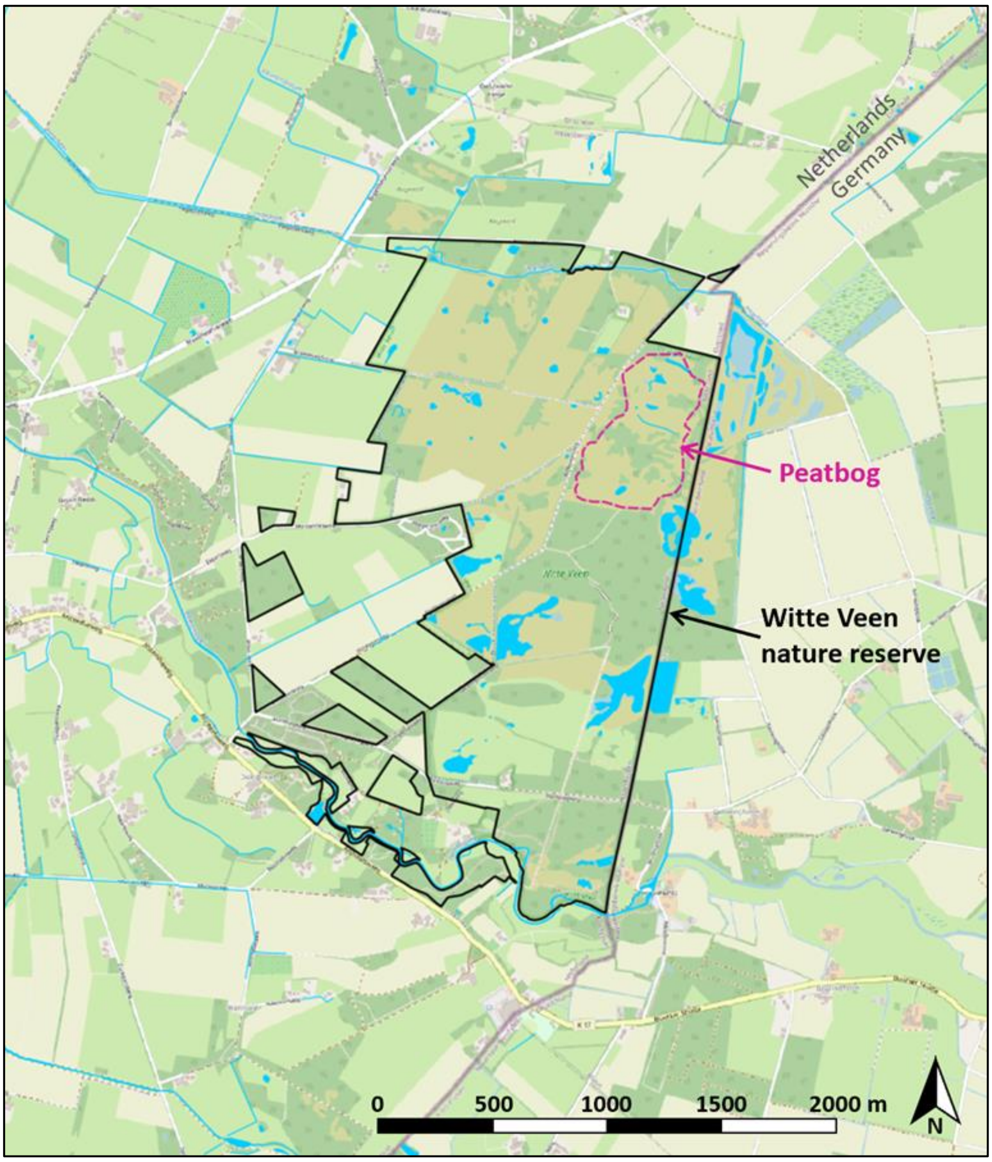


Figure 42: The Witte Veen nature reserve and the location of the peat bog.

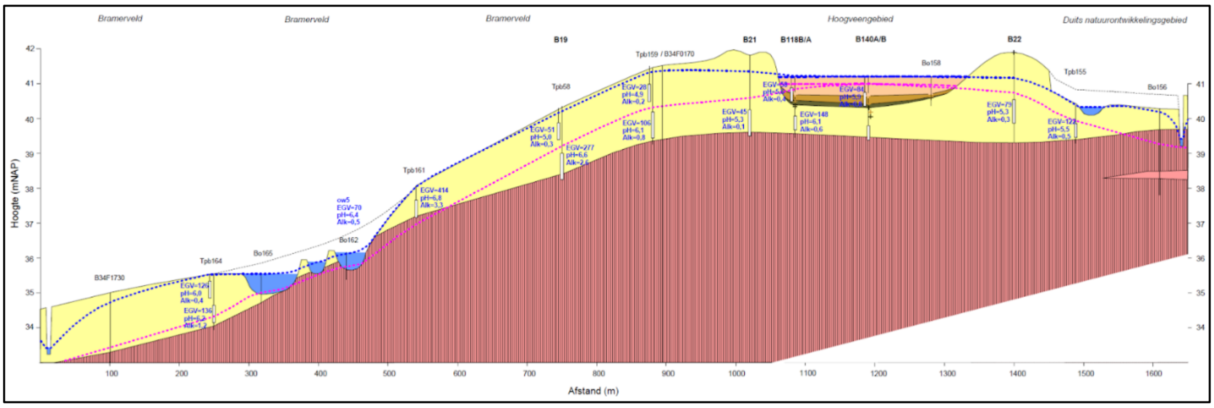


Figure 43 West-east cross section illustrating the geomorphological setting.

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 44. 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 45 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.

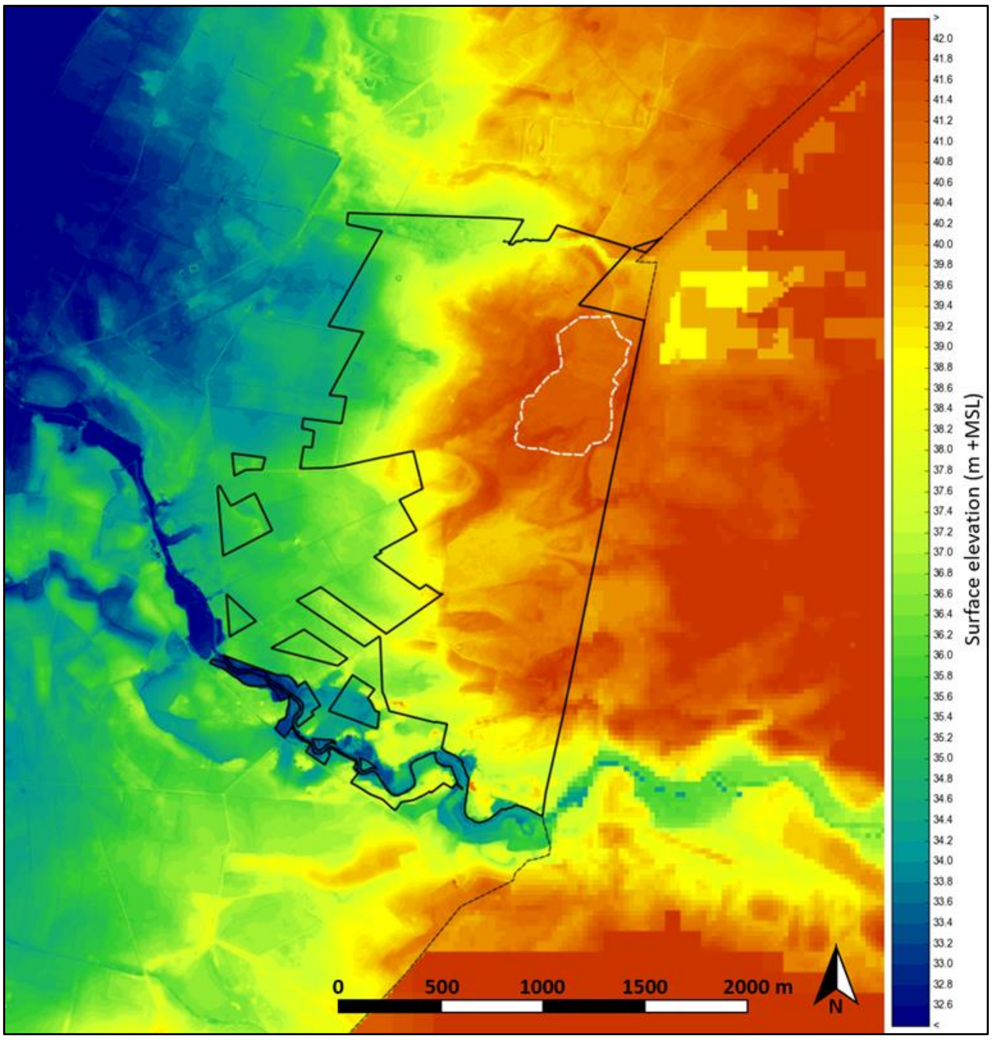


Figure 44: *DEM (5x5 meter resolution) of the Witte Veen and its surroundings.*

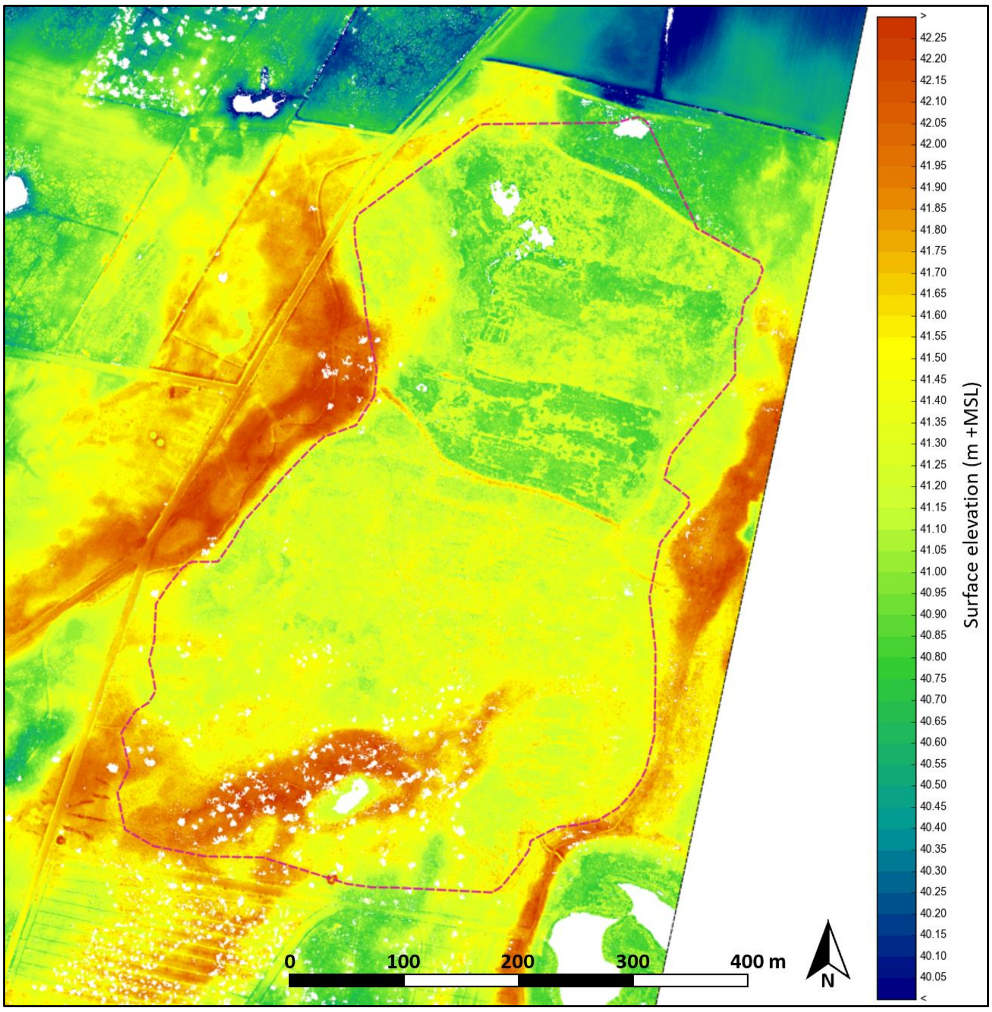


Figure 45: DEM (0.5x0.5 meter resolution) of the peat bog within Witte Veen.

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.

Vegetation was mapped in 2021 just prior to the start of the project. The vegetation map - shown in Figure 46 - 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 47. 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.

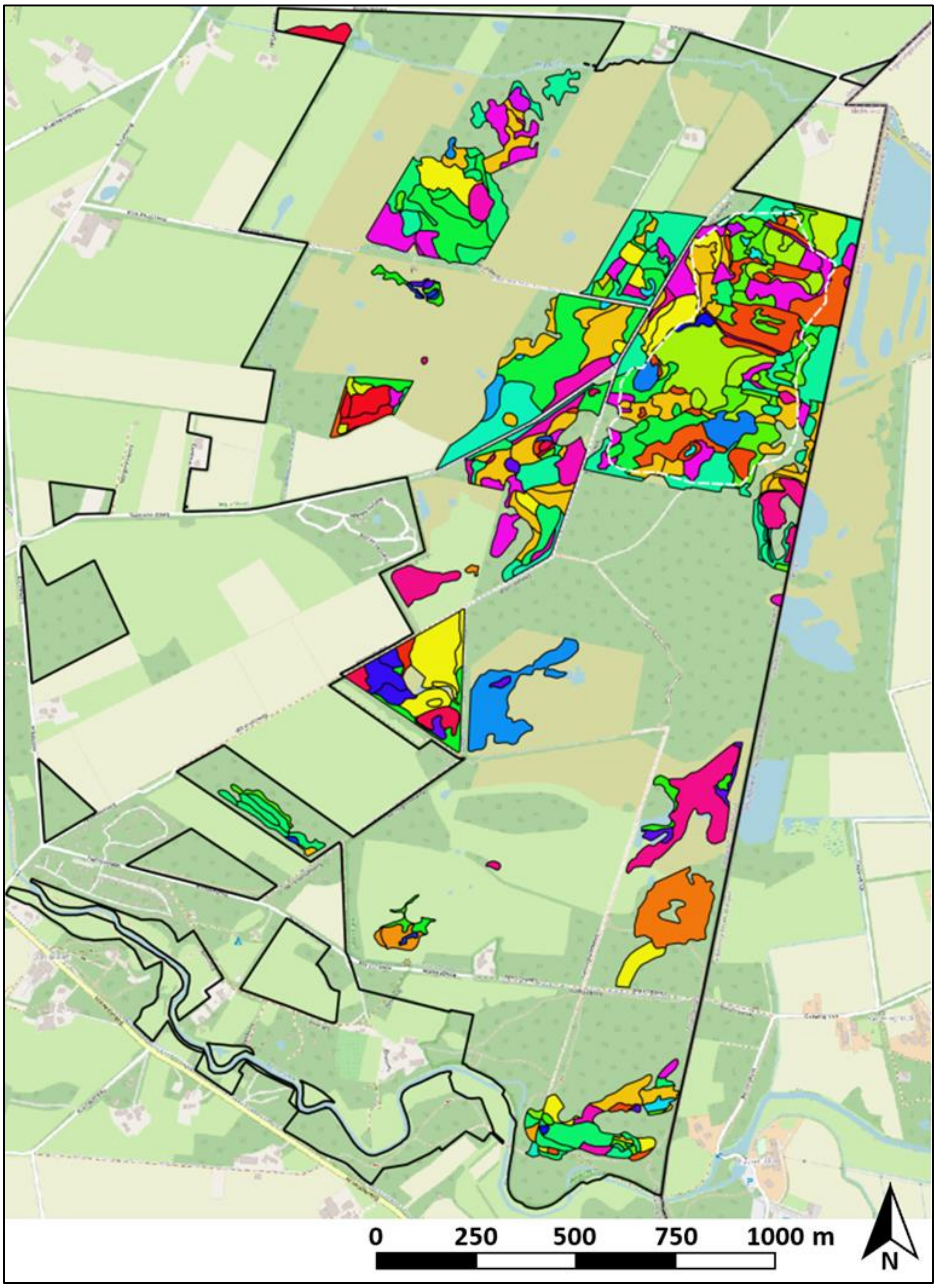


Figure 46: Vegetation mapped in 2021 in the Witte Veen.

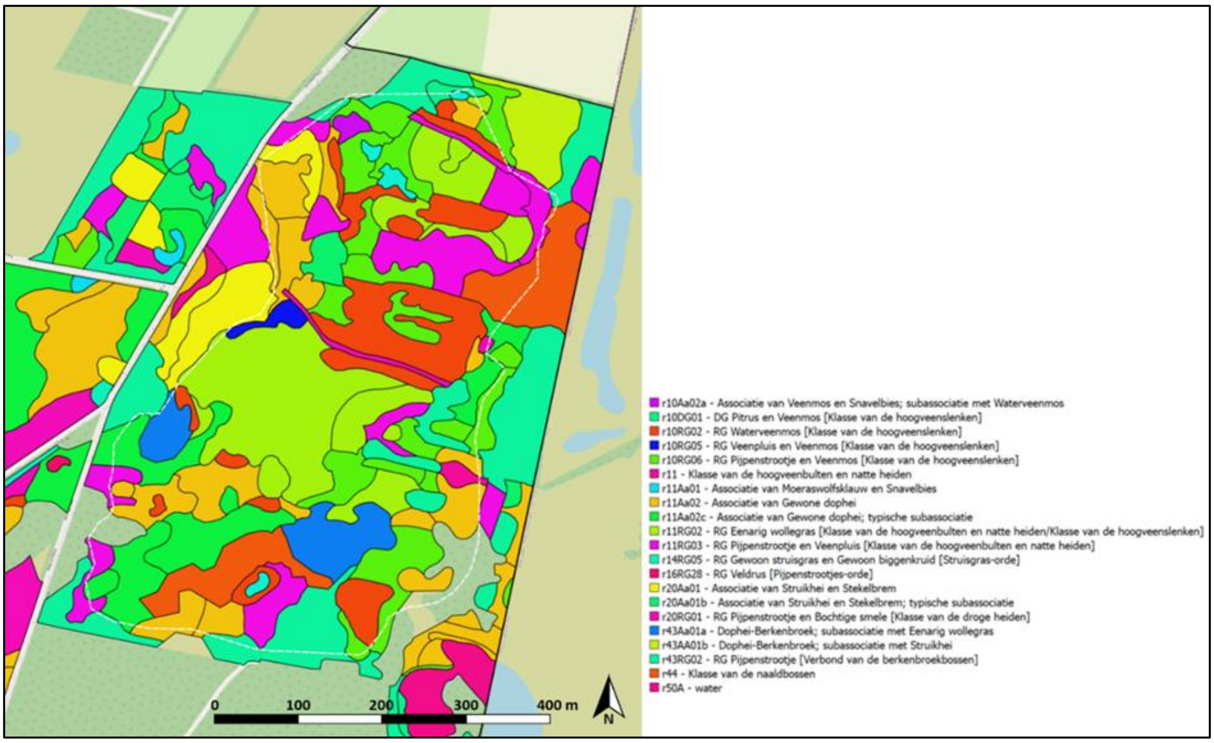


Figure 47: Vegetation map (2021), zoomed in on the peat bog in the Witte Veen.

Reference site

Together with the research partner GEMCE – which will measure the GHG fluxes – we have further discussed the most suitable reference site, because the other options turned out less optimal due to recent or ongoing restoration works. We have decided that the Engbertsdijksveen in the Netherlands (managed by SBB, the state forestry organization) is the most suitable site. 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.

6.2 Methods-Adaptations

In the Dutch project the following adaptations to the methods described in chapter 2 apply:

Above ground carbon stock

The change in carbon stock of above ground vegetation (trees) due to the restoration works is estimated by the weight of the removed trees. This is done by the contractor which performs the restoration works. From ground survey and aerial pictures the spatial fractions of removed and remaining trees will be estimated. This will be done after the restoration works and will be based on ground survey – performed at the start of the project and repeated after the restoration works – and aerial pictures.

UAV monitoring

This is not part of the monitoring in the Dutch site, since detailed ground data of the vegetation is available.

6.3 Current State

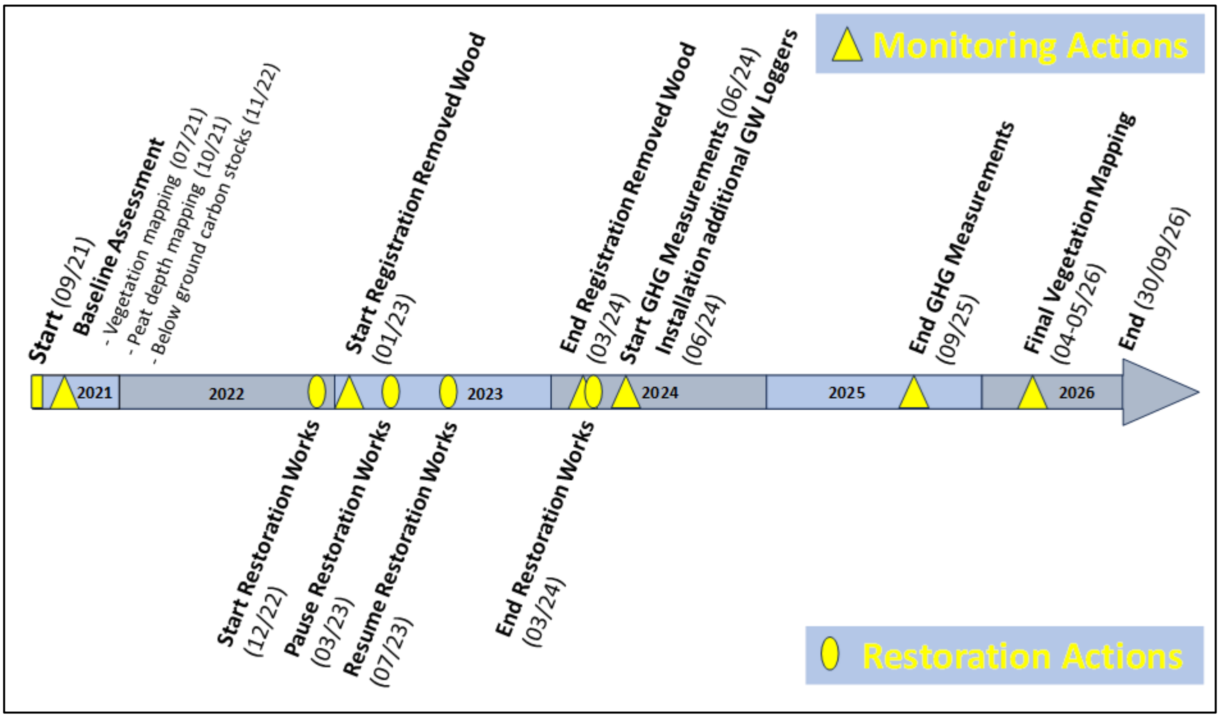


Figure 48: Timeline showing restoration- and monitoring progress for the Netherlands

6.4 Results

6.4.1 Carbon Stocks

The estimated carbon stock below ground in the peat bog is 5.144 tons C (18.865 tons CO_2-eq); see Annual Monitoring Report 1 (LIFE Multi Peat, 2023).

The carbon stock in the above ground biomass will be estimated by the contractor doing the restoration works; see section 6.2. Up to November 2023 the following biomass has been removed:

- Removed as stems: 303 tons
- Removed as wood chips: 2.144 tons
- Total removed wood: 2.448 tons

The carbon content in this removed wood (up to November 2023) is approximately 1.224 tons C (4.489 tons CO_2-eq). In 2024 the restoration works continue and additional wood will be removed. The above ground biomass – removed and remaining – in tons per hectare will be calculated after the works have finished.

6.4.2 Hydrological Monitoring

Monitoring of groundwater and surface water levels is continued in 2023 at the locations shown in Figure 49. Monitoring frequency is daily at datalogger locations and 14-daily at locations which are measured manually. Figure 50 shows an example timeseries, including a timeseries model. The modeled long-term linear trend is negative, which stresses the need for the restoration.

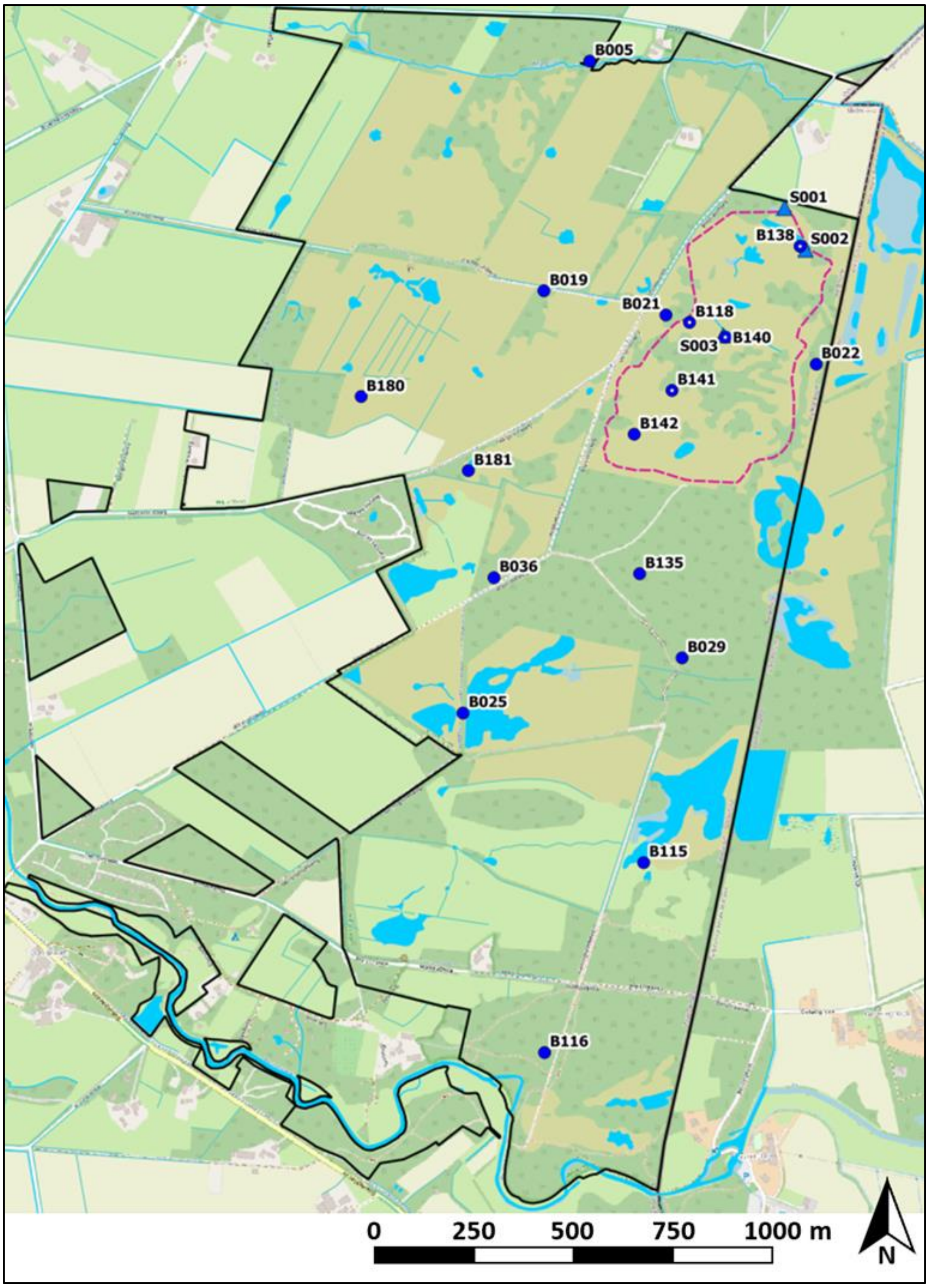


Figure 49: Location of the piezometers in the Witte Veen.

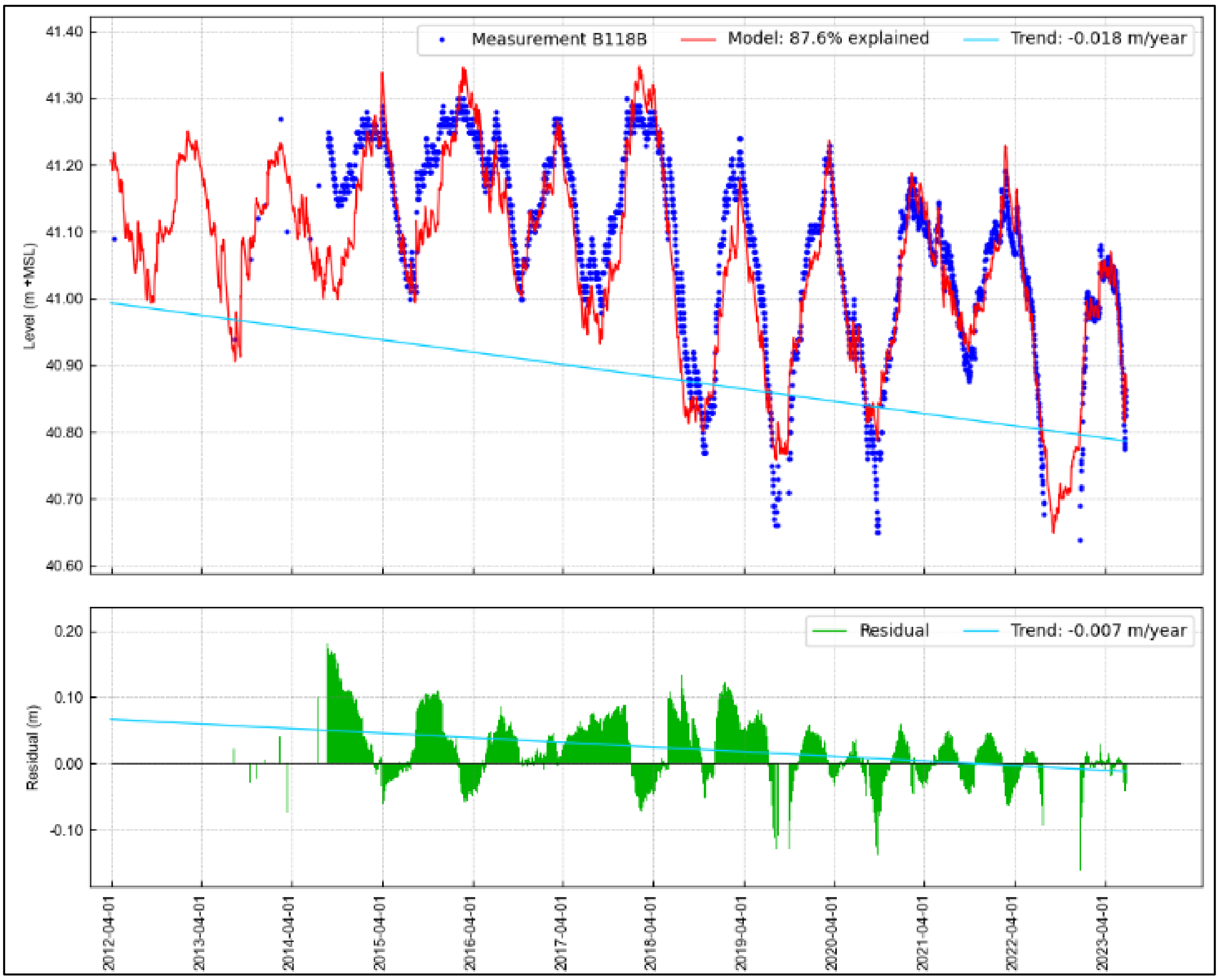


Figure 50: Groundwater timeseries of piezometer B118B: measurements (blue), timeseries model (red) and residuals (green). The light blue line is the modeled linear trend.

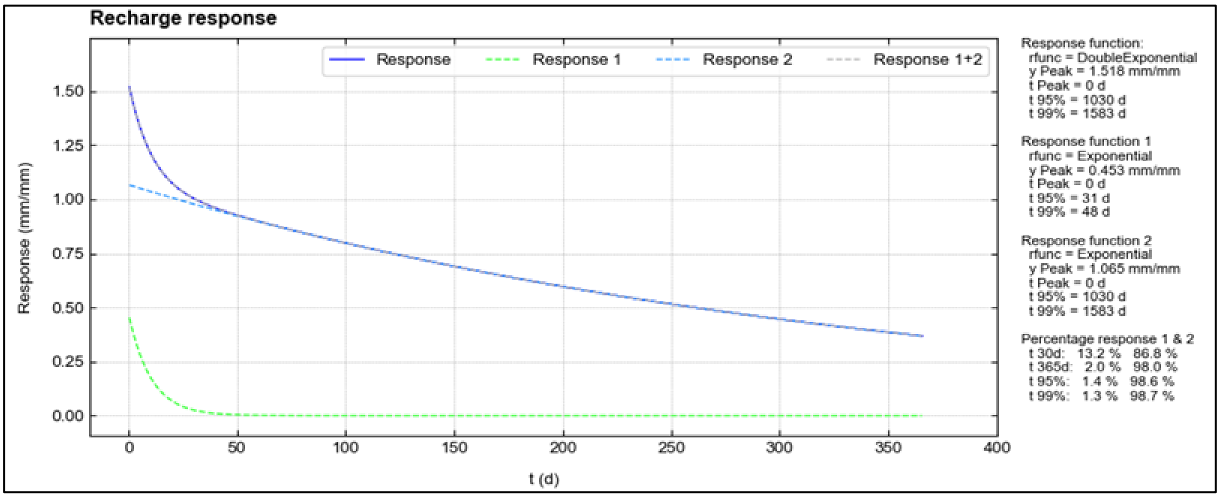


Figure 51: Modeled response to recharge (precipitation excess) of piezometer B118B. Total response (continuous blue line) and the decomposition into quick response (dotted green line) and slow response (dotted blue line).

6.4.3 GHG-Measurements

GHG measurements have not yet been carried out. First measurements on the selected habitat types in both the Witte Veen and the reference site (Engbertsdijksveen) are scheduled for 2024.

6.4.4 Environmental Parameters (if applicable)

Meteo data are derived from nearby weather stations of the Royal Dutch Meteorological Survey (KNMI) (see Figure 52).

On-site environmental parameters have not yet been measured.

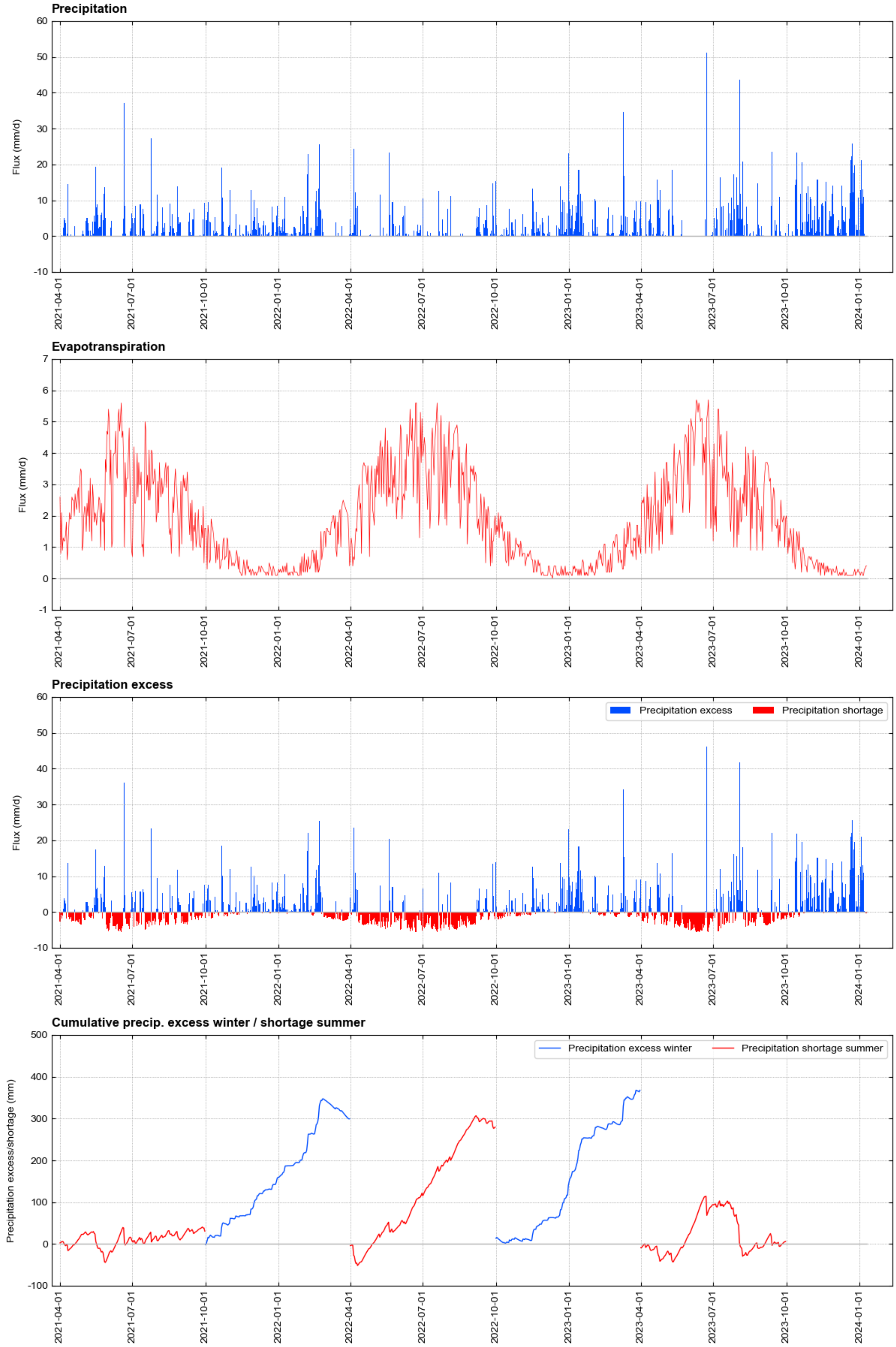


Figure 52: Meteo data for the Witte Veen in periode 2021-04-01 to 2023-12-31. Precipitation, evapotranspiration (reference), precipitation excess/shortage and cumulative winter excess and summer shortage.

6.4.5 *UAV/Satellite Image Monitoring*

Not applicable in the Dutch site.

6.5 *Discussion and Challenges*

In recent years the Netherlands faced various dry spring and/or summer periods, while the autumn of 2023 was 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 – 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.

The selection of the reference site turned out to be more difficult than expected. In most peat bogs in the Netherlands restoration works have been carried out very recently, are ongoing or are planned in next years. Further, geomorphological situations similar to the Witte Veen are hard to find. The most suitable site turned out to be the Engbertsdijksvenen. 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. However, there are some differences to the Witte Veen in terms of peat depth, degradation/exploitation history etcetera. This will be a challenge in the interpretation of the results.

6.6 Communication indicators

The Netherlands							
	INDICATORS						
	DIRECT			INDIRECT			
Units	**Economic contribution**	**Ecosystem regulating services** (GHG emissions)	**Awareness raising**	**Ecosystem supporting services** (habitat for species)	**Ecosystem provisioning services** (raw materials, freshwater)	**Ecosystem regulating services** (Fire/flood prevention)	**Ecosystem cultural services** (recreation, aesthetic appreciation, and inspiration)
Stakeholder and Duty holder engagement			40				
Information boards/panels							
Employment (Individuals/companies hired by the project)	5						
Amount spent (€)[5]	€ 411,337						
Number of jobs (FTE and PTE)	2						
Number of events organised or participated		6	6				
Number of participants in events organised by the beneficiary			50				
Number of hectares restored		56 ha					
GWP reduction[6] (tons of GWP CO_2-eq/ha/yr)		To be estimated after restoration					
Number of Print media -		2	2				
Number of Publications/Reports, promotional material produced			2				
Media coverage (newspaper articles, press releases, radio, podcast)		2	2				
Website – visits[7]							
Climate Performance (tons/year CO2)		To be estimated after restoration					
Climate Performance (tons/year CH4)		To be estimated after restoration					
Environmental Performance – resilience to flooding (ha)		N/A				0 ha	
Baseflow contribution of receiving water (m3/s) by percentage		To be estimated after restoration				0 %	

Sustainable land use, agriculture, and forestry (hectares of agricultural land under sustainable management)		N/A			0 ha		
Habitats positively affected (ha) and change in percent cover of indicator species associated with their respective target habitat		To be estimated after restoration		0% 0 ha			0% 0 ha

7 Poland

7.1 Project Site

Torfowiska Orawsko-Nowotarskie (Orawa-Nowy Targ Peat Bogs) PLC120003 is a Natura 2000 site located in southern Poland, in the Carpathian Mountains (Figure 53). 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.

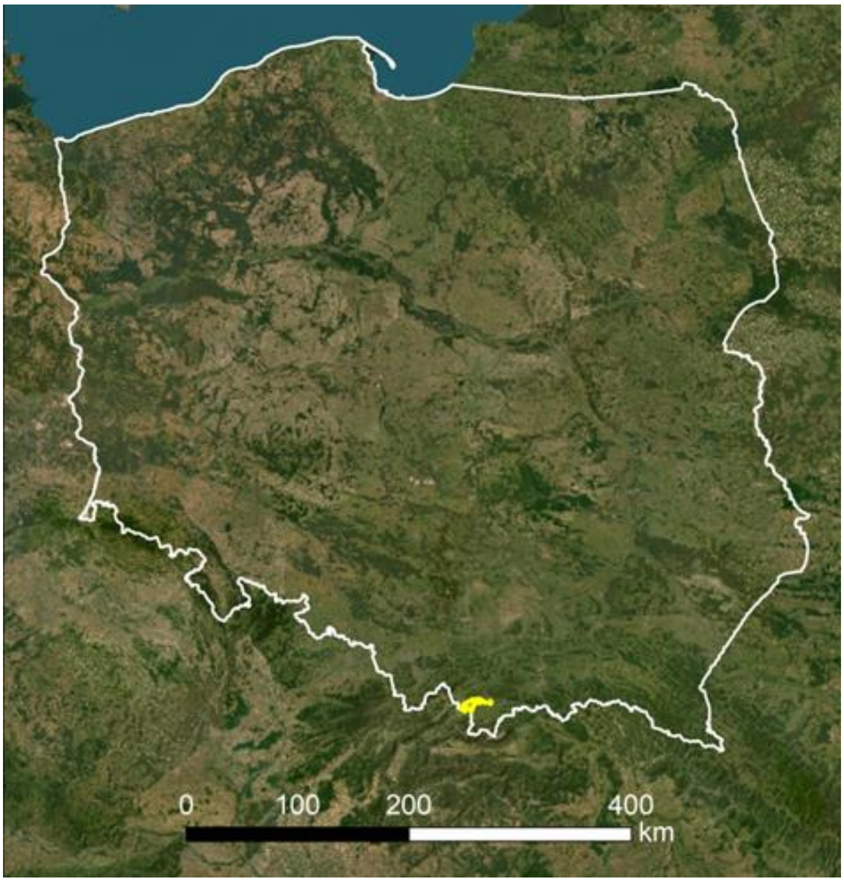


Figure 53: Map of Poland showing the location of the Torfowiska Orawsko-Nowotarskie PLC120003 Natura 2000 site (yellow polygon).

The first is Baligówka (Figure 54 left), one of the largest peat bogs in the region, with an area of 160 ha, and the second is Bór za Lasem Kaczmarka (Figure 54 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.

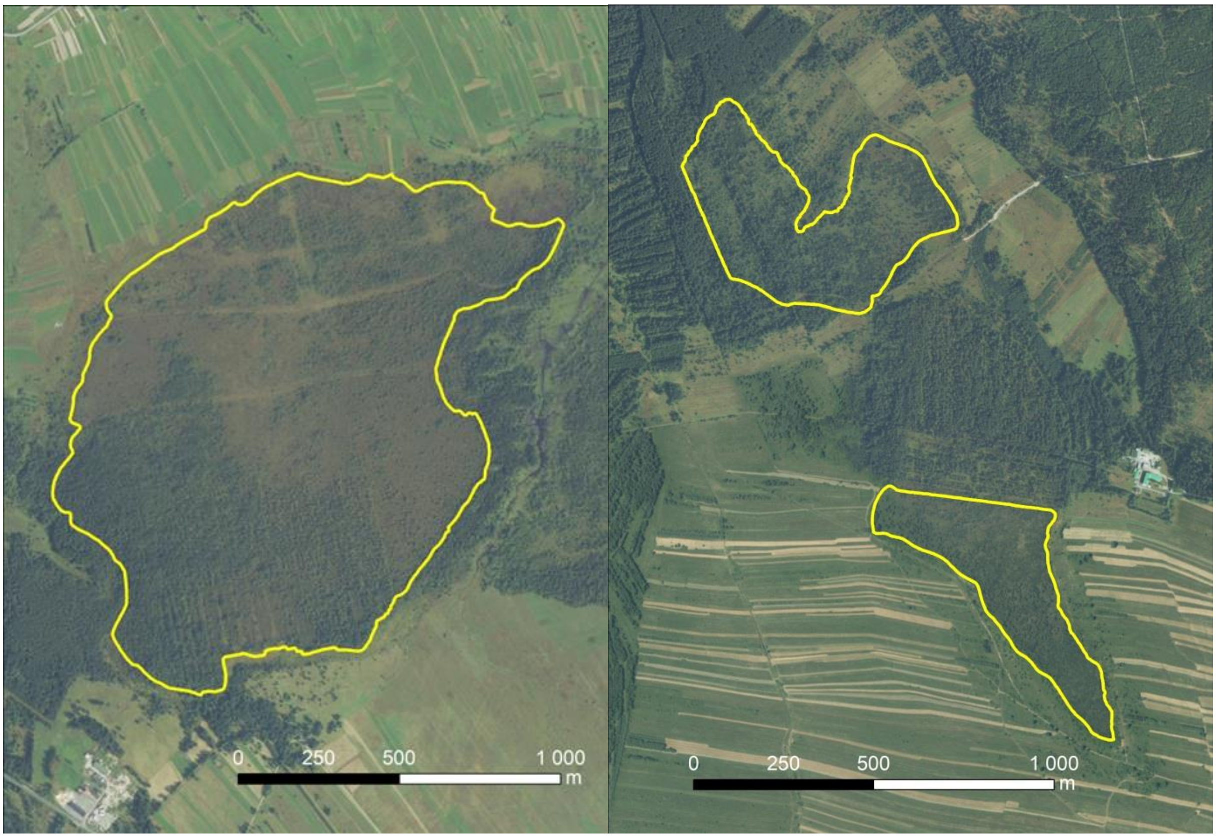


Figure 54: Map showing two project sites: Baligówka (left panel) and Bór za Lasem Kaczmarka (right panel), located within the Torfowiska Orawsko-Nowotarskie PLC120003 Natura 2000 site.

7.2 Methods-Adaptations

All methods are used as described in chapter 2.

7.3 Current State

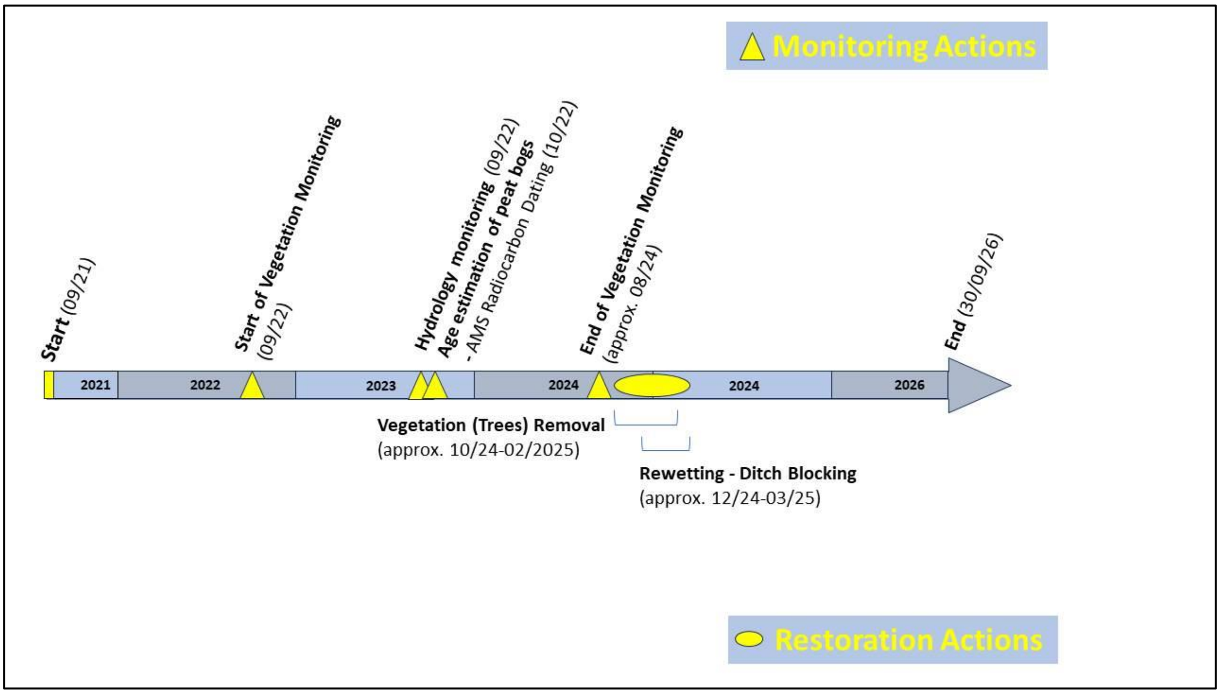


Figure 55: Timeline showing restoration- and monitoring progress for Poland.

7.4 Results (items can be different for each country)

7.4.1 Carbon Stocks

The **below-ground carbon** stock was estimated by recognizing of peat stratigraphy. The peat deposit thickness was measured by peat coring and considered together with the literature data (in particular Lipka & Zając 2014). At Baligówka bog, the peat deposit covers ca 280 ha and is an average 3,64 m deep (Figure 56). The total peat amount is estimated for 10.228.000°m³.

The carbon stock was estimated using average bulk density and carbon content in 10 samples collected in the field, analysed in laboratory. The total of organic carbon stored in the peat of the Baligówka sums up to 613.000 tons, which is equivalent to 2.268.000 tons of CO_2.

At the two additional bogs: Bór za Lasem and Kaczmarka (Figure 57), the total of organic carbon was estimated, by the same method, as: 59.000 and 27.000 tons respectively, which is equivalent to 219.780 and 100.000 tons of CO_2.

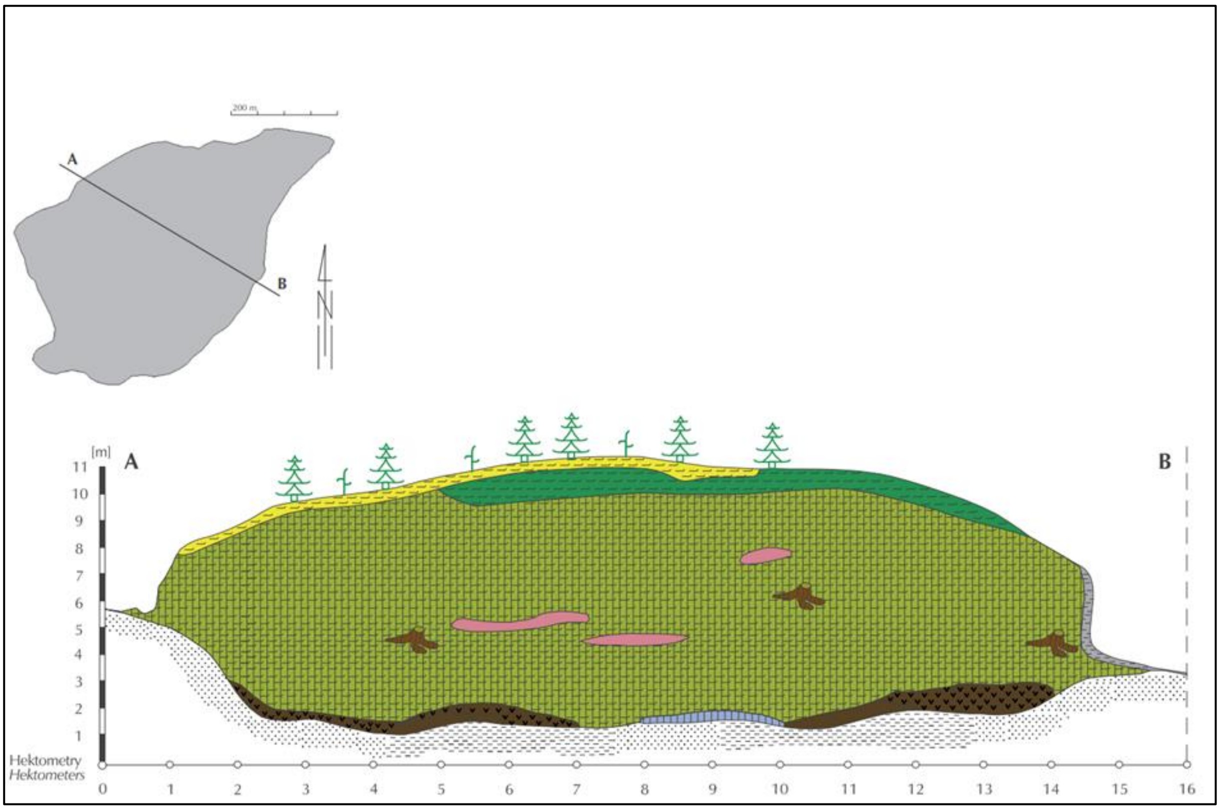


Figure 56: Peat stratigraphy of Baligówka bog.

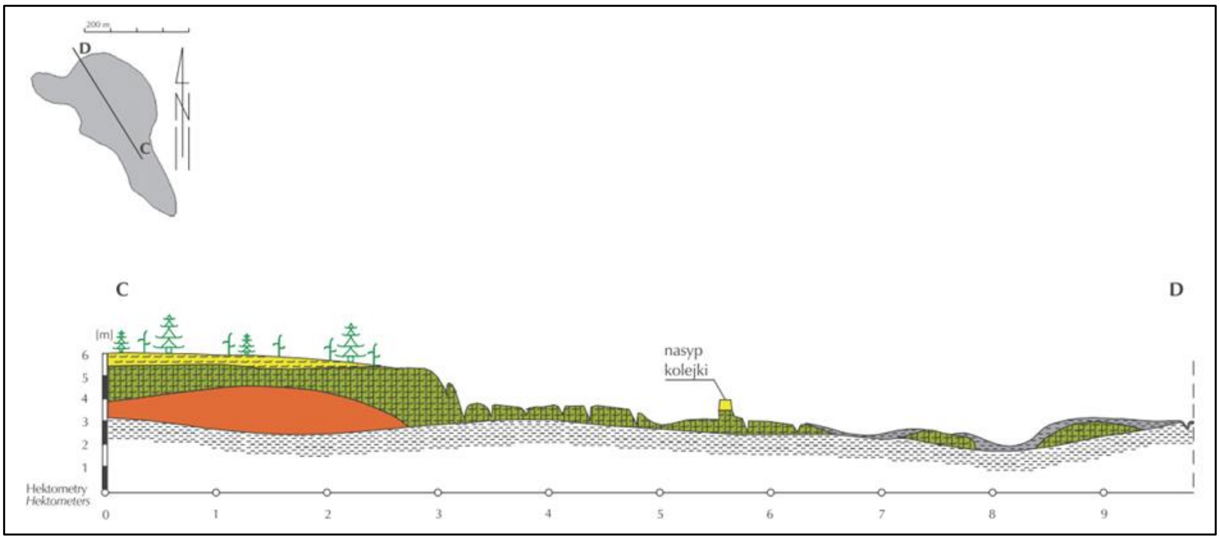


Figure 57: Peat stratigraphy of Bór za Lasem and Kaczmarka bog

The above ground carbon stock was estimated on the basis of tree measurements made on permanent vegetation plots. The total volume of the trees at Baligówka bog was estimated as 7.041 m³, which is (taking 50% of carbon, 0.75g/cm³ bulk density) the equivalent of 2.640 C tons. In the beginning of 2023, conservation measures of removing trees were implemented on the Baligówka bog by conservation authority, regional Directorate of Environment Protection (outside the scope of LIFE Multi Peat project). After finalising it, trees volume will be recalculated in 2024 on the base of next repetition of vegetation monitoring.

On the Bór Za Lasem and Kaczmarka bogs, trees volume was estimated as: 2.750 m^3 and 2.250 m^3, which is equivalent of 1.031 and 843 tons of carbon. The figures are negligible in comparison to below-ground carbon.

7.4.2 Hydrological Monitoring

Hydrological equipment (sensors and data loggers) for water level and temperature monitoring was installed in autumn 2023. 31 sensors were installed in the field + 2 barodivers were used for atmospheric pressure compensation.

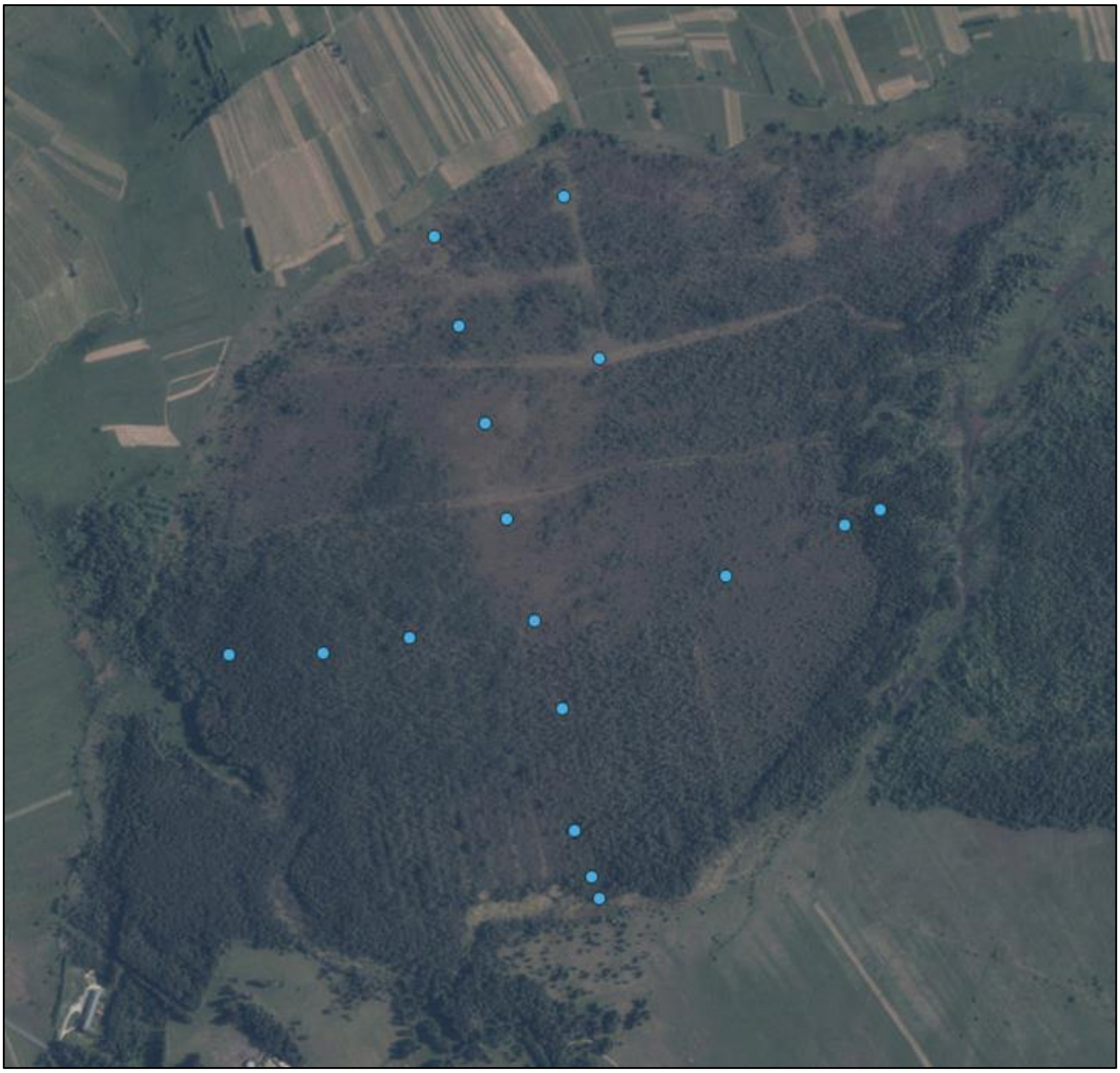


Figure 58: Water monitoring points on the Baligowka bog

Figure 59: Water monitoring points on the Bor Za Lasem and Kaczmarka bogs.

Complete results from all data loggers were not collected yet. However, for checking the equipment, preliminary data from two piezometeres on Baligówka, filtered on 1m and 2m, were analysed (Figure 60, Figure 61).

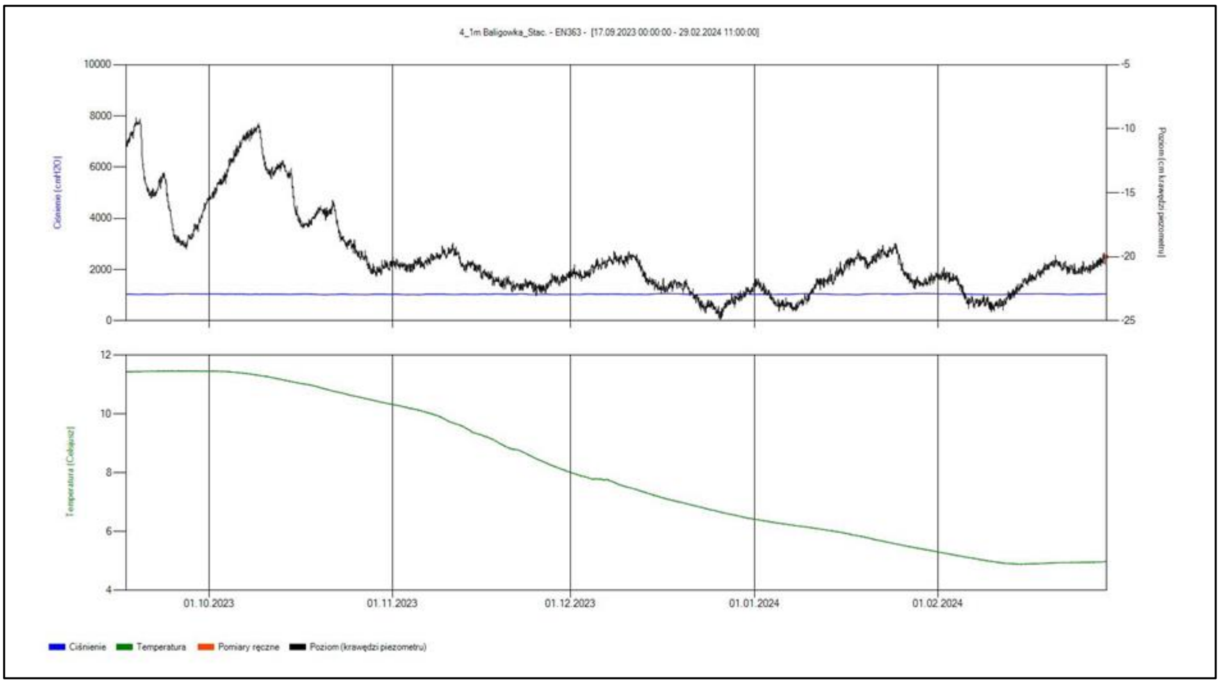


Figure 60: Water table and temperature for sample Baligówka piezometer 1.

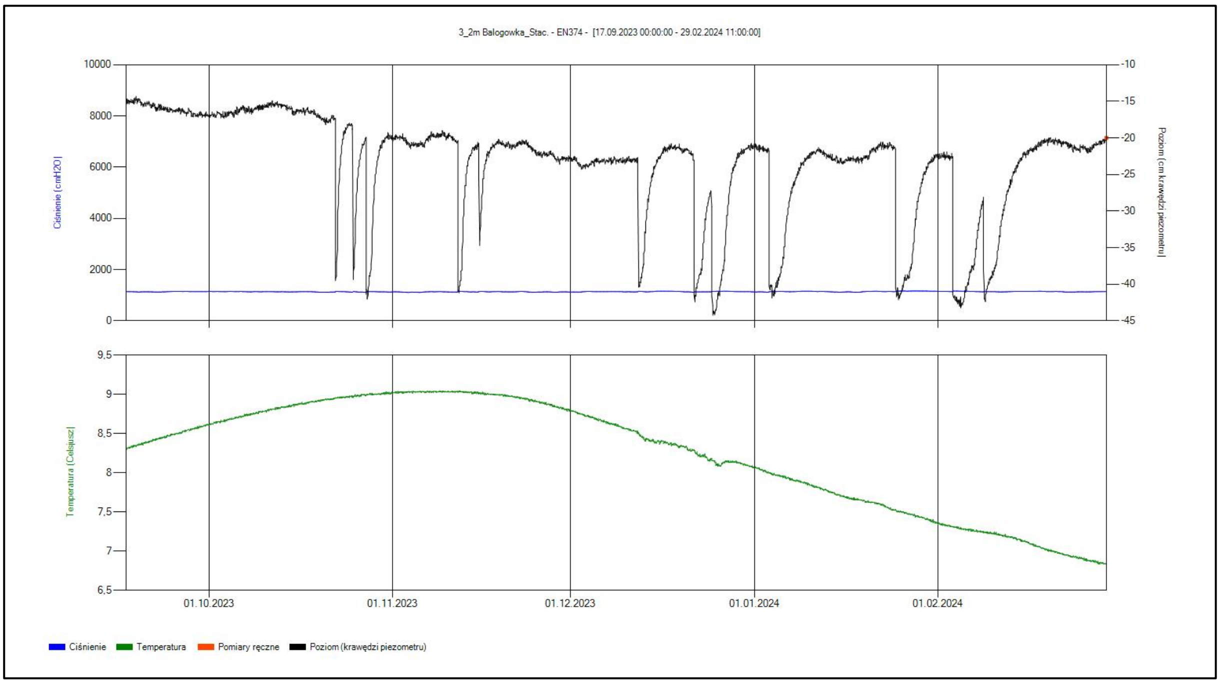


Figure 61: Water table and temperature for sample Baligówka piezometer 2.

7.4.3 GHG-Measurements

Greenhouse gas measurements are conducted at three monitoring sites, all of them located in the Natura 2000 site Torfowiska Orawsko-Nowotarskie. 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* (Figure 63 right). 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 (Figure 62). This raised-bog has been intensively drained in the past, and it will be affected directly by rewetting measures 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). 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 (Figure 63 left). At the beginning of 2024 restoration measures start at Bór na Czerwonem reserve (as a part of abother project), with tree removal and ditch blocking actions implemented, which may have impact on the GHG results from that site.

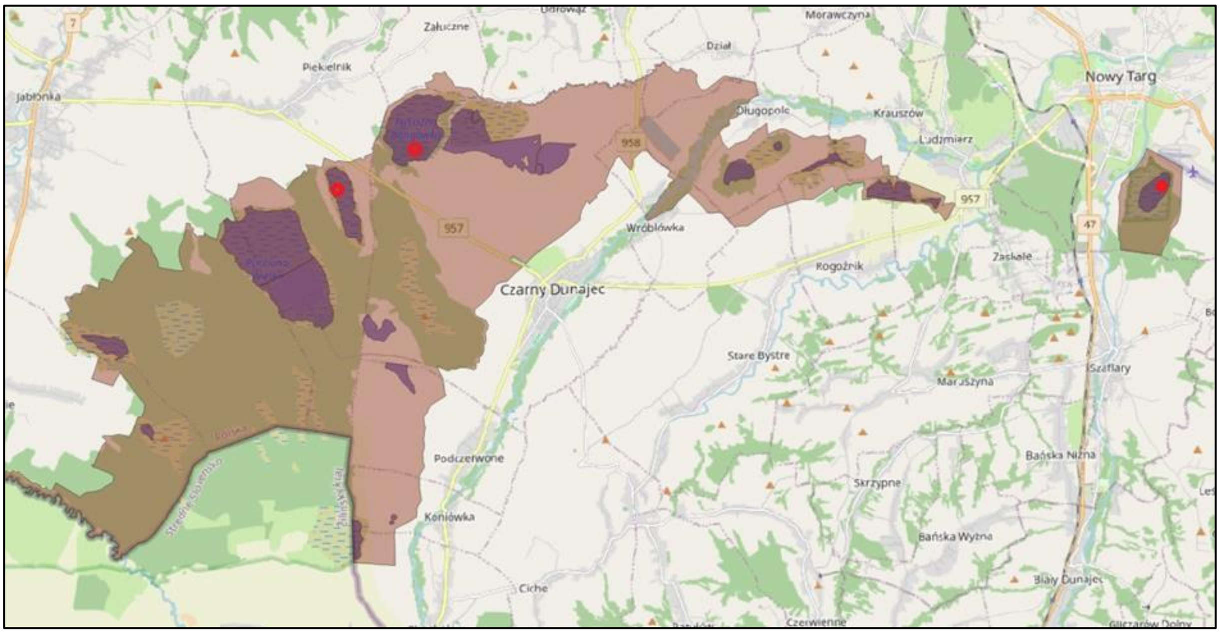


Figure 62: Location of three GHG monitoring plots (red dots). Pinkish area shows boundaries of Natura 2000 site, and violet polygons show raised bogs domes

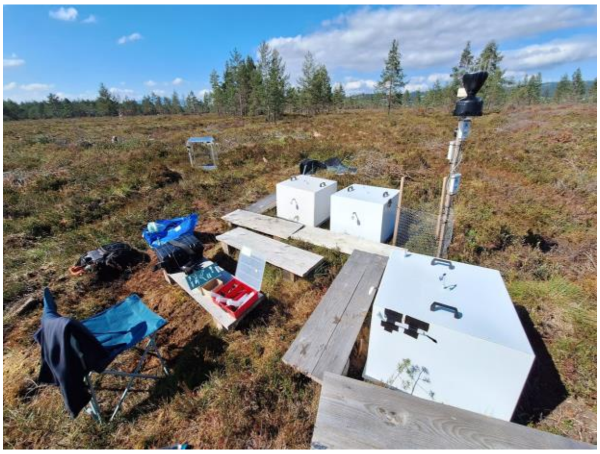


Figure 63: GHG monitoring plot on Bór na Czerwonem (left) and Baligówka (right). Photos: Tomasz Wilk.

7.4.4 Environmental Parameters

At the three sites, where the GHG-measurements are conducted, 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) 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.

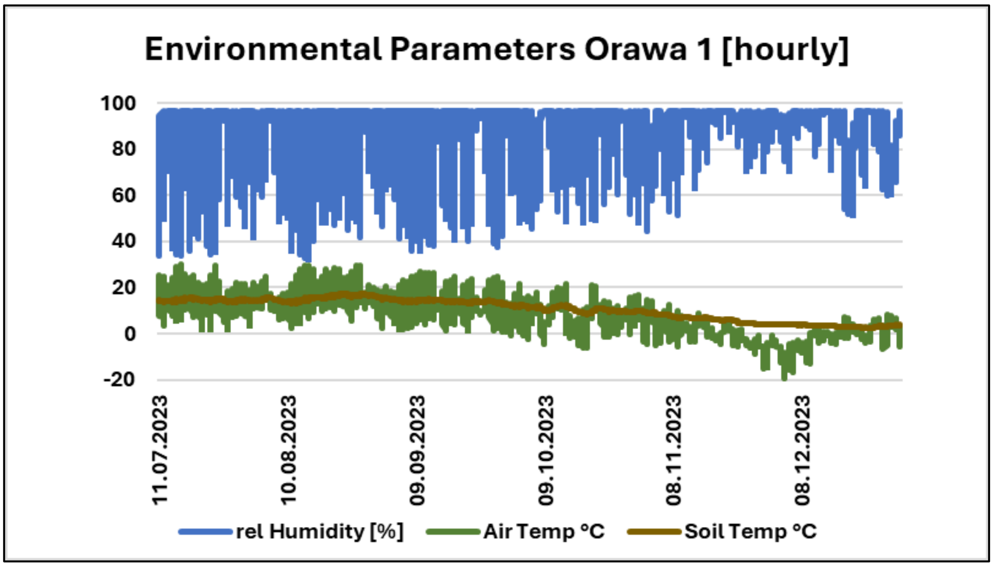


Figure 64: Environmental parameters at Orawa1

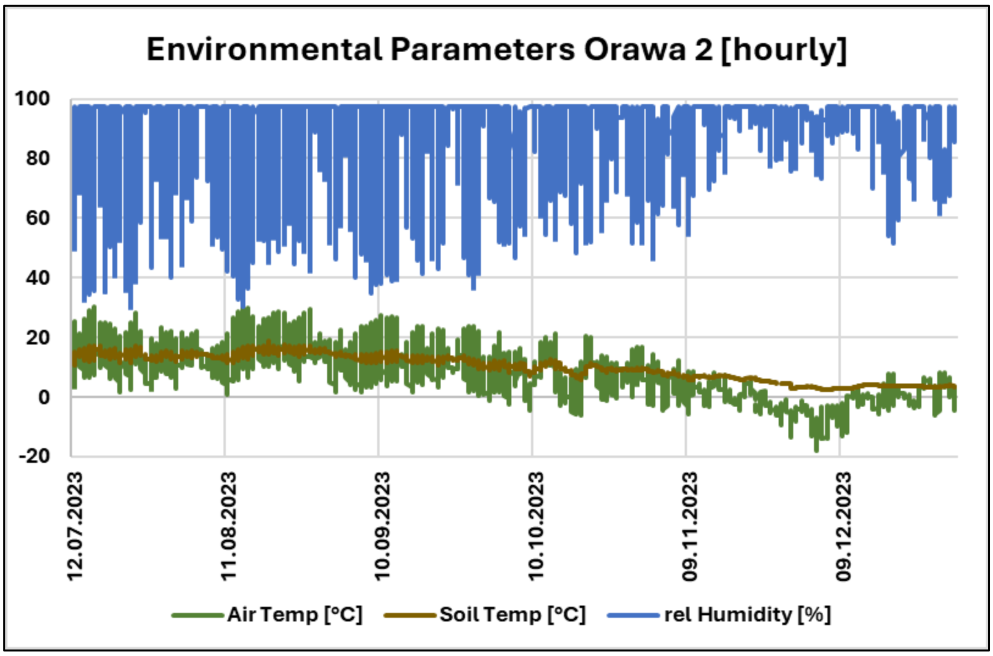


Figure 65: Environmental parameters at Orawa2

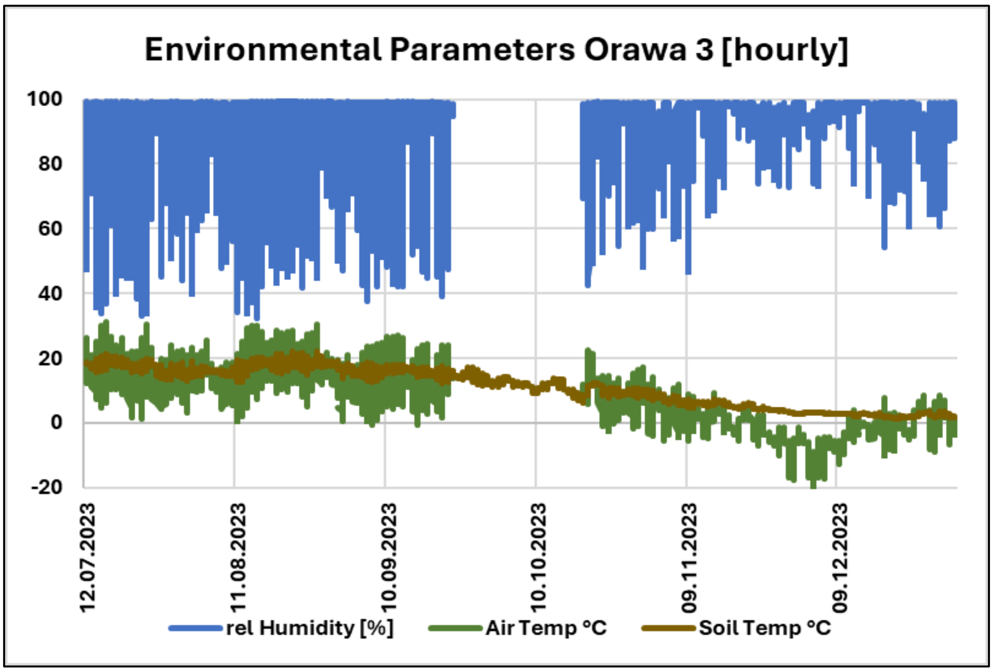


Figure 66: Environmental parameters at Orawa 3

All sites show the similar pattern. Mean annual air temperature is respectively: 8,2°C (Orawa1), 8,1°C (Orawa2) and 7,7°C (Orawa3), with only slight difference between the plots in this parameter. Also, other parameters do not differ significantly between monitoring sites – eg. humidity (mean – respectively: 86, 84, 84%) and soil temperature (mean – respectively 10,5, 10,0, 11,0°C).

All environmental factors will be analysed in detail at later stages of project implementation, when GHG data will be available.

As a part of the project environmental monitoring, the annual survey of the Black Grouse *Lyrurus tetrix* population has been performed. The Black Grouse serves as an umbrella species for the local peatland habitats, being one of the most important management objectives in Natura 2000 site. Long term monitoring of the species is carried out with the support of group of ca. 15 OTOP volunteers and has been continued in the years 2022 and 2023 within LIFE MultiPeat. The bird is monitored during lekking period, with volunteers surveying all known lekking sites at the same time during two field visits in March and April. In total 11 and 12 males of Black Grouse have been counted respectively in 2022 and 2023.

7.4.5 UAV/Satellite Image Monitoring

The drone flight was conducted on the 27th and 28th of July 2023 with a DJI Mavic 3 drone with Multi spectral camera". In total, 3460 pictures were taken and stitched together. An orthophoto showing the visible light spectrum can be seen in Figure below.

Figure 67: Drone orthophotomap of Baligówka bog (with example of resolution)

Figure 68. Drone orthophotomaps of Bor Za Lasem and Kaczmarka bogs (with example of resolution)

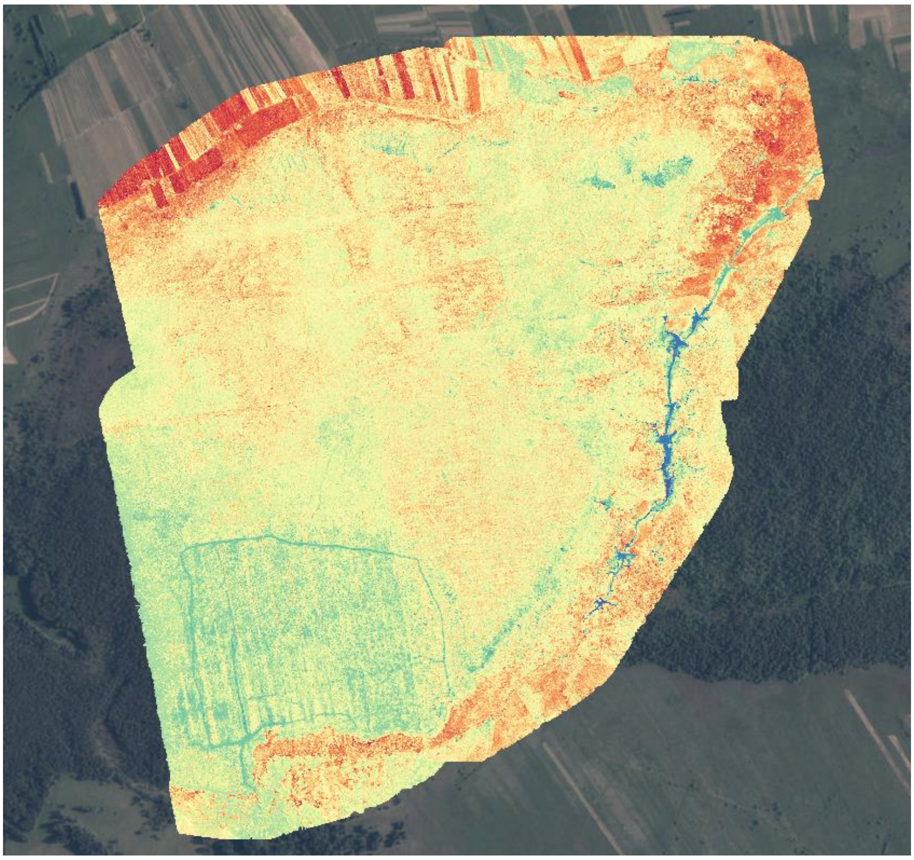


Figure 69: NDVI of Baligówka bog

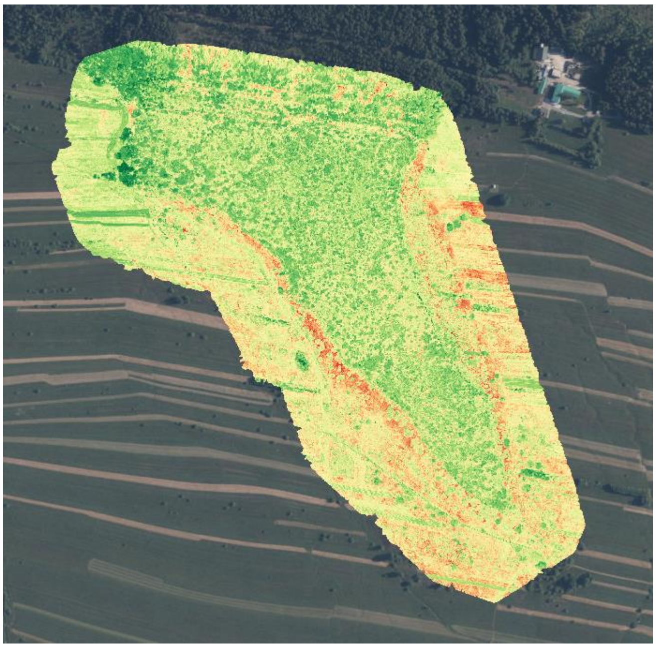


Figure 70: NDVI of Bór za Lasem bog

7.5 Discussion and Challenges

The data collected in 2023 constitute part of the baseline before implementation the restoration measures. No restoration measures under LIFE Multipeat have been implemented yet.

The monitoring technologies (incl. water level data loggers and drone photo-mapping) were successfully tested.

7.6 Communication indicators

POLAND (OTOP)							
	INDICATORS						
	DIRECT			INDIRECT			
Units	**Economic contribution**	**Ecosystem regulating services** (GHG emissions)	**Awareness raising**	**Ecosystem supporting services** (habitat for species)	**Ecosystem provisioning services** (raw materials, freshwater)	**Ecosystem regulating services** (Fire/flood prevention)	**Ecosystem cultural services** (recreation, aesthetic appreciation, and inspiration)
Stakeholder and Duty holder engagement			9				
Information boards/panels			0				
Employment (Individuals/companies hired by the project)	5						
Amount spent (€)[5]	83,892,84 €						
Number of jobs (FTE and PTE)	0 FTE, 5 PTE						
Number of events organised or participated			5				
Number of participants in events organised by the beneficiary			15				
Number of hectares restored		0 ha		0 ha		0 ha	0 ha
GWP reduction[6] (tons of GWP CO_2-eq/ha/yr)		0 tons of GWP eq.					
Number of Print media -							
Number of Publications/Reports, promotional material produced			6				
Media coverage (newspaper articles, press releases, radio, podcast)			2				
Website – visits[7]			160				
Climate Performance (tons/year CO2)		To be estimated after restoration					
Climate Performance (tons/year CH4)		To be estimated after restoration					

Environmental Performance – resilience to flooding (ha)		To be estimated after restoration				0 ha	
Baseflow contribution of receiving water (m3/s) by percentage		n.a.				0 %	
Sustainable land use, agriculture, and forestry (hectares of agricultural land under sustainable management)		To be estimated after restoration			0 ha		
Habitats positively affected (ha) and change in percent cover of indicator species associated with their respective target habitat				0% 0 ha			0% 0 ha

8 References

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