Hydrological, vegetation, greenhouse gas and GEST monitoring in project sites in Latvia

2nd Monitoring Report

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2nd Monitoring report

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LIFE21 - CCM - LV - LIFE – PeatCarbon

Peatland restoration for greenhouse gas emission reduction and carbon sequestration in the Baltic Sea region

Content

1. Project Sites

The aim of LIFE PeatCarbon project monitoring program is to assess the cumulative effect of hydrological regime stabilization on the water level of the project sites, plant communities and GHG gas emissions. Therefore, territories were selected: (a) in which restoration has been carried out earlier before 6 to 15 years, in order to follow the vegetation succession and capture the moment after how long the effect is achieved also in other indicative parameters like increased groundwater level; (b) where restoration will only be carried out during the project and serves as the starting situation or the worst state of the degraded peatland.

In Latvia, within the framework of LIFE PeatCarbon project, monitoring is carried out in four territories - in two of them, stabilization of the hydrological regime will also be implemented, and in two - only the monitoring (Figure 1.1, Table 1.1). Several project sites have already undergone restoration as well as vegetation, hydrological and GEST monitoring and the results will serve as a reference, but some are monitored for the first time; GHG flux monitoring was performed for the first time in all locations. Cena Mire was restored in 2006 in LIFE "MIRES" project, the Melnais Lake Mire was restored in 2012 in LIFE "Raised bogs" project, but Sudas-Zviedru Mire was restored in 2017 in the LIFE "Wetlands" project.

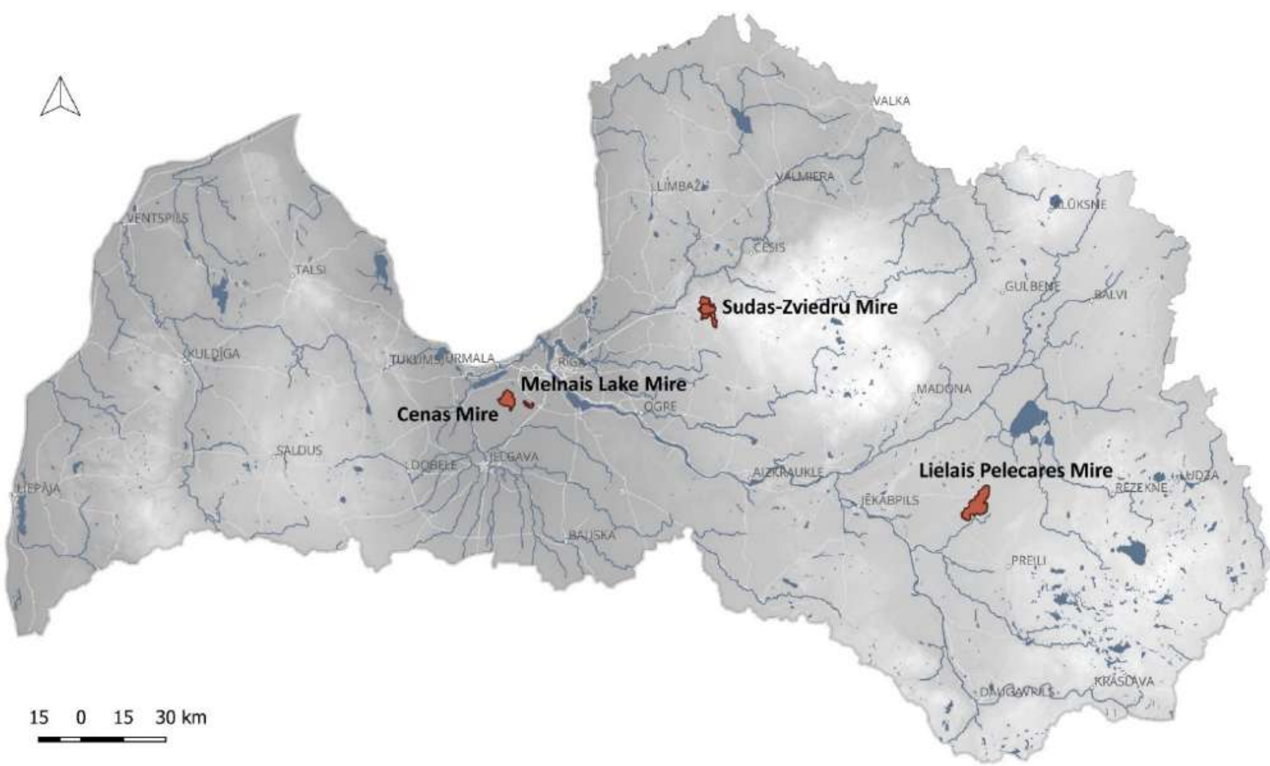


Figure 1.1. *Location of the LIFE PeatCarbon project sites in Latvia. Image: © L. Strazdiņa*

All project sites correspond to the Natura 2000 territory and nature reserve status, their total area reaches 11,838 ha. All sites are active raised bogs and have been affected by peat extraction and drainage. Large scale peat mining has never been initiated in Sudas-Zviedru Mire and Lielais Pelečāre Mire but is still taking place in the immediate vicinity of Cena Mire and Melnais Lake Mire. Accordingly, the first two sites are in relatively better condition, however, all sites have degraded areas that are either open drained or irrigated peat fields or overgrown with shrubs and trees along drainage ditches. In all places, except for Sudas-Zviedru Mire, the issue of fire safety is relevant, and several cases of burning have been recorded in them.

Table 1.1. *Status of the project sites in Latvia regarding previously completed and/or newly planned restoration and monitoring within this LIFE PeatCarbon project (abbr. "LIFE" in the table).*

Project site	Hydrological regime stabilization		Monitoring							
			Hydrological		Vegetation		GHG flux		GEST	
	before	LIFE	before	LIFE	before	LIFE	before	LIFE	before	LIFE
Cenas Mire	✓	✓	✓	✓	✓	✓	-	✓	-	✓
Melnais Lake Mire	✓	-	✓	✓	✓	✓	-	✓	-	✓
Lielais Pelečāres Mire	-	✓	-	✓	-	✓	-	✓	-	✓
Sudas-Zviedru Mire	✓	-	✓	✓	✓	✓	-	✓	✓	-

Hydrological and vegetation monitoring is carried out by the University of Latvia; GHG flux monitoring is implemented by the Latvian State Forest Research Institute "Silava"; GEST mapping and monitoring is performed by the Institute for Environmental Solutions with assistance from the University of Latvia.

1.1. Cena Mire Nature Reserve

1.1.1. Protection status

- Protected area since 1999
- Total area 2295.79 ha
- Natura 2000 site since 2004, site code LV0519800
- Site-centre location [decimal degrees]: 23.849200, 56.857300.

1.1.2. Nature values

Cena Mire Nature Reserve consists of a complex of wetland habitats, namely intact raised bog, transition mire, dystrophic lakes, pine dominated bog woodland. Hummock-hollow complex and bog pools characterize the bog.

It is one of few bogs in Latvia that supports *Trichophorum caespitosum* as species of western distribution and *Betula nana* and *Chamaedaphne calyculata* as species of eastern and northern distribution. Site is used as trespassing area by wolfs. Highly important for conservation of bird species breeding and staging on raised bogs, e.g. Black Grouse, Golden Plover, Wood Sandpiper and Common Crane.

1.1.3. Habitats of EU importance

In total, seven different types of habitats of EU importance were identified in the Cena Mire, and their total cover occupies 88% of the Nature Reserve (Appendix 6.1, 6.2). Most of it belongs to Active raised bogs (7110*) (1769 ha). Other mire habitats at the site include Degraded raised bogs (7120) (50 ha) and Transition mires and quacking bogs (7140) (17 ha). The total coverage of Degraded raised bogs (7120) is probably even greater after the extension of the boundary of the Nature Reserve and the inclusion of an additional drained area of the bog. The other habitats belong to two forest types (Western Taiga (9010*) and Bog woodland (91D0*), total 112 ha) and Natural dystrophic lakes (3160) (67 ha).

Drainage has affected almost all habitat types, apart from Transition mire (7140), which is in the central part of the Nature Reserve. In addition, most of the Natural dystrophic lakes (3160) are in good to excellent condition.

Figure 1.2. *Success of previous hydrological regime restoration around Lake Skaista is indicated by pine decay. Situation in 2006 short before activities (left) and in 2024 (right). Images: © M. Pakalne*

1.1.4. Drainage impact in the area

The territory of Cena Mire Nature Reserve has changed little in the period from middle of the 19th century to the middle of the 20th century. Later, the entire territory of the Nature Reserve and the adjacent mire massifs were little affected because of human economic activity. Change begins after World War 2. Around 1962, peat extraction was started in the areas adjacent to the SE of the Nature Reserve. Ditches have also been created near to Skaista Lake (Figure 1.2). Around 1967, the peat extraction fields were further expanded, reaching the S and W border of the Nature Reserve. Later, even more ditches have been installed in the S part of the mire (Figure 1.3).

Figure 1.3. *Peat dam built in 2006 (left) and still functioning ditch where restoration will be performed during LIFE PeatCarbon project (right) in the SE part of Cena Mire. Images: © M.Pakalne, L. Strazdiņa*

In following years, peat extraction fields were established along entire E border of Nature Reserve, and the situation did not change significantly until the 1990s. In the second half of the 90s, in the 2000s, no new peat fields are developed or are created only irregularly, including the territory adjacent to NE part of mire where restoration of the hydrological regime is planned.

1.2. Melnais Lake Mire Nature Reserve

1.2.1. Protection status

- Protected area since 2004
- Total area 342.89 ha
- Natura 2000 site since 2004, site code LV0528700
- Site-centre location [decimal degrees]: 23.986300, 56.836500.

1.2.2. Nature values

Site includes raised bog vegetation with bog lakes. It is surrounded by peat cutting fields located outside the site.

Main qualifying features are Active raised bogs (7110*) and Natural dystrophic lakes (3160). A relatively high diversity and abundance of rare bird species for a small area. 12 Annex I bird species recorded in 2002. The most important are Wood Sandpiper, Spotted Crake and Whooper Swan (one of the few breeding sites for the latter in the central region of Latvia). Bean and White-fronted Geese use the site as a roosting place during the autumn passage.

1.2.3. Habitats of EU importance

In total, four types of habitats of EU importance have been identified in the Melnais Lake Mire. The total cover of all habitats takes 87% of the Nature Reserve (Appendix 6.1, 6.2). Most of it belongs to Active raised bogs (7110*) (186 ha), and about a half of that cover belong to Degraded raised bogs (7120) (88 ha). The habitat Natural dystrophic lakes (3160) take 18 ha, while only 3 ha belong to Western Taiga (9010*). About 25 ha of the Nature Reserve is taken by irrigated open peat mining field.

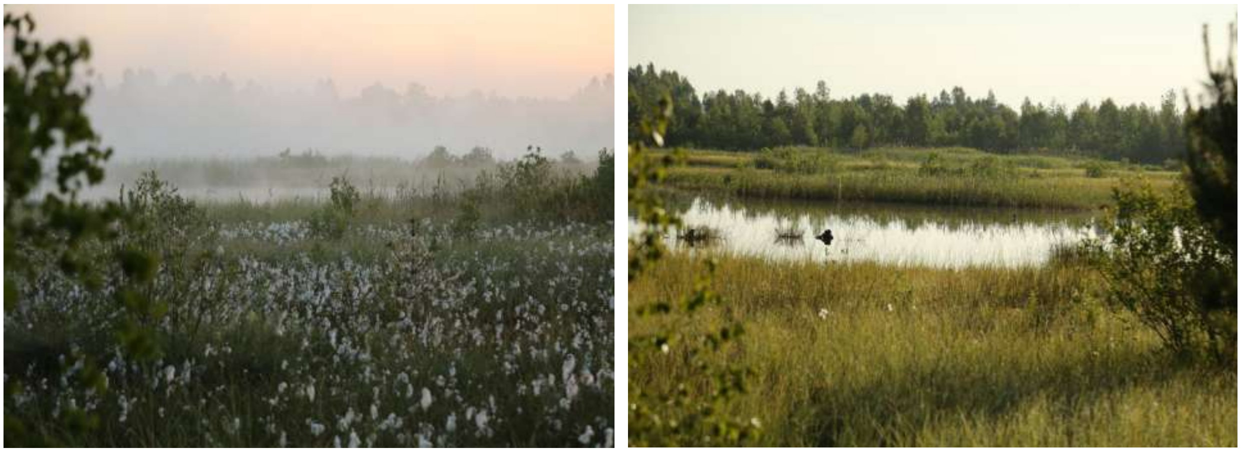


Figure 1.4. *Species poor (left) and fen (right) vegetation in overflooded peat-mining fields in Melnais Lake Mire in 2024 after completed hydrology stabilization in 2012. Images: © M.Pakalne*

1.2.4. Drainage impact in the area

Melnais Lake Mire has a dome formed from the accumulation of peat over thousands of years. In the centre of the dome is Melnais Lake. It collects water from the immediate surroundings, but in the previous century a ditch was dug to connect the lake to a drainage system. In general, the hydrological conditions of Melnais Lake Mire have been significantly changed by human activity, 84% of the territory is surrounded by drainage ditches. Peat mining was started in the 1930s in the vicinity of the Nature Reserve and continues to this day.

After peat extraction, it is not possible to fully restore the natural vegetation of the raised bog. However, the impact of drainage can be reduced, and the hydrological situation stabilized. To raise the groundwater level and reduce seasonal fluctuations, dam building on ditches was finished in 2012 (Figure 1.4).

1.3. Lielais Pelečāre Mire Nature Reserve

1.3.1. Protection status

- Protected area since 1977
- Total area 5683.26 ha
- Natura 2000 site since 2004, site code LV0512200
- RAMSAR site together with Teiču Mire Strict Nature Reserve
- Site-centre location [decimal degrees]: 26.556500, 56.497200.

1.3.2. Nature values

Site includes a raised bog surrounded by bog woodland. In the site periphery transition mires are found.

Qualifying features are Active raised bogs (7110*), Transition mires and quaking bogs (7140) and Bog woodland (91D0*). Qualifying species is butterfly Large Copper. Apart from the vast area of open peatland (raised bog and transition mire) that is important for breeding waders etc, surrounding forests also important for woodpeckers and owls. Up to 5 estimated pairs of Ural Owl and perhaps 5 to 10 pairs of Tengmalm's Owl occur within the site.

Figure 1.5. *Hollow-bog pool-ridge relief in the natural active raised bog (left) strongly contrasts with the almost square-shaped drained area that has overgrown by birches and pines (right) in Lielais Pelečāre Mire. Drone image: © J. Matuko*

1.3.3. Habitats of EU importance

Ten habitats of EU importance with a total area of 5177 ha or 91.1% from the Nature Reserve have been found throughout the project site (Appendix 6.1, 6.2). The remaining 9% of the area belong to forest stands of various ages, mainly on the periphery of the Nature Reserve, which do not meet the quality requirements of protected habitats.

Of all habitats of EU importance, the largest area is occupied by Active raised bogs (7110*), which takes around 67% of the entire Nature Reserve. The habitat is in the central part of the Lielais Pelečāre Mire and around Deguma Lake, as well as small, isolated fragments are separated by forest areas on the periphery of the mire. During the 1960s and 1970s, preparatory works for peat extraction were started in the area to the SW from Deguma Lake. Here, the habitat Degraded raised bogs (7120), with a total area of 25 ha has developed. A dense network of draining ditches was installed, and the top layer of vegetation has been partially removed, however, peat extraction has not taken place (Figure 1.5). The habitat Transition mires and quacking bogs (7140) takes a small area, in only two places - in a narrow strip around the Deguma Lake and in the NW part of the territory around bog pools. In the nature reserve, freshwater habitats are represented by Natural dystrophic lakes (3160) - both the largest lake in the mire, Deguma Lake, and bog pools with the area over 0.1 ha. Five different protected forest habitats of EU importance were found in the site. The largest cover belongs to Bog woodland (91D0*). They have developed naturally on the edges of the mire, as well as around Deguma Lake. However, the drainage system created in the Nature Reserve and the adjacent territory has contributed to the mineralization of peat and the more intensive growth of pine trees.

1.3.4. Drainage impact in the area

The territory of the Lielais Pelečāre Mire has changed little in the period from the middle of 19th century to middle of 20th century. At that time the entire territory of the Nature Reserve was only little affected by human economic activity. The first ditches in the mire were built at the beginning of the last century (1920s) and in 1934. Later, around 1952, the ditches are not only at the S and SE parts of the Deguma Lake, but also at the N end of the mire. In the late 1980s and early 1990s, ditches were created in the bog woodland along the NW edge of the reserve, as well in the S part of the mire to the E of Deguma Lake. In later years, new changes in the hydrological system of the mire are not observed.

1.4. Sudas-Zviedru Mire in the Gauja National Park

1.4.1. Protection status

- Protected area since 1973
- Total area 3516 ha
- Natura 2000 site since 2004, site code LV0200100
- Belongs to the Gauja National Park (total area 91786.74 ha)
- Site-centre location [decimal degrees]: 25.016100, 57.141692.

1.4.2. Nature values

Sudas-Zviedru Mire is the most outstanding raised bog in the Gauja National Park due to the presence of carst phenomena. The three main mire types are represented here – fens, transition mires and raised bogs. Zušu-Staiņu Springs and the beginning of Suda River is in the S part of the mire. Several lakes occur in the mire, forming a joint ecological system. Protected plant species *Trichophorum cespitosum* occurs in the bog. Rare bird species are known in the mire, like Black Stork and Black Grouse. The mire is important for migrating bird species, such as Greater White-fronted Goose, and a nesting place to Common Cranes.

According to the Law on Gauja National Park (in force since 01.01.2000) the territory of Gauja NP is divided into five functional zones: strict nature reserves (4%), restricted nature areas (31%), neutral zone (18%), landscape protection zone (44%) and zone of cultural and historical value (3%). Sudas-Zviedru Mire is in the S part of the national park, approximately 10 km from Sigulda City. The area is divided in several zones – Sudas Mire Strict Nature Reserve, Ratnieki Lake and Mire Nature Reserve, Mežaki Nature Reserve, and More Nature Reserve.

1.4.3. Habitats of EU importance

In total, 15 types of habitats of EU importance have been identified in the Sudas-Zviedru Mire. The total cover of all habitats takes 81% of the Nature Reserve (Appendix 6.1, 6.2).

Fennoscandian mineral-rich springs and springfens (7160), Transition mires and quaking bogs (7140), and Active raised bogs (7110*) are found in Sudas-Zviedru Mire. The largest area is covered by bogs (2089 ha), while fens (0.14 ha) and transition mires (53.5 ha) are located near the edges. In areas where the drainage ditches have been excavated, Degraded raised bogs still capable of natural regeneration (7120) has formed (total area 58.7 ha) (Figure 1.6).

About 14% from the mire area is taken by different forest habitats, from which the Bog woodland (91D0*) (307 ha) and Western Taiga (9010*) (167 ha) are the most common.

Figure 1.6. *Active raised bog (left) and degraded part in 2024 where restoration has been completed in 2017 (right) in Sudas-Zviedru Mire. Images: © M. Pakalne*

1.4.4. Drainage impact in the area

Relatively high human activity has occurred in Sudas-Zviedru Mire. In the 1930's, peat extraction was carried out in the area, therefore a dense system of drainage ditches was installed. Although part of the ditches has already overgrown with vegetation, they still function, and the water is carried away from the mire. As the result of the draining, heather, birch, and pine have become dominant species along the ditches. To reduce the impact of drainage ditches, 67 dams were built within the LIFE project "Conservation and Management of Priority Wetland Habitats in Latvia" LIFE13 NAT/LV/000578 in 2017.

Figure 1.7. *Drainage ditch in Sudas-Zvuedru Mire filling in with Sphagnum after dam buikding. Images: © M. Pakalne*

Figure 1.8*. The peat dam in restoration area in Sudas - Zviedru Mire in 2024. Images: © M. Pakalne*

2. Methods

2.1. Hydrological monitoring

In each of the study sites a network of hydrological, mostly, water level, observation points were set up. The observation points are equipped with 25 mm HDPE monitoring well pipes from the Dutch company Royal Eijkelkamp B.V. The typical construction of the well consists of a 1 m long pipe, followed 2 m or, less frequently, 1 m slotted filter pipe, with or without a filter fabric sock covering (Figure 2.1). The head of the well is usually approximately 0.5 m above the soil surface. The monitoring points are equipped with Solints, Canad, Levelogger 5 Junior water level and temperature probes. The water level measurement range is 0 to 5 m and a nominal accuracy ±0.1% of the measurement range, corresponding to ±0.5 cm. The probes are installed in the wells using 1 mm stainless steel wire rope (AISI 316 (A4)), typically at depths corresponding to the lower portion of the filter interval.

In the case of Lielais Pelečāre Mire, two soil water regime monitoring points were installed as well. The soil water regime is monitored with Meter, USA probes Teros 21 (soil water potential) and Teros 11 (soil water content). The soil water potential probes are installed at depths of 0.1 and 0.6 m, while the water content probes are installed at depths of 0.1, 0.3, and 0.6 m below the ground surface (Figure 2.1.1).

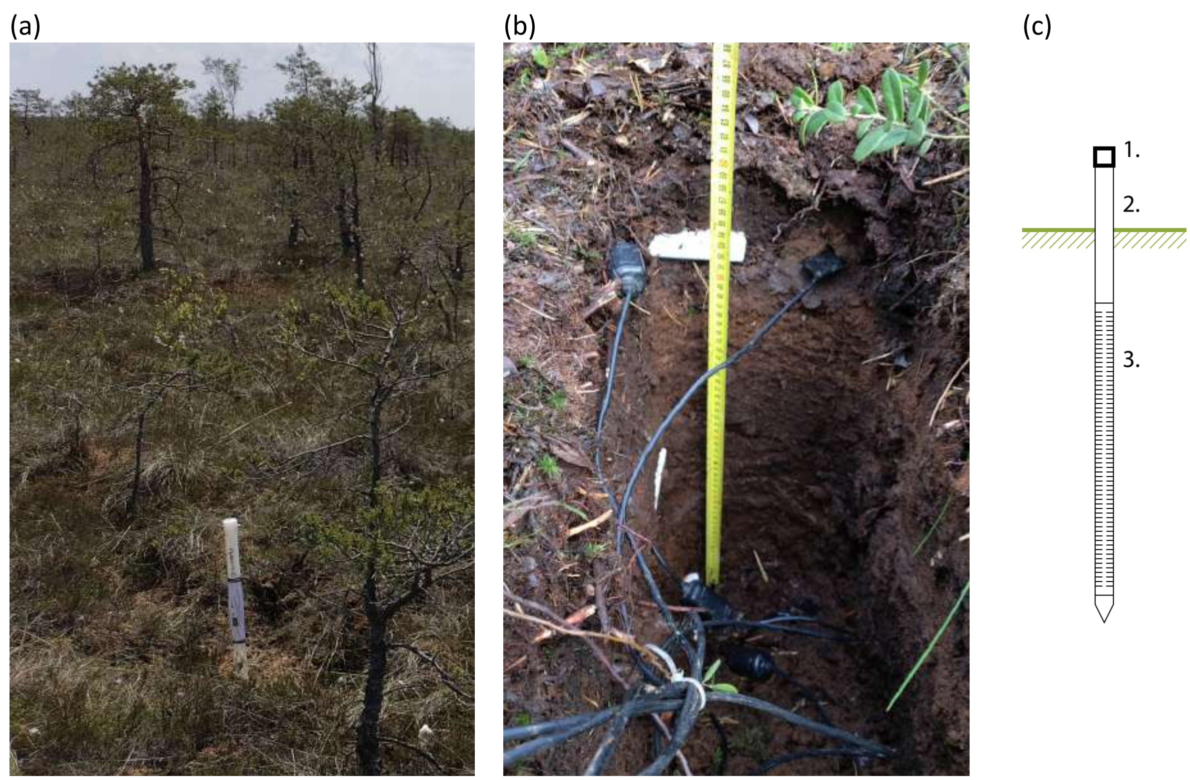


Figure 2.1.1. *Groundwater monitoring well (a) and soil water monitoring probes (b) in Lielais Pelečāre Mire. Schematic monitoring well setup (c): 1 – well cap; 2 – smooth pipe HDPE 25 mm internal diameter, usually 1 m long, about 0.5 m above surface; 3 – filter interval, usually 2 m long in some cases covered with filter fabric sock. Images: © A. Kalvāns*

During the reporting period, the hydrological monitoring was initiated in Cena Mire and Lielais Pelečāre Mire, but the monitoring has not yet been started in Melnais Lake Mire and Sudas-Zviedru Mire.

2.1.1. Cena Mire

Hydrological monitoring in Cena Mire was initiated on June 8, 2023, by establishing six monitoring points equipped with automatic water level sensors (Figure 2.2., Appendix 6.3), including one point for assessing water flow in a drainage ditch. However, due to blockage of the installed spillover by eroded peat, the discharge measurement was not possible. In the autumn of 2023, another 15 monitoring points were set up, including two points for mire lake water monitoring (Figure 2.2). Monitoring at these locations will begin as soon as water level probes become available.

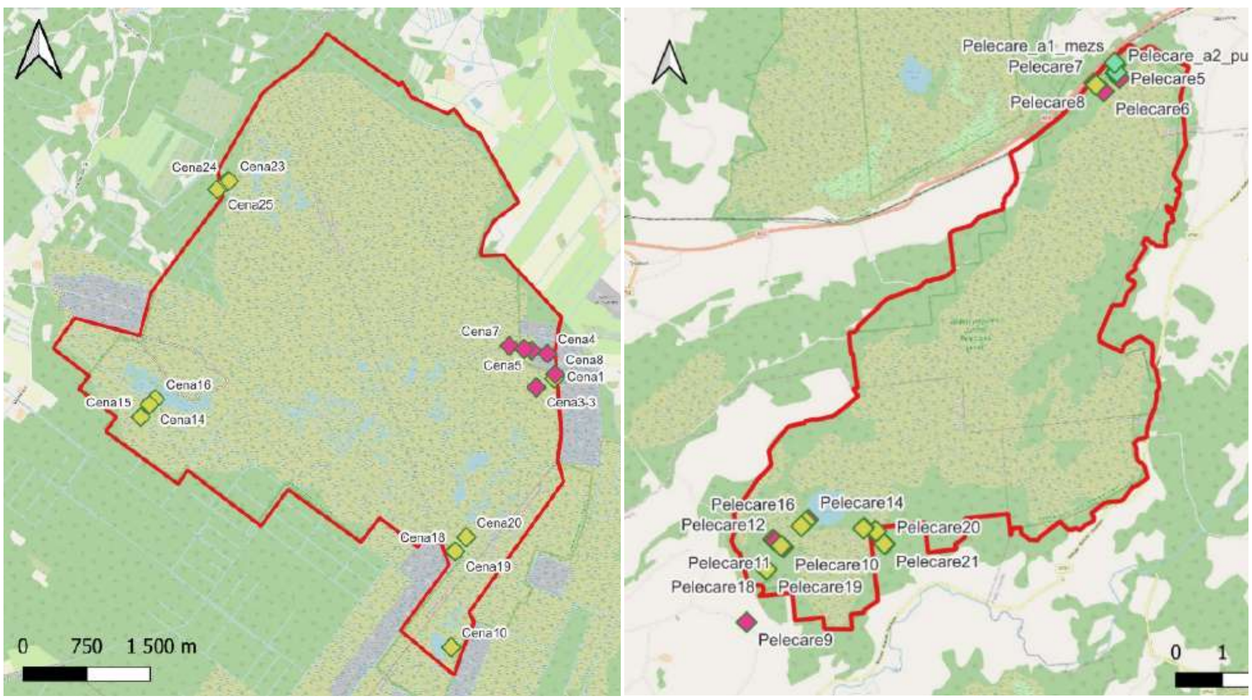


Figure 2.1.2. *Location of the hydrological monitoring points in Cenas Mire (left) and Lielais Pelečāres Mire (right). Legend: ◆ - no probe; ◆ - Levelogger 5 Junior; ◆ - Meter Teros21 and Teros11. Images: © A. Kalvāns*

2.1.2. Lielais Pelečāre Mire

The hydrological monitoring in Lielais Pelečāre Mire was initiated on June 20, 2023, when first 13 monitoring wells, including one point in the ditch (Malnupeite) for discharge volume assessment were installed (Figure 2.1.2.). Most of these monitoring points were equipped with automatic groundwater level (Appendix 6.4) probes. The water level data was retrieved on November 7, 2023.

Additionally, in the autumn of 2023, another 12 water level monitoring points were installed, which are not yet equipped with appropriate automatic probes. Monitoring at these points will commence as soon as water level probes become available. Furthermore, two soil water regime monitoring points have been set up, where observations of soil water content and potential are conducted using five probes at each site.

2.1.3. Sudas-Zviedru Mire

The water level monitoring network in Sudas-Zviedru Mire comprises 7 sites organised along two profiles (Appendix 6.5). One profile (wells Suda1, Suda6 and Suda5) was set up to monitor the water level in a blocked drainage ditch, both in opposite ends of flooded segment of the ditch and at both sides of a dam on the same ditch (Figure 2.1.3). The aim of this configuration was to observe the temporal dynamics of water level along the ditch, particularly the development of the resistance to the water flow in the flooded ditch due to development of vegetation. In a case of successful restoration, we expect to see both increasing water level gradient along the flooded section of the ditch and decreasing gradient across the dam. The other profile (Suda7, Suda4, Suda3 and Suda2) was placed radial to the slope of the raised bog dome from relatively intact mire, across two blocked ditches to degraded peatland covered by sparce pine forest. In a case of successful mire restoration, over the time, the pattern of water level fluctuations is expected to get like observations in the intact mire.

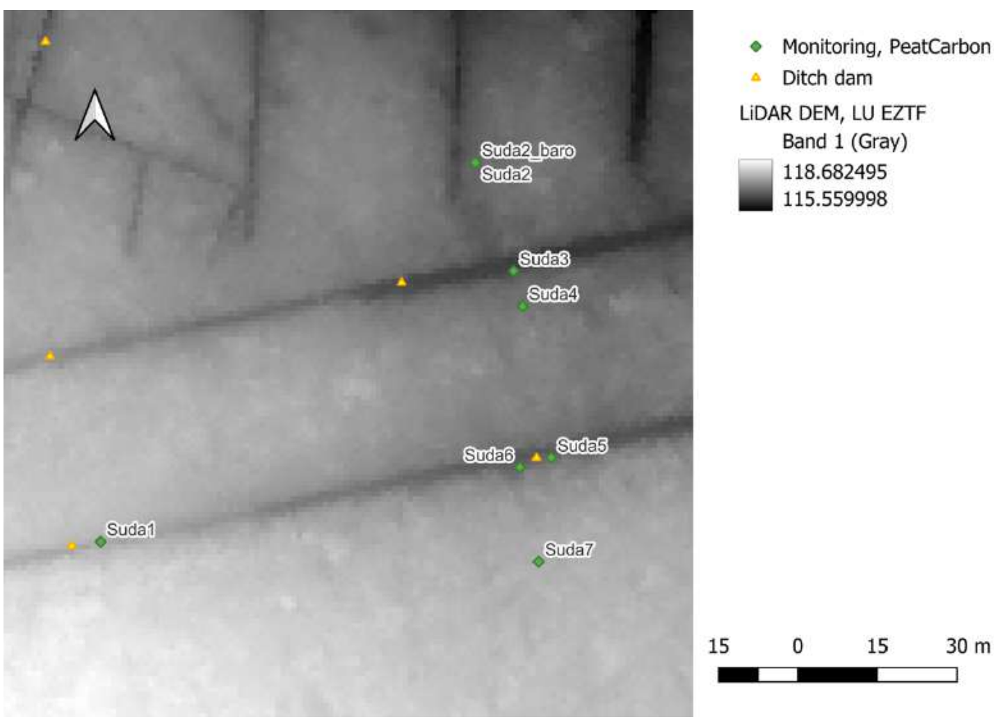


Figure 2.1.3. Water level monitoring network in Sudas-Zviedru Mire

2.1.4. Melnais Lake Mire

The water level monitoring network in Melnais Lake mire comprises 7 sites organized along three profiles (Figure 2.1.4) and additional observation point within a strip of dens pine forest in the mire (Appendix 6.6). The aim of establishing three profiles was to examine the development of the water level gradient towards blocked drainage ditch at sits with apparent successful restoration (profiles of wells Melnais4 – Melnais5 and Melnais2- Melnais3) and location with apparently unsuccessful restoration (wells Melnais6- Melnais7). In addition, the well Melnais1 was set up to gain any insights how the forested stirp affects the mire water regime and elucidate any reasons for its establishment.

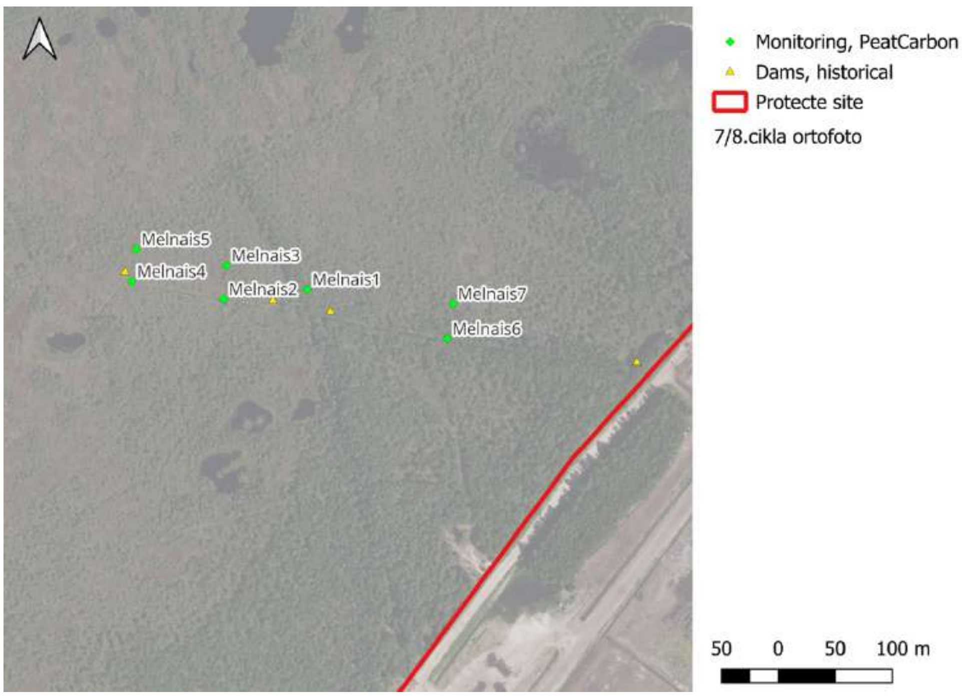


Figure 2.1.4. Location of water level monitoring wells in Melnais Lake Mire

2.2. Habitat and vegetation monitoring

The action is mostly implemented in two protected mire habitats of the European Union, i.e. Active raised bog (7110*) and Degraded raised bogs still capable of natural regeneration (7120) (Table 2.1, Appendix 6.2). Habitat monitoring is necessary to show effect of management actions in the project territories. Overall, it is expected that habitat quality and vegetation composition in degraded plots will change after the management actions are completed. According to results of previous similar studies, number of xerophytes would decrease whereas occurrence of hygrophytes would significantly increase once the water level in mire is stabilised.

Table 2.2.1. *Number of previously and recently established vegetation monitoring plots in project sites in Latvia according to EU habitats (data source: Nature Conservation Agency, 2023).*

Year	Plot size	Number of vegetation monitoring plots in EU habitat types					Outside EU habitats (i.e. peat cutting fields)
		On ditches within the Degraded raised bog (7120)	Degraded raised bog (7120)	Active raised bog (7110*)	Transition mire (7140)	Bog woodland (91D0*)	
Cenas Mire							
2005	10*10 m	-	5	2	-	-	-
	1*1 m	-	15	10	-	-	-
	1.5*2 m	25	-	-	-	-	-
2023[a]	1*1 m	-	6	37	1	2	19
Melnais Lake Mire							
2011	1*1 m	-	30	19	-	-	-
2023	1*1 m	-	18	21	-	-	11
Lielais Pelečāres Mire							
2023	1*1 m	-	3	11	1	16	2
Sudas-Zviedru Mire							
2014	10*10 m	-	-	6	-	-	-
	1*1 m	-	-	60	-	-	-
2023	1*1 m	-	-	20	-	-	-

[a] The number includes vegetation plots at hydrological regime observation points, plots at GHG transects and GEST protocols.

2.2.1. Cena Mire

In 2005, the first habitat monitoring was carried out in Cena Mire where building of dams and habitat management was planned. Permanent plots were established next to hydrological monitoring plots, in places where vegetation changes would be most likely to occur after the planned management actions take place (finished in 2006). In the monitoring design, seven 10*10 m large relevés were planned, each with 3-5 smaller sample plots (1*1 m), and additionally 1.5*2 m plots in drainage ditches. Monitoring scheme included also control plots. In total, there were 25 monitoring plots on ditches and 25 plots in raised bogs (7110*, 7120) in Cena Mire. Plant species composition and the percentage cover, the wetness of the sites, presence of adjacent pools and *Sphagnum* dominated vegetation were evaluated. The monitoring was conducted in 2005, 2007, and 2008 (Figure 2.5).

Figure 2.2.1. *Vegetation monitoring plots in Cenas Mire in 2008 (left) and in 2023 (right). Images: © M. Pakalne, L. Strazdiņa*

In 2023, vegetation monitoring was established in other places than in 2005, in connection with location of water level and GHG measurement plots (Figure 2.3). However, species composition was compared between the two time periods despite different data collection locations. In total, 29 new vegetation monitoring plots were established (Appendix 6.5). In addition, the species composition in different parts of Cenas Mire can be characterized using GEST protocols. A total of 23 such forms were completed and used for indirect estimation of GHG emissions from the project site.

2.2.2. Melnais Lake Mire

In 2011, permanent vegetation monitoring plots were established in Melnais Lake Mire. In total, 49 plots were in six transects, each with 5-10 vegetation plots. Following parameters were estimated in every plot: species composition and percentage cover, tree cover, heather cover, the total cover of *Sphagnum* species and distance to the nearest drainage ditch.

Figure 2.2.2. *Vegetation monitoring plots in GHG measurement point in Melnais Lake Mire in 2023. Images: © L. Strazdiņa*

Monitoring was only partially repeated in 2023 due to unavailability of vegetation monitoring plot coordinates. Both for this reason and because of new groundwater and GHG measurement locations, nine new vegetation plots were established (Figure 2.2.2, Appendix 6.5). Like in Cena Mire, the 26 completed GEST protocols can also be used to characterize vegetation of Melnais Lake Mire.

2.2.3. Lielais Pelečāre Mire

The area has never been monitored before and the data is only used to characterize the existing situation, but statistical analysis could not be performed. In Lielais Pelečāre Mire, a total of 33 vegetation monitoring plots (1*1 m) were established parallel to 15 water level observation wells and 18 plots around GHG measurement sites (Appendix 6.5, Figure 2.2.3).

Figure 2.2.3. *Vegetation monitoring plots near GHG measurement point with litter collector (left) and near hydrological monitoring point (right) in Lielais Pelečāre Mire in 2023. Images: © L. Strazdina*

2.2.4. Sudas-Zviedru Mire

In September 2014, permanent habitat monitoring plots in two transects were established in Sudas-Zviedru Mire. One end of each transect was located near the drainage ditches where management actions were performed, and the other end 150-250 m further leads to natural raised bog where drainage impact is not significant. In total, three plots in size of 10*10m were established on each transect. One plot represents vegetation and habitats of degraded raised bog while the second plot located 50 m further shows less impacted habitats where the drainage effect, however, is still present. The third plot works as a control.

Coordinates in WGS-84 system of each plot were measured using GPS. Following parameters were protocoled for each habitat monitoring plot – cover and vitality of heather, plant community, distance to drainage ditch or bog pool, number and vitality of tree species in different height (<0,5 m, 0,5-1 m, 1-1,5 m, > 1,5 m) of tree level. In each of these plots 10 randomly selected microplots were established. For each microplot following parameters were protocoled – location within the large plot, cover of all species in tree, bush, dwarf-shrub, herb, bryophyte and lichen level. Cover and vitality of heather and trees, most of all pine and downy birch, were used as indicators to recovery progress of whole mire ecosystem after management actions. High-res photos were also taken on site to compare the situation in nature pre and after the management actions. Habitat monitoring in Sudas-Zviedru Mire was repeated in 2015, 2016, 2018, 2020, and 2023 (Figure 2.2.4.). Only one of the previously established transects with 11 plots will be used in LIFE PeatCarbon project studies (Appendix 6.5). Additionally, nine vegetation plots were established near the GHG measuring points.

Figure 2.2.4. *Vegetation monitoring plots in Sudas-Zviedru Mire in 2018 (left) and in 2023 (right). Images: © M. Pakalne, L. Strazdiņa*

2.3. Greenhouse gas emission monitoring

Monitoring of total ecosystem emissions (CO_2 emissions reflecting ecosystem respiration, CH_4 and N_2O emissions) and soil heterotrophic respiration was initiated in June 2023 and has been implemented as part of the monitoring (Figure 2.3.1, Figure 2.3.2). In parallel, data are being obtained on environmental parameters that are essential for characterizing changes in GHG emissions: including soil and air temperature, groundwater level, soil water chemical properties, soil chemical properties, aboveground and belowground biomass of ground cover vegetation, woody plant litter, living tree biomass and carbon accumulation in non-living woody plant biomass.

The location and classification of measurement sites is provided in Table 2.3.1, the location on the map is shown on the map Figure 2.3.3, Figure 2.3.4, Figure 2.3.5. Photos of the study sites and subplots representing different habitat types are provided in the Appendix 6.7.

Figure 2.3.1. *GHG measurement in Melnais Lake Mire. Image: © M. Pakalne*

Figure 2.3.2. *GHG measurement in Melnais Lake Mire. Image: © M. Pakalne*

Table 2.3.1. Classification of study sites

Site	Site name	Subplot	Habitat	xcoord WGS84	ycoord WGS84
LPC_1	Sudas-Zviedru Mire	A	Near-natural raised bog	561650	335918
LPC_1	Sudas-Zviedru Mire	B	Rewetted degraded raised bog with direct restoration effect	561641	335948
LPC_1	Sudas-Zviedru Mire	C	Rewetted overgrown raised bog with cumulative restoration effect	561648	335997
LPC_2	Lielais Pelečāre Mire	A	Near-natural raised bog	660112	270466
LPC_2	Lielais Pelečāre Mire	B	Drained raised bog with dense tree layer in the strong drainage impact zone	660105	270512
LPC_2	Lielais Pelečāre Mire	C	Drained raised bog with dense tree layer in the weak drainage impact zone	660110	270560
LPC_3	Melnais Lake Mire	A	Near-natural raised bog	499339	299242
LPC_3	Melnais Lake Mire	B	Rewetted degraded raised bog with direct restoration effect	499347	299216

Site	Site name	Subplot	Habitat	xcoord WGS84	ycoord WGS84
LPC_3	Melnais Lake Mire	C	Degraded bog woodland	499370	299244
LPC_4	Cena Mire	A	Near-natural raised bog	488185	300722
LPC_4	Cena Mire	B	Restored raised bog along ditch with direct restoration effect	488155	300716
LPC_4	Cena Mire	C	Drained raised bog with dense tree layer with cumulative restoration effect	488103	300722
LPC_5	Cena Mire	A	Near-natural raised bog	493086	301066
LPC_5	Cena Mire	B	Peat field along drainage ditch in the strong drainage impact zone	493087	301083
LPC_5	Cena Mire	C	Dry peat field in the strong drainage impact zone	493089	301106
LPC_6	Lielais Pelečāre Mire	A	Natural raised bog	660070	270275
LPC_6	Lielais Pelečāre Mire	B	Natural raised bog	660063	270221
LPC_6	Lielais Pelečāre Mire	C	Natural raised bog	660039	270189
LPC_7	Lielais Pelečāre Mire	A	Near-natural raised bog	660392	263312
LPC_7	Lielais Pelečāre Mire	B	Natural raised bog	660352	263322
LPC_7	Lielais Pelečāre Mire	C		660299	263326

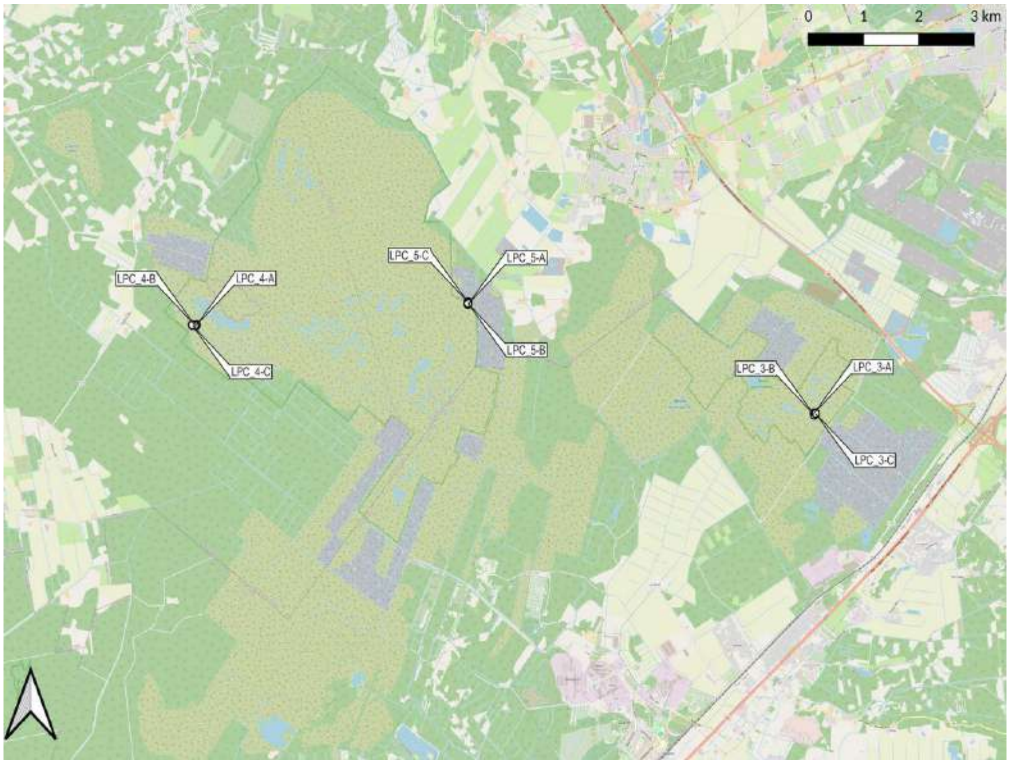


Figure 2.3.3. *Measurement sites in Riga region, Cena & Melnais Lake Mire (LPC_3, LPC_4 rewetted and LPC_5 to be rewetted).*

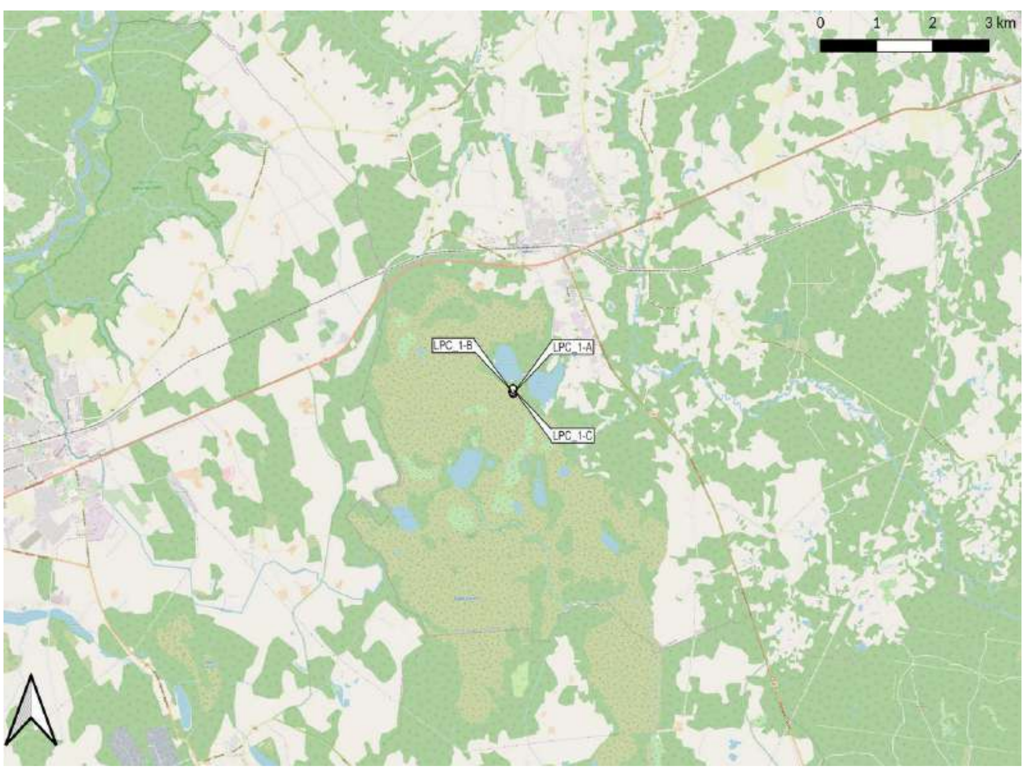


Figure 1. 3.4. *Measurement sites in Sudas – Zviedru Mire (rewetted).*

***Figure 2.3.5**. Measurement sites in Lielais Pelēčāre Mire (LPC_2 to be rewetted, LPC_6 & LPC_7 pristine).*

To conduct observations, 3 sample plots have been established at each monitoring site (at least three months before GHG emission monitoring was initiated), which characterize different ground cover vegetation composition and the impact of expected or already occurred changes in the moisture regime. In addition, 2 study sites (LPC_6 and LPC_7, Table 2.3.1) were established in the Lielais Pelečāre Mire representing natural raised bog and near-natural raised bog habitats (GHG emission monitoring was initiated in May 2024). The sample plots are located at 20-30 m from each other (Figure 2.3.6.). Three permanent collars have been installed in each sample plot to characterize total emissions and a sub-sample plot with three sampling points to characterize soil heterotrophic respiration with three gas measurement points. Sub-plots for soil respiration characterization are prepared at least three months before the start of gas exchange measurements (Figure 2.3.7.).

Ecosystem respiration – CO_2 (R_{eco} or R_{floor} depending on type of habitat), CH_4 and N_2O – is measured using the closed chamber method (Hutchinson & Livingston, 1993). The closed chamber consists of two parts – a chamber made of PVC material and is 40 cm high, with a Ø of 50 cm and a volume of 65 L and a ring that is in the soil throughout the observations. When collecting samples, the chamber is placed on the collar, which is light in colour to prevent excessive temperature increase during monitoring. A groove is made on the upper edge of the collar, which corresponds to the diameter of the chamber. This groove is filled with water, so that when placing the chamber in it, a completely closed environment is ensured (no air can enter the chamber from atmosphere).

The chambers in the plots are placed at 1-2 m from each other to reduce the need to move around the plot during gas sample collection. Gas samples are collected from the chambers using a tube inserted into the chamber and a syringe attached to it, with the help of which the air from the chambers is transferred into 100 mL bottles, from which all air has been sucked out before measurements (residual pressure <0.3 mbar). Four samples are collected from each chamber within half an hour, observing 10-minute intervals – at minute 0 (immediately after placing the chamber on the ring), at minutes 10, 20 and 30 (Bārdule et al., 2023; Butlers et al., 2023). The samples are placed in specially prepared and labelled sample boxes so that each sample has its own cell address depending on which chamber and at what minute the samples will be taken.

The subplots for measuring soil heterotrophic respiration (R_{het}) are 1.5 x 0.6 m in size with vegetation removed and delimited to a depth of 50 cm with geotextile to prevent root ingrowth (Figure 2.3.7). Between measurements, the sub-plot is covered with a light and water-permeable geotextile, which is removed from the area one hour before the start of the measurements. Soil respiration measurements are performed with an EGM5 spectrometer. The measurement lasts for 3 minutes. Soil respiration chambers are smaller than ecosystem emission measurement chambers. Soil heterotrophic respiration data are analysed using linear regression equations. If the change in CO_2 concentration does not fit the linear regression equation, the measurement is not used in further analysis, assuming that the measurement was disturbed by some external factor. The same approach is used in the analysis of ecosystem emission measurement results.

Gas samples are collected on average once a month – more often during the vegetation season and les often during winter. Every time, when collecting gas samples, the groundwater depth (cm), air temperature, soil temperature and moisture content in the soil surface are measured. Soil groundwater wells are installed for groundwater depth measurements. Groundwater wells – perforated PVC pipes (Ø50 mm), sealed in the lower 0.5 m – are placed at a depth of 1.5 m. Soil temperature is measured at four depths – 5, 10, 20 and 30 cm.

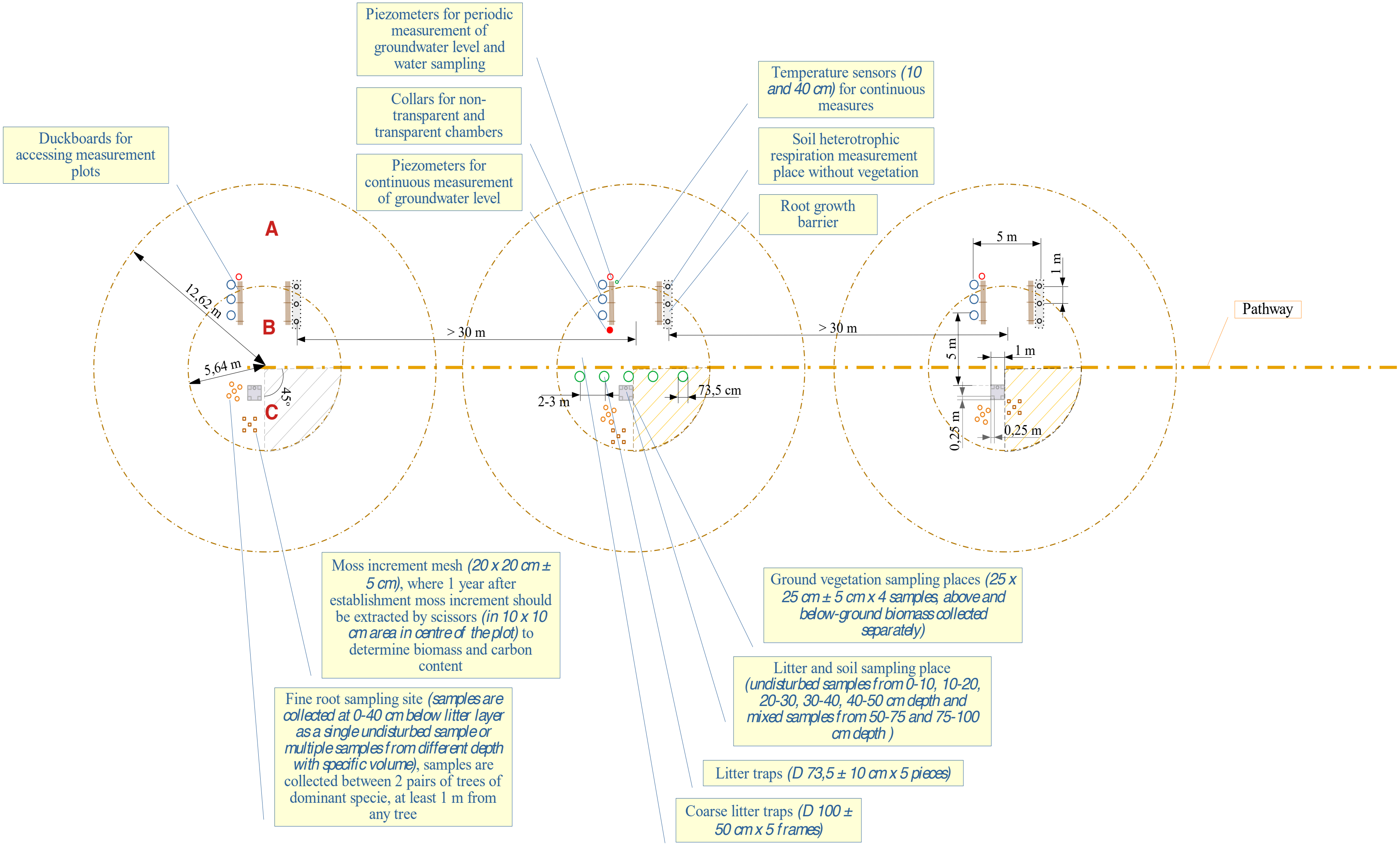


Figure 2.3.6. *Measurement site design.*

After measuring the groundwater level, the wells are pumped out to obtain fresh soil water samples for laboratory analyses. The collected water samples (collected during every gas sampling campaign) are delivered to the LSFRI Silava Forest Environmental Laboratory.

Ecosystem emissions or GHG concentrations (CO_2, CH_4 and N_2O) in the collected gas samples are analysed by the LSFRI Silava Forest Environmental Laboratory using a Shimadzu GC-2014 gas chromatograph (equipped with an electron capture detector (ESD), a flame ionization detector and a Loftfield autosampler, designed according to the principles defined by Loftfield et al. (1997). The emission level of each gas is calculated by assuming a linear increase in gas concentration over time, at a given chamber area and volume.

Figure 2.3.7. *Gas measurement plots (heterotrophic respiration on left, total ecosystem exchange (CO_2, CH_4, N_2O fluxes) in the right). Image: © G. Saule*

Simultaneously with the measurement of groundwater level, measurements and observations of factors affecting ecosystem GHG exchange are performed. Typically, groundwater characteristics such as depth, temperature, dissolved oxygen (DO), electrical conductivity, pH and oxidation-reduction potential (ORP) are determined with the ProDSS probe, as well as groundwater samples are collected for determination of the composition of (NO_3^-) and ammonium (NH_4^+) ions, as well as other parameters in the laboratory. In parallel, air and soil temperature measurements are performed at a depth of 5 cm, as well as soil electrical conductivity and soil moisture level are determined with Procheck (Figure 2.3.8.).

Figure 2.3.8. *Equipment for measuring soil temperature, moisture content and groundwater properties***.** *Image: © G. Saule*

Litter collectors (Figure 2.3.9) are installed on the outer perimeter of the plot, 10-15 m from the centre (3 pcs. in each plot) and are emptied once a month, simultaneously with gas exchange measurements. The total dry matter mass, as well as the carbon content, are determined for the litter. Large litter is not evaluated in this study, if carbon input because of natural branching or falling larger tree debris is small. The ICP Forests methodology (Ukonmaanaho et al., 2016) was used for litter collection and analysis.

Figure 2.3.9. *Water and litter sampling plots. Image: © G. Saule*

2.4. GEST monitoring

Land cover mapping at different digitalization is usually performed using spectral remote sensing data (Jakovels et al., 2016; Räsänen & Virtanen, 2019). The choice of target classes depends on available reference data as well as spectral separability. Reference data could be a community type, for instance, following a GEST typology or plant functional types and should be provided as geospatial data polygons or points. In the project, reference data have been collected according to GEST methodology (Jarašius et al., 2022) that required additional vegetation monitoring points for differentiation of all homogeneous vegetation forms present on peatland. The reference information was used directly for GEST classification, but the same information based on vegetation description by projective cover of each species will be recalculated according to their belonging to plant functional type (PFT) thus gaining reference information of PFT composition within each GEST class.

Reference data can be prepared based on existing databases or can be obtained during field visits. If spectral remote sensing data is acquired before field visits, unsupervised classification can be used for effective and targeted planning. An example of such an approach that IES have applied within the project is shown in Figure 2.4.1., where unsupervised classification based on Principal Component Analysis (PCA) was used to identify spectrally different areas. Reference GEST type class and polygon borders have been further defined during the site visit. Areas with mixed classes were not included in reference data. Obtained reference data were further used for both training of classification algorithms and the validation of produced data products.

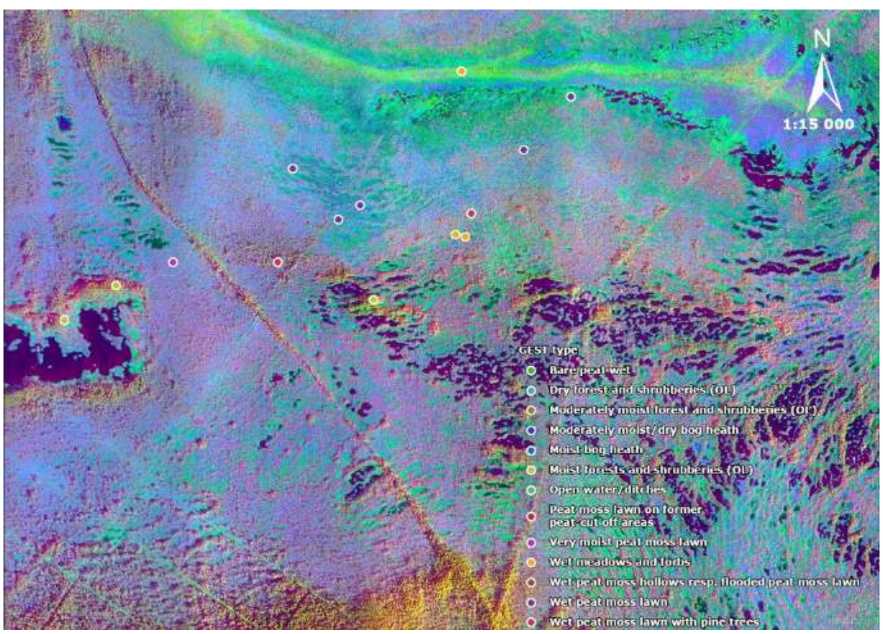


Figure 2.4.1. *Example of gathered reference data for GEST classification as input data for RS algorithm training showed on Principal Component Analysis map of Cena Mire, Latvia.*
Image: © Institute for Environmental Solutions.

If reference data is available from existing databases, it is possible to perform a separability analysis on the training data to estimate the expected error in the classification for various feature combinations (Landgrebe, 2003). The results may identify classes that cannot be separated as well as features that don't provide added value.

The choice of classification algorithms usually depends on the number of available reference data, data specifics as well as researcher's preference. There is not a best option, and the result often depends on the experience of the researcher. In Latvia, IES has previously successfully applied the Support Vector Machine (SVM) based algorithms for the classification of land cover (Jakovels et al., 2016). The SVM-based approach has been chosen as it has demonstrated relatively good performance with small reference data sets and is not sensitive to overfitting. In this case, input data standardization using mean values and standard deviations was applied, as well as RBF or Gaussian kernel was chosen.

RS experts in Luke have mostly used random forest (e.g., Räsänen & Virtanen 2019) but also SVMs and boosted regression trees. Random forest has been among the best-performing classifiers, and it is simple to use compared to some alternative classifiers. Random forest does not usually require tuning of parameters, it rarely overfits, and it is capable of handling multicollinear explanatory data with hundreds of features. Within the project different machine learning techniques will be tested for GEST classification (most probably selecting SVM or random forest) and chosen the one which demonstrates the best performance during the validation of data products.

The performance of classification algorithms was assessed during the validation procedure. It is important to separate training and validation data sets to avoid validation on data that has been already used for training. A common practice is to randomly divide available reference data into two groups where e.g., 80% are used for training and 20% for validation. In the case of small reference data sets, a k-fold cross-validation approach can be applied. For instance, in the k=5 approach training and validation are performed 5 times, each time choosing a different 20% subset for validation, and average classification accuracy is reported at the end. The k might be increased up to the total number of the reference data set where the leave-one-out validation approach is applied in such a case.

The digitalization of classification results primarily depends on the spatial resolution of spectral remote sensing data. Hyperspectral data in the visible-to-near infrared spectral range is optimal to ensure the best spectral separability, however, multispectral data with at least five spectral channels (blue, green, red, red-edge, near-infrared) is also acceptable. Data acquisition should be performed during vegetation season when the most significant spectral and textural differences could be observed among different target classes. Cloud-free sky weather conditions and flight direction in or out of the Sun are recommended to clear data with a maximal signal-to-noise ratio.

The final data products are GEST maps and PFT distribution maps used for spatial GHG emission upscaling. Those shall be based on measured flux data and flux factors, and only for rough estimation, on literature derived values. GEST approach can be tested by producing GHG emission maps using literature-based flux factor values and later validating them by flux factors based on measured GHG fluxes from the monitoring sites. Further, PFT distribution maps will be used by FMI for ecosystem model development of each project site.

3. Results

3.1. Hydrological monitoring

3.1.1. Cena Mire

Automatic water level observation probes in Cena Mire were installed on June 8 and the latest data download took place on November 11, 2023. Along with data download, manual groundwater level measurements took place using acoustic water level probe. The manual measurements are used to control the validity of automatic measurements. Water quality parameters were not measured during the reporting period.

Assessment of Water Level Observation Quality

In Cena Mire, good agreement was found between manual and automatic water level measurements (Figure 3.1.1). Differences in most cases are less than 5 cm, which overall corresponds to the uncertainty sum of manual and automatic measurements. Exception is the monitoring well No. Cena23, where in one case the difference is more than 15 cm. Reasons for the deviance and any corrective measured need to be established during future monitoring.

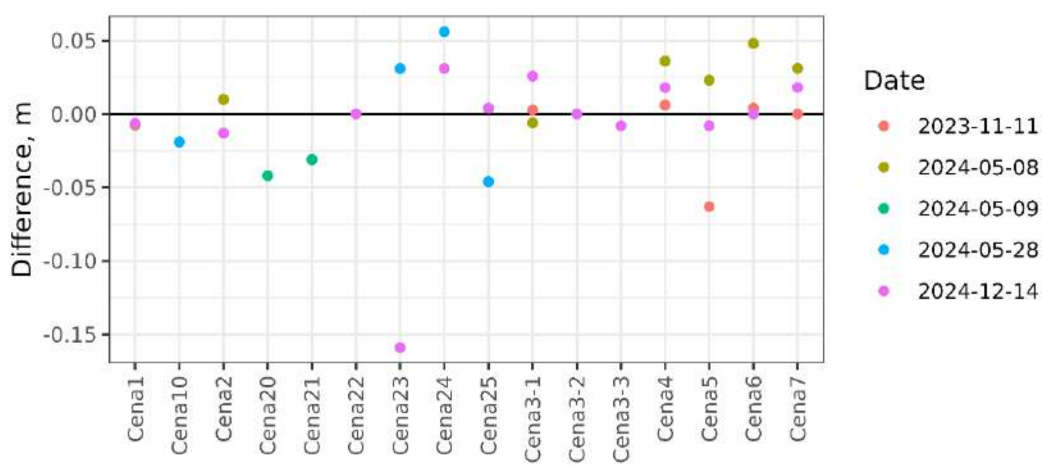


Figure 3.1.1. *The difference between automatic and manual water level measured in most observation points is 0.05 m or less, indicating overall good measurement quality.*

Results of the groundwater level monitoring

In Cena Mire 6 groups of water table measurements are distinguished:

1. 2006 restoration - Lake Skaista (Wells No. Cena14, Cena15)
2. 2006 restoration - drainage area – 2 (Wells No. Cena20, Cena21)
3. Bog woodland (Wells No. Cena23, Cena24, Cena25)
4. Mire lake dam (Wells No. Cena10, Cena11)
5. Peat extraction area (Wells No. Cena22, Cena4, Cena5, Cena6, Cena7)

6. Profile from degraded to pristine raised bog (Wells No. Cena1, Cena2, Cena3-1, Cena3-2, Cena3-3)

The water level probes at the 2006 restoration site near Lake Skaista (Wells No. Cena14, Cena15) were installed May 27, 2024, the data were downloaded in early 2025, however the analysis is limited to hydrological year up to September 30, 2024. We see that the water level range at both sites was about 20 cm with peak corresponding to Jule 29, when extreme precipitation occurred (Figure 3.1.2). Noticeably, during the summer water table decline was faster in well Cena14, that is higher on the bog dome than in Cena15, that is located further downstream in part of the bog with higher remaining tree cover. The reason for this difference remains to be investigated once a longer data time series are accumulated.

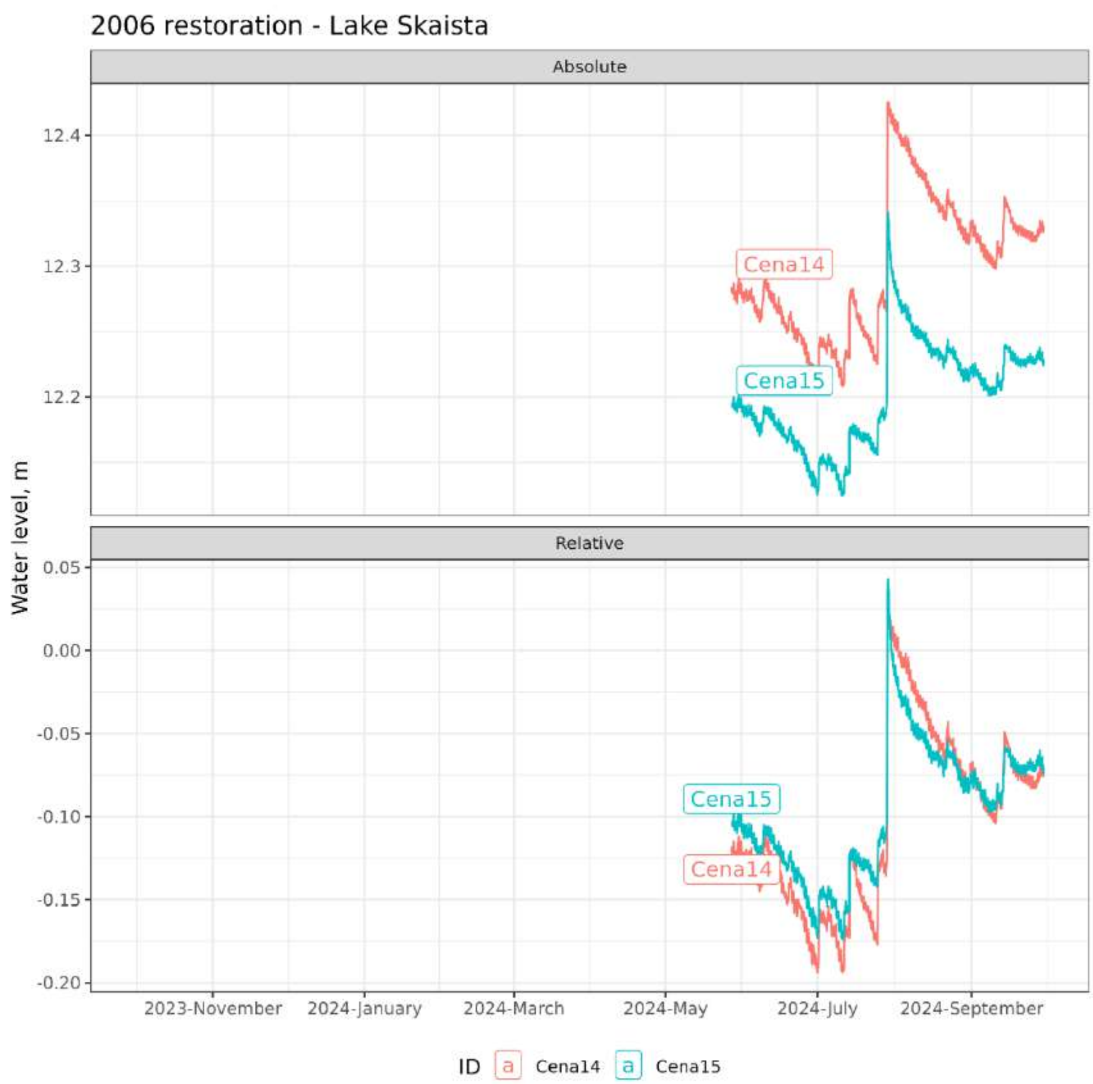


Figure 3.1.2. *Water level dynamics in a small, blocked ditch (well Cena15) and in between two small ditches (well Cena14) in a drained mire section restored in 2006.*

Table 3.1.1. *Water level monitoring data summary for Cena Mire*

Well ID	*Mean relative water table, m*	*Min relative water table, m*	*Max relative water table, m*	*Mean absolute water table, m*	*Range of the daily mean, m*
Cena1	-0.38	-0.52	-0.16	10.24	0.36
Cena10	-0.12	-0.25	0.08	11.06	0.33
*Cena11**	0.01	-0.07	0.1	8.8	0.17
*Cena14**	-0.1	-0.19	0.02	12.3	0.21
*Cena15**	-0.1	-0.17	0.02	12.2	0.19
Cena2	-0.04	-0.13	0.08	11.79	0.21
*Cena20**	-0.27	-0.41	-0.1	12.67	0.31
*Cena21**	-0.12	-0.22	0.01	12.95	0.23
*Cena22**	-0.26	-0.56	-0.06	12.77	0.5
*Cena23**	-0.55	-0.83	0.05	11.94	0.88
*Cena24**	-0.77	-1.02	-0.16	8.33	0.86
*Cena25**	-0.4	-0.72	0.06	8.28	0.78
Cena3-1	0.08	-0.06	0.19	12.55	0.25
*Cena3-2**	-0.01	-0.09	0.07	12.45	0.16
*Cena3-3**	-0.94	-1	-0.86	11.66	0.14
Cena4	-0.13	-0.39	-0.01	10.42	0.38
Cena5	-0.2	-0.38	-0.12	10.69	0.26
Cena6	-0.05	-0.15	0.03	11.32	0.18
Cena7	-0.02	-0.1	0.05	12.6	0.15

* incomplete time series, starting from May 2024

Figure 3.1.1 *Installation of the groundwater level probe in Cena21 well in a 2006 restoration site with dens network of drainage ditches, May 7, 2024. Image: © A. Kalvāns*

Figure 3.1.4. *Installation of the water level monitoring well Cena4 in the degraded part of the Cena Mire, PeatCarbon restoration site, June 8, 2023. Image: © A. Kalvāns*

In the 2006 restoration site with dense network of drainage ditches, data from two observation wells are available – one placed directly in the blocked ditch (Cena20) and the other in between ditches (Figure 3.1.3). Here the pattern of water level fluctuations is very similar (Figure 3.1.4), but the ditch has slightly smaller range of the water level (23 cm in comparison to 31 cm, Table 3.1.1) This indicates that the restoration measures are effectively keeping the water in the bog.

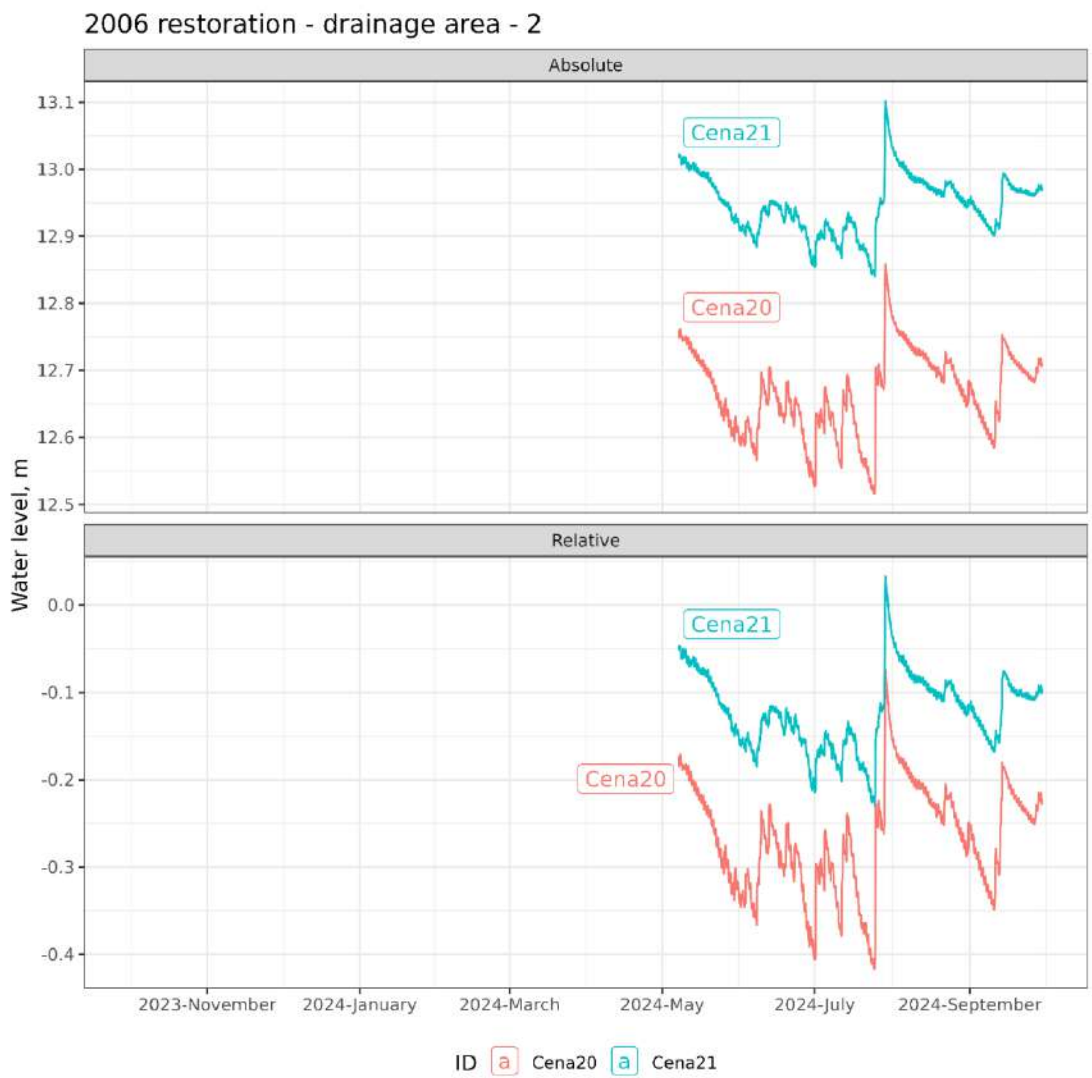


Figure 3.1.5. *Water level dynamics in observation sites near Lake Skaista where mire hydrological regime was restored in 2006.*

At the site that was prepared for peat extraction (wells No Cena4 to Cena7 and Cean22, Figure 3.1.5, Figure 3.1.6) we see a clear trend in increasing depth and range of the water table towards the main drainage ditches. However, we notice that the yearly water table range in some of these wells (Table 3.1.1) was less than in the pristine raised bog site Cena3-1. This seems to be due to deep water pooling in the pristine part of the bog during the winter, that seems to result for interaction between snow, ice and bog microtopography. It appears that in the site affected by drainage, during the autumn-winter-spring seasons the surface water effectively drained by remaining drainage capacity of existing dens ditch network. However, during the warm season the drainage of the soil water is limited by the natural clogging of the ditches.

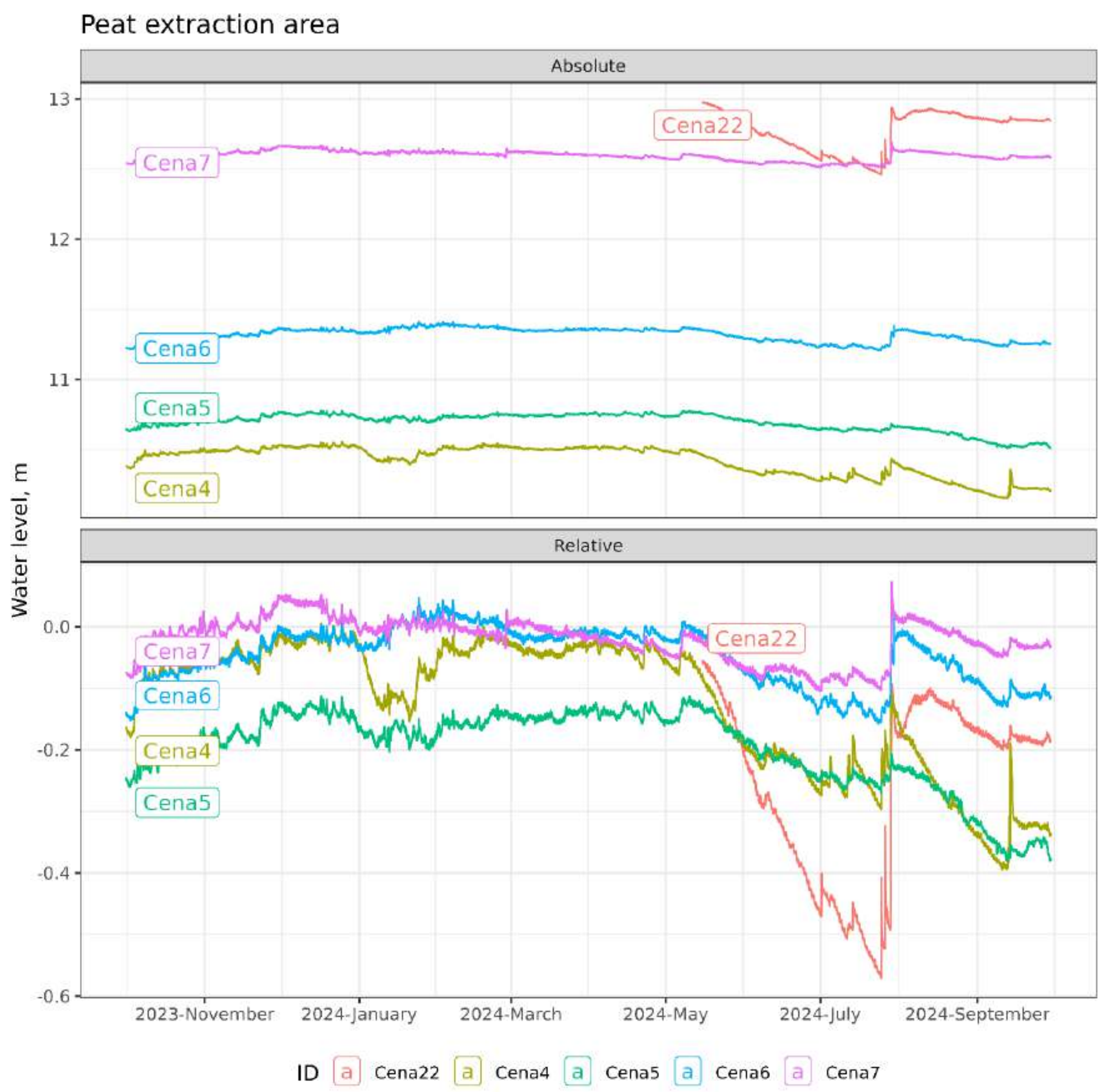


Figure 3.1.6. *Water level dynamics in observation sites in a drained bog with dens network of drainage ditches (planed restoration area No 1 "Kūdras lauks (Atpūtas)"), forming a gradient from heavily degraded bog with baren peat surface (Cena4) to largely intact mire (Cena7); well, Cena22 is at location within a patch of dens young pine tree stand.*

Figure 3.1.7 *Water level monitoring wells Cena3-1, Cena3-2 and Cena3-3 in relatively undisturbed part of the Cena mire, Jun 8, 2023*

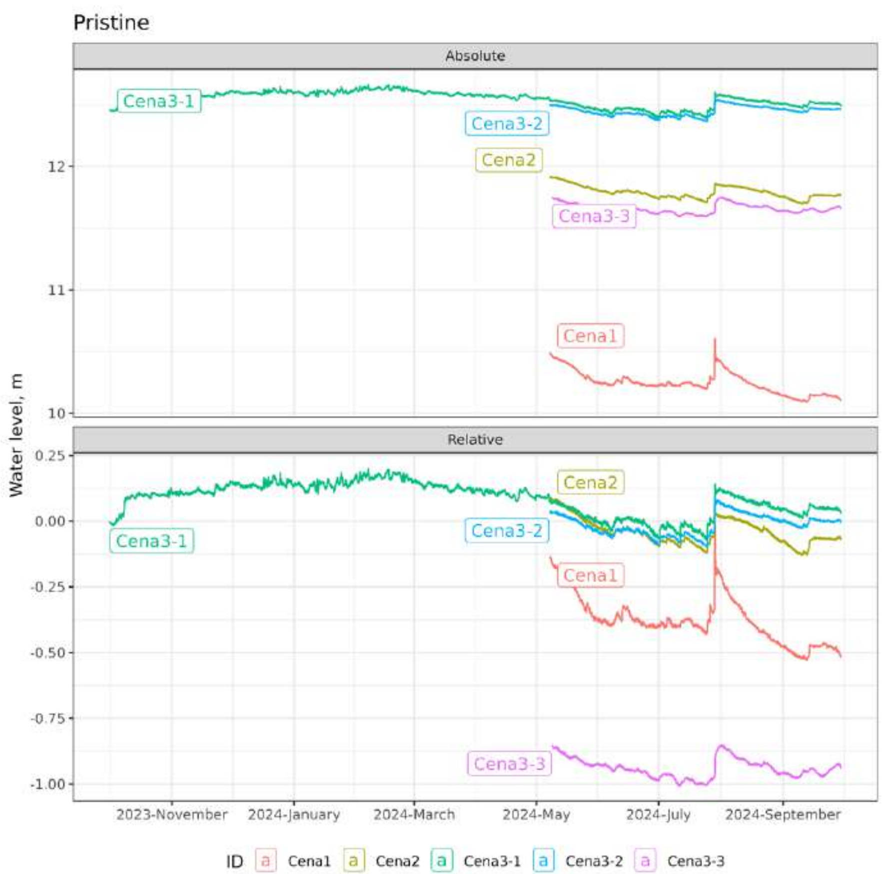


Figure 3.1.8. *Absolute (top) and relative (bottom) water level time series in radial profile at the Cena mire for hydrological year from October 1, 2023, to September 30, 2024.*

At the observation profile (Figure 3.1.7) from a drained bog margin to largely pristine raised bog we notice that the water level fluctuation rang is least further away from the drainage system (Well3-1, Figure 3.1.8) however the measurements cannot be directly compared as the only Cena3-1 cover the full hydrological year from October 1, 2023, to September 31, 2024. However, we do notice that the range and average depths at wells affected by drainage (Cena1 and Cena2) the is greater than for those deeper in the pristine raised bog. In addition, we notice that in the well Cena3-3, that penetrates the 5 m peat layer, the water table is about 1 m below the surface, demonstrating that there is downwards filtration of the water from peat into sandy mineral subsoil. Thus, the sand layer at the base of the bog keeps draining water from it and thus drainage systems penetrating this layer in the surrounding of nature conservation area do affect the water balance deep within the bog.

Discharge measurements

The water discharge (runoff) monitoring in Cena Mire was planned in the hydrological regime restoration area No. 1 (Kūdras lauks (Atpūtas)), at observation point Cena8. Upon inspecting the installed observation point in the autumn of 2023, it was discovered that the constructed spillway had become clogged with eroded peat (Figure 3.1.9.), rendering the measurement results unusable. It is planned to relocate the discharge monitoring point to a ditch where the accumulation of such peat erosion material is not anticipated in a restoration area No.2 “Akača dambis”.

Figure 3.1.9. *A discharge measurement spillway (monitoring point Cena8) clogged with eroded peat, November 10, 2023. Image: © A. Kalvāns*

3.1.2. Lielais Pelečāre Mire

Meteorological conditions

During the most of available observation period from April 23, the temperature in Lielais Pelečāre Mire was relatively high, reaching peek in late July and August, daily maximum exceed 30°C and average above 20°C (Figure 3.1.10). From mid-May to late mid-September the daily maximum was consistently above 20°C. Notable precipitation events were recorded in early June, second and third decade of July and middle of the August. April and May as well as late August and September has seen little precipitant.

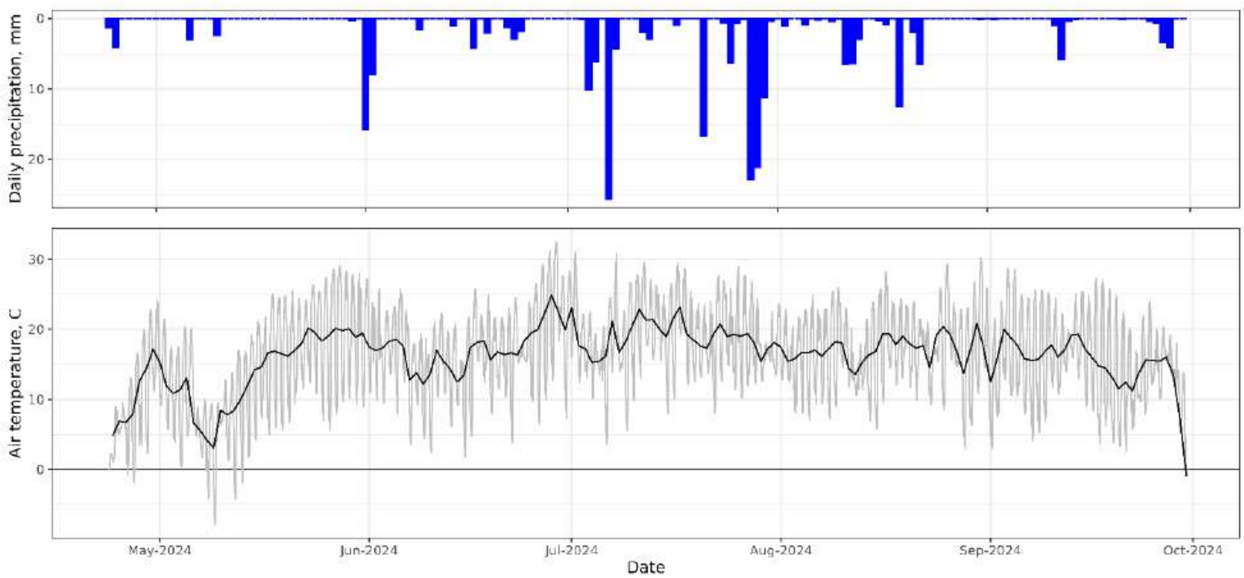


Figure 3.1.10*. Daily precipitation and air temperature in Lielais Pelečāre mire, open raised bog site (Pelecare_a3_atklats_purvs)*

Automatic water level observation probes in Lielais Pelečāres Mire were installed on June 22, 2023, additional data loggers were installed on April 23, 2024. The latest data download took place in January 15, 2025. Along with data download manual groundwater level measurements took place using acoustic water level probe. The manual measurements are used to control the validity of automatic measurements. Water quality parameters were not systematically measured during the reporting period. The analysis in this report is limited to hydrological year from October 1, 2023 to September 30, 2024.

Water level observations in Pelečāre mire is subdivided into 6 groups: Deiglu bog, drained; Deiglu bog, pristine; Lake Deguma; Malnupeite, bog woodland; Malnupeite, drained and Malnupeite, stream.

Two weather stations and soil water monitoring sites have been set up in the Lielais Pelečāre mire to study microclimatological differences between open raised bog landscape and woodland. The water quality monitoring of selected parameters is organized in along the Malnupeite River cores in the Southern part of Lielais Pelečāre Mire.

Mostly, the depth of the water level determined by automatic probes aligns well with manual control measurements, falling within the summative uncertainty limits (<5 cm). Initial measurements during setup in wells No. Pelecare3 to Pelecare6 and Pelecare18, show large deviations, but subsequent control measurements show reasonably good consistency Figure 3.1.11).

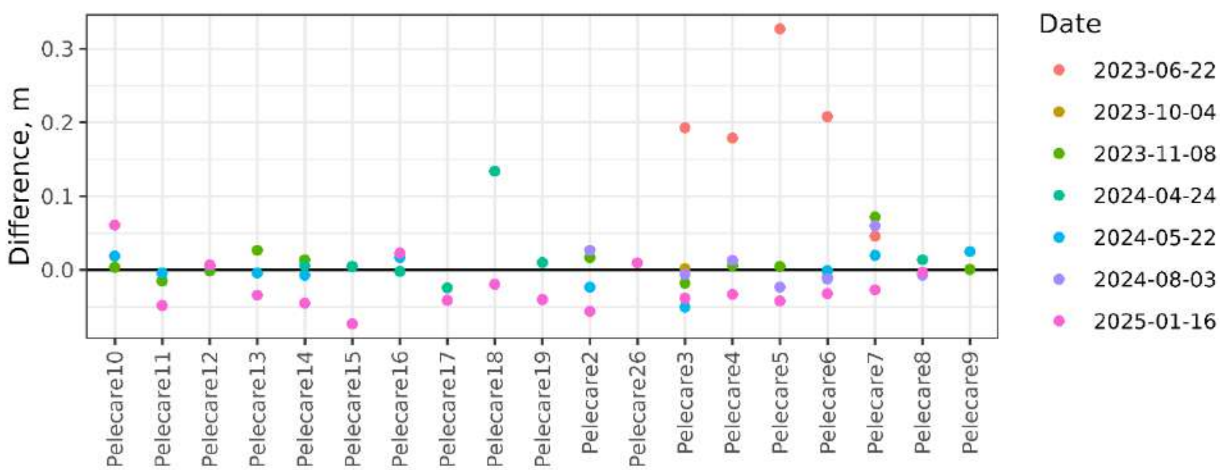


Figure 3.1.11. *The difference between automatic and manual water level measured in Lielais Pelečāres Mire*

Table. 3.1.2. *Summary statistics for the water table below soil surface in Lielais Pelečāre Mire.*

Group of observations	*Well ID*	*Mean relative water table, m*	*Min relative water table, m*	*Max relative water table, m*	*Mean absolute water table, m*	*Range of the daily mean, m*
Deiglu bog, drained	Pelecare1	-2.48	-3.41	-1.74	108.09	1.67
	Pelecare2	-0.57	-1.59	0.06	108.86	1.65
	Pelecare3	-0.19	-0.54	-0.03	110.77	0.51
	Pelecare4	-0.19	-0.41	-0.09	110.77	0.32
	Pelecare5	-0.16	-0.37	-0.05	111.14	0.32

Deiglu bog, pristine	Pelecare6	-0.15	-0.35	-0.03	111.51	0.32
	Pelecare7	-0.44	-1.53	0.2	109.16	1.73
	Pelecare8*	-0.27	-0.51	-0.03	110.45	0.48
Lake Deguma	Pelecare14	0.06	-0.12	0.24	105.33	0.36
	Pelecare15*	-0.19	-0.28	-0.02	107.05	0.26
	Pelecare16	-0.2	-0.54	-0.06	106.09	0.48
Malnupeite, bog woodland	Pelecare18*	-0.38	-0.54	-0.11	104.42	0.43
	Pelecare19*	-0.37	-0.52	-0.04	107.98	0.48
Malnupeite, drained	Pelecare10	-1.2	-1.4	-0.74	103.51	0.66
	Pelecare11	-0.41	-0.63	-0.12	104.72	0.51
	Pelecare12	-0.12	-0.29	-0.02	105.44	0.27
	Pelecare13	-0.16	-0.32	-0.06	105.95	0.26
	Pelecare17*	-0.54	-0.64	-0.43	104.68	0.21
Malnupeite, stream	Pelecare9	-1.71	-1.93	-1.29	98.66	0.64

* Incomplete time series starting from April 23, 2024

Results of the water level observations in a section of the Deigļu Mire least affected by drainage

At this location, there are 3 wells equipped with automatic water level probes: Pelecare6 on the slope of the raised bog dome; Pelecare8 at a hinge of the raised bog dome and Pelecare7 in the bog woodland, forming the transition zone between the raised bog and the upland forest (Figure 3.1.12, 3.1.13). We see gradual increase of the mean groundwater depth and the range of groundwater level fluctuations in a direction from bog dome to the marginal bog woodland. At the slope of the dome the yearly range of the water level was 32 cm, while at the marginal hinge of the dome (Pelecar8), for an incomplete series it was already 48 cm and more than 173 cm at bog woodland (Pelecare7), where the minimum levels were not detected as the water table plunged below the well depth (Table 3.1.2). Interestingly, at this site temporal flooding we detect only at the bog woodland, but not in the raised bog itself.

Figure 3.1.12.
Monitoring wells Pelecare6 (left) and Pelecare7 (right) forming a profile from relatively undisturbed raised bog to bog forest at its margin, June 21, 2024. Image: © A. Kalvāns

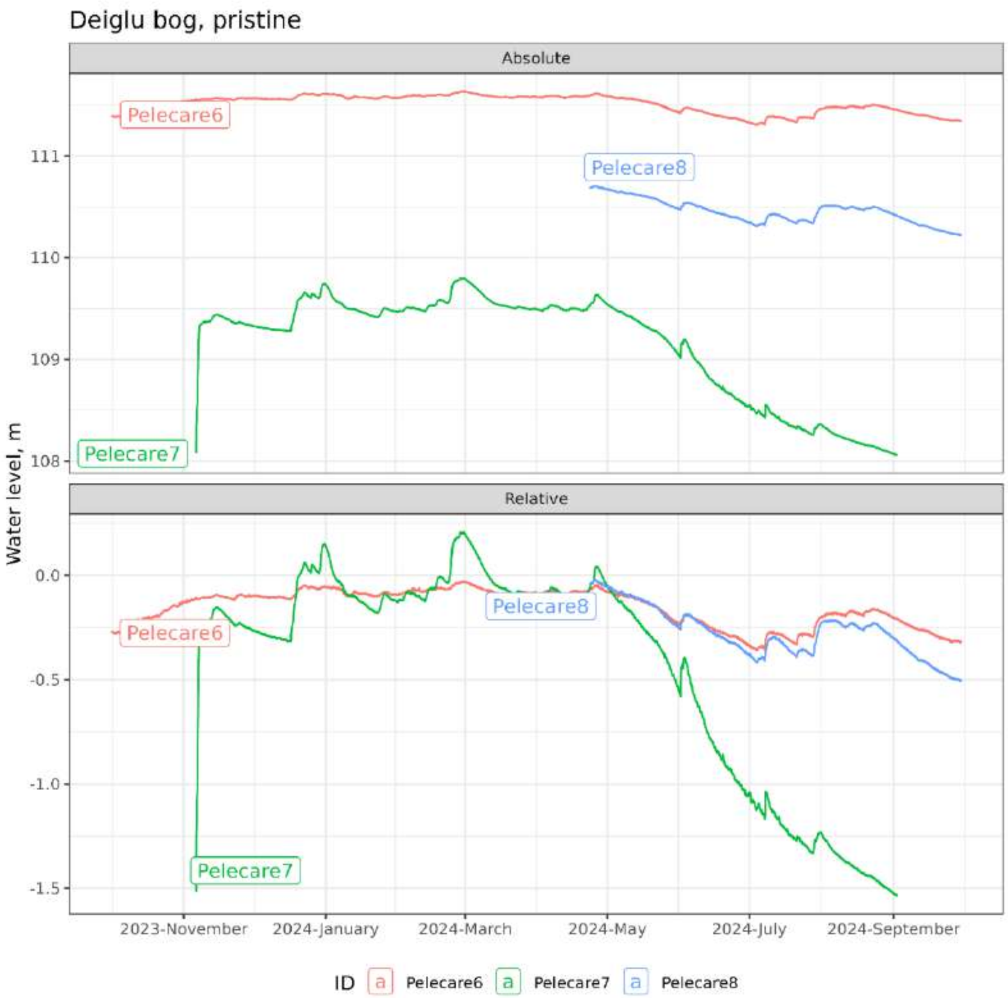


Figure 3.1.13. *Observed water level in the less affected by drainage part of the Lielais Pelečāre Mire, Deigļu Mire section: Pelecare6 – observation point located on the slope of the raised bog dome; Pelecare7 – observation point in the bog woodland in the transition zone between the raised bog and dry forest.*

Results of the water level observation in the section of the Deigļu Mire affected by drainage

In the drained part of the Deigļu Mire, 5 water level observation points have been set up, forming a profile line from the dry forest (Pelecare1), continuing through the bog woodland formed drained peatland (Pelecare2, Pelecare3, Pelecare4), and into the raised bog less affected by the drainage (Pelecare5; Figure 3.1.14).

Here we see that the water level in mineral soil near bog margin (No. Pelecare1 and Pelecare2) (Figure 3.1.15) is consistently lower than in the bog, indicating groundwater recharge – infiltration of the water emanating from the raised bot. This has implications for the planed restoration measures – simple dams on the ditches will not completely stop water loss from the bog woodland, still some of the water will infiltrate into the sandy subsoil. Full closure of the ditches would provide better restoration results.

Figure 3.1.14. *One of two weather stations for microclimatological analysis and data logger at the Pelecare_a1_mezs observation site near well Pelecare1. Image: © A. Kalvāns*

Water level observations in the Lake Deguma

A water level monitoring profile towards the lake Deguma (Error! Reference source not found.) consists of monitoring points No. Pelecare15, Pelecare16 and Pelecare14, the later recording the water level in the lake Figure 3.1.15).

The range of the Lake Deguma water level in 2024 hydrological year was 36 cm (Error! Reference source not found.), that is like that seen in other monitoring sites with pristine raised bog conditions. The water level peek was recorded in March 2024, probably reflecting the meltwater input. Meanwhile the extreme precipitation event at the end of July, that is prominent in many of the groundwater monitoring sites, is barely seen in lake Deguma hydrograph. The Pelecare16 site is located at the elevation hinge between raised bog dome and bog lake, covered by a strip of pine forest. Here the water level dynamics were much like one observed in the margins of the raised bog (wells No. Pelecare2 and Pelecer7) – sharp rise of the water level in late autumn or early winter, stable levels in winter, and decline in summer and autumn with peaks corresponding to major precipitation events.

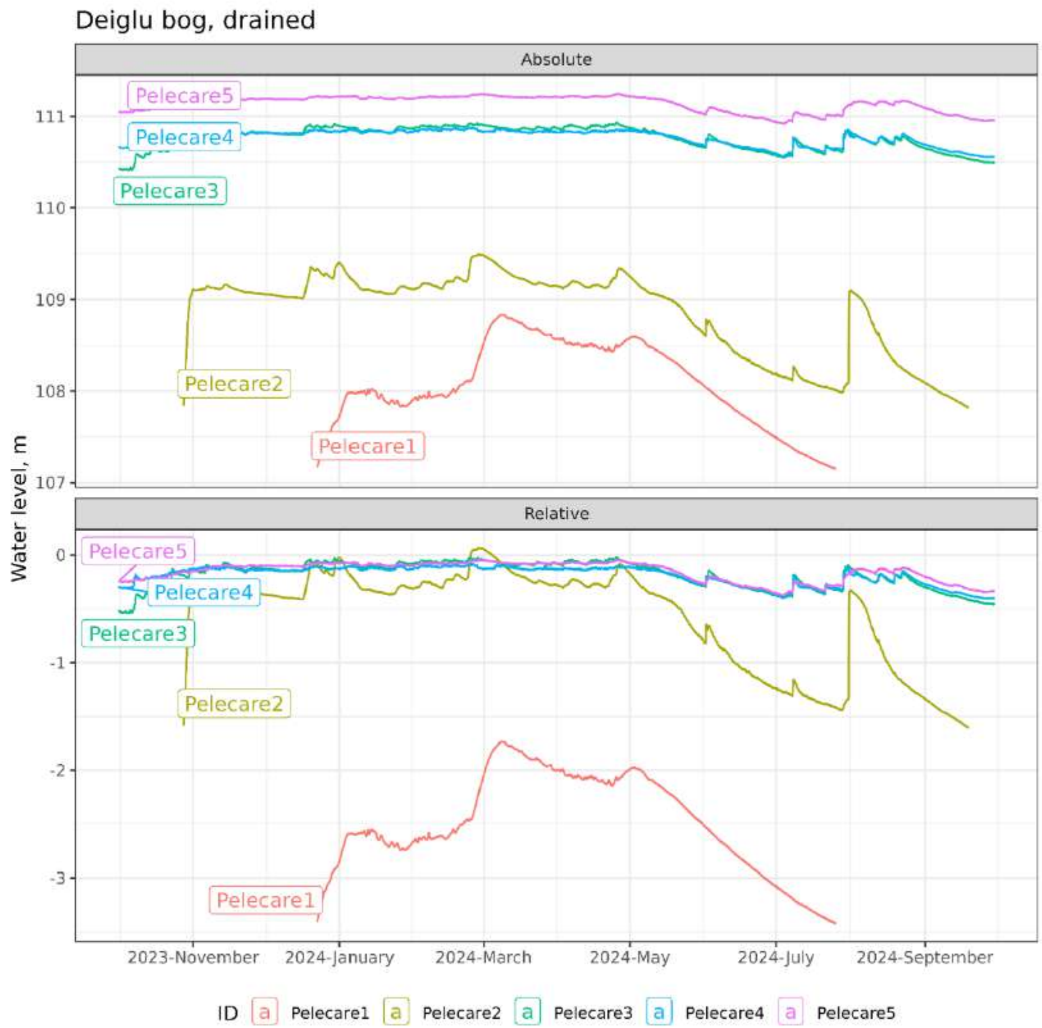


Figure 3.1.15. *Observed water level in the drained part of the Deigļu Mire (southern part of the Lielais Pelečāre Mire): Pelecare1 – dry forest at the edge of the bog; Pelecare2, Pelecare3, Pelecare4 – bog woodland, partially formed because of drainage on the slope of the raised bog dome; Pelecare5 – observation point least affected by the drainage at the bog side of the last drainage ditch.*

Figure 3.1.16. *Installation of the water level monitoring equipment at the floating shore of the Lake Deguma, June 20, 2023. Image: © A. Kalvāns*

Figure 3.1.17 *Deep drainage ditch cut into the peat that is known as river Malnupeite, near water level monitoring well Pelecare10, August 27, 2022. Image: © A. Kalvāns*

Water level observations in the drained section of the Malnupeite River catchment

The group of water level observation points in the drained section (Figure 3.1.18) of Malnupeite River catchment consists of 5 water level monitoring wells. Here we see a clear pattern of increasing depth to water table and range of water table fluctuations towards the main drainage ditch, that is about 2 m deep near the water level monitoring profile (Table 3.2).

We can note an interesting pattern: in the parts drained section of the bog further away from the main, deep drainage channel (Malnupeite) the yearly range of the groundwater level (26 to 27 cm) is slightly less than in more pristine locations (Pelecare6, 32 cm). Similar pattern we can notice in Cena mire as well. One explanation for this might be that the derelict drainage system does not affect the water level once it is bellow soil surface, but still effectively evacuates any above-surface water consists of water level observations in the watercourse of national significance named “Nr.25”, that collects water from Malnupeite River outside the raised bog (Pelecare9), a profile of four observation points in a raised bog section drained by a dens network of small ditches (Pelecare10, Pelecare11, Pelecare12, Pelecare13) drained by deep collector ditch named Malnupeite River, and an observation point of the Deguma Lake water level (Pelecare14, Figure 3.1.19).

During the reporting period, water flow in ditch Nr.25 (Pelecare9) outside the Lielais Pelečāre Mire appeared only in the second half of October 2023 (Figure 3.9), presumably due to an increase in groundwater levels because of autumn rains. During the observation period, one instrumental flow measurement was carried out there using the salt tracer method: on November 7, 2023, at 12:26, the calculated discharge was 32.6 l/s and the corresponding relative water level was -1.66 m relative to the zero mark of the observation point.

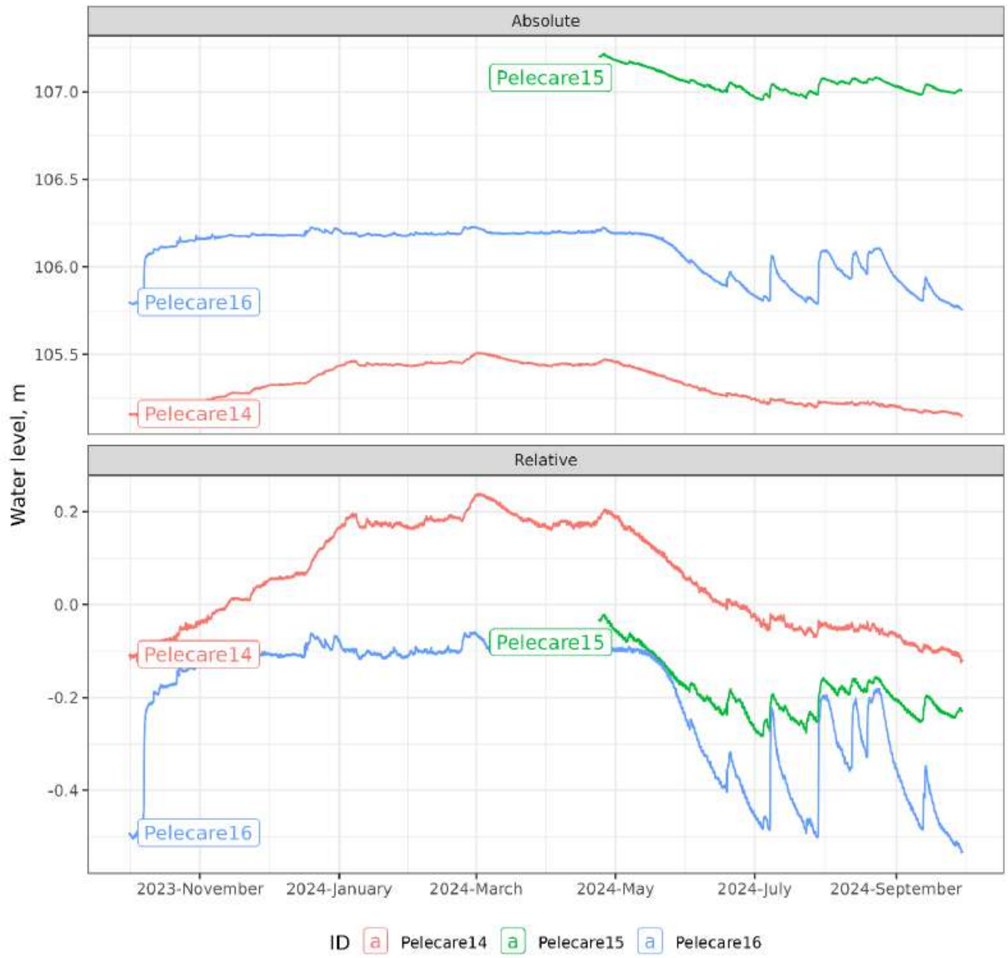


***Figure 3.1.18**. Observed water level near Lake Deguma: Pelecare 14, Pelecare 16 – bog woodland along lake shore; Pelecare 15 – open raised bog.*

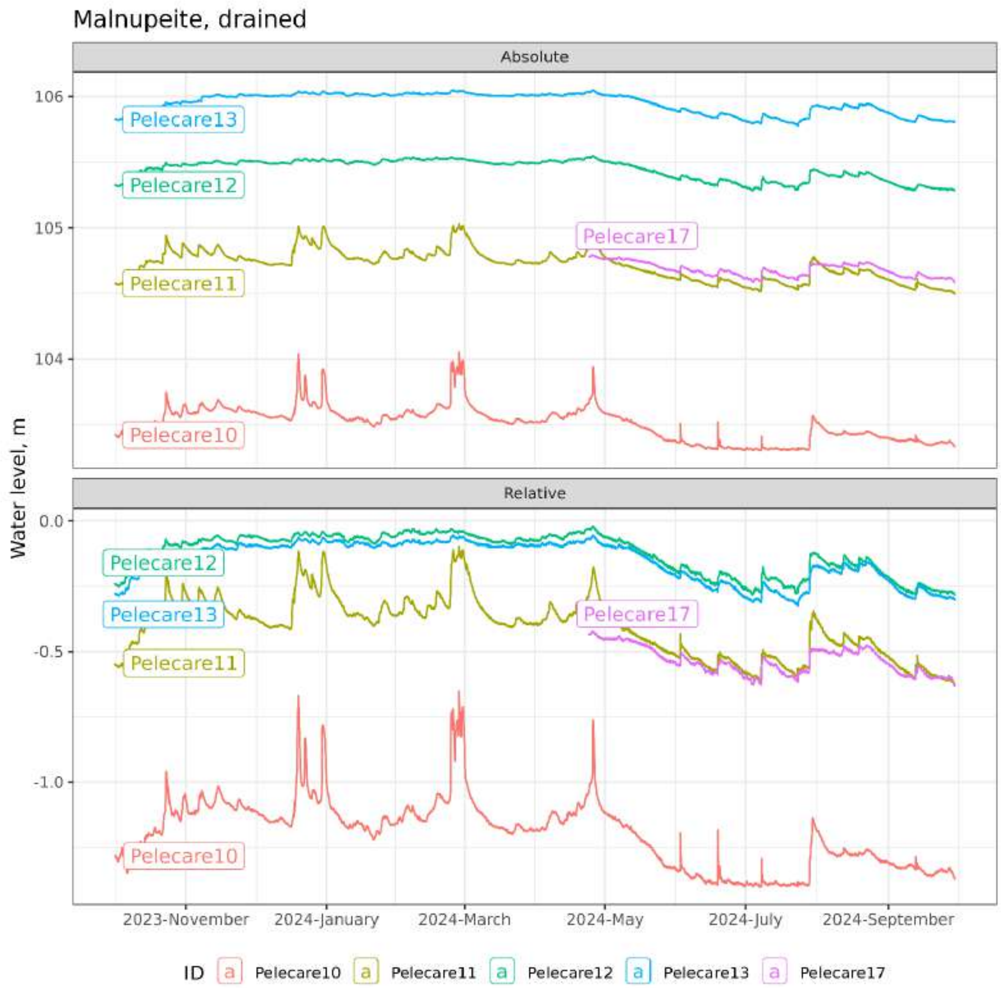


Figure 3.1.19. *Observed water level in the southern part of Lielais Pelečāres Mire, within the drainage basin of watercourse of national significance named "Nr.25" (Malnupeite) and Deguma Lake: Pelecare9 – Malnupeite River (watercourse of national significance named "Nr.25"); Pelecare10, Pelecare11, Pelecare17, Pelecare12, Pelecare13 – profile of observation points perpendicular to the deep collector ditch (Malnupeite) within the Lielais Pelečāre Mire.*

Water level observations in bog woodland in Malnupeite River catchment

A profile of two wells (No. Pelecare18 and Pelecare19) were installed near Malnupeite River channel in the bog woodland in the forested marginal zone of the Lielais Pelečāre Mire. The two wells since April 2024 had similar range of the groundwater level fluctuations for the observation (43 to 48 cm, Table 3.1.2. (Figure 3.1.20.), however the well near the channel had more flashy behaviour with higher increase of water level in response to moderate precipitation events, showing the impact of the drainage from upstream catchment.

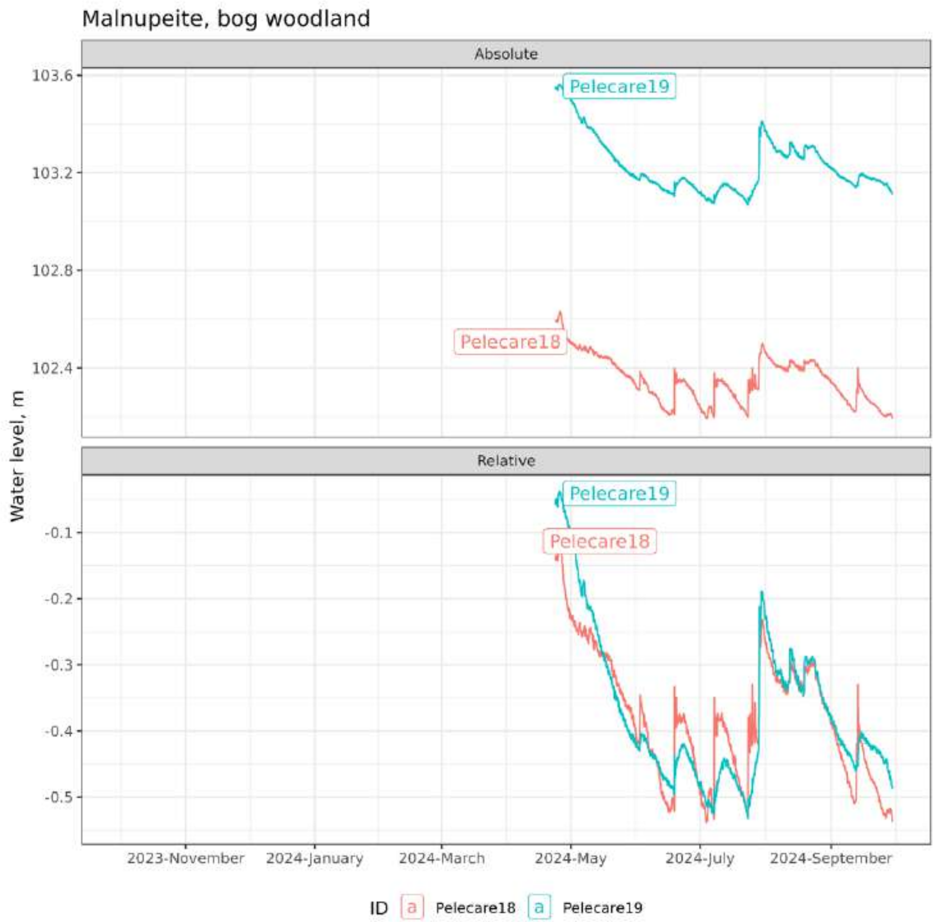


Figure 3.1.20. *Observed water level at a profile towards the Malnupeite ditch at the bog woodland located at the margin of the raised bog: Pelecare19 – 20 m distance from the ditch; Pelecare18 – within 0,5 from the ditch.*

The along-stream water level of Malnupeite River

Three monitoring wells record the water level along the stream of the Malnupeite River: No. Pelecare10, Pelecare18 and Pelecare9 Figure 3.1.21). Strictly speaking, only Pelecare9 records the river water level, while the rest are placed in the sediments near the stream channel. Along the stream some sensitive chemical parameters were measured. At the Pelecare9 site the discharge was periodically measured using salt tracing method (Table 3.1.3).

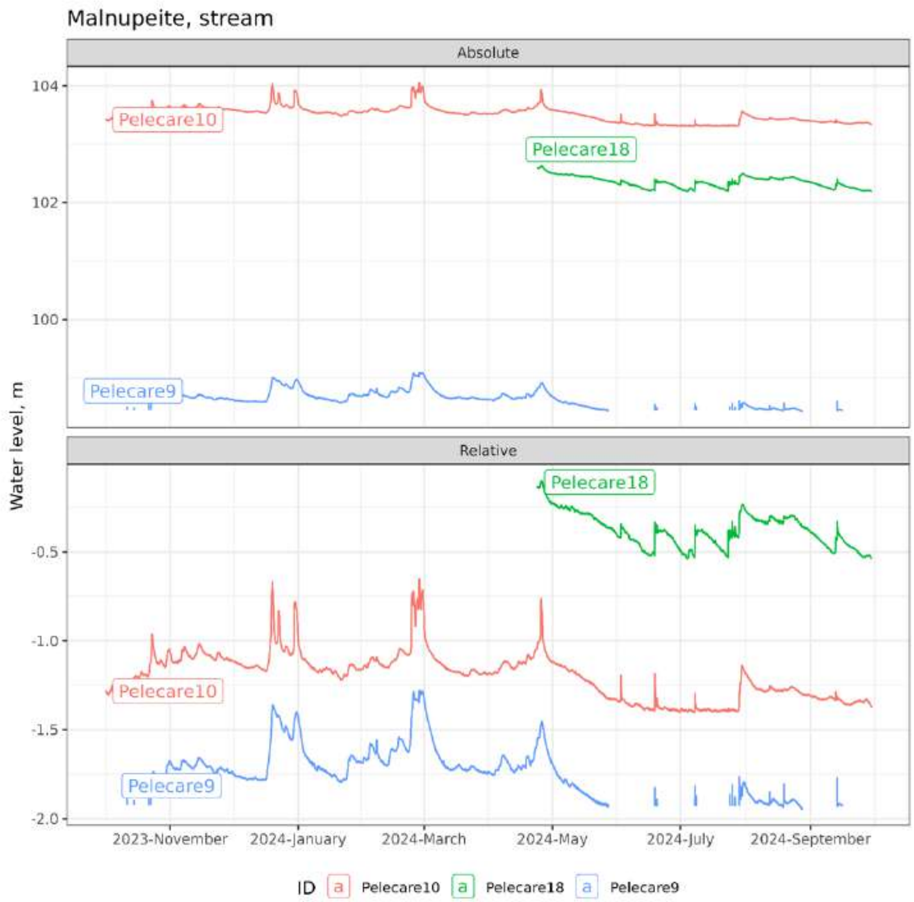


Figure 3.1.21. *Observed water level observed in wells near the Malnupeite ditch from the heavily drained raised bog (Pelecre10), to bog woodland between raised bog and dryland (Pelecare18) to a ditch outside the bog (Pelecare8).*

Table 3.1.3. *Water quality monitoring results along the Malnupeite stream.*

ID	*Date*	*pH*	*EC, µS/cm*	*N-total, Mg/l*	*P-total PO_4 mg/l*	*Alkalinity, $CaCO_3$ mg/l*	*TOC, C-mg/l*	*Q, l/s*
Pelecare10g	2023-03-08	4.409	38.2	3.6	0.84	7	50	
PelecareMellzt	2023-03-08	3.774	67.7	0.9	0.44	1	59	
Pelecare9	2023-07-11							62.6
Pelecare9	2024-16-04	6.085	52.7	1.3	0.33	16	81	27.1
Pelecare18g	2024-16-04	3.715	78.6	2.6	0.22	1	64	
Pelecare10g	2024-16-04	3.701	69.7	1.1	0.18	4	51	
PelecareMellzt	2024-16-04	3.729	57.3	0.6	0.26	1	66	
Pelecare9	2024-21-05							0
Pelecare9	2024-03-08	6.29	88.6	3	0.36	29	105	1.88
Pelecare18g	2024-03-08	3.674	95.2	1.5	0.2	<1	87	

Pelecare10g	2024-03-08	3.645	90.5	1.5	0.34	<1	102	
PelecareMellzt	2024-03-08	3.648	95.9	2.2	0.31	<1	80	
PelecareMellzt	2025-15-01	3.57	84.9	<0.1	0.23	<1	56	
Pelecare9	2025-15-01	5.645	64.1	1.1	0.35	<1	122	62.5
Pelecare10g	2025-15-01	3.47	98.1	<0.1	0.24	<1	69	
Pelecare18g	2025-15-01	3.458	110.1	<0.1	0.2	<1	104	

3.1.3. Sudas-Zviedru Mire

Assessment of Water Level Observation Quality

Water level probes in Sudas-Zviedru mire were installed on June 11, 2024 while the data were download on October 21, 2024, however for the consistency we limit the data set to the end of water year (September 30, 2024). The water level measurements at Sudas-Zviedru Mire shows an excellent agreement between automatic and manual measurements – in most cases the difference is less than 2 cm (Figure 3.1.23.).

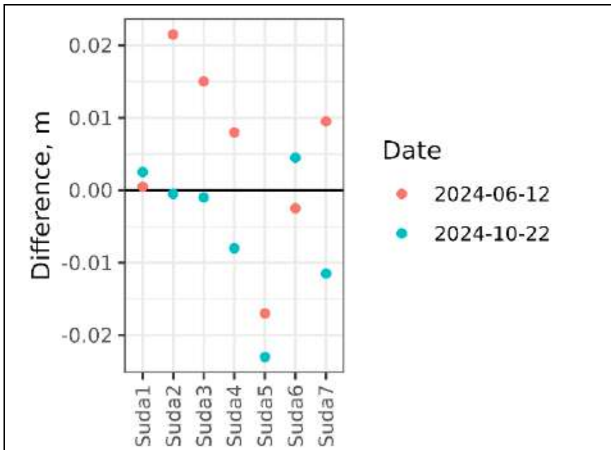


Figure 3.1.22. *The difference between automatic and manual water level measured at all observation points is 0.05 m or less, indicating overall good measurement quality.*

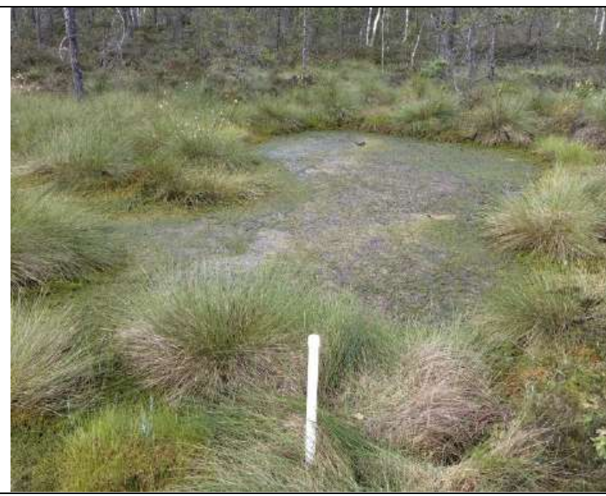


Figure 3.1.23*. Water level monitoring well in Suda6 in Sudas-Zviedru Mire restored area in 2017, June 22, 2024. Image: © A. Kalvāns*

Results of the groundwater level monitoring

We analyse the water level observations in tow overlapping profiles. One is oriented radially in respect to the raised bog dome, across the two parallel ditches, that have been blocked in previous project, from bog woodland closet to the margin to the open raised bog (wells No. Suda2 to Suda7). The other is along the ditch axis, tangential in respect to the bog dome (wells No. Suda5, Suda6 and Suda1) (Figure 3.1.23).

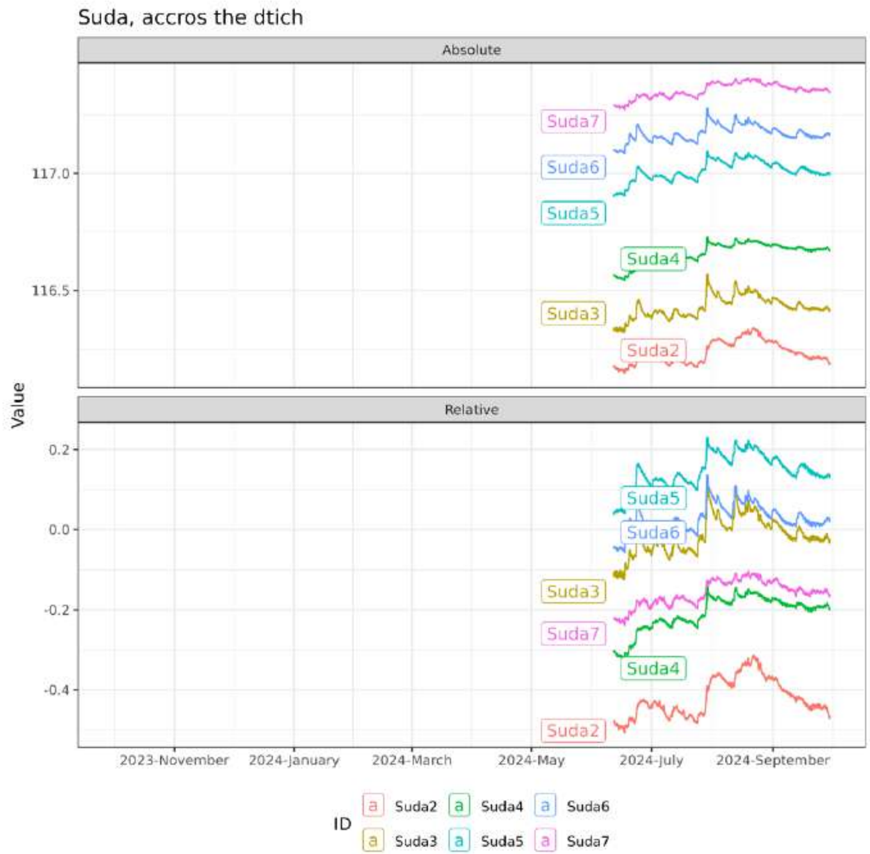


Figure 3.1.24. *Absolute (top) and relative (bottom) water level time series in radial profile at the Sudas-Zviedru Mire.*

In the radial profile we see gradually lower water table from the open raised bog to the bog woodland (Figure 3.1.24). The similar albeit less clear trend is in the relative water table as well, it is on average deepest in the bog woodland (well No. Suda2) and shallower between blocked drainage ditches (Suda4) and open raised bog (Suda7) except for the wells located directly in the water of drainage ditches (Suda3, Suda5 and Suda6). A clear trend is seen for the water depths range (Table 3.1.4.) as well – it is highest in the forested bog (Suda2, 18 cm) and least in open raised bog (Suda7, 12 cm).

Table 3.1.4. *Summary statistics of the water table measurements in Sudas-Zviedru Mire for the period from June 11 to September 30, 2024.*

Well ID	***Mean relative water table, m***	***Min relative water table, m***	***Max relative water table, m***	***Range of the daily mean, m***	***Mean absolute water table, m***
*Suda1**	-0.03	-0.09	0.15	0.18	117.50
*Suda2**	-0.42	-0.51	-0.31	0.18	116.24
*Suda3**	-0.02	-0.12	0.12	0.22	116.43
*Suda4**	-0.21	-0.33	-0.14	0.17	116.66
*Suda5**	0.15	0.04	0.23	0.18	117.01
*Suda6**	0.03	-0.06	0.14	0.16	117.17
*Suda7**	-0.16	-0.24	-0.1	0.12	117.35

* limited observation period from June 11 to September 30, 2024

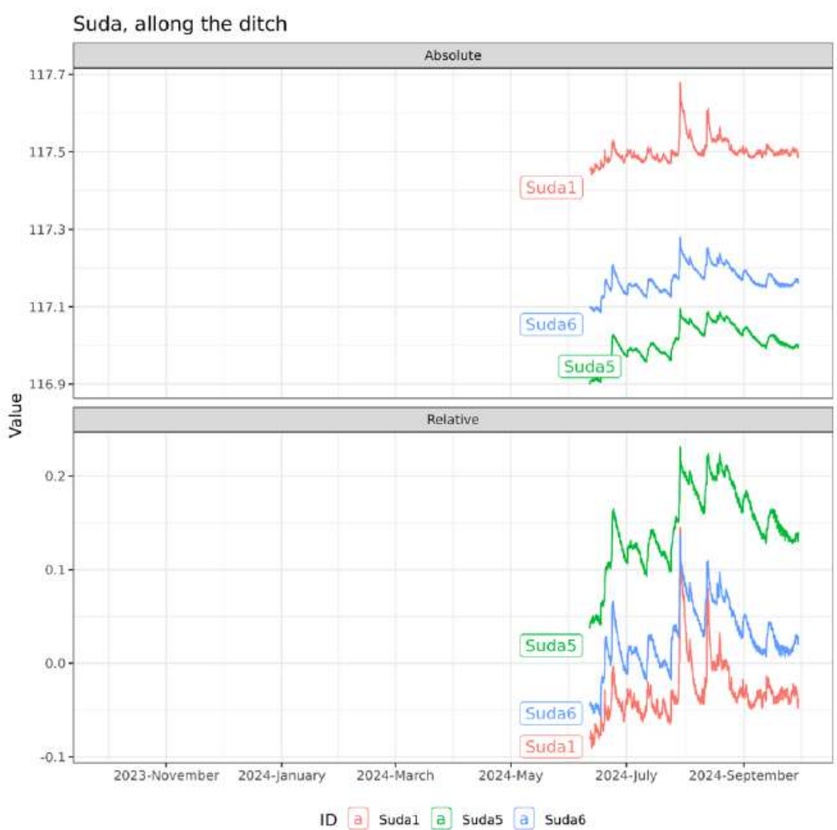


Figure 3.1.25. *Absolute (top) and relative (bottom) water level time series in a profile along blocked drainage ditch at the Sudas-Zviedru Mire.*

The profile along a drainage ditch (Figure 3.16) shows the water table difference along a flooded (continuous open water surface) drainage ditch section without dams in between (Suda1 to Suda6, 80 m) and in two sides of a dam (Sufa 6 to Suda1). Here we see a water table gradient in the flooded ditch of 0.004 m/m, indicating that the vegetation in the ditch offers some resistance to the water flow so that a permanent water table gradient can develop

3.1.4. Melnais Lake Mire

Water level monitoring equipment in Melnais Lake Mire was installed on May 30, 2024. The data download took place in early 2025, however the data for barometric water pressure level compensation was available up to December 13, 2024. The water level monitoring network in Sudas-Zviedru Mire comprises 7 sites organised along two profiles (Appendix 6.5).

Assessment of Water Level Observation Quality

Comparing the manual and automatic water level measurements (Figure 3.1.26.) we see that at 5 out of 7 observation points the difference is less than 5 cm, that is rather close to combined measurement uncertainty. For the remaining two observation wells reasons for rather large discrepancies need to be clarified and eliminated during future monitoring, when more of the control data will be available. The manual reading was taken during the installation of the groundwater pressure probes, several hours before the actual start of probe operation. Thus, one of the explanations of the discrepancy can be the water level changes during this lag period.

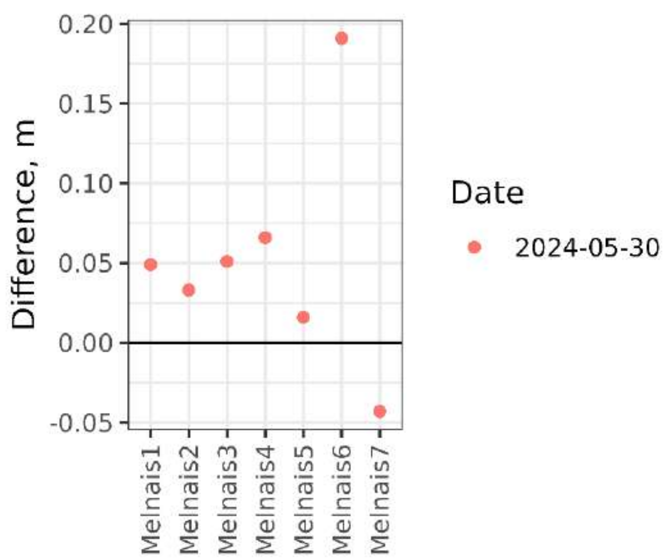


Figure 3.1.26. *The difference between automatic and manual water level measured at all but two observation points is 0.05 m or less, indicating overall good measurement quality*

Results of the groundwater level monitoring

The groundwater level monitoring results in Melnais Lake Mire can be analysed in respect to profiles (pairs of observation wells) perpendicular to the blocked drainage ditch and along the axis of the same ditch.

Two pairs (profiles) of wells (Figure 3.1.27, Figure 3.1.28.) located in apparently successfully restored part of the raised bog show groundwater level range of only about 15 cm. It must be noted that the highest water level was observed on July 29 associated with extreme precipitation event. The water level fluctuation range is only slightly higher in wells located in the former ditch (Melnais2 and Melnais4) compared to those located some 20 m from the ditch. At location closer to the bog canter, the water level in the ditch just below a ditch dam (Melnais4) is lower than in the surrounding bog (Melnais5) indicating a remaining drainage towards the ditch at the study site. While in the profile closer to the margin of the mire water level in the ditch just above a dam (Melnais2) is somewhat higher than in a 20 m distance (Melnais3), that, probably, is due to water filtration around the dam towards remaining open ditch.

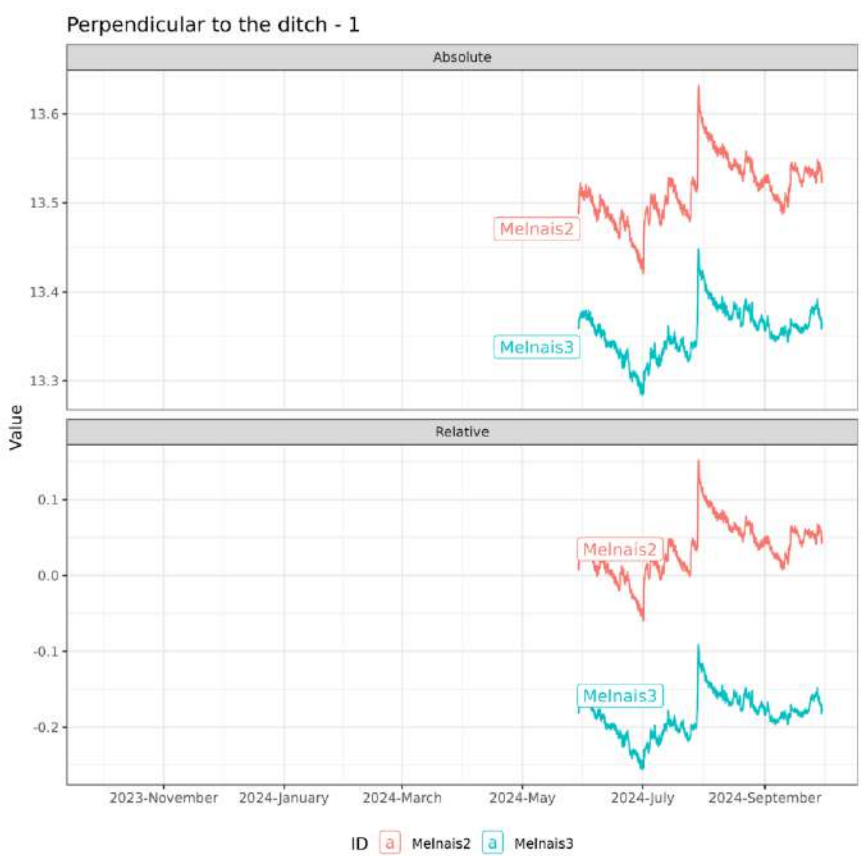


Figure 3.1.27. *The absolute (top) and relative (bottom) water level in profile towards successfully blocked drainage ditc*

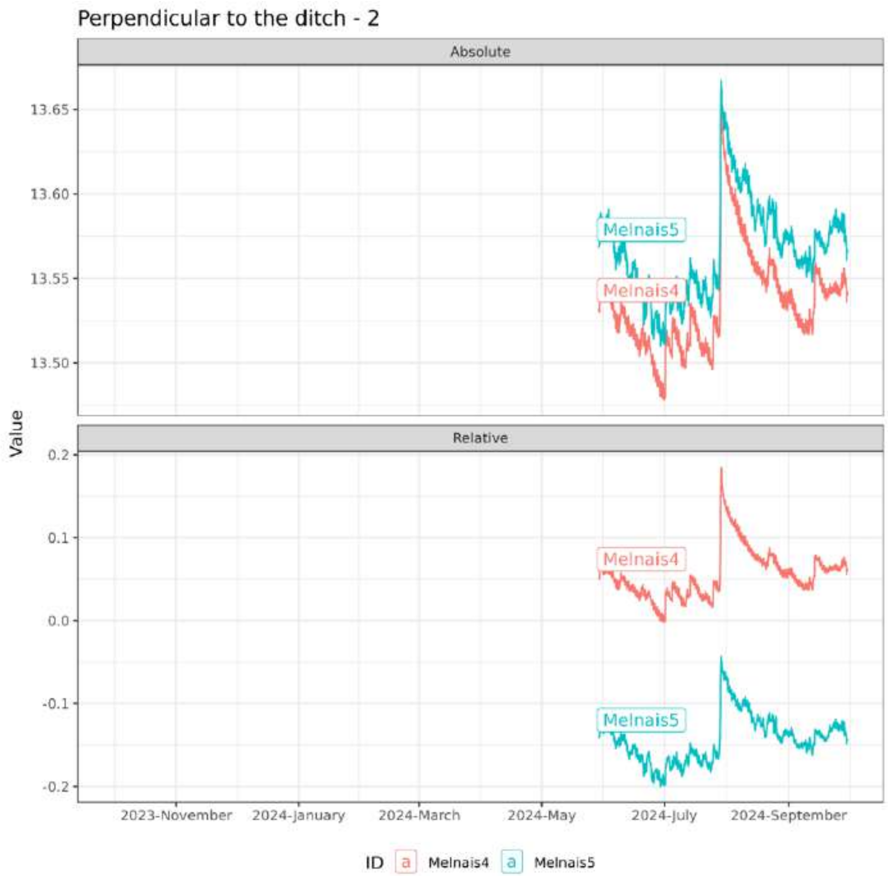


Figure 3.1.28. *The absolute (top) and relative (bottom) water level in profile towards successfully blocked drainage ditch.*

Table. 3.1.5. *Summary statistics of the water table measurements in Lake Melnais for the period from May 30 to September 30, 2024.*

Well ID	***Mean relative water table, m***	***Min relative water table, m***	***Max relative water table, m***	***Range of the daily mean, m***	***Mean absolute water table, m***
*Melnais1**	-0.36	-0.49	-0.24	0.24	12.93
*Melnais2**	0.03	-0.06	0.15	0.18	13.51
*Melnais3**	-0.18	-0.26	-0.09	0.14	13.36
*Melnais4**	0.06	0	0.18	0.16	13.54
*Melnais5**	-0.14	-0.2	-0.04	0.13	13.57
*Melnais6**	-0.47	-0.71	0.47	1.05	12.07
*Melnais7**	-0.33	-0.43	-0.22	0.18	13.32

* incomplete time series from May 30 to September 30.

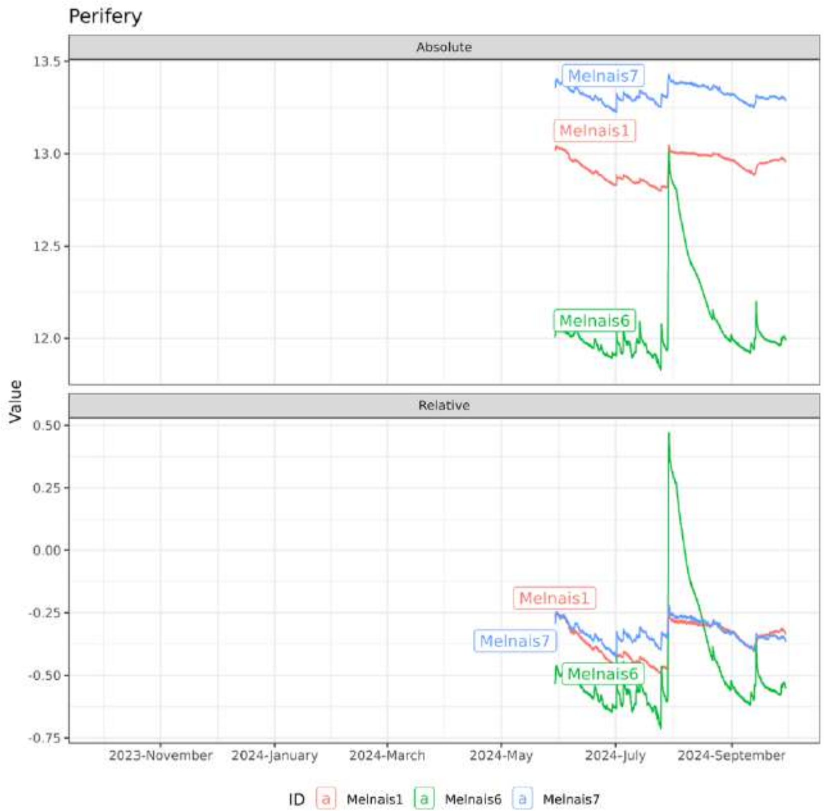


***Figure 3.1.29**. The absolute (top) and relative (bottom water level in profile towards unsuccessful blocked drainage ditch (Melanis6 and Melnais7) and dens pine forest strip in a zone between successful and unsuccessful restoration (Melnais1).*

***Figure 3.1.30**. Monitoring well Melnais6 installed in the successfully blocked ditch in Melnais Lake Mire, May 29, 2024.*

In the observation wells located at the peripheral zone of the Lake Melnais Mire near section of the ditch that was not successfully blocked higher water level fluctuations were observed (Figure

3.1.31). Within the ditch (Melnais6) the water table range was more than 1.0 m (Table 3.1.5). Already at 20 m distance from the ditch (Melnais7) the rang was less than 20 cm, however on average the water table was relatively deep - 33 cm below the surface. Within a dens pine forest strip in the peatland (Melnais1) the average water table debs were similar, but a more rapid decline rate in spring can be noticed, suggesting that higher water volume was lost to the evapotranspiration than at other locations. Alternatively, the faster water table drawdown can be due to small water capacity of the degraded peat at forest strip or localized infiltration mineral subsoil.

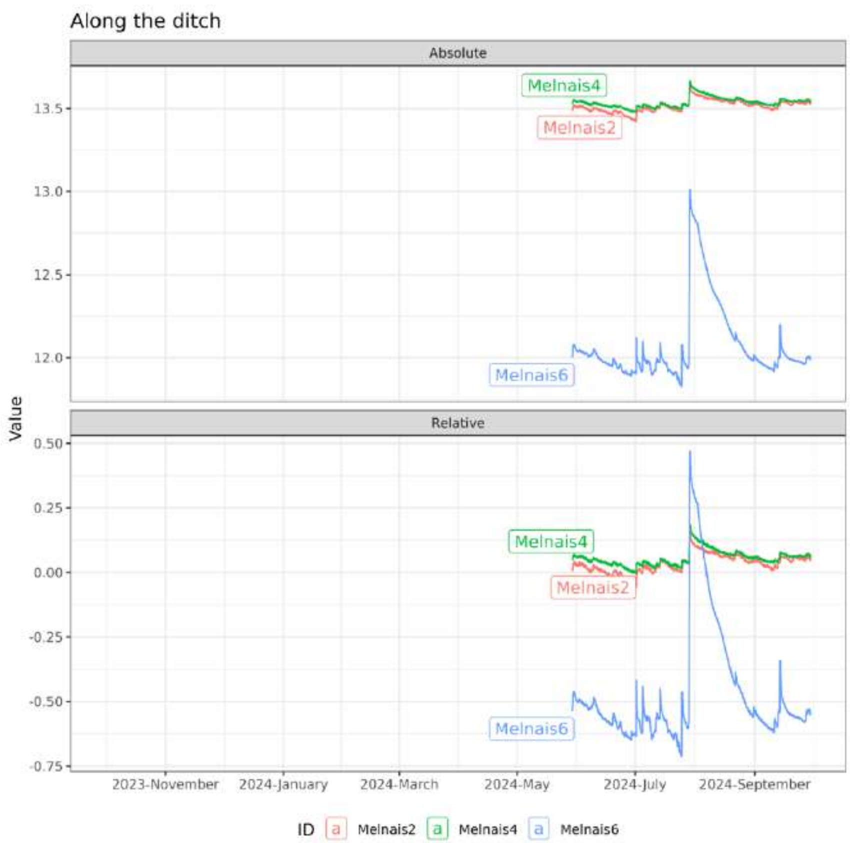


Figure 3.1.31. *The absolute (top) and relative (bottom) water level in along the axis of blocked drainage ditch.*

Considering the water level along the blocked ditch (Figure 3.1.22) we notice an encouraging sign: there water table at well Melnais4 remains higher than at downstream well Melnais2 both during periods of relatively high and low water table, although the difference (3 cm for 82 m distance) is close to measurement uncertainty. Particularly, differences I the water table after the extreme rainfall on July 29, 2024 indicates that the vegetation development in the flooded ditch creates sufficient resistance to the water flow so that a water table gradient is maintained, despite the fact the form ditch excavation is full to the brink with water.

3.2. Habitat and vegetation monitoring results

The species composition from all vegetation monitoring plots (including plots from GHG transects and GEST points) shows that the highest species richness was in Melnais Lake Mire (53), followed by Cena Mire with 44 species and the Lielais Pelečāre Mire with a total of 39 species of vascular plants, bryophytes, and lichens.

The lowest number of species was found in Sudas-Zviedru Mire with 32 species (Appendix 6.6). Altogether, 68 species were found at least in one monitoring plot. Some of the most common species that were recorded in all project sites are *Betula pendula, Pinus sylvestris, Andromeda polifolia, Calluna vulgaris, Drosera rotundifolia, Empetrum nigrum, Eriophorum vaginatum, Ledum palustre, Oxycoccus palustris, Rhynchospora alba, Rubus chamaemorus, Vaccinium uliginosum, Dicranum polysetum, Pleurozium schreberi, Sphagnum cuspidatum, S. fuscum,* and *S. medium*.

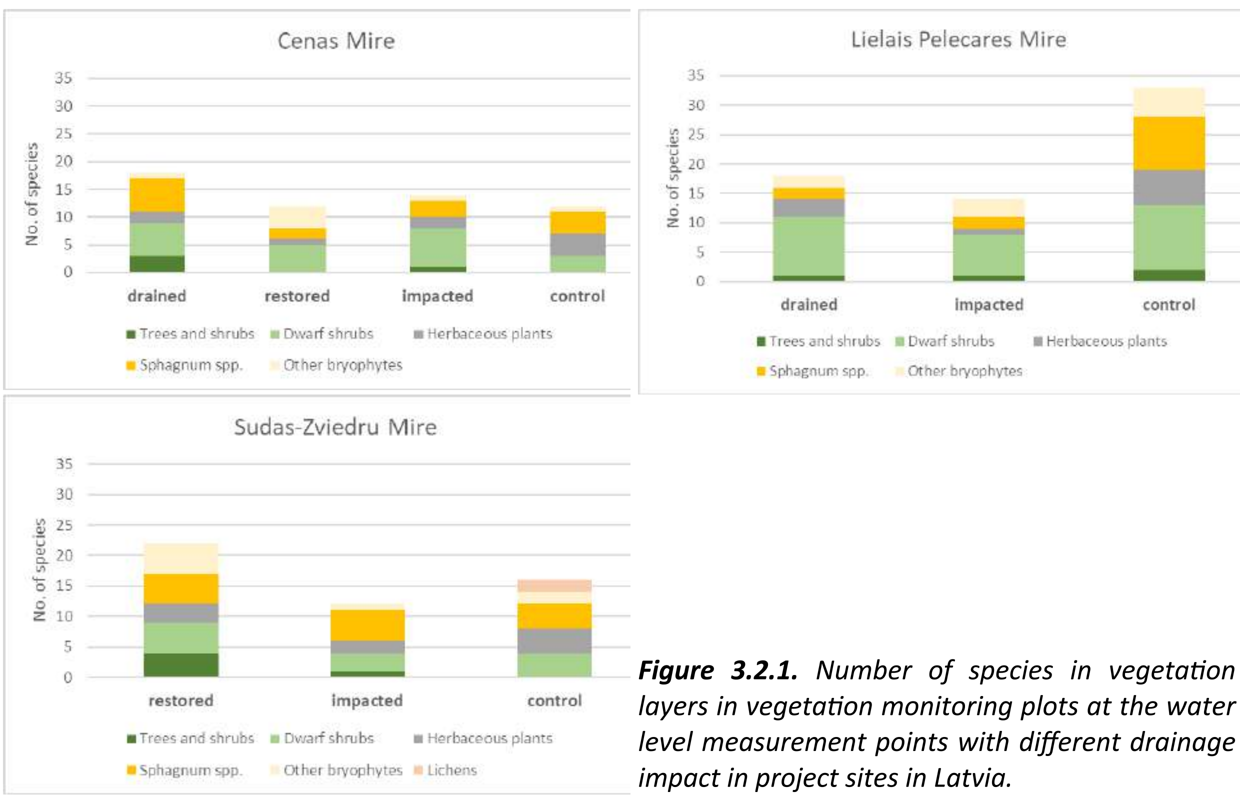


Figure 3.2.1. *Number of species in vegetation layers in vegetation monitoring plots at the water level measurement points with different drainage impact in project sites in Latvia.*

Next, the species composition is analysed among vegetation monitoring plots that were (i) close to water level measurement points or (ii) in GHG measurement transects.

The vegetation at the water level measurement points varies greatly between the sample plots with different drainage impact - depending on whether they have been previously restored, significantly or only indirectly drained, or not affected by changes in the water regime at all.

Accordingly, the number of trees, shrubs and dwarf shrubs is higher in the drained plots, while the number of herbaceous plants is higher in the natural habitats (Figure 3.22).

The most common tree species are *Betula pendula* and *B. pubescens, Pinus sylvestris*, occasionally also *Frangula alnus* and *Picea abies*. Dwarf shrub layer is species rich and especially in Lielais Pelečāre Mire with 11 species. The most common species are *Andromeda polifolia, Calluna vulgaris, Chamaedaphne calyculata, Ledum palustre, Oxycoccus palustris, Rubus chamaemorus, Vaccinium uliginosum*. *Sphagnum spp.* does not show a certain relationship with the drainage impact, as in Lielais Pelecares Mire they are more common in the natural part of the bog, in Cenas Mire - in the degraded part, while in Sudas-Zviedru Mire the number of *Sphagnum* is relatively similar in all plot types. The other bryophyte species like *Pleurozium schreberi, Dicranum polysetum* and other forest mosses are more common in restored bog monitoring plots.

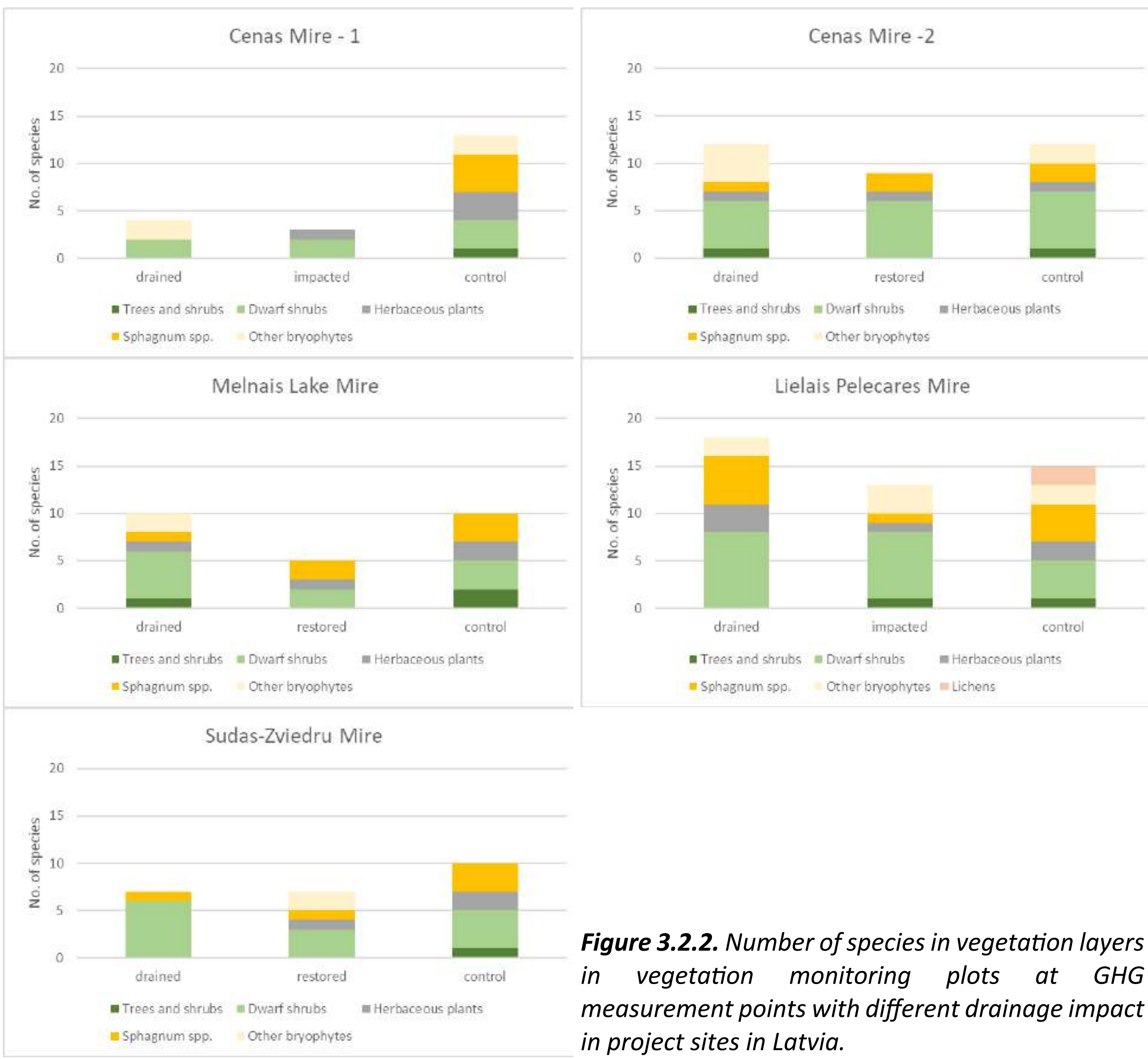


Figure 3.2.2. *Number of species in vegetation layers in vegetation monitoring plots at GHG measurement points with different drainage impact in project sites in Latvia.*

Some of the species richness trends described above are also found in the GHG measurement transects (Figure 3.2.2). Number of drought resistant dwarf shrub species is higher in drainage impacted plots in all project sites except Cena Mire. Whereas the number of herbaceous plants and *Sphagnum* species shows relation with natural plots in all plots except Lielais Pelečāre Mire. In general, it cannot be argued that a natural, active raised bog has a higher species diversity than a degraded mire. However, it can be observed that the species composition is more balanced between different vegetation layers in natural habitats. Whereas in the drained parts of the mire, one of the species groups clearly dominates and disrupts the balance. Since the data series of the vegetation monitoring are still relatively short, it is not possible to analyse the restoration progress after the stabilization of the hydrological regime.
A more detailed data analysis could be performed only for the Sudas-Zviedru Mire, where the previously recorded data were directly compared with the existing species composition. In other project sites (i.e. Cena Mire and Melnais Lake Mire), some important information is missing from the historical vegetation monitoring data - either the coordinates of the sample plots or the species lists, so they can only be used to observe changes in the general species composition, but not to specifically characterize the monitoring transects.

3.2.1. Vegetation monitoring data analysis for Sudas-Zviedru Mire

Data were collected six times in the same monitoring plots in the mire. The total number of plots has been reduced, so only half of the previously recorded data was used in the analysis. As indicated by the DCA ordination succession vectors, the species composition is almost similar between the natural (or control) plots and the impacted plots (Figure 3.2.3).

In addition, the species composition does not change significantly between monitoring years, so the points of these plots form a relatively compact cluster in the left side of DCA ordination. With monitoring sample plots in the restoration area, exactly opposite situation is observed - from 2014 to 2023, the composition of species has changed, so they "move" away from each other in the DCA ordination. In addition, the species composition becomes more like the natural part of the mire.

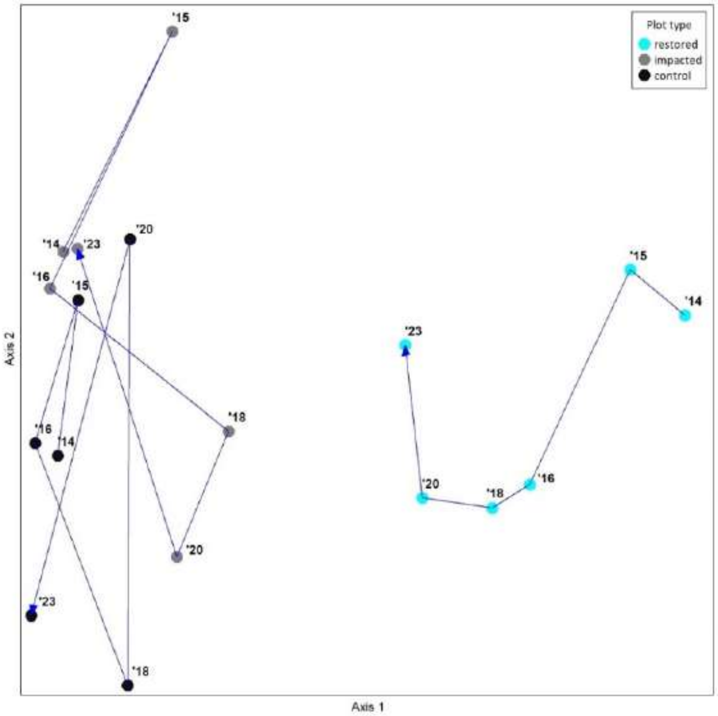
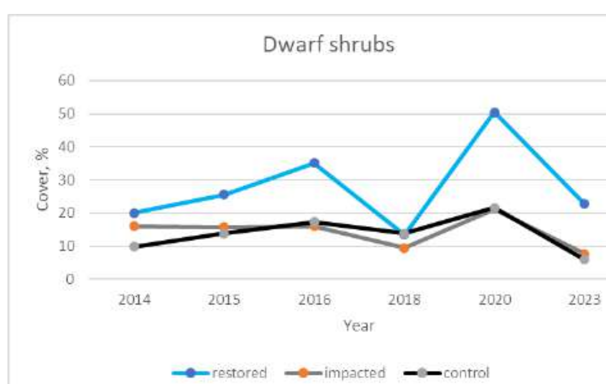
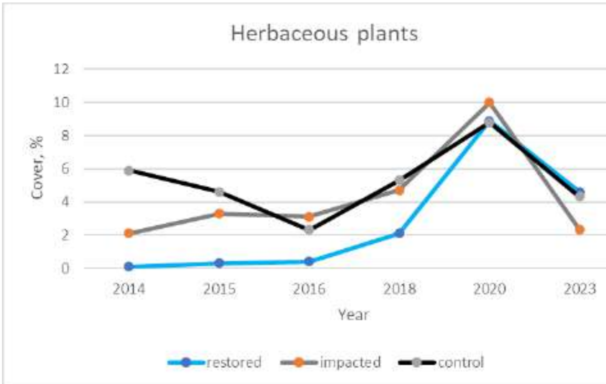


__Figure 3.2.3.__ DCA ordination of vegetation monitoring plots of Sudas-Zviedru Mire during nine years from 2014 to 2023.

The total cover of species in different vegetation layers in Sudas-Zviedru Mire was compared between six monitoring years (Figure 3.2.4.). The curve shows almost no fluctuations in the control and the little impacted monitoring plots. On the other hand, in the restored part of the mire, there is a significant drop immediately after the restoration works, because machinery moved mechanically or operated in the sample plots. During the following four years, the vegetation has stabilized and shows tendencies to approach the natural part of the mire.





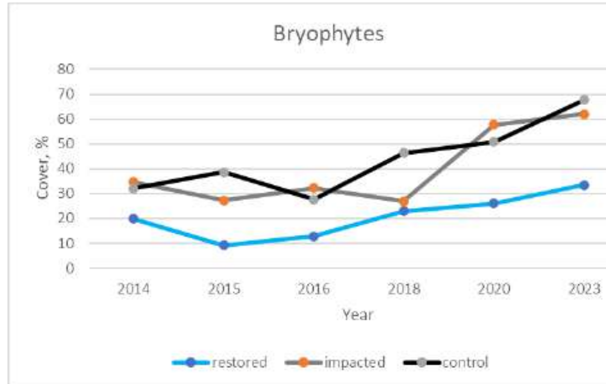


Figure 3.2.4. *Changes of the total cover (%) of species in different vegetation layers ((i) trees and shrubs; (ii) dwarf shrubs; (iii) herbaceous plants; (iv) bryophytes) during nine years in Sudas-Zviedru Mire. Hydrology stabilization in the mire was completed in 2017.*

The withering of trees near the restored ditches was also visually assessed. Positive changes over time are also expected in the dwarf shrub layer. The total cover of *Calluna vulgaris* could slowly decrease and be replaced by herbaceous plants or *Sphagnum* species.

3.3. Greenhouse gas emission monitoring

Variation in ecosystem CO_2 emissions (R_{eco}) in areas without tree cover and forest floor CO_2 emissions (R_{floor}) in forested areas during the study period by different seasons and habitat types is shown in Figure 3.3.1 and Appendix 6.7. Statistically significant differences in variation of ecosystem CO2 emissions between different habitat types were observed ($p < 0.05$).

According to the preliminary estimates (June 2023 – December 2024), the highest CO_2 emissions (R_{eco} or R_{floor} depending on habitat type, including both soil heterotrophic respiration and autotrophic respiration) were observed during summer months (June – August).

In summer months, the highest ecosystem CO_2 were observed in drained raised bog with dense tree layer (mean 153.9 mg CO_2-C m^{-2} h^{-1}) followed by degraded bog woodland (mean 145.1 mg CO_2-C m^{-2} h^{-1}) and restored and rewetted raised bog (mean 135.9 mg CO_2-C m^{-2} h^{-1}), while the lowest ecosystem CO_2 emissions were observed in peat fields (108.8 mg CO_2-C m^{-2} h^{-1}) and natural and near-natural raised bog (mean 115.1 mg CO_2-C m^{-2} h^{-1}).

Specifically in drained raised bog with dense tree layer, the highest mean CO_2 flux value (in summer months) was observed in drained raised bog with dense tree layer in the strong drainage impact zone (200.1 mg CO_2-C m^{-2} h^{-1}). In general, the lowest CO_2 fluxes were observed in winter months (December – February). Further steps include estimation of net annual CO_2 emissions considering share of soil heterotrophic respiration (R_{het}) and carbon input into soil with above- and belowground litter of vegetation (Figure 3.3.2.)

Figure 3.3.1. *Greenhouse gas emission monitoring study sites and subplots representing different habitat types.*

	
Subplot A (near-natural raised bog) in LPC_1 Sudas-Zviedru Mire. Image: © G. Saule.	Subplot B (rewetted degraded raised bog with direct restoration effect) in LPC_1 Sudas-Zviedru Mire. Image: © G. Saule.

	
Subplot C (rewetted overgrown raised bog with cumulative restoration effect) in LPC_1 Sudas-Zviedru Mire. Image: © G. Saule.	Subplot A (near-natural raised bog in LPC_2 Lielais Pelečāre Mire. Image: © G. Saule.

	
Subplot B (drained raised bog with dense tree layer in the strong drainage impact zone) in LPC_2 (Lielais Pelečāre Mire). Image: © G. Saule.	Subplot C (drained raised bog with dense tree layer in the weak drainage impact zone) in LPC_2 (Lielais Pelečāre Mire). Image: © G. Saule.

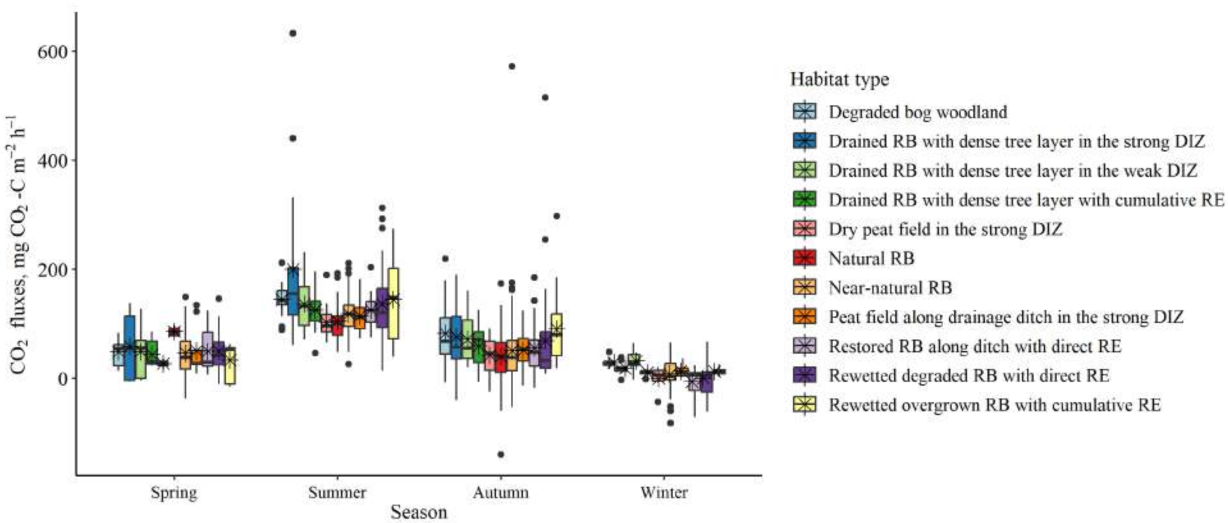


Figure 3.3.2. *Variation in ecosystem CO_2 emissions (R_{eco}) in areas without tree cover and forest floor CO_2 emissions (R_{floor}) in forested areas during the study period by different seasons and habitat types*[1].

[1] DIZ – drainage impact zone; RE – restoration effect; RB – raised bog. The boxes show 25th and 75th percentiles, horizontal line – median value, asterisk – mean value, whiskers – minimal and maximal values or 1.5 time the interquartile range if outlier values are presented (points).

Variation in soil heterotrophic respiration (R_{het}) during the study period (2023-2024) by different seasons (spring, summer, autumn) and habitat types is shown in Figure 3.3.3. Among all studied habitat type, the highest mean soil heterotrophic respiration was observed during summer months (June – August). In summer months, the highest mean soil heterotrophic respiration was observed in degraded bog woodland, while the lowest in natural and near-natural raised bog. Furthermore, statistically significant differences in variation of soil heterotrophic respiration between different habitat types were observed ($p < 0.05$). Further steps include estimation of net annual CO_2 emissions considering carbon input into soil with above- and belowground litter of vegetation.

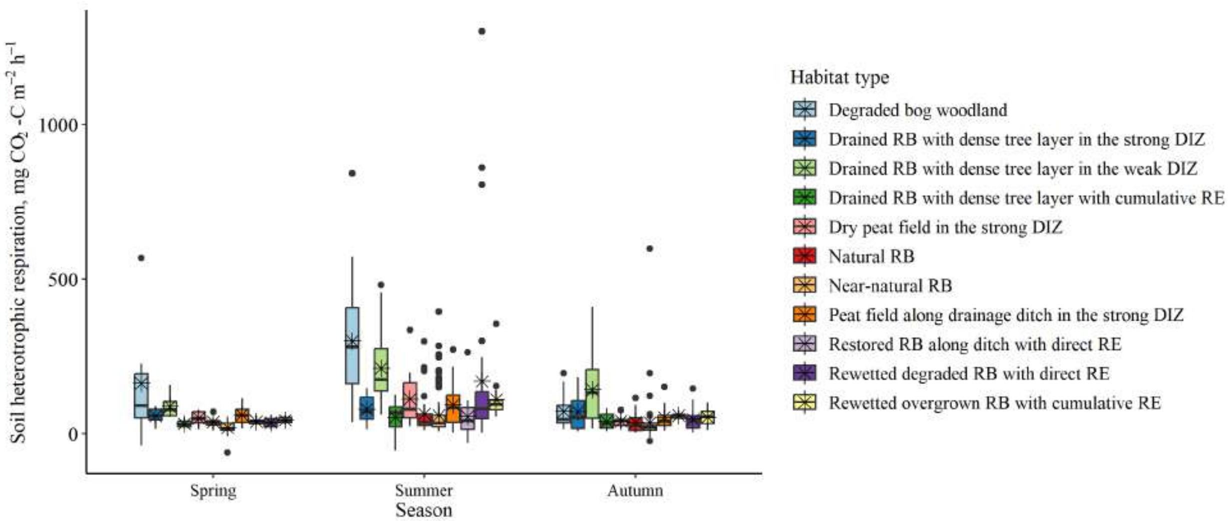


Figure 3.3.3. *Variation in soil heterotrophic respiration (R_{het}) during the study period (vegetation period) by different habitat types[2].*

Variation in CH_4 emissions during the study period by different seasons and habitat types is shown in Figure 3.3.4. According to the preliminary estimates (June 2023 – December 2024), the highest mean CH_4 fluxes were observed in rewetted degraded raised bog with direct restoration effect (5036.9 µg CH_4-C m^{-2} h^{-1} in summer months June – August and 3389.8 µg CH_4-C m^{-2} h^{-1} in autumn months September – November), followed by restored raised bog along ditch with direct restoration effect (2609.9 µg CH_4-C m^{-2} h^{-1} in summer months June – August and 2714.4 µg CH_4-C m^{-2} h^{-1} in autumn months September – November), while soils in drained raised bog with dense tree layer with cumulative restoration effect during autumn months (September-November) were sink of CH_4 (CH_4 removals were observed, mean -65.7 µg CH_4-C m^{-2} h^{-1}). Statistically significant differences in variation of CH_4 emissions between different habitat types were observed ($p < 0.05$).

[2] DIZ – drainage impact zone; RE – restoration effect; RB – raised bog. The boxes show 25th and 75th percentiles, horizontal line – median value, asterisk – mean value, whiskers – minimal and maximal values or 1.5 time the interquartile range if outlier values are presented (points).

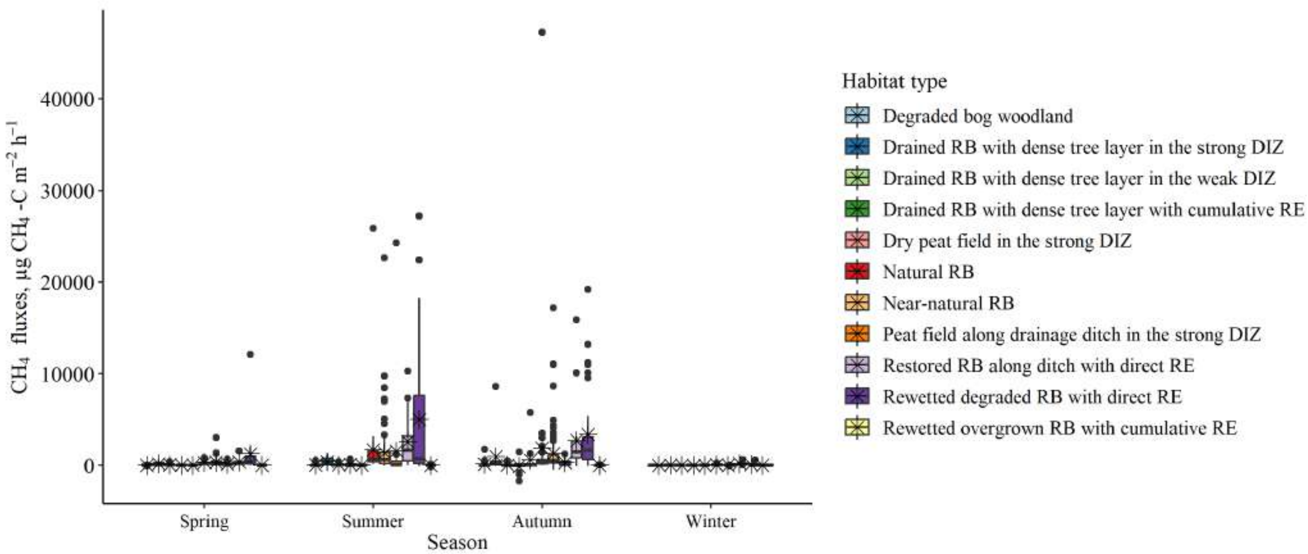


Figure 3.3.4. *Variation in CH_4 emissions during the study period by different seasons and habitat types*[3]

Variation in N_2O emissions during the study period by different seasons and habitat types is shown in Figure. 3.3.5. According to the preliminary estimates (June 2023 – December 2024), the highest mean N_2O fluxes (64.4 µg N_2O-N m^{-2} h^{-1}) were observed in peat field along drainage ditch in the strong drainage impact zone in spring months (March – May) followed by restored raised bog along ditch with direct restoration effect in summer months (June – August, mean 50.3 µg N_2O-N m^{-2} h^{-1}). Statistically significant differences in variation of N_2O emissions between different habitat types were observed ($p < 0.05$).

[3] DIZ – drainage impact zone; RE – restoration effect; RB – raised bog. The boxes show 25th and 75th percentiles, horizontal line – median value, asterisk – mean value, whiskers – minimal and maximal values or 1.5 time the interquartile range if outlier values are presented (points).

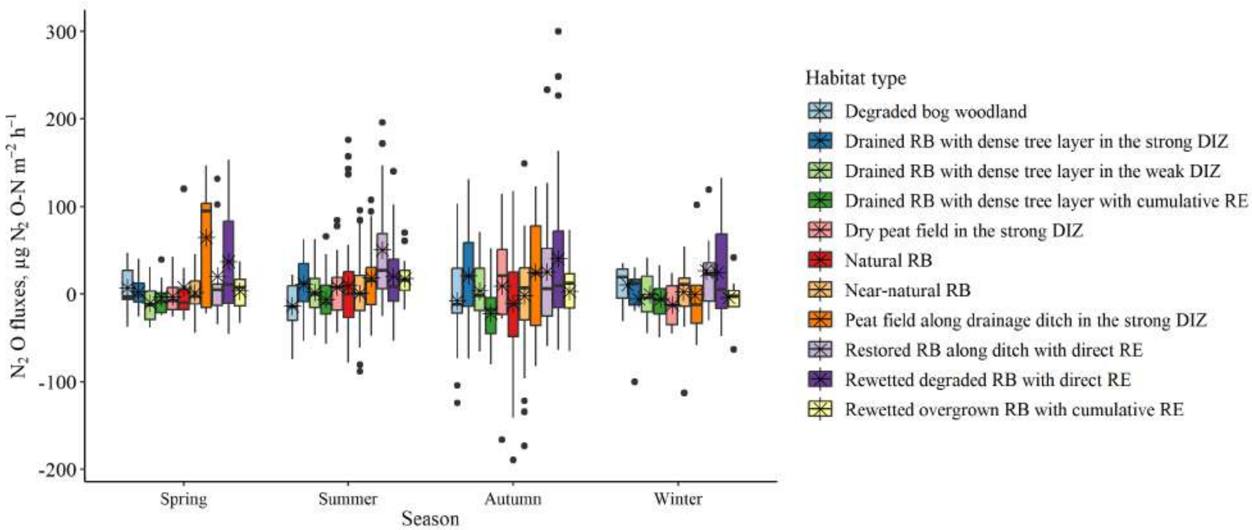


***Figure 2** Variation in N_2O emissions during the study period by different seasons and habitat types[4].*

In general, preliminary estimates of GHG emissions including CO_2 (both ecosystem respiration and soil heterotrophic respiration), CH_4 and N_2O emissions showed significant variation in GHG emissions between different habitat types including restored/rewetted raised bog and areas that will be rewetted (for instance, peat fields). Seasonal (temperature) effect were particularly noticeable in relation to CO_2 emissions, while groundwater level, which directly depends on management activities, showed impact on magnitude of CH_4 emissions. Further steps include estimation of total net GHG emission balance (annual) across different habitats including estimation of net annual CO_2 emissions (soil CO_2 balance) considering carbon input into soil with above- and belowground litter of vegetation.

3.4. Soil chemical properties

The main soil chemical properties in different topsoil layers (O horizon if presented in the study sites, 0-10 cm and 10-20 cm soil layer) in different habitat types are shown in Figure 3.3.6 (soil bulk density), Figure 3.3.7 (soil pH $CaCl_2$), Figure 3.3.8 (organic carbon (OC) concentration), Figure 3.3.9 (total nitrogen (TN) concentration) and Figure 3.3.10 (concentrated nitric acid (HNO_3) extractable potassium (K) concentration). Among studied habitat types mean soil bulk density in 0-10 cm soil layer ranged from 40.4 kg m^{-3} (in rewetted degraded raised bog with direct restoration effect) to 160.1 kg m^{-3} (dry peat field in the strong drainage impact zone), while in 10-20 cm soil layer mean soil bulk density ranged from 67.0 kg m^{-3} (in natural raised bog) to 481.6 kg m^{-3} (in degraded bog woodland). In deeper analysed soil layers (20-50 cm), soil bulk density among studied habitat types ranged from 33.6 to 256.5 kg m^{-3}.

[4] DIZ – drainage impact zone; RE – restoration effect; RB – raised bog. The boxes show 25th and 75th percentiles, horizontal line – median value, asterisk – mean value, whiskers – minimal and maximal values or 1.5 time the interquartile range if outlier values are presented (points).

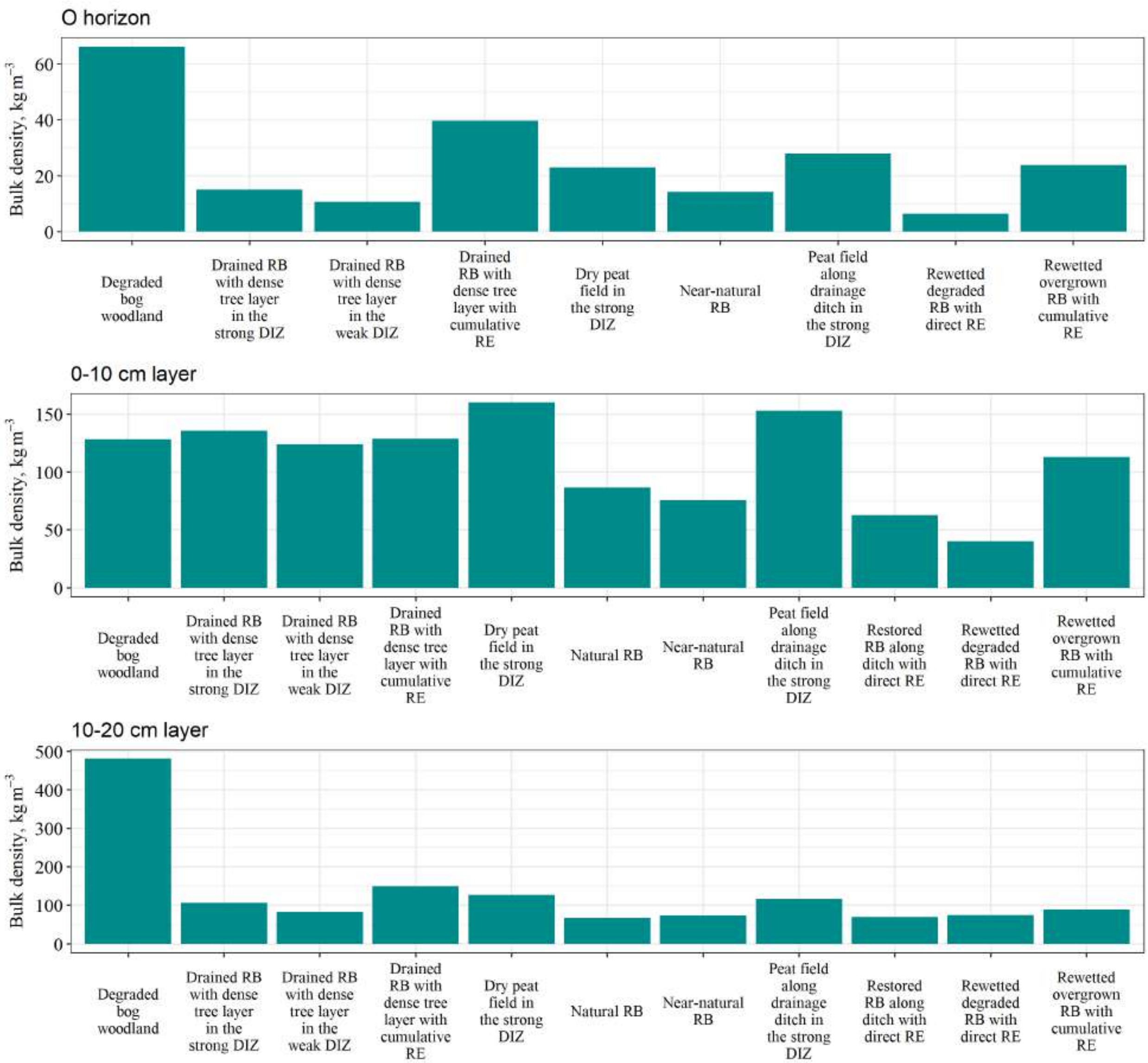


Figure 3.3. 6. *Soil bulk density (O horizon, 0-10 cm and 10-20 cm soil layer) by habitat types*[5].

Among studied habitat types mean soil pH ($CaCl_2$) in topsoil layers (0-10 cm and 10-20 cm soil layer) ranged from 2.4 (in drained raised bog with dense tree layer with cumulative restoration effect and in restored raised bog along ditch with direct restoration effect) to 3.1 in natural raised bog (Figure 3.3.7.). In deeper analysed soil layers (20-50 cm), soil pH ($CaCl_2$) ranged from 2.4 to 3.7.

5 DIZ – drainage impact zone; RE – restoration effect; RB – raised bog.

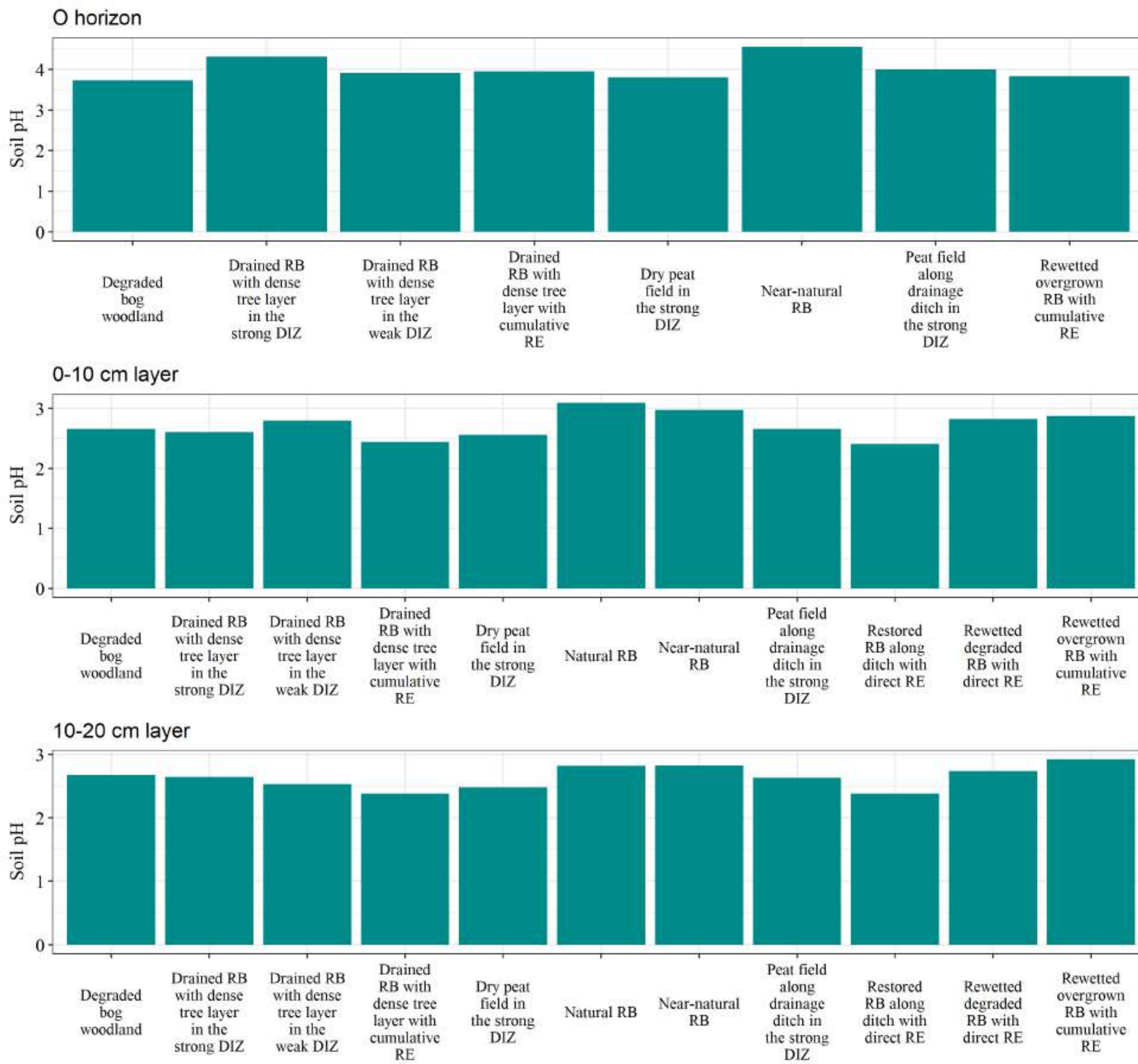


Figure 3.3.7. *Soil pH ($CaCl_2$) in different soil layers (O horizon, 0-10 cm and 10-20 cm soil layer) by habitat types*[6]*.*

Among studied habitat types mean organic carbon (OC) concentration in 0-10 cm soil layer ranged in a relatively narrow range – from 492.5 g kg^{-1} in natural raised bog to 528.9 g kg^{-1} in drained raised bog with dense tree layer in the strong drainage impact zone. In 10-20 cm soil layer, OC concentration ranged from 379.3 g kg^{-1} in degraded bog woodland to 540.8 g kg^{-1} in restored raised bog along ditch with direct restoration effect (Figure 3.32). In deeper analysed soil layers (20-50 cm), OC concentration ranged from 433.8 to 539.7 g kg^{-1} reflecting organic matter rich (peat) soil also in deeper soil layers.

6 DIZ – drainage impact zone; RE – restoration effect; RB – raised bog.

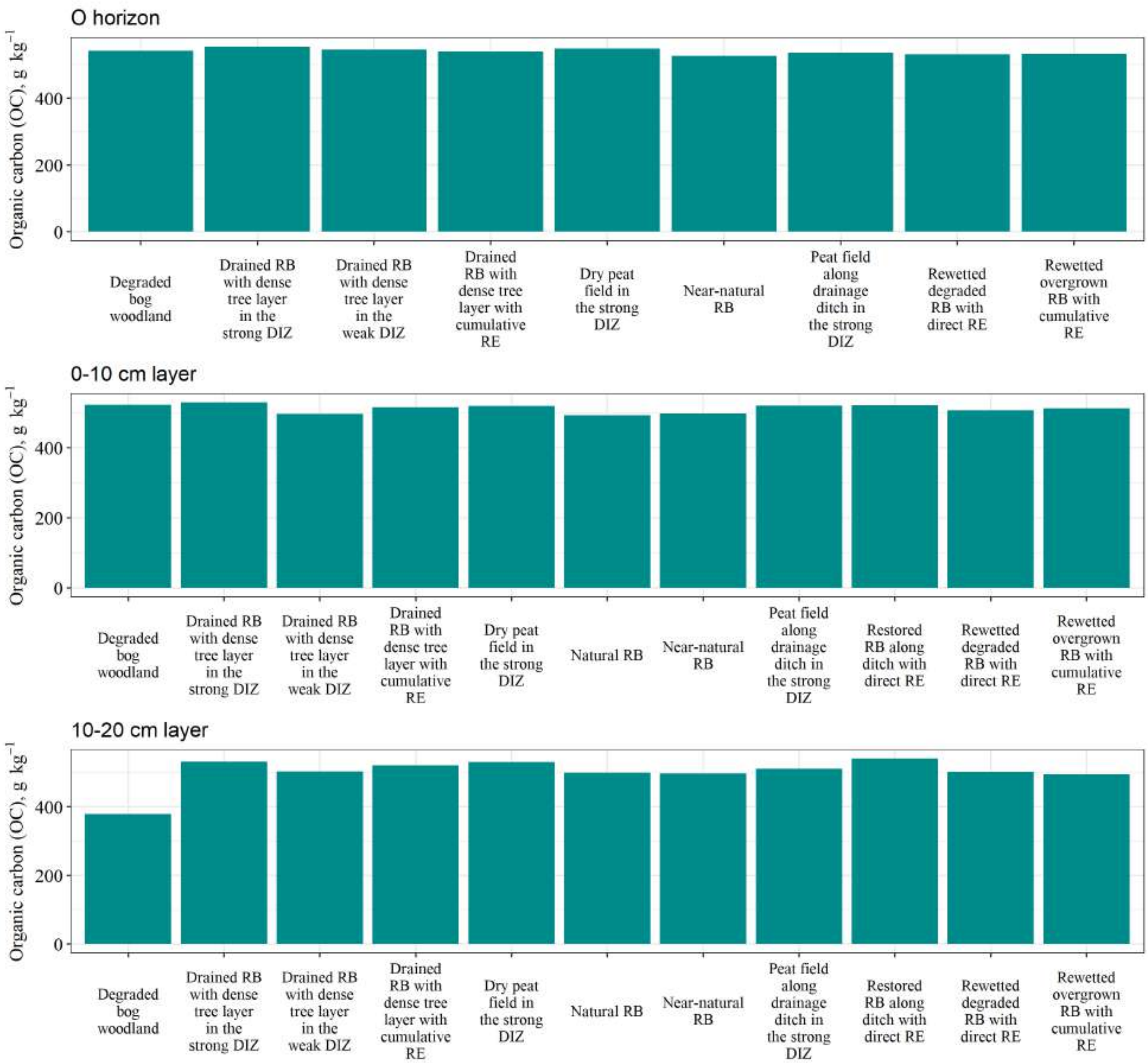


Figure 3.3.8. *Organic carbon (OC) concentration in different soil layers (O horizon, 0-10 cm and 10-20 cm soil layer) by habitat types*[7]

Among studied habitat types mean total nitrogen (TN) concentration in 0-10 cm soil layer ranged from 12.2 g kg^{-1} in natural raised bog to 17.0 g kg^{-1} in peat field along drainage ditch in the strong drainage impact zone. In 10-20 cm soil layer, TN concentration ranged from 9.5 g kg^{-1} in drained raised bog with dense tree layer in the weak drainage impact zone to 19.4 g kg^{-1} in drained raised bog with dense tree layer in the strong drainage impact zone (Figure 3.33). In deeper analysed soil layers (20-50 cm), TN concentration ranged from 7.8 to 20.3 g kg^{-1}.

[7] DIZ – drainage impact zone; RE – restoration effect; RB – raised bog.

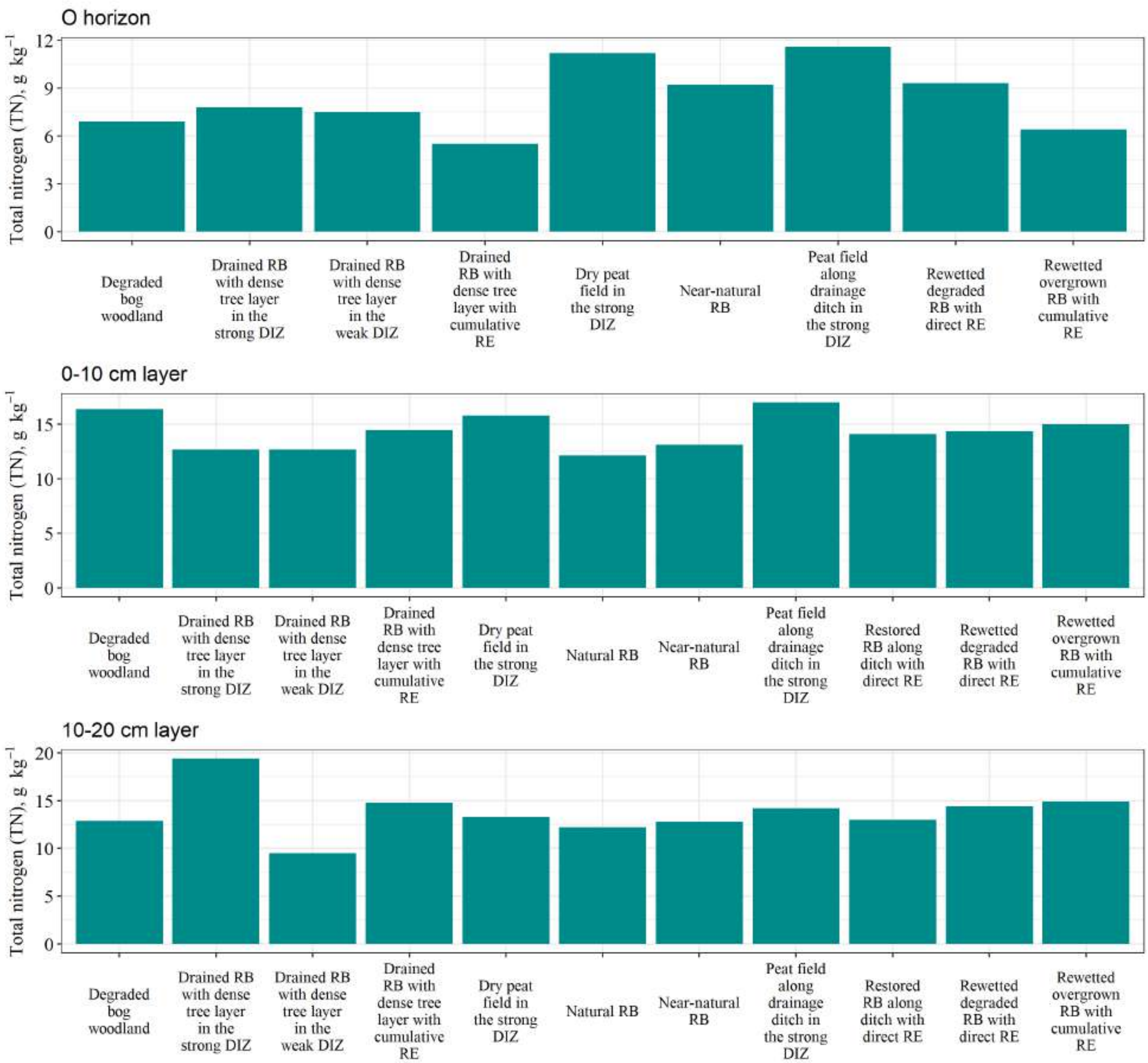


Figure 3. 3.9. *Total nitrogen (TN) concentration in different soil layers (O horizon, 0-10 cm and 10-20 cm soil layer) by habitat types[8].*

Among studied habitat types mean concentrated nitric acid (HNO_3) extractable potassium (K) concentration in 0-10 cm soil layer ranged from 0.25 g kg^{-1} in drained raised bog with dense tree layer in the strong drainage impact zone to 1.11 g kg^{-1} in rewetted degraded raised bog with direct restoration effect. In 10-20 cm soil layer, K concentration ranged from 0.14 g kg^{-1} in drained raised bog with dense tree layer in the weak drainage impact zone to 0.62 g kg^{-1} in drained raised bog with dense tree layer in the strong drainage impact zone (Figure. 3.34). In deeper analysed soil layers (20-50 cm), K concentration ranged from 0.02 to 0.48 g kg^{-1}.

8 DIZ – drainage impact zone; RE – restoration effect; RB – raised bog.

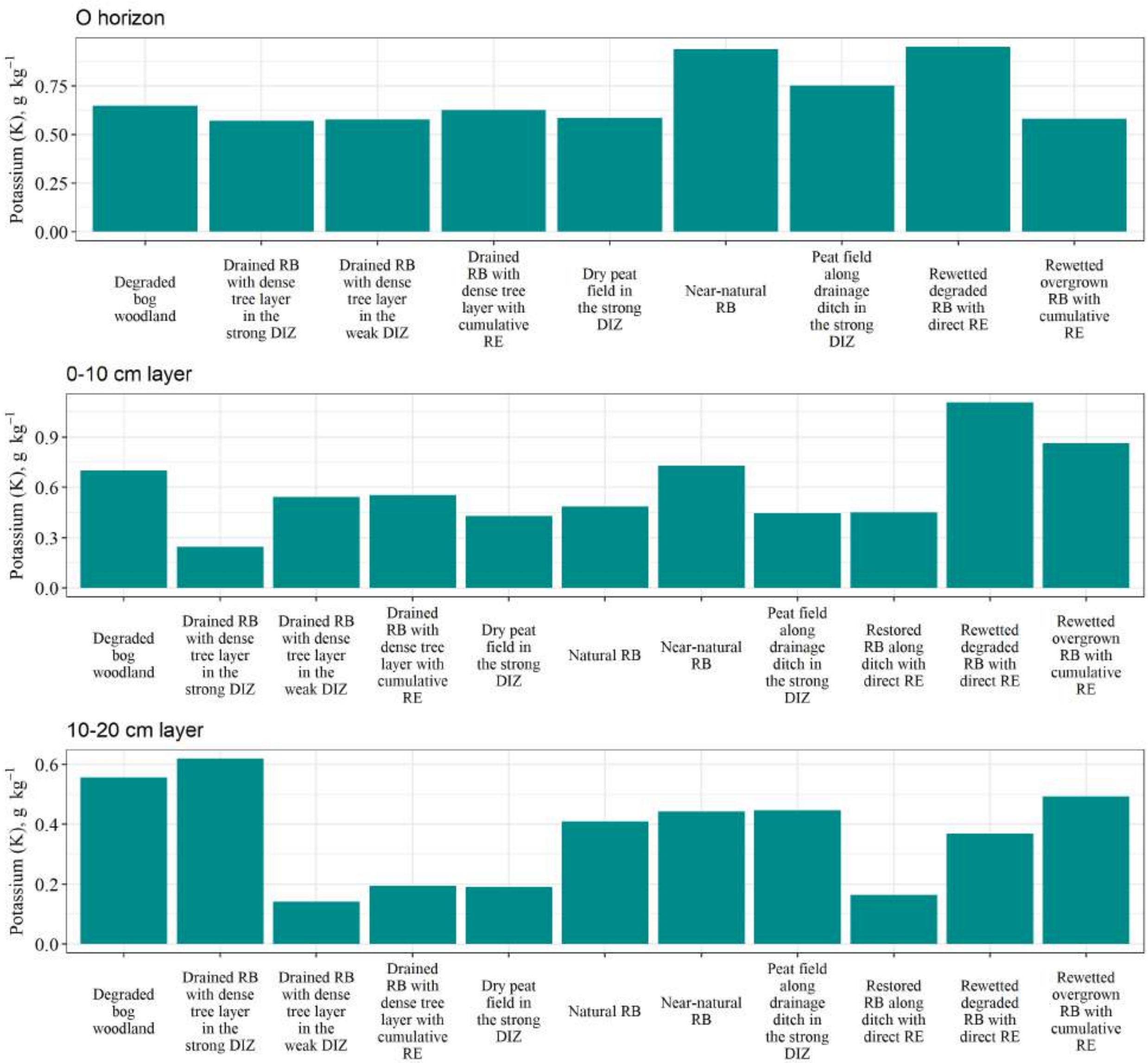


Figure 3.3.10. *Concentrated nitric acid (HNO_3) extractable potassium (K) concentration in different soil layers (O horizon, 0-10 cm and 10-20 cm soil layer) by habitat types[9].*

3.5. Environmental variables

The variation in main environmental variables during the study period in different habitat types is shown in Figure 3.3.11 and Figure 3.3.12 (groundwater level below soil surface and soil moisture), Figure 3.3.13 and Figure 3.3.14 (air and soil temperature).

9 DIZ – drainage impact zone; RE – restoration effect; RB – raised bog.

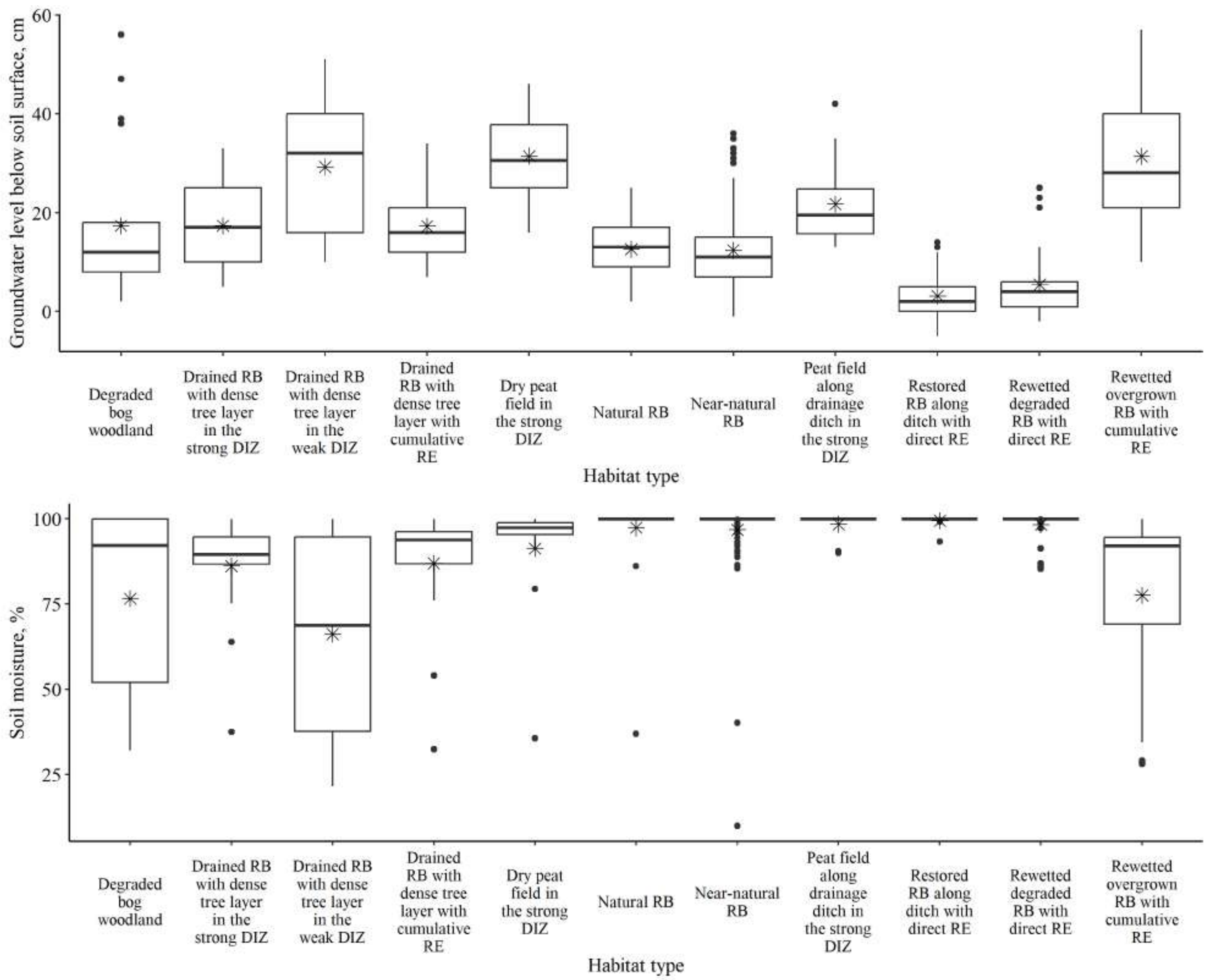


***Figure 3.3.11**. Variation in groundwater level below soil surface and soil moisture during the study period by habitat types[10].*

[10] DIZ – drainage impact zone; RE – restoration effect; RB – raised bog. The boxes show 25th and 75th percentiles, horizontal line – median value, asterisk – mean value, whiskers – minimal and maximal values or 1.5 time the interquartile range if outlier values are presented (points).

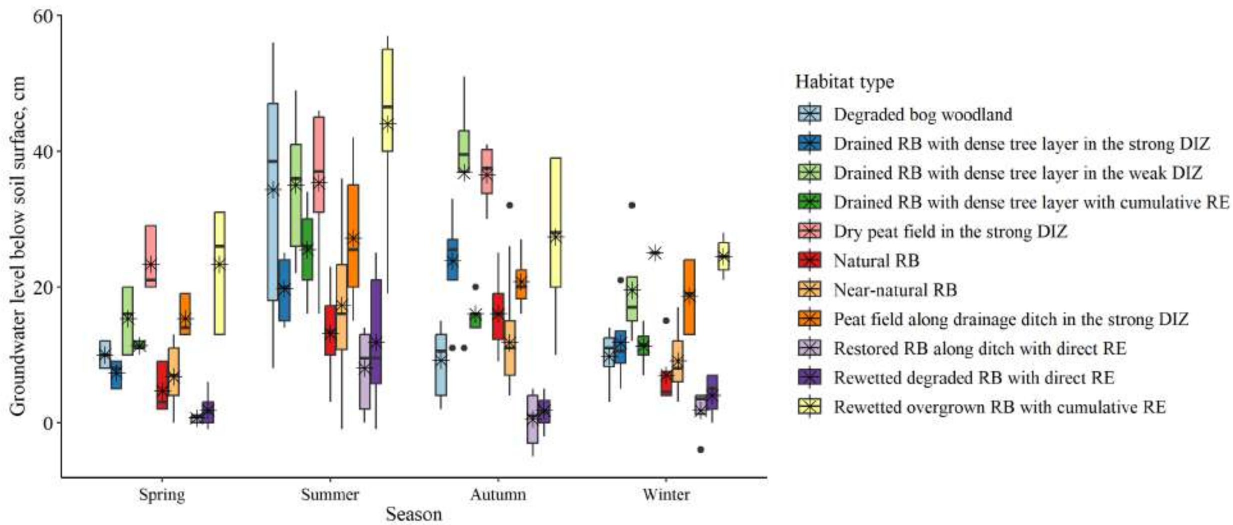


Figure 3.3.12. *Variation in groundwater level below soil surface during the study period (different seasons) by habitat types[11].*

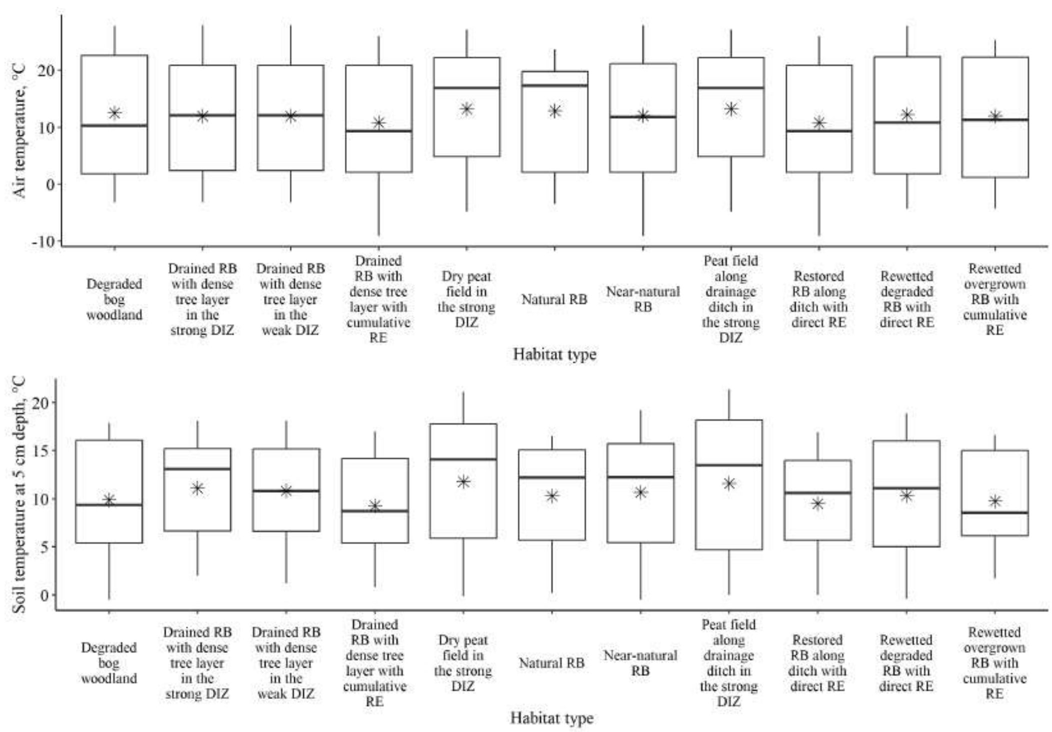


Figure 3.3.13. Variation in air and soil temperature during the study period by habitat types[12]

[12] DIZ – drainage impact zone; RE – restoration effect; RB – raised bog. The boxes show 25th and 75th percentiles, horizontal line – median value, asterisk – mean value, whiskers – minimal and maximal values or 1.5 time the interquartile range if outlier values are presented (points).

3.5. GEST monitoring

In 2024 GEST monitoring occurred in accordance with the calibrated remote sensing methodology of the project published in the 1st Monitoring report. The main progress of GEST monitoring was continuation in classification of remote sensing data collected in 2023, besides expeditions of the reference data collection for GEST classification needs of Lielais Pelečāre Mire that was postponed to 2024. The overall progress of the GEST monitoring in 2024 is described for each project site separately below.

3.4.1. Cena Mire

In 2024, based on data collected by aircraft on 2023 September 16 and subsequent reference data collected on 2023 October 17, 19. In the 1st Monitoring report 13 GEST types were described found in Cena Mire. Based on the reference information of the GEST types of GEST classification map was made (Figure 3.4.1). Later the GEST map was converted into GHG maps - CO_2, CH_4 and GWP maps (Figure 2).

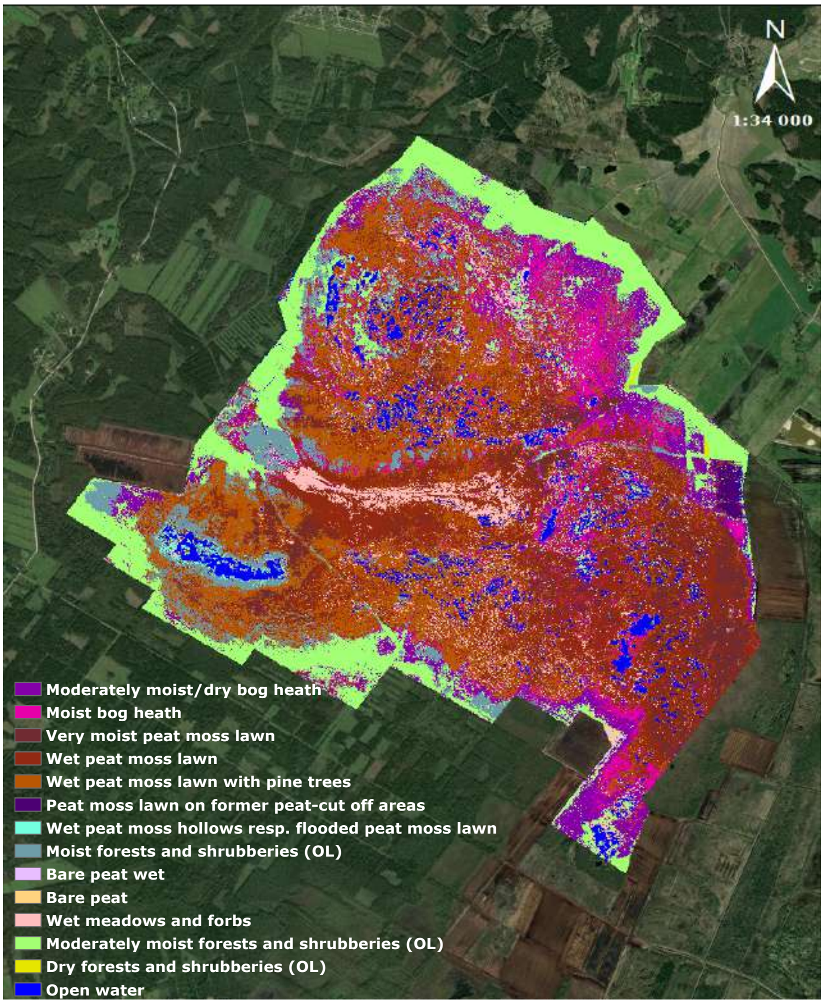


***Figure 3.4. 1**. GEST classification map of Cena Mire in 2023. © Institute for Environmental Solutions*

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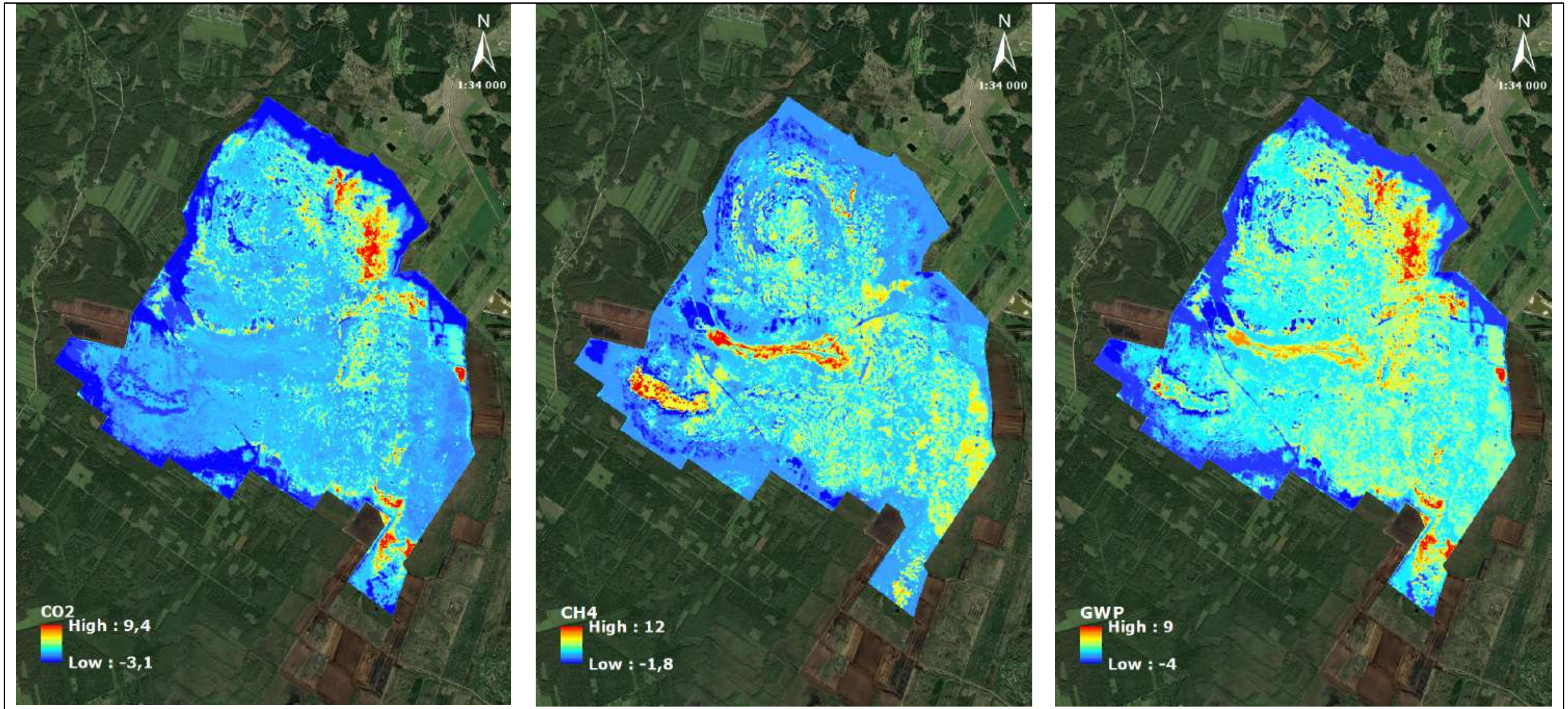


CO_2 emission image (t CO_2 eq./ha/year) CH_4 emission image (t CO_2 eq./ha/year) GWP emission image (t CO_2 eq./ha/year)

***Figure 3.4.2**. GHG maps of Cena Mire in 2023 including wood biomass data. Abbreviation: GWP – global warming potential. © Institute for Environmental Solutions.*

The conversion of the GEST map into the GHG maps was based on data published in the Handbook for Assessment of Greenhouse Gas Emissions from Peatlands (Jarašius et al. 2022[13]). However, four GEST types missed the required values in the book: 1) Moderately moist/dry bog heath; 2) Dry Forest and shrubberies (OL); 3) Open water/ditches; 4) Wet peat moss lawn with pine trees. As it is noticeable in Table 3.4.1, some of those GEST types are very common or even dominant in Cena Mire. Therefore, the produced GHG maps (Figure 2) are quite incomplete to represent GHG emissions of the site. Due to the reason, IES organised meeting on November 12 with SILAVA asking to advise for gap-filling of the missing GHG values for the particular GEST type. SILAVA accepted IES suggestions for the gap-filling. The refreshed GHG value dataset of GEST types is presented in Table 3.4.2.

***Table 3.4.1**. The classified GEST types and their area in Cena Mire*

GEST type	**Area, ha**
Wet peat moss lawn with pine trees	488.82
Wet peat moss lawn	454.80
Moderately moist forest and shrubberies (OL)	332.28
Moist forests and shrubberies (OL)	194.72
Moderately moist/dry bog heath	188.65
Very moist peat moss lawn	183.83
Moist bog heath	173.76
Wet meadows and forbs	139.76
Open water/ditches	110.54
Peat moss lawn on former peat-cut off areas	16.98
Wet peat moss hollows resp. flooded peat moss lawn	7.19
Bare peat wet (OL)	2.48
Bare peat dry (OL)	2.27
Dry forest and shrubberies (OL)	1.53

[13] Jarašius L. *et al*. 2022. Handbook for assessment of greenhouse gas emissions from peatlands. Applications of direct and indirect methods by LIFE Peat Restore. Lithuanian Fund for Nature, Vilnius, 201 p.

Table 3.4.2. *GHG values of GEST types used for the GEST map conversion into GHG maps. Letter colour marks: black – values published in GEST Handbook[1]; purple – gap-filling values extrapolated by IES from other scientific publications describing similar vegetation types. Green colour: GEST types that data with wood biomass is relevant in GHG calculations)*

GEST type	Water level	Data without wood biomass (t CO_2 -eq./ha/year)			Water level	Data with wood biomass (t CO_2 -eq./ha/year)		
		CO_2	CH_4	GWP		CO_2	CH_4	GWP
Open peatland								
Bare peat dry (OL)	2-/3-	7	0.4	7.5	2-/3-	7	0.4	7.5
Moderately moist/dry bog heath	2+/2-	13.5	0.1	13.6	2+/2-	13.5	0.1	13.6
Moderately moist (forb) meadows	2+	20	0	20	2+	20	0	20
Moist reeds and (forbs) meadows	3+	4.6	7.5	12.2	3+	4.6	7.5	12.2
Moist bog heath	3+	9.4	0	9.4	3+	9.4	0	9.4
Bare peat moist (OL)	3+	6.2	0	6.2	3+	6.2	0	6.2
Bare peat wet (OL)	4+	1.5	0.1	1.6	4+	1.5	0.1	1.6
Very moist meadows, forbs and small sedges reeds	4+	-0.5	2.3	1.9	4+	-0.5	2.3	1.9
GEST type	**Water level**	Data without wood biomass (t CO_2 -eq./ha/year)			**Water level**	Data with wood biomass (t CO_2 -eq./ha/year)		
		CO_2	CH_4	GWP		CO_2	CH_4	GWP
Open peatland								
Very moist bog heath	4+	1.7	3	4.6	4+	1.7	3	4.6
Very moist peat moss lawn	4+	-1.1	3.4	2.3	4+	-1.1	3.4	2.3
Very moist tall sedges reeds	4+	0.5	6.9	7.4	4+	0.5	6.9	7.4
Wet peat moss lawn with pine trees	4+	3.9	0.2	4.1	4+	1.17	0.2	1.37
Very moist/Wet calcareous meadows, forbs and small sedges reeds (EU)	4+/5+	2.4	0.5	2.9	4+/5+	2.4	0.5	2.9
Wet meadows and forbs	5+	0	5.8	5.8	5+	0	5.8	5.8
Wet bog heath	5+	3.1	21.6	24.7	5+	3.1	21.6	24.7
Wet tall sedges reeds	5+	-0.1	8.5	8.4	5+	-0.1	8.5	8.4
Wet small sedges reeds mostly with moss layer	5+	-3.5	6.8	3.3	5+	-3.5	6.8	3.3
Wet tall reeds	5+	-2.3	6.3	4	5+	-2.3	6.3	4
Wet peat moss lawn	5+	-0.5	0.3	-0.3	5+	-0.5	0.3	-0.3
Peat moss lawn on former peat-cut off areas	5+	1.5	0.4	1.9	5+	1.5	0.4	1.9
Wet peat moss hollows resp. flooded peat moss lawn	5+	-3.1	12	8.9	5+	-3.1	12	8.9
Open water/ditches	6+	1.42	2.8	4.22	6+	1.42	2.8	4.22
Forested peatland								
Dry forest and shrubberies (OL)	2-/3-	26	0	26	2-/3-	**nd**	**nd**	**nd**
Moderately moist forest and shrubberies (OL)	2+	20	0	20	2+	**-3.1**	**-0.11**	**-3.22**
Moist forests and shrubberies (OL)	3+	9.4	0	9.4	3+	**-2.2**	**-1.8**	**-4**
Very moist forest and shrubberies (OL)	4+	1.7	3	4.7	4+	**-2.3**	**1.75**	**-0.55**
Dry forests and shrubberies (ME/EU)	2-/3-	43.4	0	43.4	2-/3-	**nd**	**nd**	**nd**
Moderately moist forest and shrubberies (ME/EU)	2+	20	0	20	2+	**1**	**nd**	**1**
Moist forests and shrubberies (ME/EU)	3+	4.6	7.5	12.2	3+	**21.59-24.98**	**0.004-5.35**	**21.59-30.33**
Very moist forest and shrubberies (ME/EU)	4+	-0.5	2.1	1.6	4+	**-10.72-(-5.97)**	**0.81-4.27**	**-9.91-(-1.7)**
Wet forests and shrubberies (ME/EU)	5+	-3.5	6.8	3.3	5+	**-4.98**	**0.04-11.46**	**-4.85-6.57**

In the following years of the project, the GHG maps of the Cena Mire will be re-produced on the basis of gap-filling values shown in the Table 2. Few GEST types are monitored by chambers in GHG monitoring of the project. When will be accumulated the longest data queue possible during the project years in the GHG monitoring done by SILAVA, a comparison will be made between literature based GHG values of GEST types and the values determined by GHG monitoring. If significant differences will be observed in these data, GHG maps will be updated according the GHG monitoring results.

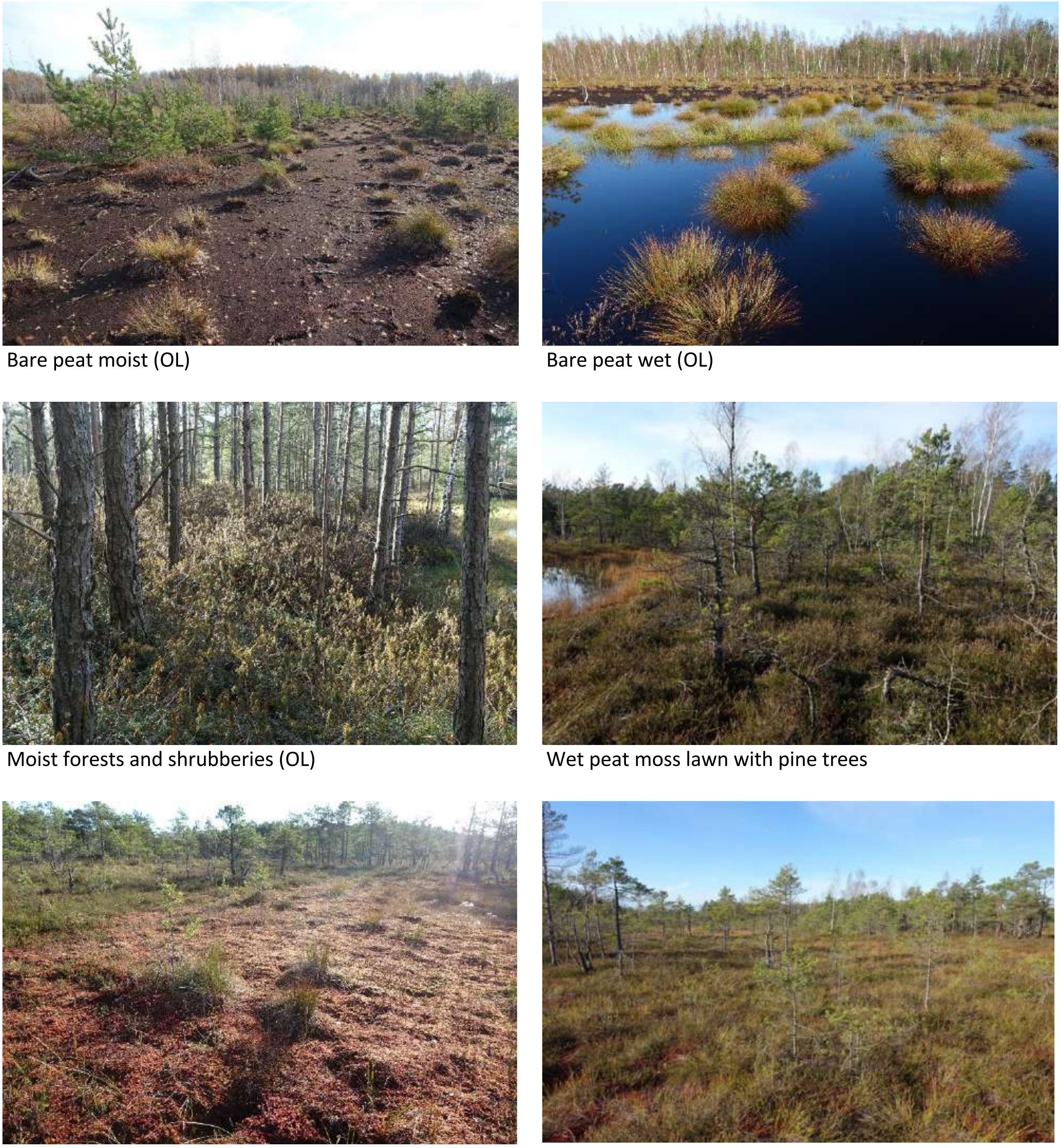
3.4.2. Melnais Lake Mire

In 2024, the processing of the reference data collected on 2023 November 2 was carried out to produce a database for GEST classification of Melnais Lake Mire exactly in the same way as is it was done for Cena Mire in 2023. In total 17 different GEST types were classified in the Melnais Lake Mire (Table 3.4.3). Four GESTs belong to forest types, and the other 13 to open types.

Table 3.4. 3. *List of classified GEST types in Melnais Lake Mire*

OPEN / FORESTED	GEST type
FORESTED	Dry forest and shrubberies (OL)
FORESTED	Dry forests and shrubberies (ME/EU)
FORESTED	Moderately moist forest and shrubberies (OL)
FORESTED	Moist forests and shrubberies (OL)
OPEN	Bare peat dry
OPEN	Bare peat moist
OPEN	Bare peat wet
OPEN	Moderately moist (forbs) meadows
OPEN	Wet meadows and forbs
OPEN	Open water/ditches
OPEN	Very moist bog heath
OPEN	Wet tall reeds
OPEN	Peat moss lawn on former peat-cut off areas
OPEN	Very moist peat moss lawn
OPEN	Wet peat moss hollows resp. flooded peat moss lawn
OPEN	Wet peat moss lawn
OPEN	Wet peat moss lawn with pine trees

Few examples of classified GEST types observed during the references data collection in Melnais Lake Mire are showed in the Figure 3.4.3.



Bare peat moist (OL)

Bare peat wet (OL)

Moist forests and shrubberies (OL)

Wet peat moss lawn with pine trees

Wet peat moss lawn

Very moist bog heath

***Figure 3.4.3**. Examples of GEST types in Melnais Lake Mire. Images: © L. Strazdiņa.*

The database of GEST reference information was further used to obtain the GEST classification map from the hyperspectral remote sensing data collected for the work on 2023 September 16 (Figure 3.4.4).

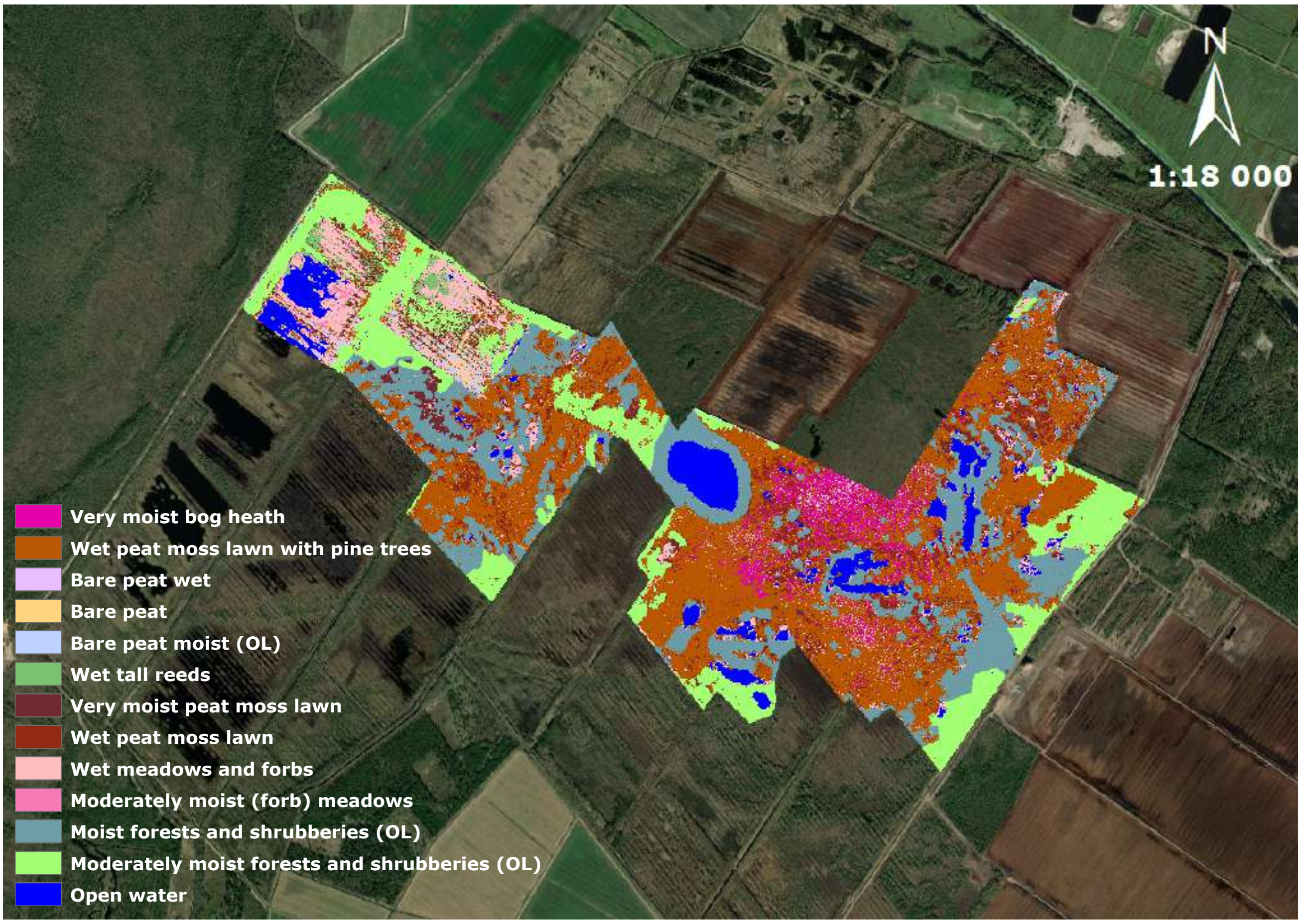
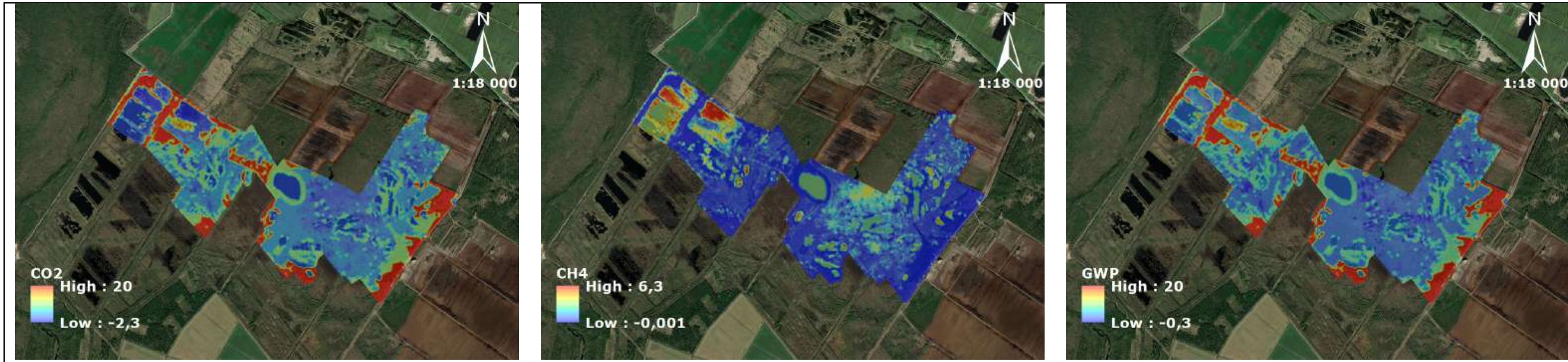


Figure 3.4.4. *GEST classification map of Melnais Lake Mire, 2023. © Institute for Environmental Solutions.*

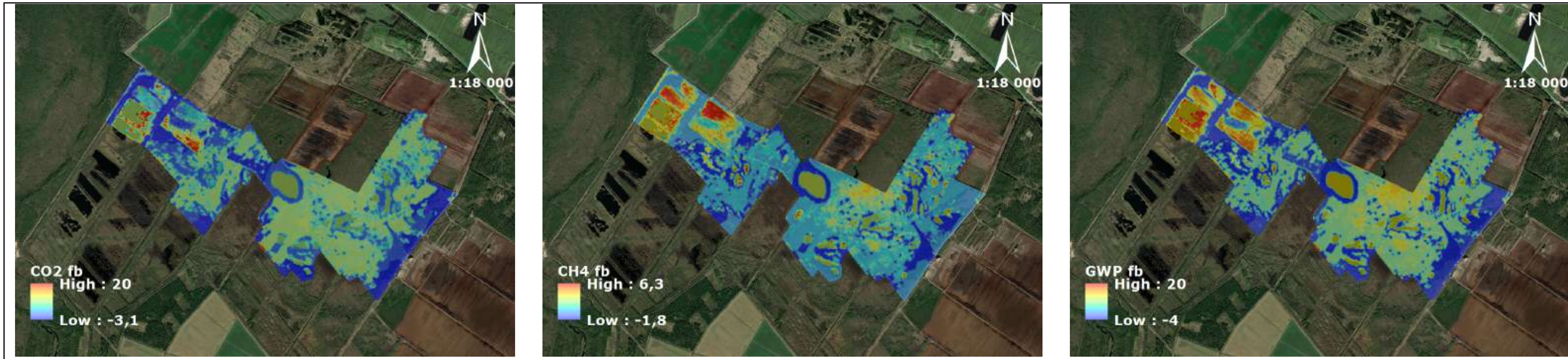
Further the GEST maps of Melnais Lake Mire were converted into GHG maps – maps of CO_2, CH_4, GWP maps. It was done according to the GHG values presented in Table 2, including IES extrapolated gap-filling values. As a result, two versions of the GHG maps were created – with or without wood biomass data (Figure 3.4.5, 3.4.6).

In Melnais Lake Mire GHG monitoring is carried out by SILAVA using climate chambers. For few GEST types there will be GHG values assessed. During next reporting periods the values will be integrated as well in the GEST monitoring for the Melnais Lake Mire and compared with literature based GHG mapping results.



CO_2 emission image (t CO_2 eq./ha/year) CH_4 emission image (t CO_2 eq./ha/year) GWP emission image (t CO_2 eq./ha/year)

***Figure 3.4.5**. GHG maps of Melnais Lake Mire in 2023 without wood biomass data. Abbreviation: GWP – global warming potential. © Institute for Environmental Solutions.*



CO_2 emission image (t CO_2 eq./ha/year) CH_4 emission image (t CO_2 eq./ha/year) GWP emission image (t CO_2 eq./ha/year)

***Figure 3.4.6**. GHG maps of Melnais Lake Mire in 2023 including wood biomass data. Abbreviation: GWP – global warming potential. © Institute for Environmental Solutions.*

3.4.3. Lielais Pelečāre Mire

In 2024, May 21, 22, 30, 31 four expeditions of reference data gathering were organised in Lielais Pelečāre Mire. It was necessary for remote sensing data (collected in 2023, August 16) classification into GEST map of the project site. According to collected vegetation data (tree, shrub, herb and bryophyte layer), land usage history, drainage impact, peat characteristics and water table observations, a total of 12 different GESTs were classified in the Lielais Pelečāre Mire (Table 4). Four GESTs belong to forest types, and the other 8 to open types.

***Table 4**. List of classified GEST types in Lielais Pelečāre Mire*

OPEN / FORESTED	GEST type
FORESTED	Dry forest and shrubberies (OL)
FORESTED	Moderately moist forest and shrubberies (OL)
FORESTED	Moist forests and shrubberies (OL)
FORESTED	Moist forests and shrubberies (ME/EU)
OPEN	Very moist meadows, forbs and small sedges reeds
OPEN	Wet meadows and forbs
OPEN	Open water/ditches
OPEN	Very moist bog heath
OPEN	Very moist peat moss lawn
OPEN	Wet peat moss hollows resp. flooded peat moss lawn
OPEN	Wet peat moss lawn
OPEN	Wet peat moss lawn with pine trees

Few examples of classified GEST types observed during the references data collection in Lielais Pelečāre Mire are showed in the Figure 2.4.7.

Very moist bog heath

Wet meadows and forbs

Wet peat moss lawn

Wet peat moss hollows resp. flooded peat moss lawn

Wet peat moss lawn with pine trees

Moist forests and shrubberies (OL)

Very moist peat moss lawn

Very moist meadows, forbs and small sedges reeds

***Figure 3.4.7**. Examples of GEST types in Lielais Pelečāre Mire. Images: © L. Strazdiņa.*

GEST monitoring of Lielais Pelečāre Mire will be continued in the same way as for Cena and Melnais Lake Mire in next reporting period.

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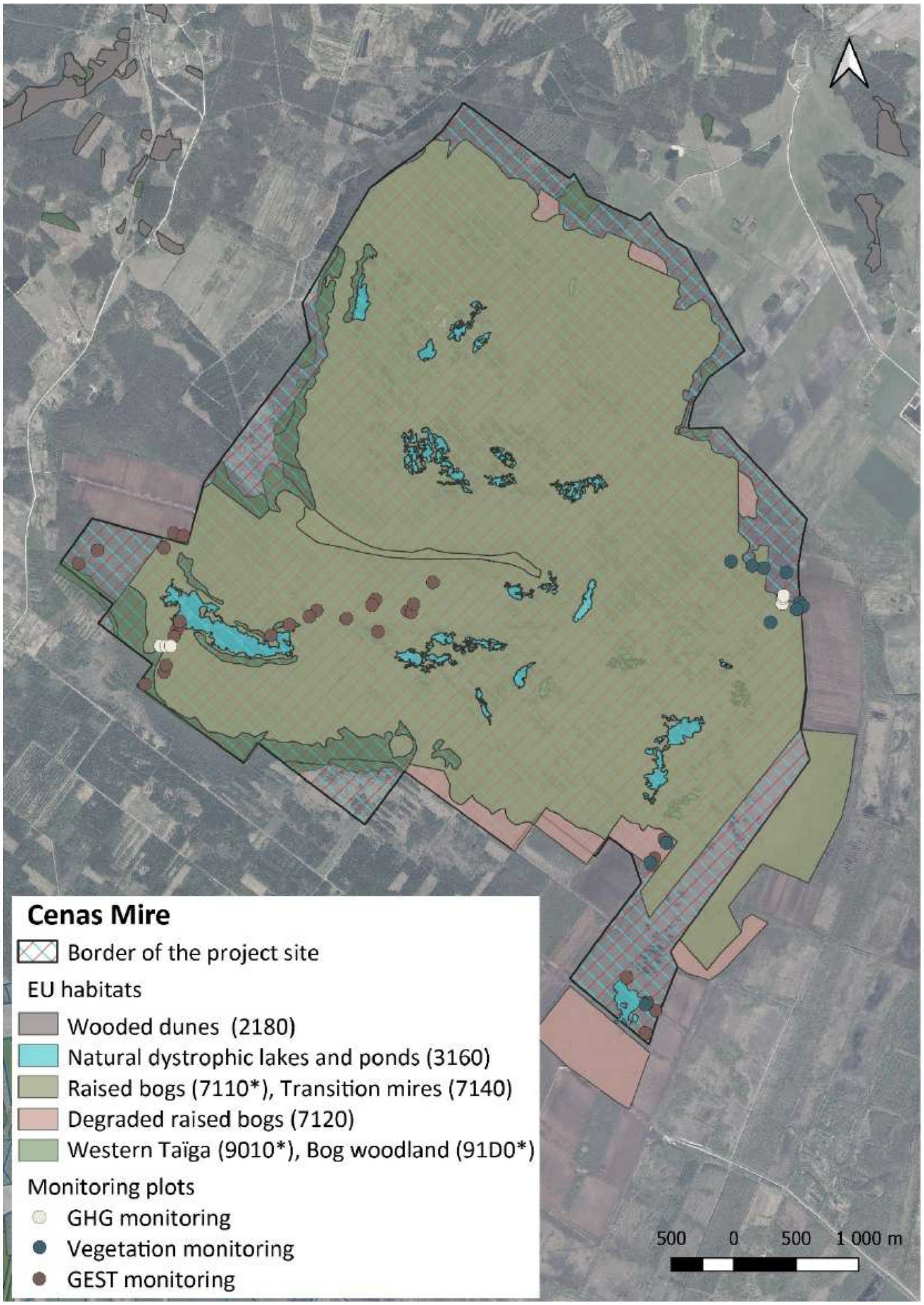
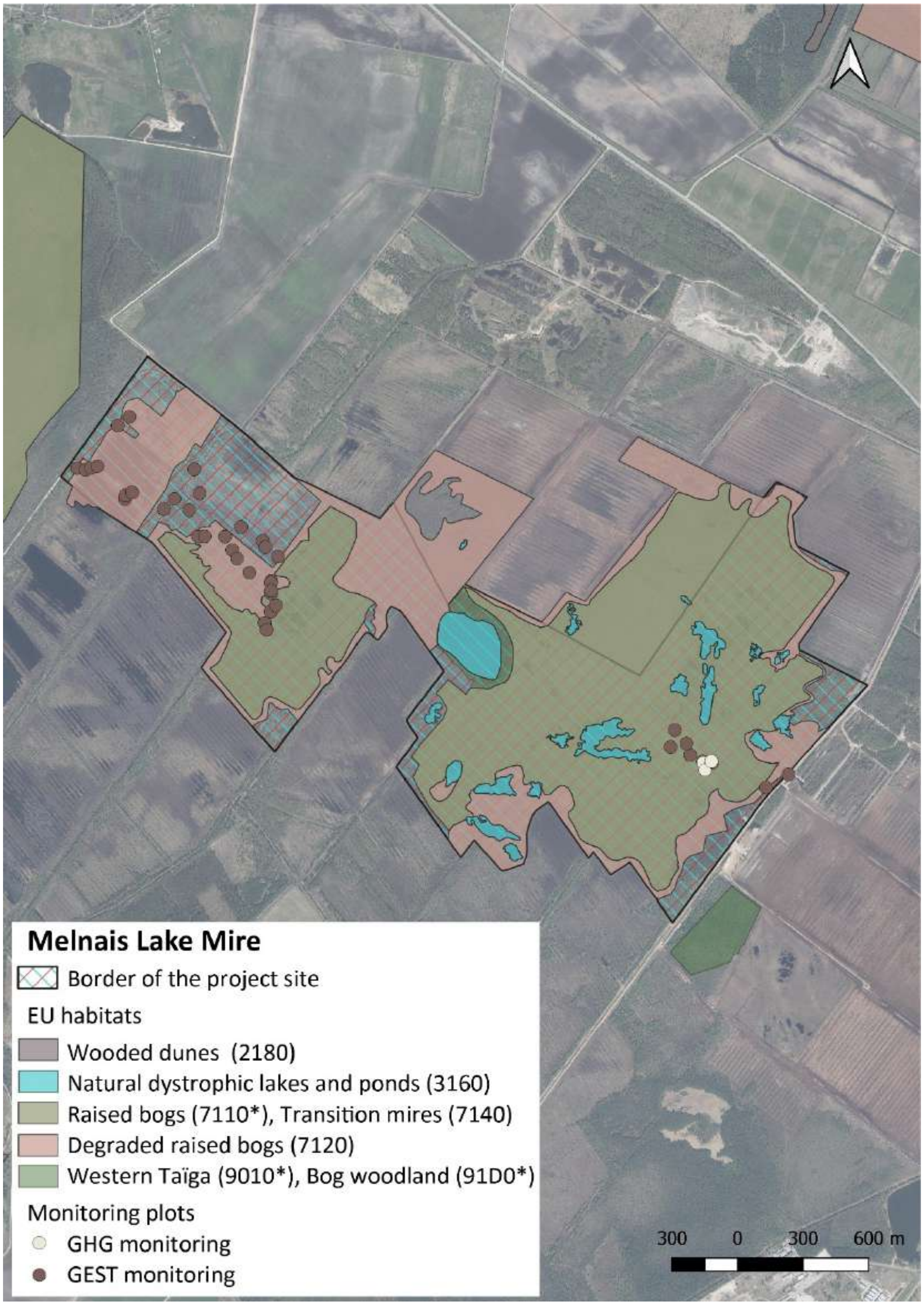
Appendices

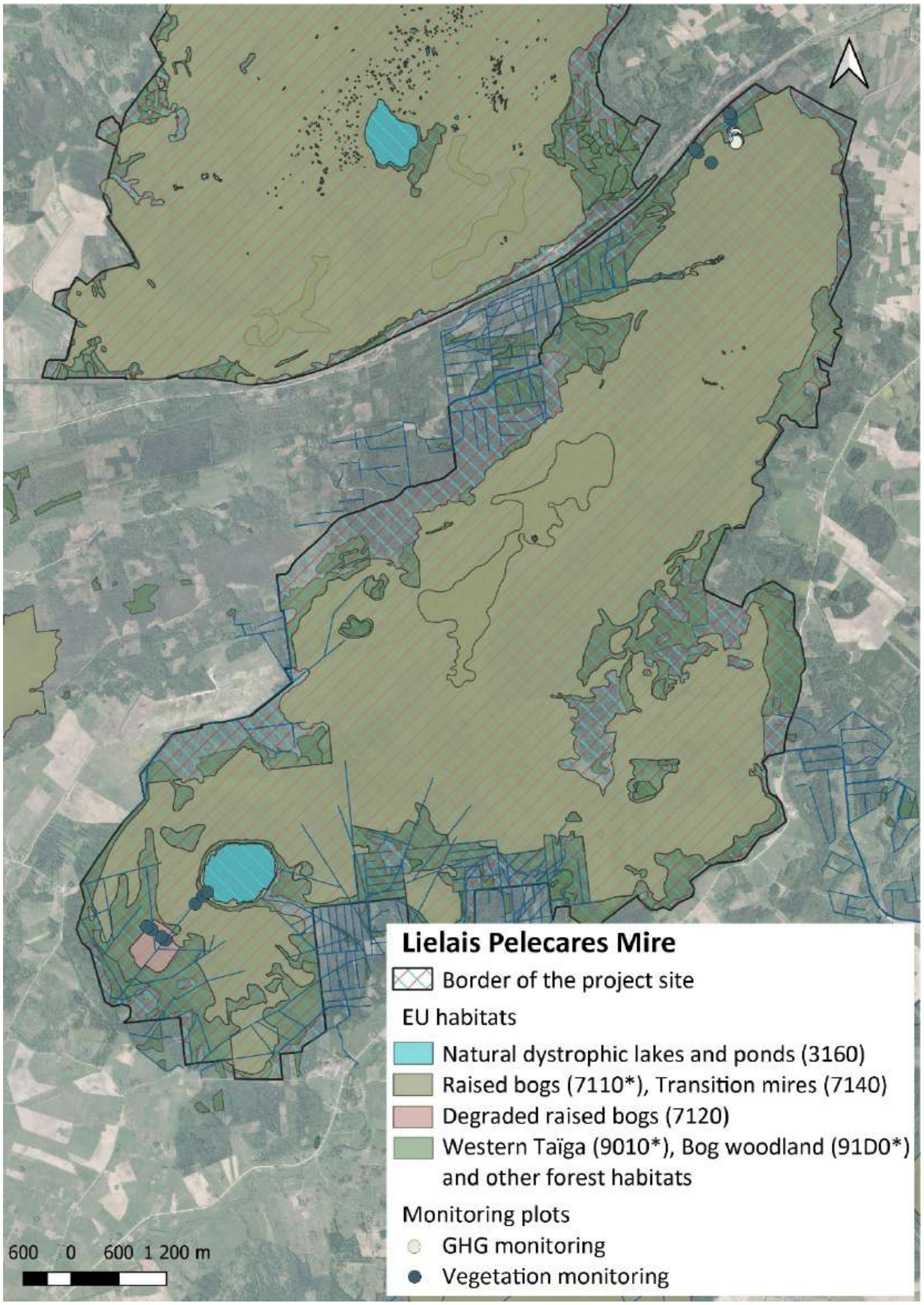
Appendix 6.1. *Cover of habitats of EU importance in the project sites in Latvia. Source: Nature Conservation Agency, 2023.*

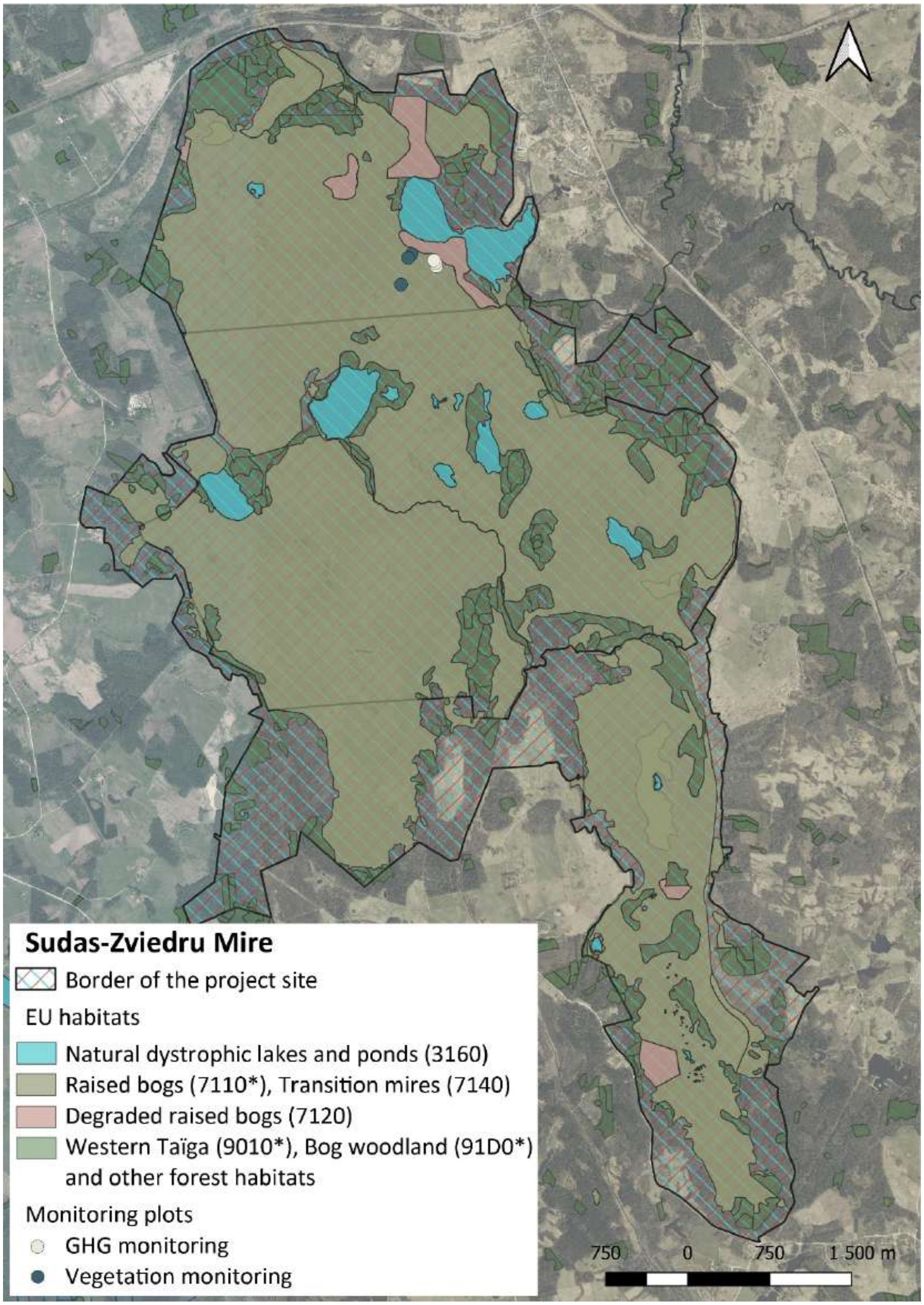
Habitat Code	Habitat type	Cover, ha			
		Cenas Mire	Melnais Lake Mire	Lielais Pelecares Mire	Sudas-Zviedru Mire
2180	Wooded dunes of the Atlantic, Continental and Boreal region	0.8	-	-	-
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation	-	-	-	61.21
3160	Natural dystrophic lakes and ponds	67.53	18.79	55.45	52.26
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation	-	-	-	0.66
7120	Degraded raised bogs still capable of natural regeneration	50.34	88.68	25.56	58.79
7140	Transition mires and quaking bogs	17.12	-	10.63	53.51
7150	Depressions on peat substrates of the Rhynchosporion	-	-	168.1	29.44
7160	Fennoscandian mineral-rich springs and springfens	-	-	-	0.14
7110*	Active raised bogs	1769.19	186.29	3809.36	2089.39
9010*	Western Taïga	27.8	3.97	26.54	167.68
9020*	Fennoscandian hemiboreal natural old broad-leaved deciduous forests (Quercus. Tilia. Acer. Fraxinus or Ulmus) rich in epiphytes	-	-	14.42	5.76
9050	Fennoscandian herb-rich forests with Picea abies	-	-	-	12.49
9080*	Fennoscandian deciduous swamp woods	-	-	0.86	2.35
9160	Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli	-	-	24.58	7.09
91D0*	Bog woodland	85.05	-	1041.62	307.34
91E0*	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion. Alnion incanae. Salicion albae)	-	-	-	0.65
	In total:	**2017.83**	**297.73**	**5177.12**	**2848.76**

Appendix 6.2. *Distribution of habitats of EU importance and location of monitoring plots in project sites in Latvia. Source: Nature Conservation Agency, 2023. Images: © L. Strazdiņa*




Melnais Lake Mire
Border of the project site
EU habitats
Wooded dunes (2180)
Natural dystrophic lakes and ponds (3160)
Raised bogs (7110*), Transition mires (7140)
Degraded raised bogs (7120)
Western Taïga (9010*), Bog woodland (91D0*)
Monitoring plots
GHG monitoring
GEST monitoring
300 0 300 600 m


Lielais Pelecares Mire
Border of the project site
EU habitats
Natural dystrophic lakes and ponds (3160)
Raised bogs (7110*), Transition mires (7140)
Degraded raised bogs (7120)
Western Taïga (9010*), Bog woodland (91D0*) and other forest habitats
Monitoring plots
GHG monitoring
Vegetation monitoring
600 0 600 1 200 m



Sudas-Zviedru Mire
Border of the project site
EU habitats
Natural dystrophic lakes and ponds (3160)
Raised bogs (7110*), Transition mires (7140)
Degraded raised bogs (7120)
Western Taïga (9010*), Bog woodland (91D0*) and other forest habitats
Monitoring plots
GHG monitoring
Vegetation monitoring
750 0 750 1 500 m

Appendix 6.3. *Parameters of hydrological regime monitoring automatic measurement points in Cena Mire.*

ID	Type*	Lat / Lon	Well head hight m a.s.l. LAS 2000.5 / relative hight	Type of probe Installation date	Construction	Aim of the monitoring
Cena1	MW	56.853095 / 23.888816	11.26 / 0.64	Levelogger 5 Junior 2024-05-07	Well filter interval: 1.36-3.36 m	Monitoring the water level gradient from the contour ditch to the undisturbed raised bog
Cena2	MW	56.852887 / 23.888461	12.15 / 0.32	Levelogger 5 Junior 2024-05-07	Well filter interval: 0.68 -2.68	
Cena3-1	MW	56.851967 / 23.884983	13.12 / 0.66	Levelogger 5 Junior 2023-06-08	Well filter interval: 0.34-2.34 m	
Cena3-2	MW	56.85197 / 23.884984	13.12 / 0.66	Levelogger 5 Junior 2024-05-07	Well filter interval: 0.34-2.34 m	Investigate the impact of mire surface movement on the borehole without anchoring
Cena3-3	MW	56.851965 / 23.884992	13.10 / 0.66	Levelogger 5 Junior 2024-05-07	Well filter interval: 4.34-5.34 m	Piezometric water level comparison in the upper part (acrotelm) and base (catotelm) of the raised bog
Cena4	MW	56.855515 / 23.887163	11.03 / 0.48	Levelogger 5 Junior 2023-06-08	Well filter interval: 0.52-2.52 m	Water level observations in the peatland area with hydrological regime restoration measures
Cena5	MW	56.855852 / 23.884118	11.12 / 0.23	Levelogger 5 Junior 2023-06-08	Well filter interval: 0.77-2.77 m	
Cena6	MW	56.856034 / 23.882628	11.66 / 0.29	Levelogger 5 Junior 2023-06-08	Well filter interval: 0.71-2.71 m	
Cena7	MW	56.856342 / 23.879809	12.80 / 0.18	Levelogger 5 Junior 2023-06-08	Well filter interval: 0.82-2.82 m	
Cena22	MW	56.856748 / 23.882486	13.23 / 0.20	Levelogger 5 Junior 2024-05-07	Well filter interval: 0.80-2.80 m	
Cena8	Q	56.853344 / 23.888705	10.12 / 0.58	Levelogger 5 Junior 2023-06-08	Rectangular spillway, 0.13 m wide, discontinued, no data available	Dithc discharge monitoring
Cena10	MW	56.824516 / 23.8686	12.11 / 0.93	Levelogger 5 Junior 2024-05-07	Well filter interval: 1.07-2.07 m, anchored into mineral subsoil	Monitoring water level fluctuations in the mire lake and ditch that is draining it, in the area where restoration measures are planned

Cena11	Q	56.823796 / 23.870205	9.39 / 0.60	Levelogger 5 LTC	Water level monitoring in a ditch	
Cena14	MW	58.536282 / 23.801378	12.87 / 0.47	Levelogger 5 Junior 2024-05-27	Well filter interval: 0.53-2.53 m	Water level monitoring in the raised bog where hydrological regime restoration measures were carried out in 2007 near Skaists Lake
Cena15	MW	56.848839 / 23.808701	12.74 / 0.44	Levelogger 5 Junior 2024-05-27	Well filter interval: 0.56 – 2.56 m	
Cena16	MW	56.850719 / 23.811501	12.88 / 0.48	NA	Well filter interval: 0.52 – 1.52, anchored into mineral subsoil, Skaists Lake	
Cena18	MW	56.834618 / 23.869317	12.41 / 0.28	NA	Well filter interval: 0.72 – 2.72 m	Water level monitoring in the raised bog where hydrological regime restoration measures were carried out in 2007 in the S part of the Cena Mire NR
Cena19	MW	56.834647 / 23.869363	12.99 / 0.71	NA	Well filter interval: 0.29 – 2.29	
Cena20	MW	56.836139 / 23.87148	13.53 / 0.59	Levelogger 5 Junior 2024-05-07	Well filter interval: 0.41 – 2.41 m	
Cena21	MW	56.836138 / 23.87148	13.67 / 0.58	Levelogger 5 Junior 2024-05-07	Well filter interval: 0.42 – 2.42 m	
Cena23	MW	56.87376 / 23.825739	12.86 / 0.37	Levelogger 5 Junior 2024-05-27	Well filter interval: 0.63 – 1.63 m	Water level monitoring in the transition zone between raised bog and drained forest for assessing the impact of restoration measures on adjacent areas
Cena24	MW	56.873682 / 23.825327	9.65 / 0.55	Levelogger 5 Junior 2024-05-27	Well filter interval: 0.45 – 1.45 m	
Cena25	MW	56.872862 / 23.823469	8.86 / 0.18	Levelogger 5 Junior 2024-05-27	Well filter interval: 0.00 – 0.82 m	

* MW – monitoring well; Q – discharge monitoring

Appendix 6.4. Summary data of hydrological monitoring points in Lielais Pelečāre Mire.

ID	Type *	Lat / Lon	Well head-hight m a.s.l. LAS 2000.5 / relative hight	Type of probe Installation date	Construction	Aim of the monitoring
Pelecare_a1_mezs	SW	56.55436 / 26.60368	111.04 (soil surface)	Meter Teros 21 water potential probe and Teros 11 volumetric water content probe 2023-10-04	Teros 21: 0.1 m and 0.6 m Teros 11: 0.1, 0.3 and 0.6 m deep	The drained portion of the Deigļu Mire (part of Lielais Pelečāres Mire), selected as a detailed monitoring plot for the impact of the restoration measures. The objective of water level observations is to assess the overall impact of restoration measures. Monitoring includes a profile of monitoring points in a section of raised bog least affected by drainage.
Pelecare_a2_purvs	SW	56.55248 / 26.60430	111.22 (soil surface)	Meter Teros 21 water potential probe and Teros 11 volumetric water content probe 2023-10-04	Teros 21: 0.1 m and 0.6 m Teros 11: 0.1, 0.3 and 0.6 m deep	
Pelecare1	MW	56.5543 / 26.6037	110.95 / 0.48	Levelogger 5 Junior 2023-06-20	Filter depth: 1.62-3.62 m	
Pelecare2	MW	56.5539 / 26.6040	109.64 / 0.21	Levelogger 5 Junior 2023-06-20	Filter depth: 0.79-1.79 m	
Pelecare3	MW	56.5524 / 26.6043	111.64 / 0.69	Levelogger 5 Junior 2023-06-20	Filter depth: 0.31-2.31 m	
Pelecare4	MW	56.5515 / 26.6050	111.63 / 0.67	Levelogger 5 Junior 2023-06-20	Filter depth: 0.33-2.33 m	
Pelecare5	MW	56.5513 / 26.6052	111.84 / 0.55	Levelogger 5 Junior 2023-06-20	Filter depth: 0.45-2.45 m	
Pelecare6	MW	56.5489 / 26.5995	112.14 / 0.47	Levelogger 5 Junior 2023-06-20	Filter depth: 0.53-2.53 m	
Pelecare7	MW	56.5506 / 26.5963	109.87 / 0.28	Levelogger 5 Junior 2023-06-20	Filter depth: 0.72-1.72 m	
Pelecare8	MW	56.5502 / 26.5969	111.18 / 0.45	Levelogger 5 Junior 2024-04-23	Filter depth: 0.55-2.55 m	
Pelecare26	MW	56.55237 / 26.60392	111.19 / 0.53	NA	Filter depth: 0.47-1.47 m	
Pelecare9	Q	56.4492 / 26.4684	99.37 / NA	Levelogger 5 Junior 2023-06-20	Filter depth: 0-1 m	The monitoring site includes heavily drained portion of the Malnupeite River catchment and Deguma Lake, that has lesser drainage impact. Given the considerable peat thickness affected by drainage, changes of the water composition (quality) can be expected. The objective of monitoring is to assess the success of hydrological regime restoration in the significantly degraded and
Pelecare10	MW	56.4634 / 26.4821	104.92 / 0.21	Levelogger 5 Junior 2023-06-20	Filter depth: 0.79-2.79 m	
Pelecare11	MW	56.4638 / 26.4814	105.86 / 0.73	Levelogger 5 Junior 2023-06-20	Filter depth: 0.27-2.27 m	
Pelecare12	MW	56.4646 / 26.4795	106.04 / 0.47	Levelogger 5 Junior 2023-06-20	Filter depth: 0.53-2.53 m	
Pelecare13	MW	56.4650 / 26.4786	106.52 / 0.41	Levelogger 5 Junior 2023-06-20	Filter depth: 0.59-2.59 m	
Pelecare14 (Deguma Lake)	MW	56.4686 / 26.4911	105.75 / 0.48	Levelogger 5 Junior 2023-06-20	Filter depth: 0.52-2.52 m	
Pelecare15	MW	56.4674 / 26.4886	107.75	Levelogger 5 Junior 2024-04-23		
Pelecare16	MW	56.4683 / 26.4903	106.80 / 0.51	Levelogger 5 Junior 2023-06-20	Filter depth: 0.49-2.49 m	

ID	Type *	Lat / Lon	Well head-hight m a.s.l. LAS 2000.5 / relative hight	Type of probe Installation date	Construction	Aim of the monitoring
Pelecare17	MW	56.46375 / 26.48132	105.64 / 0.42	Levelogger 5 Junior 2024-04-23	Filter depth: 0.58-2.58 m	forested portion of the mire, as well as in the less affected raised bog dome area including the relatively large Deguma Lake.
Pelecare18	MW	56.45932 / 26.47571	105.30 / 0.50	Levelogger 5 Junior 2024-04-23	Filter depth: 0.5-1.5 m	
Pelecare19	MW	56.45928 / 26.47601	108.73 / 0.37	Levelogger 5 Junior 2024-04-23	Filter depth: 0.63-1.63 m	
Pelecare20	MW	56.46333 / 26.51757	107.65 / 0.87	Levelogger 5 Junior 2024-04-23	Filter depth: 0.13-1.13 m	The ditch Azara Grovs and drainage network connected to it encompass both the nature reserve (NR) territory and the State Forest Service (LVM) lands outside the NR, where forest on drained peat soils is found. The aim of the water level monitoring is to evaluate the restoration success by comparing similar sites with and without restoration measures.
Pelecare21	MW	56.46336 / 26.51723	107.53 / 0.67	Levelogger 5 Junior 2024-04-23	Filter depth: 0.33-1.33 m	
Pelecare22	MW	56.46586 / 26.51413	104.43 / 0.51	Levelogger 5 Junior 2024-04-23	Filter depth: 0.49-1.49 m	
Pelecare23	MW	56.46590 / 26.51454	104.78 / 0.48	Levelogger 5 Junior 2024-04-23	Filter depth: 0.52-1.52 m	
Pelecare24	MW	56.46650 / 26.51017	105.11 / 0.77	Levelogger 5 Junior 2024-04-23	Filter depth: -0.27-1.73 m	
Pelecare25	MW	56.46664 / 26.51040	105.13 / 0.78	Levelogger 5 Junior 2024-04-23	Filter depth: -0.28-1.72 m	

* SW – soil water monitoring point; MW – monitoring well; Q – discharge monitoring site

Appendix 6.5. Summary data of hydrological monitoring points in Sudas-Zviedru Mre.

ID	Type*	Lat / Lon	Well head-hight m a.s.l. LAS 2000.5 / relative hight	Type of probe Installation date	Construction	Aim of the monitoring
Suda1	MW	57.16235 / 25.01733	118.259 / 0.63	Leveloger5 Junior 2024-06-11	Filter depth 0.37 -1.37 m	Profile radial to the slope of the bog dome across blocked ditches, to examine the gradient from healthy raised bog to degrade bog with forest cover
Suda2	MW	57.16298 / 25.01852	117.228 / 0.52	Leveloger5 Junior 2024-06-11	Filter depth - 0.48 -2.48 m	
Suda3	MW	57.1628 / 25.01863	116.935 / 0.37	Leveloger5 Junior 2024-06-11	Filter depth - 0.63 -2.63 m	
Suda4	MW	57.16274 / 25.01866	117.244 / 0.35	Leveloger5 Junior 2024-06-11	Filter depth - 0.65 -2.65 m	
Suda7	MW	57.16231 / 25.0187	117.951 / 0.37	Leveloger5 Junior 2024-06-11	Filter depth - 0.63 -2.63 m	Profile along the axis of a ditch to examine dynamics the water level gradient across a dam and in flooded segment of the ditch
Suda5	MW	57.16248 / 25.01874	117.317 / 0.44	Leveloger5 Junior 2024-06-11	Filter depth - 0.56 -2.56 m	
Suda6	MW	57.16247 / 25.01864	117.702 / 0.54	Leveloger5 Junior 2024-06-11	Filter depth - 0.46 -2.46 m	

* MW – monitoring well

Appendix 6.7. *Summary data of hydrological monitoring points in Melnais Lake Mire.*

ID	Type*	Lat / Lon	Well head-hight m a.s.l. LAS 2000.5 / relative hight	Type of probe Installation date	Construction	Aim of the monitoring
Melnais1	MW	56.83686 / 23.98986	13.69 / 0.4	Leveloger5 Junior 2024-05-30	Filter depth - 0.60 -2.60 m	Examine the water level dynamics in a strip of dens pine forest in the raised bog
Melnais2	MW	56.83678 / 23.98865	13.94 / 0.46	Leveloger5 Junior 2024-05-30	Filter depth - 0.54 -2.54 m	A profile perpendicular to blocked ditch to examine water level gradient near the ditch
Melnais3	MW	56.83705 / 23.98869	13.97 / 0.43	Leveloger5 Junior 2024-05-30	Filter depth - 0.57 -2.57 m	
Melnais4	MW	56.83692 / 23.98733	13.84 / 0.36	Leveloger5 Junior 2024-05-30	Filter depth - 0.64 -2.64 m	A profile perpendicular to blocked ditch to examine water level gradient near the ditch
Melnais5	MW	56.83718 / 23.9874	14.17 / 0.46	Leveloger5 Junior 2024-05-30	Filter depth - 0.54 -2.54 m	
Melnais6	MW	56.83647 / 23.99187	13.06 / 0.52	Leveloger5 Junior 2024-05-30	Filter depth - 0.48 -1.48 m	A profile perpendicular to unsuccessful blocked ditch to examine water level gradient near the ditch
Melnais7	MW	56.83675 / 23.99196	14.29 / 0.64	Leveloger5 Junior 2024-05-30	Filter depth - 0.36 -2.36 m	

* MW – monitoring well

Appendix 6.5. *Summary data of vegetation, GHG and GEST monitoring points in project sites.*

Plot name	Comments	Date	Coordinates
CM1	Peat field along ditch	22.08.2023	56.853386, 23.888896
CM2	Peat field along ditch	22.08.2023	56.853090, 23.889289
CM3	Impacted raised bog	22.08.2023	56.852883, 23.888502
CM4	Natural, active raised bog	22.08.2023	56.851952, 23.885061
CM5	Peat field	22.08.2023	56.855533, 23.887116
CM6	Drained raised bog along ditch	22.08.2023	56.855851, 23.884141
CM7	Impacted raised bog	22.08.2023	56.856014, 23.882665
CM8	Natural, active raised bog	22.08.2023	56.856324, 23.879880
CM9	Restored peat field with trees	17.10.2023	56.834659, 23.869344
CM10	Restored peat field	17.10.2023	56.836074, 23.871436
CM11	Drained raised bog along ditch	17.10.2023	56.824436, 23.868726
CM GHG 1-3	Near-natural raised bog	22.08.2023	56.853273, 23.886614
CM GHG 4-6	Peat field along drainage ditch	22.08.2023	56.853726, 23.886711
CM GHG 7	Dry peat field	22.08.2023	56.853878, 23.886777
CM GHG 10-12	Near-natural raised bog	17.10.2023	56.85024482, 23.80636698
CM GHG 13-15	Restored raised bog along ditch	17.10.2023	56.85008141, 23.80575113
CM GHG 16-18	Drained raised bog with dense tree level	17.10.2023	56.85017528, 23.80492508
Cena 1	Moderately moist/dry bog heath	17.10.2023	56.834638, 23.869352
Cena 2	Moist bog heath	17.10.2023	56.836039, 23.871523
Cena 3	Moist bog heath	17.10.2023	56.8363523, 23.8711842
Cena 4	Dry forest and shrubberies (OL)	17.10.2023	56.8344698, 23.8695558
Cena 5	Wet meadows and forbs	17.10.2023	56.824519, 23.868922
Cena 6	Wet meadows and forbs	17.10.2023	56.8245814, 23.8689807
Cena 7	Dry forest and shrubberies (OL)	17.10.2023	56.82637936, 23.86618683
Cena 8	Wet meadows and forbs	17.10.2023	56.82401213, 23.87008753
Cena 9		17.10.2023	56.8223757, 23.8687601
Cena 10	Moderately moist forest and shrubberies (OL)	17.10.2023	56.84741392, 23.80267463
Cena 11	Open water/ditches	17.10.2023	56.84830575, 23.80543272
Cena 12	Moist forests and shrubberies (OL)	17.10.2023	56.8488333, 23.80542164
Cena 13	Moist forests and shrubberies (OL)	17.10.2023	56.85082086, 23.80660195
Cena 14	Wet peat moss hollows resp. flooded peat moss lawn	17.10.2023	56.85133077, 23.80705896
Cena 15	Wet peat moss hollows resp. flooded peat moss lawn	17.10.2023	56.8516829, 23.8075365
Cena 16	Wet peat moss hollows resp. flooded peat moss lawn	17.10.2023	56.8519144, 23.8074872
Cena 17	Wet peat moss hollows resp. flooded peat moss lawn	17.10.2023	56.85182283, 23.80762653
Cena 18	Wet peat moss lawn	19.10.2023	56.85320014, 23.83215685
Cena 19	Wet peat moss lawn	19.10.2023	56.8535187, 23.8331735
Cena 20	Wet peat moss lawn	19.10.2023	56.85605784, 23.84295525
Cena 21	Wet peat moss lawn	19.10.2023	56.854768, 23.840716
Cena 22	Wet peat moss lawn with pine trees	19.10.2023	56.85322957, 23.83819603
Cena 23	Wet meadows and forbs	19.10.2023	56.85270925, 23.83745568
Cena 24	Wet meadows and forbs	19.10.2023	56.85264650, 23.83791090
Cena 25	Moist forests and shrubberies (OL)	19.10.2023	56.85116025, 23.83361897
Cena 26	Wet peat moss lawn with pine trees	19.10.2023	56.85218585, 23.82932086
Cena 27	Very moist peat moss lawn	19.10.2023	56.85226881, 23.82450318
Cena 28	Moist forests and shrubberies (OL)	19.10.2023	56.85173110, 23.82187277
Cena 29	Moist forests and shrubberies (OL)	19.10.2023	56.8509298, 23.8194702
Cena 30	Bare peat wet	19.10.2023	56.8582709, 23.8066641

Plot name	Comments	Date	Coordinates
Cena 31	Moderately moist/dry bog heath	19.10.2023	56.858168, 23.802378
Cena 32	Moist forests and shrubberies (OL)	19.10.2023	56.85786318, 23.79527779
Cena 33	Moderately moist forest and shrubberies (OL)	19.10.2023	56.85616756, 23.7941930
MP GHG 1-3	Near-natural raised bog	02.11.2023	56.83702901, 23.98912981
MP GHG 4-6	Restored raised bog along drainage ditch	02.11.2023	56.83673032, 23.98926006
MP GHG 7-9	Drained raised bog with dense tree level	02.11.2023	56.83708759, 23.98972926
Melnais 1		02.11.2023	56.84922436, 23.94222253
Melnais 2		02.11.2023	56.84909677, 23.94279974
Melnais 3		02.11.2023	56.84914538, 23.94316302
Melnais 4		02.11.2023	56.84921344, 23.94366542
Melnais 5		02.11.2023	56.84802554, 23.94578550
Melnais 6		02.11.2023	56.84809560, 23.94613376
Melnais 7		02.11.2023	56.84789070, 23.94580028
Melnais 8		02.11.2023	56.84746759, 23.94872531
Melnais 10		02.11.2023	56.84766832, 23.95017148
Melnais 11		02.11.2023	56.84634404, 23.95125298
Melnais 12		02.11.2023	56.84633233, 23.95185218
Melnais 13		02.11.2023	56.84636535, 23.95326559
Melnais 15		02.11.2023	56.84556047, 23.95423035
Melnais 16		02.11.2023	56.84485431, 23.95510741
Melnais 17		02.11.2023	56.84444105, 23.95668284
Melnais 18		02.11.2023	56.84450052, 23.95670793
Melnais 19		02.11.2023	56.84413314, 23.95685522
Melnais 21		02.11.2023	56.84348948, 23.95696519
Melnais 26		02.11.2023	56.84544407, 23.95710973
Melnais 27		02.11.2023	56.84589941, 23.95635171
Melnais 30		02.11.2023	56.84874957, 23.95050136
Melnais 33		02.11.2023	56.83708759, 23.98972926
Melnais 34		02.11.2023	56.83702901, 23.98912981
Melnais 37		02.11.2023	56.83772569, 23.98670962
Melnais 38		02.11.2023	56.8335960, 23.98700026
Melnais 39		02.11.2023	56.83606504, 23.99414192
PM1	Bog woodland	17.08.2023	56.554451, 26.603734
PM2	Bog woodland	17.08.2023	56.553834, 26.604048
PM3	Impacted raised bog margin	17.08.2023	56.552468, 26.604359
PM4	Drained bog along ditch	17.08.2023	56.551442, 26.604957
PM5	Near natural raised bog	17.08.2023	56.551300, 26.605113
PM6	Natural, active raised bog	17.08.2023	56.548955, 26.599563
PM7	Natural bog margin	17.08.2023	56.550194, 26.596978
PM8	Bog woodland	17.08.2023	56.550577, 26.596307
PM10	Drained bog along ditch	18.08.2023	56.463422, 26.482182
PM11	Drained raised bog	18.08.2023	56.463760, 26.481407
PM12	Drained raised bog	18.08.2023	56.464678, 26.479470
PM13	Impacted raised bog with trees	18.08.2023	56.465033, 26.478486
PM15	Natural, active raised bog	18.08.2023	56.467399, 26.488595
PM16	Woodland around lake	18.08.2023	56.468257, 26.490226
PM17	Transition mire	18.08.2023	56.468654, 26.491079
PM GHG 1-3	Near natural raised bog	17.08.2023	56.551057, 26.604783
PM_GHG_1'_1	Near-natural raised bog	17.08.2023	56.551128, 26.604788

Plot name	Comments	Date	Coordinates
PM_GHG_1'_2	Near-natural raised bog	17.08.2023	56.551121, 26.604756
PM_GHG_1'_3	Near-natural raised bog	17.08.2023	56.551186, 26.604778
PM GHG 4-6	Drained raised bog along ditch	17.08.2023	56.551595, 26.604743
PM_GHG_4'_1	Drained raised bog along ditch	17.08.2023	56.551613, 26.604804
PM_GHG_4'_2	Drained raised bog along ditch	17.08.2023	56.551551, 26.604802
PM_GHG_4'_3	Drained raised bog along ditch	17.08.2023	56.551545, 26.604708
PM GHG 7-9	Impacted raised bog margin	17.08.2023	56.552159, 26.604630
PM_GHG_7'_1	Impacted raised bog margin	17.08.2023	56.552073, 26.604759
PM_GHG_7'_2	Impacted raised bog margin	17.08.2023	56.552045, 26.604818
PM_GHG_7'_3	Impacted raised bog margin	17.08.2023	56.552002, 26.604753
SZ1_1-5	Restored raised bog along drainage ditch	26.07.2023	57.163416, 25.015646
SZ2_1-3	Impacted raised bog	26.07.2023	57.163084, 25.015113
SZ3_1-3	Natural, active raised bog	26.07.2023	57.160901, 25.013935
SZ GHG 1-3	Near-natural raised bog	26.07.2023	57.162342, 25.019327
SZ GHG 4-6	Restored raised bog along ditch	26.07.2023	57.162627, 25.019203
SZ GHG 7-9	Drained raised bog with dense tree level	26.07.2023	57.162848, 25.018991

Appendix 6.6. *The list of vascular plant, bryophyte and lichen species recorded in project sites in vegetation monitoring plots, GHG monitoring plots and GEST points in 2023.*

	Cenas Mire			Melnais Lake Mire		Lielais Pelečāres Mire		Sudas-Zviedru Mire	
	Vegetation monitoring	GHG	GEST	GHG	GEST	Vegetation monitoring	GHG	Vegetation monitoring	GHG
TREES AND SHRUBS									
Betula pendula	x		x		x	x		x	
Betula pubescens	x			x	x		x	x	
Frangula alnus					x	x			
Picea abies			x		x			x	
Pinus sylvestris	x	x	x	x	x	x	x	x	x
Prunus padus					x				
Salix sp.					x				
Sorbus acuparia					x				
DWARF SHRUBS									
Andromeda polifolia	x	x	x	x	x	x	x	x	x
Calluna vulgaris	x	x	x	x	x	x	x	x	x
Chamaedaphne calyculata	x		x			x	x		
Empetrum nigrum	x	x	x	x	x	x			x
Ledum palustre	x	x	x	x	x	x	x		x
Oxycoccus microcarpa	x					x			
Oxycoccus palustris	x	x	x	x	x	x	x	x	x
Rubus chamaemorus	x	x	x		x	x	x	x	x
Rubus idaeus					x				
Vaccinium myrtillus			x		x	x	x		
Vaccinium uliginosum		x	x		x	x	x	x	
Vaccinium vitis-idaea		x	x	x	x	x	x		x
HERBACEOUS PLANTS									
Carex rostratum			x						
Carex sp.					x				
Deschampsia caespitosa					x				
Drosera anglica	x							x	
Drosera rotundifolia	x	x	x	x	x	x	x	x	x
Dryopteris filix-mas					x				
Epilobium sp.					x				
Eriophorum angustifolium					x				
Eriophorum vaginatum	x	x	x	x	x	x	x	x	x
Juncus sp.					x				
Luzula pilosa						x			
Lycopodium annotinum			x		x				
Melampyrum pratense						x			
Molinia caerulea					x				
Phragmites australis	x				x				
Rhynchospora alba	x		x		x	x	x	x	x
Scheuchzeria palustris			x		x	x	x		
BRYOPHYTES									
Aulacomnium palustre	x	x	x	x	x	x			
Brachythecium rutabulum	x				x				
Campylopus introflexus					x				

	Cenas Mire			Melnais Lake Mire		Lielais Pelečāres Mire		Sudas-Zviedru Mire	
	Vegetation monitoring	GHG	GEST	GHG	GEST	Vegetation monitoring	GHG	Vegetation monitoring	GHG
Dicranum bergeri					x		x	x	
Dicranum bonjeanii									x
Dicranum polysetum	x	x	x		x	x	x	x	
Dicranum scoparium	x	x	x		x	x		x	
Hylocomium splendens			x		x				
Hypnum cupressiforme	x								
Mylia anomala	x								
Plagiomnium affine					x				
Pleurozium schreberi	x	x	x	x	x	x	x	x	
Pohlia nutans					x				
Polytrichum commune			x		x		x		
Polytrichum juniperinum	x	x	x		x			x	
Polytrichum strictum			x			x	x	x	x
Sphagnum angustifolium	x		x	x	x	x	x	x	x
Sphagnum capillifolium	x	x	x		x	x	x	x	
Sphagnum contortum						x			
Sphagnum cuspidatum	x	x	x	x	x	x	x	x	
Sphagnum fallax					x				
Sphagnum flexuosum	x	x	x	x	x	x			
Sphagnum fuscum	x	x	x		x	x	x	x	
Sphagnum girgensohnii			x			x			
Sphagnum medium	x	x	x	x	x	x	x	x	x
Sphagnum recurvum			x						
Sphagnum rubellum	x	x	x	x	x	x	x	x	x
Sphagnum tenellum	x							x	
LICHENS									
Cladonia stellaris					x		x	x	
Cladonia stygia							x	x	
Cladonia sp.					x				

Appendix 6.7. *Photos of the greenhouse gas emission monitoring study sites and subplots representing different habitat types*

Subplot A (near-natural raised bog).

Subplot B (rewetted degraded raised bog with direct restoration effect)

Subplot C (rewetted overgrown raised bog with cumulative restoration effect)

Figure 6.7.1. *Study site LPC_1 (Sudas-Zviedru Mire). Images: © G. Saule*

Subplot A (near-natural raised bog)

Subplot B (drained raised bog with dense tree layer in the strong drainage impact zone)

Subplot C (drained raised bog with dense tree layer in the weak drainage impact zone)

Figure 6.7.2. *Study site LPC_2 (Lielais Pelečāre Mire). Images: © G. Saule*


Subplot A (near-natural raised bog)


Subplot B (rewetted degraded raised bog with direct restoration effect)


Subplot C (degraded bog woodland)

Figure 6.7.3. *Study site LPC_3 (Melnais Lake Mire). Images: © G. Saule*


Subplot A (near-natural raised bog)


Subplot B (restored raised bog along ditch with direct restoration effect)


Subplot C (drained raised bog with dense tree layer with cumulative restoration effect)

Figure 6.7.4. *Study site LPC_4 (Cenas Mire). Images: © G. Saule*


Subplot A (near-natural raised bog)


Subplot B (peat field along drainage ditch in the strong drainage impact zone)


Subplot C (dry peat field in the strong drainage impact zone)

Figure 6.7.5. *Study site LPC_5 (Cena Mire). Images: © G. Saule*


Subplot A (natural raised bog)


Subplot B (natural raised bog)


Subplot C (natural raised bog)

Figure 6.7.6. *Study site LPC_6 (Lielais Pelečāres Mire). Images: © G. Saule*


Subplot A (near-natural raised bog)


Subplot B (natural raised bog)


Subplot C (near-natural raised bog)

Figure 6.7.7. *Study site LPC_7 (Lielais Pelečāre Mire). Images: © G. Saule*