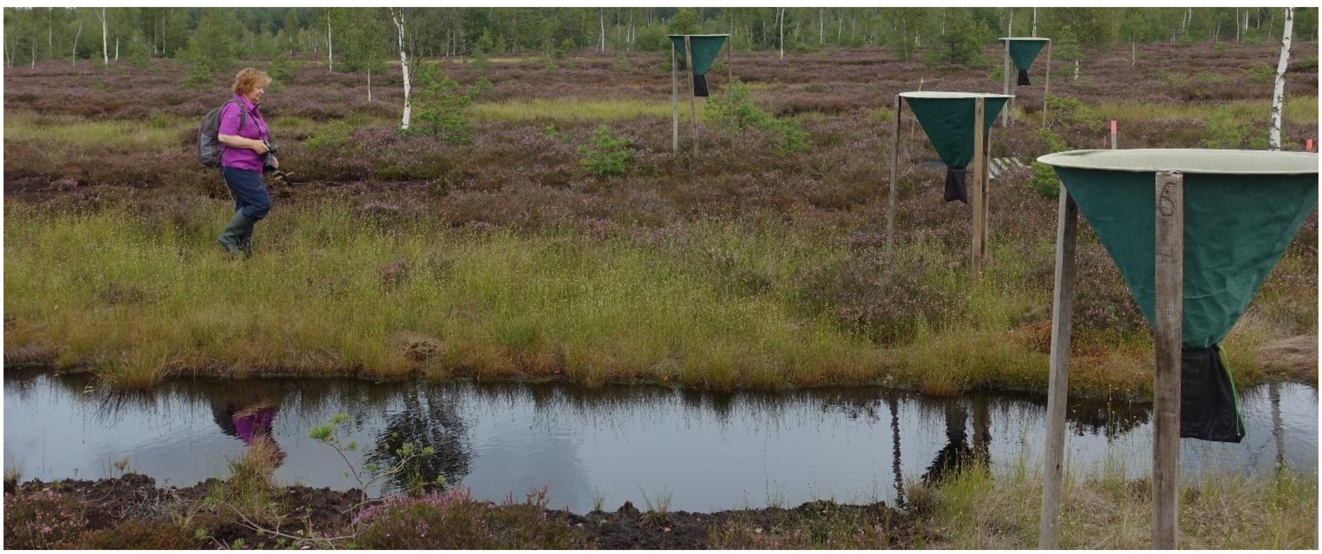
Hydrological, vegetation, greenhouse gas and GEST monitoring in project sites in Latvia

1st Monitoring report



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Hydrological, vegetation, greenhouse gas and GEST monitoring in project sites in Latvia. 1st 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. Cenas 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 Pelečāres Mire, but is still taking place in the immediate vicinity of Cenas 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, with the exception of 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. Cenas 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

Cenas 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 Cenas 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 Taïga (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 Skaists Lake is indicated by pine decay. Situation in 2005 short before activities (left) and in 2023 (right). Images: © M. Pakalne, L. Strazdiņa*

1.1.4. Drainage impact in the area

The territory of Cenas 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 Skaists 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. *Drainage system with peat dams from 2006 (left) and still functioning ditch where restoration will be performed during LIFE PeatCarbon project (right) in the SE part of Cenas Mire. Images: © 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) takes 18 ha, while only 3 ha belong to Western Taïga (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 after completed hydrology stabilization in 2012. Images: © L. Strazdiņa*

1.2.4. Drainage impact in the area

The Melnais Lake Mire has a dome formed from the accumulation of peat over thousands of years. In the centre of the dome is the 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 Pelečāres 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 Pelečāres 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 located in the central part of the Lielais

Pelečāres 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 Pelečāres 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 located 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 located 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 Taïga (9010*) (167 ha) are the most common.

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

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. In order 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.

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 Pelečāres 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).

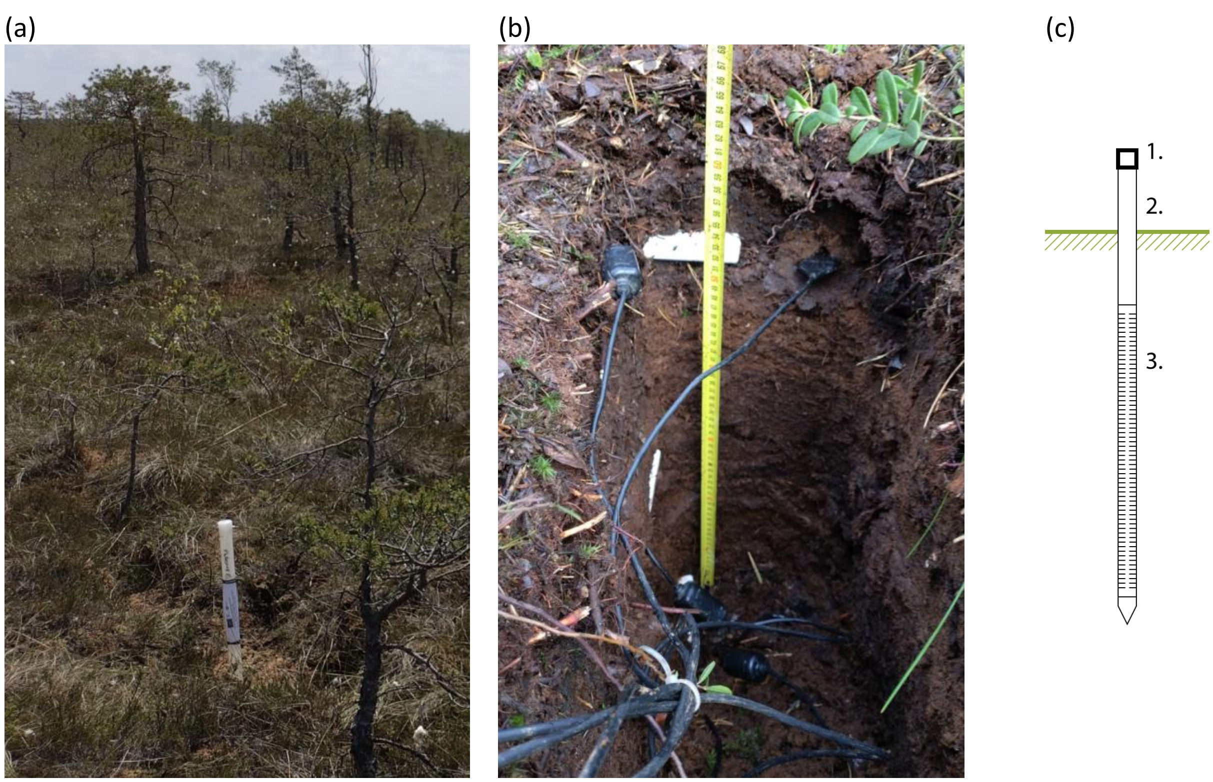


Figure 2.1. *Groundwater monitoring well (a) and soil water monitoring probes (b) in Lielais Pelečāres Mire. Schematic monitoring well setup (c): 1 – well cap; 2 – smooth pipe HDPE 25 mm internal diameter, usually 1 m long, about 0.5 m above surface; 3 – filter interval, usually 2 m long in some cases covered with filter fabric sock. Images: © A. Kalvāns*

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

2.1.1. Cenas Mire

Hydrological monitoring in Cenas 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.

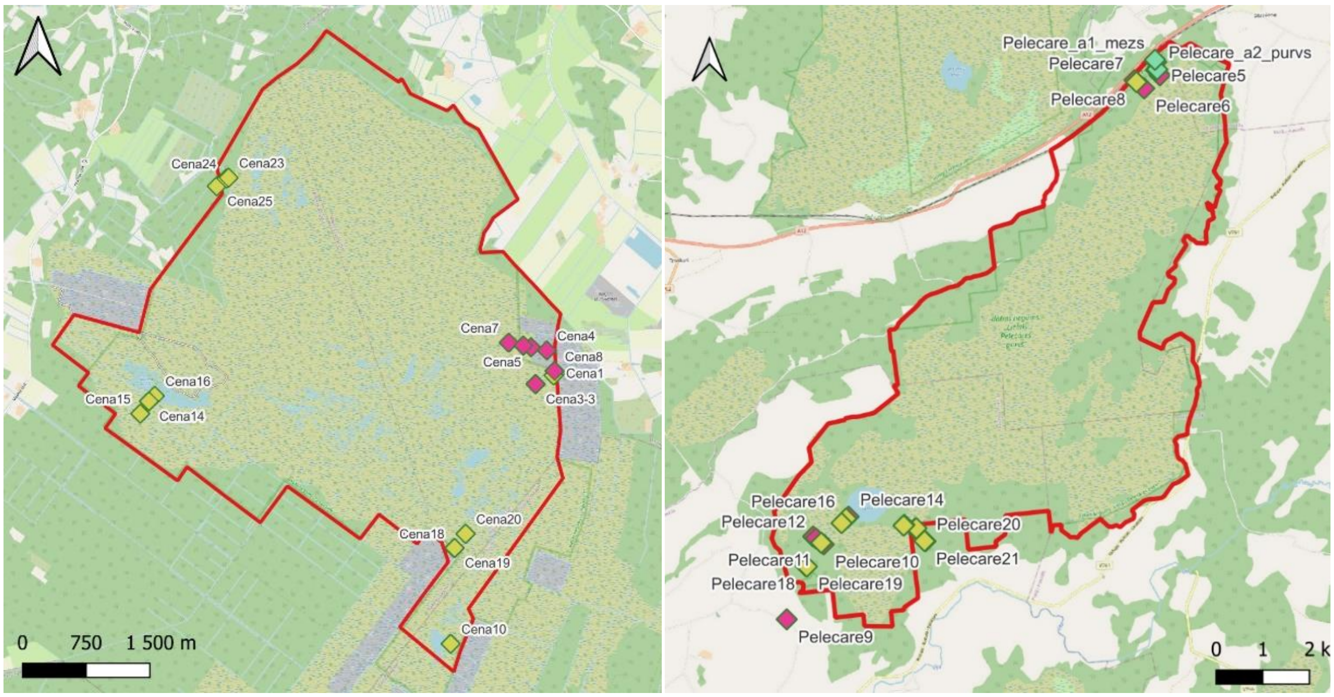


Figure 2.2. *Location of the hydrological monitoring points in Cenas Mire (left) and Lielais Pelečāres Mire (right). Legend: ◆ - no probe; ◆ - Levelogger 5 Junior; ◆ - Meter Teros21 and Teros11. Images: © A. Kalvāns*

2.1.2. Lielais Pelečāres Mire

The hydrological monitoring in Lielais Pelečāres 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 2.2). 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.

2.2. 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 2.1. *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. Cenas Mire

In 2005, the first habitat monitoring was carried out in Cenas 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 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 Cenas 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 2.3).

Figure 2.3. *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 located 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 2.4. *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 2.4, Appendix 6.5). Like in Cenas Mire, the 26 completed GEST protocols can also be used to characterize vegetation of Melnais Lake Mire.

2.2.3. Lielais Pelečāres 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 Pelecares 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 2.5).

Figure 2.5. *Vegetation monitoring plots near GHG measurement point with litter collector (left) and near hydrological monitoring point (right) in Lielais Pelecares 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 2.6). 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 2.6. *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

As part of the monitoring program, the measurement of total ecosystem emissions (ecosystem respiration) and soil respiration (heterotrophic respiration) has been started. At the same time, data are obtained on environmental parameters that are essential for the changes of the GHG emissions: including, soil and air temperature, groundwater level, soil water chemical properties, soil chemical properties, above-ground and underground biomass of ground cover vegetation, woody plant litter in forest land, live trees biomass and carbon storage in dead trees.

In order to carry out observations, 3 sample plots have been established in each monitoring object, which characterize the different composition of understorey vegetation and the effect of expected or already occurred changes in the moisture regime. The plots are located 20-30 m apart. In each sample plot, three rings (Figure 2.8) are installed for characterizing total emissions and a sub-plot with three sampling points for characterizing soil respiration with three gas measurement points. Sub-plots for characterizing soil respiration are established at least three months before the start of gas exchange measurements.

Ecosystem respiration – CO_2, CH_4 and N_2O – will be measured using the closed chamber method (Hutchinson & Livingston, 1993). The closed chamber consists of two parts – a chamber that is made of PVC material and is 40 cm high, with a Ø of 50 cm and a volume of 65 L, and a collar that is inserted in the soil during the entire observation period. When collecting samples, the camera is placed on the collar, which is white to prevent excessive temperature rise during monitoring. A groove corresponding to the diameter of the camera is formed on the upper edge of the collar, this groove is filled with water during measurement to ensure a completely closed environment (no air enters) when the camera is placed in it.

The collars are placed in the sample plots at a distance of 1-2 m from each other to reduce the need to move around the sample plot during the collection of gas samples (Figure 2.7). 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 air is collected from the chambers into 100 mL bottles, from which all the air has been aspirated (residual pressure <0.3 mbar). Four samples are collected from each chamber within half an hour at 10-minute intervals – 0 minute (immediately after placing the chamber on the collar), 10, 20 and 30 minutes (Bārdule et al., 2023; Butlers et al., 2023). The samples are placed in specially prepared and marked sample boxes so that each sample has its own cell address depending on which cell and in what minute the samples will be taken.

Figure 2.7. *Gas measurement chambers (left) and soil heterotrophic measurement chamber (right). Images: © M. Vanags-Duka*

Gas samples are collected on average once a month. Groundwater depth (cm), air temperature, soil temperature and moisture content in the top layer of the soil are measured monthly simultaneously with collecting gas samples. Soil groundwater wells (piezometers) are installed for groundwater depth measurements. Piezometers – perforated pipes of PVC material (Ø50 mm), sealed in the lower 0.5 m – placed at a depth of 1.5 m. Soil temperature is measured at four depths – 5, 10, 20 and 30 cm.

After measuring the groundwater level, the piezometers are pumped to obtain fresh soil water samples for laboratory analysis.

The collected samples are delivered once a month to the LVMI Silava Forest Environmental Laboratory. Samples are stored at room temperature under normal pressure.

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 an automatic sampler device constructed 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.

Simultaneously with the measurement of the groundwater level, measurements and observations of the factors influencing the gas exchange of the ecosystem are carried out. Typically, the determination of groundwater characteristics such as depth, temperature, dissolved oxygen (ODO), electrical conductivity, pH and oxidation-reduction potential (ORP) is performed with the ProDSS probe, as well as groundwater samples (NO_3^-) and ammonium (NH_4^+) ion are collected, as well as other parameters for determining the composition in the laboratory. Temperature measurements of the air and soil at a depth of 5 cm are performed in parallel, and the electrical conductivity of the soil and the moisture level in the soil are determined with Procheck (Figure 2.8).

Figure 2.8. *Equipment for measuring soil temperature, moisture content and groundwater properties. Image: © M. Vanags-Duka*

Litter collectors (Figure 2.5) are installed on the outer perimeter of the sample plot, 10-15 m away from the center (3 pieces in each sample plot) and are emptied once a month, simultaneously with gas exchange measurement. The total dry mass as well as the carbon content are determined for the droppings. Large falls are not evaluated in this study, assuming that carbon inputs from natural defoliation or from the fall of larger tree debris are small. The ICP Forests methodology (Ukonmaanaho et al., 2016) was used for litter collection and analysis.
Sub-plots for soil heterotrophic respiration measurement are 1.5 x 0.6 m area with vegetation removed and fenced with geotextile to a depth of 50 cm to prevent root ingrowth. In between measurements, the sub-sample area is covered with a light and water-permeable light-colored geotextile, which is removed from the area at least one hour before starting the measurements. Measurements of soil respiration are performed with an EGM5 spectrometer. The measurement continues for 3 minutes. Soil respiration chambers are smaller (Figure 2.7) than ecosystem emission measurement chambers. Soil heterotrophic respiration data are analyzed 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.

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 particular 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 2.9, 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.

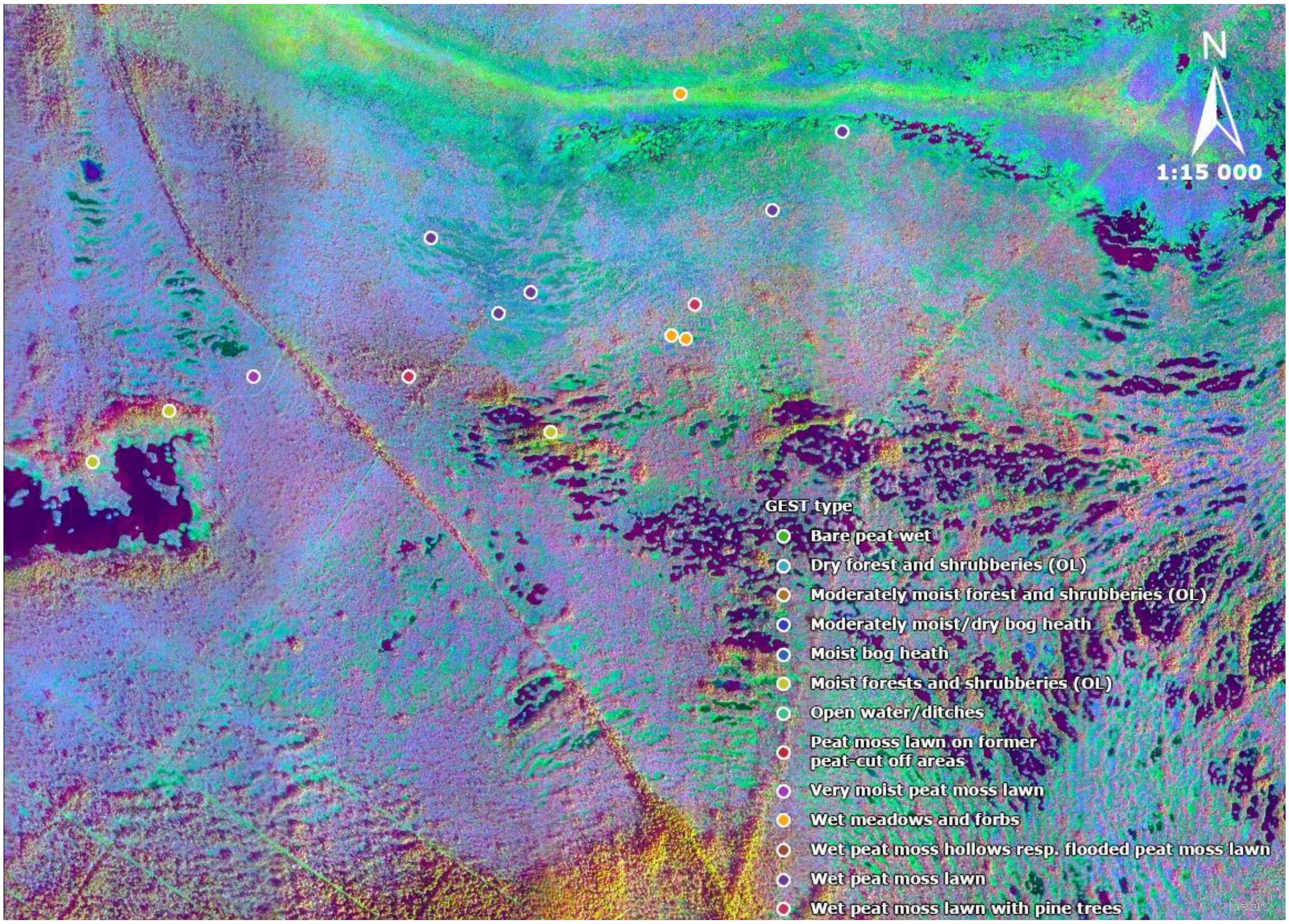


Figure 2.9. *Example of gathered reference data for GEST classification as input data for RS algorithm training showed on Principal Component Analysis map of Cena Mire, Latvia.*
Image: © Institute for Environmental Solutions

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. Cenas 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 Cenas Mire, good agreement was found between manual and automatic water level measurements (Figure 3.1). Differences are no greater than 5 cm, which overall corresponds to the uncertainty sum of manual and automatic measurements.

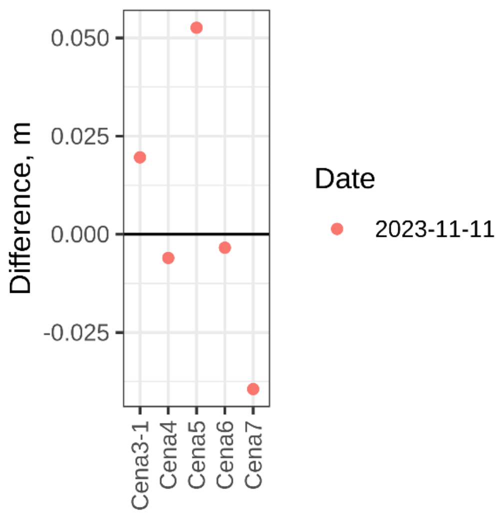


Figure. 3.1. *The difference between automatic and manual water level measured at all observation points is 0.05 m or less, indicating overall good measurement quality.*

Results of the groundwater level monitoring

During the observation period in summer, up to the mid-July, a gradual decrease in water level is observed, interrupted by occasional precipitation events (Figure 3.2). The water level drops up to 0.4 m below the ground surface. That was followed by a two-week period of gradual water level raise and relative stabilization. Beginning of October was marked by another raising and stabilization of water level at a new high. In two observation points, Cena3-1 and Cena7, located in peat areas least affected by drainage, the water level rises even up to 0.1 m above the ground surface. While in the other locations affected by drainage, the water level remains below soil surface.

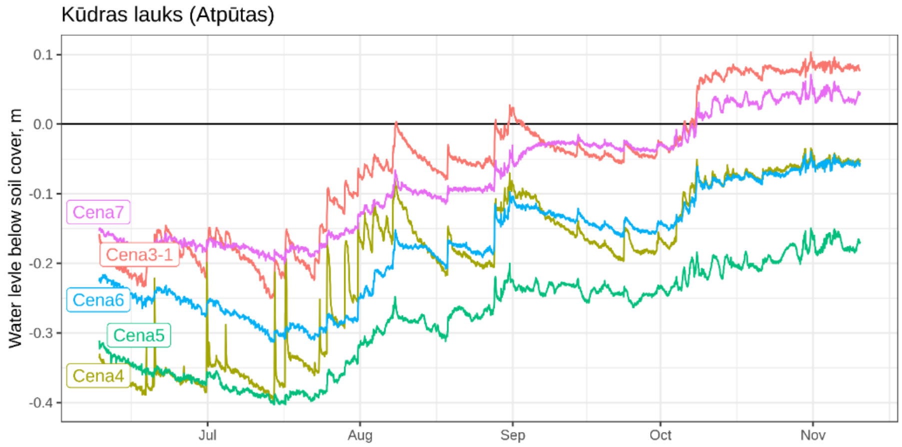


Figure 3.2 *Observed water level below soil surface in Cenas Mire in 2023.*

The water level closest to the soil surface is observed at monitoring points Cena3-1 and Cena7, that are at locations least affected by artificial drainage (Figure 2.2). Here, the water level only occasionally drops up to 0.2 m below the soil surface. However, the fluctuations of the water level at these two points have different characteristics. In the Cena3-1 point, each precipitation episode is marked by a rapid rise in level followed by a gradual decline, while the fluctuations in the Cena7 point are smooth and gradual. Perhaps, these differences are influenced by their locations: Cena3-1 is situated on the slope of the raised bog dome, while Cena7 is on the surface elevation hinge line, dividing the part of the bog with significant drainage impact from the less affected conditions.

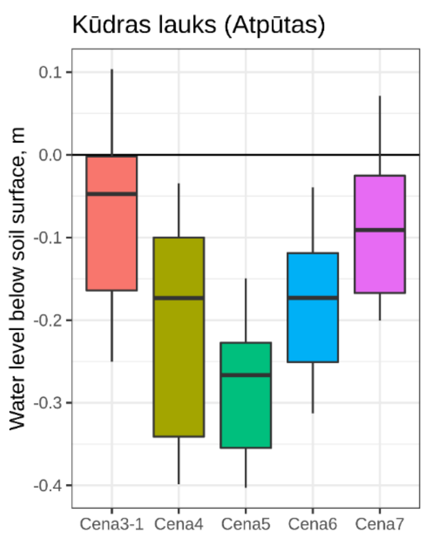


Figure 3.3 *Distribution of water level during the observation period from June 8 to November 11, 2023.*

Monitoring point ID	Water level depth, m		
	Average	Min	Max
Cena3-1	0.06	-0.10	0.25
Cena4	0.20	0.03	0.40
Cena5	0.28	0.15	0.40
Cena6	0.18	0.04	0.31
Cena7	0.08	-0.07	0.20

Table 3.1. *Summary statistics for the water table level below soil surface.*

The water level in the bog sector significantly affected by drainage (observation points Cena4, Cena5, and Cena6, Figure 2.2) is on average, about 0.10 to 0.20 m deeper than in the peatland areas with less drainage impact (Cena3-1, Cena7, Figure 3.3, Table 3.1). Particularly in the monitoring point Cena4, noticeable sharp fluctuations in the water level were observed, related to precipitation episodes. This observation point is in a degraded part of the peatland where the soil surface largely is baren peat. In other observation points with dense non-bog vegetation cover, water level fluctuations are more smoothed out.

Discharge measurements

The water discharge (runoff) monitoring in Cenas 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 3.4), 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 3.4. *A discharge measurement spillway (monitoring point Cena8) clogged with eroded peat, November 10, 2023. Image: © A. Kalvāns*

3.1.2. Lielais Pelečāres Mire

Automatic water level observation probes in Lielais Pelečāres Mire were installed on June 22 and the latest data download took place on November 7, 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 systematically measured during the reporting period.

Validation of automatic water level observations

Overall, the depth of the water level determined by automatic probes aligns well with manual control measurements, falling within the summative uncertainty limits (<5cm). However, large disparities are observed at points Pelecare3 to Pelecare7 (Figure 3.5). The most significant deviation in measurements occurs at well Pelecare7 (more than 50 cm). This is due to a rapid rise in water level during the manual control measurements. For measurements made in June 2023 at wells Pelecare3 to Pelecare6, discrepancies are likely due to slow stabilization of the water level after the well installation, as the automatic measurements commenced only the following day. Nonetheless, ambiguity persists regarding the inconsistencies in measured levels at points Peleacare4 to Peleacare6 in November 2023 – this requires resolution in subsequent observation periods.

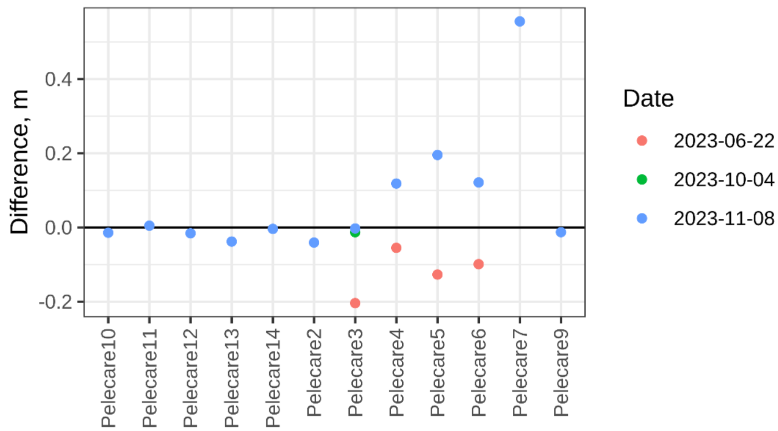


Figure 3.5. *The difference between automatic and manual water level measured in Lielais Pelečāres Mire.*

Monitoring point ID	Water level depth, m		
	Average	Min	Max
Pelecare1	3.23	2.89	3.52
Pelecare2	1.27	0.27	1.65
Pelecare3	0.40	0.08	0.53
Pelecare4	0.37	0.23	0.47
Pelecare5	0.40	0.32	0.45
Pelecare6	0.34	0.22	0.40
Pelecare7	1.29	0.32	1.55
Pelecare9	1.89	1.66	1.92
Pelecare10	1.29	0.93	1.40
Pelecare11	0.53	0.17	0.70
Pelecare12	0.23	0.06	0.37
Pelecare13	0.27	0.12	0.38
Pelecare14	0.09	0.01	0.12
Pelecare16	0.50	0.20	0.69

Table 3.2. *Summary statistics for the water table level below soil surface.*

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

At this location, there are two wells equipped with automatic water level probes: Pelecare6 – on the slope of the raised bog dome – and Pelecare7 – in the bog woodland, forming the transition zone between the raised bog and the upland forest (Figure 2.2). In the slope of the bog dome, a relatively deep but stable groundwater level was observed, ranging from 0.22 to 0.40 m below the ground surface (Table 3.2, Figure 3.6).

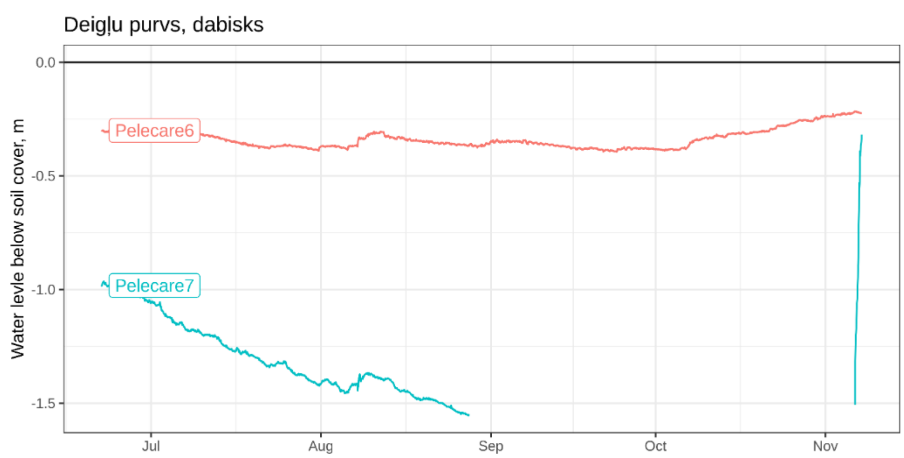


Figure 3.6. *Observed water level in the less affected by drainage part of the Lielais Pelečāres bog, Deigļu Mire section: Pelecare6 – observation point located on the slope of the raised bog dome; Pelecare7 – observation point in the bog woodland in the transition zone between the raised bog and dry forest.*

Conversely, in the bog woodland (observation point Pelecare7), the water level at the beginning of the observation period was nearly 1.0 m below the soil surface and decreased further during the summer, reaching depths below the automatic level probe (<1.55 m below the ground surface). However, at the end of the observation period, a very rapid rise in the water level was observed, increasing by 0.32 m below the ground surface within a few hours. Such rapid flooding is likely due to gradual saturation of the dried peat in autumn with rainwater resulting in abrupt saturation and renewed groundwater seepage from the raised bog.

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 (Pelecare2, Pelecare3, Pelecare4), and into the raised bog less affected by the drainage (Pelecare5; Figure 2.2).

A gradual decrease in water level was observed in the boreholes Pelecare1 (dry forest) and Pelecare2 (bog woodland) during the summer of 2023. By the end of October, the water level in the bog woodland (Pelecare2) rapidly increased and stabilized at a depth of approximately 0.3 m below ground level, while in the dry forest water level remained below the installation depth of the water level probe. The rise in water level is likely associated with the gradual saturation of the dry peat after exceptionally dry summer of 2023, replenishing with precipitation water and to resumed diffuse flow from the raised bog.

In the degraded part of the bog, at observation points Pelecare3 and Pelecare4, where a bog woodland established because of the drainage, a gradual decrease in relative water level was observed during the summer (July) (Figure 3.7, Figure 3.8). This trend was interrupted by a sharp rise in level at the beginning of August, presumably associated with heavy rainfall. However, the decrease in level resumes in August and September, reaching the minimum in the second half of September (0.53 m below ground level at observation point Pelecare3). The water level range reaches 0.45 m (Table3.2).

At the observation point Pelecare5, located in the bog side of the last drainage ditch, the water level fluctuation range is from 0.32 to 0.45 m below ground level (Figure 3.8) - significantly smaller than in other observation points. However, the water table remains well below the recorded soil surface, presumably due to its location on a bog hummock.

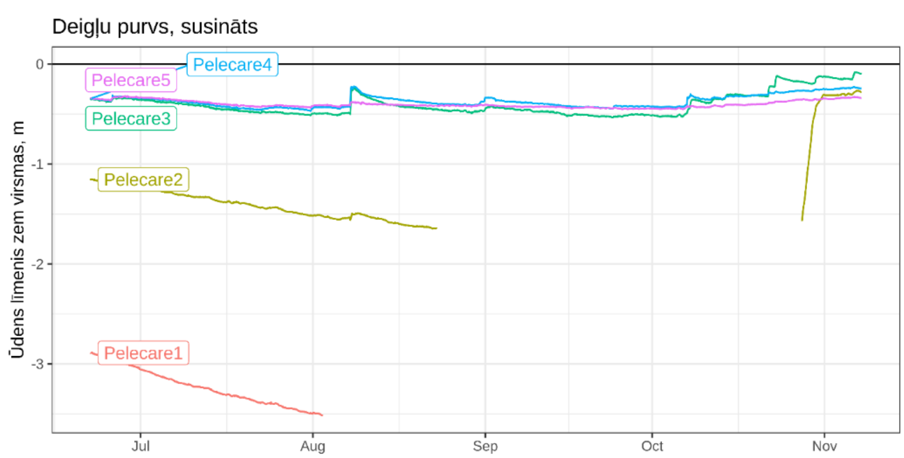


Figure 3.7. *Observed water level in the drained part of the Deigļu Mire (southern part of the Lielais Pelečāres Mire): Pelecare1 – dry forest at the edge of the bog; Pelecare2, Pelecare3, Pelecare4 – bog woodland, partially formed because of drainage on the slope of the raised bog dome; Pelecare5 – observation point least affected by the drainage at the bog side of the last drainage ditch.*

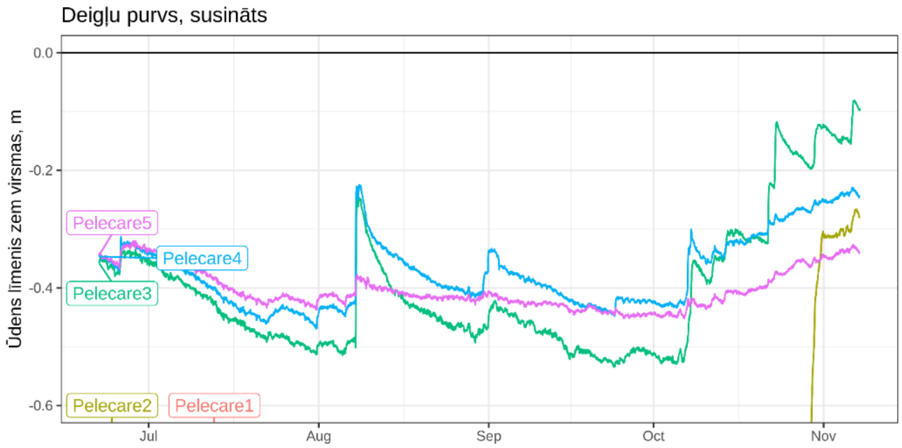


Figure 3.8. *Close-up of the water level time series shown in the Figure 3.7.*

Water level observations in the Malnupeite River catchment and near Deguma Lake

The group of observation points in Melnupeite River catchment 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 2.2).

During the reporting period, water flow in ditch Nr.25 (Pelecare9) outside the Lielais Pelečāres 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.

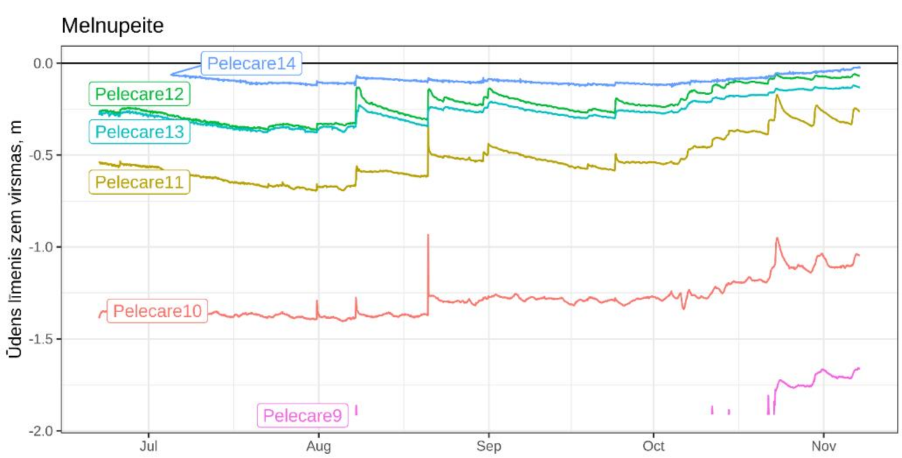


Figure 3.9. *Observed water level in the southern part of Lielais Pelečāres Mire, within the drainage basin of watercourse of national significance named "Nr.25" (Malnupeite) and Deguma Lake: Pelecare9 – Malnupeite River (watercourse of national significance named "Nr.25"); Pelecare10, Pelecare11, Pelecare12, Pelecare13 – profile of observation points perpendicular to the deep collector ditch (Malnupeite) within the Lielais Pelečāres Mire; Pelecare14 – water level in Deguma Lake.*

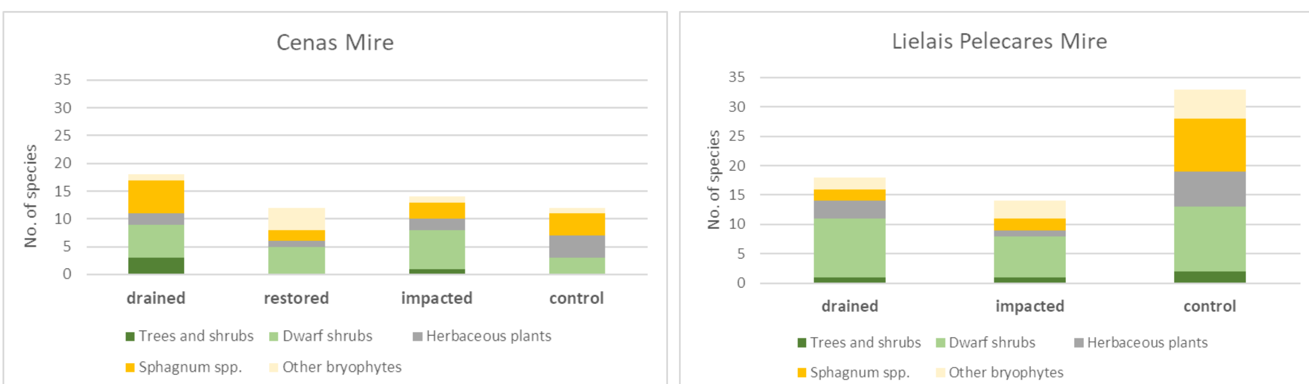
In the profile line of observation points (Pelecare10 to Pelecare13), perpendicular to the deep collector ditch (Malnupeite) within heavily drained section of the raised bog, a gradual increase in water level away from the collector ditch was observed (Figure 3.9). Several episodes of intense rainfall starting from August 2023 are noted as rapid rise in water level followed by a gradual decline. In the second half of October, at observation points further from the collector ditch (Pelecare12 and Pelecare13), the water level stabilizes relatively close to the ground surface (<0.25 m), while at points closer to the drainage ditch, rapid level fluctuations persist during the autumn period.
In Deguma Lake (Pelecare14), minor fluctuations in water level are observed. The water level range was only 0.12m, contrasting with significant fluctuations at other observation points.

Soil water regime observations

Soil water (water potential and water content) probes were installed on October 4, 2023, but the observation data have not been downloaded.

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 Cenas Mire with 44 species and the Lielais Pelečāres 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*.



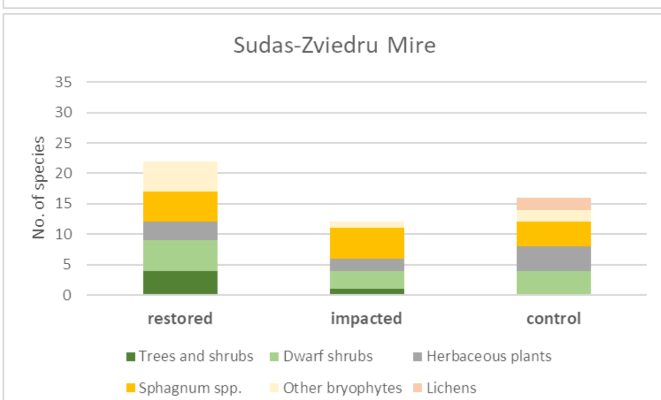


Figure 3.10. *Number of species in vegetation layers in vegetation monitoring plots at the water level measurement points with different drainage impact in project sites in Latvia.*

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 3.10). 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 Pelecares 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.

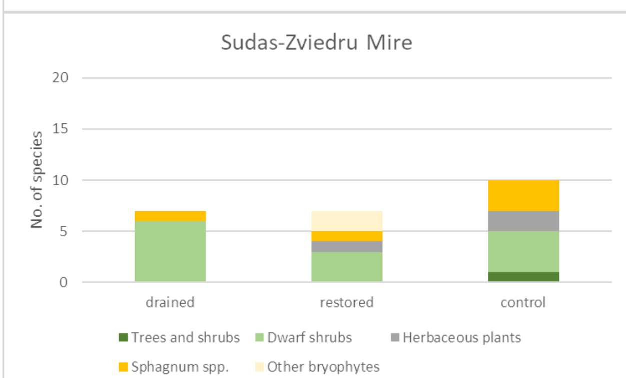


Figure 3.11. *Number of species in vegetation layers in vegetation monitoring plots at GHG measurement points with different drainage impact in project sites in Latvia.*

Some of the species richness trends described above are also found in the GHG measurement transects (Figure 3.11). Number of drought resistant dwarf shrub species is higher in drainage impacted plots in all project sites except Cenas Mire. Whereas the number of herbaceous plants and *Sphagnum* species shows relation with natural plots in all plots except Lielais Pelečāres 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. Cenas 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 3.12). 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.

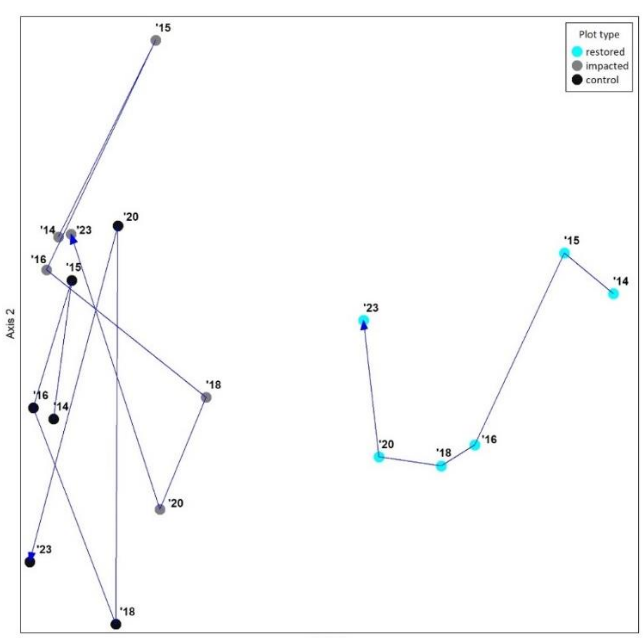


Figure 3.12. *DCA ordination of vegetation monitoring plots of Sudas-Zviedru Mire during nine years from 2014 to 2023.*

The total cover of species in different vegetation layers in Sudas-Zviedru Mire was compared between six monitoring years (Figure 3.13). 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 3.13. *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

Further, preliminary greenhouse gas emission results are shown. The data is provided for all five GHG measurement sites in Latvia as follows: Sudas-Zviedru Mire (LPC_1), Lielais Pelečāres Mire (LPC_2), Melnais Lake Mire (LPC_3), Cenas Mire (restoration) (LPC_4), Cenas Mire (LPC_5). Measurements in all established sites will be continued throughout the year 2024 and until 2025. Comparing annual results from all monitoring sites, up to now on average, CO_2 emissions (soil heterotrophic respiration) were highest in LPC_2 and the lowest - 64 mg CO_2-C m^{-2} h^{-1} in LPC_5. The highest average CO_2 emissions were registered in August (on average 117 mg CO_2-C m^{-2} h^{-1}) closely followed by June (113 mg CO_2-C m^{-2} h^{-1}). On the other hand, lowest values were recorded in December (16 mg CO_2-C m^{-2} h^{-1}, Figure 3.14).

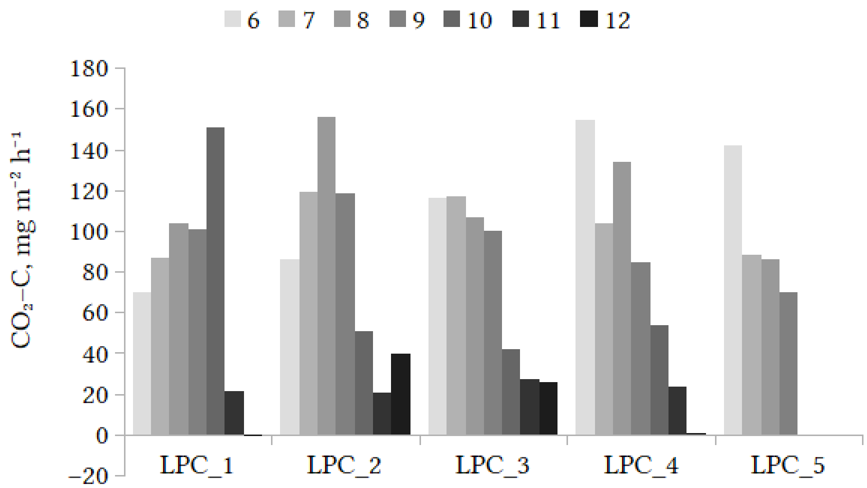


Figure 3.14. *Comparison of recorded CO_2 emissions (soil heterotrophic respiration) in all monitoring sites in Latvia, year 2023.*

Methane emissions in peak of the vegetation season 2023 remained relatively stable and low (on average 0,10 to 0,41 mg CH_4-C m^{-2} h^{-1}) in all sites except LPC_5 where the average fluxes ranged from 1.83 mg CH_4-C m^{-2} h^{-1} in July to 3.96 mg CH_4-C m^{-2} h^{-1} in August, sharply decreasing throughout September. On the other hand, the rest of the monitoring sites show a trend of emission increase during the end of 2023 vegetation season. The increase of methane emission by approximately 82 % above the other sites' average was noticed in Sudas-Zviedru Mire, reaching its peak around mid-November (1.78 mg CH_4-C m^{-2} h^{-1}) (Figure 3.15).

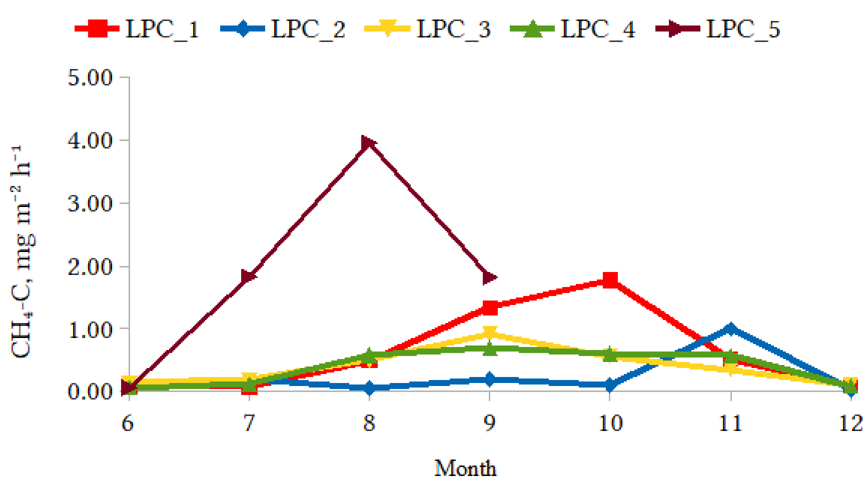


Figure 3.15. *Methane emission results of 2023 season compared between all GHG monitoring sites in Latvia.*

In the monitoring sites LPC_2 and LPC_5, some inconsistencies in groundwater table were detected (noticed fluctuations against the overall trend). Sites LPC_3 and LPC_4 acted more consistent and predictably. Separately, the previously mentioned larger CH_4 emissions in Sudas-Zviedru Mire may be associated to steadily rising groundwater level (Figure 3.16).

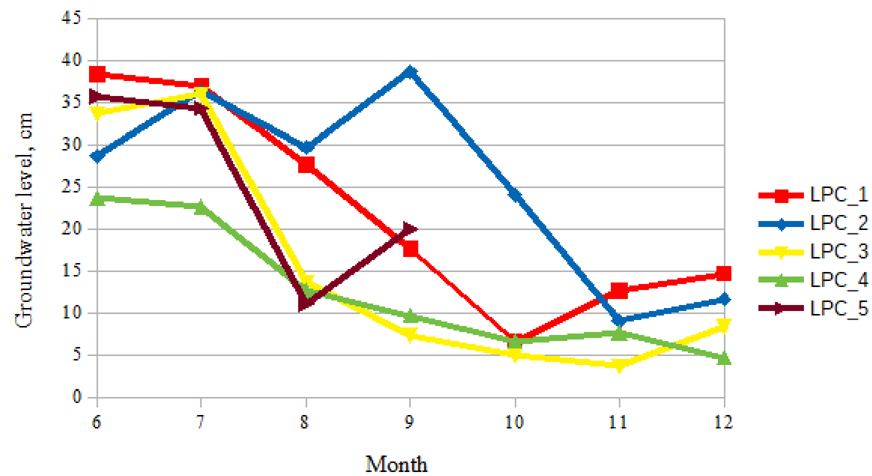


Figure 3.16. *Groundwater table level changes in all GHG monitoring sites in Latvia, year 2023.*

Although on site level, the water table increase was more linear and smaller than in the rest of monitoring sites with an average increase of 7.4 % per month (other sites ranged from 12.3 % to 32 %), the noticeable CH_4 emission increase mostly manifested itself in subplot B (Figure 3.17), where the water level was by far the highest throughout the year (10.6 cm in subplot B; whereas subplot A- 20.4 cm; subplot C- 35.3 cm). On the other hand, in subplot C which in this case represents the forested scenario, the CH_4 emissions were negligible, at some months even resulting in small sinks (from -0.005 to 0.009 mg CH_4-C m^{-2} h^{-1}). The scenario of natural mire (subplot A) produced more emissions than in subplot C but nevertheless, on average by 60 % less than in the case of subplot B.

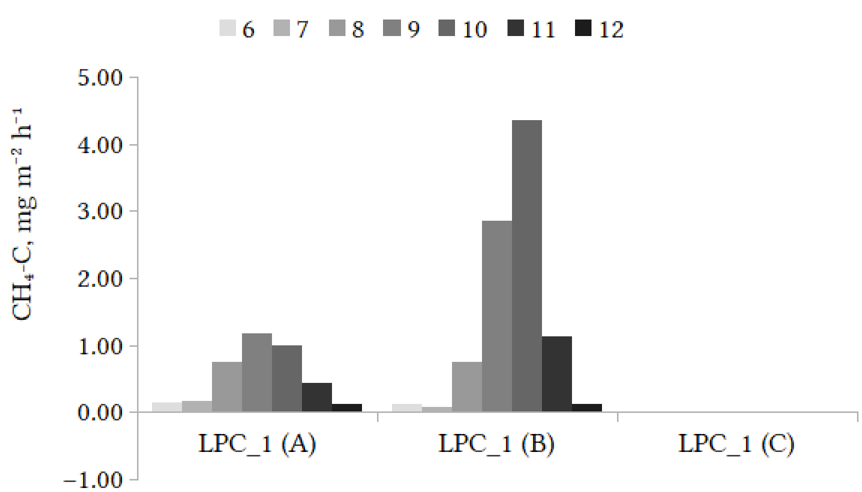


Figure 3.17. *Methane CH_4 emission comparison between subplots in Sudas-Zviedru Mire, year 2023.*

Further analysing the rest of samples collected in other sites, similar trends can be seen as mentioned above, where methane emissions almost always have been consistently higher near subplot B which is subject to higher groundwater levels annually. On the contrary, with few exceptions smaller emission values come from the forested scenarios which in all Latvian sites are represented by subplot C. Natural mire scenarios come second in terms of produced emissions (Figure 3.18).

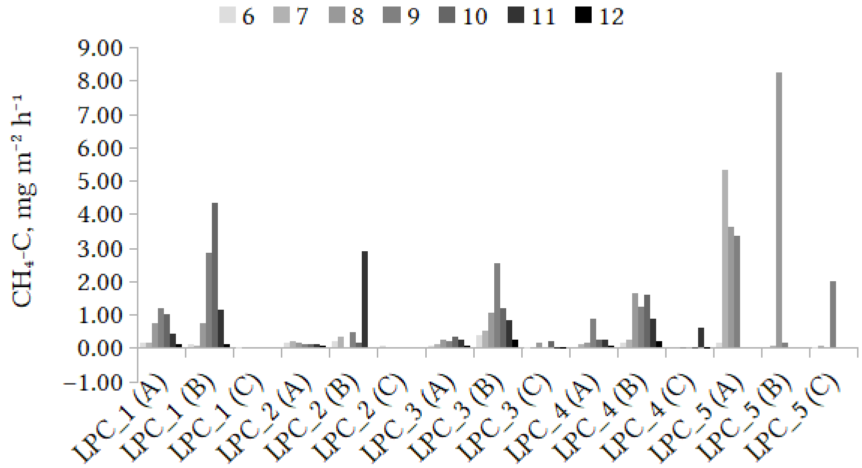


Figure 3.18. *Comparison of methane CH_4 emissions between sites and subplots in all monitoring sites in Latvia in year 2023.*

Lastly, N_2O results were also compiled. Several cases of small N_2O sinks were detected throughout the measurement season. Most such cases were recorded in June (11 of 15 results throughout all sites), but several also in October (6 cases). The most active period for N_2O emissions was during peak vegetation season in August (Figure 3.19).

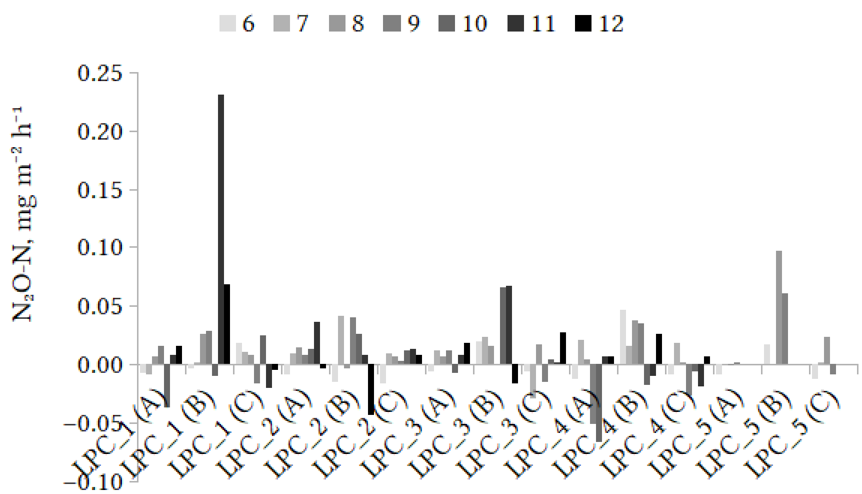


Figure 3.19. *Comparison of nitrous oxide N_2O emissions between sites and subplots in all monitoring sites in Latvia in year 2023.*

3.4. GEST monitoring

According to vegetation data (tree, shrub, herb and bryophyte layer), land usage history, drainage impact, peat characteristics and water table observations, a total of 13 different GESTs were classified in the Cenas Mire (Table 3.3). Three GESTs belong to forest types, and the other ten to open types, such as raised bog or peat cutting field. The largest cover is occupied by the GEST type "Wet peat moss lawn" corresponding to the EU habitat Active raised bogs (7110*) and "Wet meadows and forbs" corresponding to the EU habitat Transition mires and quaking bogs (7140) (Figure 3.10).

__Table 3.3.__ List of classified GEST types in Cenas Mire

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

However, the mire microtopography and diverse plant communities create a mosaic pattern in the area, so the GEST classification is not equally similar to EU habitat mapping. A more detailed analysis of the spectral data remains to be performed to calculate the total area and emission factors for each GEST for Cena Mire and for the rest of project sites in Latvia and Finland during next reporting periods.

Wet peat moss lawn

Wet meadows and forbs

Moist bog heath

Wet peat moss hollows resp. flooded peat moss lawn

Wet peat moss lawn with pine trees

Dry forest and shrubberies (OL)

Bare peat wet

Open water/ditches

Moderately moist forest and shrubberies (OL)

Moist forests and shrubberies (OL)

Figure 3.20. *Examples of GEST types in Cenas Mire. Images: © L. Strazdiņa*

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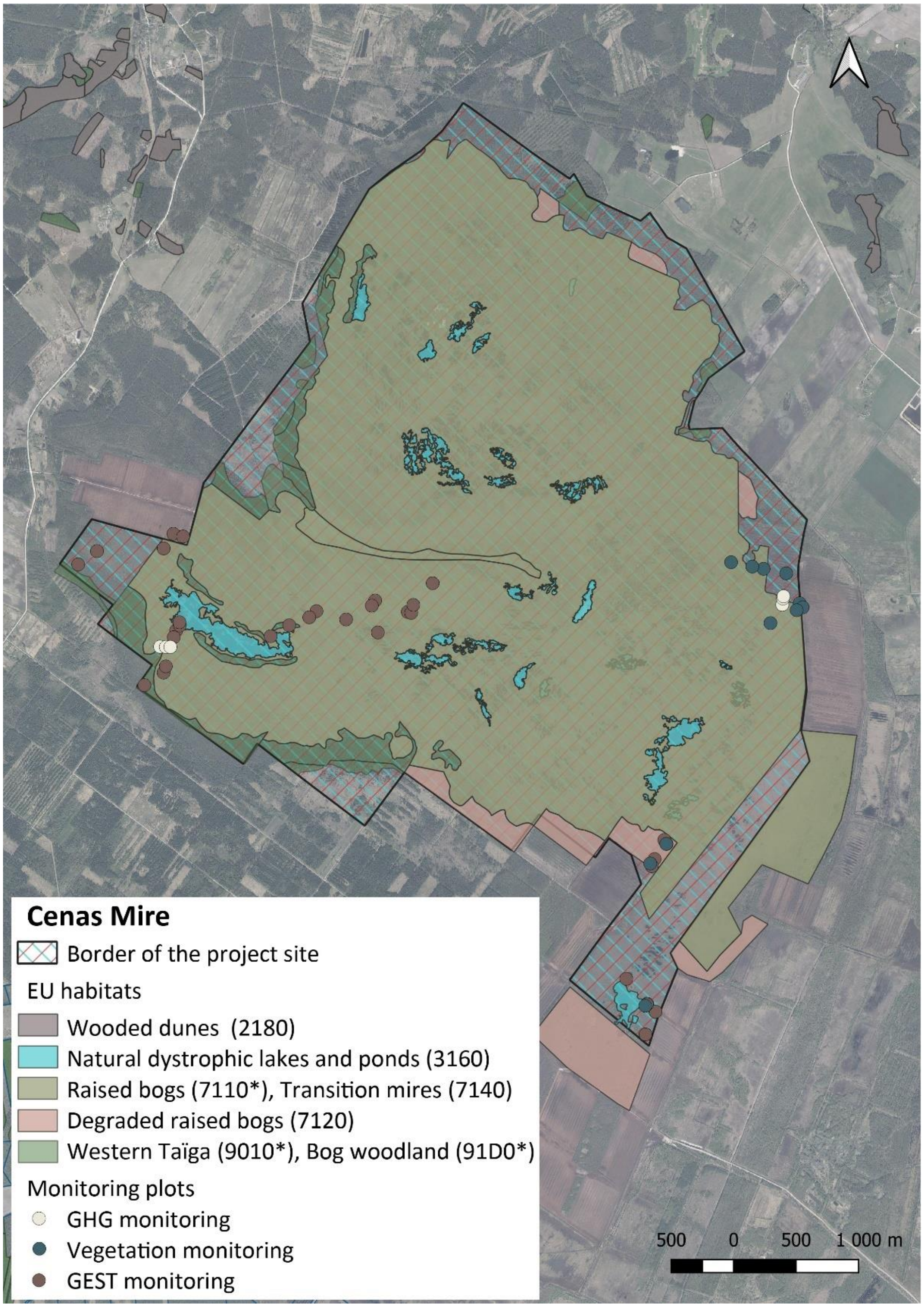
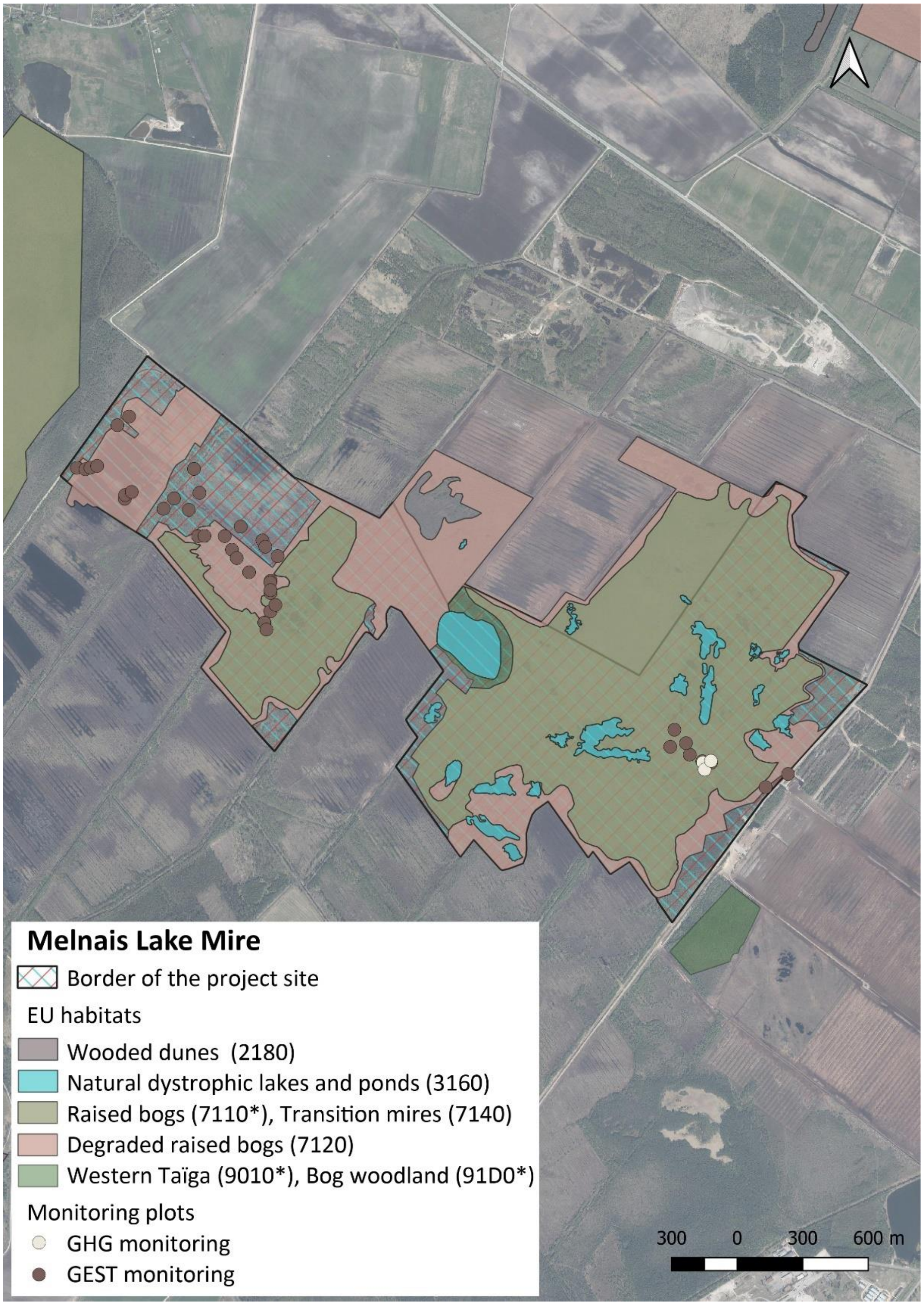
Appendices

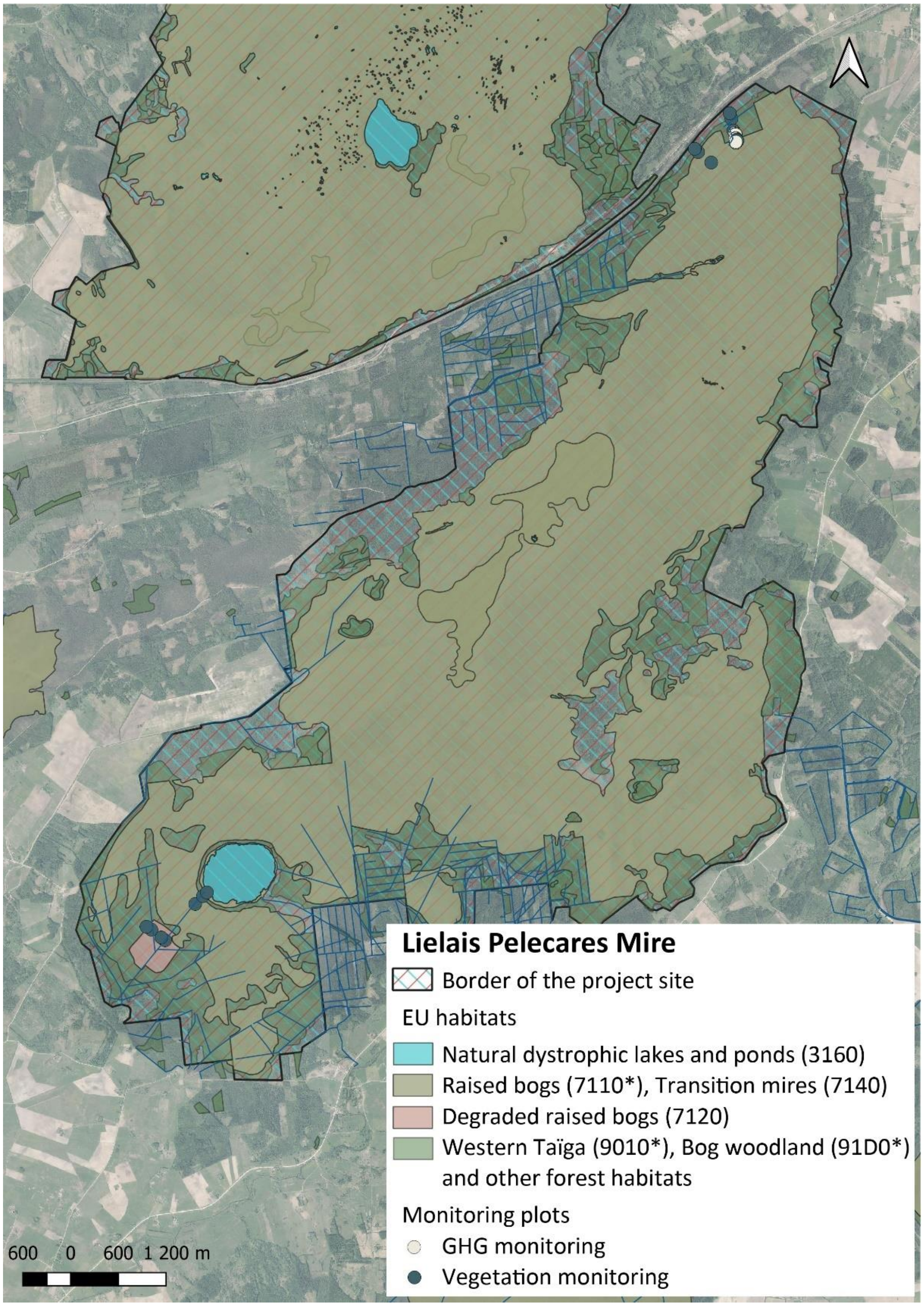
Appendix 6.1. *Cover of habitats of EU importance in the project sites in Latvia. Source: Nature Conservation Agency, 2023.*

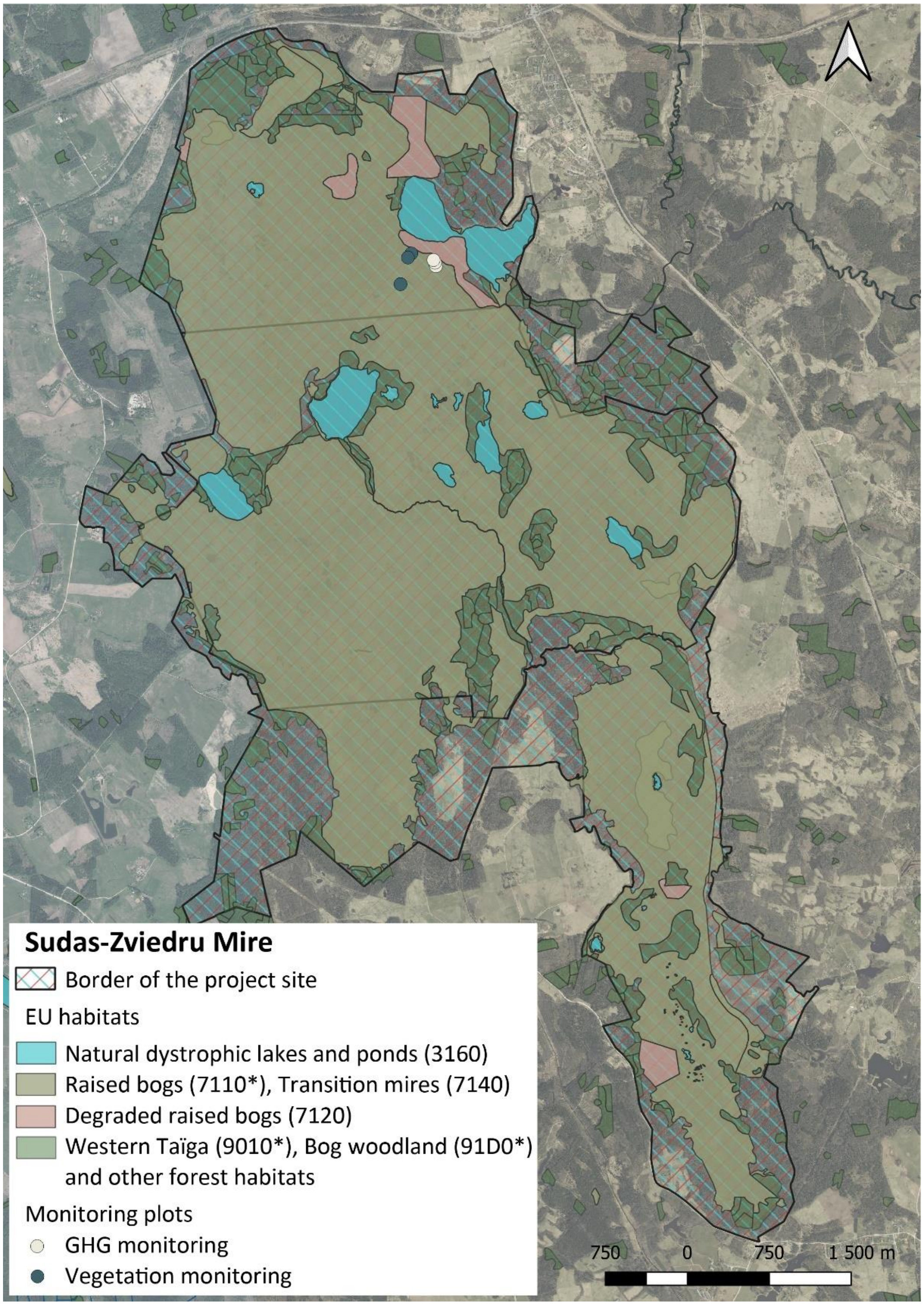
Habitat Code	Habitat type	Cover, ha			
		Cenas Mire	Melnais Lake Mire	Lielais Pelecares Mire	Sudas-Zviedru Mire
2180	Wooded dunes of the Atlantic, Continental and Boreal region	0.8	-	-	-
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation	-	-	-	61.21
3160	Natural dystrophic 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 Cenas 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	NA	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	NA	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	NA	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	13.1 / 0.66	NA	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	12.8 / 0.18	Levelogger 5 Junior 2023-06-08	Well filter interval: 0.82-2.82 m	
Cena8	Q	56.853344 / 23.888705	10.12 / 0.58	Levelogger 5 Junior 2023-06-08	Rectangular spillway, 0.13 m wide	Dithc discharge monitoring
Cena10	MW	56.824516 / 23.8686	12.11 / 0.93	NA	Well filter interval: 1.07-2.07 m, anchored into mineral subsoil	Monitoring water level fluctuations in the mire lake affected by drainage, in the area where restoration measures are planned
Cena14	MW	58.536282 / 23.801378	12.87 / 0.47	NA	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	NA	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

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
Cena19	MW	56.834647 / 23.869363	12.99 / 0.71	NA	Well filter interval: 0.29 – 2.29	hydrological regime restoration measures were carried out in 2007 in the S part of the Cena Mire NR
Cena20	MW	56.836139 / 23.87148	13.53 / 0.59	NA	Well filter interval: 0.41 – 2.41 m	
Cena21	MW	56.836138 / 23.87148	13.67 / 0.58	NA	Well filter interval: 0.42 – 2.42 m	
Cena23	MW	56.87376 / 23.825739	12.86 / 0.37	NA	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	NA	Well filter interval: 0.45 – 1.45 m	
Cena25	MW	56.872862 / 23.823469	8.86 / 0.18	NA	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 Pelečāres 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	NA	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	NA		
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	NA	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	NA	Filter depth: 0.5-1.5 m	
Pelecare19	MW	56.45928 / 26.47601	108.73 / 0.37	NA	Filter depth: 0.63-1.63 m	
Pelecare20	MW	56.46333 / 26.51757	107.65 / 0.87	NA	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	NA	Filter depth: 0.33-1.33 m	
Pelecare22	MW	56.46586 / 26.51413	104.43 / 0.51	NA	Filter depth: 0.49-1.49 m	
Pelecare23	MW	56.46590 / 26.51454	104.78 / 0.48	NA	Filter depth: 0.52-1.52 m	
Pelecare24	MW	56.46650 / 26.51017	105.11 / 0.77	NA	Filter depth: -0.27-1.73 m	
Pelecare25	MW	56.46664 / 26.51040	105.13 / 0.78	NA	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 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				