land

IMPACT FACTOR 3.2

CITESCORE 4.9

Article

Hydrological Response to Rewetting of Drained Peatlands—A Case Study of Three Raised Bogs in Norway

Marta Stachowicz, Anders Lyngstad, Paweł Osuch and Mateusz Grygoruk

MDPI

https://doi.org/10.3390/land14010142

land

Article

Hydrological Response to Rewetting of Drained Peatlands—A Case Study of Three Raised Bogs in Norway

Marta Stachowicz [1,2,*], Anders Lyngstad [3], Paweł Osuch [1,2] and Mateusz Grygoruk [1,2,*]

[1] Institute of Environmental Engineering, Warsaw University of Life Sciences-SGGW, ul. Nowoursynowska 166, 02-787 Warsaw, Poland
[2] Centre for Climate Research, Warsaw University of Life Sciences-SGGW, ul. Nowoursynowska 166, 02-787 Warsaw, Poland
[3] Norwegian Institute for Nature Research, P.O. Box 5685 Torgard, NO-7485 Trondheim, Norway
* Correspondence: marta_stachowicz@sggw.edu.pl (M.S.); mateusz_grygoruk@sggw.edu.pl (M.G.)

Abstract: The proper functioning of peatlands depends on maintaining an adequate groundwater table, which is essential for ecosystem services beyond water retention. Most degraded peatlands have been drained for agriculture or forestry primarily through ditch construction. Rewetting through ditch blocking is the most common initial step in peatland restoration. This study analyzed the hydrological response to ditch blocking in three drained raised bogs in Norway (Aurstadmåsan, Midtfjellmåsan and Kaldvassmyra) using a Before–After–Control–Impact (BACI) design. Following rewetting, all sites demonstrated an average increase in groundwater levels of 6 cm across all piezometers affected by ditch blocking. The spatial influence of ditch blocking extended 12.7–24.8 m from the ditch with an average of 17.2 m. Additionally, rewetting increased the duration of favorable groundwater levels for peatland functioning by 27.7%. These findings highlight the effectiveness of ditch blocking in restoring hydrological conditions, although its impact is spatially limited. Future assessments should also address vegetation recovery and greenhouse gas emission reductions to ensure comprehensive restoration success.

Keywords: ditch blocking; drainage; restoration; groundwater level

Academic Editor: Krish Jayachandran

Received: 2 December 2024
Revised: 31 December 2024
Accepted: 7 January 2025
Published: 11 January 2025

Citation: Stachowicz, M.; Lyngstad, A.; Osuch, P.; Grygoruk, M. Hydrological Response to Rewetting of Drained Peatlands—A Case Study of Three Raised Bogs in Norway. *Land* **2025**, *14*, 142. https://doi.org/10.3390/land14010142

1. Introduction

One of the key questions in peatland management and restoration is identifying the prerequisites for success. This is a complex issue, as peatlands vary in type and degradation state, which affects restoration outcomes [1]. Nonetheless, defining success criteria for peatland rewetting is essential for future restoration planning and decision-making. A major challenge lies in identifying measurable indicators of restoration effectiveness. One issue is the uncertain time lag between the restoration and materialization of effects. The most prominent changes, such as the recovery of vegetation and microbial communities resembling pristine conditions, are expected a long time after restoration [2], with some studies suggesting timeframes of 45–55 years [3]. This complicates the assessment of long-term outcomes using short-term monitoring. However, this is not always the case. For instance, rewetting measures in a fen and a bog in Finland restored the carbon balance to near-pristine levels and triggered vegetation changes within two years of ditch blocking [4]. Another challenge is the lack of adequate monitoring to measure the effects of restoration accurately [5]. Effective monitoring requires planning that includes baseline data collection before restoration actions and continued monitoring afterward.

The presence of water is a fundamental factor influencing all components of a well-functioning peatland [6]. The average groundwater level in peatlands, as well as its variability, are factors that have a profound impact on peat properties and greenhouse gas fluxes [7]. A stable and sufficiently high groundwater table is essential for carbon sequestration and the slow decomposition of organic matter [8–10]. Consequently, rewetting is a critical initial step in reducing greenhouse gas emissions and restoring peatland functions [11]. This process aims to restore favorable groundwater levels, often through ditch blocking with dams, as well as backfilling and the use of regulation devices [12]. Additional restoration measures, such as tree removal [13] or the reintroduction of peatland vegetation using techniques like seeding or peat moss layer transfer, may further enhance restoration efforts [3,14]. Despite the variety of available restoration actions, rewetting remains the most essential measure, as it directly addresses the hydrological conditions necessary for peatland recovery. Given the central role of water in peatland ecosystems, hydrological indicators are valuable tools for assessing the current status of peatlands and predicting their potential for long-term changes, which often require extended time frames to materialize.

Peatlands cover approximately 12.9% to 13.8% of Norway's land area, depending on the source (41,660 km^2; 44,700 km^2) [15,16]. The majority of degraded peatlands in Norway have been drained for forestry and agriculture with approximately 200,000 ha drained for agriculture by 1992 and about 400,000 ha drained for forestry by 1995 [17]. Draining peatlands for forestry in Norway has been prohibited since 2009 [18]. Although at the beginning of the 21st century, some mires were still being drained for agriculture [19], in June 2020, it was decided to give up the cultivation of peatlands to protect these ecosystems as critical carbon sinks [20].

Although peatland restoration has been a focus of research for years, significant knowledge gaps remain, leading some to question the purpose, importance, and effectiveness of rewetting [21]. One of the most prominent gaps is the lack of long-term monitoring data [22,23]. Additionally, a deeper understanding of groundwater level responses and their dynamics in rewetted peatlands is required [24], highlighting the need for further research in this area. A few isolated studies are insufficient to provide a comprehensive understanding of the hydrological dynamics of rewetted peatlands. More extensive monitoring studies are necessary to gain insight into the typical responses of various peatland types.

This study aims to address these gaps by analyzing the groundwater level response to rewetting in three drained raised bogs in Norway: Aurstadmåsan, Midtfjellmåsan, and Kaldvassmyra. The pilot bog rewetting project, implemented by the Norwegian Environment Agency (Miljødirektoratet), aimed to restore near-natural hydrological conditions of formerly drained peatlands. To assess the hydrological impact, groundwater levels were monitored both before and after rewetting to compare the pre- and post-rewetting periods and evaluate the average changes resulting from these measures. While the expected outcome is an increase in groundwater levels across the study sites, the extent of the response remains uncertain due to the limited number of comparable published studies.

2. Materials and Methods

2.1. Study Sites

The study was conducted at three ombrotrophic peatlands in Norway. Raised bog is the dominant mire massif type at the study sites [18]. Aurstadmåsan and Midtfjellmåsan are located in southeastern Norway (Akershus county), and Kaldvassmyra is located in central Norway (Trøndelag county) (Figure 1). Both Kaldvassmyra and Midtfjellmåsan are situated in the southern boreal vegetation zone and weakly oceanic vegetation section, whereas Aurstadmåsan is situated in the southern boreal vegetation zone and the transitional vegetation section [25]. Meteorological conditions at the study sites in the period 2015-2021, including temperature and precipitation, are presented in Table 1.

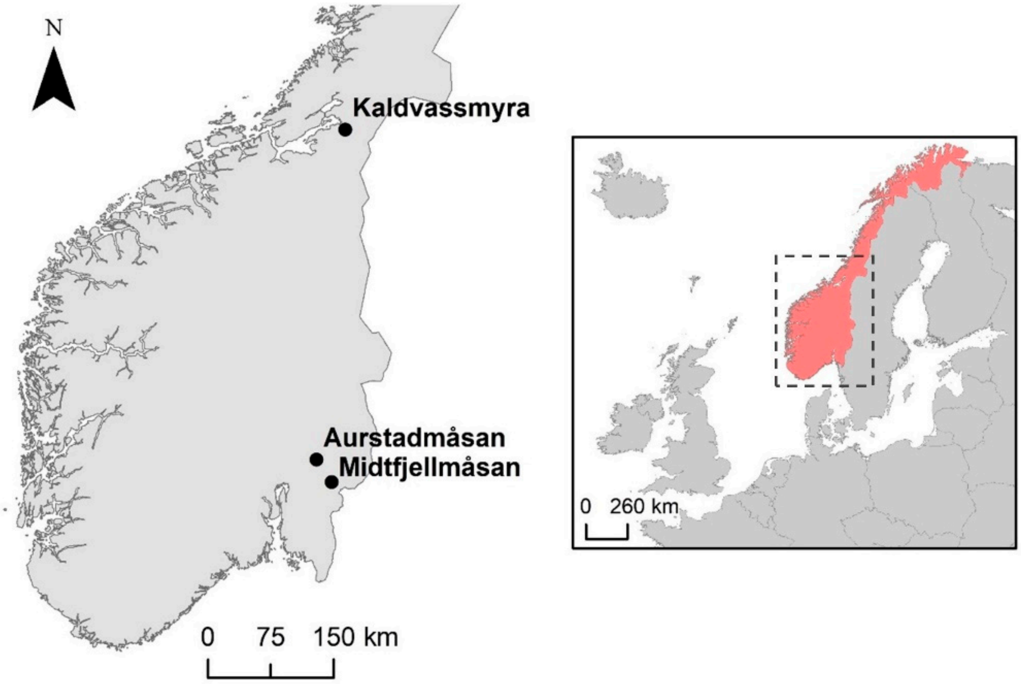

Figure 1. A map of southern Norway showing the location of the study sites Kaldvassmyra, Aurstadmåsan, and Midtfjellmåsan.

Kaldvassmyra (50 ha, 185 m a.s.l., 63.72428° N, 11.58956° E) has plateau-raised bog as the dominant mire massif type, but spring-fed flat fen and terrestrialization mire covers a substantial area in the west [26,27]. The mire sits on fluvial and glaciofluvial deposits [28] with phyllite and limestone in the bedrock [29]. Numerous calcareous springs support extremely rich fen vegetation, and there is tufa formation in spring seeps and in Lake Kaldvatnet.

The Kaldvassmyra Nature Reserve (established in 1984) covers ca. 85% of the mire complex, excluding a plateau raised bog mire massif southeast of a drainage ditch. Based on historical aerial photographs [30], the southernmost 125 m of this ditch was dug before 1952, whereas the remaining ca. 400 m was dug between 1966 and 1973. This ditch was implemented for forest production purposes and stretched across the southeastern corner of the peatland. The southern half generally followed a former lagg zone, and the northern half was placed in a soak between two plateau raised bog mire massifs. The ditch was blocked in 2017 but drained the eastern, bog-dominated area of Kaldvassmyra for about 50 years before restoration.

The average depth of the ditch was measured at 0.64 m in 2015, and the water table in the ditch was approximately 0.56 m (average of measurements at 18 locations in the ditch) [31]. The drainage effect on vegetation was visible through a gradual encroachment of bushes and trees along the ditch and in adjacent mire margin vegetation. The mire expanse has remained open despite the drainage.

Table 1. Climatic conditions at the study sites Kaldvassmyra, Aurstadmåsan, and Midtfjellmåsan in the period 2015–2021 [32]. Mean = average annual air temperature and mean annual sum of precipitation, respectively.

Study Site	Temperature (°C)			Precipitation (mm)				
	Mean	Min	Max	Mean	Min	Max	Driest Year	Wettest Year
Kaldvassmyra [1]	6.2	−2.1 (Jan)	15.1 (Jul)	900	50 (Feb)	114 (Sep)	789 (2018)	1006 (2021)
Aurstadmåsan [2]	6.1	−3.9 (Jan)	16.7 (Jul)	839	32 (Apr)	101 (Sep)	601 (2018)	1037 (2015)
Midtfjellmåsan [3]	5.9	−4.2 (Jan)	16.1 (Jul)	713	36 (Apr)	86 (Nov)	470 (2018)	926 (2020)

[1] Temperature data obtained from the Verdal-Reppe weather station (code SN70150) from the period 2015–2018. Precipitation data were obtained from the Buran weather station (SN69960) from the period 2015–2021. [2] Temperature and precipitation data obtained from the Gardermoen weather station (code SN4780) from the period 2015–2021. [3] Temperature and precipitation data obtained from the Aurskog II weather station (code SN2650) from the period 2015–2021.

Aurstadmåsan (92 ha, 180 m a.s.l., 60.18759° N, 11.34243° E) is one of approximately 30 localities with a concentric raised bog in Norway [33] and was protected as the Aurstadmåsan Nature Reserve in 1981. The mire complex consists of two concentric raised bog mire massifs, and bog vegetation dominates [34]. The mire sits on thick marine and glaciofluvial deposits [28] with granite in the bedrock [29].

A single ditch (ca. 1 km) was dug through the center of the peatland before 1953 [30], affecting the largest mire massif. The average depth of the ditch was measured at 0.85 m in 2015, and the water table was approximately 0.72 m (average of measurements at 35 locations in the ditch). This ditch was plugged in 2016. Comparing recent and historical aerial photographs, it is evident that there has been a substantial encroachment of Scots pine (Pinus sylvestris) in the northeast section of the bog in particular and in the mire margin in general. The mire expanse southwest of the ditch has remained predominantly open, and this area includes the highest point of the peat dome. Downy birch (Betula pubescens) has established close to the ditch, suggesting a long-term increase in nutrient availability in the soil and a decline in the groundwater table.

In the southern part of the bog, along the course of the ditch, dying pine trees likely indicate the re-establishment of wet conditions as the ditch's drainage function diminishes. Within the core region of the dome, more pronounced hummock structures appear to have developed since 1953, potentially signifying that the bog has been functioning under slightly drained conditions in recent years. The smaller concentric raised bog massif in the southeast has been severely impacted by peat excavation and cultivation, the latter continuing until around 1970, which drained the adjacent peatland area. The areas affected by peat excavation have been excluded from the Nature Reserve.

Midtfjellmåsan (407 ha, 280 m a.s.l., 59.95141° N, 11.68354° E) is a large mire landscape that was partly protected as the Midtfjellmåsan Nature Reserve in 2013. Ombrotrophic vegetation covers about 55% of the peatland area, and the mire contains several mire complexes and ca. 90 mire massifs. The mire massif types present are plateau raised bog, eccentric raised bog, plane bog, flat fen, terrestrialization mire, and soligenous surface flow mire [35]. A peat layer has developed over shallow, waterlogged morainic sediments across the majority of the site, while in certain areas, the peat directly overlays the underlying granite or gneiss of the bedrock [28,29].

A network of 18 drainage ditches with an average distance of 26 m between them was dug during the 1950s and 1960s, impacting three mire massifs in the central, western part of the protected area. The mire massif types affected were plateau raised bog, plane bog, and soligenous surface flow mire. The average depth of the ditches was measured at 0.71 m in 2015, and the water table was approximately 0.31 m (average of measurements at 94 locations in the ditches). The ditched area was rewetted in 2018. Among the three sites studied in this research, Midtfjellmåsan stands out as the one that has experienced the most pronounced drainage. Encroachment by trees, bushes, and dwarf bushes like heather (*Calluna vulgaris*) is easily seen in aerial photographs and is also apparent in the field.

2.2. Installation of Piezometers and Water Level Measurements

Water level data were obtained using automatic pressure transducers, which were placed in strategically located piezometers within the study sites (Figure 2). The loggers recorded measurements at 3 h intervals. Data were compensated based on readings from loggers that recorded atmospheric pressure at each site and were calibrated with manual measurements. The installation of piezometers and water level loggers took place on 19 August 2015 in Kaldvassmyra, 21 August 2015 in Midtfjellmåsan, and 22 August 2015 in Aurstadmåsan. The data collection for Kaldvassmyra continued until 18 October 2021, while for Aurstadmåsan and Midtfjellmåsan, the last data were collected on 7 July 2021. At the Kaldvassmyra site, a total of 11 piezometers were initially installed. However, 3 of these piezometers stopped logging, so the data were available only from 8 piezometers distributed across 3 transects and 2 individual points. K.REF was used as the reference point (Figure 2B). Within the bog section of the Kaldvassmyra mire, the depths of the peat layer ranged from 1.2 m to 2.5 m. At the Aurstadmåsan site, a total of 10 piezometers were installed, which were organized into 2 groups that formed 8 transects and 2 additional individual measurement points (Figure 2A). Point A9P was selected as a reference point. In the northern part of the site, the depths of peat reached from 1.5 to 4 m, while in the southern part, the reported peat layer thickness did not exceed 1.3 m. At the Midtfjellmåsan site, 11 piezometers were installed in 3 transects and 1 individual point as a reference point (M6P) (Figure 2C). The peat thickness in Midtfjellmåsan varied from 1.4 m to 3.5 m. The details of peat depths at specific locations are presented in Table A1 in Appendix A.

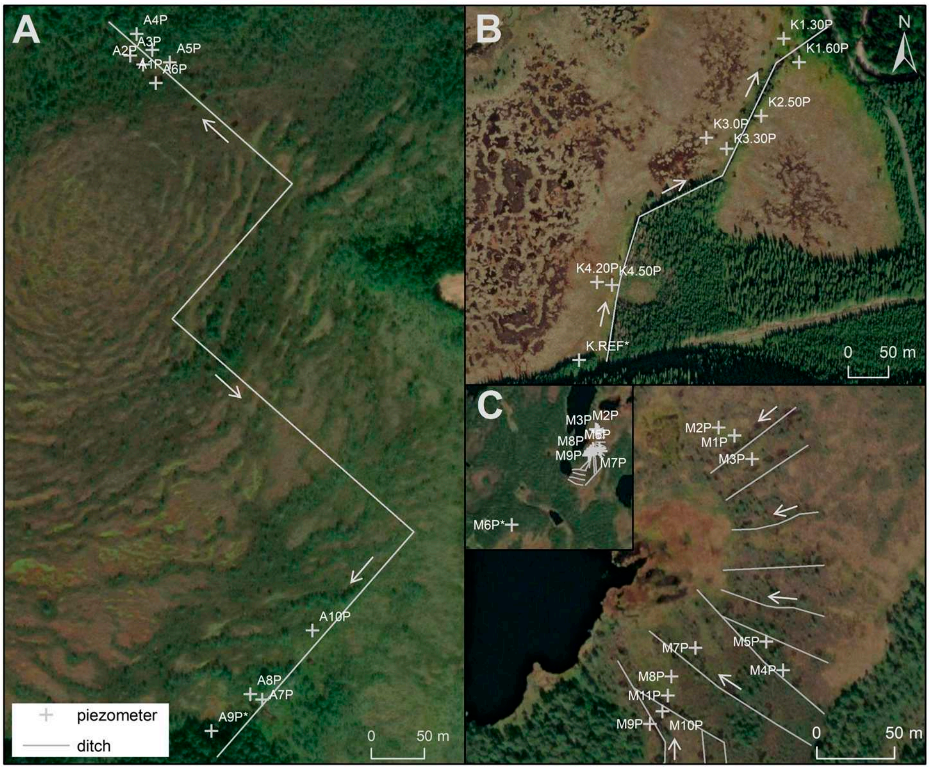

Figure 2. Maps with the locations of piezometers in Aurstadmåsan (**A**), Kaldvassmyra (**B**) and Midtfjellmåsan (**C**) sites ('*' indicates a reference point; arrows indicate flow directions in the ditches).

The preparation of the piezometers followed the instructions provided in the description depicted in Figure A1 (Appendix A). The body of each piezometer was made of a

PVC pipe of 40–50 mm diameter. The length of each piezometer was adjusted to match the actual depth of the peat in the respective installation location. For the majority of the piezometers, the lower section of the pipe was hammered into the underlying sand or till layer. In cases where the peat directly rested on the mineral bedrock, the bottom of the piezometers was positioned to make contact with the rock surface. In sites where the peat depth exceeded 3 m, the piezometers were installed directly in the peat, assuming that no vertical movements of these piezometers could have occurred over the monitoring period. Elevations of heads of installed piezometers and elevations of the ground in places of installation were measured with an accurate DGPS receiver. Reference piezometers were placed in areas that are unlikely to be affected by damming the ditch.

2.3. Implementation of Restoration Measures

The restoration of the study sites was conducted as part of the Norwegian Environment Agency's 2015–2020 plan, which aimed to adapt to climate change by reducing greenhouse gas emissions and improving the ecological condition of peatlands [36,37]. The rewetting technique employed was ditch blocking with peat dams, which is a proven cost-effective and successful method [38,39]. The locations of the dams were set based on hydrological modeling [31] which reflected the principle of designing one peat dam for every 0.2 m of water level slope in the ditch. The peat dams were designed to be approximately 0.5 m higher than the maximum ditch depth and extended several meters beyond the ditch boundaries. Details on the construction process are provided in Appendix B.

Rewetting measures were implemented on 2 December 2016 (Aurstadmåsan), on 24 April 2017 (Kaldvassmyra), and on 14 September 2018 (Midtfjellmåsan). In Kaldvassmyra, 12 peat dams were constructed, with an average spacing of 35.4 m (median 29.8 m) between dams, ranging from 14.7 m to 115.8 m. In Aurstadmåsan, 7 peat dams were installed with an average spacing of 34.7 m (median: 36.5 m) and a range of 26.1 m to 41.6 m. Notably, 4 dams were placed in the northern section of the ditch and 3 in the southern section, leaving the middle 730 m unblocked. Data for the dams in Midtfjellmåsan were unavailable due to unclear aerial photos and the lack of a field inventory.

2.4. Data Analysis

The study employed a BACI (Before/After Control/Impact) design to compare groundwater and precipitation data collected before and after the implementation of rewetting measures. Water level loggers recorded data at 3 h intervals, from which daily averages were calculated for further analysis. Daily precipitation data were obtained from meteorological stations near the study sites, as summarized in Table 1.

To analyze groundwater table changes following rewetting, equal time intervals before and after ditch blocking were compared. These intervals were defined relative to the rewetting date for each site. At Kaldvassmyra and Aurstadmåsan, data were grouped into five intervals: one year before rewetting and four consecutive years after rewetting. A one-day discrepancy during leap years was disregarded. At Midtfjellmåsan, where rewetting occurred later in the monitoring period, data were divided into two equal intervals of 1027 days each. Mean groundwater levels from piezometers within the influence range of ditch blocking (referred to as "impact piezometers") were calculated, while control piezometers were analyzed separately. The same method was applied to evaluate changes in monthly precipitation sums over the monitoring period and assess whether variations in weather conditions could account for observed changes in groundwater levels. Additionally, average annual precipitation totals were analyzed. Differences between pre- and post-rewetting periods were assessed using the non-parametric Wilcoxon test.

For simplicity, further analyses encompassed the entire monitoring period, which was divided into two unequal pre- and post-rewetting periods. These analyses investigated differences at the level of individual piezometers and seasonal effects of rewetting as indicated by changes in monthly mean groundwater levels. Additional assessments included determining the impact radius of ditch blocking and analyzing changes in groundwater table duration curves. Time series trends were evaluated using linear regression [40]. All analyses used a significance level of 0.05. Data processing and analysis were conducted using R Statistical Software version 4.1.2 [41], employing the ggplot2 package version 3.3.6 [42] for data visualization.

3. Results

3.1. Changes in Groundwater Tables

In almost all cases, a significant increase in mean groundwater tables was observed within each site after rewetting (Figure 3). At Kaldvassmyra, the mean increase was 0.08 m, which was consistently observed each year following rewetting. At Aurstadmåsan, the change was not significant in the second year (2018), which was identified as the driest year during the monitoring period for both Aurstadmåsan and Midtfjellmåsan.

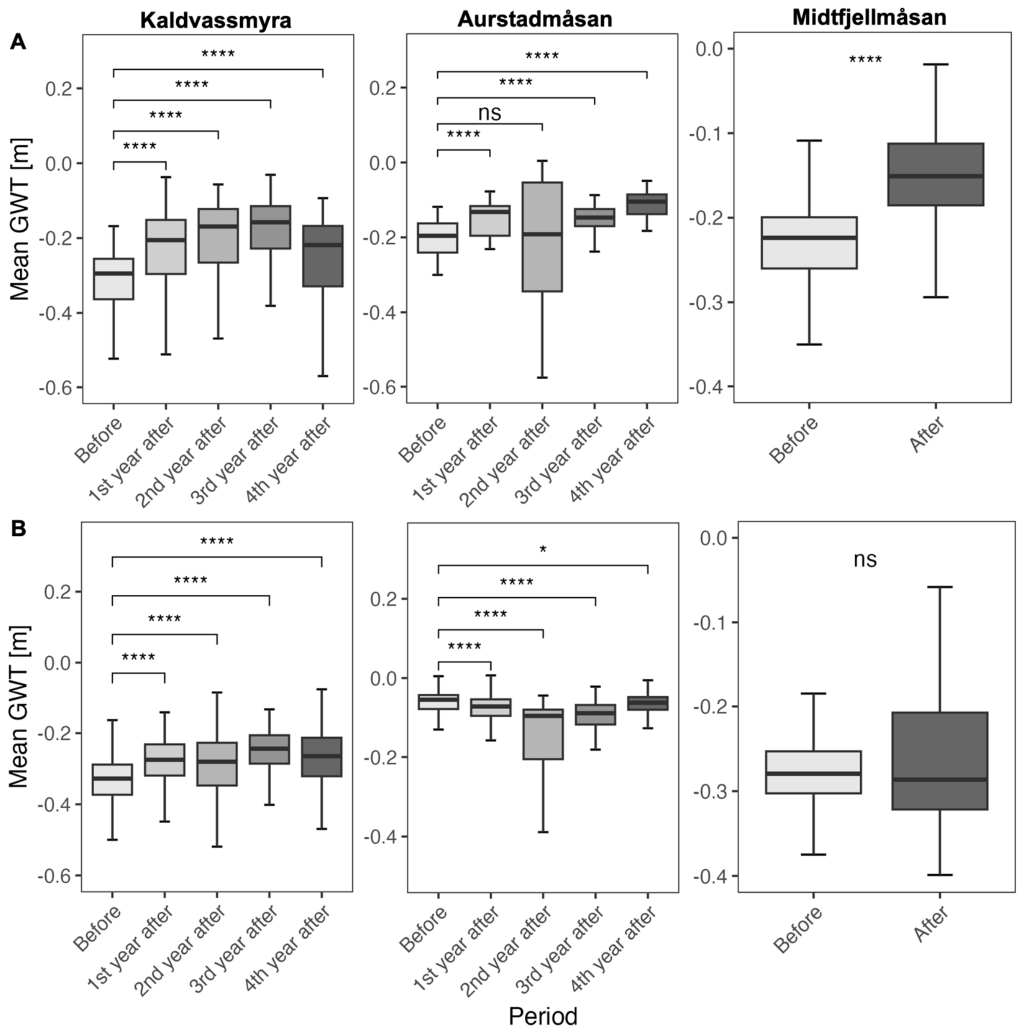

Figure 3. Boxplots illustrating groundwater table comparisons across equal time intervals before and after rewetting. Row (**A**) represents the mean groundwater tables from impact piezometers, while row (**B**) shows the control piezometers. 'ns'—$p > 0.05$; '*'—$p \leq 0.05$; '****'—$p \leq 0.0001$.

Time series analysis revealed a notable drop in groundwater levels at these sites during that year, which was attributed to exceptionally low precipitation. However, on average, the groundwater tables increased by 0.04 m at Aurstadmåsan and 0.08 m at Midtfjellmåsan. Across all sites, the average increase in groundwater levels was 0.06 m. For the control piezometers, the mean groundwater table change was 0.02 m in Kaldvassmyra, −0.04 m in Aurstadmåsan, and 0.01 m in Midtfjellmåsan, resulting in an average change of −0.01 m across all sites.

The analysis of groundwater table data before and after rewetting revealed spatial variations in hydrological responses across the sites, depending on piezometer locations. At each site, piezometers that showed increased mean groundwater levels following rewetting were identified (Figure 4, Appendix D). However, not all impact piezometers responded positively to ditch blocking. In Kaldvassmyra, three out of eight piezometers exhibited an increase in mean groundwater levels, while the remaining five piezometers showed a decrease. In Aurstadmåsan, seven out of ten piezometers recorded higher mean groundwater levels post-rewetting, whereas the remaining three piezometers, along with the control piezometer, showed a decline. In contrast, nearly all piezometers in Midtfjellmåsan (10 out of 11) demonstrated an increase in mean groundwater levels after rewetting.

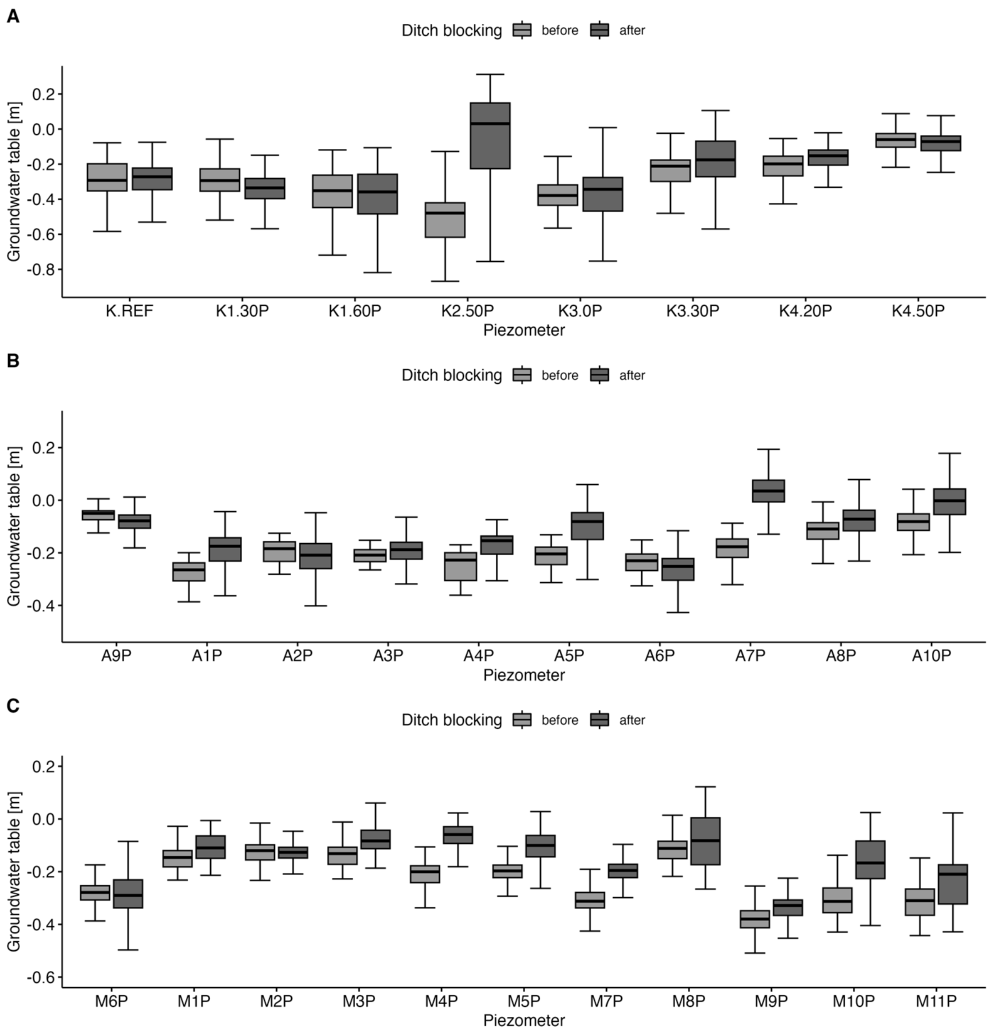

Figure 4. Boxplots of groundwater tables before and after rewetting for each piezometer in Kaldvassmyra (**A**), Aurstadmåsan (**B**), and Midtfjellmåsan (**C**). K.REF, A9P, and M6P represent control piezometers.

Hydrographs illustrating changes in average daily groundwater tables during the monitoring period for individual piezometers are presented in Appendix C. The trend lines and corresponding equations generally reflect the observed changes in average groundwater depths before and after rewetting. In Kaldvassmyra, an increasing trend line was observed at three out of eight measurement points (K2.50P, K3.30P, K4.20P). A decreasing trend was recorded at the control piezometer (K.REF) and four impact piezometers (K1.30P, K1.60P, K3.0P, K4.50P). In Aurstadmåsan, most measurement points exhibited an increasing trend line, while a decreasing trend was noted in the control piezometer (A9P) and one impact piezometer (A2P). In Midtfjellmåsan, a decreasing trend was observed in only one piezometer (M2P).

Monthly mean groundwater tables in the impact piezometers increased in nearly all cases during the post-rewetting period (Figure 5). The only exceptions were in August and September at Aurstadmåsan, where the mean groundwater table was lower after rewetting compared to the pre-rewetting period. This decline may be attributed to lower mean precipitation totals in these months following rewetting.

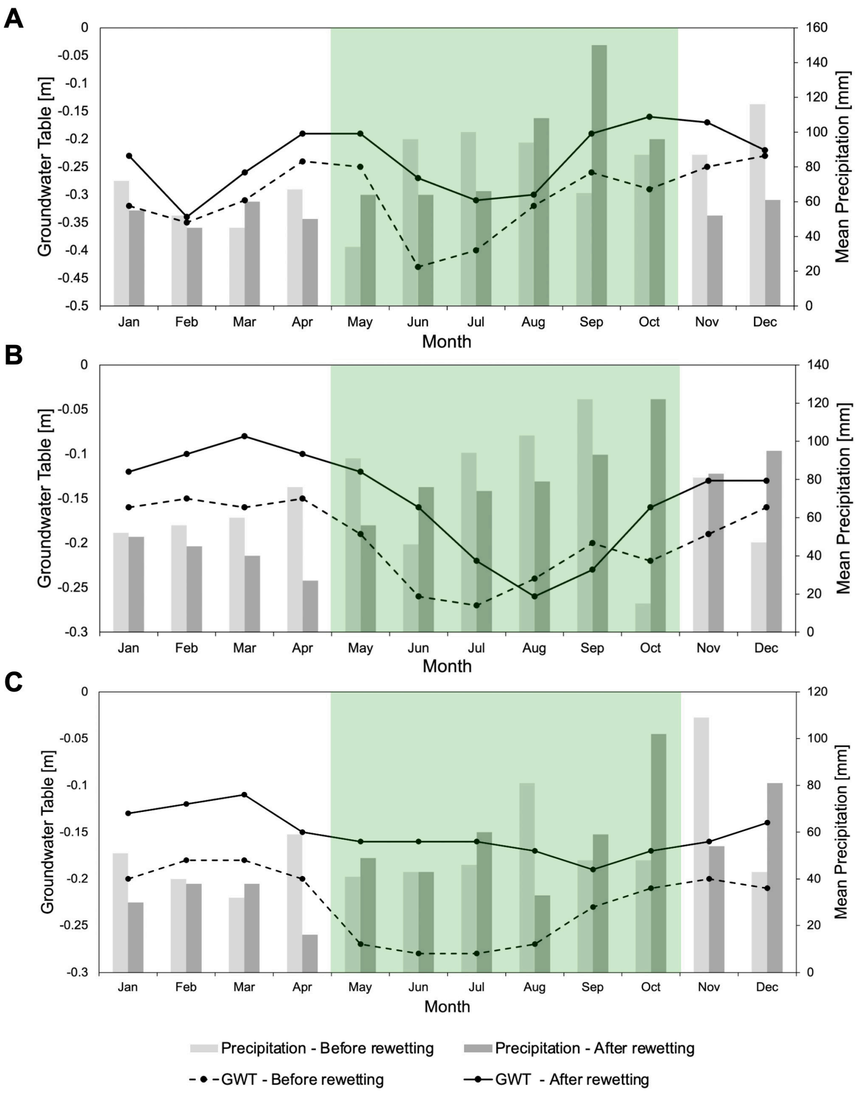

Figure 5. Monthly mean groundwater tables of the impact piezometers and the monthly mean sum of precipitation from the pre-and post-rewetting period in Kaldvassmyra (**A**), Aurstadmåsan (**B**), and Midtfjellmåsan (**C**). The green areas represent the growing season in Norway (May–October).

In contrast, the monthly mean groundwater tables of the control piezometers generally decreased or remained unchanged in the post-rewetting period. Positive changes in control piezometers were observed in June (0.05 m) and October (0.07 m) at Kaldvassmyra, in June (0.01 m) at Aurstadmåsan, and in February (0.01 m), May (0.04 m), June (0.06 m), July (0.06 m), and August (0.05 m) at Midtfjellmåsan.

3.2. Impact Radius of Ditch Blocking

The average distance affected by ditch blocking, where a rise in groundwater levels was observed, was 24.8 m in Kaldvassmyra, 12.7 m in Aurstadmåsan, and 14.1 m in Midtfjellmåsan (Figure 6). The overall average range of influence of ditch blocking was 17.2 m. Analysis of p-values in relation to distance from the ditch indicates that changes in groundwater depths before and after rewetting are statistically significant up to 35.2 m from the ditch.

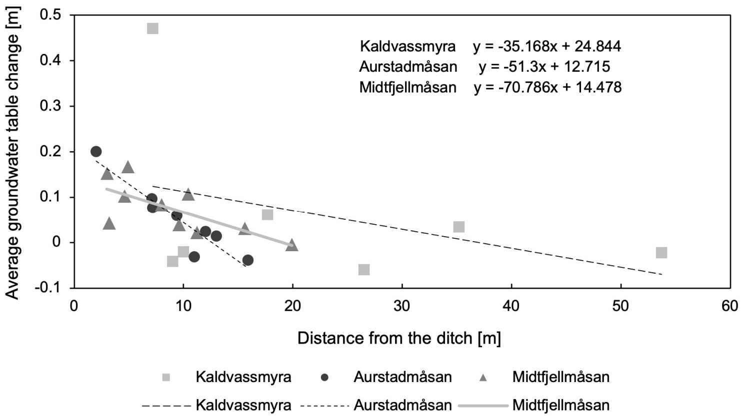

Figure 6. Relationship between the average groundwater level change and the distance from the ditch in Kaldvassmyra, Aurstadmåsan, and Midtfjellmåsan (control piezometers excluded).

3.3. Changes in GWD Exceedance Frequencies

Groundwater table duration curves for each site, divided into pre- and post-rewetting periods, are presented in Figure 7. The graph includes curves for the reference piezometers and the curve representing the average groundwater depth from all impact piezometers (excluding the reference piezometer). On average, the impact piezometers at each site showed a noticeable increase in the groundwater table after rewetting with a frequency of exceedance of approximately 80%.

Figure 8 illustrates changes in the occurrence of specific groundwater levels before and after rewetting. In Kaldvassmyra, durations of higher groundwater tables after rewetting (ranging from −0.2 to −0.1 m and higher) extended in piezometers K2.50, K3.30P, and K4.20P. Most other piezometers exhibited a decreased amount of time with higher groundwater tables post-rewetting. Piezometers that recorded the water table at the surface or above ground level during the post-rewetting monitoring period included K2.50P (54.2% of the time), K3.0P (0.4% of the time), and K3.30P (7.7% of the time). In Aurstadmåsan, durations of higher groundwater tables after rewetting increased in piezometers A1P, A3P, A4P, A5P, A7P, A8P, and A10P. Piezometers that showed a significant increase in the occurrence of the water table at the surface or above ground level during the post-rewetting period included A5P (8.1% of the time), A7P (71.7% of the time), A8P (5.2% of the time), and A10P (48.4% of the time). In Midtfjellmåsan, the duration of higher groundwater tables after rewetting increased in piezometers M6P (reference piezometer), M1P, M3P, M4P, M5P, M7P, M8P, M9P, M10P, and M11P. Piezometers with a significant change in the occurrence of the water table at the surface or above ground level during the post-rewetting period included M6P (21.8% of the time), M5P (7.8% of the time), M8P (27.0% of the time), and M10P (6.4% of the time).

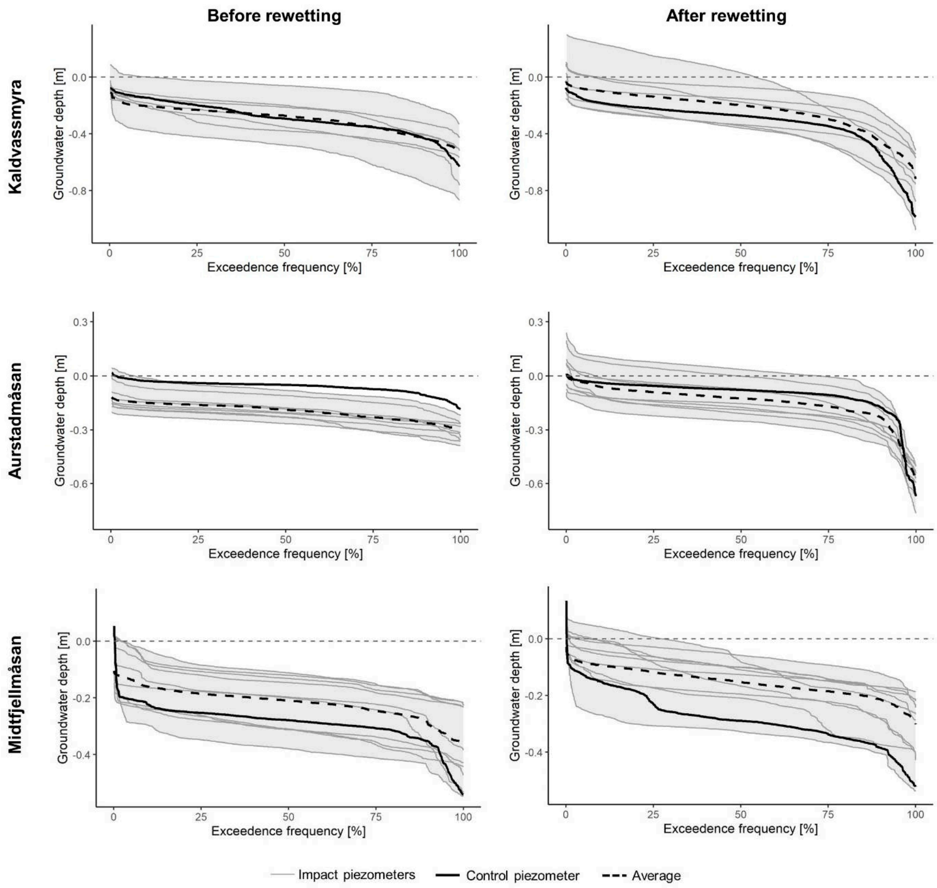

Figure 7. Groundwater depth duration curves before and after rewetting at Kaldvassmyra, Aurstadmåsan, and Midtfjellmåsan.

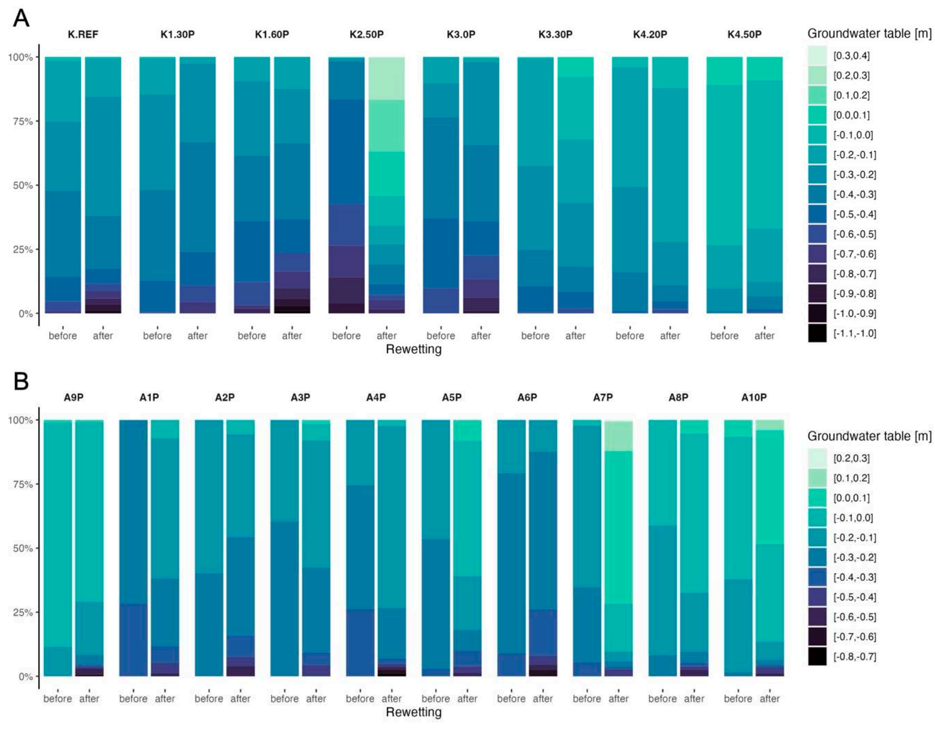

Figure 8. *Cont.*

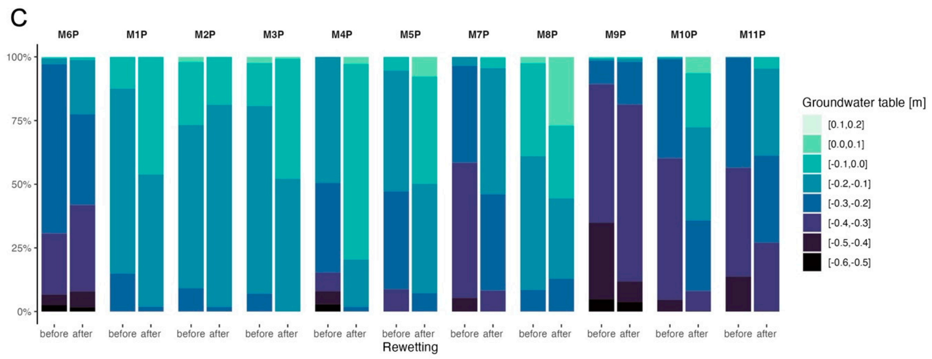

Figure 8. Changes in the occurrence of specific ranges of groundwater tables before and after rewetting in Kaldvassmyra (**A**), Aurstadmåsan (**B**), and Midtfjellmåsan (**C**) (control piezometers: K.REF, A9P, M6P).

3.4. Analysis of Meteorological Conditions

Analyses of two key precipitation factors were conducted. Before rewetting, the average annual precipitation totals at Kaldvassmyra, Aurstadmåsan, and Midtfjellmåsan were 836 mm, 859 mm, and 649 mm, respectively. After rewetting, these averages were 885 mm, 827 mm, and 681 mm, respectively. The medians of the average monthly precipitation sums at Kaldvassmyra were 71 mm before rewetting and 64 mm after rewetting. At Aurstadmåsan, the medians were 70 mm before rewetting and 75 mm after rewetting, while at Midtfjellmåsan, the medians were 47 mm before rewetting and 46 mm after rewetting.

Changes in monthly precipitation sums were not significant between the pre- and post-rewetting periods at any of the sites (Figure 9). This suggests that differences in precipitation patterns alone cannot explain the changes in the groundwater tables observed after ditch blocking.

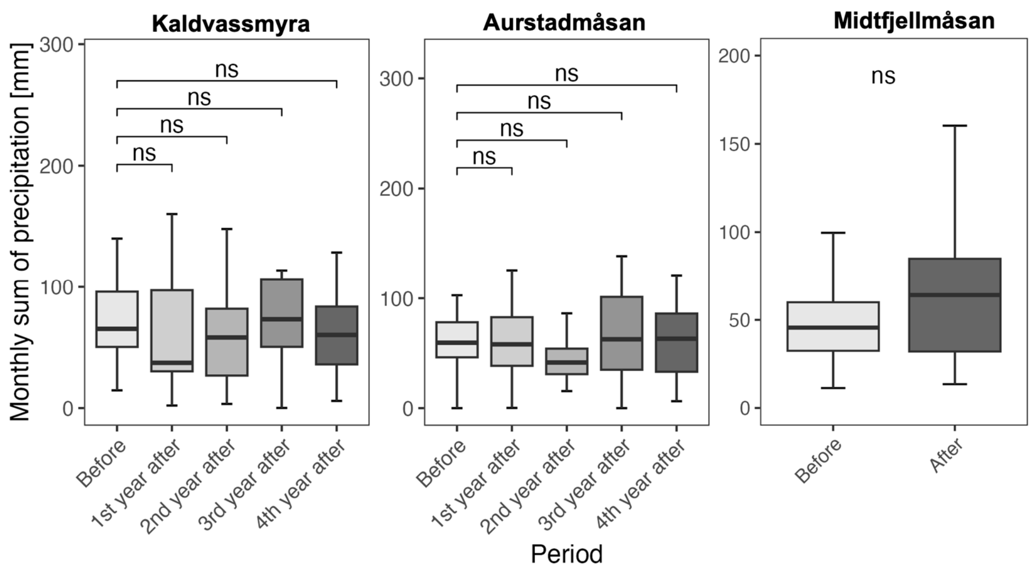

Figure 9. Boxplots of average monthly sums of precipitation in Kaldvassmyra, Aurstadmåsan, and Midtfjellmåsan. 'ns'—$p > 0.05$.

4. Discussion

4.1. Response to Ditch Blocking

The results indicate that the rewetting measures applied led to a general increase in water levels in the peatlands studied. However, the success of rewetting is spatially limited and dependent on the distance from a ditch block. The average impact radius of ditch blocking in the three analyzed bogs ranged from 12.7 to 24.8 m. Consistent with the present study, previous research has shown that ditch blocks have a limited range of impact, affecting – at the time - the groundwater table only within a certain distance (Table 2).

Most of the values found in other field studies align with our results. One study reported that the effect of ditch blocking extends up to nearly 1 km with an average water level increase of 9.8 to 12.2 cm [43], although it did not specify how the effect is distributed along a transect. A hydrological model applied to a tropical peatland in Indonesia also observed an effect of ditch blocking up to 1 km, but the water level increase at the farthest point was only 1 mm [44], which may be either insignificant or below the model's accuracy. The groundwater table response may vary due to multiple factors, such as peat quality, soil structure, and vegetation cover [45]. Additionally, the recovery of the groundwater table depends on the elevation difference from the constructed dam with the response expected only up to a 17 cm difference [46].

Table 2. Examples of estimated impact ranges of ditch blocking in peatlands from other field studies.

Name	Country	Peatland Type	Impact Radius of Ditch Blocking [m]	Reference
Bullock Creek Polje	New Zealand	Fen	30	[47]
Kamanos mire	Lithuania	Raised bog	980	[43]
Burns Bog	Canada	Raised bog	20	[48]
Burns Bog	Canada	Raised bog	<50	[45]
Grande plée Bleue bog	Canada	Raised bog	25	[46]

The meta-analysis conducted by Bring et al. [49] revealed that the impact of restoration (including ditch blocking) in bogs reaches up to 80 m from the ditch, and the groundwater table rise after restoration decreases to 50% after 9 m. In contrast, the corresponding value for the impact of drainage is 21 m, indicating that the impact radius of drainage is more than twice as large, making restoration more challenging than draining. On average, for all peatland types, excluding blanket bogs, the restoration measures were found to raise groundwater levels in the vicinity of undertaken actions by 22 cm.

It is noteworthy that the responses of drained peatlands to rewetting, including specifically raised bogs, can vary significantly depending on the meteorological conditions following rewetting [50]. A site experiencing dry conditions during the post-rewetting period may not show a rise in water levels due to a lack of water. Higher temperatures can affect the rate of evaporation [51], potentially hindering a positive response to rewetting [52]. These factors must be considered when evaluating the long-term effectiveness of peatland restoration, as climate change is likely to influence its success. In light of changing climatic conditions, it may become unfeasible to restore a hydrological regime that favors the original, pre-drainage peatland type (e.g., hydromorphological type). However, this does not mean that peatland restoration is unnecessary, as rewetting is likely to facilitate a successful transition toward a peatland adapted to future climate regimes [53,54]. Additionally, a drained peatland without any action taken toward rewetting is likely to continue deteriorating and may even disappear under future climatic pressures [55,56].

4.2. Was Rewetting a Success?

Following rewetting, all sites demonstrated an average increase in groundwater levels of 6 cm across piezometers affected by ditch blocking. A similar study observed comparable results, reporting a 6 cm rise in groundwater levels in a rewetted fen in Sweden [57]. Likewise, rewetting measures increased the groundwater table by an average of 8 cm in a drained raised bog in the Czech Republic [58]. However, a broader study by Menberu et al. [59] which examined 24 rewetted peatlands—including spruce mires, pine mires, and fens—found a mean groundwater table rise of 21.9 cm.

Although the 6 cm mean rise observed in this study might appear modest and insufficient as a positive response of a drained peatland to rewetting, recent findings suggest otherwise. According to Koch et al. [60], even small increases in the groundwater table can significantly reduce CO_2-equivalent emissions. Specifically, a water table depth of 40 cm below the surface has been identified as a critical tipping point for limiting CO_2 release. Based on these findings, the groundwater table increases observed in Kaldvassmyra, Aurstadmåsan, and Midtfjellmåsan may have contributed to reductions of approximately 7, 8, and 9 t CO_2 eq. ha^{-1} year^{-1}, respectively. Altogether, the rewetting of these sites could potentially lead to an estimated reduction of approximately 75.5 t CO_2 eq. annually. This is a very careful and rough estimate and requires future research on the carbon balance in rewetted raised bogs.

Other studies have also found a relationship between groundwater tables and carbon emissions. A model-based approach applied by Urzainki et al. [44] revealed that the rise in mean annual groundwater level after blocking drainage canals in a tropical peatland complex in Indonesia was only 1.5 cm. Nevertheless, the study predicted that canal-blocking could reduce the emission of 1.07 t CO_2 eq. ha^{-1} in the dry year and 1.17 t CO_2 eq. ha^{-1} in the wet year. This suggests that even the smallest changes in the groundwater table can trigger ecologically beneficial processes or gradually reverse the negative impacts of drainage.

Another observation from the data analysis is that in most cases across all study sites, there is a longer period with a higher groundwater table. A study by Liu et al. [10] identified the critical groundwater table depth as 30 cm, representing a turning point for changing the functionality of a peatland. The research revealed that a groundwater table deeper than 30 cm implies a reduction in carbon sequestration rates. In a different study, Lamentowicz et al. [61] found that a critical value for the functioning of the peatland ecosystem is approximately 11.7 cm, which is based on plant community composition. Other sources also mention that the groundwater table of 10–15 cm below the surface is a tipping point for *Sphagnum* spp. growth [62]. Considering these depths as indicative of a well-functioning peatland, they could be used as threshold values for a hydrology indicator to assess the successful restoration of these ecosystems.

In the case of the rewetted sites in this study, the period with a groundwater table of 30 cm or higher in Kaldvassmyra increased by 13.7% after ditch blocking (from 61.9% to 75.6%). In Midtfjellmåsan, there was a change of 9.3% (90.7–100%). In the Aurstadmåsan site, the situation was somewhat different, as the groundwater table was already around 30 cm deep throughout the study period before rewetting (99.9%). When the threshold was lowered to 20 cm in this case, a more noticeable difference was observed: the period with a groundwater table of 20 cm or higher increased by 23.9% (from 58.8% to 82.7%). Overall, rewetting increased the time during which the groundwater table was 30 cm or higher by 11.5%.

Considering the period with a groundwater table at or above 11.7 cm, there was a significant increase at all of the sites after rewetting. In Kaldvassmyra, the increase was 15.8% (from 0.6% to 16.4%), in Aurstadmåsan it was 43.7% (from 0% to 43.7%), and in Midtfjellmåsan it was 23.7% (from 0.7% to 24.4%). On average, ditch blocking increased the period when the groundwater table was 11.7 cm or higher by 27.7%. These calculations were based on the average groundwater table from all the impact piezometers. In conclusion, the duration of favorable hydrological conditions for peatland functioning has been prolonged.

Changes in the study sites can also be observed visually not only through piezometer data. At both the Midtfjellmåsan and Aurstadmåsan sites, *Sphagnum* spp. and graminoids such as *Eriophorum vaginatum* and *Rhynchospora alba* have colonized the blocked ditches, at least in ombrotrophic mire massifs. A field visit to Midtfjellmåsan in July 2021 revealed that the blocked ditches of the raised bog mire massif were water-filled, while the blocked ditches of the soligenous surface flow mire were partly dry between peat dams. The piezometer readings do not seem to support this observation, as the raised bog piezometers (M1P–M3P, Figure 3) suggest less ditch blocking effect than the fen piezometers (M4P–M5P and M7P–M11P, Figure 3). The most likely explanation is that the hydrology of the raised bog mire massif was less impacted by drainage than that of the fen mire massif and that rewetting has had a relatively higher impact on groundwater levels in the fen. Additionally, there may be greater variability in the fen groundwater levels, which probably reflects both the innate hydrological characteristics of soligenous surface flow mires and the effects of drainage.

In the Kaldvassmyra site, the response of the groundwater table to ditch blocking is not evident in individual piezometer readings. In this site, Kyrkjeeide et al. [63] found no changes in species composition that can be related to restoration five years after rewetting. However, there are changes in the area, indicating a rise in the groundwater table. The forest vegetation established in the drained mire margin close to the ditch has been flooded, and trees show signs of dying, indicating an apparent shift in hydrological conditions. Taking a closer look at the restored ditch and the placement of piezometers may shed some light on the lack of a clear, measured impact. During field visits, the water level in the ditch has always been high in the soak between the raised bog mire massifs. This is in the interior of the mire complex and is covered by piezometers K2.50, K3.0, and K3.30, among which at least K2.50 documents increased water level after restoration (Figure 4). Contrastingly, in the lagg zone (mire margin area), the water level in the blocked ditch fluctuates and can dry out completely. This is covered by piezometers K1.30, K1.60, K4.20, and K4.50 with little evidence of increased water level after rewetting. At this site, the rewetting appears to be either partly successful or the natural hydrological pattern of the mire margin and lagg zone is not fully understood. These observations highlight that relying solely on raw data from piezometers can lead to overlooking important changes and missing the bigger picture.

It is important to note that there is a time lag in the reaction of a peatland to rewetting measures [59]. A rise in the groundwater table is not immediately accompanied by a simultaneous positive response in vegetation [63,64], gas fluxes [65], or peat physical properties [66]. To document long-term changes, the monitoring period after rewetting should be extended [67]. A case of a raised bog in Norway, Rønnåsmyra, which underwent restoration [18], provides a comparable example to the sites in this study. It was drained in 1973 and rewetted in 1982 by blocking the ditches with peat dams [68]. A study by Nordbakken et al. [68] on vegetation changes after rewetting revealed that 22 years after restoration, the vegetation of the restored area resembled that of the pristine area. A similar assessment conducted 6 years post-rewetting (1988) found no evident changes at that time. The study's general conclusion was that the ditch blocking of the raised bog at Rønnåsmyra was successful. This confirms that the results of rewetting may take decades to materialize rather than years.

4.3. Future Challenges and Limitations

Examining potential future challenges of rewetted sites from this study, they will need to contend with various changing meteorological conditions in Norway. According to the more pessimistic, high-emission scenario (RCP8.5), temperatures in Norway are projected to increase by approximately 4.5 °C by the end of the 21st century [69]. Considering the lower greenhouse gas emissions scenario (medium—RCP4.5), the increase in temperature might reach, on average, 2.8 °C. In any case, an increase in the evaporation rate is inevitable.

The medium emissions scenario projects that the evaporation rate will increase by approximately 15–35% in eastern and southern Norway by the end of the century. In other regions of the country, this change may reach up to 75% [70]. Despite the expectation of a roughly 18% increase in annual precipitation in Norway (RCP8.5), future soil moisture is predicted to decrease [69]. It has also been found that the warming effect in the Scandinavian regions will be more noticeable in winter rather than in summer [71]. This indicates that we can expect more rainfall in winter instead of snowfall, leading to a general decrease in snow cover and a reduction in the occurrence of snowmelt flooding [72,73]. Considering meteorological projections, a decline in the groundwater table in peatlands might be expected to occur throughout the century. A study by Bertrand et al. [74] modeled that there will be more seasonal fluctuations in the groundwater table, with a significant decline from the second half of the 21st century, especially in the RCP8.5 scenario.

Other factors will also influence the effectiveness of ditch blocking, such as the initial condition of a drained peatland—namely, the extent to which the peat has been degraded and how its properties were changed [59]. The depth of drainage also seems to be the factor affecting the effectiveness of raising the groundwater table—shallow drained peatlands have a better chance of a positive reaction to rewetting [46].

5. Conclusions

Our research indicates that the described measures of slowing down runoff from the ditches by building peat dams have effectively contributed to the rise in the groundwater tables of the analyzed peat bogs. The average influence range of the ditch blocking was 12.7–24.8 m. Considering the data from all the impact piezometers, groundwater levels increased by an average of 6 cm, while the same value for control piezometers was −1 cm. Rewetting significantly increased the duration of groundwater levels favorable for restoring peatland functions. On average, ditch blocking increased the period when the groundwater was 11.7 cm (used threshold for the functioning of peatland ecosystem) or higher by 27.7%. Considering another measure, rewetting increased the time when the groundwater table was 30 cm or higher by 11.5%. The results suggest that ditch blocking can be an effective tool in restoring the hydrological conditions of peatlands, although its effectiveness may be limited in time and space. The assessment of restoration success could be complemented by analyses of other conditions, including changes in vegetation cover and greenhouse gas emissions (CO_2, CH_4, N_2O). Our conservative estimates highlighted that rewetting of these three sites could lead to a reduction of 75.5 t CO_2 eq. per year, but the direct impact of rewetting on greenhouse gas emissions should be evaluated more thoroughly and field proven. The scale and extent of the positive impact of the rewetting measures on peatlands presented in this research will most likely increase over time. Although progressing climate change and changes in water availability may limit the effectiveness of rewetting, it appears that continued restoration measures are the only way to increase the resilience of peatlands and the value of the benefits that a well-preserved environment provides to society.

Author Contributions: M.S.: Conceptualization, Methodology, Field research, Formal analysis, Visualization, Writing—original draft; A.L.: Investigation, Supervision, Contextualization, Writing—review and editing; P.O.: Field research, Data curation; M.G.: Conceptualization, Field research, Methodology, Funding acquisition, Resources, Supervision, Writing—review and editing, Project administration. All authors have read and agreed to the published version of the manuscript.

Funding: Part of the field research leading to these results has received funding from the Norwegian Financial Mechanism 2014–2021 (project no. 2019/34/H/ST10/00711).

Data Availability Statement: Restrictions apply to the datasets. The datasets presented in this article are not readily available because the data are part of an ongoing study. Requests to access the datasets should be directed to the Norwegian Environment Agency (Miljødirektoratet).

Acknowledgments: The research was conducted in the framework of Pilot Bog Restoration Project supervised by the Norwegian Environment Agency. We thank Kjell Tore Hansen, Vibeke Husby, Pål Martin Eid, and Erlend Skuttberg from Miljødirektoratet for the effective management of the pilot bog restoration project and outstanding assistance in field research and data collection.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Appendix A

Piezometers' Details

Table A1. Details of the piezometers ('*'—reference piezometer).

Site	Piezometer	XY Coordinates (WGS)	Peat Thickness [m]	Remarks
Kaldvassmyra	K-REF *	11.59038, 63.72181	1.90	-
	K1-30P	11.59584, 63.7253	1.60	sand
	K1-60P	11.59621, 63.72503	1.75	sand
	K2-50P	11.5952, 63.72445	1.90	sand
	K3-0P	11.5938, 63.72423	2.20	sand
	K3-30P	11.5943, 63.7241	2.00	sand
	K4-20P	11.59091, 63.72267	1.85	sand
	K4-50P	11.59128, 63.72263	1.20	sand
Aurstadmåsan	A1P	11.34372, 60.1897	>3.0	-
	A2P	11.34355, 60.18958	>3.0	-
	A3P	11.34334, 60.18966	>3.0	-
	A4P	11.34346, 60.18984	1.50	silt (gyttia?)
	A5P	11.34401, 60.18959	>3.0	-
	A6P	11.34376, 60.18942	>3.0	-
	A7P	11.34519, 60.18417	1.20	silt (gyttia?)
	A8P	11.34499, 60.18422	1.20	silt (gyttia?)
	A9P *	11.34431, 60.18392	1.10	silt
	A10P	11.34608, 60.18474	1.30	silt (gyttia?)
Midtfjellmåsan	M1P	11.68344, 59.95217	3.20	-
	M2P	11.68326, 59.95222	2.80	sand
	M3P	11.68363, 59.95203	2.70	sand
	M4P	11.68389, 59.9508	1.40	calcareaous sand
	M5P	11.68371, 59.95097	1.40	sand
	M6P *	11.67236, 59.94601	1.80	bedrock
	M7P	11.68289, 59.95095	1.60	till
	M8P	11.6826, 59.95079	2.50	-
	M9P	11.68233, 59.95052	1.70	bedrock
	M10P	11.68248, 59.95059	3.40	-
	M11P	11.68255, 59.95068	3.50	-

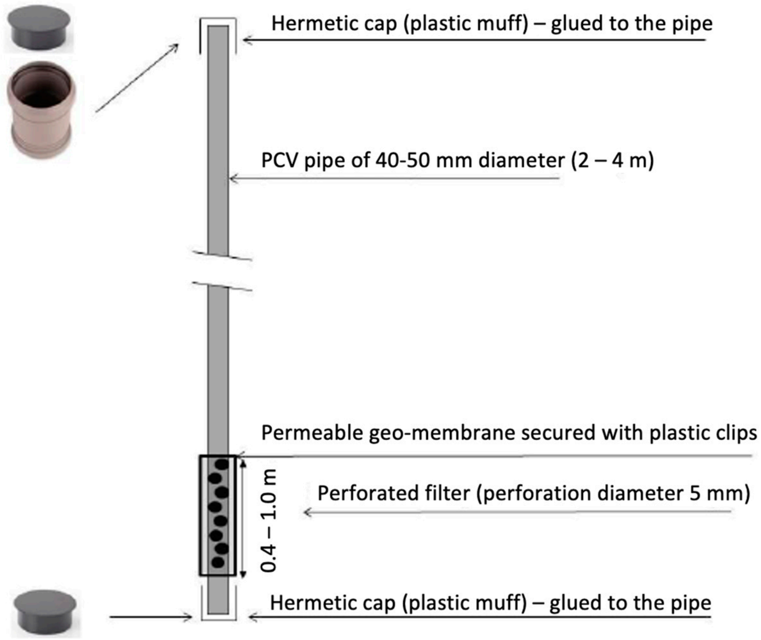

Figure A1. Piezometer's design.

Appendix B

The Procedure of Ditch Dam' Construction Applied in the Described Case Studies

Step 1:

Select an appropriate site (dams should be constructed in a pattern of one dam per approximately 0.2 m of water table/ditch bottom gradient). Clean the ditch banks and excavate peat/mineral material in the ditch bed and slightly beyond: below the ditch bottom elevation determined at the design stage.

Step 2:

The material for the dam should be taken from a site adjacent to the ditch (e.g., within 5 m of the ditch bed). The top layer of dried peat (approximately 0.2) should be set aside and not used for dam construction. Peat from the deeper layers of the soil profile taken in the vicinity of the ditch bed should be placed in the created depression to the ordinate about 0.3–0.5 m higher than the ditch banks. A dam built perpendicular to the ditch bed should "extend" beyond the ditch bed for about two ditch widths on the right bank and two ditch widths on the left bank. This allows—in wet periods—the water to be diverted from the ditch into the peat bog area, increasing the effectiveness of the operation.

Step 3:

The ditch bed between constructed dams should be filled with surplus material taken for dam construction. The introduction of dried peat from the topsoil profile into the ditch should be avoided.

Step 4:

The banks of small waterbodies (ponds) created by the extraction of material for the construction of the dam should be profiled so that their slope does not impede the ingress (and egress) of amphibians and other animals.

Appendix C

Hydrographs

Kaldvassmyra

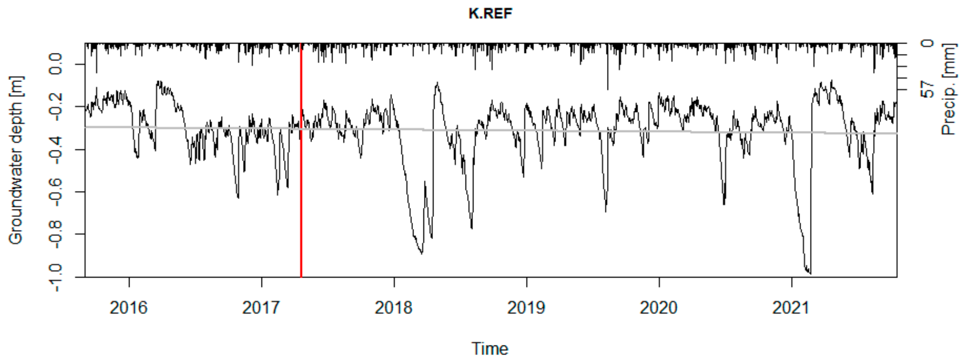

Figure A2. Groundwater depth and precipitation before and after rewetting in piezometer K.REF. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -0.0722695196313581 + -1.34471724148549 \times 10^{-5} \times x$.

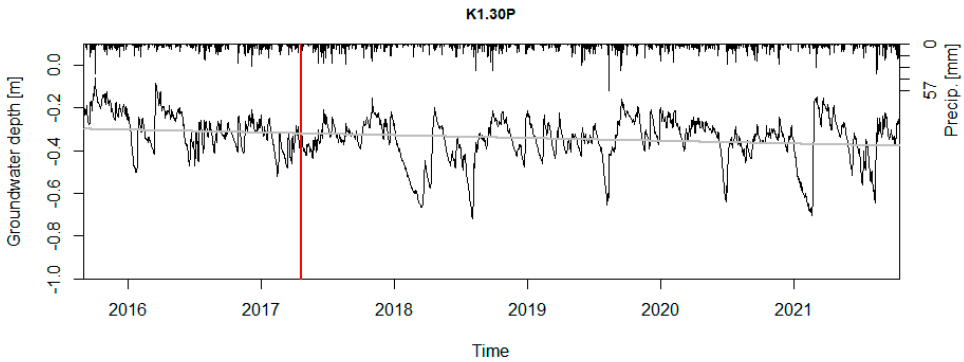

Figure A3. Groundwater depth and precipitation before and after rewetting in piezometer K1.30P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = 0.295372352980613 + -3.56069167565431 \times 10^{-5} \times x$.

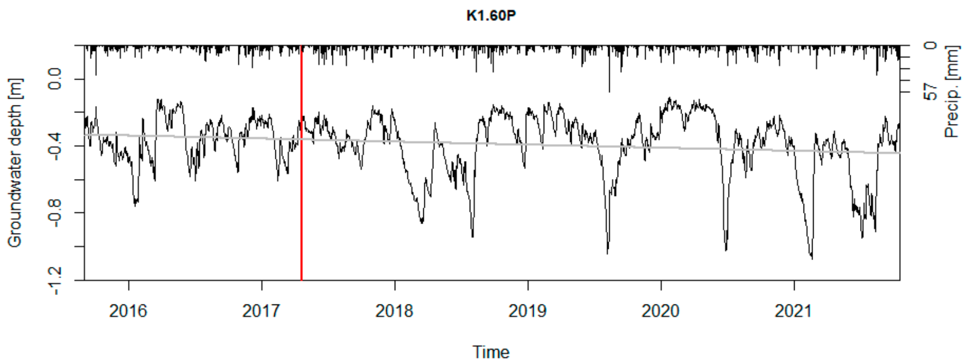

Figure A4. Groundwater depth and precipitation before and after rewetting in piezometer K1.60P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = 0.500276621282405 + -4.99935728099233 \times 10^{-5} \times x$.

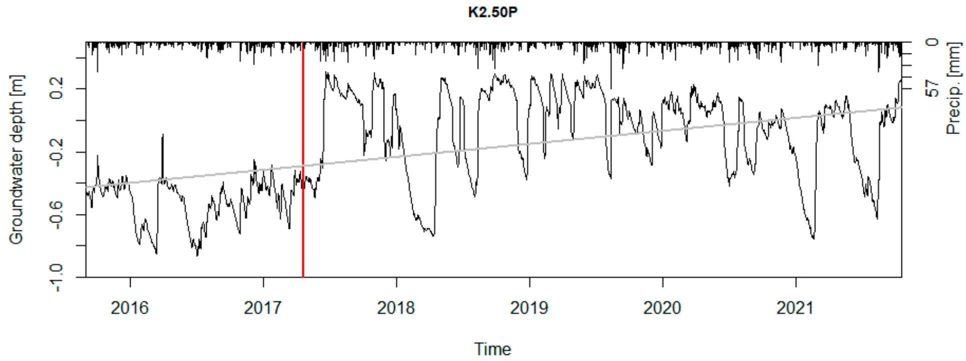

Figure A5. Groundwater depth and precipitation before and after rewetting in piezometer K2.50P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -4.21537097970746 + 0.000227020587660996 \times x$.

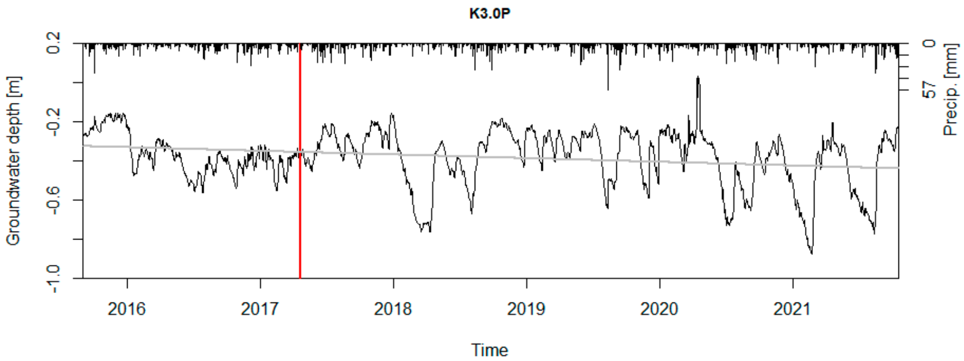

Figure A6. Groundwater depth and precipitation before and after rewetting in piezometer K3.0P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = 0.527673900033183 + -5.11983475251307 \times 10^{-5} \times x$.

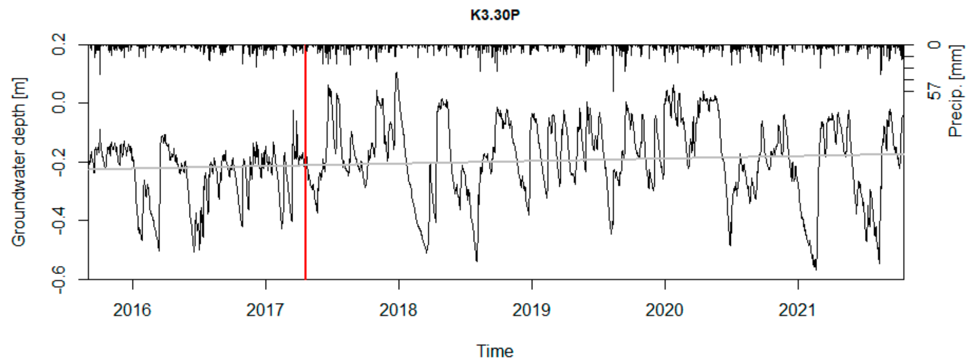

Figure A7. Groundwater depth and precipitation before and after rewetting in piezometer K3.30P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -0.617217750141572 + 2.34234704348353 \times 10^{-5} \times x$.

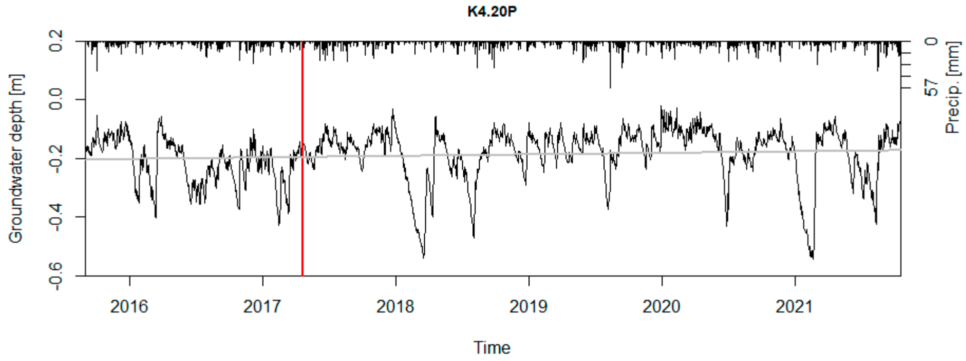

Figure A8. Groundwater depth and precipitation before and after rewetting in piezometer K4.20P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = $-0.438316010368798 + 1.40341469065934 \times 10^{-5} \times x$.

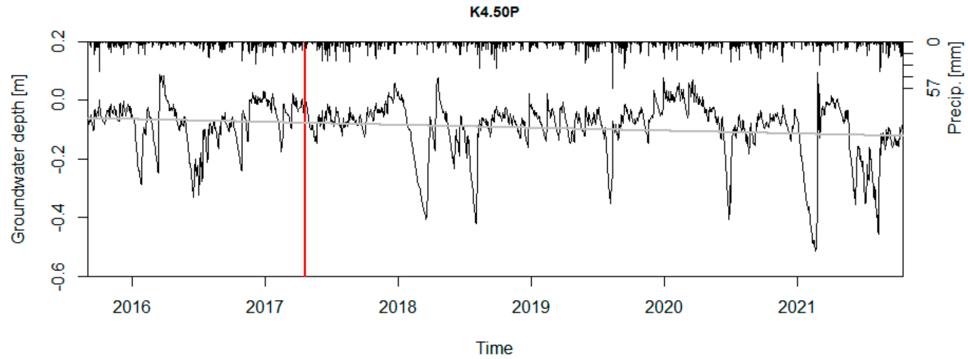

Figure A9. Groundwater depth and precipitation before and after rewetting in piezometer K4.50P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = $0.391328050472584 + -2.71376863007763 \times 10^{-5} \times x$.

Aurstadmåsan

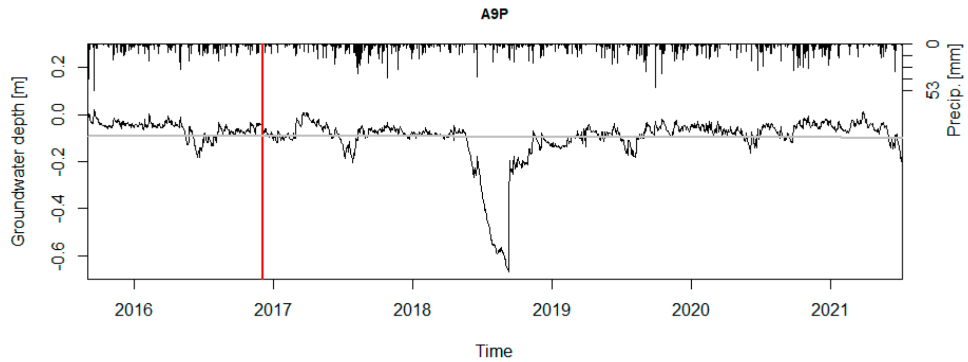

Figure A10. Groundwater depth and precipitation before and after rewetting in piezometer A9P (control piezometer). Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = $-0.016332267477855 + -4.4304690170292 \times 10^{-6} \times x$.

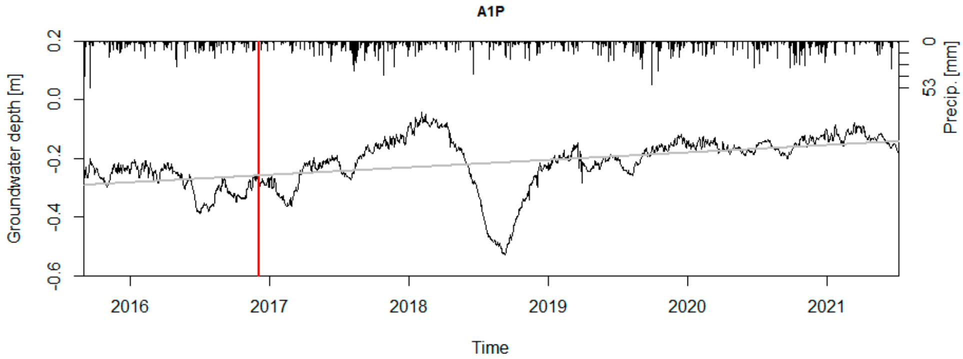

Figure A11. Groundwater depth and precipitation before and after rewetting in piezometer A1P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = −1.45232389277605 + 6.96421961149087 × 10^{-5} × x.

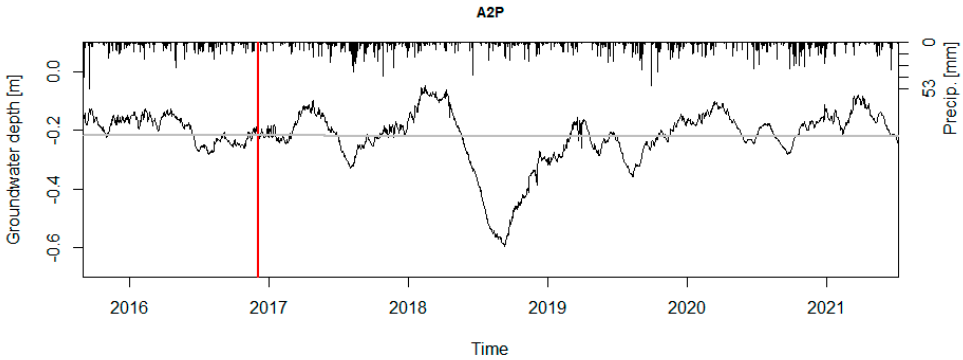

Figure A12. Groundwater depth and precipitation before and after rewetting in piezometer A2P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = −0.199593765095243 + −1.1320486546341 × 10^{-6} × x.

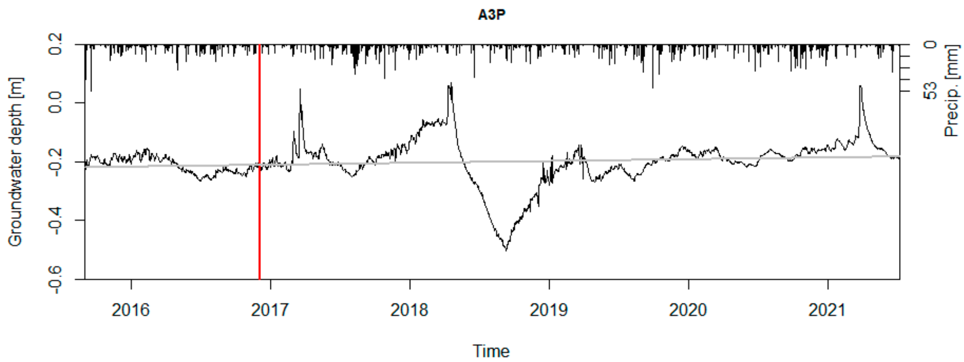

Figure A13. Groundwater depth and precipitation before and after rewetting in piezometer A3P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = −0.504720685205623 + 1.71058635569323 × 10^{-5} × x.

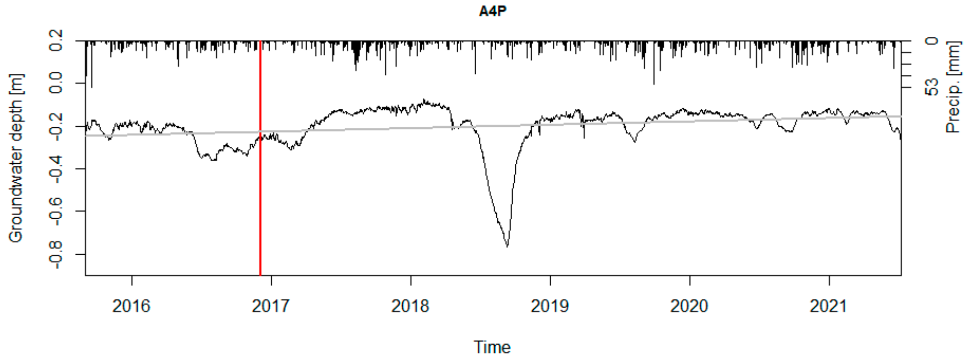

Figure A14. Groundwater depth and precipitation before and after rewetting in piezometer A4P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -0.97242567190085 + 4.34024429775599 \times 10^{-5} \times x$.

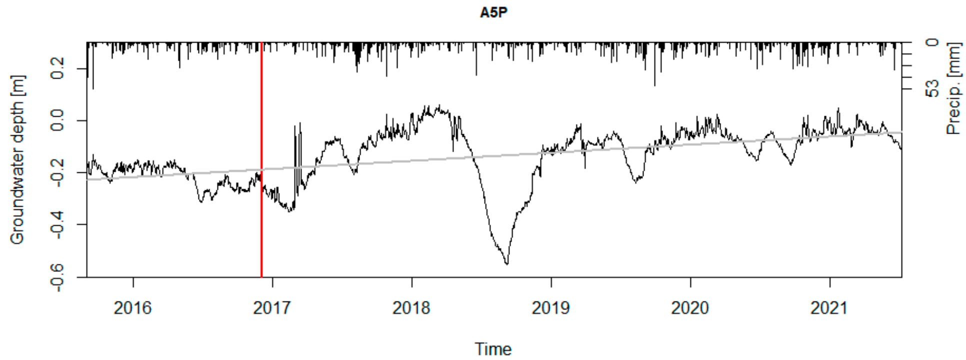

Figure A15. Groundwater depth and precipitation before and after rewetting in piezometer A5P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -1.64729627235141 + 8.50666940383836 \times 10^{-5} \times x$.

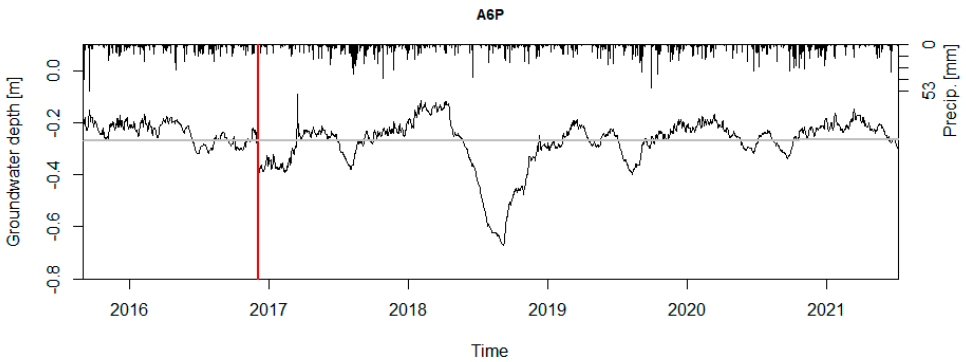

Figure A16. Groundwater depth and precipitation before and after rewetting in piezometer A6P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -0.305726611559842 + 2.07597152667249 \times 10^{-6} \times x$.

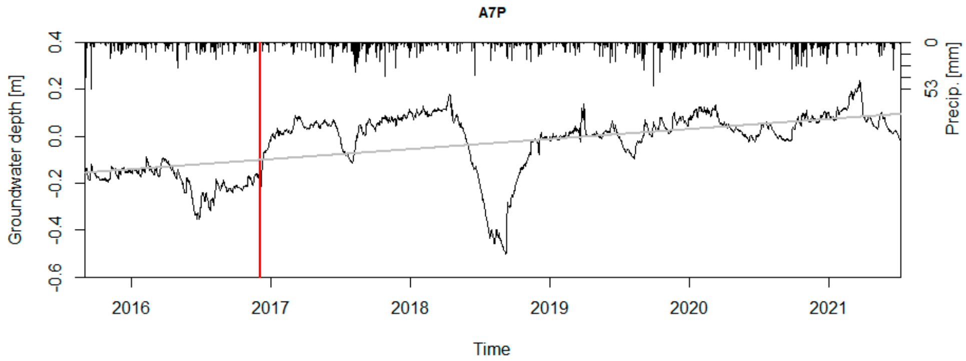

Figure A17. Groundwater depth and precipitation before and after rewetting in piezometer A7P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -2.10986538059255 + 0.000117160946097971 \times x$.

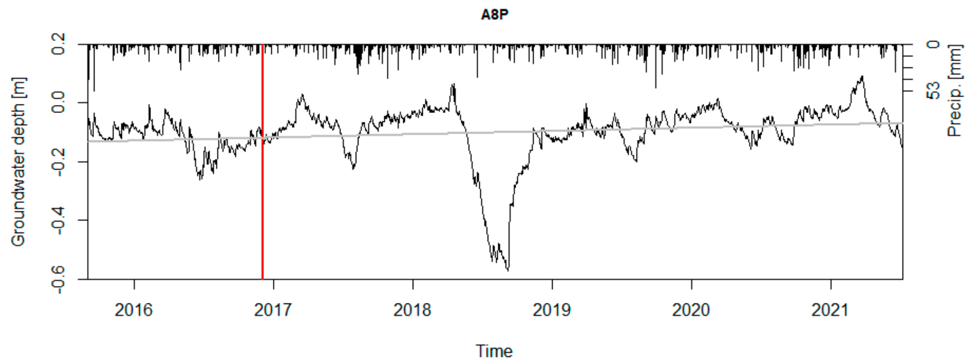

Figure A18. Groundwater depth and precipitation before and after rewetting in piezometer A8P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -0.634947112113461 + 3.00869747950434 \times 10^{-5} \times x$.

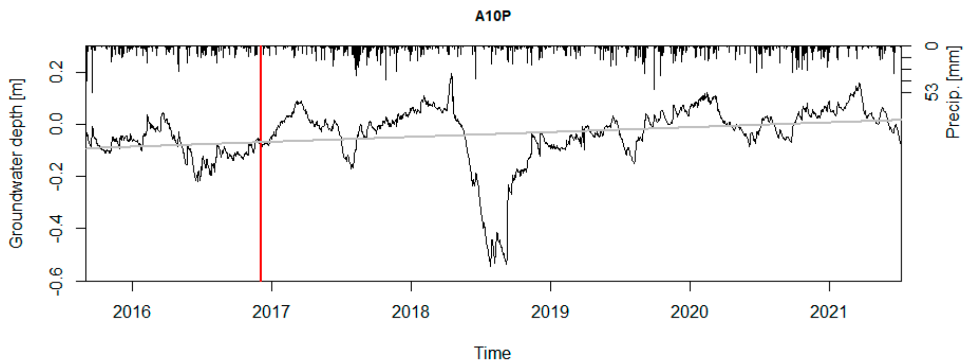

Figure A19. Groundwater depth and precipitation before and after rewetting in piezometer A10P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -0.941198521843798 + 5.08352721298071 \times 10^{-5} \times x$.

Midtfjellmåsan

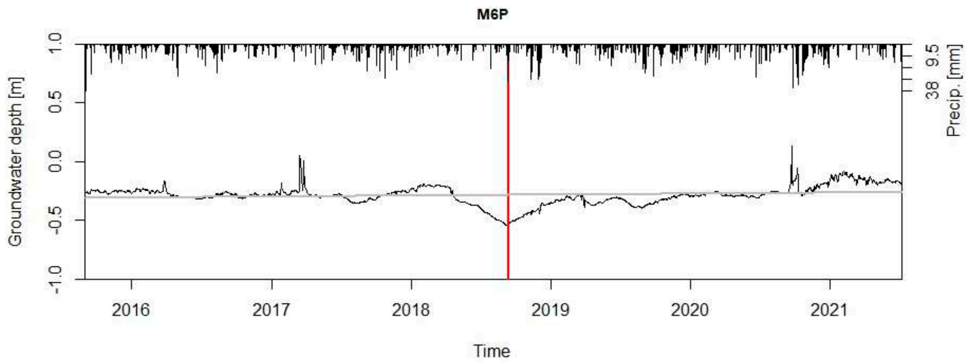

Figure A20. Groundwater depth and precipitation before and after rewetting in piezometer M6P (control piezometer). Red line represents the date of peat dam construction; gray line represents a trend line). Trend line equation: y = $-0.686592923503051 + 2.25822604941247 \times 10^{-5} \times x$.

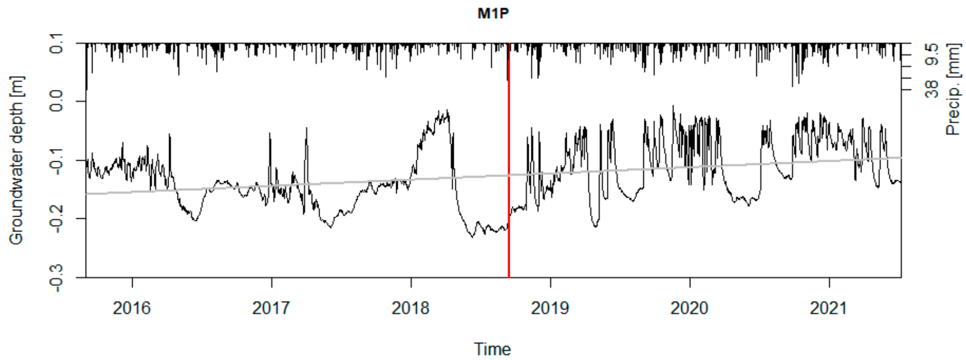

Figure A21. Groundwater depth and precipitation before and after rewetting in piezometer M1P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = $-0.644078444823363 + 2.91070802712557 \times 10^{-5} \times x$.

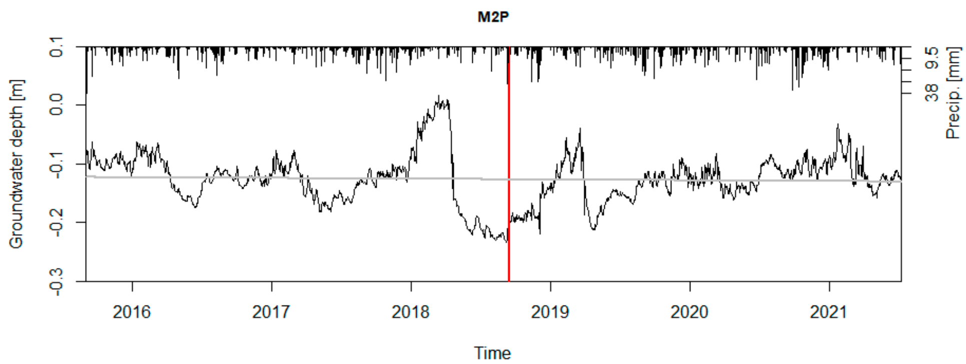

Figure A22. Groundwater depth and precipitation before and after rewetting in piezometer M2P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = $-0.0632860575727428 + -3.55878203137512 \times 10^{-6} \times x$.

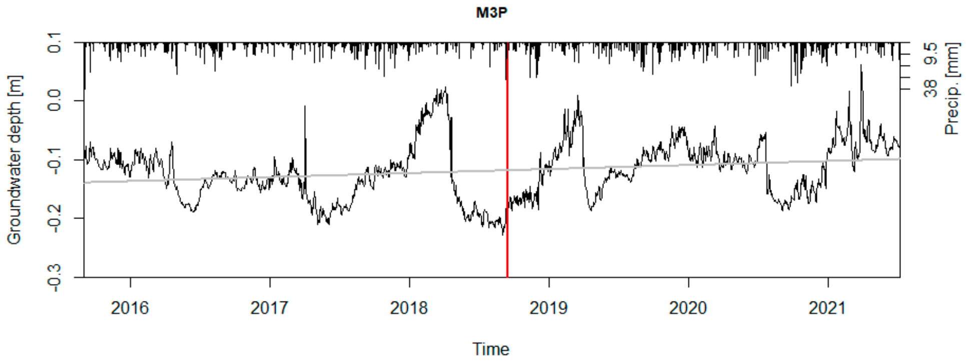

Figure A23. Groundwater depth and precipitation before and after rewetting in piezometer M3P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = −0.452081832899084 + 1.87555571383385 × 10^{-5} × x.

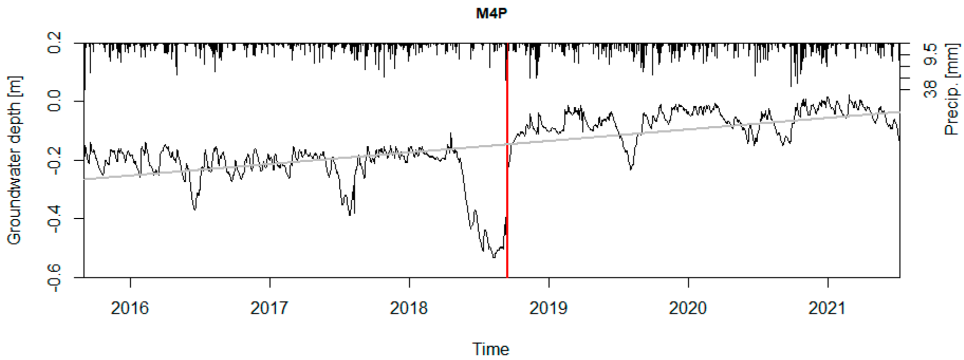

Figure A24. Groundwater depth and precipitation before and after rewetting in piezometer M4P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = −2.06541350159327 + 0.000107846578587073 × x.

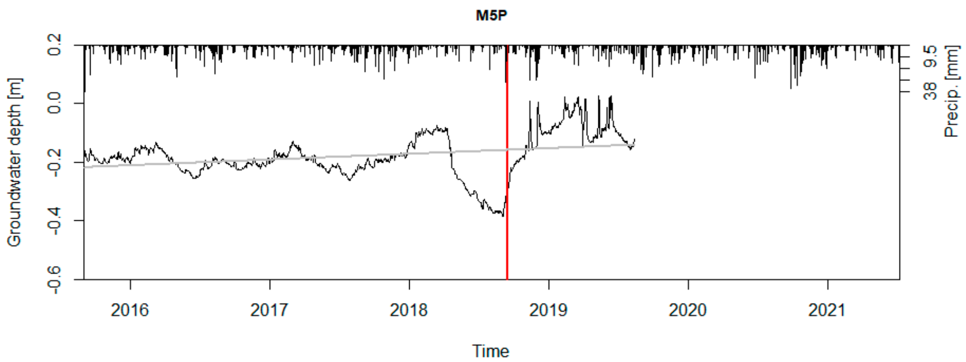

Figure A25. Groundwater depth and precipitation before and after rewetting in piezometer M5P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = −1.10483425625354 + 5.31894780911463 × 10^{-5} × x.

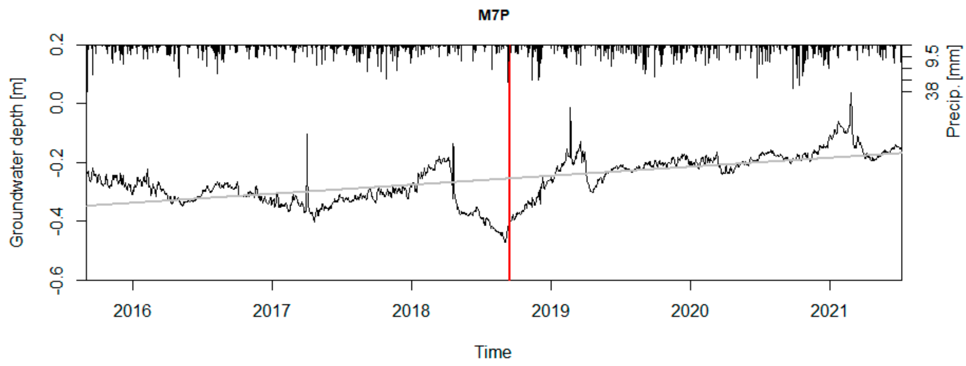

Figure A26. Groundwater depth and precipitation before and after rewetting in piezometer M7P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -1.74867144833594 + 8.39537419663912 \times 10^{-5} \times x$.

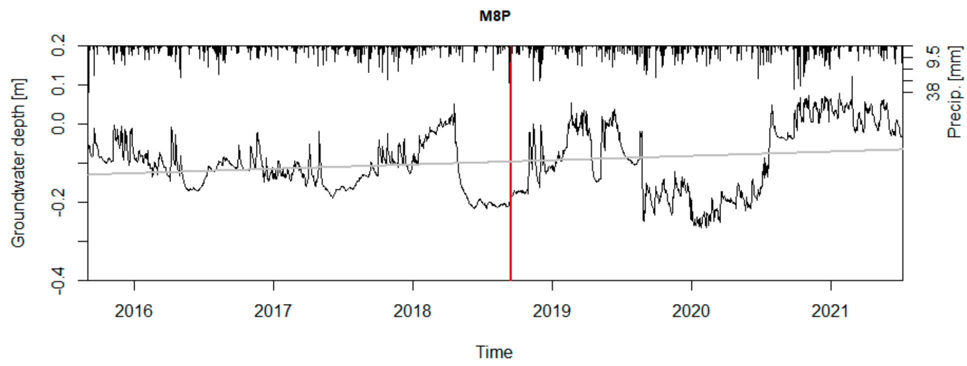

Figure A27. Groundwater depth and precipitation before and after rewetting in piezometer M8P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -0.632890216671114 + 3.01224454111323 \times 10^{-5} \times x$.

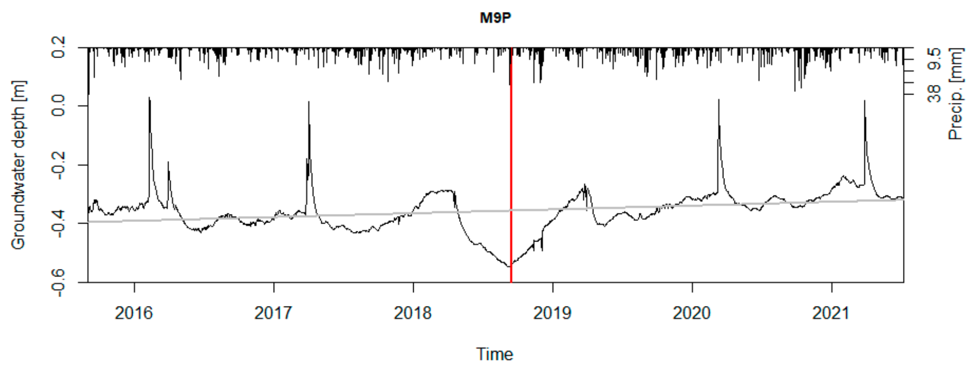

Figure A28. Groundwater depth and precipitation before and after rewetting in piezometer M9P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: $y = -0.990506727499476 + 3.56123765081276 \times 10^{-5} \times x$.

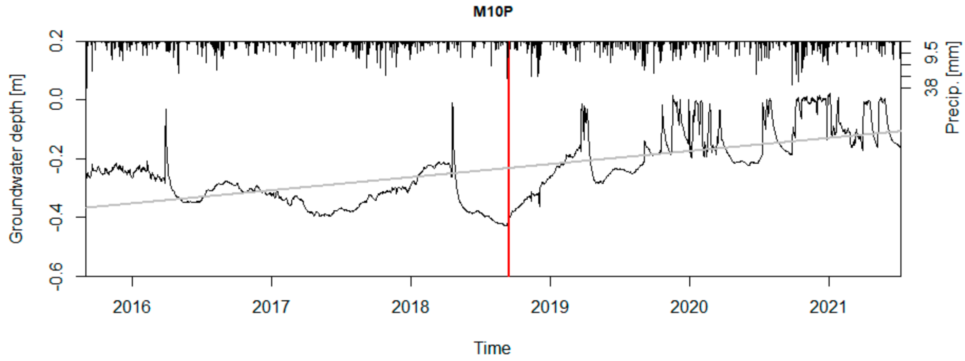

Figure A29. Groundwater depth and precipitation before and after rewetting in piezometer M10P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = −2.40381758748658 + 0.00012206384827724 × x.

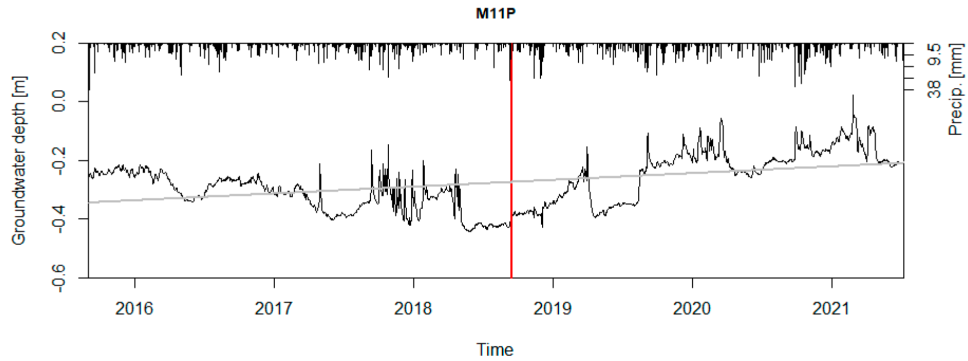

Figure A30. Groundwater depth and precipitation before and after rewetting in piezometer M11P. Red line represents the date of peat dam construction; gray line represents a trend line. Trend line equation: y = −1.40014199790285 + 6.32920737061399 × 10^{-5} × x.

Appendix D

Table A2. Groundwater tables at each piezometer before and after rewetting (minimum, maximum, mean and median), changes in average groundwater tables and distance of the piezometer from the ditch ('*' control piezometer).

Site	Piezometer	Groundwater Table [m]								Groundwater Table Change [m]	Distance from the Ditch [m]
		Min		Max		Mean		Median			
		Before	After	Before	After	Before	After	Before	After		
Kaldvassmyra	K.REF *	−0.63	−0.98	−0.08	−0.08	−0.29	−0.32	−0.29	−0.27	−0.03	42.0
	K1.30P	−0.52	−0.72	−0.06	−0.15	−0.29	−0.35	−0.29	−0.34	−0.06	26.5
	K1.60P	−0.76	−1.08	−0.12	−0.11	−0.36	−0.40	−0.35	−0.36	−0.04	9.0
	K2.50P	−0.87	−0.76	−0.09	0.31	−0.52	−0.05	−0.48	0.03	0.47	7.2
	K3.0P	−0.56	−0.88	−0.16	0.03	−0.37	−0.39	−0.38	−0.34	−0.02	53.7
	K3.30P	−0.51	−0.57	−0.02	0.11	−0.24	−0.18	−0.21	−0.18	0.06	17.7
	K4.20P	−0.43	−0.54	−0.05	−0.02	−0.21	−0.18	−0.20	−0.15	0.03	35.2
	K4.50P	−0.33	−0.52	0.09	0.09	−0.08	−0.10	−0.06	−0.07	−0.02	10.0
Aurstadmåsan	A9P *	−0.18	−0.67	0.02	0.01	−0.06	−0.10	−0.05	−0.08	−0.04	17.0
	A1P	−0.39	−0.53	−0.20	−0.04	−0.28	−0.20	−0.26	−0.18	0.08	7.2
	A2P	−0.28	−0.60	−0.13	−0.05	−0.19	−0.23	−0.18	−0.21	−0.03	11.0
	A3P	−0.26	−0.50	−0.15	0.07	−0.21	−0.20	−0.21	−0.19	0.01	13.0
	A4P	−0.36	−0.76	−0.17	−0.07	−0.25	−0.19	−0.23	−0.15	0.06	9.4
	A5P	−0.31	−0.55	−0.13	0.06	−0.21	−0.12	−0.20	−0.08	0.10	7.1
	A6P	−0.34	−0.67	−0.15	−0.09	−0.24	−0.28	−0.23	−0.25	−0.04	15.9
	A7P	−0.35	−0.50	−0.09	0.24	−0.19	0.01	−0.18	0.04	0.20	2.0
	A8P	−0.26	−0.57	−0.01	0.09	−0.12	−0.10	−0.11	−0.07	0.02	12.0
	A10P	−0.22	−0.54	0.05	0.20	−0.08	−0.03	−0.08	0.00	0.06	13.7

Table A2. *Cont.*

Site	Piezometer	Groundwater Table [m]								Groundwater Table Change [m]	Distance from the Ditch [m]
		Min		Max		Mean		Median			
		Before	After	Before	After	Before	After	Before	After		
Midtfjellmåsan	M6P *	−0.54	−0.52	0.05	0.13	−0.29	−0.28	−0.28	−0.29	0.01	150.0
	M1P	−0.23	−0.21	−0.01	−0.01	−0.15	−0.11	−0.15	−0.11	0.04	9.6
	M2P	−0.23	−0.22	0.02	−0.03	−0.12	−0.13	−0.12	−0.13	−0.01	19.9
	M3P	−0.23	−0.19	0.02	0.06	−0.13	−0.11	−0.13	−0.10	0.02	11.2
	M4P	−0.53	−0.24	−0.11	0.02	−0.23	−0.07	−0.20	−0.06	0.17	4.9
	M5P	−0.38	−0.29	−0.08	0.03	−0.20	−0.10	−0.20	−0.10	0.10	4.6
	M7P	−0.47	−0.40	−0.10	0.04	−0.31	−0.20	−0.31	−0.20	0.11	10.4
	M8P	−0.22	−0.27	0.05	0.12	−0.11	−0.08	−0.11	−0.08	0.03	15.6
	M9P	−0.55	−0.54	0.03	0.02	−0.38	−0.34	−0.38	−0.33	0.04	3.2
	M10P	−0.43	−0.40	−0.01	0.02	−0.31	−0.16	−0.31	−0.17	0.15	3.0
	M11P	−0.44	−0.43	−0.15	0.02	−0.32	−0.23	−0.31	−0.21	0.08	8.0

References

1. Williamson, J.; Rowe, E.; Reed, D.; Ruffino, L.; Jones, P.; Dolan, R.; Buckingham, H.; Norris, D.; Astbury, S.; Evans, C.D. Historical Peat Loss Explains Limited Short-Term Response of Drained Blanket Bogs to Rewetting. *J. Environ. Manag.* **2017**, *188*, 278–286. [CrossRef]
2. Urbanová, Z.; Bárta, J. Recovery of Methanogenic Community and Its Activity in Long-Term Drained Peatlands after Rewetting. *Ecol. Eng.* **2020**, *150*, 105852. [CrossRef]
3. Allan, J.M.; Guêné-Nanchen, M.; Rochefort, L.; Douglas, D.J.T.; Axmacher, J.C. Meta-analysis Reveals That Enhanced Practices Accelerate Vegetation Recovery during Peatland Restoration. *Restor. Ecol.* **2024**, *32*, e14015. [CrossRef]
4. Komulainen, V.-M.; Tuittila, E.-S.; Vasander, H.; Laine, J. Restoration of Drained Peatlands in Southern Finland: Initial Effects on Vegetation Change and CO_2 Balance. *J. Appl. Ecol.* **1999**, *36*, 634–648. [CrossRef]
5. Stachowicz, M.; Banaszuk, P.; Ghezelayagh, P.; Kamocki, A.; Mirosław-Świątek, D.; Grygoruk, M. Estimating Mean Groundwater Levels in Peatlands Using a Bayesian Belief Network Approach with Remote Sensing Data. *Sci. Rev. Eng. Environ. Sci.* **2024**, *33*, 329–351. [CrossRef]
6. Harris, L.I.; Roulet, N.T.; Moore, T.R. Drainage Reduces the Resilience of a Boreal Peatland. *Environ. Res. Commun.* **2020**, *2*, 065001. [CrossRef]
7. Yan, L.; Li, Y.; Zhang, X.; Wu, H.; Kang, E.; Yan, Z.; Zhang, K.; Li, M.; Yang, A.; Niu, Y.; et al. Carbon Fluxes of Alpine Peatlands Were Jointly Affected by Water Table Level Changes and the Duration. *J. Soils Sediments* **2023**, *23*, 3776–3786. [CrossRef]
8. Kim, J.; Rochefort, L.; Hogue-Hugron, S.; Alqulaiti, Z.; Dunn, C.; Pouliot, R.; Jones, T.G.; Freeman, C.; Kang, H. Water Table Fluctuation in Peatlands Facilitates Fungal Proliferation, Impedes *Sphagnum* Growth and Accelerates Decomposition. *Front. Earth. Sci.* **2021**, *8*, 579329. [CrossRef]
9. Rydin, H.; Jeglum, J.K. *The Biology of Peatlands*; Oxford University Press: Oxford, UK, 2013; ISBN 9780199602995.
10. Liu, H.; Gu, Y.; Ge, J.; Yu, Z.; Xu, X.; Zhang, Z.; Cheng, S.; Xie, S. The Response of the Dajiuhu Peatland Ecosystem to Hydrological Variations: Implications for Carbon Sequestration and Peatlands Conservation. *J. Hydrol.* **2022**, *612*, 128307. [CrossRef]
11. Wilson, D.; Mackin, F.; Tuovinen, J.; Moser, G.; Farrell, C.; Renou-Wilson, F. Carbon and Climate Implications of Rewetting a Raised Bog in Ireland. *Glob. Change Biol.* **2022**, *28*, 6349–6365. [CrossRef]
12. Landry, J.; Rochefort, L. *The Drainage of Peatlands: Impacts and Rewetting Techniques*; Laval Univeristy: Quebec, QC, Canada, 2012; pp. 1–62.
13. Haapalehto, T.; Juutinen, R.; Kareksela, S.; Kuitunen, M.; Tahvanainen, T.; Vuori, H.; Kotiaho, J.S. Recovery of Plant Communities after Ecological Restoration of Forestry-drained Peatlands. *Ecol. Evol.* **2017**, *7*, 7848–7858. [CrossRef]
14. Mander, Ü.; Espenberg, M.; Melling, L.; Kull, A. Peatland Restoration Pathways to Mitigate Greenhouse Gas Emissions and Retain Peat Carbon. *Biogeochemistry* **2023**, *167*, 523–543. [CrossRef]
15. Tanneberger, F.; Tegetmeyer, C.; Busse, S.; Barthelmes, A.; Shumka, S.; Mariné, A.M.; Jenderedjian, K.; Steiner, G.M.; Essl, F.; Etzold, J.; et al. The Peatland Map of Europe. *Mires Peat* **2017**, *19*, 1–17. [CrossRef]
16. Bryn, A.; Strand, G.-H.; Angeloff, M.; Rekdal, Y. Land Cover in Norway Based on an Area Frame Survey of Vegetation Types. *Nor. Geogr. Tidsskr.* **2018**, *72*, 131–145. [CrossRef]
17. Johansen, A. Myrarealer Og Torvressurser i Norge [Mire Area and Peat Resources in Norway]. *Jordforsk Rapp.* **1997**, *1*, 1–37. (In Norwegian)
18. Moen, A.; Lyngstad, A.; Øien, D.I. Country Chapters: Norway. In *Mires and Peatlands of Europe Status, Distribution and Conservation*; Joosten, H., Tanneberger, F., Moen, A., Eds.; Schweizerbart science publishers: Stuttgart, Germany, 2017; pp. 536–548.
19. Grønlund, A. Arealbruk Og Klimagasser [Land Use and Greenhouse Gases]. *Bioforsk Fokus* **2013**, *8*, 78–80. (In Norwegian)

20. Farstad, F.M.; Hermansen, E.A.T.; Grasbekk, B.S.; Brudevoll, K.; van Oort, B. Explaining Radical Policy Change: Norwegian Climate Policy and the Ban on Cultivating Peatlands. *Glob. Environ. Change* **2022**, *74*, 102517. [CrossRef]
21. Kløve, B.; Berglund, K.; Berglund, Ö.; Weldon, S.; Maljanen, M. Future Options for Cultivated Nordic Peat Soils: Can Land Management and Rewetting Control Greenhouse Gas Emissions? *Environ. Sci. Policy* **2017**, *69*, 85–93. [CrossRef]
22. Escobar, D.; Belyazid, S.; Manzoni, S. Back to the Future: Restoring Northern Drained Forested Peatlands for Climate Change Mitigation. *Front. Environ. Sci.* **2022**, *10*, 834371. [CrossRef]
23. Rowland, J.A.; Bracey, C.; Moore, J.L.; Cook, C.N.; Bragge, P.; Walsh, J.C. Effectiveness of Conservation Interventions Globally for Degraded Peatlands in Cool-Climate Regions. *Biol. Conserv.* **2021**, *263*, 109327. [CrossRef]
24. Tuohy, P.; O' Sullivan, L.; Bracken, C.J.; Fenton, O. Drainage Status of Grassland Peat Soils in Ireland: Extent, Efficacy and Implications for GHG Emissions and Rewetting Efforts. *J. Environ. Manag.* **2023**, *344*, 118391. [CrossRef] [PubMed]
25. Moen, A. *National Atlas of Norway: Vegetation*; Norwegian Mapping Authority: Hønefoss, Norway, 1999; 199p.
26. Moen, A. Myrundersøkelser i Nord-Trøndelag i Forbindelse Med Den Norske Myrreservatplanen [Mire Investigation in Nord-Trøndelag, a Report Prepared in Connection with the Norwegian National Plan for Mire Nature Reserves]. *K. norske Vidensk. Selsk. Mus. Rapp. Bot. Ser.* **1983**, *1*, 1–160.
27. Moen, A.; Singsaas, S. Excursion Guide for the 6th IMCG Field Symposium in Norway 1994. *Univ. Trondheim Vitensk mus. Rapp. Bot. Ser.* **1994**, *2*, 1–159.
28. Løsmasser (Ngu.No). Available online: https://geo.ngu.no/kart/losmasse_mobil/ (accessed on 24 November 2023).
29. Berggrunn (Ngu.No). Available online: https://geo.ngu.no/kart/berggrunn_mobil/ (accessed on 24 November 2023).
30. Norge i Bilder. Available online: https://www.norgeibilder.no/?id=3502 (accessed on 24 November 2023).
31. Grygoruk, M. *Hydrological Background of Bog Restoration in Norway: Case Studies of Aurstadmåsan, Kaldvassmyra and Midtfjellmåsan*; Miljødirektoratet Internal Report; Miljødirektoratet: Warsaw, Poland; Trondheim, Norway, 2015; 96p.
32. Seklima.Met.No. Available online: https://seklima.met.no/ (accessed on 29 September 2022).
33. Lyngstad, A.; Moen, A.; Øien, D.-I. Konsentrisk Høymyr, Våtmark. Norsk Rødliste for Naturtyper 2018. Artsdatabanken, Trondheim. 2018. Available online: https://artsdatabanken.no/RLN2018/147 (accessed on 23 November 2023).
34. Moen, A. Vurdering Av Noen Verneverdige Myrer i Østfold Og Akershus. Rapport Til Miljøverndepartementet. *K. norske Vidensk. Selsk. Mus. Trondheim.* 1976. Available online: https://www.ntnu.no/documents/10476/18307797/18+%C3%98stfold-Akershus+1976.pdf (accessed on 28 November 2023).
35. Lyngstad, A.; Vold, E.M. A Survey of Typical Raised Bog Using Aerial Photographs. Østfold County, Akershus County and the Southern Part of Hedmark County. *NTNU Vitenskapsmuseet Naturhist. Rapp.* **2015**, *3*, 1–367.
36. *Miljødirektoratet Plan for Restaurering Av Våtmark i Norge (2016–2020)*; Miljødirektoratet og Landbruksdirektoratet: Trondheim, Norway, 2016; 67p, Available online: https://www.miljodirektoratet.no/globalassets/publikasjoner/m644/m644.pdf (accessed on 22 November 2023).
37. *Miljødirektoratet Plan for Restaurering Av Våtmark i Norge (2021–2025)*; Miljødirektoratet: Trondheim, Norway, 2020; 70p. Available online: https://www.statsforvalteren.no/contentassets/7759cdee40734dd490491681d712f9e7/plan-for-restaurering-av-vatmark-i-norge-2021-2025.pdf (accessed on 22 November 2023).
38. Armstrong, A.; Holden, J.; Kay, P.; Foulger, M.; Gledhill, S.; McDonald, A.T.; Walker, A. Drain-Blocking Techniques on Blanket Peat: A Framework for Best Practice. *J. Environ. Manag.* **2009**, *90*, 3512–3519. [CrossRef] [PubMed]
39. Stachowicz, M.; Manton, M.; Abramchuk, M.; Banaszuk, P.; Jarašius, L.; Kamocki, A.; Povilaitis, A.; Samerkhanova, A.; Schäfer, A.; Sendžikaitė, J.; et al. To Store or to Drain—To Lose or to Gain? Rewetting Drained Peatlands as a Measure for Increasing Water Storage in the Transboundary Neman River Basin. *Sci. Total Environ.* **2022**, *829*, 154560. [CrossRef]
40. Agresti, A.; Kateri, M. *Foundations of Statistics for Data Scientists*; Chapman and Hall/CRC: Boca Raton, FL, USA, 2021; ISBN 9781003159834.
41. R Core Team. *R: A Language and Environment for Statistical Computing*; R. Foundation for Statistical Computing: Vienna, Austria, 2021; Available online: https://www.R-project.org/ (accessed on 29 March 2022).
42. Wickham, H. *Ggplot2: Elegant Graphics for Data Analysis*, 2nd ed.; Springer International Publishing: Berlin/Heidelberg, Germany, 2016.
43. Ruseckas, J.; Grigaliūnas, V. Effect of drain-blocking and meteorological factors on ground water table fluctuations in kamanos mire. *J. Environ. Eng. Landsc. Manag.* **2008**, *16*, 168–177. [CrossRef]
44. Urzainki, I.; Palviainen, M.; Hökkä, H.; Persch, S.; Chatellier, J.; Wang, O.; Mahardhitama, P.; Yudhista, R.; Laurén, A. A Process-Based Model for Quantifying the Effects of Canal Blocking on Water Table and CO_2 Emissions in Tropical Peatlands. *Biogeosciences* **2023**, *20*, 2099–2116. [CrossRef]
45. D'Acunha, B.; Lee, S.-C.; Johnson, M.S. Ecohydrological Responses to Rewetting of a Highly Impacted Raised Bog Ecosystem. *Ecohydrology* **2018**, *11*, e1922. [CrossRef]
46. Gaffney, P.P.J.; Hugron, S.; Jutras, S.; Marcoux, O.; Raymond, S.; Rochefort, L. Ecohydrological Change Following Rewetting of a Deep-drained Northern Raised Bog. *Ecohydrology* **2020**, *13*, e2210. [CrossRef]

47. Sorrell, B.K.; Partridge, T.R.; Clarkson, B.R.; Jackson, R.J.; Chagué-Goff, C.; Ekanayake, J.; Payne, J.; Gerbeaux, P.; Grainger, N.P.J. Soil and Vegetation Responses to Hydrological Manipulation in a Partially Drained Polje Fen in New Zealand. *Wetl. Ecol. Manag.* **2007**, *15*, 361–383. [CrossRef]
48. Howie, S.A.; Whitfield, P.H.; Hebda, R.J.; Munson, T.G.; Dakin, R.A.; Jeglum, J.K. Water Table and Vegetation Response to Ditch Blocking: Restoration of a Raised Bog in Southwestern British Columbia. *Can. Water Resour. J.* **2009**, *34*, 381–392. [CrossRef]
49. Bring, A.; Thorslund, J.; Rosén, L.; Tonderski, K.; Åberg, C.; Envall, I.; Laudon, H. Effects on Groundwater Storage of Restoring, Constructing or Draining Wetlands in Temperate and Boreal Climates: A Systematic Review. *Environ. Evid.* **2022**, *11*, 38. [CrossRef] [PubMed]
50. Putra, S.S.; Holden, J.; Baird, A.J. The Effects of Ditch Dams on Water-level Dynamics in Tropical Peatlands. *Hydrol. Process* **2021**, *35*, e14174. [CrossRef]
51. Konapala, G.; Mishra, A.K.; Wada, Y.; Mann, M.E. Climate Change Will Affect Global Water Availability through Compounding Changes in Seasonal Precipitation and Evaporation. *Nat. Commun.* **2020**, *11*, 3044. [CrossRef] [PubMed]
52. Bourgault, M.-A.; Larocque, M.; Garneau, M. How Do Hydrogeological Setting and Meteorological Conditions Influence Water Table Depth and Fluctuations in Ombrotrophic Peatlands? *J. Hydrol. X* **2019**, *4*, 100032. [CrossRef]
53. Glenk, K.; Faccioli, M.; Martin-Ortega, J.; Schulze, C.; Potts, J. The Opportunity Cost of Delaying Climate Action: Peatland Restoration and Resilience to Climate Change. *Glob. Environ. Change* **2021**, *70*, 102323. [CrossRef]
54. Planas-Clarke, A.M.; Chimner, R.A.; Hribljan, J.A.; Lilleskov, E.A.; Fuentealba, B. The Effect of Water Table Levels and Short-Term Ditch Restoration on Mountain Peatland Carbon Cycling in the Cordillera Blanca, Peru. *Wetl. Ecol. Manag.* **2020**, *28*, 51–69. [CrossRef]
55. Loisel, J.; Gallego-Sala, A. Ecological Resilience of Restored Peatlands to Climate Change. *Commun. Earth Environ.* **2022**, *3*, 208. [CrossRef]
56. Bielańska-Grajner, I.; Mieczan, T.; Cieplok, A. Ecology of Moss-Dwelling Rotifers in a Raised Bog: Differentiation of Rotifer Communities in Microhabitats. *Biologia* **2017**, *72*, 175–183. [CrossRef]
57. Karimi, S.; Maher Hasselquist, E.; Salimi, S.; Järveoja, J.; Laudon, H. Rewetting Impact on the Hydrological Function of a Drained Peatland in the Boreal Landscape. *J. Hydrol.* **2024**, *641*, 131729. [CrossRef]
58. Lanta, V.; Mach, J.; Holcová, V. The Effect of Dam Construction on the Restoration Succession of Spruce Mires in the Giant Mountains (Czech Republic). *Ann. Bot. Fenn.* **2006**, *43*, 260–268.
59. Menberu, M.W.; Tahvanainen, T.; Marttila, H.; Irannezhad, M.; Ronkanen, A.; Penttinen, J.; Kløve, B. Water-table-dependent Hydrological Changes Following Peatland Forestry Drainage and Restoration: Analysis of Restoration Success. *Water Resour. Res.* **2016**, *52*, 3742–3760. [CrossRef]
60. Koch, J.; Elsgaard, L.; Greve, M.H.; Gyldenkærne, S.; Hermansen, C.; Levin, G.; Wu, S.; Stisen, S. Water-Table-Driven Greenhouse Gas Emission Estimates Guide Peatland Restoration at National Scale. *Biogeosciences* **2023**, *20*, 2387–2403. [CrossRef]
61. Lamentowicz, M.; Gałka, M.; Marcisz, K.; Słowiński, M.; Kajukało-Drygalska, K.; Dayras, M.D.; Jassey, V.E.J. Unveiling Tipping Points in Long-Term Ecological Records from *Sphagnum*-Dominated Peatlands. *Biol. Lett.* **2019**, *15*, 20190043. [CrossRef]
62. Regan, S.; Swenson, M.; O'Connor, M.; Gill, L. *Ecohydrology, Greenhouse Gas Dynamics and Restoration Guidelines for Degraded Raised Bogs (EPA Research Report No. 342)*; Environmental Protection Agency, Johnstown Castle, Co.: Wexford, Ireland, 2020.
63. Kyrkjeeide, M.O.; Jokerud, M.; Mehlhoop, A.C.; Lunde, L.M.F.; Fandrem, M.; Lyngstad, A. Peatland Restoration in Norway—Evaluation of Ongoing Monitoring and Identification of Plant Indicators of Restoration Success. *Nord. J. Bot.* **2024**, e03988. [CrossRef]
64. Kreyling, J.; Tanneberger, F.; Jansen, F.; van der Linden, S.; Aggenbach, C.; Blüml, V.; Couwenberg, J.; Emsens, W.-J.; Joosten, H.; Klimkowska, A.; et al. Rewetting Does Not Return Drained Fen Peatlands to Their Old Selves. *Nat. Commun.* **2021**, *12*, 5693. [CrossRef]
65. Schaller, C.; Hofer, B.; Klemm, O. Greenhouse Gas Exchange of a NW German Peatland, 18 Years After Rewetting. *J. Geophys. Res. Biogeosci* **2022**, *127*. [CrossRef]
66. Schimelpfenig, D.W.; Cooper, D.J.; Chimner, R.A. Effectiveness of Ditch Blockage for Restoring Hydrologic and Soil Processes in Mountain Peatlands. *Restor. Ecol.* **2014**, *22*, 257–265. [CrossRef]
67. Page, S.E.; Baird, A.J. Peatlands and Global Change: Response and Resilience. *Annu. Rev. Environ. Resour.* **2016**, *41*, 35–57. [CrossRef]
68. Nordbakken, J.-F.; Halvorsen, R. Vegetasjonsutvikling På Nordre Del Av Rønnåsmyra Naturreservat (Grue, Hedmark) Etter Gjenfylling Av Grøfter (in Norwegian). In *Upubl. Notat til Fylkesmannen i i Hedmark, Miljøverna*; 2004; p. 10. Available online: https://www.nibio.no/publikasjoner?sok=%22gr%C3%83%C2%B8nn+kunnskap%22&page=3950 (accessed on 1 December 2024).
69. Hanssen-Bauer, I.; Førland, E.J.; Hadde-Land, I.; Hisdal, H.; Lawrence, D.; Maye, S.; Nesje, A.; Nilsen, J.E.Ø.; Sandven, S.; Sandø, A.B.; et al. *Climate in Norway 2100—A Knowledge Base for Climate Adaptation*; Norwegian Environment Agency (Miljødirektoratet): Trondheim, Norway, 2017; ISSN 2387.

70. Klimaservicesenter.No. Available online: https://klimaservicesenter.no/climateprojections (accessed on 16 November 2023).
71. Engen-Skaugen, T.; Haugen, J.E.; Tveito, O.E. Temperature Scenarios for Norway: From Regional to Local Scale. *Clim. Dyn.* **2007**, *29*, 441–453. [CrossRef]
72. Huo, R.; Li, L.; Engeland, K.; Xu, C.Y.; Chen, H.; Paasche, Ø.; Guo, S. Changing Flood Dynamics in Norway since the Last Millennium and to the End of the 21st Century. *J. Hydrol.* **2022**, *613*, 128331. [CrossRef]
73. Mayer, S.; Khasandi Kuya, E.; Antonsen, K.; Abegg, B.; Hanssen-Bauer, I. Warmer and Wetter: Outlining Climate Services for Snow-Dependent Tourism in Norway—The Case of Lofoten. *Clim. Serv.* **2023**, *32*, 100405. [CrossRef]
74. Bertrand, G.; Ponçot, A.; Pohl, B.; Lhosmot, A.; Steinmann, M.; Johannet, A.; Pinel, S.; Caldirak, H.; Artigue, G.; Binet, P.; et al. Statistical Hydrology for Evaluating Peatland Water Table Sensitivity to Simple Environmental Variables and Climate Changes Application to the Mid-Latitude/Altitude Frasne Peatland (Jura Mountains, France). *Sci. Total Environ.* **2021**, *754*, 141931. [CrossRef]