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From Haymaking to Wood Production: Past Use of Mires in Northern Sweden Affect Current Ecosystem Services and Function

Gudrun Norstedt*, Eliza Maher Hasselquist† and Hjalmar Laudon†

Mires form a large part of the boreal Swedish landscape and are important for biodiversity and natural ecosystem processes. Historically, mires also played a key role for the expansion of agricultural practices, and later to create new forest land, but knowledge is limited on how the land use has affected the current ecosystem services and functions of mires. In this case study from northern Sweden, we have combined historical maps with remote-sensing data to analyze the use of mires over time. Here, 22% of the mire area has been used for hay harvesting, an activity that peaked in the late 1800s. Later, about 3% was reclaimed for intensive agriculture. Drainage to enhance wood production followed in the 1940s, and about 40% of the original mire area is currently forested. The most productive mires have been relatively more affected by human measures. We suggest that this past land use has legacy effects on several ecosystem services. Haymaking likely had positive effects on biodiversity, but may have negatively influenced carbon sequestration. Reclamation led to habitat loss and likely less carbon sequestration. Drainage to promote forest growth generally lowered the ground water level, which in turn enhanced peat decomposition and subsequently released CO₂. However, if tree growth outpaces peat decomposition, drainage could increase carbon sequestration. The overall carbon balance is hence influenced by past management regimes, which implies that past human use must be taken into account when considering the role of mires in providing ecosystem services.

Keywords: cultural history; ditching; land use; legacy effects; mire meadows; mires

Introduction

Agricultural expansion and population growth in northern Sweden was largely based on the use of wetlands well into the 20th century (Bylund, 1956: 283; Campbell, 1982 [1948]: 172; Hellström, 1917: 510). The most important type of wetland in this context was the mire, defined as a wetland dominated by peat-forming plant communities and with a yearly production of wood biomass below 1 m³/ha (Nilsson et al., 2019). In northernmost Sweden, mires currently cover more than 25% of the otherwise forest-dominated land surface below the alpine mountain range (Nilsson et al., 2019). Thanks to their large water-holding capacity, peat content, open surfaces, and distinctive plant communities, mires play a key role for water regulation (Karlsen et al., 2016), carbon sequestration (Nilsson et al., 2008), biodiversity (Saarimaa et al., 2019), and cultural history (Elveland, 1983).

In most of northern Sweden, the indigenous Sami have been present for a long time. Reindeer herding is a

characteristic of both ancient and present Sami culture, and mires provide important grazing resources in summer and also open space for gathering reindeer (Blind et al., 2015; Warenberg, 1988). Mires are therefore core areas, especially for the practitioners of forest reindeer husbandry, who work all year round in the forest zone (Blind et al., 2015).

When it comes to the farming population, hay was historically the resource most commonly extracted from mires. Harvested fodder was, and still is, an absolute prerequisite for livestock's survival during the long period of snow cover, which lasts about half the year in northern Sweden (Laudon and Ottosson Löfvenius, 2016). Whereas uncultivated hay meadows in upland areas were important fodder resources in other parts of Europe (Frödin, 1940), including neighboring parts of Norway (Reinton, 1955), most of the fodder gathered in northern Sweden was provided by natural wetland meadows, often mires (Frödin, 1952; Kardell, 2018). This was the situation until cultivated grasslands became common in the early 1900s (Elveland, 1983). The yearly production of graminoids on the acidic mires that are common in northern Sweden may amount to around 50 g/m², whereas less acidic mires and those influenced by spring water may produce up to

* Umeå University, SE

† Swedish University of Agricultural Sciences, SE

Corresponding author: Gudrun Norstedt (gudrun@skogsfrun.se)

250 g/m² (Moen, 1976). In the coastal part of northern Sweden, practically all mires suitable for hay production were in use already in the beginning of the Middle Ages (Zackrisson, 1976a), and by the late 1800s, this was the case also in the interior (Bylund, 1956; Zackrisson, 1976b).

Because haymaking implies a substantial removal of biomass, it is believed to cause nutrient depletion (Frödin, 1952). In addition, the disturbance caused by mowing may induce a reduction in biomass (Moen, Lyngstad, and Øien, 2015). Therefore, it was common practice to harvest mire meadows only every second year (Frödin, 1952; Moen, Lyngstad, and Øien, 2015). By contrast, periodically flooded littoral meadows could be harvested every year. Inspired by this natural productivity boost, many farmers turned to artificial flooding of mires through either seasonal damming or installation of catchwork irrigation systems (Campbell, 1982 [1948]; Elveland, 1979). In Västerbotten County in northern Sweden, at least 10,000 ha of irrigated meadows were reportedly created between 1834 and 1860 (Frödin, 1952: 171).

More radical measures were both widely discussed and attempted in Sweden during the 1700s and 1800s (Strandin Pers, 2012). The population was growing, more arable land was desperately needed, and reclamation of mires seemed to be the obvious solution (Arrhenius, 1884). Despite the skepticism of some authors, influential scholars asserted that virtually all mires were potentially arable, if only they were ditched and fertilized (Hellström, 1917: 204; Osvald, 1937: 233; Strandin Pers, 2012: 128–132). In northern Sweden, mires were considered to be particularly suitable for the production of animal fodder such as oat, turnips, and hay, enabling the keeping of even more livestock and thus the production of more manure to fertilize fields on mineral soils (Bosin, 1901). Ditching of mires was also believed to prevent frost damage on nearby arable land (Hellström, 1917: 36–41). In the 1840s, the Swedish government therefore introduced subsidies for ditching projects (Hellström, 1917: 222). Between 1841 and 1914, subsidies funded more than 1,500 such projects in Västerbotten County, leading to the creation of more than 138,000 ha of drained land (Hellström, 1917: 223). Similar payments continued well into the 1930s (Bunte, Borgegård, and Gaunitz, 1982: 199).

During the 1800s, forestry became a growing industry, and some large landowners believed that trees could be produced on almost any mire if only it was properly ditched (Kempe, 1909). Forest ditching became a common practice during the first half of the 1900s, periodically subsidized by the state to mitigate unemployment (Eliasson, 2008). According to the Swedish Wetland Survey, between 25% and 90% of the larger wetlands in Västerbotten County (depending on municipality) have been subjected to ditching for either agricultural or silvicultural purposes (Forslund, Löfroth, and Rundlöf Forslund, 1994). Ditching to increase tree growth was much more common and also continued longer, because marginal arable lands began to be abandoned around 1920 (Hånell, 1990). In 1986, new legislation introduced permitting requirements for drainage of new wetlands for silvicultural purposes, leading to an almost complete abandonment of this activity (Hånell, 1990).

Finally, mires have been used for extraction of peat. During the late 1800s, it became common practice in northern Sweden to use dried peat as beddings in stalls (Hellström, 1917). Later, the peat extraction industry developed for both energy production and soil amendment in parts of Sweden. This type of industrial-scale extraction is totally destructive for mires. Only relatively small areas have been exploited, however. In 2002, there were about 20 permits for peat extraction in Västerbotten County, covering about 5,000 ha, but only one active peat pit (Länsstyrelsen Västerbotten, 2008).

Today, all hay is produced in fertilized fields, new ditching has essentially stopped, and peat extraction is minor. Mires are no longer considered to be assets for the rural population but are classified as 'unproductive land' (Nilsson et al., 2019). At the same time, mires are increasingly in focus as providers of ecosystem services for climate change mitigation, most importantly biodiversity, water regulation, and carbon sequestration (Joosten, 2015). To take full advantage of these services, mire dynamics must be understood, including a thorough knowledge of the long-lasting effects of former land use. However, our knowledge of the cumulative extent of such land use is limited. Here, we explore in detail the use of mires in a village territory in northern Sweden through an interdisciplinary combination of sources. We aim to identify the various types of land use, quantify the proportion of mires concerned, establish a timeline of impact, and discuss possible legacy effects. By doing so, we lay down a basis for further analyses of the dynamics of northern Swedish mires and their capacities for providing ecosystem services in a landscape marked by climate change.

Materials and Methods

Study area

The study area covers 1,839 ha in Vindelns Municipality, Västerbotten County, northern Sweden (**Figure 1**). It corresponds to the territory of the village of Abborrtjärn as it was defined through the procedure of enclosure (sw. 'laga skifte') in 1880 (see Sources section below). Almost all of the study area is included in the Krycklan Catchment, a research infrastructure for state-of-the-art hydrological, biogeochemical, and ecological studies (Laudon et al., 2013).

Today, the study area consists of about 89% forest, 5% open mires, 3% arable land, and 3% water (Lantmäteriet, 2020b). When it comes to mires, the area is located in the southern subregion of the northern fen region, which covers most of northern Sweden and is characterized by relatively high humidity, a short growing season, abundant snow cover, and high groundwater tables (Joosten, Tanneberger, and Moen, 2017). According to data from the Swedish Wetland Survey, which covered all mires larger than 50 ha, the mires of the study area are mostly topogenous or soligenous fens, although northern bogs also make up a significant part (CAB Västerbotten, unpublished data). These are also the most common mire types in the subregion as a whole (Gunnarsson and Löfroth, 2014).

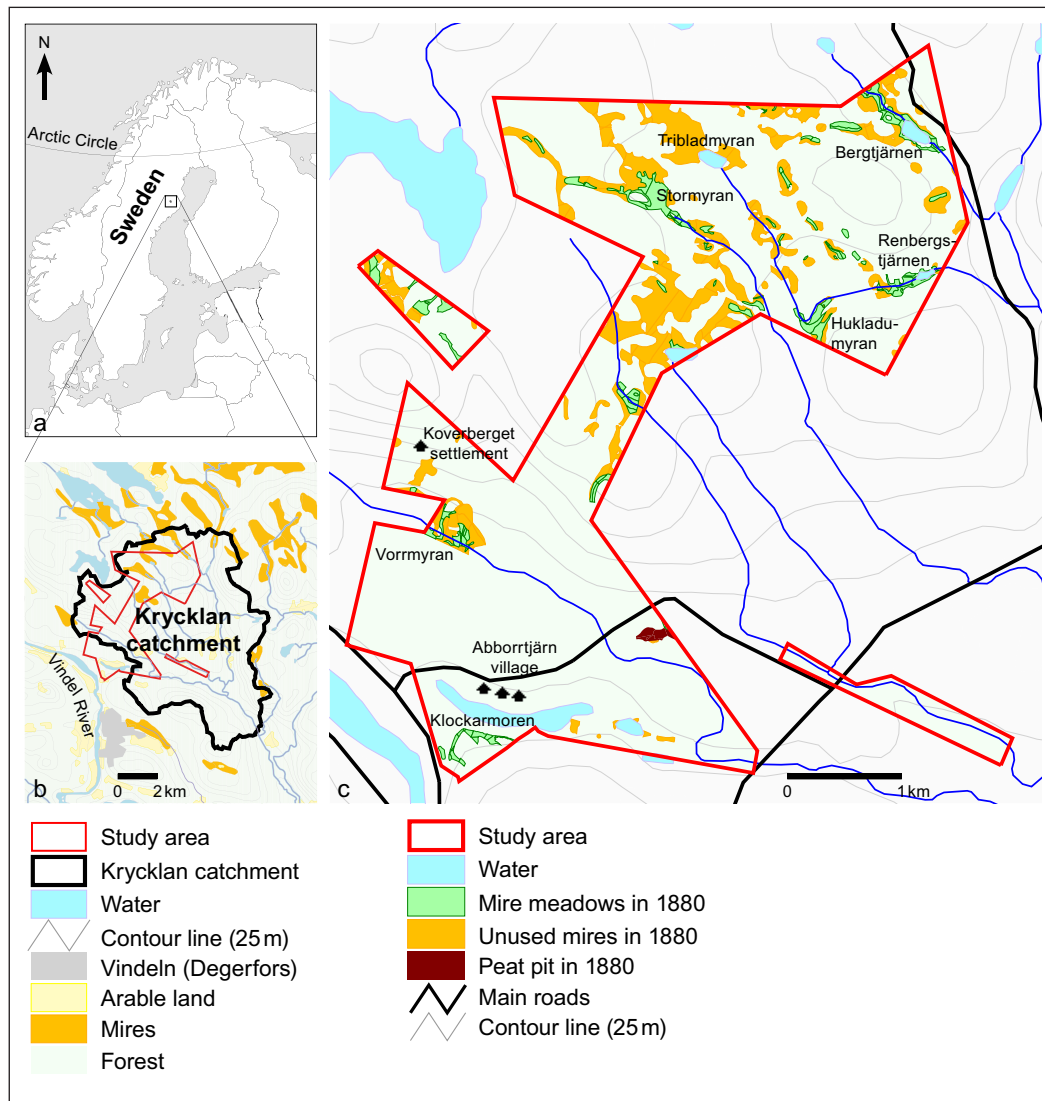


Figure 1: Study area. The area is located in northern Sweden (a), within the Krycklan Catchment (b). It corresponds to the village territory of Abborrtjärn as it was defined in 1880 (c). Included in map c are the polygons digitized by us for the study, i.e., mire meadows, a peat pit and unused mires marked on the map from 1880, the sum of which we have defined as the total mire area.

From a cultural perspective, the study area belongs to the inner part of the coastland of Västerbotten County. Before farmers settled, it is probable that indigenous Sami controlled the area and possibly also used the mires for grazing reindeer, but next to nothing is known of this early history (Norstedt and Laudon, 2019). The first scattered farming settlements were established along the Vindel River during the Middle Ages. The population then remained relatively stable until the mid-1700s, when a number of new settlements were created in the forest lands farther from the river (Bunte, Borgegård, and Gaunitz, 1982). The village in the focus of our study, Abborrtjärn, was one of these new settlements, established in 1778. Until then, the study area had been part of the zone of interest of the neighboring medieval village Degerfors (nowadays known as Vindel) (Bunte, Borgegård, and Gaunitz, 1982; Egerblad, 1972). Although agriculture remained the foundation of the region's economy well into the 1900s, forestry became more and more important during the late 1800s, and the building of the railroad around 1890 stimulated various kinds of trade (Bunte,

Borgegård, and Gaunitz, 1982). Today, only 9% of the population of Vindel Municipality work in agriculture or forestry, whereas most people are in the manufacturing industry or in the public sector (Företagarna, 2020).

Sources

We have consulted a number of sources: 1) all historical maps we could find from both Abborrtjärn and surrounding villages, dating from the early 1700s to the 1920s (Lantmäteriet, 2020a); 2) ditching maps and plans, created for state-subsidized ditching projects in the late 1800s and early 1900s; 3) reports from the Swedish Roads and Waters Agency, which were published as a part of Sweden's Official Statistics around the turn of the 20th century and provide information on the reclamation of mires performed each year (Väg- och vattenbyggnadsstyrelsen, 1872–1910); 4) forestry maps from 1941 that contained information on forestry measures, including ditches, established by the forest company Sandviks Ångsågs AB and covering about half of the study area, which had been acquired by the company; 5) the archives of the Umeå Timber Floating

Association (Umeå flottningsförening), which contain information on dams and other installations; 6) aerial photos from 1963 and 2013; and finally 7) a LiDAR derived DTM from 2015.

The single most important source was the *enclosure* (sw. 'laga skifte') *map of Abborrtjärn* from 1880 (**Figure 2c**), which we used to define the study area. It was drawn to equitably share the village common land among

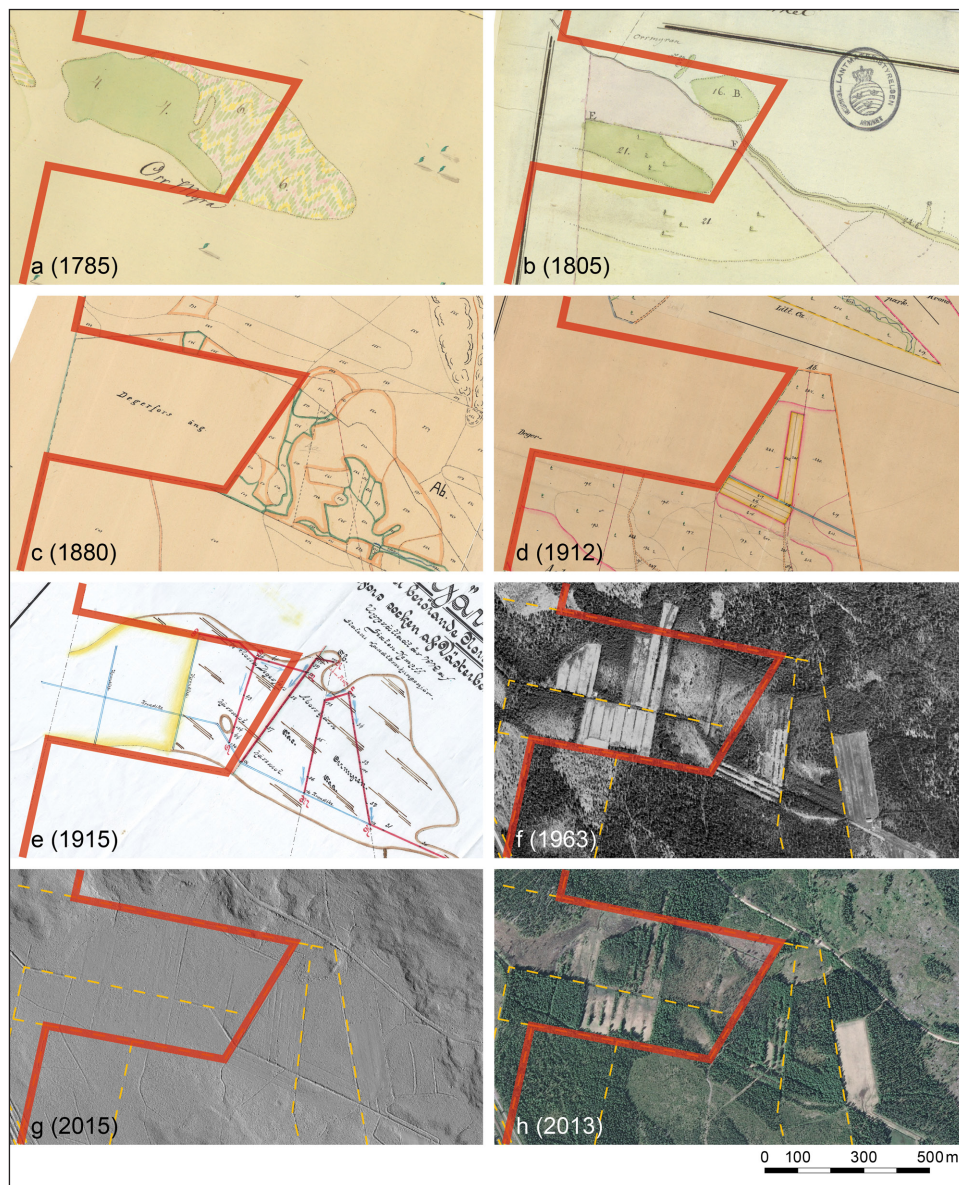


Figure 2: Some of the sources. A collection of maps and remote-sensing images used in the study. All images show the same area, Vormmyran (Figure 1). The red line is the outer limit of the study area, which lies east of the line. **a)** Delineation map of Degerfors village (1785). The western part of Vormmyran was then used as a meadow by farmers from Degerfors (green area). The multicolor part labeled with the number '6' was unused mire. **b)** Taxation map of Abborrtjärn village (1805). The meadows marked on Vormmyran on this map do not comply with the ones marked on other maps. According to our interpretation, the mire meadows marked here were located outside the study area. **c)** Enclosure map of Abborrtjärn (1880). The part already claimed by farmers from Degerfors was not included in Abborrtjärn village and thus not in our study area. Areas delimited by green lines are mire meadows, those in orange lines are unused mires. **d)** Cadastral map for the division of a farmstead in Abborrtjärn village (1912). The map shows a large central ditch through the mire, which had probably been dug during the large state-financed project that concerned both Abborrtjärn and several other neighboring villages a couple of years earlier. Also, the irregular meadows have been changed into rectangular fields. **e)** Ditching plan for Vormmyran (1915). All ditches were created according to the plan, and at some point connecting ditches were added along the narrow fields that were created. **f)** Aerial photo from 1963, showing both arable land still in use and fields that have been abandoned and where brush and forest is growing back. Current property boundaries have been added as orange dashed lines to this and the following two images. **g)** Digital terrain model (DTM) with a 0.5×0.5 m grid, derived from a LiDAR flight from 2015. All ditches are clearly visible. **h)** Aerial photo from 2013, showing the continued overgrowth of abandoned fields, and the only field still in use (in the far right of the photo). © Lantmäteriet.

the owners, and therefore shows the entire area divided into a large number of polygons which were classified as mire, meadow, forest, and so on. Each polygon was marked on the map and described in a table containing information on area and a grade representing value, by us interpreted as productivity. The grading was relative, with the most valuable land classified as grade 1 and less valuable land as proportionally higher numbers up to 100.

As for older conditions, the first map that gives any substantial information is the *geometrical and geographic map of Degerfors* from 1702, where land use is sketched and the amount of hay produced on different kinds of land is noted. The study area is included in the geographical part of the map, which gives an overview of the area around the village but does not include detailed measurements of the study area. Then follows the *delineation map of Degerfors* from 1785 (**Figure 2a**), drawn to establish the borders between Crown land and village land, but also showing fields, natural meadows, and other important resources claimed by the villagers, as well as a selection of unused mires. About 40% of the study area was included in this map. The first document focusing on our study area, the *taxation map of Abborrtjärn*, is from 1805 (**Figure 2b**), where the new village was formally recognized. Here, all units of arable land and meadows were assessed and graded according to an elaborate method (Björck, 1851: 531–533). For each meadow, a drawing was provided as well as the area and an estimated yield in weight. The area covered by this map was much smaller than the study area, but almost all of the mire meadows of the 1805 map were also included in the enclosure map from 1880.

To explore more recent conditions, we used data sets gathered for other studies with modern remote-sensing methods and made available through the Krycklan Catchment. Land cover in 1963 (**Figure 2f**) and 2013 (**Figure 2h**) had been classified from *aerial photographs* by a well-trained analyst from the Swedish National Forest Inventory (NFI), who defined polygons and classified them into standard land classes (Hasselquist et al., 2019). Also, most of the ditches of the area had been mapped and quantified using a 0.5×0.5 m *digital terrain model* (DTM) derived from a LiDAR flight from 2015 (Hasselquist et al., 2018). In both cases, the existing data sets were reused, but also slightly expanded with more data from the same sources because a small part of the study area had not been covered by the previous studies.

Definitions

It is common practice to divide mires into bogs and fens, bogs receiving water only from precipitation and therefore being extremely nutrient-poor, whereas fens receive water that has been in contact with mineral soil and therefore has a higher content of minerals (Gunnarsson and Löfroth, 2014). However, as our study is based on both historical sources and current land-cover classification where this distinction is not followed, we have chosen to treat mires as one entity.

The entire study area had been mapped in great detail during the process of enclosure in 1880, so that map was used to define the *total mire area* of the study as the sum of all unused mires, mire meadows, and peat pits. Unused

mires were delimited with orange lines on the map (**Figure 2c**), and in the tables they were usually classified as 'myra', sometimes as 'mosse', 'myrsly', 'myrländig', 'myrhals' or any of a few other Swedish terms for different kinds of mires. Mire meadows were not as easily defined, because all kinds of meadows were delimited with green lines on the map and called 'äng'. Therefore, we distinguished mire meadows from meadows on mineral soil through their location. Usually this was evident from the map tables, where mire meadows were located inside areas with names ending with '-myran' (i.e., 'the mire' in the form typical of the dialects of northern Sweden). However, there were a few cases where such labels were absent, thus, we judged these as mire meadows or not based on their appearance on both historical and modern maps, as well as on aerial photographs. As for the peat pit, only one such area existed, and it was delimited by an orange line and unequivocally labeled 'peat and moss pit' (sw. 'torf och måssetag') on the map, and 'mire pit' (sw. 'myrtag') in the tables.

As to the other maps used in the study, the definition of mires and mire meadows was straightforward. On the map from 1702, each mire meadow was noted as 'myrewald' in the table, whereas a few other mires were roughly outlined on the map. The 1785 map contained two classes of mire; first the mire meadows, described as 'meadows rendering sparse and less rewarding sedge hay on swampy and wet mires' (sw. 'slåtter gifva glest och mindre bördigt starrhö på sanko och våtländta myror'), second, the unused mires, 'bogs, partly treeless, partly with small pine trees' (sw. 'måssar dels skoglöse dels med små tall beväxte'). In the map from 1805, hay harvested from mires was clearly defined as 'mire hay' (sw. 'myrhö'), and the related areas were represented as drawings showing mires, so the classification was usually simple. The only ambiguity regarding the 1805 map was the borderline between mire meadows and meadows alongside creeks, because the latter were not included in this study. However, these issues could be solved through a careful consideration of the map's descriptions and drawings.

Mire areas

The maps from 1785 (**Figure 2a**), 1805 (**Figure 2b**) and 1880 (**Figure 2c**) were scanned and then georeferenced using GIS software (ArcView 3.3 with Image Analysis) (the map from 1702 was excluded as it clearly did not include any mires in the study area). From the 1785 map, mire meadows and unused mires inside and adjacent to the study area were digitized, but when we saw that none of the mire meadows were located inside the study area, the data was not treated any further. The map from 1805 did not lend itself to georeferencing, because the mire meadows were rarely shown in their geographical locations. Regardless, all of the mire meadows on the 1805 map could be identified from their names and shapes, and the area of each meadow was given in the map tables, so the area of the mire meadows located inside the study area was simply summed from this information. From the georeferenced 1880 map, all mires—mire meadows, peat pits, and unused mires—were digitized manually into polygons, and the area of each one was calculated using GIS.

Overall productivity of mires

The detailed relative grading included in the map tables from 1880 was used to assess the proportion of mire meadows and unused mires of different productivity and to explore whether there was any difference between the two types of mire.

Furthermore, we tried to identify management efforts undertaken to increase the productivity of mire meadows through a comparison of the 25 meadows that were listed in both 1805 and 1880. Because the 1805 data consisted of absolute yield assessments whereas the gradings from 1880 were relative to each other, the two data sets could not be compared directly, so we created rankings. For 1805, a yield in kg/ha was calculated for each meadow, and we then ranked meadows relative to each other. For 1880, the ranking was produced directly from the relative grades. We then compared the two rankings and identified the meadows that had raised at least 10 rank positions between 1805 and 1880, assuming that such a large change might be an indication of increased productivity due to active management.

As artificial irrigation through flooding was a common way of increasing the productivity of mire meadows, the archives of the Timber Floating Association were searched for information on dams used for this purpose. We also looked for records or signs of catchwork irrigation systems in all available sources.

Reclamation of mires

We searched available literature for information on the reclamation of mires, including the *reports from the Swedish Roads and Waters Agency (Väg- och vattenbyggnadsstyrelsen, 1872–1910)*. In those reports, we found data concerning Abborrtjärn village in the reports from 1898–1903. Also, among the historical maps available from Abborrtjärn village (Lantmäteriet, 2020a) we found a *cadastral map* from 1912 (**Figure 2d**), established for the division of a property, which showed a portion of a mire that had been reclaimed as arable land. Furthermore, we searched the archives of the County Administrative Board of Västerbotten for *ditching maps and plans*, created for state-subsidized ditching projects for agricultural purposes, and evaluated the ones concerning mires in the study area, dating from 1915–1933 (**Figure 2e**).

As we did not know if the archival sources covered all reclaimed mires, we assessed what proportion of the total mire area had been converted to arable land using the existing data set on land cover in 1963 obtained from aerial photos (**Figure 2f**). Because the abandonment of arable land in the municipality began in the early 1950s (Bunte, Borgegård, and Gaunitz, 1982: 300), the land that was no longer used could be expected to be distinguishable on these aerial photographs. We selected all polygons classified as 'arable and pasture land', or found in another land class but with a note of 'former arable land', and then used GIS to clip the areas which overlapped with the total mire area as defined from the map from 1880. We could then calculate the total area of reclaimed mires and thus the proportion of the total mire area that had become arable land.

Ditch impact

The existing data set on ditches, obtained from the DTM, was classified according to purpose (road ditches were excluded). Ditches included in plans aimed at the creation of arable land or at frost prevention, or concerning areas appearing as present or former arable land on the aerial photographs from 1963, were classified as having been dug for agricultural purposes. The rest were classified as ditches aimed at the enhancement of forest production.

The ditch data set was then clipped with the polygons representing the total mire area, using GIS. The length of ditches was summed according to purpose. The same data set was used to analyze how much of the total mire area may still be influenced by ditches. Previously, Marcotte et al. (2008) showed significant impacts on groundwater levels on organic soils up to 60 m from ditches; therefore we used GIS to create a 60 m buffer around all ditches in the data set, representing the area potentially affected. We then clipped the affected area with the polygons representing the total mire area to see what parts of the mires were likely to be affected. Finally, we used the grading from the 1880 map tables to calculate what proportion of mires of different grades were included in the areas likely to be affected by ditching.

Unlike the ditches made to reclaim mires for agricultural purposes, no plans have been found for the ditches made for the purpose of increasing tree growth. However, most of the silvicultural ditches in the study area are located on land that was acquired by the forest company Sandviks Ångsågs AB. Therefore, the company's forestry maps from 1941, which typically show existing ditches, were used as a means to approximately date those ditches.

Long-term land-class changes

The existing data set on land cover in 2013, obtained from aerial photos (**Figure 2h**), was used to estimate the proportion of the total mire area that today is arable land or forest. We selected all polygons classified as 'arable and pasture land' or 'forest land' and then used the GIS software to clip the areas which coincided with the total mire area from 1880. In this way, we assessed the proportion of the total mire area that has undergone long-term land-class change.

Results

Total mire area

The original total mire area, defined as the sum of all polygons classified as 'mire', 'mire meadow', or 'peat pit' on the enclosure map of Abborrtjärn village from 1880, was 273 ha or 15% of the study area. Mire meadows covered 60 ha (22% of the total mire area), and the peat pit 3.3 ha (about 1%), while the rest (77%) is labeled as unused mire in this paper.

Proportion of mires used as meadows

According to the map from 1702, the farmers of Degerfors were using a number of nearby mire meadows but had not yet extended their impact into our study area. In 1785, the impact had become more widespread and included a mire partly located in the study area (Vorrmyran) (**Figures 1 and 2**). About 40% of Vorrmyran was used as a meadow in

1785 (**Figure 2a**), but because the managed part belonged to Degerfors, it was excluded from the village territory of Abborrtjärn when it was defined in 1880 (**Figure 2c**) and is therefore also excluded from our study area. In other words, we have no indications that any part of the mires in the study area was used for a particular purpose during the 1700s, although human activities were clearly increasing in the surroundings.

In 1805, the village of Abborrtjärn used mire meadows covering about 30 ha, of which 27 ha were inside our study area. Of the latter, a little more than 3 ha was classified as 'land to be cleared' (sw. 'röjningsland') and about 2.5 ha partly so, which means that they were not yet managed as meadows. However, as all of these areas were included in the evaluation on which taxes were based, we assume that they were prepared soon after 1805, and we have included them in the mire meadow area of that year, corresponding to 10% of the total mire area. In 1880, the area of mire meadows used by farmers in Abborrtjärn had grown to 60 ha, or 22% of the total mire area (**Figure 3**).

Overall productivity of mires

When the productivity of mire meadows and unused mires was compared, as graded in 1880, we found that mire meadows had grades from 1 (=best grade) to 50 (median 11.5), whereas unused mires had grades from 8 to 100 (median 50) (**Figures 4 and 5**). There were thus both considerable differences and considerable overlap

between used and unused mires. Meadows with good grades represented very small areas, whereas most unused mires were considered to be of low value and covered much larger areas. When the mire-meadow area peaked in the late 1800s, all of the best-grade and most medium-grade mires were being routinely harvested (**Figure 4**).

Increased productivity of mire meadows

When we compared the rankings of the 25 mire meadows that were classified in both 1805 and 1880, four meadows had risen 10 positions or more, suggesting that some measures had been taken to enhance their productivity. In only one case, however, do we have a record of this, namely Klockarmoren, which went from the second-lowest position in 1805 to the absolute top in 1880. Although nothing is said in the official documentation, local tradition has it that Klockarmoren was illegally reclaimed in the early 1800s by a farmer from a neighboring village (Anon., 2015), and today it is arable land. Assuming active human intervention, such as fertilization, as the cause of the increased productivity of all four abovementioned meadows, the area affected would be around 4.5 ha, or less than 2% of the total mire area.

Artificial irrigation

We found no traces of catchwork irrigation systems in the study area, but we identified two cases where the mire meadow area had been increased through artificial flooding. The records from the timber floating association

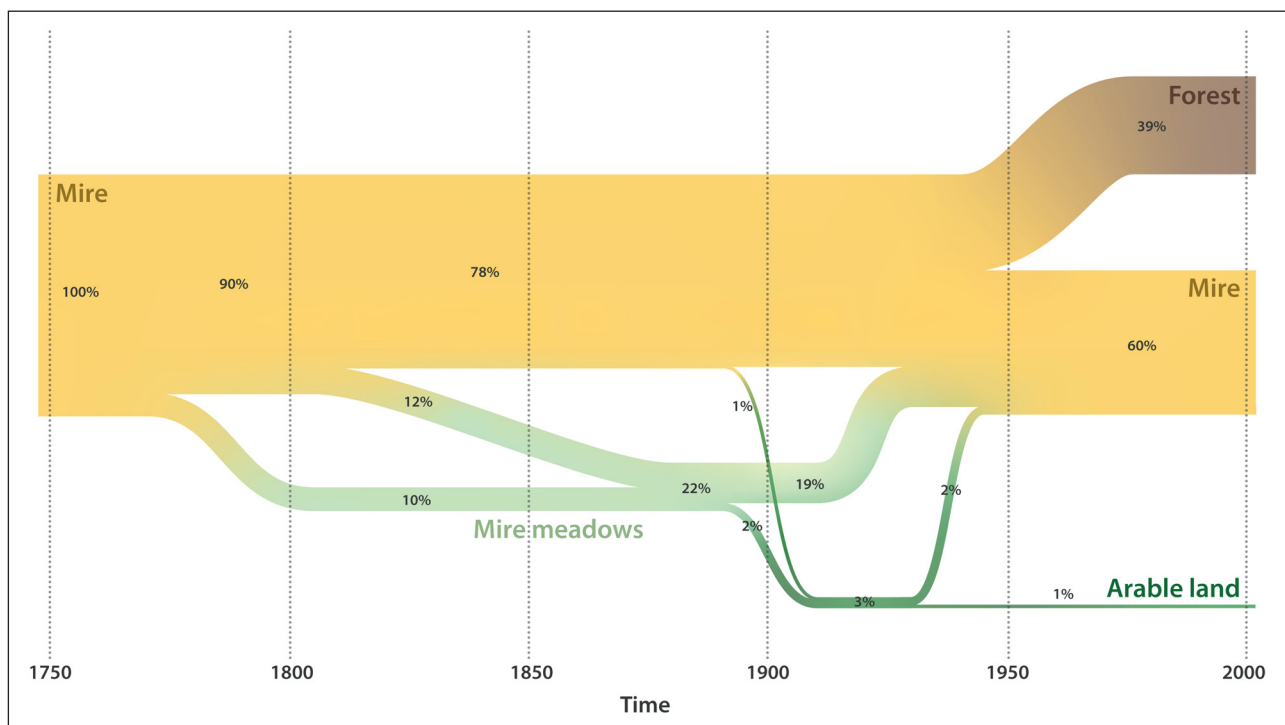


Figure 3: Mire use through time. The figure shows the development in Abborrtjärn village, Västerbotten County, from the late 1700s onwards. Until the late 1800s, haymaking concerned 22% of the mire area after which a portion of both mire meadows and unused mires were reclaimed as arable land, corresponding to 3% of the original total mire area. All of the mire meadows and most of the arable land were then abandoned and reverted to mires. Only 1% of the total mire area is cultivated today. In the 1940s and '50s, mires were ditched to increase wood production, and about 39% of the total mire area is currently forested. The '60%' number of the current mire area includes 1% of open water surface. Illustration: J. Lokrantz/Azote.

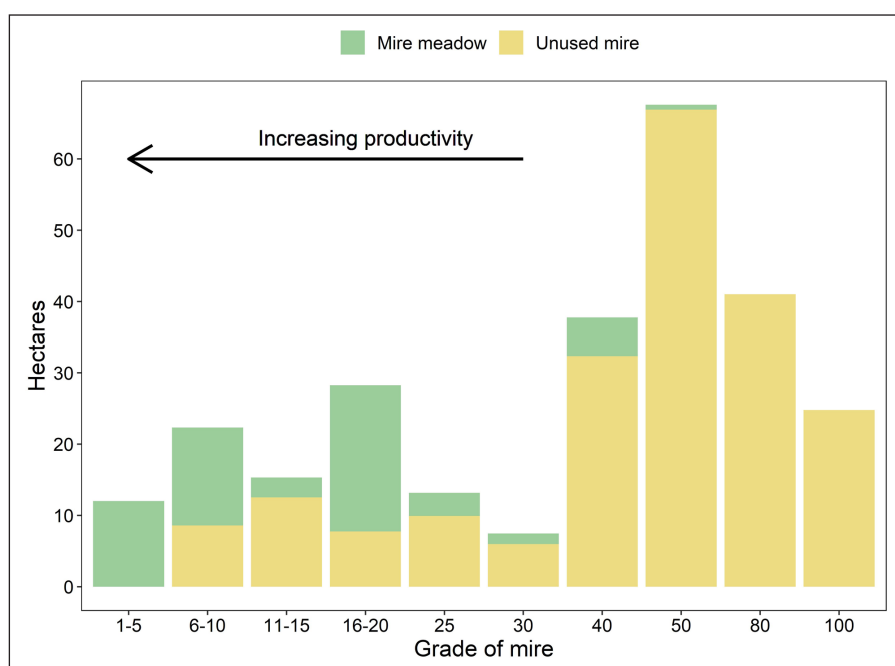


Figure 4: Area of mires of different productivity. In the enclosure documentation from 1880, all mire meadow and unused mire were graded according to productivity. Grade 1 was assigned to the most highly valued meadows, whereas higher grades represented relatively less productive meadows. Because the better (i.e., lower) grades are more detailed than the less productive (i.e., higher) grades, the former have been summed into classes.



Figure 5: Different mires types in the study area. See Figure 1 for locations. **a)** Former mire meadow of grade 4, i.e., among the very best (Hukladumyr). The ground vegetation is currently mostly dominated by *Carex rostrata* together with *C. magellanica* and *C. pauciflora*, as well as *Eriophorum angustifolium*, *Comarum palustre*, and *Menyanthes trifoliata* in wetter parts. The surface is slowly being colonized by *Betula* and *Salix*. *Carex rostrata* and *Menyanthes trifoliata* were among the most highly valued fodder species, and *Eriophorum angustifolium* was also considered to be good (Frödin, 1952). **b)** Former mire meadow of grade 16, the most common grade but on the less productive side of the median (Stormyr). The mire is dominated by *Carex lasiocarpa* with some *Molinia caerulea* and *Trichophorum alpinum*. In wetter parts, *Menyanthes trifoliata* is found. Small bushes of *Betula* and *Salix* are growing into the mire. *Carex lasiocarpa* and *Trichophorum alpinum* were among the most highly valued fodder species, and *Molinia caerulea* was considered to be fairly good (Frödin, 1952). **c)** Former mire meadow of grade 20 (Stormyr, NW part). The vegetation is dominated by *Eriophorum vaginatum* and *Carex pauciflora* with patches of *Carex rostrata*. **d)** Unused mire of grade 50 (Tribladumyr). *Calluna vulgaris* is common and *Cladonia* lichens grow on drier tussocks. This photo was taken in June, when the vegetation was still poorly developed, whereas the other photographs are from August. Photos: G. Norstedt.

state that two dams existed in 1864, when timber floating was just beginning. Both of these dams were located at the outlet of lakes surrounded by mire meadows, Bergtjärnen and Renbergstjärnen. A comparison of the maps from 1805 and 1880 shows that the meadow area increased from 0.3 to 7.9 ha around Bergtjärnen and from 0.3 to 4.7 ha around Renbergstjärnen. The map from 1805 does not contain any data on unused mires, so we do not know whether the increased meadow areas were gained from forest or from mire. If we assume the latter, the conclusion would be that about 12 ha of mires, or 4%, were converted into meadows through artificial flooding. Later, damming was mainly adapted to the needs of timber floating. The dam at Renbergstjärnen was abandoned in 1935 and the one at Bergtjärnen in 1967, when timber floating ceased (Archives of Umeå flottningsförening).

Reclamation of mires

As previously mentioned, the mire meadow Klockarmoren is said to have been illegally reclaimed already in the early 1800s (Anon., 2015). It eventually became arable land, and is one of the very few former mire meadows that is currently cultivated. There is a central ditch through the field, and possibly also covered ditches. However, we do not know what measures were taken to reclaim the area during the 1800s; it was still classified as a mire meadow in 1880, with irregular shape, and does not appear in any official documentation on ditching projects. Another early reclamation project was connected to a new settlement, Koverberget, which was established in 1886 on land belonging to Abborrtjärn village, but which is now abandoned (Larsson, 1988). The DTM reveals that there are ditches, probably dug around that time, along the former fields of the settlement, and most of these ditches concern areas that were in 1880 classified as 'mire'. This small-scale, private initiative was followed around 1900 by a large state-financed project to prevent frost damage in Abborrtjärn and several neighboring villages (Väg- och vattenbyggnadsstyrelsen, 1872–1910). The cadastral map from 1912 shows a large central ditch through Vorrmyran (**Figure 2d**), which was probably a result of that project. In 1915, another ditching plan was established for Vorrmyran (**Figure 2e**), and at some point before 1963 connecting ditches were dug along the narrow fields that were created (**Figure 2f**). In 1919, a ditch plan to prevent frost damage was made for another mire, Hukladumyran. Although the plan was realized, it was never followed by cultivation. The analysis of the aerial photos from 1963 shows that these ditching projects, together with the abovementioned reclamation of Klockarmoren, led to the creation of about 9 ha of arable land from 6 ha of mire meadows and 3 ha of unused mires, corresponding to about 3% of the total mire area.

The mires chosen for reclamation were among the more productive ones, especially the ones that were ultimately cultivated. Klockarmoren had probably already been concerned by some measures before 1880, when the meadows of the site were classified as best grades, 1–1.2. The largest well-known ditching project, Vorrmyran, drained mire meadows with grades 1.5–8 and formerly unused mires with grades 10–20. At Koverberget, the

reclamation transformed two formerly unused mires of grade 12. By contrast, the ditching of Hukladumyran, which never lead to cultivation, drained mire meadows with grades 4–16 and unused mires with grades 50–100.

Ditch impact

The analysis of the DTM shows that there are currently almost 39 km of ditches in the study area, road ditches excluded. About 40%, or about 15 km, run through the total mire area as defined from the 1880 map. Most of the ditches affecting mires, about two thirds, were dug to enhance wood production, whereas the rest were for agricultural purposes.

Most ditches dug for agriculture are well documented and can be dated almost to the year, but we have not been able to date the ditches dug for silvicultural reasons. Forestry maps of Sandviks Ångsågs AB from the region generally show both ditches and the year they were dug, but on the maps covering Abborrtjärn, drawn in 1941, ditches are absent. We therefore assume that forest ditching in the study area generally took place after that year.

The buffer analysis showed that about 106 ha of the total mire area, or 39%, is located within 60 m from ditches and therefore likely to be affected by past drainage activity. A larger proportion of productive mires, that is, mires with good grades, have been affected by ditches than less productive mires, mires with poor grades (**Figure 6**).

Long-term land-class changes

The 273 ha that made up the total mire area in 1880 had become reduced to 161 ha (59%) by 2013. The remainder is currently 106 ha forest (39%), 3.4 ha arable land (1.2%) and 2.7 ha water (1%) (**Figure 3**).

Discussion

Legacy effects

The various types of past management that we identified and quantified have affected essentially all of the ecosystem services provided by mires in the study area. The mires were used almost exclusively for haymaking starting in the late 1700s and ultimately reaching 22% in the late 1800s, after which they were abandoned and mostly left to slowly and passively recover. Thereafter, the effects of water regulation dominated—partly through dams that flooded some areas to enhance hay production and later extend the timber-floating season, but mostly through the use of drainage ditches to promote agriculture and later forest growth. Approximately 40% of the mires in our study area have permanently been converted to forest or arable land through drainage over the time frame of our study. These 300 years of management have legacy effects for the region's biodiversity, water regulation, and carbon (C) sequestration (Elveland, 1983; Karlsen et al., 2016; Saarimaa et al., 2019).

At least two aspects of mire management have likely had mostly positive impacts on biodiversity: haymaking and seasonal flooding via damming. First, previous research has revealed that haymaking simplified the habitat structure, as all tussocks and shrubs were obstacles for scythes and the mires were therefore usually cleaned before the first

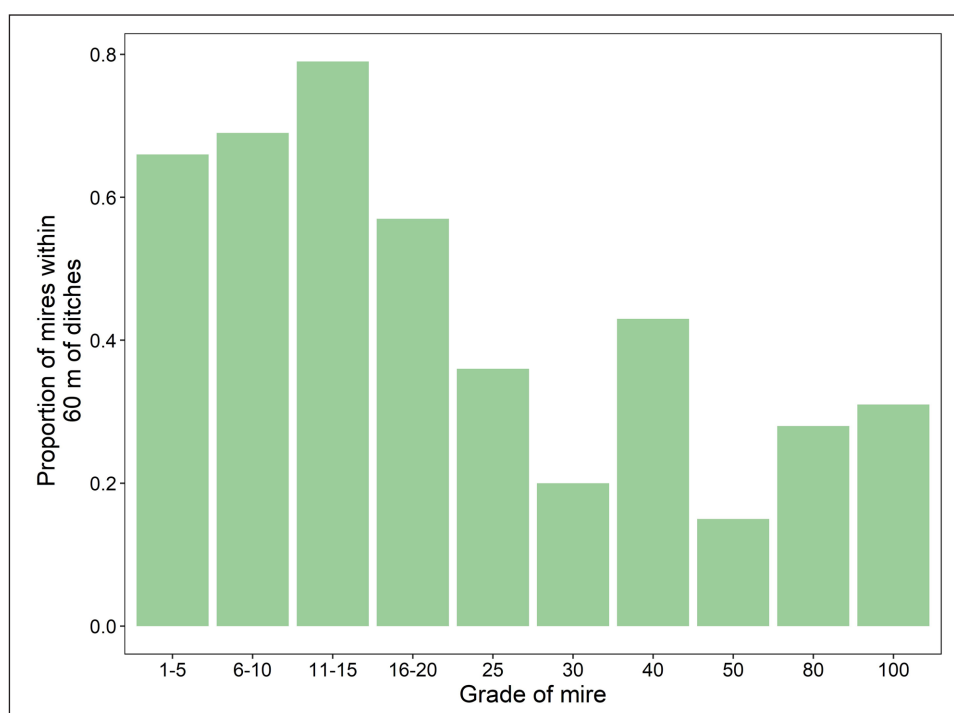


Figure 6: Mires influenced by drainage. Proportion of original mire areas (including former mire meadows, unused mires, and peat pit) of different grades that are located within 60 m from presently existing ditches.

harvest, after which the continual use kept the surface even (Zackrisson, 1976a). Trampling during harvest compacted the mire's surface and generated wetter surface conditions, which favored the replacement of *Sphagnum* mosses with 'brown mosses' such as *Drepanocladus*, *Scorpidium*, and *Campylium* (Elveland, 1983; Moen, 1976). The shorter vegetation also allowed more sun to reach the ground surface. This allowed the low-statured, heliophytic plants such as *Parnassia palustris* and the currently red-listed *Saxifraga hirculus* to thrive (Elveland, 1983) and also favored several species of invertebrates (Sjöberg, 1982). Thanks to these effects, past haymaking is not considered a negative impact when wetlands are assessed according to the criteria for natural habitats of European interest in the sense of the EU Habitats Directive (Gardfjell and Hagner, 2016). On the contrary, continued or reintroduced harvest is recommended to preserve both ecological and cultural values of the last remaining mire meadows (Svensson and Moreau, 2012; Tenning, 2015). In our study area, however, no mires are currently used as meadows. In general, mire meadows in northern Sweden were abandoned in the 1920s and 1930s (Elveland, 1983), and this area probably followed the general pattern because the mires that were reclaimed as arable land in the early 1900s could produce much higher volumes of hay. When haymaking ceased, many of the abovementioned effects were reversed naturally. *Sphagnum* species came back to replace the brown mosses (Moen, 1976), tussocks formed, and bushes and trees started to colonize the area (Elveland, 1983). A manmade habitat of importance for biodiversity was thus lost.

Second, management through damming also affected the biodiversity of the mires in the region. In some cases dams such as the one at Renbergstjärnen in our study area were abandoned in the 1930s and thus, those mires

have not since been subjected to annual flooding. In other locations, such as Bergtjärnen, the timber-floating dams were used until the 1960s, and later beavers (*Castor fiber*) moved in and sustained the flooding by building supplementary dams. As a result, these new water surfaces became important nesting habitats for ducks (Sjöberg, 1982) and have increased the biodiversity of tree species in the area now that the lake's immediate surroundings have been colonized by deciduous trees, mostly *Betula pubescens*. In a forest landscape otherwise dominated by conifers, deciduous stands offer attractive habitats for a number of species (Berg et al., 1994). Ultimately, these habitats are likely to be colonized by *Picea abies*, but not as long as flooding continues. Thus, damming that was originally introduced for haymaking has become long-lasting due to other needs, first of timber floaters and then of beavers, all of which has been important for promoting local and landscape biodiversity.

Other kinds of management were less beneficial for biodiversity. Actions to reclaim arable land were introduced in the late 1800s and ultimately affected 3% of the total mire area. The common procedure was to ditch and then to prepare the soil with spades and ploughs and add fertilizer (Osvald, 1937). When a mire was turned into arable land, the natural ecosystem was destroyed as opposed to when it was just modified by haymaking. In our study area, we could see that the mires selected for cultivation were in most cases mire meadows, and generally among the most productive ones. Although reclamation was only performed on a small part of the total mire area, a relatively large proportion of the productive mires habitats were thus lost.

As hay from natural meadows became less valuable, foresters increasingly tried to turn mires into productive forest land using ditches. Regarding the real effects of

these ditches, our results are ambiguous, because the conversion from mire to forest does not closely follow the presence of ditches. The part of the total mire area that is now covered with forest is as large as the area located close to ditches, 106 ha, or 39%. Although the size is the same, however, the two areas do not overlap, as only 61 ha of the former mires that are today covered with forest is located within 60 m of a ditch. One reason for this mismatch could be methodological biases, due to changing definitions of mire and forest. Also, any lack of correspondence between the mire polygons defined on the 1880 map and the actual landscape would distort the results. Nevertheless, we conclude that approximately 40% of the total mire habitat area has been lost through ditching for forestry purposes. These ditches probably promoted the establishment of forests on wet sites, but it is unclear how important they continue to be in maintaining tree growth, now that high volumes of trees are keeping groundwater levels low. But, when forests are harvested and the groundwater level subsequently rises, the ditches will likely become important again to provide drier conditions for the establishment of tree seedlings. The effects are not only local, however, as drainage has been suggested to negatively affect the mire's ability to protect downstream areas from drought and storm flooding (Menberu et al., 2016). We have no evidence of ditching after the 1980s, when drainage of new wetlands was essentially banned in Sweden. But, as long as ditches are functional, drainage will remain effective and in most cases lead to less water storage in the peat, increased annual runoff, and higher flood peaks (Holden, Chapman, and Labadz, 2004). Increased runoff also generally leads to higher levels of organic C in rivers (Asmala, Carstensen, and Räike, 2019).

Implications for climate change

Carbon (C) sequestration and storage is another important ecosystem service promoted by mires. Haymaking affected C sequestration because a major part of the plant production was removed with the hay, resulting in less litter and a slower accumulation of organic matter to form peat (Elveland, 1982). However, the most important long-term implications for climate change are connected to the C stored in peat and the conversion of mires to other land classes, especially forest, through drainage. Northern peatlands have sequestered about 270–547 Gt of C since the end of the last glacial period, which represents 20–30% of the organic C currently stored in soils worldwide (Järveoja et al., 2020). Although primary production is limited in this region, decomposition is also constrained by cool temperatures and water-saturated, oxygen-deficient conditions, resulting in net accumulation of organic matter (Clymo, 1984). However, drier conditions associated with climate warming and/or drainage may accelerate the aerobic mineralization of organic matter (Järveoja et al., 2020; Laiho, 2006). If the rate of decomposition then exceeds production, peatlands will become a C source (carbon dioxide, CO₂ release to atmosphere) rather than a C sink. An important finding from our study is that productive mires, with the greatest peat C sequestration, were affected

by drainage to a larger degree than less productive mires. But, afforestation on drained mires has the potential to increase C sequestration if tree growth outpaces peat decomposition (Minkinen et al., 1999).

These C sequestration processes are likely influenced by past management in several ways. The establishment of mire meadows was preceded by cleaning, usually of bushes but sometimes also of trees. According to the tables of the 1805 map, several of the mires that were then classified as land to be cleared had at least sparse tree cover, and this could previously have been the case also with the mires that were already managed as meadows. When trees grew back on these mires, this might have been a return to the original state, caused by ceased management, and not necessarily the result of ditching. In those cases, the mire would become a net C sink due to forestation, at least since the peak in haymaking occurred, but maybe not so in relation to the original—partly forested—state. However, for most mires, we do not know the extent of earlier forestation, and because many of the former mire meadows have also been subjected to ditching, it is not always clear whether the major cause of forestation is ditching or the abandonment of management. Regardless, the important implication of this discussion is that the effects of ceased management should be taken into account when assessing the long-term impact of ditching on mire vegetation and C sequestration, especially when it comes to productive mires that are likely to have been used as meadows but may once have been at least partly forested.

Development of the method

In this case study, we have demonstrated how historical maps and other kinds of archival sources can be combined with remote-sensing data such as aerial photographs and LiDAR-based DTMs to create a detailed picture of mire use over time. As the same type of sources exist for most of Sweden, there is a large potential for similar studies elsewhere. Northernmost Sweden is especially suitable for such studies because most cultivation has occurred during historical times, whereas in other parts of Sweden extensive management of these systems may have occurred before records started being kept. When Strandin Pers (2012) used historical maps to study the reclamation of mires in nine parishes distributed over most of southern Sweden, she found that some mires had been converted to arable land already before the creation of the earliest maps in the late 1600s. Along the coast of northernmost Sweden, mires could have been converted to arable land just as early, but there is evidence to the contrary. Even in the relatively early and densely populated Umeå area, reclamation of mires does not seem to have commenced before the late 1700s (Zackrisson, 1976a).

A problem when studying mires through a combination of historical sources and modern remote-sensing data is the very definition of the object of study. Here, we have chosen the definition currently in use for official Swedish statistics, which specifies that a mire is a *wetland* where the dominating plant communities are *peat-forming*, and that it is *not a forest*, because the production of trees does not exceed 1 m³/ha (Nilsson et al., 2019). This is a very exact definition that was not in use in the 1800s. As long

as there are records, however, the Swedish word 'myr' has been used for peatlands, and predominantly for wetland habitats, where there could be some trees but not closed forest (Svenska Akademien, 2020). An analysis of the wetland terminology of a group of dialects of northern Sweden supports this definition (Wiklund, 1992: 97–99). In future studies, one should explore how the term 'myr' has been applied in Swedish land surveys over time and across Sweden. In this study, we base the definition on the current interpretation of the word and our own experiences of the maps and aerial photos that we have studied, concluding that what was called 'myr' in 1880 and today is essentially the same.

Another crucial concept of our study is the *total mire area*, which we used to calculate the proportions of mire managed for different purposes. Defining the total mire area as the sum of all mire meadows, peat pits and unused mires indicated on the enclosure map from 1880, is likely a conservative estimate of what occurred before mire management began. Indeed, mires mapped in 1880 could exclude mires that once existed but that had been converted to other land classes earlier. However, when we checked all available historical maps from both Abborrtjärn and surrounding villages, we did not find any indications of such changes. In 1880, all cultivated fields of the study area were located close to the farmsteads on sandy soils with varying proportions of clay, according to the map tables, and thus not on peatland. Unlike Strandin Pers (2012), who was able to detect fields that once had been mires from their names, ending in 'fen' (sw. '-kärr') or 'bog' (sw. '-mosse'), we found no such cases on the maps of Abborrtjärn, neither in 1805 nor 1880.

Another land class that could potentially have included mires in 1880 is 'land suitable for cultivation' (sw. 'odlingsmark'), but in our study area, those areas were mostly located next to existing fields on sandy soils. Other kinds of land use were indicated on the 1880 map, such as 'gravel pits', but they were unlikely to have affected any mires. In other words, although we may have misclassified small areas, we believe that the sum of the land classes 'mires', 'mire meadows', and 'peat pits', as we have defined them from the enclosure map of 1880, gives the best possible representation of the total mire area as it was before any intensive human intervention began in the study area.

Conclusions

We have identified the various types of historical land use in mires, quantified the proportion of mires concerned, established a timeline of impact, and discussed possible legacy effects, in particular with respect to climate change. We have shown that the former use of mires can be mapped in detail through an interdisciplinary analysis involving sources and methods ranging from historical maps to state-of-the-art remote-sensing analysis. Our mapping shows that although mires have not been subjected to any active use for more than 30 years, legacy effects are still substantial, most importantly through the conversion of mires into forest. In addition, many open mires continue to change,

due to both previous ditching and the abandonment of management. Therefore, it can be difficult to separate these two factors and predict how mire habitats will develop in the future. Such factors should be taken into account to achieve a predictable outcome of mire management aimed at the improvement of important ecosystem services such as biodiversity, water regulation, and carbon sequestration.

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

GN designed the study, and digitized and processed the data. The results were discussed and analyzed jointly by all authors, and conclusions were drafted during these discussions. GN and EMH wrote the manuscript with important contributions from HJ.

References

- Anon. (2015). *Abborrtjärn och Svarberget: två små byar strax utanför Vindeln i Västerbotten*. Abborrtjärn. [Abborrtjärn and Svarberget: two small villages just outside Vindeln in Västerbotten].
- Arrhenius, J. P. (1884). *Om mossar och andra vattendränkta marker: deras odling och vidare behandling: meddelanden* (Vol. 24). Stockholm: J. Arrhenii förl. [On bogs and other waterlogged lands: Their cultivation and further treatment: Communications].
- Asmala, E., Carstensen, J., & Räike, A. (2019). Multiple anthropogenic drivers behind upward trends in organic carbon concentrations in boreal rivers. *Environmental Research Letters*, 14(12), 1–10. DOI: <https://doi.org/10.1088/1748-9326/ab4fa9>
- Berg, Å., Ehnström, B., Gustafsson, L., Hallingback, T., Jonsell, M., & Weslien, J. (1994). Threatened plant, animal, and fungus species in Swedish forests – Distribution and habitat associations. *Conservation Biology*, 8(3), 718–731. DOI: <https://doi.org/10.1046/j.1523-1739.1994.08030718.x>
- Björck, T. (1851). *Samling af alla gällande K:gl. förordningar, instruktioner, författningar och reskripter m.m., samt Kammarkollegii och Direktörsembetets wid Landtmäteriet och Justeringsverket i riket utfärdade cirkulärbref och föreskrifter rörande landtmäteriet och dermed sammanhang egande ämnen*. Stockholm. [Collection of all existing regulations, instructions, laws and letters etc., as well as communications and provisions concerning mapping and cadastral matters, issued by various State Agencies].

- Blind, A.-C., Kuoljok, K., Axelsson Linkowski, W., & Tunón, H.** (2015). *Myrens betydelse för renen och renskötseln: biologisk mångfald på myrar i renskötselland*. Uppsala: Naptek. [The importance of mires for reindeer and reindeer husbandry: Biodiversity on mires in reindeer herding areas]. Retrieved from <http://urn.kb.se/resolve?urn=urn:nbn:se:slu:epsilon-e-3424>
- Bosin, A.** (1901). Hvilken betydelse har mosskulturen i de norrländska länen och i hvilken riktning bör den utvecklas? Västerbottens län. *Svenska mosskulturföreningen tidskrift* (pp. 177–182). [What is the present and future importance of mire cultivation in the counties of northern Sweden? Västerbotten county].
- Bunte, R., Borgegård, L.-E., & Gaunitz, S.** (1982). *Vindelns: en norrländsk kommuns ekonomiska utveckling 1800–1980*. Lund: Selector. [Vindeln: The economic development of a municipality in northern Sweden 1800–1980].
- Bylund, E.** (1956). *Koloniseringen av Pite lappmark t.o.m. år 1867*. (Doctoral dissertation, Uppsala University, Uppsala). [The colonization of Pite lappmark until 1867].
- Campbell, Å.** (1982 [1948]). *Från vildmark till bygd: en etnologisk undersökning av nybyggarkulturen i Lappland före industrialismens genombrott*. Umeå: Två förläggare. [From wilderness to settled country: an ethnological study of the settlers culture in Swedish Lapland before the industrial breakthrough].
- Clymo, R. S.** (1984). The limits to peat bog growth. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences*, 303(1117), 605–654. DOI: <https://doi.org/10.1098/rstb.1984.0002>
- Egerbladh, O.** (1972). *Degerfors: 1700-talets kolonisation*. Umeå: Bokförl. Björken. [Degerfors: The colonization of the 1700s].
- Eliasson, P.** (2008). Skogsdikning och skogsväxt under 1900-talet. In L. Runefelt (Ed.), *Svensk mosskultur: Odling, torvanvändning och landskapets förändring 1750–2000* (pp. 181–195). [Forest ditching and forest growth during the 20th century]. Stockholm.
- Elveland, J.** (1979). *Dammängar, silängar och raningar: norrländska naturvårdsobjekt*. Solna: Naturvårdsverket. [Irrigated and naturally flooded hay-meadows in North Sweden: A nature conservancy problem].
- Elveland, J.** (1982). Västekologiska undersökningar. In J. Elveland & K. Sjöberg (Eds.), *Några effekter av återupptagen slåtter och andra skötselåtgärder på vegetation och djurliv i norrländska våtmarker* (pp. 19–59). [Studies in plant ecology]. Solna: Naturvårdsverket.
- Elveland, J.** (1983). *Norrländska våtmarker: bevarande av ett gammalt kulturlandskap*. Solna: Statens naturvårdsverk. [Northern Swedish wetlands formerly mown for hay: Conservation of an old cultural landscape].
- Företagarna.** (2020). *Företagarfakta: Vindelns kommun* [Business facts: Vindeln Municipality]. Retrieved from <https://www.foretagarna.se/contentassets/62837703e90d4f9eae815af6b3b0a9b0/vindeln.pdf>
- Forslund, M., Löfroth, M., & Rundlöf Forslund, S.** (1994). *Våtmarker i Västerbottens län*. Umeå: Länsstyrelsen Västerbotten. [Wetlands of Västerbotten County].
- Frödin, J.** (1940). *Zentraleuropas Alpwirtschaft*. Oslo: Aschehoug.
- Frödin, J.** (1952). *Skogar och myrar i norra Sverige i deras funktioner som betesmark och slåtter*. Oslo: Aschehoug. [Forests and mires of Northern Sweden as pastures and meadows]. DOI: <https://doi.org/10.1080/00291955308551746>
- Gardfjell, H., & Hagner, Å.** (2016). *Instruktion för habitatinventering i NILS och MOTH*. Umeå: Sveriges Lantbruksuniversitet. [Instructions for habitat surveys in NILS and MOTH].
- Gunnarsson, U., & Löfroth, M.** (2014). *The Swedish wetland survey: Compiled excerpts from the national final report*. Stockholm: Naturvårdsverket. Retrieved from <http://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6618-5.pdf>
- Hånell, B.** (1990). *Torvtäckta marker, dikning och sumpskogar i Sverige* (Vol. 22). Umeå: Swedish University of Agricultural Sciences. [Peatlands, ditching and swamp forests in Sweden].
- Hasselquist, E. M., Lidberg, W., Sponseller, R. A., Ågren, A., & Laudon, H.** (2018). Identifying and assessing the potential hydrological function of past artificial forest drainage. *Ambio*, 47(5), 546–556. DOI: <https://doi.org/10.1007/s13280-017-0984-9>
- Hasselquist, E. M., Mancheva, I., Eckerberg, K., & Laudon, H.** (2019). Policy change implications for forest water protection in Sweden over the last 50 years. *Ambio*. DOI: <https://doi.org/10.1007/s13280-019-01274-y>
- Hellström, P.** (1917). *Norrlands jordbruk*. Uppsala: Almqvist & Wiksell. [Agriculture in Norrland].
- Holden, J., Chapman, P. J., & Labadz, J. C.** (2004). Artificial drainage of peatlands: hydrological and hydrochemical process and wetland restoration. *Progress in Physical Geography*, 28(1), 95–123. DOI: <https://doi.org/10.1191/0309133304pp403ra>
- Järveoja, J., Nilsson, M. B., Crill, P. M., & Peichl, M.** (2020). Bimodal diel pattern in peatland ecosystem respiration rebuts uniform temperature response. *Nature Communications*, 11(1), 4255. DOI: <https://doi.org/10.1038/s41467-020-18027-1>
- Joosten, H.** (2015). Peatlands, climate change mitigation and biodiversity conservation. *Nordic Council of Ministers*. DOI: <https://doi.org/10.6027/ANP2015-727>
- Joosten, H., Tanneberger, F., & Moen, A.** (Eds.). (2017). *Mires and peatlands of Europe: Status, distribution and conservation*. Stuttgart: Schweizerbart Science Publishers.
- Kardell, L.** (2018). *Ett försök med myrslåtter i Klövsjö samt något om mad- och myrslåtter i allmänhet*. Uppsala: Institutionen för skoglig landskapsvård, Sveriges

- lantbruksuniversitet. [A mire-meadow harvest trial in Klövsjö and haymaking on wetlands in general].
- Karlsen, R. H., Grabs, T., Bishop, K., Buffam, I., Laudon, H., & Seibert, J.** (2016). Landscape controls on spatiotemporal discharge variability in a boreal catchment. *Water Resources Research*, 52(8), 6541–6556. DOI: <https://doi.org/10.1002/2016WR019186>
- Kempe, F.** (1909). *Skogshushållning i Norrland: ett program*. Uppsala: Almqvist & Wiksell. [Forest economy in Norrland: a program].
- Laiho, R.** (2006). Decomposition in peatlands: reconciling seemingly contrasting results on the impacts of lowered water levels. *Soil Biology & Biochemistry*, 38(8), 2011–2024. DOI: <https://doi.org/10.1016/j.soilbio.2006.02.017>
- Länsstyrelsen Västerbotten.** (2008). *Strategi för skydd och restaurering av våtmarker i Västerbottens län*. Umeå: Länsstyrelsen (County Administrative Board) Västerbotten. [Strategy for the protection and restoration of wetlands in Västerbotten County].
- Lantmäteriet.** (2020a). Historiska kartor, free historical map service of the Swedish National Land Survey. Retrieved from <https://etjanster.lantmateriet.se/historiskakartor/s/advancedsearch.html>
- Lantmäteriet.** (2020b). *Terrain Map, vector format*.
- Larsson, H.** (1988). *Nybyggaröden i gamla Degerfors socken*. Vindeln. [Settler lives in old Degerfors Parish].
- Laudon, H., & Ottosson Löfvenius, M.** (2016). Adding snow to the picture – Providing complementary winter precipitation data to the Krycklan Catchment Study database. *Hydrological Processes*, 30(13), 2413–2416. DOI: <https://doi.org/10.1002/hyp.10753>
- Laudon, H., Taberman, I., Ågren, A., Futter, M., Ottosson-Löfvenius, M., & Bishop, K.** (2013). The Krycklan catchment study – A flagship infrastructure for hydrology, biogeochemistry, and climate research in the boreal landscape. *Water Resources Research*, 49(10), 7154–7158. DOI: <https://doi.org/10.1002/wrcr.20520>
- Marcotte, P., Roy, V., Plamondon, A. P., & Auger, I.** (2008). Ten-year water table recovery after clearcutting and draining boreal forested wetlands of eastern Canada. *Hydrological Processes*, 22(20), 4163–4172. DOI: <https://doi.org/10.1002/hyp.7020>
- Menberu, M. W., Tahvanainen, T., Marttila, H., Irannezhad, M., Ronkanen, A.-K., Penttinen, J., & Kløve, B.** (2016). Water-table-dependent hydrological changes following peatland forestry drainage and restoration: analysis of restoration success. *Water Resources Research*, 52(5), 3742–3760. DOI: <https://doi.org/10.1002/2015WR018578>
- Minkinen, K., Vasander, H., Jauhiainen, S., Karsisto, M., & Laine, J.** (1999). Post-drainage changes in vegetation composition and carbon balance in Lakkasuo mire, Central Finland. *Plant and Soil*, 207(1), 107–120. Retrieved from <Go to ISI>://WOS:000080183000011. DOI: <https://doi.org/10.1023/A:1004466330076>
- Moen, A.** (1976). Slåttermyrers vegetasjon, produksjon og verneverdi: forelopig meddelelse fra forskningsprosjekt. In *Gjengroing av kulturmark; internordisk symposium 27–28 nov. 1975*. [The vegetation, productivity and conservation values of hay fens: Preliminary communication from a research project]. Ås: NLH.
- Moen, A., Lyngstad, A., & Øien, D.-I.** (2015). Hay crop of boreal rich fen communities traditionally used for haymaking. *Folia Geobotanica*, 50(1), 25–38. DOI: <https://doi.org/10.1007/s12224-015-9204-1>
- Nilsson, M., Sagerfors, J., Buffam, I., Laudon, H., Eriksson, T., Grelle, A., ... Lindroth, A.** (2008). Contemporary carbon accumulation in a boreal oligotrophic minerogenic mire – A significant sink after accounting for all C-fluxes. *Global Change Biology*, 14(10), 2317–2332. DOI: <https://doi.org/10.1111/j.1365-2486.2008.01654.x>
- Nilsson, P., Roberge, C., Fridman, J., & Wulff, S.** (2019). *Skogsdata 2019*. Umeå: Swedish University of Agricultural Sciences. [Forest statistics 2019].
- Norstedt, G., & Laudon, H.** (2019). *Krycklan: markanvändning från forntid till nutid*. Umeå: Department of Forest Ecology and Management, SLU. [Krycklan: Land use from ancient times to present].
- Osvald, H.** (1937). *Myrar och myrodling*. Stockholm: Kooperativa Förb Bokf. [Mires and mire cultivation].
- Reinton, L.** (1955). *Sæterbruket i Noreg. 1, Sætertypar og driftsformer*. Oslo: Aschehoug. [Mountain summer farming in Norway. 1, Types of summer farms and types of management].
- Saarimaa, M., Aapala, K., Tuominen, S., Karhu, J., Parkkari, M., & Tolvanen, A.** (2019). Predicting hotspots for threatened plant species in boreal peatlands. *Biodiversity and Conservation*, 28(5), 1173–1204. DOI: <https://doi.org/10.1007/s10531-019-01717-8>
- Sjöberg, K.** (1982). Zoöekologiska undersökningar. In J. Elveland and K. Sjöberg (Eds.), *Några effekter av återupptagen slåtter och andra skötselåtgärder på vegetation och djurliv i norrländska våtmarker* (pp. 60–96). [Studies in animal ecology]. Solna: Naturvårdsverket.
- Strandin Pers, A.** (2012). *Mark i marginalen: drivkrafter, pionjärer och myrodlingslandskap*. (Stockholm University, Stockholm). [Marginal lands: Drivers, pioneers and landscapes of mire cultivation].
- Svenska Akademien.** (2020). Ordbok. Retrieved from <https://www.saob.se/>
- Svensson, J., & Moreau, A.** (2012). *Ängar: biologisk mångfald och variation i odlingslandskapet*. Jönköping: Jordbruksverket. [Meadows: Biological diversity and variation in the agricultural landscape].
- Tenning, L.** (2015). *Life to ad(d)mire: Restoration of wetlands and mires in seven counties*. Östersund:

County Administrative Board of Jämtland. Retrieved from <https://www.lansstyrelsen.se/download/18.4e0415ee166afb59324102de/1541684410926/LifeToAddmire-en.pdf>

Väg- och vattenbyggnadsstyrelsen. (1872–1910). *Bidrag till Sveriges officiella statistik. S. Allmänna arbeten. Väg- och vattenbyggnadsstyrelsens underdåniga berättelser.* Stockholm. [Sweden's official statistics: Reports from the Swedish Roads and Waters Agency]. Retrieved from <https://www.scb.se/hitta-statistik/sok/Index?Subject=allsubjects&Serie=s=BISOS+S+Allmänna+arbeten+1872-1910&From=1872&To=1910&Sort=relevance&Query=&Page=1&Tab=older&Exact=false>

Warenberg, K. (1988). *Myrarnas betydelse från renbetessynpunkt.* Jönköping: Lantbruksstyr. [The importance of mires for reindeer husbandry].

Wiklund, S. (1992). *Våtmarksord i lulemålen: en ordgrupp sedd ur informant- och intervjuarperspektiv.* (Doctoral dissertation, Umeå University, Umeå). [Wetland terms in the Swedish Lule dialect: A group of words seen from the perspectives of informants and interviewer]. Retrieved from <http://umu.diva-portal.org/smash/get/diva2:615112/FULLTEXT02.pdf>

Zackrisson, O. (1976a). Vegetation dynamics and land use in the lower reaches of the river Umeälven. In O. Zackrisson, R. Engelmark, I. Renberg & I. U. Olsson (Eds.), *Palaeo-ecological investigations in coastal Västerbotten, N. Sweden*, 9: 7–74. Stockholm: Kungl. Vitterhets-, historie- och antikvitetsakad.

Zackrisson, O. (1976b). Vegetationsdynamik på kulturmark i övre Norrland under historisk tid. In *Gjengroing av kulturmark; internordisk symposium 27–28 nov. 1975*. [Vegetation dynamics on agricultural land in northernmost Sweden during historical times]. Ås: NLH.

Archival materials

Lantmäteriet (Swedish National Survey)

Degerfors, geometrical and geographic map (1702), Z6-40:1.

Degerfors, delineation map (1785), Z6-40:3.

Abborrtjärn, taxation map (1805), Z6-2:1.

Abborrtjärn, enclosure map (1880), 24-deg-500.

Abborrtjärn, cadastral map for the division of farmstead Aa (1912), 24-deg-481.

Länsstyrelsen Västerbotten (County Administrative Board)

Ditching map, Abborrtjärn no 1541, map of Vorrmyran (1915).

Ditching map, Abborrtjärn no 2668, map and project description of Hukladumyran (1919).

Wetland survey unpublished catalogue of objects.

Former archives of Sandviks Ångsågs AB, now Holmen AB

Forestry map of Sandviks Ångsågs AB's property Abborrtjärn (1941).

The Popular Movement Archive in Västerbotten

Archives of Umeå flottningsförening, the timber floating association.

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