Master thesis 2022:01
Department of Forest Ecology and Management

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– early logging, natural forests and the frontier concept

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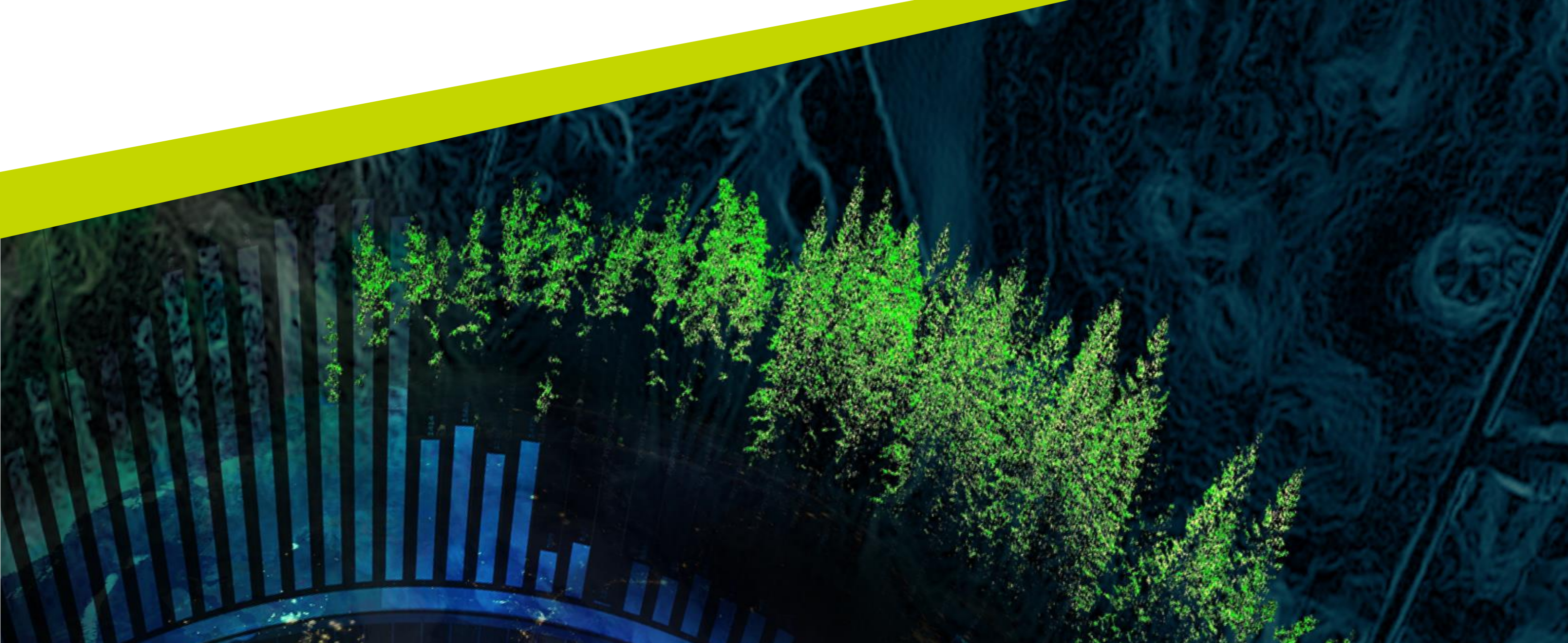
Master's thesis • 30 hp
Swedish University of Agricultural Sciences, SLU
Faculty of Forest Sciences, Department of Forest Ecology and Management
Master's program in Forest Ecology and Sustainable Management
2022:01 • ISSN 1654-1898
Umeå, 2022



The end of the timber frontier in northern Sweden – early logging, natural forests and the frontier concept

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Credits:	30 hp
Level:	Advanced level, A2E
Course title:	Master's thesis in Forest Science at the Department of Forest Ecology and Management
Course code:	EX0958
Programme/education:	Master's program in Forest Ecology and Sustainable Management
Course coordinating dept:	Department of Forest Ecology and Management

Place of publication:	Umeå
Year of publication:	2022
Title of series:	Examensarbeten / SLU, Institutionen för skogens ekologi och skötsel
Part number:	2022:01
ISSN:	1654-1898

Keywords: timber frontier, northern Sweden, Tjeggelvas nature reserve, Piteälven, Norrbotten, high-grading

Swedish University of Agricultural Sciences
Faculty of Forest Sciences
Department of Forest Ecology and Management

Publishing and archiving

I denna rapport redovisas ett examensarbete utfört vid Institutionen för skogens ekologi och skötsel, Skogsvetenskapliga fakulteten, SLU. Arbetet har handletts och granskats av handledaren, och godkänts av examinator. För rapportens slutliga innehåll är dock författaren ensam ansvarig.

This report presents a MSc thesis at the Department of Forest Ecology and Management, Faculty of Forest Sciences, SLU. The work has been supervised and reviewed by the supervisor and has been approved by the examiner. However, the author is the sole person responsible for the content.

Abstract

The Fennoscandian forests experienced drastic changes in the 19th century. The high demand for timber during the European industrialization pushed the timber companies towards increasingly remote forest landscapes for resource extraction. This study explores the concept of the so-called timber frontier which seeks to demarcate waves of forest use change, on priorly natural forest land, often inhabited by indigenous populations. The research scope of this study is confined to northernmost Sweden and aims to elucidate the dynamics defining its specific development and pinpoint where the timber frontier ended in this region. The timber frontier reached the uppermost Piteälven watershed area during the end of the 19th century. Historical logging traces of high-grading were searched for during a field survey in Tjeggelvas nature reserve. Independently collected archival data support the findings of the field survey. By analyzing a gradient from the lakeshore to the inner parts of the forest, the end of the timber frontier could be marked out. The results show clearly that logging occurred close to the river and along the lakeshore. The long-term ecological impact, however, remains blurred due to the low impact of historical high-grading extraction practices and the long time period that has passed since then. The historical records indicate that high costs for timber floating and low stand productivity were limiting further exploitation. Furthermore, the timber frontiers' late arrival and the establishment of the first nature reserves in Sweden overlapped and might be reasons why the timber frontier came to an end in the researched area. Even after one frontier has come to a halt, there is a general tendency for new frontiers of resource extraction to arrive repeatedly on the same lands. Therefore, I suggest that a stronger protection is needed for this unique forest, and that the Sami land use rights are reinforced in order to protect Tjeggelvas nature reserve for future generations.

Keywords: timber frontier, northern Sweden, Tjeggelvas nature reserve, Piteälven, Norrbotten, high-grading

Sammanfattning

Skogarna i norra Skandinavien genomgick dramatiska förändringar under slutet av 1800-talet. Den stora efterfrågan på timmer under den europeiska industrialiseringen ledde till en omfattande skogsexploatering i alltmer avlägsna skogslandskap. Denna studie är inriktad mot den så kallade ”timmerfronten”, det vill säga avverkning i tidigare oexploaterade skogar bebodd av urbefolkningar. Min studie är inriktad mot nordligaste Sverige och syftar till att undersöka timmerfrontens dynamik och var den slutade i denna region. Timmerfronten nådde Piteälvens översta delar under slutet av 1800-talet. Historiska spår av dimensionsavverkning och nutida skogsstruktur insamlades och analyserades vid en fältundersökning i Tjeggelvas naturreservat. Oberoende insamlad arkivdata stöder resultaten av fältundersökningen. Genom att analysera en gradient från sjön Tjeggelvas strand till de inre delarna av skogen fann jag var timmerfronten slutade. Resultaten visar också tydligt att tidiga dimensionsavverkningar skedde nära älven och längs sjöstranden men inte längre in. Den långsiktiga ekologiska påverkan på skogen är dock relativt diffus, dels på grund av att avverkningen var begränsad och dels på grund av att så lång tid har gått sedan denna avverkning. De historiska dokumenten tyder på att höga kostnader för timmerflottning och låg produktivitet i skogen begränsade ytterligare exploatering. Dessutom hade man strax efter denna avverkning börjat diskutera skydd av skog i norra Sverige och det kan vara en bidragande orsak till att exploateringen upphörde i området. Även efter det att en front – i detta fall en timmerexploateringsfront – har avstannat, finns det en allmän tendens att nya fronter för resursutvinning kommer upprepade gånger till samma marker. Därför hävdar jag att det behövs ett förstärkt skydd av detta unika område liksom att samernas markrättigheter stärks för att bevara Tjeggelvas naturreservat för alla kommande generationer.

Nyckelord: timmerfronten, norra Sverige, Tjeggelvas naturreservat, Piteälven, Norrbotten, dimensionsavverkning

Zusammenfassung

Die fennoskandischen Wälder wurden im 19. Jhd. drastisch verändert. Die hohe Nachfrage nach Holz während der europäischen Industrialisierung ließ die Holzindustrie zunehmend in immer entlegenere Waldgebiete vorstoßen. Diese Studie untersucht die sogenannte „Nutzholzfront“, welche die Abholzung von davor zumeist von indigenen Bevölkerungen bewohnten Wäldern beschreibt. Der Forschungsbereich dieser Studie beschränkt sich auf das nördlichste Schweden und zielt darauf ab, die Dynamiken der Nutzholzfront aufzuklären und zu bestimmen, wo diese endet. Die Nutzholzfront erreichte Ende des 19. Jhd. den obersten Teil des Einzugsgebiets des Piteälven. Bei einer Felduntersuchung im Naturreservat Tjeggelvas wurde nach historischen Holzeinschlagsspuren gesucht. Unabhängig erhobene Archivdaten unterstützen die Ergebnisse der Felduntersuchung. Durch die Analyse eines Gradienten, von der Küste des Sees Tjeggelvas bis in die inneren Teile der Naturreservats, konnte ich das Ende der Nutzholzfront abgrenzen. Die Ergebnisse zeigen deutlich, dass Einzelstammnutzungen in Flussnähe und entlang des Seeufers stattfanden. Die langfristigen ökologischen Folgen bleiben jedoch, aufgrund des geringen Einflusses der historischen Einzelstammnutzungen und des langen Zeitraumes, der seitdem vergangen ist, verschwommen. Historische Aufzeichnungen weisen darauf hin, dass hohe Kosten für das Holztriften und eine geringe Standortsproduktivität weitere Nutzungen begrenzten. Darüber hinaus überlappten sich die späte Ankunft der Nutzholzfront und die Begründung erster Naturschutzgebiete in Schweden und könnten Gründe dafür sein, dass die Nutzholzfront im untersuchten Gebiet endete. Selbst nachdem eine Front zum Stillstand kommt, gibt es eine allgemeine Tendenz, dass neue Fronten der Ressourcengewinnung dieselben Gebiete erreichen. Daher empfehle ich, dass dieses einzigartige Waldgebiet stärker geschützt und die Landnutzungsrechte der Samen gestärkt werden müssen, um das Naturreservat Tjeggelvas für zukünftige Generationen zu schützen.

Schlagwörter: Nutzholzfront, Nordschweden, Naturreservat Tjeggelvas, Piteälven, Norrbotten, Einzelstammnutzung

Sommario

Le foreste della Fennoscandia hanno subito drastici cambiamenti nel XIX secolo. L'elevata richiesta di legname durante l'industrializzazione europea ha spinto le aziende dell'industria del legname verso foreste sempre più remote per l'estrazione delle risorse. Questo studio esplora il concetto del cosiddetto "fronte di abbattimento" che cerca di delimitare i vari periodi di tagli nelle foreste confrontandole con le foreste vergini abitate da popolazioni indigene. L'ambito di ricerca di questo studio è limitato alla Svezia più settentrionale e mira a chiarire le dinamiche che definiscono il suo sviluppo specifico ed individuare dove finiscono i tagli forestali in questa regione. Il fronte di abbattimento raggiunse l'area più alta dello spartiacque del Piteälven alla fine del XIX secolo. Durante un'indagine sul campo nella riserva naturale di Tjeggelvas sono state cercate tracce storiche dei vari tagli forestali. I dati d'archivio raccolti in modo indipendente sostengono i risultati dell'indagine sul campo. Analizzando un soprassuolo forestale dalla sponda del lago verso l'interno del bosco, è stato possibile tracciare il fronte di abbattimento. I risultati mostrano chiaramente che un taglio a scelta si è verificato vicino al fiume e lungo la riva del lago. L'impatto ecologico a lungo termine, tuttavia, rimane debole a causa delle pratiche del taglio a scelta di quel periodo storico e del lungo tempo da allora trascorso. I documenti storici indicano che i costi troppo alti per il trasporto del legname e la bassa produttività del suolo limitavano l'ulteriore sfruttamento. Inoltre, l'arrivo tardivo del fronte di abbattimento e l'istituzione delle prime riserve naturali in Svezia si sono sovrapposte e potrebbero essere le ragioni per cui il fronte di abbattimento si arresta nell'area studiata. Anche dopo che un fronte di abbattimento si è fermato, c'è la tendenza generale di aprire nuovi fronti di estrazione delle risorse sulle stesse terre. Pertanto, suggerisco che è necessaria una protezione più forte per questa foresta unica e che i diritti di utilizzo della terra dei Sami siano rafforzati al fine di proteggere la riserva naturale di Tjeggelvas per le generazioni future.

Parole chiave: fronte di abbattimento, Svezia settentrionale, riserva naturale di Tjeggelvas, Piteälven, Norrbotten, taglio a scelta

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1. Introduction

1.1. Background

Sweden played a particular role during the industrial revolution in Europe, as industrialization arrived later than in other European countries (Fisher, 1992), but from the very beginning it could provide important raw materials for the developing economies in Western Europe. Low population density and distance from European economic centers were among the main reasons for a later development (Moore, 2010). The country's wealth in vast forest resources put it in a special position (Heckscher, 1932). Rapidly increasing demand for timber products during industrial revolution accelerated the process of land-use change at the European peripheries (Pollard, 1997). Consequently, increased timber demand led to the first large commercial timber harvesting operations in northern Sweden (Moore, 2010). From the 1850s onwards, the export of timber increased significantly. This was mainly driven by the demand from the British market, where the steam engine had been introduced at industrial level in 1849 (Bernes, 2011). A key event for the development of the Swedish forestry industry was the removal of regulations that had previously limited access of ironworks to forest land and resources in 1863. This catalyzed the establishment of further sawmills on the northern Swedish coast (Björklund, 1984; Kardell, 2004). By the 1870s Sweden had become the world's biggest exporter of sawn wood (Winberg, 1944).

One particular aspect of Sweden's history of land and forest use compared to continental Europe is the history of its indigenous population, the Sami. Particularly the country's northern interior was inhabited by Sami people who have used the land in a low intense but spatially broad way for thousands of years (Bergman et al. 2003, Andersson et al., 2005; Josefsson et al., 2010a; Norstedt et al., 2014; Rautio et al., 2016). While southern and central parts of Sweden had been cleared early on in order to make space for agricultural as well as for charcoal and timber production, the agricultural colonization movement took much longer to reach Sami territory and gained momentum in the 18th century, moving from south to north, from the east coast towards the inland parts, and upstream along the rivers, from merged streams to where watershed divides. (Östlund et al., 1997; Östlund and Norstedt, 2021). Most of the new farming villages and homesteads were located along the coast and at the lower parts along the main rivers, and in the north-western interior parts only very sparse settlements were established.

Still, the legitimization of colonization processes always demand a certain narrative for land to be declared as “empty”. Only a landscape that is declared “empty” can be claimed and used by anyone wanting to exploit its resources (Tsing, 2005). Frontier narratives, for example, have been utilized in colonization processes to justify the “opening” up of those areas as available new land resources (Larsen, 2015). A central frontier narrative for framing forest resource exploitation is the concept of the timber frontier. This concept is not only present in northern Europe but was a global phenomenon that followed the colonization and settlement processes in different forest-dominated regions worldwide (Andersson et al., 2005; Williams, 2000). Similarities in the development and land-use pattern can be seen in North America, Patagonia and Russia. Mostly, timber frontiers have a connection to a rather abrupt land-use change, from low-intensity subsistence livelihoods to intensive forest exploitation. This leads to persecution or displacement of indigenous peoples (Hagg, 1948; Smith, 1974; Björklund, 1984; Zegers et al., 2019). Human impact in these forest landscapes was minor due to low population densities and subsistence practices, adapted to the scarce and slowly regenerating resource availabilities. The timber frontiers’ arrival led to drastic land use changes, induced through logging processes and thus, irreversibly transformed the forest landscape (Andersson et al., 2005; Lundmark et al., 2013; Östlund and Norstedt, 2021).

The beginning of the timber frontier in Sweden has been studied by Östlund (1995) and the frontiers’ movement in Fennoscandia has been reviewed by Östlund and Norstedt (2021). Still no research has been done yet on how far the timber frontier reached and which parts might have escaped it. The timber frontier in Fennoscandia was a movement that started in Norway during the early 19th century (Sejersted, 1980) and moved northwards and from the coast to the inland. During mid-19th century the timber frontier reached the regions from Värmland up to the western parts of Västerbotten, continuing northwards and upstream in Norrbotten during the second half of the 19th century (Björklund, 1984; Östlund and Norstedt, 2021).

The first commercial logging era affected the Piteälven watershed in northernmost Sweden during 1870-1910 (Rautio et al., 2016). Loggers constantly moved to new places in search for large-diameter pines that could be cut (Östlund, 1995). Logging was performed during the first logging frontier movement as high-grading, which means that only the large and valuable stems were taken out of the forest. No further silvicultural measures were taken afterward as it was believed that natural regeneration and remaining tress will close the created gaps (Wahlgren, 1914). The next waves of logging were enforced by a fast-growing pulp industry and its demand for smaller diameter trees, which led to a shift from high-grading to clear-cutting (Lundmark et al., 2013).

1.2. Aim of the study

The overall aim of this study was to search for and analyze the "end of the timber frontier" in a currently protected old-growth forest in northernmost Sweden. The study area is located within the large nature reserve Tjeggelvas close to the Fennoscandian mountain range. The methods include an analysis of historical records and a detailed field survey within Tjeggelvas nature reserve.

The objectives were to:

1) Analyze the historical logging, e.g. high-grading intensity, along a gradient into Tjeggelvas nature reserve.
2) Analyze the forest structure along this gradient focusing on tree-age, species distribution, timber volume and diameter at breast height (DBH).
3) Determine the ecological consequences of the early logging a century after it took place.

Based on these results, I am discussing the possible reasons why the logging ended in Tjeggelvas nature reserve, what the implications of logging and other forms of land use in boreal ecosystems were, and finally, I will provide broader perspectives on the concept of timber frontiers.

2. Material and Methods

In this study I searched and used archival material to understand the early logging, did a fieldwork and sampling in Tjeggelvas nature reserve (Figure 1) to investigate the forest structure at the selected field site and finally did dendrochronological analyses on samples from the field study.

2.1. Study area

The study area covers around 300ha and lies within Tjeggelvas nature reserve (66°N, 17°E), located in the boreal zone in northern Sweden. Tjeggelvas nature reserve is part of a large roadless landscape and is highly appreciated in the scientific community for not showing traces of modern forest management (Josefsson et al., 2010a). The reserve lies within the region called Sápmi, which extends over Fennoscandia and the Kola peninsula in Russia. Native Sami people have inhabited this area for thousands of years (Bergman et al., 2003). Up until the 19th century, their traditional subsistence livelihood was based on small-scale reindeer herding, fishing and hunting. Furthermore, the land historically was subdivided in Sami taxation lands. This was the state's legal framework for collecting taxes from the indigenous population, which simultaneously endowed the native Sami people with land use rights (Josefsson et al., 2010c).

Boreal climatic conditions, with long cold winters and a short vegetation period limit vegetation growth in the area (Rautio et al., 2016). The research area is dominated by semi-open late-successional coniferous forest, with Scots pine (*Pinus sylvestris* L.) as the dominant tree species. Downy birch (*Betula pubescens* Ehrh.) is present scattered in the second layer. Ground vegetation is dominated by dwarf shrubs, lichens, and feather mosses. Big granite boulder fields and hilly terrain characterize the topography of the area. The forest area is interrupted by dispersed mires, creeks and small lakes.

Tjeggelvas nature reserve was selected as study site due to its geographic location, forest structure and scientific insights from previous studies conducted by e.g. Andersson et al. (2005), Berg et al. (2008), Josefsson et al. (2010a) and Rautio et al. (2016).

Figure 1. Overview picture of the research area. Viewed from north to south taken from gradient K on the non high-graded plot 5. To the right: Tjeggelvas lake. Photo by: Alice Cosatti, 2020.

2.2. Archival material

The analyzed primary historical sources are derived from the Swedish National Forest Service (Domänverket). Sources were used that describe the area, logging records, management plans and historical maps to reconstruct the land-use history in the *Luottonlandet kronoparken,* the forest area owned by the state, close to the area where Tjeggelvas nature reserve is located nowadays. The uppermost river valley of Piteälven was the selected geographical area for the analysis. Similar methodological approaches such as done by Berg et al. (2008) were applied to screen the primary sources. This archival material data provides additional independently collected information about the history of the timber frontier.

2.3. Field data sampling and measurements

In order to delineate the logging frontier and to reconstruct the anthropogenic disturbance effects on forest structure in our research area a sampling design with parallel transects and additional sample plots was selected.

The transects were placed according to information from the archival material and from information obtained in a previous study by Josefsson et al. (2010a) and went from the shore of the lake Tjeggelvas and inland oriented 90° to the lakeshore. The transects are 30m wide and 200m apart and were established to locate traces of logging such as stumps, as well as other cultural traces. The transects run from southeast to northeast, from the lake shore to the inner parts of the reserve.

Additionally, randomly set circular plots along the transects with an area of 0,1ha were added to analyze the forest structure. A grid was set over the area and the closest grid intersect point to the transect was selected to be the sample plot. The first plot of a transect was set at a 50m distance from the lakeshore to diminish the influence caused by the lake. All other plots were set 100m apart from each other. New plots were established if there were traces of logging along the transect. Eleven transects and a total of 53 plots were established for this study. If a plot was located in an inaccessible area, it was either discarded or the next closest point on the grid was taken. In case more logging traces were found along the transect, an extension of further plots would be established along the transect line until one plot without cultural traces was reached. All coordinates and types of cultural traces along the transects and in the sample plots were noted. A total area of 300ha was sampled in this study.

Forest structure and vegetation on each circular sample plot was described. The basal area was estimated by using a relascope and by counting the trees that were included in the sample plot. Upper tree height of the two biggest pines, which were in a proximity of 20m between each other was measured, as well as the upper tree height of birches. All living and dead trees in a quarter of the sample plot with a DBH >5cm were measured and tree species was noted (total number of measured trees over all plots n=974). The quarter was defined from north to east. The derived stand volume was then upscaled to the whole circle. Every fifth tree noted while estimating the basal area was marked and later cored for dendrochronological analyses.

A detailed description of the measurement procedures can be found in the supplementary information.

2.4. Dendrochronological analyses

Tree age of both Scots pine and Downy birch trees (total number of cores n=276) was determined in the laboratory using standard methods. Annual tree ring counting for Scots pine cores was conducted on a PC using the software CDendro and CooRecorder 8.1 (Larsson and Larsson, 2014). Due to the low visibility of the scanned images, tree ring counting for Downy birch cores was done under the microscope. All cores were first mounted and sanded with sandpaper, so that tree rings could be seen clearly. If the pith of the tree was not visible, the missing year rings were estimated calculating the average tree rings included between concentric circles that were 0,5cm apart from each other. As the Scots pines were cored at DBH, 46 years were added to the age of each core (Josefsson et al., 2010a).
To estimate the age of rotten Scots pine cores, methods described by Baudet et al. (2021) were applied. A total of 24 Scots pine cores with a perfect tree pith were used to get an estimate of how many rings are in a centimeter of the inner part of the core. This estimate was added to the counted tree rings, to calculate the approximate number of missing tree rings.

2.5. Statistical and spatial analyses

Tree volumes in m^3/ha were calculated using volume functions including latitude, derived from Brandel (1990) and used by Josefsson et al. (2010a). Consequently, the mean was calculated, as well as standard error and range of the selected forest characteristics (Table 2).

To compare every forest characteristic parameter between high-graded plots and plots where no high-grading had occurred (Figure 2) a Welch’s t-test was run using the statistical software R v.3.6.2 (R Core Team, 2021). Test outcomes were considered to be significantly different at a probability of 5%.

Visualization of the collected GPS data pinpointing the registered cultural traces was created using the free and open-source software QGIS 3.16 (QGIS.org, 2021).

3. Results

3.1. Archival material

The analyzed archival material (Table 1) describes *Luottonlandet kronoparken*, which is the closest state forest area to the study area. It is divided into three management blocks (bl. I-III), in which block III is adjacent to Piteälven on its northern border. Block III lies closest to the research area in Tjeggelvas nature reserve. The management plan for block III includes a historical description of *Luottonlandet kronoparken's* establishment on 10 July 1902. Following the laws passed by the king of Sweden on 1 February 1893 and on 31 December 1898, the areas covered by "Arjeplog revir" were established and named "Kronoparken vid Pite älv". The area is described to be above the productive forest growth line (*skogsolingsgränsen*).

The forest management plans describe the area as very blocky, with a lot of mires, and with sparse, very open and low productive forests. According to the descriptions in the management plans of 1925 of block I-III the rotation period on better pine stands is 160 years. The time for regeneration to be secured is calculated to be 30 years. Moreover, it is described that former high-grading of the areas had left space for the remaining trees to grow but management for regeneration was difficult then. Block III, which is closest to Piteälven had been high graded and most of the timber floated down Luodokbäcken. The forest is described to have had a very low economic value due to trees being sparse, of low wood quality, bad tree trunk shape and due to the long delivery distances.

Table 1. Archival sources used in the study.

The provincial archives, Härnösand, Sweden (Landarkivet)
Kungliga domänstyrelsen/Domänverkets arkiv (Archives of the Forest Service)
Arjeplogs revir – Skogsindeliningsplaner äldre (Older forest management plans)
Krp Luottonlandet 1925 bl. I – III (F II 1)
Skogsindelningsplan Krp. Luottonlandet bl. I
Skogsindelningsplan Krp. Luottonlandet bl. II
Skogsindelningsplan Krp. Luottonlandet bl. III

3.2. Data analysis

General site conditions (vegetation and edaphic factors) varied in the study area, if only slightly. Main influencing factors for those minor variations among the plots were the proximity to the lakeshore, as well as the morphology of the area. Closeness to the lakeshore, streams, mires, bare rock, and large boulders affected the growing conditions of trees.

3.2.1. Current forest characteristics of the study area

The forest characteristic variables describing the forest structure of the studied area (Table 2) varied noticeably among sampled plots. Tree ages of Scots pine ranged from 110 to 569 years (for trees DHB $\geq$ 5cm). The mean age of Scots pine was 271 years and of Downy birch 114 years. 29% of all cored Scots pines were older than 300 years and 7% were older than 400 years. 60% of all cored Downy birches were older than 100 years and 16% were older than 150 years. Diameters of Scots pine and Downy birch varied considerably between 6 to 56 cm (average 25.5 cm) and 5 to 25 cm (average 8.9 cm), respectively. The mean volume of Scots pine ranged across the plots from 7 to 316.7 m^3/ha with a mean volume of 104.9 m^3/ha. Mean volumes of Downy birch varied from 0.3 to 39.6 m^3/ha, averaging with 11.5 m^3/ha. It is important to point out, that the mean basal area of deadwood is approximately the same both for lying and standing dead wood with 2.2 m^2/ha. The total volume of standing deadwood with is notably high 26.5 m^3/ha, however, there is a wide range across the sample plots.

Table 2. Forest characteristics of the whole study area.

Variable	Mean ± SE	Range [e]
Living trees		
Tree height [a]	10.5 ± 0.14	4 – 20
Tree height of: [a]		
Scots pine	15.6 ± 0.09	10.5 – 20
Downy birch	7.6 ± 0.05	4 – 11
Mean tree age (years)	235 ± 6.32	50 – 569
Mean tree age of:		
Scots pine (years)	271 ± 6.20	110 – 569
Downy birch (years)	114 ± 4.81	50 – 246
Basal area [b]	5.3 ± 0.37	0 – 23
Scots pine	13.3 ± 0.55	1 – 23
Downy birch	3.6 ± 0.44	0 – 14
Diameter of: [c]		
Scots pine	25.5 ± 0.53	6 – 56
Downy birch	8.9 ± 0.15	5 – 25
Total volume [d]	116.5 ± 5.67	0.3 – 316.7
Total volume of: [d]		
Scots pine	104.9 ± 10.03	7 – 316.7
Downy birch	11.5 ± 1.32	0.3 – 39.6
Lying deadwood		
Basal area [b]	2.2 ± 0.21	0 – 6
Standing deadwood		
Basal area [b]	2.2 ± 0.21	0 – 7
Total volume [d]	26.5 ± 3.47	0.4 – 99.5

[a] Arithmetical mean tree height in meters for the 100 largest trees per hectare.

[b] Basal area in m^2/ha

[c] Mean DBH in cm.

[d] Volumes in m^3/ha

[e] Range is the variation within the sample plots.

3.2.2. Spatial distribution of logging traces

Amongst the 53 sampled plots, 25 (47%) had signs of logging. 16 plots had 1 stump, 3 plots had 2 stumps, 2 plots had 3 stumps, 3 plots had 4 stumps and 1 plot had 5 stumps (Figure 2). The two southernmost transects (A and B) close to the river and the shore showed an overall high concentration of logging activity (Figure 3). Plots close to the shore showed that in every transect the logging activity was concentrated along the shore and close to the river (Figure 3). This is especially visible in plots on transects A, B, F, H, I, J and K (Figure 2 and 3). Two plots (D5 and I5) showed logging activity in Figure 2 and can be defined as outliers compared to the other high graded plots. Furthermore, as presented in Figure 4, these two plots show a high number of Sami cultural traces (e.g. lichen tree stumps and bark peelings), but no high-grading stumps in Figure 3. Logging activity is found as far as a maximum of 250m inland from the shore on transects C to K, with one outlier in C (Figure 3). Transects A and B show logging activities along the whole transect until 450m inland from the lakeshore, whilst being both very close to the river (Figure 3).

Figure 2. Map of the study area with transects (yellow lines), sample plots where high-grading occurred (red cross) with the amount of found high-grading stumps per plot and sample plots where no high-grading stumps were found. Map by: Alice Cosatti, 2020.

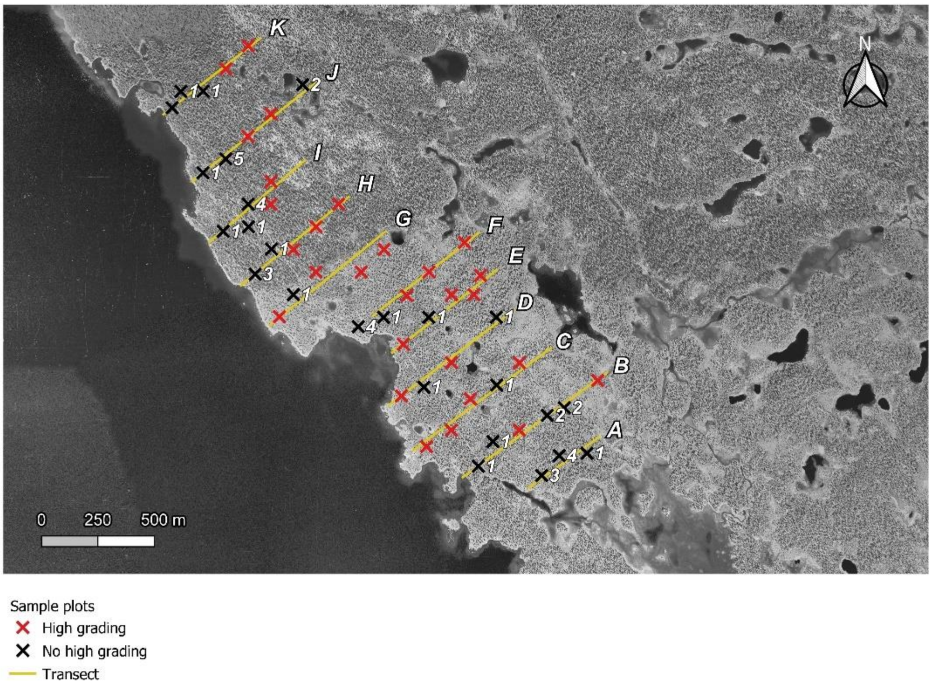
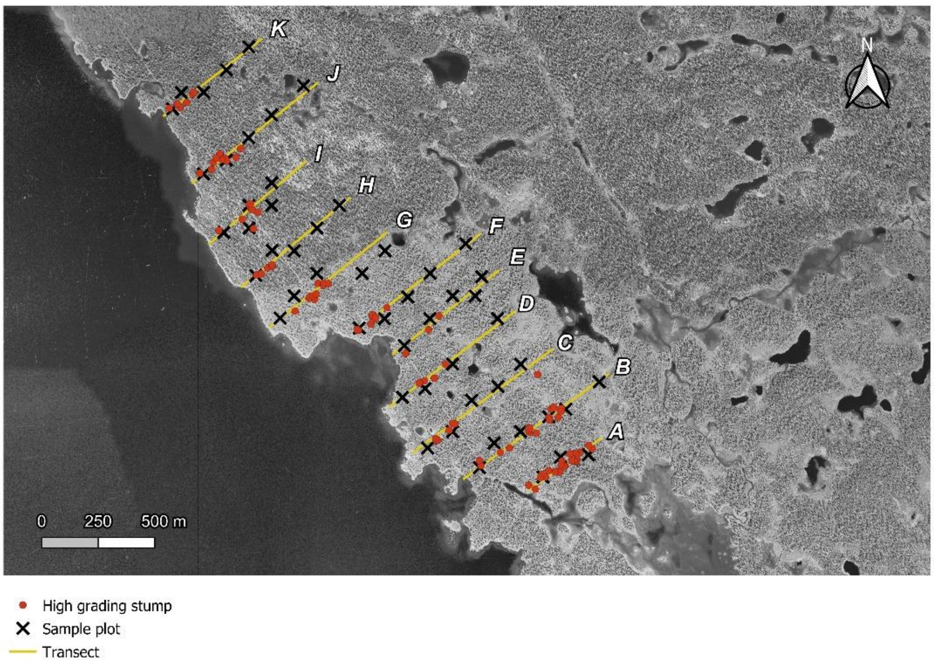


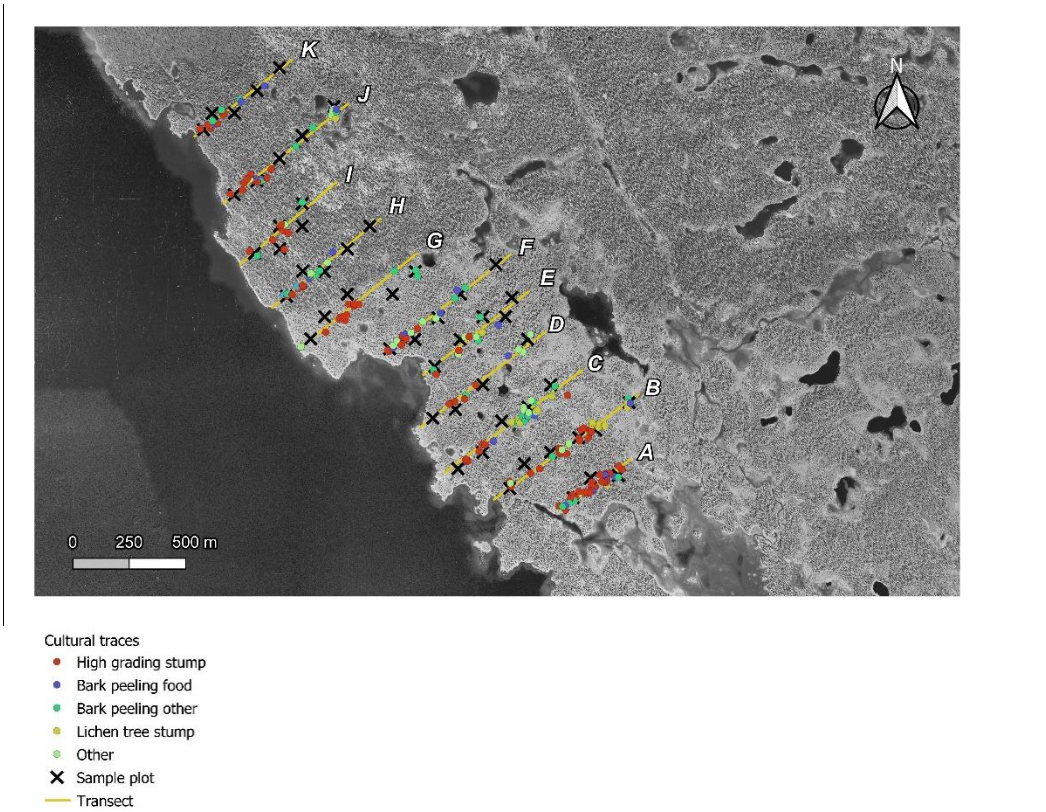
Figure 3. Map of the study area showing recorded high-grading stumps (red dots) along the transects and plots. Map by: Alice Cosatti, 2020.



3.2.3. Spatial distribution of Sami and other cultural traces

Overall, 234 cultural traces were found in the study area, of which 114 were high-grading stumps, 78 Sami cultural traces as well as 42 other cultural traces. Looking at Sami cultural traces, 25 food bark peelings, 35 other bark peelings and 18 lichen tree stumps (Figure 4) were detected. Sami cultural traces were detected on all transects from the lakeshore to the inner parts of the study area.

Figure 4. Map showing the study area and all recorded cultural traces found along the transects and plots. Map by: Alice Cosatti, 2020.



3.3. Comparison between high-graded and not high-graded plots

In order to compare plots where high-grading occurred (Figure 5) and plots that were not affected by high-grading (Figure 6), forest characteristics were compiled in Table 3. Tree height was approximately the same for both Scots pine and Downy birch when comparing the two groups. The mean tree age of both Scots pine and Downy birch was higher in not high-graded plots compared to those where high-grading had been performed. The mean basal area of Scots pine was lower in not high-graded plots, however, the lower range was higher than in high-graded ones. Scots pines in not high-graded plots showed a slightly higher mean diameter compared to high-graded plots, whereas mean diameters of Downy birch were approximately the same in the two compared groups. The mean basal area of lying and standing deadwood was almost the same for both compared groups, as well. The total volume of standing deadwood was higher on average in not high-graded plots.

When looking at statistical differences between the variables listed in Table 3, a statistically significant difference in the mean Scots pine volume was found. The mean total volume of Scots pine in not high-graded plots was significantly higher compared to the mean total volume in high-graded plots ($p=0.047$). Apart from this, no significant differences were detected.

Figure 5. Cut stump found in the high-graded plot 1 on transect F close to the lakeshore. Photo by: Alice Cosatti, 2020.

Figure 6. Overview picture of the non high-graded plot 5 in the inner part of the research area on transect K showing old branchy Scots pines, standing and lying deadwood. Photo by: Alice Cosatti, 2020.

Table 3. Forest characteristics comparing plots where high-grading was observed with plots where no high-grading was observed.

Variable	High-grading		No high-grading	
	Mean ± SE	Range [e]	Mean ± SE	Range [e]
Living trees				
Tree height of: [a]				
Scots pine	15.6 ± 0.13	10.5 – 18	15.6 ± 0.13	12 – 20
Downy birch	7.7 ± 0.07	5 – 11	7.6 ± 0.07	4 – 10
Mean tree age of:				
Scots pine (years)	261.7 ± 7.97	123 – 487	279.4 ± 9.32	110 – 569
Downy birch (years)	108.8 ± 6.31	50 – 186	119.2 ± 7.28	52 – 246
Basal area [b]				
Scots pine	14.2 ± 0.94	1 – 23	12.5 ± 0.59	6 – 18
Downy birch	3.1 ± 0.52	0 – 8	4 ± 0.69	0 – 14
Diameter of: [c]				
Scots pine	24.5 ± 0.70	6 – 52	26.6 ± 0.80	7.5 – 56
Downy birch	9 ± 0.21	5 – 21.5	8.9 ± 0.20	5 – 25
Total volume of: [d]				
Scots pine	102.2 ± 15.33	18 – 316.7	107.5 ± 13.37	7 – 310.8
Downy birch	11.3 ± 1.48	1.8 – 26.8	11.7 ± 2.01	0.3 – 39.6
Lying deadwood				
Basal area [b]	2.2 ± 0.31	0 – 6	2.3 ± 0.28	0 – 5
Standing deadwood				
Basal area [b]	2.2 ± 0.29	0 – 7	2.2 ± 0.31	0 – 6
Total volume [d]	22.9 ± 5.40	0.4 – 99.5	29.7 ± 4.43	2.2 – 78.4

[a] Arithmetical mean tree height in meters for the 100 largest trees per hectare.

[b] Basal area in m^2/ha

[c] Mean DBH in cm

[d] Volumes in m^3/ha

[e] Range is the variation within the sample plots.

4. Discussion

4.1. The end of the timber frontier

The historical records (Table 1) indicate that logging moved into the upper Piteälven river valley in the late 19th century. An earlier study by Josefsson et al. (2010a) showed clearly that most of Tjeggelvas nature reserve never had been logged, but there were indications of possible logging activity in parts close to the lakeshore.

By analyzing a gradient and searching for signs of logging (e.g. cut stumps) I was able to identify relevant logging traces and thus find the end of the timber frontier in the research area. Spatial analyses (Figure 3) clearly show the timber extraction close to the river and along the lakeshore, whilst no cut stumps were found further inland. Therefore, the results demonstrate clearly where the timber frontier ended in Tjeggelvas nature reserve.

4.1.1. Historical logging at the edge of Tjeggelvas nature reserve

The analyzed archival material (Table 1) suggests that the reason for the low high-grading impact was mostly driven by the low productivity of the forest land and the openness of the forests. Only few stems had the right quality for sawn timber and most trees had too many branches, were too short or had crooked stems. Norén (2019) describes that it took two years to float the timber from the northernmost area of Piteälven to the coast. During this time logs could sink and be lost on the way to the sawmills. Moreover, looking at the morphology of the area, rapids after Tjeggelvas lake led to a loss of timber as well. The economic loss as well as the high transport costs can be an additional reason why there has not been any further intensified logging activity in the research area.

Finally, the arrival of the timber frontier in the northernmost parts of Sweden coincided with the establishment of the first national parks and nature reserves, this is how areas like Tjeggelvas nature reserve have been preserved from further exploitation through the wood industry (Östlund and Norstedt, 2021).

4.1.2. Effects of high-grading

This study provides a novel insight regarding the long-term effects on the edge of the timber frontier in a northernmost Swedish late-successional pine forest. For the first time the end of the timber frontier could be delineated and the effects of high-grading analyzed.

The results show that the logging was very light. This is supported by the low number of tree stumps found in the research area (18 cut stumps/ha), as well as by the archival data describing the forest as low productive and trees having bad trunk shapes. It can be inferred that the loggers who selected the trees for timber extraction took only trees of the highest quality. Branchy and insufficiently big enough trees were left. This led to a sparse high-grading in the research area. No clear-cutting occurred in the research area and offers the unique possibility to study the effects of high-grading.

When comparing parameters of this study (Table 2) with an earlier study done by Josefsson et al. (2010a), forest characteristics turned out to be similar. This is remarkable because the latter was conducted in the inner part of Tjeggelvas nature reserve, whereas this study focused exclusively on the vicinity of the lakeshore.

The mean age of Scots pine in high-graded plots was 261.7 ± 7.97 (range: 123-487) and 279.4 ± 9.32 (range: 110-569) in not high-graded plots. This suggests a slight difference between the logged and unlogged plots. Still, no statistically significant difference could be found. Nonetheless, a significant difference could be seen in mean total volume of Scots pine, where high-graded plots showed a significantly lower mean total volume. It can be speculated that the lack in difference regarding the age structure between high-graded and not high-graded plots can be attributed to the timber quality of old trees. The oldest trees might not have been taken as they might have been already rotten or damaged by age. Rather, loggers might have taken middle-aged trees, which probably did not substantially affect the age structure. Another reason could be that only the large diameter middle-aged timber trees were selected, lowering the total volume.

Logging activity was concentrated close to the river and the shore (Figure 3). The number of found stumps in the sample plots ranged between 1 and 5. An underestimation of logging activity is very probable, as the sample plots were scattered systematically in a grid design, whilst overall logging activity was collected on the transects as well.

According to the analyzed archival material, the logging activity in the study area occurred between 1890 and before 1925. Other studies (Östlund and Norstedt, 2021; Rautio et al., 2016) confirm that the timber frontier reached the upper parts of Piteälven around the 1890s. Consequently, the field data sampling for this study was conducted approximately 100-120 years after the logging activity. The time span between the initial industrial logging interference and date of sampling for this study is very long, therefore the effects of historic high-grading on the current forest structure is blurred. This already late-successional forest shows that a large part of the trees was already very old when the logging occurred, namely 29% of all cored Scots pines older than 300 years, 7% older than 400 years, 60% of all cored Downy birches older than 100 years as well as 16% older than 150 years.

As such a long period has already passed, the forest seems to have recovered from the initial industrial logging. It can be suggested that the developmental time frame of this boreal forest ecosystem is so long that the influence of this very light high-grading did not influence the diameter distribution. However, the standing Scots pine diameter distribution might not show large differences as this tree species does not respond as plastically to openings as Downy birch does (Beck et al., 2016). Hence, Downy birch trees might have had an advantage, as they could have reacted to openings in some areas. Even though Downy birch trees react to openings with more growth, the ecological value of very old Scots pine trees cannot be replaced.

There have not been any larger forest ecosystem disturbances like fire or windthrows since the timber frontier reached the research area. Fire suppression has been implemented since the end of the 19^{th} century and has affected the natural disturbance regime of the studied area as well (Cogos et al., 2019).

Looking only at forest structure parameters, one can conclude that the trees seem to be resilient towards the very low impact of high-grading. Still, other parts of the ecosystem can be more heavily affected in the long term e.g. wood-inhabiting fungi and saproxylic beetles who need certain microhabitats in e.g. large diameter Scots pines' coarse woody debris (Josefsson and Spirin, 2010; Josefsson et al., 2010b). Moreover, special ecological niches created by those large-diameter Scots pines disappeared (Josefsson et al., 2010a). Normand et al. (2017) describe with the concept of human perturbation that different scenarios can occur after humans interfere in an ecosystem. One of these scenarios depicts a resilient bounce-back from human perturbation to a stable state. However, the time frame from reaching this stable state is not clearly defined. Hence, it is difficult to state if enough time has already passed in this study, or if the effects of the logging are still visible. Albrich et al. (2021) observed that forests can already show characteristics of old-growth forests 100 years after logging. This suggests that the impact of the high-grading might already be balanced out to a certain extent.

4.2. Contextualizing the concept of the timber frontier

4.2.1. Global perspectives on the timber frontier

The hunger for timber during the industrial revolution led to timber frontiers in Fennoscandia, Russia, North America and Patagonia (Hagg, 1948; Smith, 1974, Björklund, 1984; Östlund, 1995). The timber frontier began in Norway and then moved northwards through Sweden, changing the forests drastically. Especially easily accessible forest areas close to rivers, to the coast, and southern areas were the first to be logged (Östlund, 1995; Östlund et al. 1997; Östlund and Norstedt 2021). From a Western European perspective, Northern European forests were viewed as an inexhaustible timber resource at that time, boosting their exploitation (Lotz, 2015). The same narrative of infinite timber resources can be seen in the North American timber frontier history (Hagg, 1948; Smith, 1974; Boucher, 2009). It is interesting that both Boucher et al. (2009) and Östlund (1995) found that the first timber frontiers in Eastern Quebec and Sweden, respectively, were initially limited to single tree extraction. Logged trees were used at that time for sawn timber products. As industrial capacity grew and most notably when the demand for pulp wood for paper production increased, logging intensity shot up and led to clear-cutting and plantations (Boucher et al., 2009; Lundmark et al., 2013). Nordberg et al. (2013) postulate that the timber frontiers in Fennoscandia and Northwestern Russia eventually led to sustainable forest management. However, it is questionable whether forest management practices such as clear-cutting and plantation systems can truly be called sustainable. Rather, it might be argued that these practices are simply a consequence of the intensification of industrial timber production that were made necessary after previous drastic land-use change had changed the entire forest ecosystem.

4.2.2. The timber frontier narrative: a social construct?

Research on the concept of the timber frontier is sparse, as is academic literature providing concise definitions of the concept. Difficulties in demarcating the line between human (industrial) interference and so-called “pristine” forest landscapes are compounded by the fact that hardly any forests are truly devoid of human interference (Cronon, 1996). Particularly indigenous populations with their subsistence livelihoods and low-impact, regenerative land stewardship practices add a layer of complexity when it comes to defining parameters for human disturbance in forest ecosystems.

The clash of industrial timber management and indigenous traditional land practices becomes especially pronounced during times of colonialization.

Justification narratives are needed by the colonizers for appropriating resources. One legitimization narrative for colonial resource exploitation attempts to “empty” the land (Tsing, 2005; Larsen, 2015). The *terra nullius* concept declares certain landscapes as “no one’s land” despite it being inhabited by indigenous peoples for hundreds of years. This strategy can even be traced back to the times of the Roman Empire (Geisler, 2012). Also, Turner (1893) describes the same process of colonization in Northern America on “free land”: it was driven by the argument of land development and proceeded westwards on a line. One characteristic of this socially constructed narrative, or rather a myth, is its procedural nature: frontiers were not unequivocally delineated but continuously reshaped and redefined (Little, 2001). By invoking the frontier narrative, new waves of people arriving with different interests and seeking to appropriate new resources in the same geographical area shape the colonized landscapes in multiple ways over and over (Little, 2001; Larsen, 2015).

According to Little (2001) and Larsen (2015), commodity frontiers are reoccurring on the same land as societal and economic needs change. This is true not only in the 19th century but also today. New frontiers appear as a voracious appetite for biomass drives the exploitation of forest land in northernmost Sweden. This dynamic is bolstered by the narrative of the bioeconomy. In addition, a surge in installations of wind power parks can be observed, representing a wave of green colonialism (Normann, 2021). Consequences of land exploitation are not always visible when the resource appropriation takes places but often lead to long-term legacies and irreversible ecosystem changes that future generations will have to deal with. Analyses of past frontiers’ long-term effects on ecosystems might hence be useful for researchers as well as political decision-makers as they attempt to gauge the effects of modern frontier waves.

Moreover, further academic discussion on the definition of the frontier concept is recommended, on its socially constructed nature and its roots in colonial history. Promoting a dialogue between social and natural sciences on the timber frontier concept is of the utmost importance as environmental history research thrives under the contributions of both disciplines.

4.3. Limitations of the methodological approach

Overall, the heterogeneity of the study area makes the comparison across sample plots particularly difficult. The soil parameters were not the same across all sampled plots, and there was a variety in conditions with plots having more rocks, bare rock or being parts of mire systems (Figure 7). Therefore, microhabitats play a crucial role in such a heterogeneous forest area. Moreover, as found by Lilja and

Kuuluvainen (2005), the structure of old Scots pine-dominated boreal forests can vary widely. Especially if natural forest disturbance regimes e.g. fire are suppressed over decades (Cogos et al., 2019).

Traces and effects of the high-grading activity might have been erased over the past 100-120 years. A larger area surveyed with closer transects and a denser grid of sample plots plus more plots further inland where no logging has occurred could help with extracting more information for analyzing the difference between high-graded and not high-graded plots. Furthermore, the effects of high-grading could by highlighted, not only by looking at forest structure but also e.g. soil parameters, ground vegetation, fungal species diversity, a detailed survey of coarse wood debris volume and distribution, or spatial parameters between the trees inside the plots.

Sami cultural traces were found all over the studied area on all transects, from the lake shore to the inner parts of the forest (Figure 4). This confirms that Sami people have been living in this area for many centuries before the land was colonized and that the timber frontier reached the area of Tjeggelvas nature reserve. Previous research done in the inner parts of Tjeggelvas nature reserve focused especially on culturally modified trees and other Sami cultural traces (Bergman et al., 2003; Andersson et al., 2005; Josefsson et al., 2010a; Norstedt et al., 2014; Rautio et al., 2016). Therefore, it is necessary to consider that Sami land use might be one reason for background noise on current forest structure. This background noise effect complicates the analysis of how the timber frontier affected the forest structure and needs to be considered in future research.

5. Conclusion

In this study I could mark out the end of the timber frontier in the Tjeggelvas nature reserve. The gradient analysis showed that the long-term effects on either side of this frontier on a late-successional boreal forest in northernmost Sweden are nowadays not clearly visible. The parts of the forest region that have been touched by the timber frontier do not differ substantially from those that remained free from logging. This serves as testimony to forests' resilience capacities of bouncing back from low-impact high-grading, especially when given long time frames for recovery after human interference. Independently collected archival data supports the results that only few trees were logged due to the low timber quality and low stand productivity in the area. Long timber floating distances to the sawmills and high costs for low-quality timber might have been driving reasons why the timber frontier stopped in the studied area. Moreover, the historical coincidence of the timber frontiers' late arrival and the establishment of the first protected nature reserves can be reasons why Tjeggelvas nature reserve escaped further logging.

Still, further research is needed to understand the effects of high-grading on other species besides tree species e.g. saproxylic insects and wood-inhabitant fungi. Moreover, a more extensive inventory in a larger area, with closer transects and sample plots, and additionally, plots reaching further inland would be needed in order to collect more accurate data. This would help with analyzing the differences in forest structure along the gradient from the lakeshore towards the inner parts of the nature reserve.

Finally, following Tsing's (2005) line of reasoning, we should recall that protected areas are not merely reference areas and biodiversity hotspots, but also serve as vital refuges for future species dispersal. Therefore, I recommend a stronger legal protection for this unique forest and a reinforcement of Sami land use rights as an acknowledgment of their expertise in regenerative land stewardship.

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Acknowledgements

First, I want to thank my parents Bernadette Lucchesi Palli and Manlio Cosatti, for always supporting me, especially when I was far away from home, and for always believing in me and my choices.

I also want to thank Per Linder from Fastighetsverket who gave me the permission to conduct my research in Tjeggelvas nature reserve. Moreover, I want to thank John-Erik Hansson from Arkivcentrum Nord from Riksarkivet in Härnösand for helping me to find the right historical sources. Furthermore, I want to thank the SHS student union for the financial scholarship I have received for this master's thesis.

Very grateful thanks to my supervisor prof. Lars Östlund who guided and motivated me through the whole process from the initial idea, to the fieldwork in Tjeggelvas nature reserve and lastly to complete this master's thesis. Even though writing this thesis was a non-linear process and external effects had an impact on the proceedings, I am very grateful for having been supported and guided through this process with so much positive energy, and especially for all the knowledge you shared with me.

Thank you Marlène Baudet for your support during the fieldwork, the productive working in the dendrolab and for sharing your knowledge about dendrochronology with me. Furthermore, thank you Torbjörn Josefsson for your valuable input regarding the methodology and fieldwork handbook, as well as for the great teamwork in Tjeggelvas nature reserve. Thank you a lot for sharing your knowledge on forest ecology and the research area with me. A very big thank you is directed to the best field assistants Lollo Aurell, Sofia Aurell and Leon Hauenschild for your help during the fieldwork and the great time spent together in Tjeggelvas nature reserve. Still, without our boatman Scholle, we would not have reached the study area, thank you for driving us safely over Tjeggelvas lake and picking us up again. Without this fantastic fieldwork team this thesis would not have been possible.

Finally, if it were not for the many friends I met in IFSA (International Forestry Students' Association) my path would not have led me to study forest ecology in Umeå. I am especially grateful for the support of my friends from "Awesome Forestry" and "QFK Stammtisch" – our endless talks and chats always gave me motivation and energy to continue staying in the forestry world.
Still, without two very special humans I would not have been able to conclude this thesis. Thank you, Iris, for being my very best forestry friend, giving me a home when I was lost and for being nerds together. And most importantly, Angelika, thank you for being my partner in life, for all the support during the final phase of this thesis and for building nests together.

Supplementary information

1. Field data collection procedures and protocols

1) General design and procedure

In this field work we are going to collect two different kinds of data:

- cultural traces – collected on transects (using iPads)
- forest data – collected on sample points/plots (using protocols)

Our measurements are conducted using parallel transects oriented 90° to the coast shore, in combination with circular sample plots aligned in a grid. Finding both cultural signs and analysing the vegetation structure is the goal of this field work. The transects are wide 20m. The person in the middle is in charge of leading the group and holding the direction of the transect, whilst to each side in a distance of 10m a person is walking and looking for cultural signs. Markings are noted on the iPad so that the type and coordinates are saved. The distance between the transects needs to be decided on in the field but should preliminary be 200m. The distance between the circular sample plots needs to be decided as well on the field but be approximately every 50-100m. Here the nearest sample plot to the transect is taken. All circular sample plots have an area of 0,1ha and a radius of ~17,84m. The transects are named alphabetically A,B,C… whilst the plots are named numerically 1,2,3…

2) Recording cultural signs

Record the marking on the iPad so that the coordinates are as accurate as possible. Note what kind of marking it is and (optional) write in the comment section details about it. If applicable note the tree species, diameter of the tree/stump, core number and take pictures of it. Note as well the number of the taken picture so that it can be assigned to the right marking.

Marking types:
1 = stump
2 = crown marking
3 = scar from logging
4 = culturally modified tree (CMT)
5 = other (specify in comments)

3) Measuring structure and recording cut stumps

The measuring procedure is described in detail in 3.1) and 3.2). Here an overview of the measurements is given:
1) Pinpointing the centre of the sample plot – marking it with a stick
2) Laying out the two 50m measuring tapes (north, east)
3) Describing forest type, field vegetation
4) Measuring basal area for each tree species including standing dead trees, marking of trees for coring
5) Measuring upper tree height (the two biggest trees, i.e. diameter at a max distance of 20m)
6) Coring of the marked trees and the oldest tree in the sample plot, including one core for each species that occurs in the plot as well
7) Recording cut stumps

3.1) Circular sample plot

Before leaving the transect mark the spot with a marking stick so that you know where to continue after you finished the measurements.
How do conduct the measurements for the vegetation structure is stated in 3.2).
The whole circular plot is searched for cut stumps. Here the same procedure is done as on the transects. The marking type and the coordinates are recorded on the iPad, and pictures of the signs are taken.

3.2) Vegetation structure

The diameter distribution is measured in ¼ of the circular sample plots. All trees with a DBH >5cm are measured in the ¼ plot area with a radius of 17,84m. One measuring tape is rolled out to the north direction and the second to the east. When doing measurements always start from the centre towards the north and then move on to the east. Mark the centre of the circular plot with a marking stick so that its position is clear during the whole measurement procedure.

Diameter is measured at breast height (DBH = 1,3m) with a pi-band or caliper of all trees with a DBH >5cm. If the tree is a birch with multiple stems, measure all stems diameter DBH >5cm. The tree species of every measured tree is noted.

The basal area for the whole plot is measured using a relascope all trees that fill up more than the gauge width are counted and according species are noted. Every second tree that does not completely fill out the gauge is counted in as well. Every 5th tree is additionally marked with tape to later be cored. From each plot at least 5 cores should be taken. A core of the oldest tree in the circular plot, which is the dominating one should always be taken. Take as well always a core of a birch tree if birch is present in the sample plot, same with spruce. Take care to stand in the centre of the plot and always start in the north direction to the right of the measuring tape. Turn 360° around yourself and count the trees you see. When looking through the gauge, point at DBH (=1,3m) and if you cannot see a tree clearly step to the side, do the measurement and step back to the centre.

The top height of trees to be measured inside the circular sample plots should be those two which have the largest diameter and are not more than 20m apart from each other. If the plot has both pines and spruces in it, then one pine and one spruce should be measured. As the trees in the nature reserve are not that high it is possible to measure their height from 15m distance. Roll out the measuring tape from the base of the tree so that it is laying horizontally on the ground to 15m. To measure the height, start with calibrating the clinometer to 15m distance. To avoid errors, it is recommended to lean the clinometer on the head and hold it steadily. Look at the base of the tree trunk and push the button. Then look to the tree top and click again, so that the tree height is measured. Always measure the same tree twice to make sure you get the correct measurement. After the fieldwork the tree heights will be used with growth tables to calculate the volumes of the plots.

To work efficiently it is for example good if one person writes, one puts the stripes on the trees that shall be cored, and one does the relascope measurement. Then the person putting on the stripes does the coring as well and the person doing the relascope measurement can continue with measuring the tree heights and the tree diameters. Finally count the cut stumps last.

4) Coring of trees

Every 5th tree falling into the relascope measurement is cored. The species does not matter for this counting. The oldest/most dominating tree in the plot should be cored as well if it is not included in the already marked trees. At least 5 trees need to be cored per circular sample plot.
Trees in the circular sample plots are always cored at 1,3m height (=DBH). When coring one is aiming to the centre of the tree. The corer is held horizontally and turned into the tree until the centre is hit. After that the core can be taken out. Be very carefully when taking it out, so that no rings get lost. The core is wrapped in paper, sealed with tape. Mark the core as described in 6): transect letter, sample plot number, core number, (coordinates – only for trees with cultural traces), species, date, tree diameter (e.g. A 1 1 N7383980 E0619447 PI 15/06/2020 60cm). If the tree is rotten, still collect the possible amount of the core and note that the tree was rotten and note how many cm are missing of the core until the tree centre.
Coring stumps, logged trees or trees with markings/relevant cultural signs should always be done very carefully. They may be rotten or in some decay stage. If the wood is fragile but year rings of a stump are visible and can be collected, then a cookie can be cut. This should be done very carefully to not lose parts. Tape the wood on one side so that it stays connected and wrap the cookie into paper. Tape the sample and mark it the same way as cores.
In the lab 46 years are added to the result, as that is the average age trees have when they reach DBH.

5) Core numbering

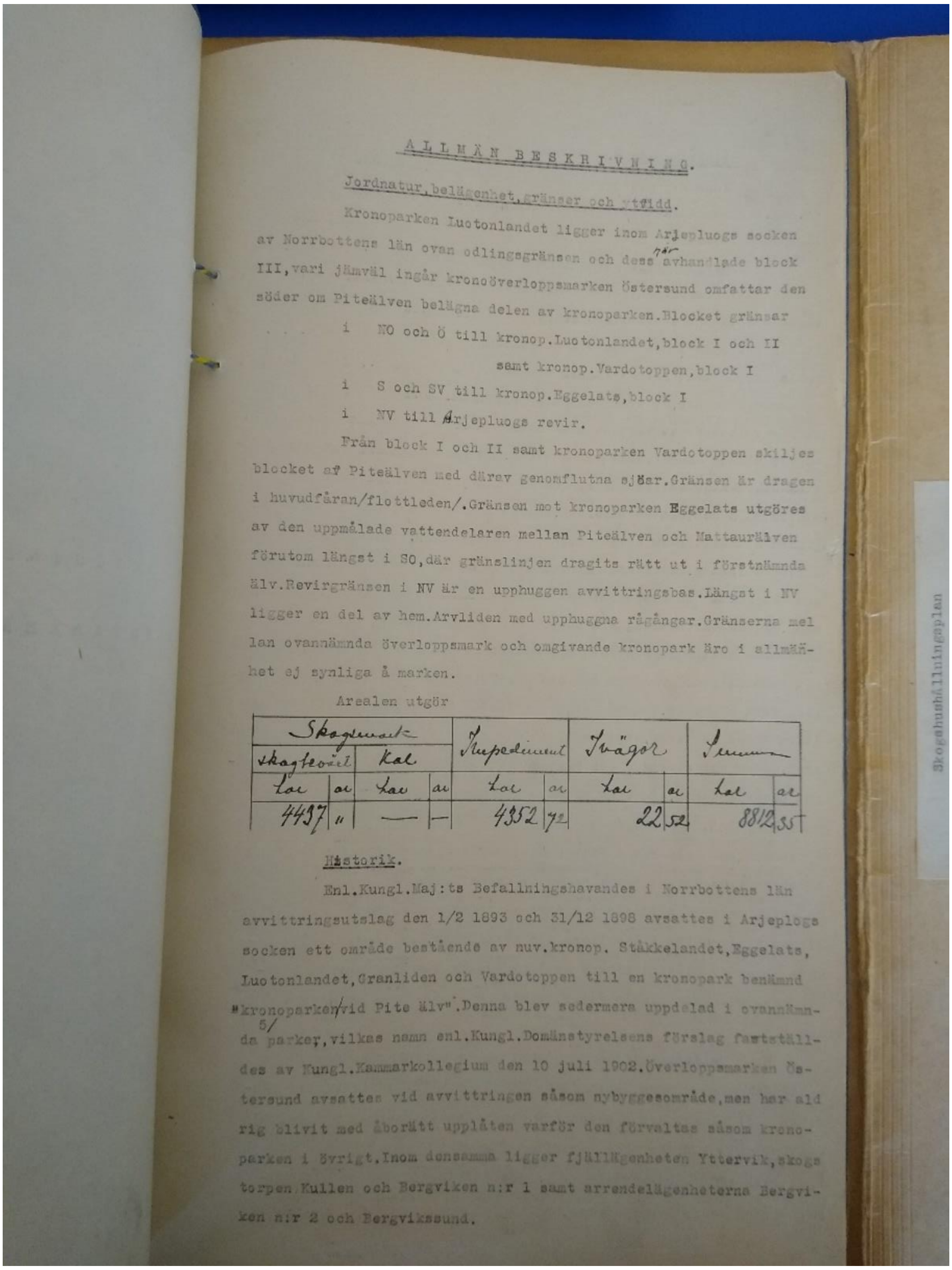
Cores or cookies from trees or stumps should be marked as following:
Transect letter, (sample plot number), core number, (coordinates – only for trees with cultural traces), species, date, tree diameter
e.g.: A (1) 1 (N7383980 E0619447) PI 15/06/2020 60cm
The abbreviations for species are: PI = pine, SP = spruce, BI = birch

6) Field work protocol

Area:			**Date:**			**Plot.no:**		**Photo-id:**	
X-coord:			**Y-coord:**			**Team:**			
Description:							**No. cored trees:** **No. cut stumps:**		
Basal area:	**Pine**	**Spruce**	**Birch**	**Dead**		**Height:**	**Tree 1**	**Tree 2**	**Birch**
Diameters:									
Area:			**Date:**			**Plot.no:**		**Photo-id:**	
X-coord:			**Y-coord:**			**Team:**			
Description:							**No. cored trees:** **No. cut stumps:**		
Basal area:	**Pine**	**Spruce**	**Birch**	**Dead**		**Height:**	**Tree 1**	**Tree 2**	**Birch**
Diameters:									
Area:			**Date:**			**Plot.no:**		**Photo-id:**	
X-coord:			**Y-coord:**			**Team:**			
Description:							**No. cored trees:** **No. cut stumps:**		
Basal area:	**Pine**	**Spruce**	**Birch**	**Dead**		**Height:**	**Tree 1**	**Tree 2**	**Birch**
Diameters:									
Area:			**Date:**			**Plot.no:**		**Photo-id:**	
X-coord:			**Y-coord:**			**Team:**			
Description:							**No. cored trees:** **No. cut stumps:**		
Basal area:	**Pine**	**Spruce**	**Birch**	**Dead**		**Height:**	**Tree 1**	**Tree 2**	**Birch**
Diameters:									

2. Selected archival material

Figure 7, 8, 9 and 10. Skogsindelningsplan Krp. Luottonlandet bl. III. General site description of Luottonlandet kronoparken block III. Photos by: Alice Cosatti, 2020.



ALLMÄN BESKRIVNING.

Jordnatur, belägenhet, gränser och vidd.

Kronoparken Luotonlandet ligger inom Arjepluogs socken av Norrbottens län ovan odlingsgränsen och dess här avhandlade block III, vari jämväl ingår kronoöverloppsmarken Östersund omfattar den söder om Piteälven belägna delen av kronoparken. Blocket gränsar

i NO och Ö till kronop. Luotonlandet, block I och II samt kronop. Vardotoppen, block I

i S och SV till kronop. Eggelats, block I

i NV till Arjepluogs revir.

Från block I och II samt kronoparken Vardotoppen skiljes blocket af Piteälven med därav genomflutna sjöar. Gränsen är dragen i huvudfåran/flottleden/. Gränsen mot kronoparken Eggelats utgöres av den uppmålade vattendelaren mellan Piteälven och Mattaurälven förutom längst i SO, där gränslinjen dragits rätt ut i förstnämnda älv. Revirgränsen i NV är en upphuggen avvittringsbas. Längst i NV ligger en del av hem. Arvliden med upphuggna rågångar. Gränserna mellan ovannämnda överloppsmark och omgivande kronopark äro i allmänhet ej synliga å marken.

Arealen utgör

Skogsmark				Impediment		Vägar		Summa	
skogbevuxet		Kal							
har	ar	har	ar	har	ar	har	ar	har	ar
4437	"	—	—	4352	72	22	52	8812	35

Historik.

Enl. Kungl. Maj:ts Befallningshavandes i Norrbottens län avvittringsutslag den 1/2 1893 och 31/12 1898 avsattes i Arjeplogs socken ett område bestående av nuv. kronop. Ståkkelandet, Eggelats, Luotonlandet, Granliden och Vardotoppen till en kronopark benämnd "kronoparken vid Pite älv". Denna blev sedermera uppdelad i ovannämnda 5/ parker, vilkas namn enl. Kungl. Domänstyrelsens förslag fastställdes av Kungl. Kammarkollegium den 10 juli 1902. Överloppsmarken Östersund avsattes vid avvittringen såsom nybyggesområde, men har aldrig blivit med åborätt upplåten varför den förvaltas såsom kronoparken i övrigt. Inom densamma ligger fjällägenheten Yttervik, skogstorpen Kullen och Bergviken n:r 1 samt arrendelägenheterna Bergviken n:r 2 och Bergvikssund.

Tjänstbarheter.

Inga av enskilda disponerade ströängar finnas inom blocket. Ang. lapparnas rätt till skogsfångst, jakt och fiske se renbeteslagen av den 1/7 1898.

Skogsmarkens och ståndskogens beskaffenhet.

Jordmånen utgöres genomgående av starkt stenbunden, ofta blockig morän av synnerligen mager beskaffenhet. Den sydvästra delen av blocket omfattande trakterna å och omkring Kartevare 634 m.ö.h. Konjokbergen samt norr - Kålrek och Lulebtjåkko 744 m., ett område om cirka 2500 har, är av typisk lågfjällnatur. De skogbärande delarna härav intagas av kortvuxen ofta topptorr och rötskadad gran merendels rikligt uppblandad med lövskog. Ett undantag härifrån utgör i viss mån sänkan mellan Konjok och Lulebtjåkko där granskogen når större höjd och bättre stamform. Norrut mot Varrasviken börjar även granen att allt mera avvika från fjällskogstypen, varvid tallen vinner ökat insteg. Östra sluttningen av Konjok utmärker sig för ganska god skogsmark och klädes av tallskog med mot berget ökad graninblandning. Mellan Varrasviken och Luotonjaur har tallskogen blivit den ~~härskande~~ utmärkande beståndstypen dock här starkt uppblandad med björk, som vunnit ökad utbredning efter den stormhärjning som för 25 år sedan övergick detta område. Trakten söder om Luotonjaur består likaledes av stormskadad tallskog, vari emellertid björken ej vunnit kraftigare insteg. Söder om Kallojaur och Mårsomjaur vidtager ett merendels försumpat blocklandskap, som dock närmare rågången mot kronop. Eggelats blir mera hedartat. Ståndskogen är här urgammal tall av dålig typ. De många stora och små holmarna i Pite - älven vilka ligga mitt för detta blocklandskap äro av samma ~~natur~~ karaktär. De nedanför Hammarholmen belägna holmarna hava däremot något bättre skogsmark och utmärka sig å översilade ställen för synnerligen god växtlighet. Den längst i SO liggande delen av blocket täckes av tallungskog med kvarstående överståndare. Blockets lägsta delar, trakterna kring Piteälven, ligga 400-430 m.ö.h.

Detaljuppgifter för de olika avdelningarna återfinnas i beståndsbeskrivningen. Beträffande massa- och tillväxtfaktorer hänvisas till blank. n:r 5 B och 6 B. Skogsstatistiken har sammanförts å blank. n:r 7 B, där bl.a. arealens fördelning på olika åldrar och boniteter samt virkesförrådets sammansättning ifråga om ålders - och mogenhetsklasser kan studeras.

Föryngringen.

Där stormfällning eller tidigare plockhuggning lämnat rum för återväxten att infinna sig och marktillståndet varit någorlunda gynnsamt såsom inom vissa delar av avd.16 har nöjaktig självföryngring erhålits. Å de alltför magra och torra ståndorterna samt de försumpade blockmarkerna äro återväxtförhållandena däremot ogynnsamma. Verkningarna av de regelrätta föryngringshuggningar som under senare år utförts hava visserligen ännu ej hunnit göra sig gällande, men även om därav rätt mycket är att hoppas kvarstår dock det faktum att marktillståndet allt framgent kommer att flerstädes lägga stora hinder i vägen för en nöjaktig reproduktion av skogen.

Skogsbete och höslåtter.

Å skogen beta ett fåtal nötkreatur och renar samt får och getter tillhöriga inom blocket eller i dess grannskap bosatta familjer. Myrängarna utnyttjas av ortens befolkning.

Lägenheter.

Inom blocket finnas följande lägenheter upplåtna samtliga liggande kring Varrasviken.

Fjällägenheten	Yttervik	6.24 har
Skogstorpet	Kullen	4.70 "
"	Bergviken n:r1	3.83 "
Arrendeläg.	Bergvikssund	1.13 "
"	Bergviken n:r2	1.12 "

Dessutom bosättningen Luoton om 5.50 har inhägnad mark.

Åverkningar och skador.

Den svåra storm som år 1899 övergick vissa delar av Arjeþluogs och Jokkmokks socknar har svårt tilltygat stora delar av blocket särskilt trakterna mellan Varrasviken och Luotonjaur samt söder om denna sjö. De stora avverkningar som härav blevo en följd medförde en kortvarig "guldålder" för dessa i många avseenden eljest så vanlottade trakter. Den ovannämnda bosättningen Luoton var de stora drivningarnas centralpunkt, ett Klondyke i miniatyr på gott och ont.

Förvaltning och bevakning.

Blocket tillhör Arvlidens bevakningstrakt av Malmesjaurs revir.

Avsättnings - och skogsarbetareförhållanden.

Virket utdrives till Piteälvens distr. Ia och II, med distriktsgräns vid Luodokbäckens inflöde. Flottningskostnaderna till kusten utgjorde åren 1921 och 1922 resp. 15.25 och 11.29 öre samt 19.95 och 13.83 öre per kbft. År 1923 flottades endast distr. II till en kostnad av 14.36 öre. Drivningsvägen växlar mellan 0 - 6 km. och är ogynnsammast för fjällskogsområdet. Tillgången på skogsarbetare är relativt god även om för avverkningar och andra större arbeten folk från andra orter kan behöva anlitas.

Ingen skiftesindelning har ägt rum.

<u>Kartläggningen och uppskattningen av virkesförrådet</u>, utfördes år 1923 av skogselev R. Ekehjelm, under skogstaxatorns ledning. Linjetaxering i 10 m. breda bälten på 400 m. inbördes avstånd verkställdes i enlighet med Kungl. Domänstyrelsens P.M. för förenklad skogsindelning av år 1921. För möjliggörande av kubikmasse- samt utbytesbestämningar för mera likartade skogsområden var för sig särprickades trädantalet samt redovisades taxerad yta för vissa större avdelningar. Resultatet härav återfinnes å blank. n:r 3 B. Cirkelprovytor med 5 m. radie utlades å prod. skogsmark på var 400 m. i och för åldersklassbestämning av skogen, varvid jämväl massa- och tillväxtfaktorer undersöktes inom cirklar av med viss brösthöjdsdimension fallande radie. Kungl. Domänstyrelsens indelningscirkulär av den 27 maj 1916 har i tillämpliga delar tjänat till efterrättelse.

Figure 11. Map showing Luottonlandet kronoparken block III and Eggelats kronoparken bl. I-IV. Photo by: Alice Cosatti, 2020.

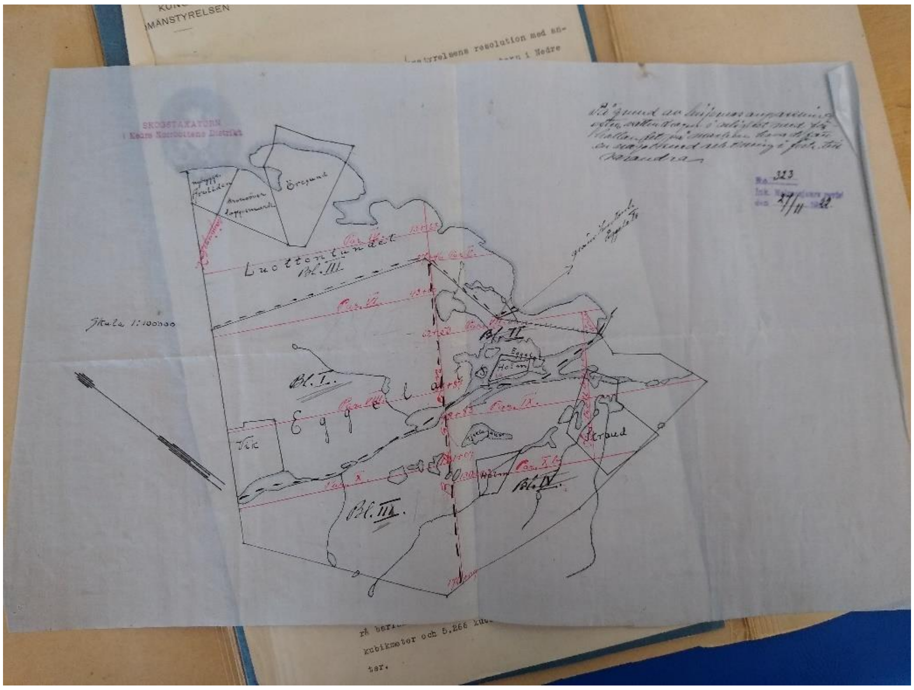
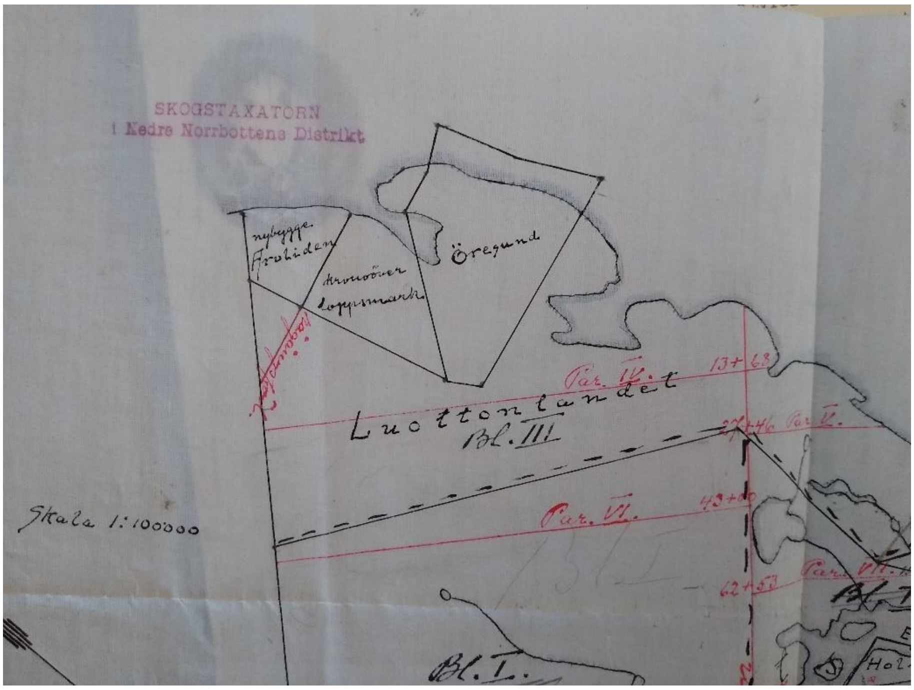


Figure 12. Detail of the map showing block III. Photo by: Alice Cosatti, 2020.



3. Selected photos illustrating the research area

Figure 13. Drone picture showing plot 5 on transect A. Lying and standing dead wood, big boulders and open forest structure with Scots pines and Downy birch. Photo by: Alice Cosatti, 2020.

Figure 14. Drone picture showing plot 4 on transect K. Very dry stand, large boulders, very sparse forest structure. Photo by: Alice Cosatti, 2020.

Figure 15. Forest structure close to plot 5 next to a mire system on transect J. Photo by: Alice Cosatti, 2020.

Figure 16. Forest structure close to plot 4 on transect J showing the late-successional Scots pine forest structure with standing dead trees, old Scots pines and some Downy birch. Photo by: Alice Cosatti, 2020.

Figure 17. Forest structure of plot 2 on transect B. Photo by: Alice Cosatti, 2020.

SENASTE UTGIVNA NUMMER

2021:02 Författare: Therese Strömvall Nyberg
Vad betyder det att skydda natur? – En europeisk jämförelse av skyddade områden

2021:03 Författare: Oscar Nilzén
The Guardian Forest – sacred trees and ceremonial forestry in Japan

2021:04 Författare: Gustaf Nilsson
Riparian buffer zones widths, windthrows and recruitment of dead wood
A study of headwaters in northern Sweden

2021:05 Författare: Louise Almén
Naturhälsokartan - Hälsofrämjande naturområden i Väster- och Österbotten

2021:06 Författare: Lisa Lindberg
Trait variation of Lodgepole Pine – do populations differ in traits depending on if they are invasive or in their home range?

2021:07 Författare: David Falk
Drivers of topsoil saturated hydraulic conductivity in three contrasting landscapes in Kenya - Restoring soil hydraulic conductivity in degraded tropical landscapes

2021:08 Författare: Jon Nordström
En märr som hette Mor – De sista härjedalska hästkörarnas berättelser från tiden innan skogsbrukets mekanisering.

2021:09 Författare: Roberto Stelstra
Implementation of native tree species in Rwandan forest plantations – Recommendations for a sustainable sector

2021:10 Författare: Kazi Samiul Islam
Effects of warming on leaf – root carbon and nitrogen exchange of an ericaceous dwarf shrub.

2021:11 Författare: Ellika Hermansson
Ett riktigt hästarbete –skogsarbete med häst i sydvästra Sverige, förr, nu och i framtiden

2021:12 Författare: Fabian Balele
Wildfire dynamics, local people's fire use and underlying factors for wildfires at Liwale

2021:13 Författare: Martina Lundkvist
Samband mellan ståndortsfaktorer, genetik och historiska skördedata från tall- och granfröplantager – krävs ökad precision vid val av lokaler för nyafröplantager?

2021:14 Författare: Maria Grånemo
"I stand here. I will not move" – Women in forestry in northern Sweden during the 20th century

2021:15 Författare: Tim Schacherl
Evaluating Drought Impacts on Ecosystem Water Use Efficiency of Three Different Boreal Forest Sites

2022:01 Författare: Alice Cosatti
The end of the timber frontier in northern Sweden – Early logging, natural forests and the frontier concept