The restoration period

-A new era in forestry

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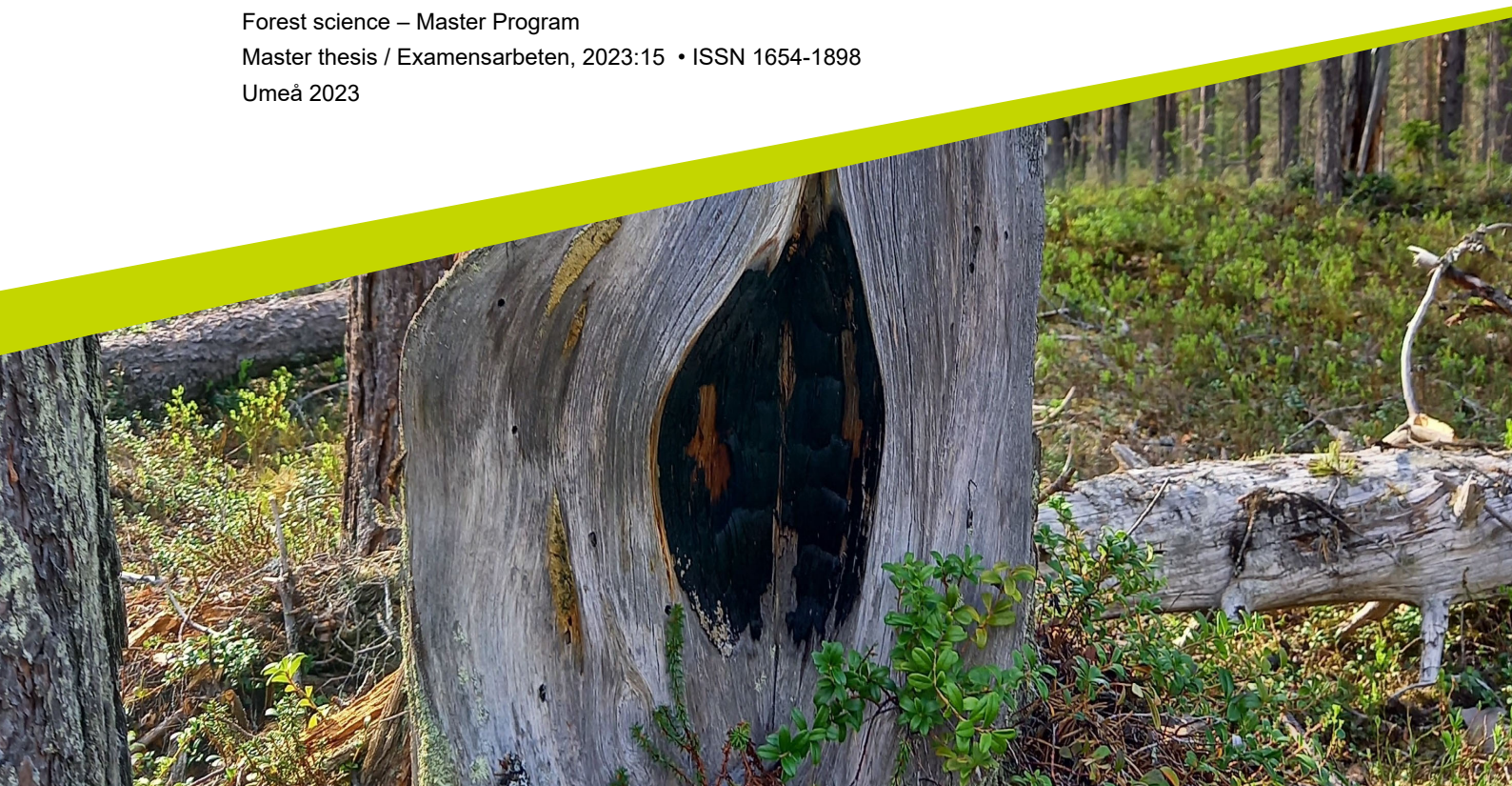
Master thesis • 60 credits
Swedish University of Agricultural Sciences, SLU
Department of Forest Ecology and Management
Forest science – Master Program
Master thesis / Examensarbeten, 2023:15 • ISSN 1654-1898
Umeå 2023



The restoration period - A new era in forestry

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Credits:	60 credits
Level:	A2E
Course title:	Master's thesis in forest science at the Department of Forest Ecology and Management
Course code:	EX0957
Programme/education:	Forest science – Master Program – SY001
Course coordinating dept:	Department of Forest Ecology and Management
Place of publication:	Umeå
Year of publication:	2023
Cover picture:	Ester Andersson

Title of series:	Examensarbeten / SLU, Institutionen för skogens ekologi och skötsel
Part number:	2023:15
ISSN:	1654-1898

Keywords:	Historical forest management, past logging, restoration

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

Förord

Sensommaren 2018 passerade årskurs 17/22 mina hemmatrakter kring Jokkmokk. Naturligt nog spetsades öronen extra mycket när Tord Magnusson tog med oss till en av mina absoluta favoritskogar i området Serri; Hästkullens naturreservat. Här knatades det runt en stund i den senvuxna skogen på snustorra renlavar under gassande sol. Som ganska nybliven student på Jägmästarprogrammet hoppades jag på att få en föreläsning om hur ovanlig, fin eller värdefull den här skogen var men Tords marklära var i vanlig ordning snabb att ta ner en på jorden. Föryngring, eller rättare sagt utebliven sådan, var vårt ”take home message” från denna dag och under mina kommande år på SLU har jag aldrig riktigt kunnat släppa den här dagen. När det så blev dags för examensarbete kunde inte mina funderingar gå obesvarade längre och lyckligtvis kunde jag övertala min handledare Lars om att få göra ett arbete om den här skogen.

Många utmaningar har mött mig längs vägen genom det här exjobbet, främst kopplat till fokus. Ibland har det varit svårt att hålla sig borta från texter om till exampel 150 fågelholkar som skulle sättas upp ute i skogen eftersom det började ta slut boträd, en båtmotor till någon stackare som tidigare fått ro längs Karatssjön eller när bränslebristen var så svår att Domänverket fick uppmana sina kronojägare att inte elda upp gamla herbren som kunde ha kulturella värden. Idéer till andra examensarbeten har inte varit ovanliga.

Tålmodigt har min handledare Lars Östlund lotsat mig vidare, mitt allra största tack till dig för det. Tack till min fantastiska fältassistent Julia Nygårdh som la sitt eget examensarbete åt sidan en hel vecka för min skull. Tack till Maria Grånemo som läst min text och ställt min diskussion mot väggen med stort engagemang trots tidspress. Tack till familj, vänner och kollegor som peppat och stöttat hela vägen. Sist men inte minst, tack till Carl-Göran Adelswärds stiftelse som finansierat det här arbetet och möjligjorde många resor till arkivet i Härnösand.

Abstract

In the last 200 years the boreal forests of Sweden have undergone a dramatic transformation. After a long history of high grading the largest trees foresters grew increasingly concerned about the state of logged over forests. The big question was how to regenerate and increase the productivity of sparse forests. Single storied forest management had been successively introduced in the beginning of the 20th century and in the 1940ties foresters came to the conclusion that this was the best way to create what they considered as healthy productive forest stands. This led to the creation of a "forest restoration program" initiated on the state-owned forests in 1950. A 20 year program that aimed at replacing forests with poor growth and low standing volumes with young growing stands that ensured long term yield. In this study I have investigated why the restoration program was initiated and what ecological and forestry related effects it has resulted in. The study is based on both historical management plans for a state owned forest management unit that was restored, articles in the Journal of the Forestry Association of Northern Sweden and a field inventory of an area that was not restored.

Three driving forces that initiated the restoration program was found in my analysis. Firstly, foresters came to the conclusion that forests did not regenerate themselves as fast as they were harvested. Secondly, foresters agreed that the insufficient regeneration was due to the forestry method used, i. e. selective logging. Thirdly, forestry laws and policies progressed over time and came to include demands on forest regeneration, this resulted in so called "restart's" in areas where no new stands had established after harvest.

My results from the time series analysis showed that the growing stock of the studied management unit has increased from 32 to 76 m³sk/ha from 1907 to 2022. At the same time, there is a severe lack of old forests and multistoried forests have been entirely eradicated from the management unit. The forests in Hästkullens nature reserve, an area within the management unit that was not restored, looks very different. Old trees, dead wood and trees of different sizes and ages are present in the area. This makes the area important from a biodiversity perspective. The restored forests surrounding Hästkullen share its early history but do not hold the same nature values. My conlusion is that the forests in northern Sweden would have looked very different and todays negative trend for nature conservation ad biodiversity could have looked very different if the restoration program had never occurred.

Keywords: Forest history, logging, regeneration, restoration, nature conservation

Sammanfattning

De senaste 200 åren har den boreala barrskogen i Sverige genomgått stora förändringar. Efter en lång tidsperiod av upprepad plockhuggning av de största träden grodde en begynnande oro för skogens framtid hos de svenska jägmästarna. Den stora frågan som skapade debatt var hur återväxten skulle säkras och hur nya produktiva skogsbestånd skulle ersätta glesa och oväxtliga skogar. Kalhyggesbruket hade successivt vunnit mark i det svenska skogsbruket under början av 1900 talet och under 1940 talet började jägmästarna enas om att kalhyggesbruk var det bästa sättet att skapa deras bild av sunda produktiva skogsbestånd. Detta ledde till att Domänverket 1950 initierade ett ”restaureringsprogram” som på 20 år skulle åtgärda misslyckade föryngringar samt ersätta glesa oväxtliga skogar och därmed säkra långsiktig avkastning från skogen.

I denna studie har jag undersökt varför restaureringsprogrammet kom till och vilka skogliga och ekologiska konsekvenser det resulterade i. Studien är baserad på gamla skogsindelningsplaner över ett block i en kronopark, artiklar i Norrlands skogsvårdsförbund tidskrift och en fältinventering av ett område som istället för att restaureras blev lämnat och idag är ett naturreservat.

Från analysen av Norrlands skogsvårdsförbunds tidskrift identifierade jag tre övergripande orsaker som ledde fram till restaureringsprogrammet. Den första var att jägmästarna insåg att skog avverkades snabbare än vad ny skog etablerades. Den andra orsaken var att jägmästarna kom fram till att den dåliga återväxten var resultatet av blädning som skogsbruksmetod. Blädningen var inte alltid det vi kallar blädning idag, ofta liknade den plockhuggning av stora träd och ibland tedde den sig även som luckhuggning. Den tredje orsaken var att lagar och skogspolicys utvecklades över tid och fick fler inslag av krav på åtgärder som genererade återväxt. Det resulterade i slutsatsen att många skogsbestånd behövde ”börja om” för att uppnå kraven som ställdes i skogsvårdslagen.

Mina resultat från tidsserieanalysen av ett block inom kronoparken Sucksåive visade att virkesförrådet har ökat från i snitt 32 till 76 m³sk/ha från år 1907 till år 2022, trots att 44% av skogarna 2022 var under 40 år. Restaureringen i området ur produktionssynpunkt tycks alltså varit lyckad. Samtidigt är det en stor brist på gammal skog i området och flerskiktade skogar har försvunnit helt. I Hästkullens naturreservat, ett område inom det studerade blocket som inte restaurerats, är situationen annorlunda. Gamla träd, död ved och träd i varierande storleksklasser förekommer i hela området. Området är därför viktigt från ett biologiskt mångfaldsperspektiv och det är också anledningen till att området är skyddat idag. Skogarna som omger Hästkullen delar dess tidigare historia men idag håller de inte samma naturvärden som Hästkullen. Jag drar slutsatsen att skogarna i norra Sverige hade hade sett annorlunda ut och den negativa situationen för många rödlistade arter också hade sett annorlunda ut.

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Abbreviations

NFI	National forest inventory
NSF	Journal of the Forestry Association of Northern Sweden (*Norrlands skogsvårdsförbunds tidskrift)*
SLU	Swedish University of Agricultural Sciences

1. Introduction

The last 200 years have witnessed a dramatic transformation of the boreal forest of Sweden. During the latter part of the 19th century timber was harvested for the sawmill industry by high-grading the largest and commercially most valuable trees (Norstedt & Östlund 2021). Successively, also smaller trees were cut and as pulp mills were established in northern Sweden the forests were logged successively. At the beginning of the 20th century modern forestry was introduced and both clearcutting and selective logging was used to harvest the forests (Lundmark et al 2013). An intensification of forest management was gradually introduced, which included prescribed burning, ditching and thinning (Östlund et al. 1997). After 1950 the mechanisation in forestry began, which had a strong positive effect on productivity (Ager 2023). Practices such as planting of seedlings, soil scarification and herbicides intensified the work (Östlund et al. 1997).

About 26% of the forests in northern Sweden is owned by private forest companies, 38% is owned by private forest owners and the remaining 36% is state owned forest and other commonly owned forests (Skogsdata 2022). All state-owned forests, sawmills and pulp mills in Sweden were previously managed by one forestry administration board called *Domänverket* (SOU 2002:40). Successively *Domänverket* has been split into several different companies, the most important ones *Sveaskog* and *Fastighetsverket*, and in the 1990s Sveaskog acquired management of most of the *Domänverket* forests and Fastighetsverket owns and manage the rest. *Sveaskog* owns about 14% of all forests in northern Sweden (Sveaskog 2022; Skogsdata 2022).

The successive exploitation of the northern forests and the state of the logged over forests in the early 20th century caused concern within the forestry profession. The big question was how to regenerate sparse forests and increase the productivity (e. g. Ebeling in Arpi 1959; Eriksson in *Skogshistoriska sällskapets Årsskrift* 2013). Harsh climate, too little light and ground vegetation were factors considered to hinder seedlings to grow in the forest (Lundmark et al. 2013). In addition, long distances and low yield from the exploited northern forests resulted in the invention of the cultivation border (Sw: "*Skogsodlingsgränsen*"). At higher elevations above this border, the forests gave such a low yield that foresters were instructed to leave them to the future, with hope that new available methods would make them

profitable (Ebeling 1972). The overlogged forest with lack of regeneration and the discussions concerning forest regeneration and management eventually resulted in a "forest restoration program" led by *Domänverket.* The program was formalized with an instruction to all the state foresters in 1950 (Cirkulär 1:1950; Stjernqvist 1973). This instruction was aimed at replacing forests with poor growth and low standing volumes with young growing stands that ensured long term yield (Cirkulär 1:1950; SOU 1981:81). It was clarified in the instruction that this should be done by removing all trees and either planting or sowing a new stand, thus effectively introducing rotation forestry (clearcutting) on the area.

Parallel with the restoration program the concern for preserving habitat for forest dwelling species have emerged (e. g. Angelstam et al. 2011; Simonsson et al. 2015). Large clear-cut areas triggered environmentalists to speak up against the demanded increased productivity in forestry (Simonsson et al. 2015). Protection of forests in the beginning of the 1900s was mainly aimed at alpine forests but after 1966 the protection of other habitat types increased, suggesting that it became more important to protect a variety of habitats (Nilsson & Götmark 1992). Protected old forests belonging to *Sveaskog* today, that was intended to be restored, is a unique opportunity to evaluate the restoration program. The detailed consequences for the restored forests and how the restoration have affected the forest landscape is known in general terms, but not in detail and a still open question is what an alternative trajectory would have been.

2. Aim of study

The overarching aim of this study were to investigate why the restoration of the north boreal forests in Sweden took place in the middle of the 20th century and what ecological and management effects it resulted in. The specific questions I wanted to answer are:

1. What were the main driving forces that initiated the restoration of the north boreal forests in Sweden?
2. How was the restoration discussed, implemented and carried out?
3. What changes occurred over time in a management unit in northern Sweden that was restored?
4. What changes occurred over time in an adjacent area that was not restored and which subsequently was protected as a forest reserve?
5. In a broader perspective, what societal, ecological and forestry related consequences has the restoration resulted in for the north boreal forests in Sweden?

These questions will be answered using historical records about forestry in northern Sweden from the time around 1950, historical records, maps and management plans about a selected study area and by a field inventory of of the adjacent forest reserve, that was not restored. The focus area for this study is northern Sweden and the field inventoried area is a former national forest called Sucksåive Crown Park (*Sw:* "*Sucksåive kronopark*") in Jokkmokk, today belonging to *Sveaskog*.

3. Materials and method

This study is based on sources that provide three different levels of detail. First, historical records, approximately between 1920 to 1970, about forestry in northern Sweden were reviewed. Second, historical records, maps and management plans, between 1907 until today, from *Sucksåive* Crown Park were examined. Third, a detailed field inventory of a partial area in the park that was not restored were carried out. Combining the historical records from the Crown Park with the field inventory resulted in a time series analysis that showed the progression of state of the forest from 1907 until today.

3.1 Study area

This study is focused on northern Sweden which is the nine northernmost provinces: *Lappland, Norrbotten, Västerbotten, Ångermaland, Medelpad, Jämtland, Härjedalen, Hälsingland* and *Gästrikland*. This area covers about 60 % of Sweden's total area and consists of 70 % forest land (SLU Skogsstatistik).

Sucksåive Crown Park was a part of larger administrative area called the district of southern *Norrbotten* which included approximately the municipalities of *Jokkmokk, Älvsbyn, Boden and Luleå*. The district contained eight smaller units *(Sw: "Revir")* and within these the forest was separated into even smaller units denoted "Crown Parks". Each Crown Park was furthermore divided into practical management units (*Sw: "Block"*). Sucksåive Crown Park had an area of 22 301 ha in 1907 and is located northeast of Jokkmokk within the *Pärlälven/Görjeå* unit.

Hästkullens nature reserve is located within the former Crown Park *Sucksåive* and has an area of 313 ha. The reserve consists of mainly Scots pine *(Pinus sylvestris)* but also Norway spruce *(Picea abies),* birch *(Betula pubescens)*, aspen *(Populus tremula)* and willow *(Salix spp.)*. The area is used by the Sami community *Slakka* as year-round pasture ground and there is a fenced collecting area inside of the nature reserve. The reserve was set aside in 2012 with the purpose of keeping its valuable environment intact for the future (Länsstyrelsen 2023).

3.2 Historical records

Several types of historical records covering forestry on state forest land in northern Sweden, both primary and secondary, have been analysed (ESM 3). Official policies (*Sw: Cirkulärskrivelser*) from between the years 1919 and 1968 were analysed. The official policies are broad instructions, that were sent to employees from the board of *Domänverket*. The official policies contained, among other things, information about for example how and what forest operations would be carried out, economics and administration changes. Also, administrative documents *(Sw: Koncept)* were analysed*,* these are letters the head forester at *Domänverket* sent out within the district, were read. Here the main focus was to find written instructions from Fredrik Ebeling who were head forester in the districts of southern Norrbotten. *Koncept* written by Ebeling were examined from 1950 to 1960 which was the time he worked as head forester. Finally, articles from 1920 to 1970 in the Journal of the Forestry Association of Northern Sweden *(Norrlands skogsvårdsförbunds tidskrift, short: "NSF")* were analysed. The journals contain various discussions about forestry methods, results from field trials, statements from the associations on current issues and detailed documentation of the common excursions that the Forestry Association of Northern Sweden provided for the foresters.

Apart from these general historical records, more detailed material from my specific study area, that contained the area for my field study, was analysed. I extracted detailed maps and forest management plans for the years 1907, 1929 and 1962. The management unit studied had the number 3 during 1907 and 1929 and number 5 in 1962. The maps contained detailed divisions of the forest into compartments. Variables such as stand age, species composition, volume and site factors were documented in each compartment. Sveaskog AB provided data about the area from 2022. Available data for the year 1938 was not included in the analysis.

The archive material have been referenced as a collected material, specific references are found in the reference list.

3.3 Field inventory

The inventory in *Hästkullens* nature reserve was conducted as follows: 50 circular 10m radius plots with total inventory, 50 additional plots with recording of only basal area and top height and an evaluation of the nature values.

3.3.1 Circular plots

The circular plots were laid out in a systematic grid with a 250m interval. The plots had a radius of 10m. The interval was calculated with respect to the number of plots to be made versus the size of the area, 313,1ha, using the following formula:

$$Interval\ (m) = \sqrt{\frac{Size\ of\ area\ (ha)}{Number\ of\ plots\ (n)}} * 100$$

In the circular plot one fourth of the circle, facing north-east, was separated with measuring tape and all trees and dead wood in it was recorded by height and diameter at breast height ("DBH"). The dead wood was also assigned a decomposition class of 0-5 according to The Swedish National Forest inventory *(Riksskogstaxeringen)* guidelines (ESM 1). After this, basal area for each tree species and dead wood was documented. Depending on how dense the forest was, every 4-7th tree counted with the relascope was drilled with an age corer in breast height of the trees. The goal was to drill 3 trees per plot and the interval between the trees was calculated after the basal area was registered. Every 20th tree for each tree species was drilled in both breast height and base of the stem to be able to learn how many years it took for the tree to grow above breast height. If there were special or exceptionally old trees they were drilled as well. Height and diameter were registered for the drilled trees.

3.3.2 Additional plots

50 additional plots were made halfway between the systematic circular plots. In these, basal area per tree species and top height were documented. If there were special or exceptionally old trees in the plot, or in close proximity of the plot, they were drilled. Height and diameter of drilled trees were noted.

3.3.3 Nature values

Skogsbiologernas method for field inventory of nature values were used to determine the nature value of the area (*Bilaga 1*, Skogsbiologerna AB 2015). In this inventory one of six types of disturbance regimes is chosen. Then one list of criteria for the site and one for the stand itself is answered to retrieve a total score for the area (ESM 2). Over 30 points is considered as very high nature values, 15-20 points is considered as high nature values and 5-10 points is considered low nature values. The nature value of the area was determined after all circular and additional plots were completed.

3.4 Lab work

3.4.1 Preparation of samples

All drilled tree cores were mounted and sanded to make the year rings more visible. Afterwards the samples were scanned at high resolution and imported into the computer.

3.4.2 Analyses

The high-resolution scans of the tree cores were examined and dated in CooRecorder. If the center of the core was missing from the sample, missing years were estimated with a sheet of concentric circles. The program determines the distance between each year ring and this information was used to look for trends in growth patterns for the area.

3.5 Creation of a time series for the area

3.5.1 Progression of forest age and stand volume

The historical maps in combination with historical data from inventories were used to create maps with volume and age. This was done for 1907, 1929 and 1962. Data about the area from the year 2022 was acquired from the forest owner Sveaskog.

ArcGIS Pro

ArcGIS Pro was used to transfer the old forest divisions into new maps. This was done by first georeferencing the old maps with known points in the landscape, such as lakes, roads or buildings, and then projecting them on top of a background map to make sure of its accuracy. Each compartment in the old maps was drawn as a polygon in the new map. This resulted in a polygon layer which was assigned compartment number according to the old maps.

Joining data

The field data about the forest from the years 1907, 1929 and 1962 were transcribed from the historical records and joined with the attribute table for each year in ArcGIS Pro. Volume were given in cubic meters in the historical records and in m^3sk (cubic meters of the whole tree above the stump minus branches) for Sveaskog's data. Volume in the historical records only included coniferous trees above 10cm at breast height. The volume data from Sveaskog contain all tree species but has no available information for volume of dead wood.

Age was separated into suitable classes depending on both age and age distribution (*Table 1*). From this two layers, one with age data and one volume data was projected.

Table 1. Age or age distribution classes for the forests for the year 1907, 1927 and 1962.

Class	Age/Age distribution
Clearcut	0 years
Young forest	Age 1-40 years
Single storied middle-aged forest	41-120 years
Single storied old forest	>121 years
Two storied forest	Forests with two separate age classes
Multistoried forest	Multistoried Forests with more than two separate age classes

The age data from Sveaskog did not contain any information about the age distribution, thus four classes were created which corresponded to the previous years in the following way:

Table 2. Age classes from 2022 and their corresponding class in previous years.

Class (age)	Corresponds to class for previous years
0-1	Clearcut
2-40	Single storied young forest
41-120	Single storied middle aged forest
121-242	Single storied old forest

3.5.2 Data from field inventory of Hästkullens nature reserve

The collected data from the field inventory was summarized and analysed in Microsoft Excel. The volume calculations were made with the following formulas from Brandel (1990):

$$Pine\ volume\ dm^3 = 10^{-1,20914} \times d^{1,94740} \times (d+20)^{-0,05947} \times h^{1,40958} \times (h-1,3)^{-0,45810}$$

$$Spruce\ volume\ dm^3 = 10^{-0,79783} \times d^{2,07157} \times (d+20)^{-0,73882} \times h^{3,16332} \times (h-1,3)^{-1,82622}$$

$$Birch\ volume\ dm^3 = 10^{-0,84627} \times d^{2,23818} \times (d+20)^{-1,06930} \times h^{6,02015} \times (h-1,3)^{-4,51472}$$

where d is diameter at breast height and h is total height.

A mean value was created for tree age, DBH, height, basal area of living trees, basal area of dead wood, volume for living trees and volume for dead wood.

4. Results

4.1 What were the main driving forces that initiated the restoration of the north boreal forests in Sweden?

To clarify the academic and professional discussion behind the restoration period I have analysed articles in the Journal of the Forestry Association of Northern Sweden. In these articles, excursion protocols and the debate between forestry professors and forestry professionals was documented. In the following sections I present the most important driving forces behind the restoration period.

4.1.1 The future lack of mature wood and regeneration issues: -Were the forests regenerating themselves sufficiently or not?

In 1924, one year after the first National forest inventory (NFI), Gunno Kinnman, a professor in forestry at the School of Forestry *(Swedish: "Skogshögskolan")* at the time, stated that we were depleting our primary forests and that we could no longer act as if we had an endless amount of mature forest to harvest. He presented a calculation that suggested that we needed to spread the harvest of older forest over a longer time-period and instead harvest smaller trees through thinning for about 20 years to keep a decent annual yield before our younger forests would come of producing age (NSF 1924a). Kinnman stated that his calculation was modest and that several of the factors could better the prognosis. In the same year another professor and researcher at the school of forestry, Tor Jonson, criticized Kinnman's statement and suggested that the time gap until younger forests would benefit us would be much longer since regeneration and growth was highly overestimated in Kinnman's calculations (NSF 1924b). Jonson argued that if Kinnman's calculation were followed we would have to *"throw our axes in the lake and like madame Pompadour shout "Aprés nous le déluge![1]""* within 20 years.

[1] "After us, the flood!". French expression for not caring what happens after we are gone.

In an excursion the following year, 1925, the problem with creating productive forests due to lack of regeneration in northern Sweden was debated (NSF 1925). The so-called raw humus forests *(Sw: "Råhumusskogarna"),* forests containing a thick layer of humus and vegetation that prevented regeneration of new plants, was at this time generally considered a widespread problem in the northern forests. The excursion this year was held in the forests belonging to the estate of Mo & Domsjö around *Örnsköldsvik.* One of the visited sites was a stripe clear cut (*Sw: "Kulisshygge"*), harvested in 1917. At that time it was a raw humus forest containing an understory of small and old spruces with very wide crowns (*Sw: "Marbuskar"*). The forest was divided into two treatment units, in one the understory spruces was kept and would together with sowed pine and spruce become the next generation. In the other unit the understory spruces was removed and sowed pine and spruce were to become the new stand (NSF 1925). Professor Jonson stated that the unit where spruces was left, it was of too poor quality and caused too much shading for this method to have positive effects on regeneration possibilities (NSF 1925). Per Olof Welander, head forester of the district of middle northern Sweden, agreed with Jonson and added that the understory spruces could shade out any already existing pines as the shoots of the spruces start to grow more due to the increase of sunlight (NSF 1925).

Mauritz Carlgren, forest management manager at Mo & Domsjö AB however, thought that if Jonson and Welander had seen this site before it's treatment they would have been of a different opinion (NSF 1925). Carlgren stated that the small spruces had indeed been of poor quality before the removal of the overstory but that they now had no similarity to their previous state. Now they had proper shoots and diameter growth that should indicate that this method would be both cheaper and successful. Carlgren also added that the fear of the spruce competing with the pine should instead be interpreted as a possibility to trust that the spruce would make for a sufficient regeneration and that the pines would survive together with the spruces with the right type of future management (NSF 1925).

In 1932, head forester and researcher Anders Holmgren proclaimed in an article that the question about the raw humus forests seemed to persist and would hardly reach a conclusion any time soon (NSF 1932a:37). He had a good insight in the matter as he had worked with and studied the raw humus forests in northern Sweden for many years. Holmgren contributed to the complex question and showed that it was not lack of seed but lack of good spots for the seeds to grow that was the likely reason for poor regeneration results (NSF 1932a). Based on this argumentation and an example site that was treated with selective logging versus a clearcut, Holmgren recommended clearcuts where the ground vegetation was entirely altered and became more fitting for regeneration due to the increase of sunlight reaching the ground (NSF 1932a).

Lack of regeneration was not only a problem in forests with thick layers of raw humus but also on pine heaths. Forester Bure Holmbäck, having worked with forests in northern Sweden since 1912, presented an article in 1932 (NSF 1932b). Here he stated that the reason for the regeneration failing and large gaps in the pine forests occurred had several explanations, the major one being the water balance. Too much sunlight in spring while the ground water had yet to thaw caused the plants to dry. Later in summer the gaps also held less water as they had less shading, thinner humus and thinner field layer. The dryness of the soil also seemed to cause a secondary lack of nutrients as they could not be dissolved in the soil without enough moisture. He deemed the solution would be to regenerate the forests under a shield of remaining trees (NSF 1932b).

Joel Wretlind, researcher and head forester in Malå, reasoned in his article from 1934 that the regeneration also was dependant on a competition zone of roots surrounding larger trees (NSF 1934a). In these zones plants had a hard time establishing as they could not compete for nutrients. Wretlind based his claim from trials where he showed that plants that grew under a shield of trees could not start to grow at a reasonable pace until their roots reached soils with less competition. At the same time they were able to start growing beneath the shield since the shield tree's roots had already grown further away from itself and thus created a secondary effect with both shelter and nutrients from litterfall beneath its crown (NSF 1934a).

Referring to Holmbäck's research, Wretlind pointed out that Holmbäck suggested far too many seed trees and proclaimed that they would only disturb the regeneration (NSF 1932b, NSF 1934a). Instead Wretlind proclaimed that when it was time to regenerate the pine forest it should be done by "*a very hard regeneration cut*" where also smaller trees were removed. This would ensure the regeneration to grow up without the risk of being outcompeted by smaller trees that were left after harvest (NSF 1934a). Wretlind was otherwise known for his enthusiasm for using fire as a tool for regeneration, but his ideas were often questioned. During the excursion in 1934 Holmgren warned the participants about "*pyromaniacs and their false truths*" (NSF 1934b). It would take until 1947 for Wretlinds "*false truths*" to become acknowledged and later even praised (NSF 1947).

Although the question about regeneration progressed in the 1920's and 1930's the faith in the forests ability to regenerate themselves sufficiently continued to be strong. In 1935 Welander stated that despite the flawed regeneration foresters continued to disregard planted seedlings as a solution (NSF 1935). In 1931, the official policy for the national forests still advised foresters to use seed trees, even if there were only "*unsuitable trees to choose from*". Welander commented this with "*This is what I call discrediting seedlings*", meaning that not even the decision makers had faith in cultivated seedlings (NSF 1935). In 1937 Welander also criticised the forestry law for being too vague in its statement that regeneration

"*should be established within reasonable time*" (NSF 1937). This, he meant, caused forest owners to not prioritize regeneration as they saw it as a cost and believed that regeneration would take care of itself.

4.1.2 Individual or group-based forestry – How were we to go on managing our forests?

As the regeneration question moved forward other issues regarding the production of wood naturally came along. For some time there had already been two main ways of managing the forests, clearcutting or selective logging, which split the foresters into two opposing groups. A lively debate about forest management methods started around 1940. Welander had in 1937 suggested that Uno Wallmo's thinning from above, i.e. selective loggings, was too harsh and would result in lack of large pines (NSF 1938). Wallmo had a background as head forester for the national forests in Bergslagen and manager for the Stockholm-Gävle district (Lundmark 2013). Wallmo defended his methods in 1938 in an article by explaining that his instructions for selective logging were always to be related to the forest at hand, thus meant no risk for the pines (NSF 1938). He showed an example from one of the estates that he had managed for 40 years. Previously the forest had been treated with clearcuts, now selective logging had been carried out every tenth year, resulting in increased production and an increase in number of pines larger than 40 cm in diameter (NSF 1938).

Thorsten Lunderquist also defended Wallmos theory (NSF 1939a). He criticised Welanders statement that it is difficult to estimate the growth of individual trees:

> *"For a person who have only been working with groups of trees and never have been interested in individuals it is hard. One who have been interested in the individuals does not notice this hardship" (NSF 1939a).*

Lunderquist also wrote *"Regarding the production of quality trees, selective logging are totally superior to clear cuts!"* (NSF 1939a). He meant that people who advocated for clear cuts only cared about creating large trees but that the actual value production was created in selective logging by growing high quality timber trees.

Both Wallmo and Lunderquist explained in their answer to Welander that selective logging is not always just individual based forestry (NSF 1938, NSF 1939a). Sometimes groups of poor quality trees should be cut. When it was time for regeneration a gap was created in the stand, wich was successively enlarged, resulting in groups of trees in various ages. This caused Welander to further question selective logging as he claimed that if Wallmo meant that groups of trees

in various ages were to be seen as uneven-aged forests, it was the exact same thing as clear cutting only it was done at a smaller scale (NSF 1939b).

Welander also questioned how foresters were to instruct their staff to manage the forests (NSF 1939b). Lunderquist had written that selective logging required the forester to measure and learn about the individual trees, which Welander implied were a practical impossibility (NSF 1939a, 1939b).

To address the question from a perspective of the common denominator of the two management methods Welander continued the discussion with different forms of thinning (NSF 1940a). He stated that selective logging were the same as thinning from above and clearcuts represented thinning from below. He argued that even if the larger trees were cut and the smaller ones had the ability to grow this would require a longer time to complete the regeneration cycle. If the largest even-aged trees were kept after thinning the best growing trees would be ready earlier, at the tree's natural growth culmination (NSF 1940a). In his conclusion he states

> *"For a long time we have used various types of thinning in our forests. However, they have always been aimed towards keeping the growing stand. We should continue to treat our forests like this until we have further knowledge about how the growth response in smaller trees actually work when the main stand is removed" (NSF 1940a).*

Several foresters answered this with their own claims. Forester Ernst Andersson stated that the risks with thinning from above were larger than thinning from below (NSF 1940b). However, he stated that forests become degraded because thinnings were too extensive when thinning from above, not due to the thinning method itself. Moderate thinning from above would minimize the risk to degrade the forest (NSF 1940b). Ullén continued with a statement that the quality of the trees would naturally be higher in stands that had been thinned from above and that Welander had overestimated the growth severely in stands that was thinned from below (NSF 1940c). Welander tried to answer the critique and reasoned that the others were missing his main point that the smaller trees had not been examined enough to say that they would even be able to become the new stand (NSF 1940d). Sven Petrini, forester and later professor in forest assessment, agreed with Welander in that it was a hardship to thin from above without risking the remaining stand too much but he withheld that if it was carried out correctly it was still better than thinning from below (NSF 1941a). Forester and researcher Harald Sjöström added to the discussion that for small forest owners thinning from above was the only management method that were practically doable as they needed a continued flow of harvest from their forests, preferably of valuable timber trees (NSF 1941b).

In 1944 Welander tried to move on from the thinning discussion by presenting statistics from the national forest inventory that showed that most of the land in

northern Sweden demanded some kind of active management for regeneration to happen. This, ha meant, was not happening in selective logging of the forest:

> *"With today's demand that the forests should be held in their full potential of production selective logging is unfit for at least 80% of the forests in northern Sweden and the statement that selective logging are a credible forestry method is a deceiving illusion that has long hindered the northern forests reproduction!" (NSF 1944).*

Wallmo, who advocated strongly for selective logging, was not slow to respond. He wrote in his answer that Welander was missing crucial points of the selective logging, namely that they were to be adapted to the properties of the forest (NSF 1945). He continued with:

> *"The groupwise unevenly aged stand form is the most advantageous of them all. It is impossible to show or imagine to construct any other stand form that have a better way of regulating access to light, air, heat and water. The free selective cutting of trees is the only method with is not irrational in an intellectual sense of all known harvesting methods! I have allowed myself to say this before and I stand by it still" (NSF 1945).*

Wallmo also stated that soil preparation and planting is sometimes required where regeneration have failed. He also accused "*even aged foresters*" of using too much of a template when the forest in fact is a much more complex thing (NSF 1945).

A couple of years ahead a Finnish forester, Erik Appelroth, looking at both Sweden and Finland, wrote that the notion that larger trees are the oldest and smaller ones successively younger need to be dropped (NSF 1949). This, he meant, were simply not true. He also commented that:

> *"In Sweden the discussion about Wallmos methods have been strong since he presented the ideas in the first place in 1897. Wallmos logging have not been selective in the true form, but they have been misinterpreted so that selective logging were carried out, even in the northern old forests, to a great loss for the northern forestry […] In general, the term selective logging have received a too wide meaning, much because of Wallmo. These logging, who became very common in the 30's, must be what now drives the Swedish foresters into their appeal to planting seedlings due to delayed and missing regeneration" (NSF 1949).*

4.1.3 The forestry laws and policies

New forestry laws were also used to steer the forest owners in a direction of sustainable forestry methods. In 1923 the debate was much focused on how the 1923 forestry law was regulating regeneration. Forest engineer Nils Almlöf wrote about the new law that he wanted more focus on natural regeneration from seed trees (NSF 1923a). He continued with:

> *"If the spruce would create such thick humus layers and cold ground climate so that the regeneration starts to wither and the ground becomes covered by lichens, we only have to cut the seed trees down and sow pine instead. The next generation needs its own problems to solve!" (NSF 1923a).*

Mauritz Carlgren wrote the same year that the 1923 forestry law would accomplish something that the "high-grading law[2]" never could, which was to create new and better growing forests (NSF 1923b). The Forestry Association in Northern Sweden made a statement about the 1923 law where they disallowed the high grading law by saying that rational harvests could not be done if there was a detailed regulation about which trees could be cut (NSF 1923c).

In the 1940's discussions about a new forestry law arose once again. County forester Karl Erik Kallin commented in 1942 the large areas of northern Sweden that operated under the Lapland border law[3] since 1915:

> *"The reason for not implementing the area above the Lapland border into the national forestry law must have been due to fear that too much freedom to harvest forest could lead to social misadventures for the people living there" (NSF 1942).*

Kallin agreed that the land above the Lapland border would be implemented in the new forestry law. He argued that all trees to be cut must be marked (with an axe-blaze) by a government employee or specially educated person, to ensure no negative effects on regeneration (NSF 1942). Several other foresters argued for more thorough legislation regarding regeneration, as forest owners might set aside regeneration as it is a cost that do not give anything back for a long time (e. g. NSF 1937, NSF 1951)

As soon as the 1948 forestry law was passed in the Swedish parliament the questions moved towards how to interpret the law. Forester Thorsten Andrén meant that the law followed economical instead of biological prerequisites and that this caused difficulties for forest owners who had degraded forests (NSF 1951). He also

[2] Swedish:"Dimensionslagen", referring to a law from the 19th century which forbid the harvest of trees below a certain diameter limit.

[3] Swedish: "Lappmarkslagen", a law that regulated only the forests in the non-costal areas of northern Sweden. The law was a complement to the national law as the forests there had very different prerequisites.

stated that the regeneration cost should be seen as a part of the forestry and that each forest owner needs to account for the cost to be allowed to manage the forest (NSF 1951).

4.1.4 A twenty year long program to restore the northernmost forests

At the end of the 1940's many foresters in northern Sweden had found a common ground: the long-term production of the forests needed to be restored and rational methods must be developed. Already in 1944 Welander said in regard to the sparsely stocked forests in northern Sweden: *"To aid this anomaly we need an extensive long term reconstruction work with the purpose of fully using the potential production as far as it is possible in practical forestry"* (NSF 1944). Plym Forshell wrote in 1948:

> *"If we look south we can see, although with certain flaws, that nature and culture, maybe mostly the former, have erased the traces of historical misuses of the forest. In other words, we have there moved on from exploiting to producing forestry. The northern forestry however, is in the transition right now. […] It is time to go from words to actions. In other case I fear that the next generation's review of our forestry will not be deemed highly" (NSF 1948).*

Erik Höijer, director-general and head of the national forests from 1950-1964, supported this writing. He said that the northern forests were now at an end of o period of exploiting which had contributed substantially to our country's economic growth (NSF 1950). He also explained that the landowners failure to create productive new stands was both due to lack of knowledge how to regenerate properly and that the forest had been a second priority in our economy the last century. He admitted the hardship of the situation:

> *"However, it should also be said, that foresters have probably never had to solve such an immense regeneration issue as on the harsh lands of the northern forests, which they have struggled with for 30 years!" (NSF 1950).*

The first official policy in 1950 stated that all management units needed to regenerate at least an equal amount of area as they cut every year (Cirkulär 1:1950). In addition it said that each year 1/15 of the older regeneration sites were to be regenerated as well, thus creating a 15 year program of restoring depleted forests to more sustainable and productive ones. Höijer explained that in practice, each management unit would not be done with their restoration at the same time, but that it would likely not take more than 20 years (NSF 1950). He also commented that

the workload, which were calculated to about 300 000 workdays each year for 20 years, would probably not be a problem but that

> *"The acquirement of good seeds, however, will cause us great problems, which we hope to solve. The production of seedlings needed in the restoration is mainly an organisation problem which will be solved" (NSF 1950).*

With the initiation of the restoration program a new era in the northern forests were founded, Höijer called it *"the first generation of cultivated forests"* (NSF 1954a). Four years into the restoration program it was commented by Nils Bergsjö with

> *"For a non-forester it may seem as we are pillaging our forests when he looks at the vast bare areas created. If he, however, were to walk onto the bare areas he would see that they are in fact re-planted or sowed and if he comes back in ten years there will be a growing young forest there" (NSF 1954b).*

Bergsjö then stressed that foresters had to educate the public to win their trust (NSF 1954b). Höijer also wrote in 1954 that forestry had now reached rural areas, mainly along the alpine border, that contained forests with little or no previous exposure to forestry (NSF 1954a). He meant that these areas could contain suitable land for productive forestry but the hardship in regenerating this land made them economically unsuitable and the focus should be on the best lands first, to not delay the restoration.

Another idea about the westernmost and least productive forests was also brought forward by Höijer. He continued the discussion about how we were to prioritize our workload with *"For many nature lovers these untouched rural forests represent a great national asset"* (NSF 1954a). For the national forests an official policy from 1945 had already stated that rational forestry leads to the depletion of certain vegetation types and which instructed the foresters to protect a part of such forests for future foresters and researchers (Cirkulär 22:1945). In 1954 Höjier said that with new guidelines for protection of rural areas and the agricultural cultivation line the forests of value for nature lovers had acquired a provisional protection (NSF 1954a). He saw this as a possibility for foresters and "nature lovers" to sort out how to manage or not to manage the low-productive forests in the future, meanwhile concentrating on the better parts of our forests (NSF 1954).

In 1961 Höijer wrote a report on how the restoration program was progressing wherein he presented statistics that showed that about half of the total work had been done in the 10 first years (NSF 1961). However, he now worried that the second half would be the harder one, as the foresters had started with the easiest tasks (NSF 1961). The official policy regarding the budget for the restoration of the

national forest said in 1960 that the foresters now had to be careful not to exceed the budgeted cost for renewal work (Cirkulär 6:1960). In 1968 the instruction was that expensive renewal work in areas with difficult regeneration prerequisites were to be put on the future due to budget restrictions (Cirkulär 2:1968).

4.2 What happened in an area that was restored?

The studied management unit in Sucksåive Crown Park had small differences in total area both for the entire management unit and for area classified as productive forest between the years (*Table 3*). The area classified as productive forest in the management unit was largest in 1907 at 6143 ha and smallest in 1962 at 4348 ha. The total area of the management unit varied between 7986 ha (2022) and 8614 ha (1929). For 1962 the total management unit area was not found. The division of the forest into compartment was relatively stable from 1907 to 1962, the mean area for all compartments ranging from 42 (1929) to 60 ha (1962). In 2022 the mean value for all the compartments were down to 15 ha.

Table 3. General statistics for the studied management unit in Sucksåive Crown Park. All variables are given in hectares.

Year	Area of studied management unit	Forested land (productive)	Mean area of compartments
1907	8336	6143	42
1929	8614	5775	42
1962	x	4348	60
2022	7986	5628	15

4.2.1 Progression of age-class distribution in the forest

When clearcuts started to replace selective logging the forests became even-aged in contrast to previous two- or multistoried forest. In 1929 almost the entire classified forest area is classified as multistoried forest (*Figure 1*). In the northernmost part there is two compartments with single storied forest and in the eastern part there are some clearcuts. The entirety of the area for Hästkullens nature reserve were classified as multistoried forest.

1929

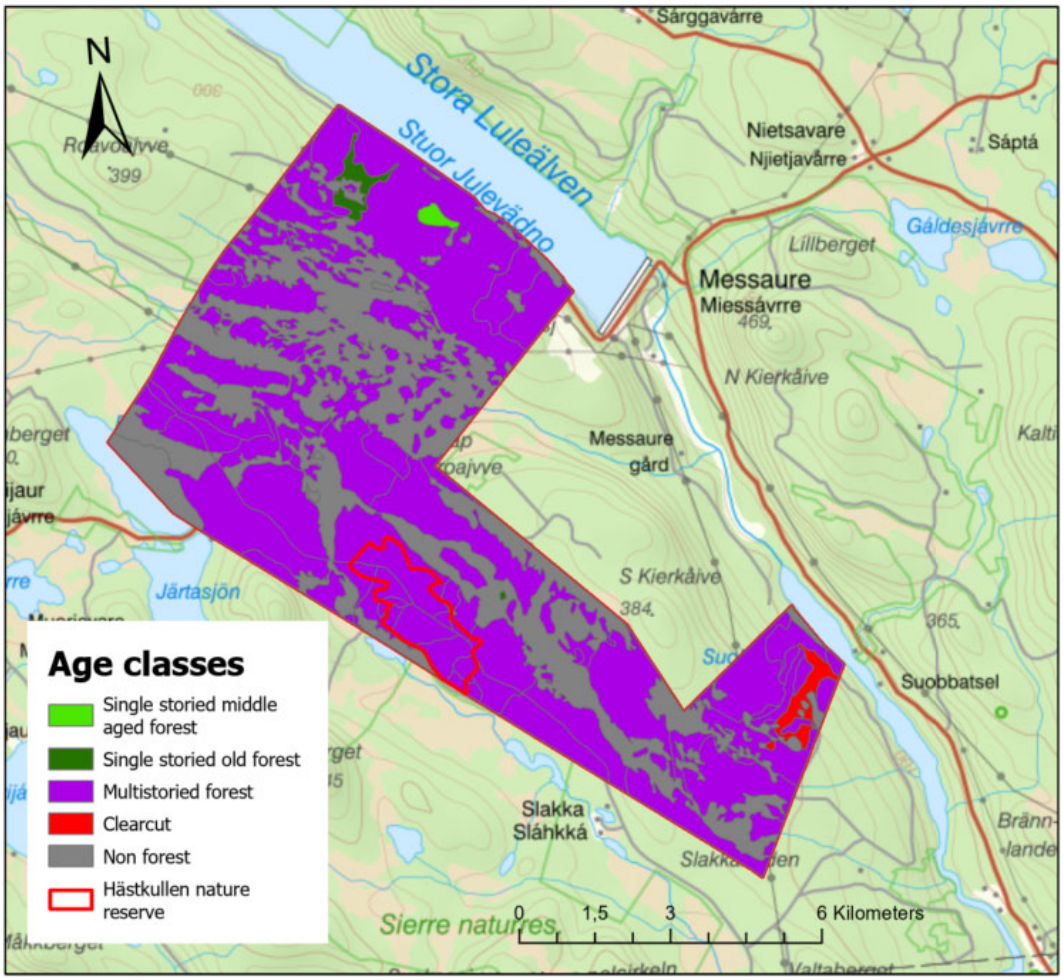

Figure 1. Age classes for 1929.

In 1962 there was no forests classified as multistoried (*Figure 2*). In the northern part of the area there was mostly single storied middle-aged forest and some young forest and clearcuts. In the middle to south-western parts of the management unit clearcuts uptake a large part. Single storied old forest and some two storied forest is found in and around the non-forested land (mires and lakes). The area for Hästkullens nature reserve were classified as single storied old forest except for two small parts of single storied middle-aged forest and one small part two storied forest.

1962

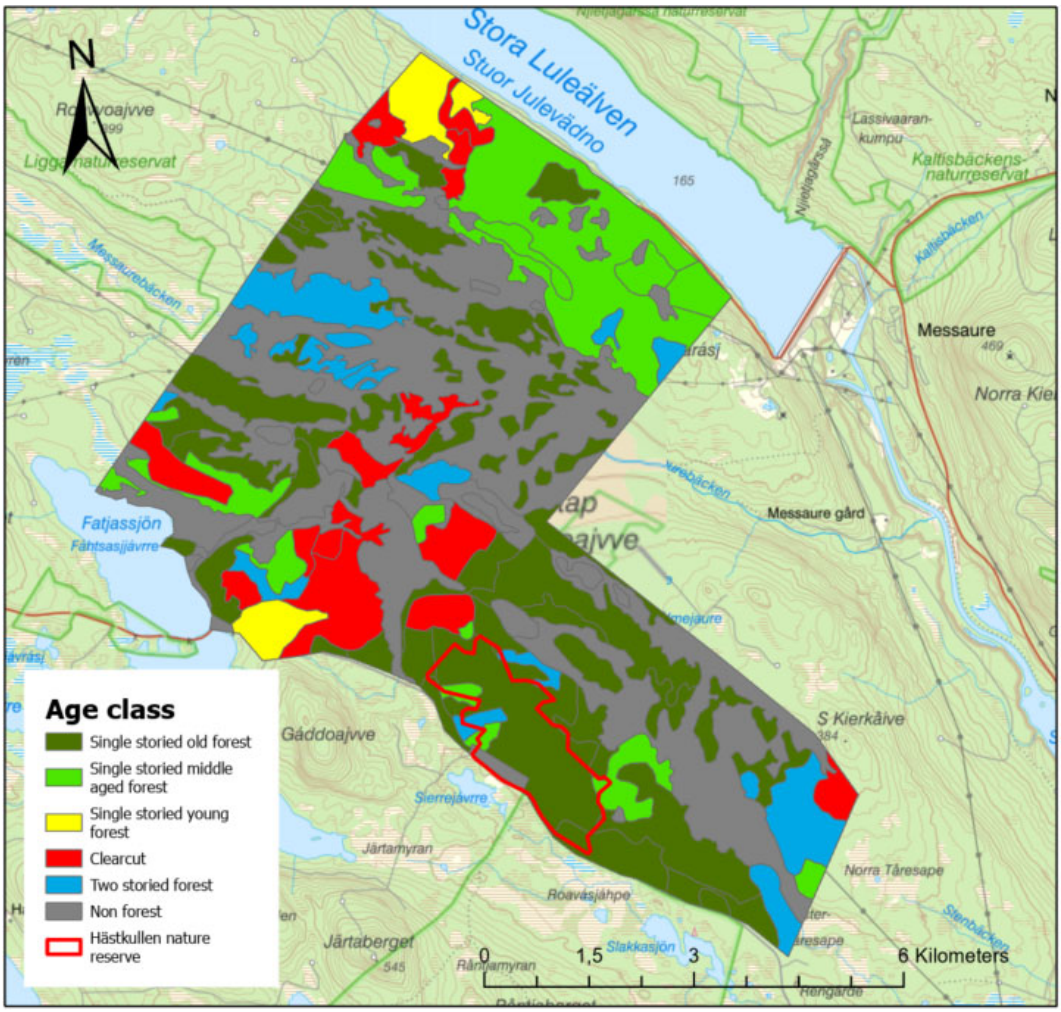

Figure 2. Age classes for 1962.

In 2022 the management unit's northern and eastern part contain some clearcuts but otherwise the management unit is mostly dominated by single storied middle aged and single storied young forest *(Figure 3)*. Small parts of single storied old forest is found spread out over the entire management unit. Hästkullen nature reserve is excluded from the year 2022 as it is not inventoried by Sveaskog, because it is not used for forestry.

2022

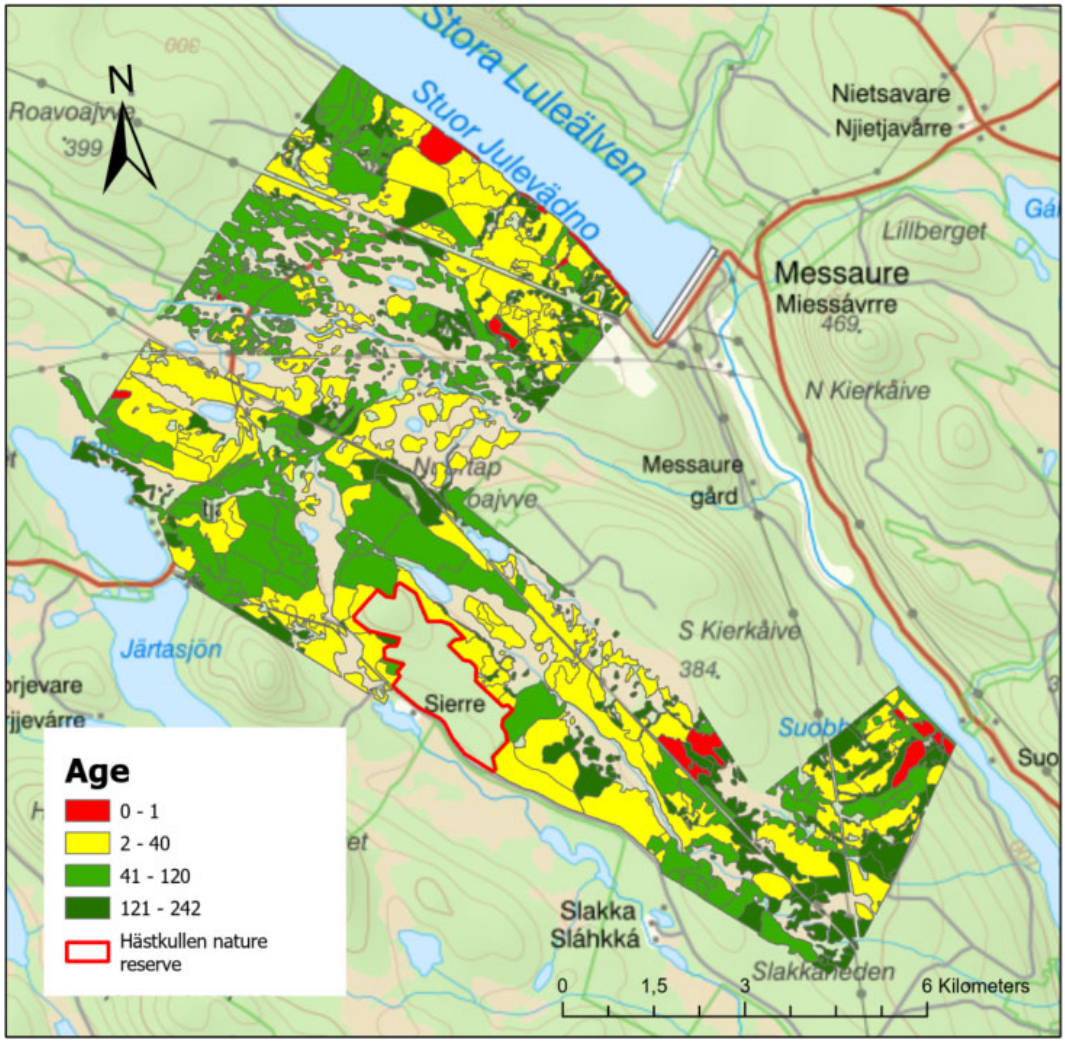

Figure 3. Age of forest in 2022. Please note that here the age is given in years, not class. The given ages correspond to previously used classes for single storied forest.

Data from 1907 was excluded as age data was not recorded the same way as in the following years and could therefore not be compared to the others.

4.2.2 Changes of age-class distribution in the forest

In 1929 almost all the forest in the studied management unit was multistoried (*Figure 4*). Clearcuts and single storied old forest were 1 % each. 33 years later, in 1962, the management unit held 12 % two storied forests but otherwise no multistoried forests. Clearcuts occupied 14 %, single storied young forest 4 % and middle-aged forests 24 %. Single storied old forest held 47 % of the area. In 2022 the management unit held only 2 % clearcuts but single storied young forest

increased to 44 %. Single storied middle-aged forest increased to 37 % and single storied old forest decreased to 17 %.

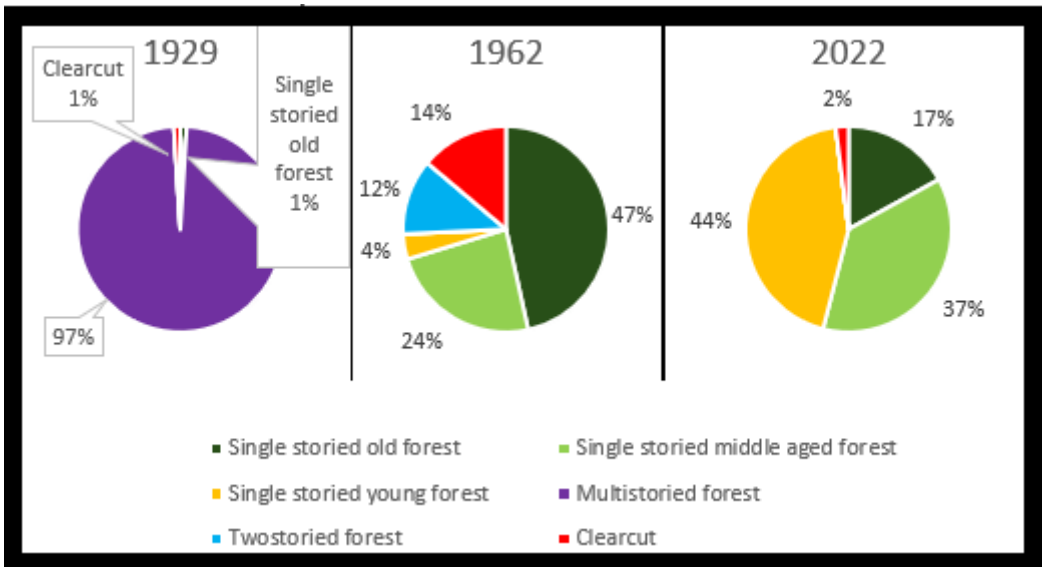

Figure 4. Age classes in 1929 as % of classified area.

4.2.3 Progression of volume over time

In 1907 the studied management unit contained mostly volumes below 50 m³/ha (*Figure 5*). There was less volume in forest closer to the river with one exception in the eastern part of the area. Hästkullens nature reserve had lower volumes (0-20 m³/ha) in its western part than the eastern parts (21-50 m³/ha).

1907

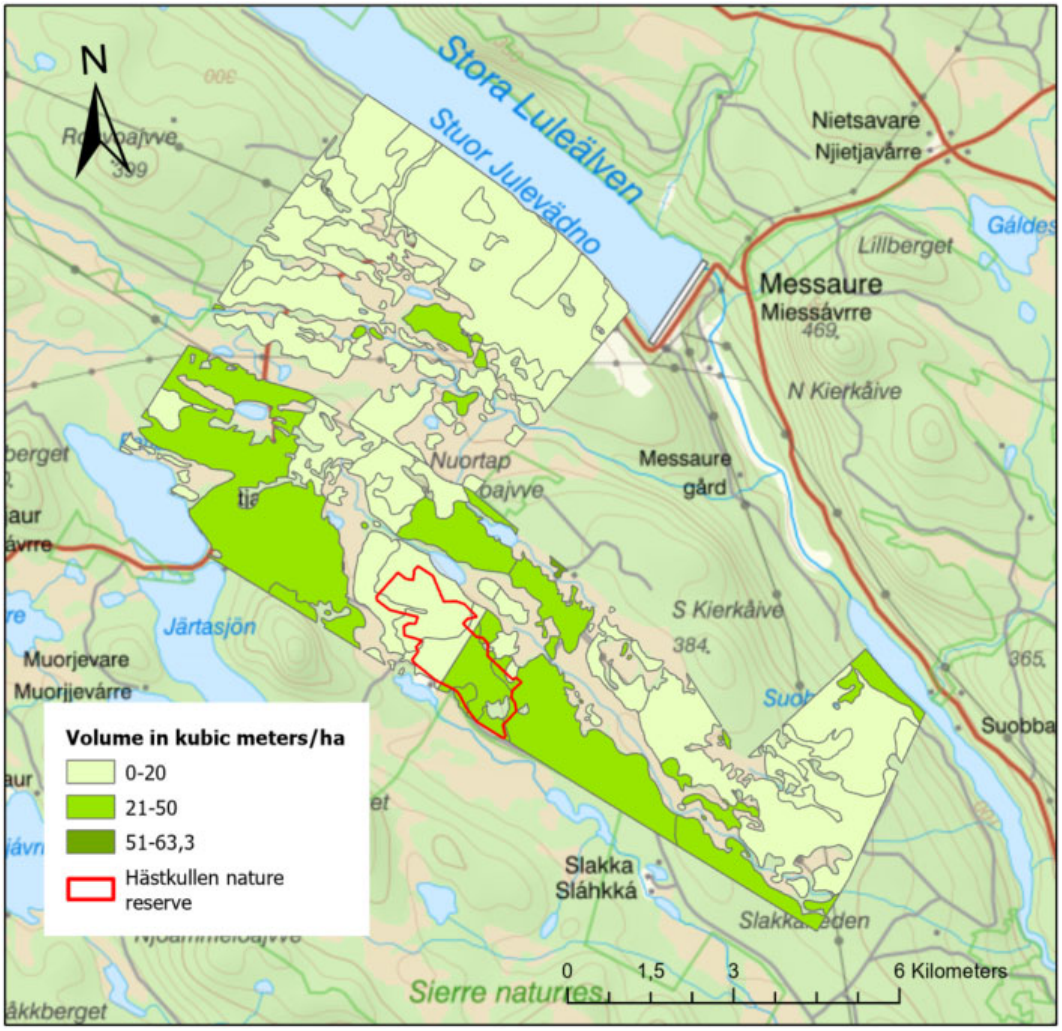

Figure 5. Volume for conifers in m³/ha for the year 1907.

In 1929 the management unit contain more forests with 21-50 m³/ha and more forests with 51-100 m³/ha (*Figure 6*). Still there are lower volumes closer to the river. Hästkullens nature reserve's western part contains 21-50 m³/ha and the eastern part 51-100 m³/ha. A small part has only 0-20 m³/ha.

1929

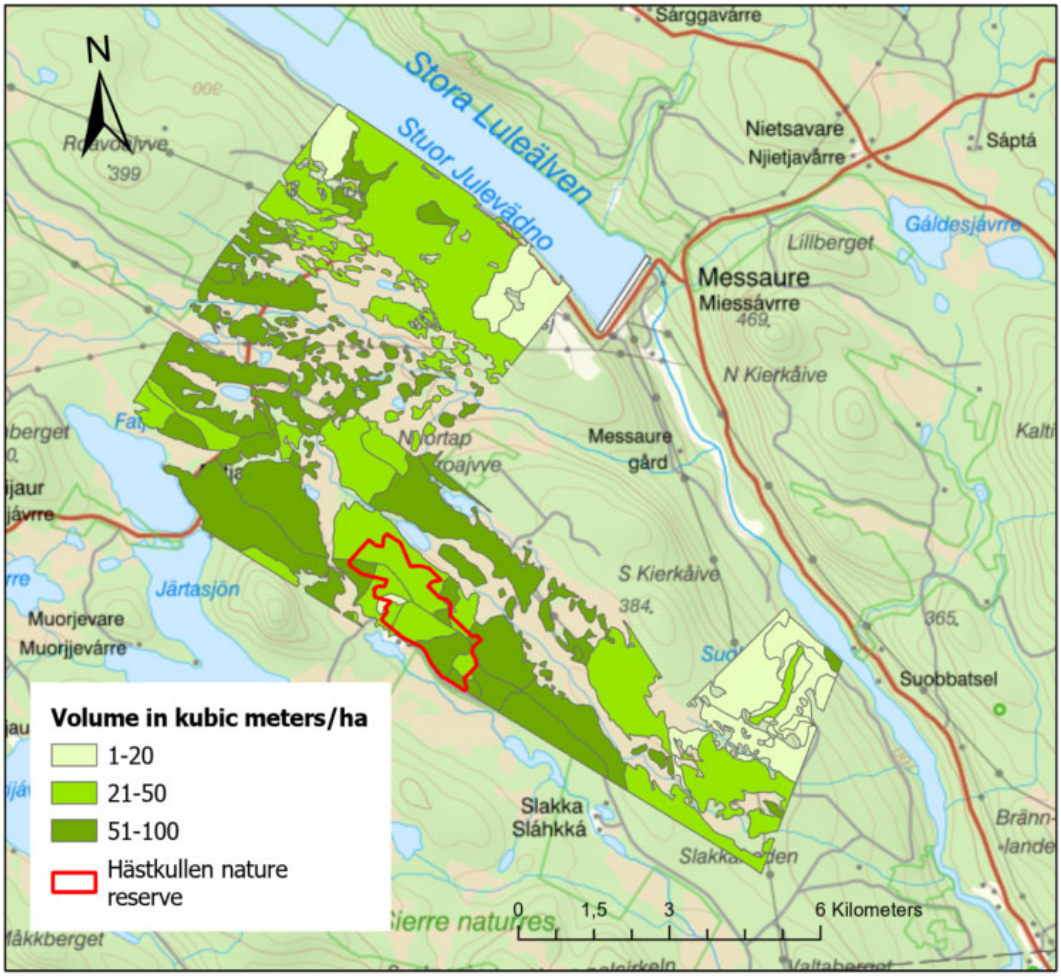

Figure 6. Volume for conifers in m³/ha for the year 1929.

In 1962 there are areas with 51-100 m³/ha both close to the river up north and in the south part of the management unit (*Figure 7*). Lower volumes are now found in the middle and western parts. Hästkullens nature reserve contains mainly forests with 51-100 m³/ha in volume.

1962

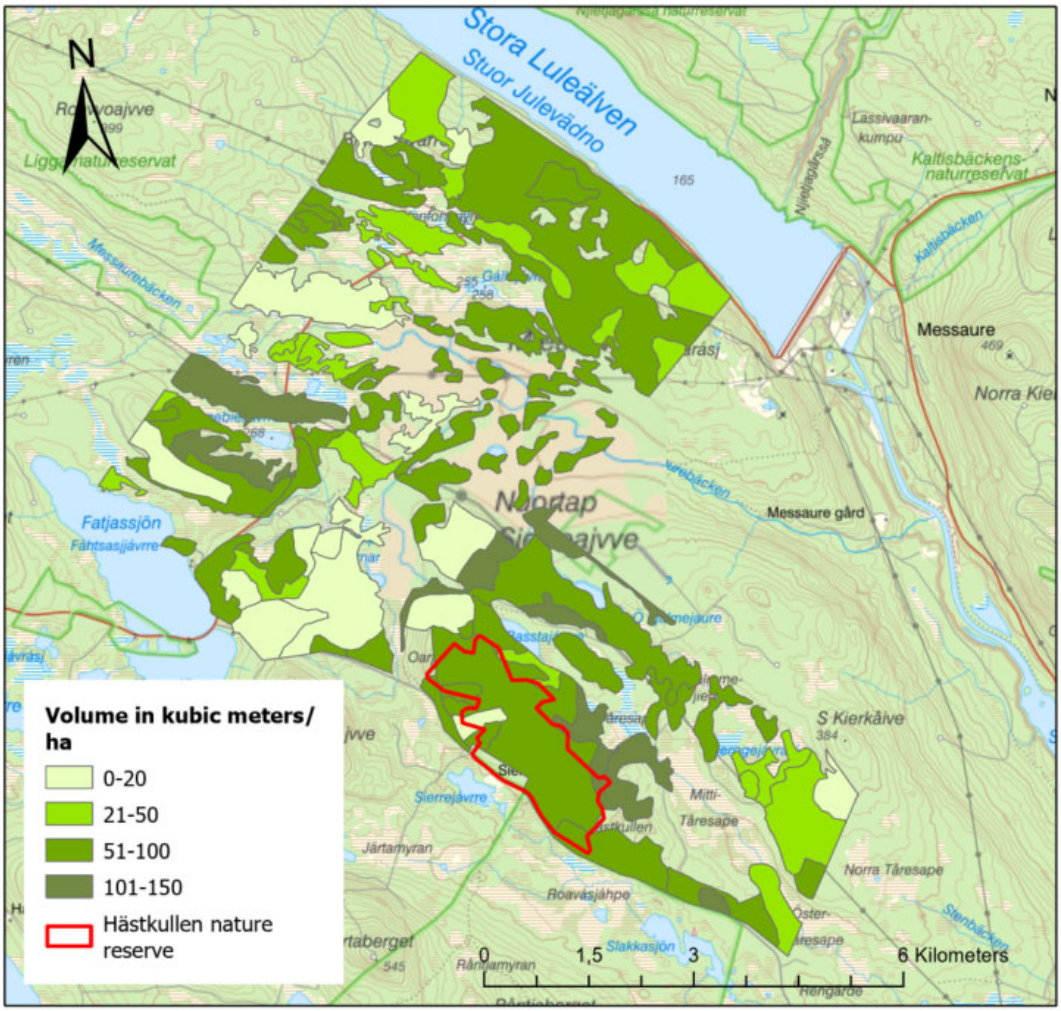

Figure 7. Volume for conifers in m³/ha for the year 1962.

In 2022 volumes up to about 300 m³sk/ha is found in some parts of the area (*Figure 8).* The entire management unit is varied with different volumes with no apparent pattern. Hästkullen nature reserve is excluded from the year 2022 as it is not inventoried by Sveaskog since it is not used for forestry.

2022

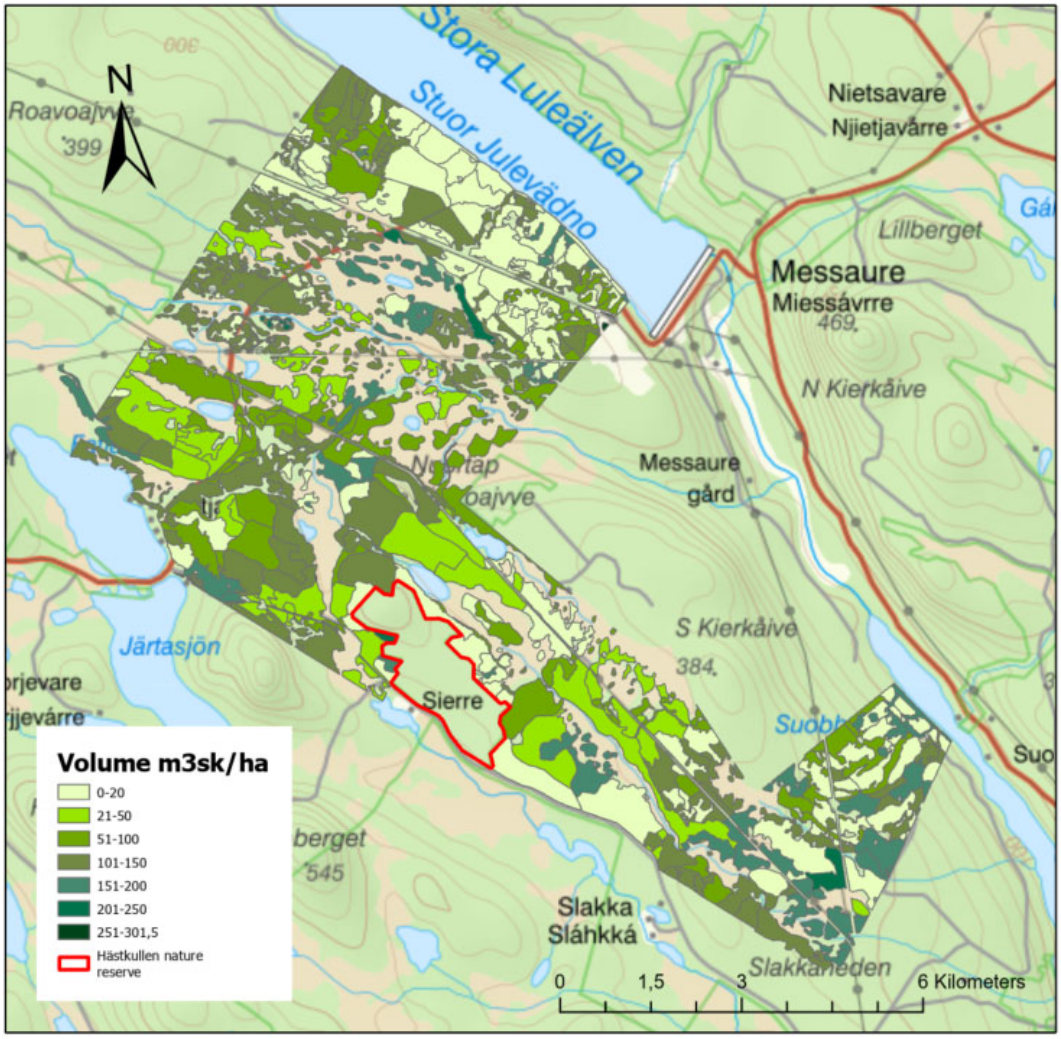

Figure 8. Volume for all tree species in m³sk/ha for the year 2022.

4.2.4 Changes in volume over time

The growing stock in the studied management unit increased over time (*Table 4*). Unclassified land such as mires or lakes are excluded. In 1907 each hectare held on average 32 m³. In 1929 it increased to 46 m³, in 1962 to 56 m³ an in 2022 it was 76 m³sk. For the year 1929 the amount of standing deadwood in the management unit was on average 4 m³/ha and the volume of deciduous trees 3 m³/ha.

Table 4. Summary of growing stock in the management unit for each year. 1907-1962 contains only conifers, 2022 is for all tree species.

Year	Total volume (m³)	Volume/ha (m³/ha)
1907	193 491	32
1929	266 747	46

1962	244 595	56
2022	425 106	76

4.3 Results from field inventory in Hästkullens nature reserve

49 circular plots and 50 additional plots were made in Hästkullen nature reserve (*Figure 9*). One of the circular plots in the south-eastern part had to be excluded as it was situated in an area with a too steep slope of rocks. One other plot was situated too close to the border and was therefore mirrored perpendicularly 20m (double radius of plot) into the area.

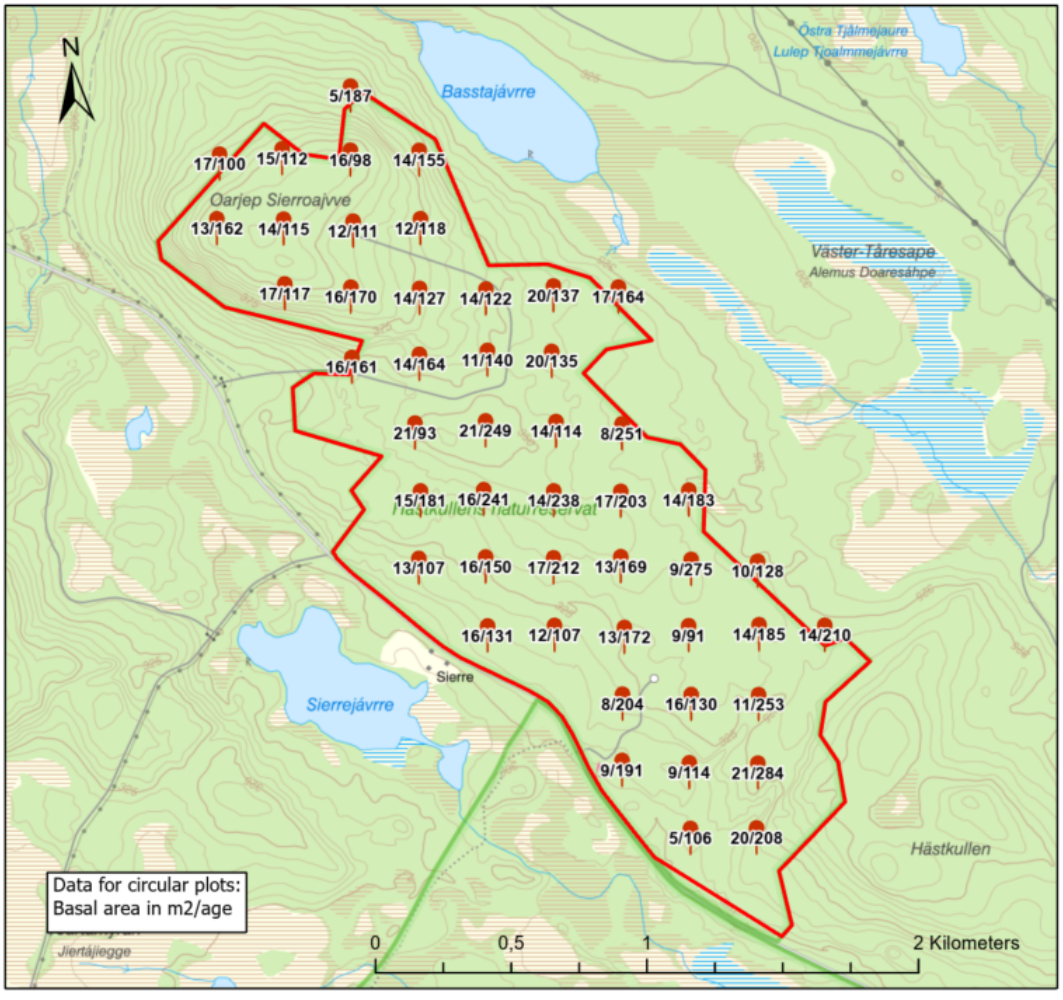

Figure 9. Data for circular plots displayed as basal area in m² versus age.

Hästkullens nature reserve has in general dry soil conditions with site indexes varying from T14 to T17. The ground vegetation consists mainly of lichens, *Calluna vulgaris* and *Vaccinium spp*. Pine trees cover 90% of the area, spruce and birch each have about 5%. At several places there were signs of previous loggings of large trees. The nature value evaluation resulted in 27 points, considered as high nature values.

Hästkullens nature reserve. Photo: Ester Andersson.

Tree age varied between 73-419 years with a mean value of 163 years (*Table 5*). The DBH had a mean value of 23,1 cm but ranged from 8,3-41,6. Mean height was 12,5 meter and varied between 3,5-21,8 meters. The mean for basal area of living trees was 14,2 m²/ha and ranged from 5-26 m²/ha. For dead wood the mean basal area was 2,9 m²/ha ranging from 0-7 m²/ha. Mean volume in the plots for the living trees (all species) was 112,4 m³/ha and the volume ranged from 0-459,9 m³ over all the plots. Mean volume for dead wood was 23,3 m³/ha and ranged from 0-211,9 m³/ha.

Table 5. Means and ranges for the inventoried structural variables in Hästkullens nature reserve.

Variable	Mean value	Range
Tree age (years)	163	73-419
DBH (cm)	23,1	8,3-41,6
Height (m)	12,5	3,5-21,8
Basal area living trees (m²/ha)	14,2	5 to 26
Basal area dead wood (m²/ha)	2,9	0-7
Volume living trees (m³/ha)	112,4	0-459,9
Volume dead wood (m³/ha)	23,3	0-211,9

The diameter distribution of the measured trees in the circular plots showed that 39% of the trees in Hästkullens nature reserve today is between 10-20 cm in diameter at breast height (*Figure 10*). 30 % of the trees were between 20-30 cm,

17% were between 30-40 cm, 3% were larger than 40cm and 12% were smaller than 10cm.

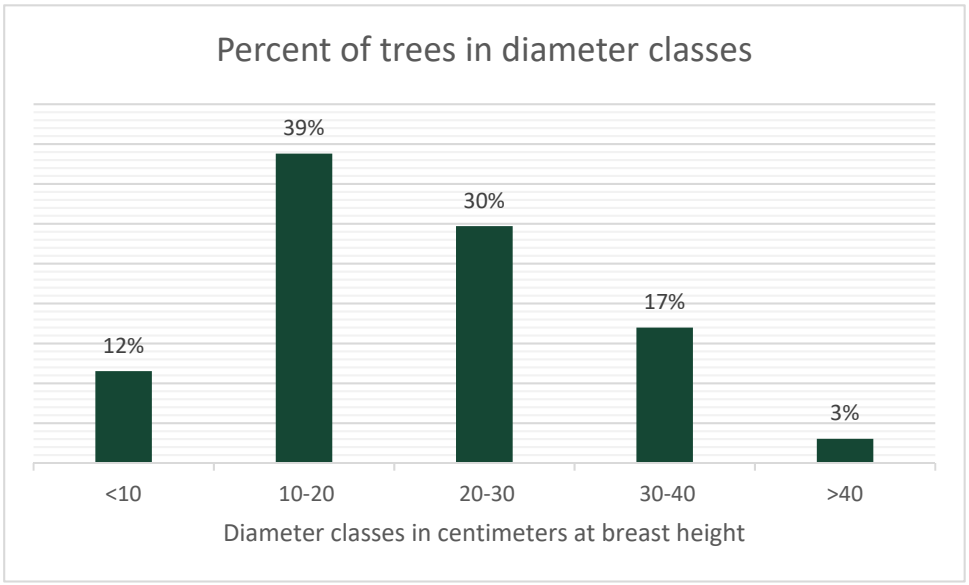

Figure 10. Distribution of trees in diameter classes in centimetres at breast height.

5. Discussion

The current state of any forest is a product of ecological drivers, human interventions and its history (Buergi, Östlund & Mladenoff 2017). The importance of history is particularly clear in slow growing ecosystems at northern locations since the legacy of past disturbance and land-use is evident for a long time. This study shows that restoration of the forests in northern Sweden strictly aimed att changing logged over forests to well stocked and high yielding production units where production of conifer wood was the main objective. This part of the forest history of northern Sweden has since the middle og the 20th century brought us both an increased standing volume of wood but also a severe lack of old forests (Skogsdata 2022).

What were the main driving forces that initiated the restoration of the north boreal forests in Sweden?

From my analysis of the articles in the Journal of the Forestry Association of Northern Sweden I identified three driving forces that initiated the restoration of the forests in northern Sweden. 1. Foresters concluded that the forests did not regenerate themselves as fast as they were harvested. This was also found by Lundmark et al. (2013) when they investigated why clearcutting was introduced to Sweden, they also saw that foresters had this worry already in the mid-1800s. 2. Foresters agreed that the insufficient regeneration was a result of the forestry method used. Clear-cuts had been introduced to Sweden already in the 1800s but due to economic difficulties selective logging was favoured between the 1930s and 1950 (Lundmark et al 2013). In the end of the 1940s, however, my study of the articles in the Journal of the Forestry Association of Northern Sweden show that many foresters wanted to dismiss selective logging entirely. 3. Forestry law and policies progressed over time and came to include demands on forest regeneration, this pin pointed the need for active measures on forest land where no new regeneration had appeared after harvest. The first official policy of 1950 från *Domänverket* was the last piece that steered foresters towards using clearcutting as a way of restoring our forests.

How was the restoration discussed, implemented and carried out?

The restoration was initiated by the first official policy in 1950 (Cikulär 1:1950). It clearly stated that for the next twenty years a program to reforest areas where previous management had caused the regeneration to fail was to be executed. From the articles in the Journal of the Forestry Association of Northern Sweden it is clear that ambitions for the program were high. This can also be seen in a review from Ebeling in 1959 where he states that only now had foresters begun the tedious work to "rebuild" our exploited natural forests (Arpi 1959).

The intense debate and the arguments from leading foresters clearly show that all focus was to create new and, in their opinion, much better forests for future generations. The wording and the strong opinions presented all show that they saw a chance to make an impact and "restore" the forests after what they idientified as a devastating previous exploitation. They acted on what they considered to be the right biological knowledge at that time, but again only concerning the production of denser and faster growing coniferous production forests. Other aspects such preservation of old remnant forests, ecological qualities (dead trees, deciduous trees and the natural dynamics) were either completely lacking or subordinated to the higher goal of creating "new" more productive forests. The fact that the restoration would lead to the demise of these other values was not unknown, as seen in the official policy in 1945 where it was stated that "rational forestry" lead to the depletion of "certain vegetation types" and that a small part of these areas should be preserved "for future foresters research" (Cirkulär 22:1945).

Why it was only production of wood that mattered in this time is a complex question. The constant worry of not having enough available wood resource in the future, seen both in this study and by Lundmark et al. (2013), perhaps pressured foresters to only focus on production. In the governmental investigation from 1978 it is stated that the economical importance of Sweden's forests in the future was likely to become even higher, probably rising the expectations on foresters even more (SOU 1978:6). Alongside this, mechanization and effectivization of forestry developed fast and the struggle to keep up might have caused foresters to set aside any thoughts of nature in favour of creating the "new forestry" (Ager 2023). Contemporal development of society in general might also have influenced the foresters to "clean up" in the forest (Skogshistoria 2023). Finally, the growning discussions of nature values came about 20 years after the restoration program was initiated (Simonsson et al. 2015). Lack of questioning of the forestry methods in the 1950s, from an ecological point of view, might have led to the believe that nature values was not as important as production at this time.

Before the restoration program came to its end economy put a stop to this big project. The restoration and management of the remaining forest was put on the future. Only a few years later a governmental investigation started that would lead to the new forestry law in 1979 (SOU 1978:6). The new law contained different

instructions on how to manage the forests to produce sufficient amount of wood for the industry and also a demand that forests with an insuffient growth must be cut down and replaced with a faster growing stand (SOU 1981:81). These forests were regulated under the fifth paragraph's third item in the law, hence the name "5§3 forests" (Asplund 2020). The 5§3 forest law was a specific restoration program as well as the previous one and thus the restoration idea was taken up again and continued in the 1980's. Similar to the restoration analysed in this study the 5§3 forests only focus was to increase production and no other values were accounted for (Asplund 2020).

What happened to the restored forest?

The result from the management unit in *Sucksåive* Crown Park showed three important results of the forest restoration. Firstly, age and age distribution are completely altered in the area if I compare the situation before the restoration, after and today. Multistoried forest in the area has been transformed to single storied forests, most of them younger than 40 years. The same trend has been found by Östlund et al (1997). In their study area of 135 000 ha multistoried forests decreased from 83% in the 1910s to 0,6 % in the 1980s. Old age and wide diameter distribution is connected to species richness and in the management unit we see that the majority of the forest have lost these traits (Pommerening et al. 2017). As a consequence to this the situation for species in this area have been entirely altered as well.

Secondly, volume of wood in the management unit have more than doubled in average volume per hectare from 32 m^3/ha in 1907 to 76 m^3/ha in 2022. This is even more interesting to acknowledge considering the fact that 44% of the forests in the unit is younger than 40 years and should thus consist of quite small trees. In essence much young forests, but with high timber volumes, and with high volumes yet to come. At the beginning of the 20th century this area was holding a very low amount of standing wood per hectare, even with the forests being multistoried and containing trees in various age classes. The National forest inventory (NFI), also show this trend from when it started in 1923 up until today (Skogsdata 2022). But has the volume really increased in the forests? In a study from Linder & Östlund (1992) they show that the forests that we had in northern Sweden at the beginning of the 20th century was a product of exploitation of the largest trees and that there had been 25-40% more volume in some investigated areas before the 20th century. Furthermore, in another study of an area in southern *Norrbotten* it is shown that logging of large old pine trees exceeded annual growth with 300% (Rautio et al 2015). From my results of the standing volume in the management unit in 1907 a gradient could be seen where volumes were lower close to the river. My interpretation is that more continous and more intensive logging was conducted

closer to the rivers since the timber was floated to the sawmill until the late 20th century.

Lastly, the mean area of the compartments was four times higher in 1962 (60ha) than in 2022 (15ha). This change I believe to be a result from the transformation of multistoried forests into single storied forests and the change in management. When almost all the forests were multistoried there was no need to separate them into smaller compartments with different treatments. Also, single storied forests are easier to separate from other single storied forests as they have an even age distribution and grows similarly within its own group.

What happened to the forest which was not restored?

From a forestry perspective

Hästkullens nature reserve is a conserved island in the studied management unit that was not treated with the same logging and subsequent regeneration practices as almost all other forests, seen in *figure 3 and 4*. It is however, not in any way unaffected by forestry. During the field inventory we continuously observed stumps cut by both axe and saw which indicates long term utilisation of this forest. The forest has increased in volume and today it holds about 112 m^3/ha. In 1907 the western part of the area held no more than 20 m^3/ha and the eastern part no more than 50 m^3/ha. The restored forest surrounding Hästkullen today have on average 76 m^3/ha, even with 44% of the forest being younger than 40 years. From a production point of view, it becomes clear that the restoration was a success for the growth in this area. In a summary of NFI data by Eriksson (2013) the same trend was found for the entire county of *Norrbotten*.

From an ecological perspective

My investigation of the ecological qualities in the non-restored forest at Hästkullen is interesting and provide a different story. Dead wood in Hästkullens nature reserve was found to be about 23 m³/ha. This is similar to the 22,5 m³/ha found for taiga forests classified as Natura 2000 habitats[4] areas in Jonsson et al (2016). For the entire management unit dead wood was measuered at about 4 m³/ha in 1929, although this included only standing trees. As downed logs were not included an entire group of dead wood is missing in this estimate, indicating a clear underestimation of the real volume of dead trees. In the study by Lie et al. (2012) they found that dead wood volume in 1925, mainly standing trees but also downed logs, was about 0,6 m³/ha according to their historical records. However, when they did a dendrochronological study, they found that much more dead wood was actually present in 1925, about 7,5 m³/ha, ranging from 0-16 m³/ha (Lie et al. 2012). For the management unit analysed in my study this can indicate that not only should there have been more dead wood counted in 1929 because of the missing downed logs, but also because all dead wood was in fact not counted. Today dead wood is not documented but on average a productive forest in Sweden have about 6 m³/ha of dead wood (Fridman & Walheim 2000). The difference in amount of dead wood in a production forest versous a set aside forest is important considering that the majority of our forests are used for production and thus the consequences of a low amount of dead wood is present in a majority of the forest.

Häskullens nature reserve. Photo: Ester Andersson

The standing forest has a wide range of ages, the average age was 163 years but there were trees older than 400 years present (the oldest being a 419 year old pine). The diameter distribution showed that large trees exist but are quite rare in the area, probably due to past loggings, indicating that the standing volume have been higher. In the evaluation of the natural values (*Sw: Naturvärdesinventering*, Skogsbiologerna AB 2015) Hästkullen recieved 27 points and the points were mostly connected to dead wood and structures such as slow growing trees. The study by Pommerening et al (2017) showed that large trees and large size

[4] Swedish: "Natura 2000 områden". Areas with high conservation values.

differences both has a positive correlation with high biodiversity in forests. In a landscape of otherwise single storied and similar sized trees this makes Hästkullen interesting from a biodiversity point of view and according to Länsstyrelsen Norrbotten, who is responsible for the nature reserve, several red-listed species inhabit the area (Länsstyrelsen 2023). It is very hard to speculate what the surrounding restored forest would have scored in a nature evaluation but since old trees are one of the main prerequisites, and my study show that old forest is scarse, I speculate that the points would be lower.

In a broader perspective, what societal, ecological and forestry related consequences has the restoration resulted in for the north boreal forests in Sweden?

In the studied management unit which was restored, 46% of the forest is single storied and younger than 40 years. 83% is single storied and younger than 120 years. Old forests have thus become a rarity in the management unit, and in addition the remaning old forests are scattered.

Charcoaled dead wood in Hästkullens nature reserve. Photo: Ester Andersson.

The non-restored forest reserve Hästkullen provides a very different picture and an interesting reference to the restored management unit surrounding it. Hästkullen can provide refugee for species that require dead wood, as the landscape otherwise in general is treated with clearcuts and thinning which have been found to reduce dead wood (Fridman & Walheim 2000). In 2020 Sweden had about 1400 red listed species that was deemed to be negatively affected by harvest of forests (Rödlistan 2020). Although Hästkullen is not entirely unaffected by forestry the inventory tells us that management since the mid 20th century has not affected the area too much. In the article by Lie et al (2012) they showed that selective logging, such as have been done in this area, left the forest in a multistoried state that continued to provide habitat for various forest species. When looking at the age distribution and compartment sizes of the entire management unit today one might argue that we have mutistoried forests, only in larger cohorts. From a landscape point of view this might be true but it is important to remember that many species need available substrate continuously in close proximity and might not be able to

move over large distances (e. g. Esseen et al. 1996; Nordén et al. 2013). On the other hand, we have scattered remants of old forests in the management unit. Perhaps this is an opportunity to create some connectivity in the landscape still?

Apart from forests ability to provide us with ecosystem services such as climate mitigation, timber or biomass production, they can provide us with health benefits as well (e.g. Sonntag-Öström et al. 2011; Dolling et al. 2017). The forest reserve Hästkullen provide important resources for the reindeer herding communities in the area since it has good lichen pasture (including pendulus lichens in the trees). The good lichen pasture is a result of the open forest structure and presence of very old trees. These conditions and the absence of modern forest management is is very important for the continuation for good lichen pasture (Sandström et al 2016). Seeing as almost all other forests in the management unit is used for forestry it makes Hästkullen important on a larger scale than only the reserve itself.

Traces of fire on a cut dead wood stump in Hästkullens nature reserve. Photo: Ester Andersson.

Strengths and weaknesses of this study

When studying historical records there are always uncertainties. The major strength of this study is the primary sources from Domänverket, which have proven to be reliable and accurate in other studies (Östlund et al 1997; ESM 3). The major challenge has been to compare data from different times as inventory methods might change, different people carry out the data collection and different objectives might influence the work. In this study the years 1929 and 1962 I believe are the most comparable, but slightly less so before and after this period. Furthermore, there is a large number of other historical records available and only a selection could be examined in this study. The used source material from the Journal of the Northern Forestry Association present other challenges. It is clear that most of the material is secondary sources with opinions from different people. I have therefore tried to make a rational selection of records from this material to show these different opinions and contrast them to some primary sources such as the official policies and the administrative documents from Domänverket.

In the field inventory occasional human and equipment errors such as missing structures, placing plots off from the systematic grid, measuring height wrong etc. might have occurred. However, as we repeated the same procedure in 49 plots and 50 additional plots, no large errors should be present in the collected data.

Conclusions

The forests in northern Sweden have been subject to dramatic changes in the 20th century, transforming semi-natural forests with high biodiversity values to fast growing production forest (Josefsson & Östlund 2010). This research illustrates a changing forestry and the transformation process of it, as well as it identifies some of the most important drivers. In the beginning of the century the larger trees had been harvested and the remaining forest continued to be selectively harvested until foresters in the 1940s started to argue that we needed to restore large areas which had poor regeneration and productivity. This led to the "forest restoration program" and the extensive spread of clear cuts as the dominant harvesting method. Now, previously harvested mutistoried forests with very low standing volume was one by one replaced by single storied even aged stands. Hästkullens nature reserve was a part of this management unit that had the same history, but was in contrast not restored with these methods and just left unmanaged for almost a century. Today it is a nature reserve with high conservation values. This gives us the opportunity to make comparisons and understand how the restoration period fundamentally changed the forest landscape in the interior of northern Sweden. It is interesting to think about how the managed forests around Hästkullen looked prior to their restoration. One hand the restoration gave us an increased forest growth compared to the beginning of the 20th century, which is important for providing us with for example timber resources and climate mitigation. However, with the knowledge we have today, if all this area would have been left without management, would it all have been set aside from forestry today? How would the situation for the red listed species have looked? How would the forests in northern Sweden have looked? From my results I believe that without the restoration habitat for redlisted species would not be so scarse but perhaps we would not have sequestere as much carbon dioxide in growing trees instead. I believe that we have reached the opposite end of the restoration and are now in need of a new restoration, but in another direction.

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2023:03 Författare: Carl Åhlund
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2023:04 Författare: Johan Engström
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A comparison of natural regeneration and active restoration

2023:05 Författare: Magdalena Fassl
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2023:06 Författare: Ruben Baan Hofman
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An observational study into the effects of forest management on understory vegetation communities along boreal headwaters

2023:07 Författare: Nils Helge Havertz
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Identifying training needs for the implementation of Continuous Cover Forestry in Sweden

2023:09 Författare: Ylva Kungsman
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Major forest companies and owner associations interpretation of policies and certification programs regarding riparian buffer zones

2023:12 Författare: Gaya Marike ten Kate
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