Uncovering climate and human signals in near-millennium annual fire chronology for Norrbotten county, Northern Sweden

Odkrywanie sygnałów klimatycznych i ludzkich w prawie tysiącletniej chronologii pożarów w hrabstwie Norrbotten w północnej Szwecji

Agnieszka Jabłońska

Master´s thesis • 60 credits
Swedish University of Agricultural Sciences, SLU
Southern Swedish Forest Research Centre
Alnarp 2021

Uncovering climate and human signals in near-millennium annual fire chronology for Norrbotten county, Northern Sweden

Odkrywanie sygnałów klimatycznych i ludzkich w prawie tysiącletniej chronologii pożarów w hrabstwie Norrbotten w północnej Szwecji

Agnieszka Jabłońska

Supervisor:	Igor Drobyshev, SLU, Southern Swedish Forest Research Centre
Co-supervisor:	Mats Niklasson, SLU, Southern Swedish Forest Research Centre
Examiner:	Jörg Brunet, SLU, Southern Swedish Forest Research Centre

Credits:	60 ECTS
Level:	Advanced Level A2E
Course title:	Master´s thesis in Forest Science
Course code:	EX0983
Programme:	Euroforester Master's programme SM001
Publisher:	Swedish University of Agricultural Sciences
Place of publication:	Alnarp
Year of publication:	2021

Cover illustration:	Igor Drobyshev
Keywords:	Dendrochronology, forest fire history, climate, human impact, boreal forests

Swedish University of Agricultural Sciences
Faculty of Forest Sciences
Southern Swedish Forest Research Centre

Abstract

Forest fire is one of the major factors driving the dynamics of the boreal forest. Climate has the most significant contribution in shaping the fire occurrence, its spatial extent and severity. Anthropogenic activities have contributed to variation in fire activity, although the timing and the scale of the human impact are still heavily debated.

Millennia-long annual records, which can inform us on the interplay of climate and human influences on fire activity in a long-term perspective, are largely missing for European boreal forests. To address this knowledge gap, I developed a dendrochronological reconstruction of fire activity using fire-scarred dead and live Scots pine trees in Norrbotten county, northern Sweden. Site reconstructions (n = 24) extended from 900-1200 AD to the present time. To assess the degree of climatic forcing upon fire activity, I conducted superposed epoch analysis using the ten largest fire years and Old World Drought Atlas.

Fire occurrence varied significantly with time, with the most extensive fire years occurring during the drier-than-average conditions. Analysis of fire activity with the human population data extending to the mid-1500s suggested a negative correlation between the two factors.

Keywords: dendrochronology, forest fire history, climate, human impact, boreal forests

Table of contents

List of tables

List of figures

1. Introduction

Forest fires are one of the main drivers of forest ecosystem dynamics. Understanding their role in the natural dynamics of the boreal forest is crucial for modelling forest responses to environmental changes. Fires are essential to maintain the diversity and successional pathways of boreal forests (Bergeron et al., 2004) and biochemical cycles at different temporal and spatial scales.

Dendrochronology and dendroclimatology are efficient tools for documenting the temporal component of past fires and the role of climate in controlling fire activity (Cook et al., 2006). The long-term perspective of dendrochronological analysis is particularly useful for ecosystems characterized by long fire return intervals, such as northern boreal forests. Reconstructions of fire histories cover the period of 300 to 800 years and help us deduce the extent of fire activity in particular years and seasonal fire patterns (Niklasson & Granström, 2000; Groven & Niklasson, 2005; Wallenius, Lilja & Kuuluvainen, 2007). Previous research shows that it is indeed rare to reconstruct a period exceeding 800 years based only on tree-ring proxy, making the chronology presented here quite unique.

Fire regime describes the overall spatial pattern, frequency and characteristics of fires in space and time dimensions (Swetnam et al., 2016; Rolstad et al., 2017). To decipher the factors affecting fire regimes, we analyse climate variability and land-use patterns (Niklasson & Granström, 2000; Drobyshev et al., 2004; Granström & Niklasson, 2008; Ryzhkova et al., 2020).

Topographic features and fuel properties have explained spatial variation in fire regime characteristics. In northern Sweden, Zackrisson (1977) found dry forests of Scots pine to have burned more frequently (mean fire interval ~50 years) than mesic forests of Norway spruce (80–120 years).

Pines exhibit a range of adaptations to fire. These include thick bark and self-pruning, resulting in a low amount of ladder fuels (Agee, 1998; Keeley & Zedler, 1998; Keeley, 2012; Zin, 2016). This species has a wide amplitude of occurrence due to those adaptations. The spatial range of pines is defined by resistance to low to medium severity fires. The probability of surviving the fire by Scots pine is rising with age (Fernandes et al., 2008). Fires have been an important factor in maintaining Scots pine's dominant position over Norway Spruce in boreal and temperate Europe (Zin, 2016).

Climate is a critical driver of fire activity in boreal forests, with large scale atmospheric circulation processes controlling the occurrence and severity of fire-prone weather (Drobyshev et al., 2016). Rapid temperature increases, potential shifts to more flammable vegetation, and increased lightning strikes and man-made fires are expected to increase forest fires in Fennoscandia (Flannigan et al., 2013).

1.1. Objectives of the thesis

The main objective of the master thesis is to analyze the fire history of a boreal landscape and understand the strength of the impact of human and climate activity on forest fires. In Norrbotten county, large areas of remaining old-growth and deadwood rich forests allow for long-term dendrochronological reconstruction of fire history. Living and deadwood of Scots pine were used for building fire chronology.

The specific objectives are:
(1) To reconstruct fire activity for the study area in Norrbotten county over the past millennium.
(2) To analyze the strength of the human population and climate impacts on fire activity.

The following hypotheses were tested:
(1) The relationship between fire activity and the human population should be positive since the active presence of humans leads to an increase in the number of ignitions. Moreover, low technology culture could increase fire frequency by using it as a tool to create agricultural land through the slash-and-burn method.
(2) Years with increased fire activity were drier, suggesting a climate forcing upon fires. Dating fire scars, as done in this study, resulted in the development of a fire chronology that spans three periods: The Medieval Warm Period, the Little Ice Age, and the Modern Warm Period (Fig. 1). Characteristics of those epochs are expected to correspond with fire occurrence.

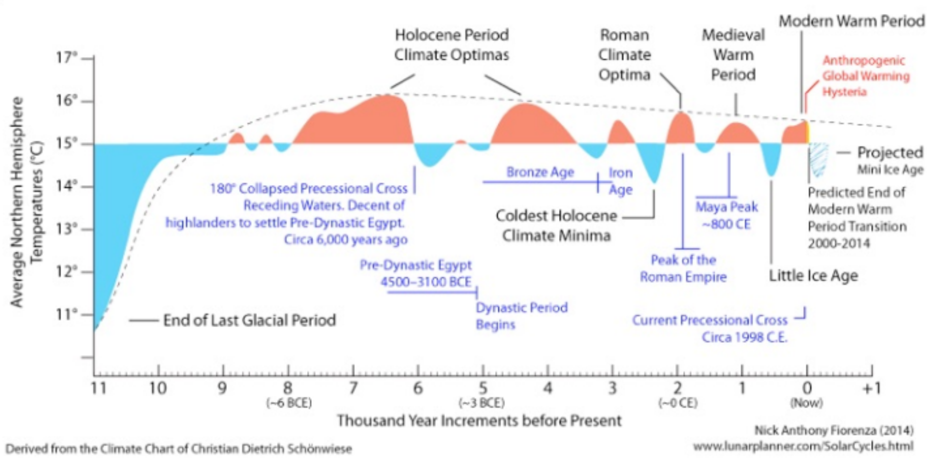

Figure 1. Long terms trends in climate variability in Holocene. (Nurtaev & Nurtaev, 2016).

1.2. History of fire in Northern Sweden

Fire history in Northern Europe since 1400 AD is generally well-known (Angelstam & Kuuluvainen, 2004). The first studies on the history of fires formed a simplified view that boreal forests are usually subject to devastating fires replacing tree stands approximately every 100 years. The knowledge of the historical fire regimes of the boreal vegetation zone has increased significantly (e.g., Lehtonen, 1998; Niklasson & Granström, 2000; Drobyshev et al., 2004; Wallenius et al., 2010; de Groot et al., 2013).

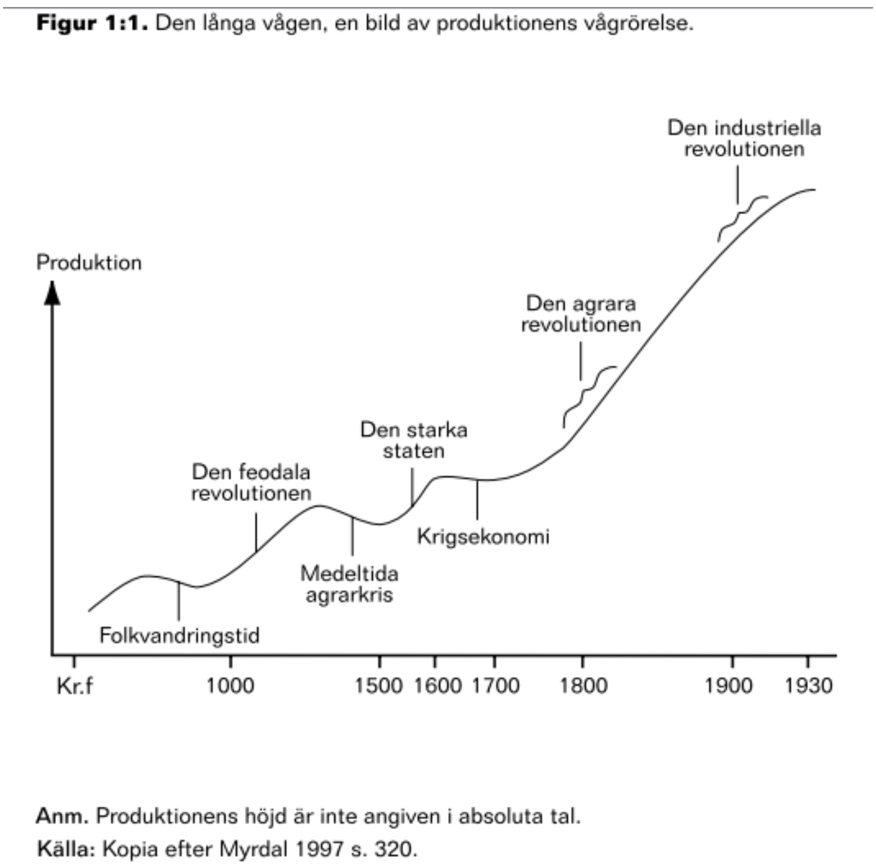

Figure 2. Dynamics of agricultural production and important periods in the history of Sweden. From Larsson (2009).

Studies of fire ecology and history are challenged by demographics and a long history of agriculture and commercial forest management (Fig. 2). Dendroecological studies have produced relatively strong evidence for an anthropogenic influence on fire regimes during the last 500 years. Humans promoted fires through slash-and-burn agriculture and forest pasture burning during 1500–1800s. Later, they suppressed fires due to the increased value of timber resources (Lehtonen & Huttunen, 1997; Niklasson & Granström, 2000; Groven & Niklasson, 2005; Storaunet et al., 2013). A pivotal study by Niklasson & Granström (2000) documented a large variability in the occurrence of fires and sizes of historical fires with a transition from less frequent but large fires towards more frequent. Small fires were linked to the human colonization wave in the early 1600s. Further increase in fire occurrence was due to reindeer herders and continuing enlargement of their settlements (Granström & Niklasson, 2008). Before the turn of the 20th century, wildfires had an annual area burnt more than 250 times higher than today (Drobyshev et al., 2015). Although humans have had the dominant control of the fire regime over the last 300 years, the climate has been an important factor (Drobyshev et al., 2012).

The relevance of climatic fluctuation has been revealed by current experiments with different modelling tools that indicate global warming in northern Fennoscandia. It is also linked with the rising amount of summer rainfall, reducing the risk of possible fire ignition and spread (Flannigan et al., 1998). Since 1996, the annual burned area of the forest in Sweden ranges between 1 000 and 5 000 ha (MSB, 2019) Under these conditions, close to 0,008% of the forest area has been burned annually (MSB, 2017). This corresponds to the fire cycle of around 10^4 years in Sweden (Drobyshev et al., 2012). In Northern European boreal forests, it is estimated to be between 50 and 300 years (Niklasson & Granström, 2000; Drobyshev et al., 2012; Ryzhkova et al., 2020). Comparison with the fire cycle in Canada and Russia indicated that fire activity in today's Sweden is much lower than in areas with abundant natural forests and low infrastructure density (Drobyshev et al., 2015).

Even though fire history in the Scandinavian boreal zone is well recognized, the vast majority of studies do not cover the mesic and heavily managed forests (Pinto et al., 2020). Existing chronologies have been developed based on data from protected areas or xeric sites with low management intensity (Drobyshev et al., 2014). Mesic sites were primarily excluded from dendrochronological studies, although they represent 94% of the total area in Sweden (Pinto et al., 2020).

1.3. Human impact

Humans and their ancestors are unique in that they are fire-generating species, but "natural" (i.e., non-human) fires have an ancient geological history on Earth. It is often difficult to distinguish between ignitions from humans versus natural lighting sources in fire-regime changes (Pausas & Keele, 2009). Natural fires may become large since they often burn in a non-controlled way, under the condition of rapid spread and high intensity (Granström & Niklasson, 2008; Rolstad et al., 2017). Human-caused fires occurred on a smaller spatial scale and happed more often than natural fires. We do not know when human hands lit a habitual and control fire. It is a vividly debated issue. However, fire use could have been among the oldest technologies invented by humans.

The human impact may be recognized from the perspective of fuels, ignitions and culture (Granström & Niklasson, 2008). It is essential to go beyond the scientific approach and deeper into cultural value, illuminating how different cultures think about fire and how their institutions manage it (Bowman et al., 2011). The basis for studying the man-fire relationship is the combination of cultural aspects and the fire activity looked at. Culture evolves, and so does human needs. Fire met these needs in different ways from one century to the next. From the 16th century onwards, human activities influenced the fire regime in northern Sweden (Niklasson & Granström, 2000). Henceforth, an increase in anthropogenic fires is observed. People affected the landscape with fire in several ways. The paper of Granström & Niklasson (2008) mentions settlement for reindeer breeding as one of them. At different times, a significant increase in ignition frequencies was noticed due to the expansion of slash-and-burn agriculture, i.e. the use of fire to clear forested land for agricultural production (Kirby & Watkins, 2015). This trend did not change until the late 1800s. The decline in fire activity was caused by another shift in the wood industry. From this time, landowners abandoned practises including fire (slash-burn-agriculture) due to the growing economic value of timber (Kirby & Watkins, 2015). The increase in the value of wood forced pressure on this raw material. The desire to intensify production was the driving force behind changes in existing forest silviculture practices.

Changes to emerging forest practices have also resulted in a transformation of succession dynamics and species composition. That happened due to an agriculture system shift, after slash and burn agriculture grazing practise became more widely used. However, often harvested forests exposed for livestock grazing may dry out more quickly than canopy-closed stands with lush vegetation. In terms of fire, the shift in land use has changed the quality and configuration of access to fuel in the forest (Blaken et al., 1997).

The fire was used as a management tool in production forestry for a short period from the middle 1920s to the late 1960s (Hallsby, 1995; Hornsten et al., 1995). At that time, Swedish foresters realized that fire used to affect the productivity of sites positively. The process of burning was considered as adjunctive for seeding and regeneration (Söderström, 1981). The most intensive time for prescribed burning was in the late 1950s. Despite the noticeable benefits, the use of the method decreased with each passing year. Planning difficulties and dependence on the weather were handicaps. Foresters also considered the consequences of long-term burning of the forest land like eg. clear-cutts.

A new modern era for the timber industry brought subsequent changes like high demands for pulpwood which targets the smaller diameter trees. The production target of the forest and machine harvesting techniques made it necessary to adapt the infrastructure. The forest was filled in with a network of roads that became natural fire barriers. In addition, they are used to move quickly to extinguish the fire. The traceability and effectiveness of firefighting activities have increased significantly due to greater availability. The effectiveness of fire prevention practices is confirmed by observations of current and historical fire cycles. According to Niklasson & Granström (2000), in 1300-1650, the fire cycle was 150-300 years, but now it is 10^4 years, as reported by Drobyshev et al. (2012).

In addition, the prescribed burning culture currently makes a return as a conservation tool. Although we have dropped the powerful practices of slash-and-burn, and our main focus is fire fighting, our actions still shape fire activity. As people, we actively participate in this process.

1.4. Land use impact

Land use alters the wildfire regime through deliberate or accidental ignitions, suppression, fuel alteration, including vegetation treatments, prescribed fire, forest clearing, and cultivation and fuel continuity and landscape fragmentation (Balch et al., 2017; Syphard et al., 2019).

Landscape characteristics are crucial for fire spread. For example, mires affect spatial and temporal patterns of forest fires (Hellberg et al., 2004). Natural barriers like wetlands, lakes, watercourses and rock outcrops moderate the direction and the rate of fire spread (Niklasson & Granström, 2000). Mires cover approximately 17% of northern Sweden´s terrain (SOS, 2020) and maybe a firebreak. However, prolonged droughts make mires conducive to fire activity (Hellberg et al., 2004).

In Fennoscandia, today's forest landscape is characterized by single-storied stands, each of a specific age, created by intensive management (Kouki et al., 2001). According to Elkie & Rampel (2001), current management practices in boreal forests are causing severe landscape changes. The commercially managed forests differ significantly from that formed by occasional wildfires in size of gaps, species composition, and forest structure. Forest structure impacts fire spread, and monodominant forests composed of coniferous species are particularly conducive to fire. Rather than changing the total area of forestland, the changes that occurred during the 20th century caused reductions in old-growth and mature forests and changes in patch size. Therefore, currently, in the concept of managing natural resources, the method of mimicking natural perturbations of the pattern has been accepted as a less risky way to protect the value of the ecosystem and meet the requirements of sustainable forest management.

2. Study area

I conducted the study in the north-western section of the county of Norrbotten (Fig. 3). There are six bioclimatic domains in Sweden, including the alpine zone, northern boreal forests, mid-and south boreal forests, boreo- nemoral and nemoral forests. Norrbotten lies in the alpine, northern boreal and middle boreal climatic zone (Ahti et al., 1968). Continental cold climate dominates in the study region. The average temperature is 0.7 ° C (Arjeplog). The cold months are January and - February, the coldest of which is January, with an average maximum temperature of -10.8 ° C. The hottest month is July, with an average maximum temperature of 16.5°C. Total annual precipitation is 743 mm, which is variability at higher elevations. The month with the highest average precipitation is July, while the driest month is May. Around 50 % to 30% of total annual precipitation falls as snow (Raab & Vedin, 1995). The number of days with a mean temperature above 5°C is between 100 and 160 days (Raab & Vedin, 1995). The majority of the forest fires in the study area occurs early in the fire season (Drobyshev et al., 2012). In Northern Sweden, fires may occur already in May. However, fires with the most significant contribution in total burned area in the fire season occur in August (Drobyshev et al., 2012).

Species composition in the forest tree layer is dominated by Scots pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* (L.) H. Karst), and birch (*Betula pubescens* Ehrn. and *Betula pendula* Roth). The landscape is commonly used for reindeer herding and timber harvesting in large scale clear cuts among pine and spruce monocultures. Most forest types are flammable due to presence of dry reindeer lichens (*Cladina*), mosses (*Pleurozium schreberi* (Willd.) Mitten.) and dwarf shrubs (*Vaccinium vitis-idea* L., *Vaccinium myrtillus* L., *Calluna vulgaris* L., *Ledum palustre* L.). This type of understory is conducive to the spread of fires, especially in the dry season. The landscape contains mires, lakes, and rivers, which form a natural fire break among vegetation.

The region is sparsely populated, especially in the Lapland sub-region. The dominance of poor acidic soils and harsh climate makes it less attractive for human settlement.

Figure. 3. Location of the study sites

2.1. Data collection

A data set of 29 sites and >400 samples were collected during the summer fieldwork in Norrbotten county in summer 2020. The sites were chosen based on the availability of old, well-preserved wood and the amount of rock facilitating the preservation[1]. In general, wooden stumps, snags, and standing trees preserve better in dry conditions with rocky outcrops on a south-facing slope. This combination of the condition provides much slower rutting and less moisture wood. Samples were taken from dead and living Scots pine trees. Live trees, on the other hand, were a minority and were used to estimate the cambium damage caused by past fires. To collect samples chainsaw has been used, focusing on old trees and deadwood with fire scars.

[1] Source of information about sites can be found here: https://skyddadnatur.naturvardsverket.se/

3. Methods

3.1. Laboratory work

Laboratory work included three stages. The first was focused on the preparation of study material. Each sample was dried and polished up to 400-grid. High graduation has been used to obtain a clear view of the tree rings and fire scars using a binocular microscope with 40 times magnification lens. The second stage included samples scanning with high-resolution (2400 dpi) to determine tree rings and fire scars with high diligence. Measuring of tree rings was done by using computer programs Cybis AB CooRecorder and CDendro 9.1. To evaluate dating quality, i.e. the strength of the correlation among chronologies, we used a t-test (Holmes, 1983, 1999; Grissino-Mayer, 2001) calculated in CDendro software. The third stage involved the dating of fire scars and identifying scars positions within the rings to secure seasonal dating. Seasons of fire were summed up in three groups: early season (spring), mid (summer) and late (autumn). I also relied on the visual pointer year method (Stokes and Smiley, 1968) and used a newly-developed pointer year chronology. Some instrumental pointer years were 1703 (dark), 1601 (pale), 1390 (dark), 1347 (dark), 1195 (dark), 961 (very pale), and 922 (dark).

3.2. Analytical approach

3.2.1. Regime shift analysis

The number of fires was adjusted using a novel algorithm: the considerations outlined above assumed that the study period features a constant number of recording sites, a situation which is rarely observed on real data, since site reconstructions always vary in their length. To ensure that the period under consideration had a constant number of recording sites, we adjusted the number of recorded fire years, capitalizing on the relationship between the number of recorded fire years and the length of a period. In particular, we assumed that over the period with declining site coverage the fire regime had remained constant and changes in the number of reconstructed fire years was a function of the changing site replication. For the 20-year segments within this period, we obtained the number of fire years and the number of sites representing that segment. We then estimated the difference between the maximum number of sites over the whole period and the site replication for a focal segment. We then used this difference (deltaS) as an argument in the regression with the number of fire years as the dependent variable:

$$\mathbf{Number\_of\_\ fire\_years = f\ (deltaS)}$$

The regression provided us with an estimation of the number of missing fire years, which was the difference between expected and observed fire years. Finally, we added these years at random positions within that segment. The algorithm provided a conservative solution to the adjustment problem, since it assumed the same "process density".

3.2.2. Superposed Epoch Analysis (SEA)

Superposed Epoch Analysis (SEA) is a statistical method used to identify the link between discrete events and continuous-time or spatiotemporal processes and test the probability of such an association occurring by chance (Haurwitz & Brier, 1981). SEA has been widely applied in climatology and dendroclimatology to test for the impact of volcanic eruptions on climate (Kelly & Sear, 1984; Lough & Fritts, 1987), the significance of soil moisture and climate conditions on the occurrence of forest fires (Swetnam & Betancourt, 1998; Swetnam et al., 2016), and to evaluate tree growth response to drought events (Orwig & Abrams, 1997).
Conducting SEA, I correlated the Palmer Drought Severity Index (PDSI) with large fire years (LFY). PDSI data was obtained from the website (http://drought.memphis.edu/OWDA/). The principle is to compare chronology from Norrbotten with other chronologies on the continent. I tested for the significance of departures of PDSI chronology during LFY's across Europe.
Positive values of PDSI suggest wetter-than-normal conditions, and negative values indicate drought (Palmer, 1965).

4. Results

4.1. The temporal pattern in fire activity

In the total number of samples <400 on 29 sites, 189 event years were found (Fig. 4). The oldest ring was dated to the year 508 AD. The earliest fire was dated to 905 AD and the most recent to 1868 AD. The composite chronology covered the period between 508 AD and 2020 AD. The oldest samples were found on the IKSJ1 site, and the shortest chronology was determined for the site 130. Site replication stayed above 20 sites from ca. the 1900s to 1200s, then dropped to even 5 sites in years <1200s (Fig. 5). The most fire-prone year was 1640 AD, with the total number of 19 sites recording fire in that year.

4.2. The decadal occurrence data

I distinguish five epochs with different decadal mean frequencies (Table 1). The base of this division was fire frequency among years. Its occurrence creates a particular pattern characteristic for a given epoch. Confidence intervals inform us how far we can trust the value. The smaller the value, the greater the accuracy of the estimation, but at the same time, the slightly inflated risk of error. The confidence intervals lower limit varied from -0.04% to 0.98%, whereas confidence intervals for higher limit range from 0% to 1.2%.

Table.1. The decadal fire occurrence in the study area for the period from 900 AD to 2020 AD.

Period	Start of fire epoch	End of fire epoch	Mean frequency of fire occurrence per decade	95% confidence intervals Lower limit	95% confidence intervals higher limit
1	900	1280	0.61	0.55	0.70
2	1300	1440	1.10	0.98	1.20
3	1450	1670	0.67	0.53	0.83
4	1680	1890	0.44	0.30	0.60
5	1900	2020	0	0	0.00

4.3. Reconstruction of fire activity

Analysis revealed five fire regimes over a millennium (Tab. 1 and Fig. 5). The longest epoch lasted from 900 AD to 1280 AD (Fig. 4). I observed a significant increase in fire activity during the second regime (1300 AD- 1440 AD). Climatic features must be considered active factors when people play a minor role in the landscape.

Further, there is a steady decrease until the 21st century. Human presence has been reported since the last three fire regimes. Although there is a peak in population density and then a radical drop around mid- 1900s, the population dynamic did not reveal any synchrony with fire activity changes.

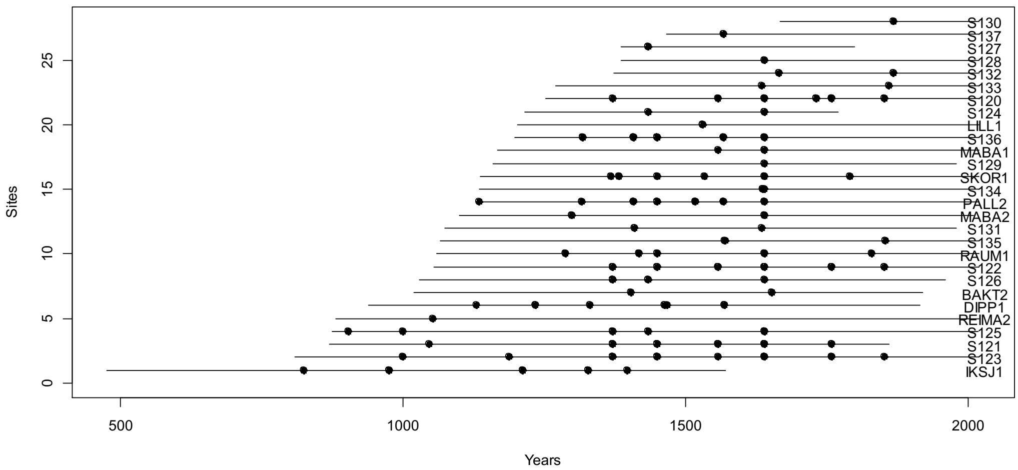

Figure. 4. The timespan of site chronologies and reconstructed fire events marked as black dots.

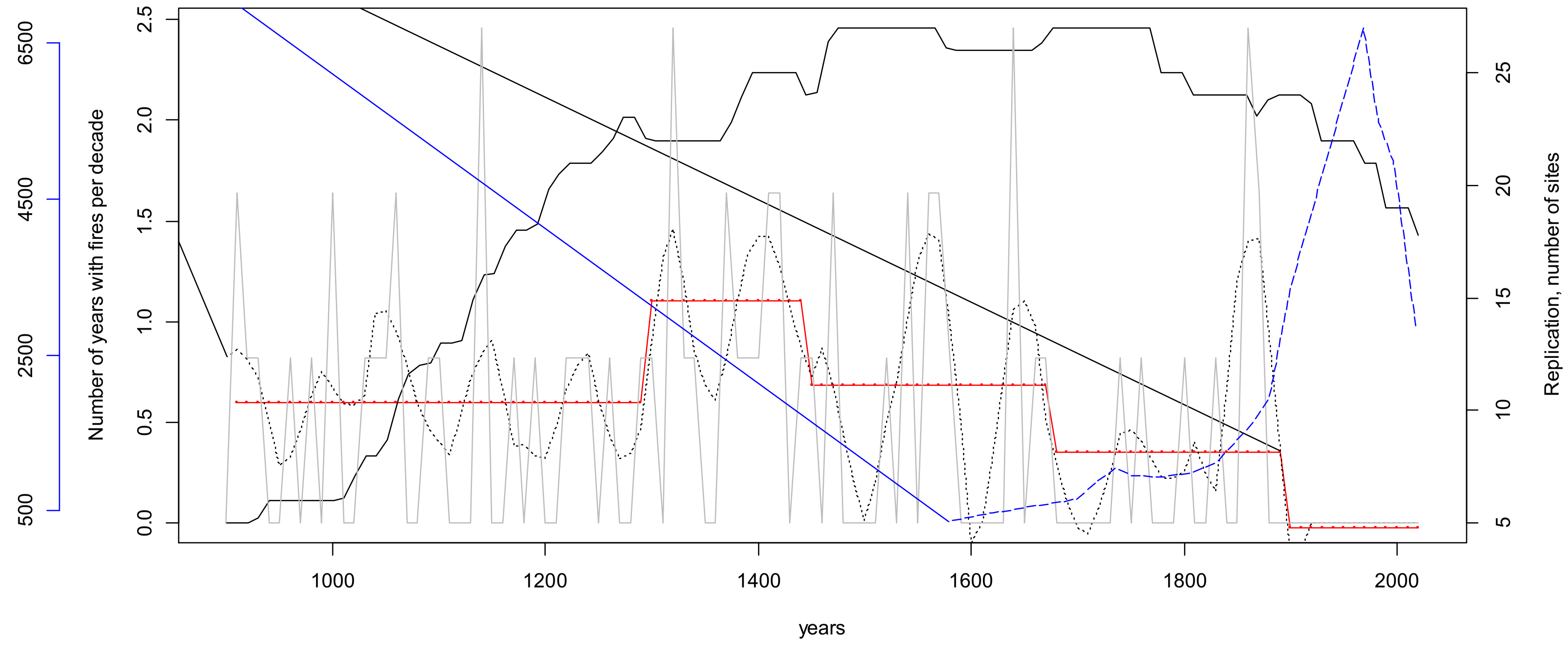

Figure 5. The decadal fire occurrence in the study area over the period 900 – 2020 AD. Red line refers to periods with constant fire occurrence; solid black line shows replication (number of sites covering a given decade); grey line presents the number of fire years per decade; black dotted line is a smoothed chronology of fire occurrence; dashed blue line represents dynamics of the human population

4.4. Correlations of Palmer Drought Severity Index (PDSI) with the occurrence of large fire years (LFY)

Analysis of PDSI reveals that during the LFY region was exposed to significantly drier conditions. Red and orange grids along the Norrbotten county indicates that dry conditions have made the whole landscape more fire-prone. The red colour tells us that there is a negative PDSI anomaly in a particular grid cell. (Fig. 6). In contrast, blue coloured grids point to the positive PDSI anomaly during LFYs, (Fig. 6). Remained ones, white grids are not representing any of the relationships with the analyzed list of LFYs.

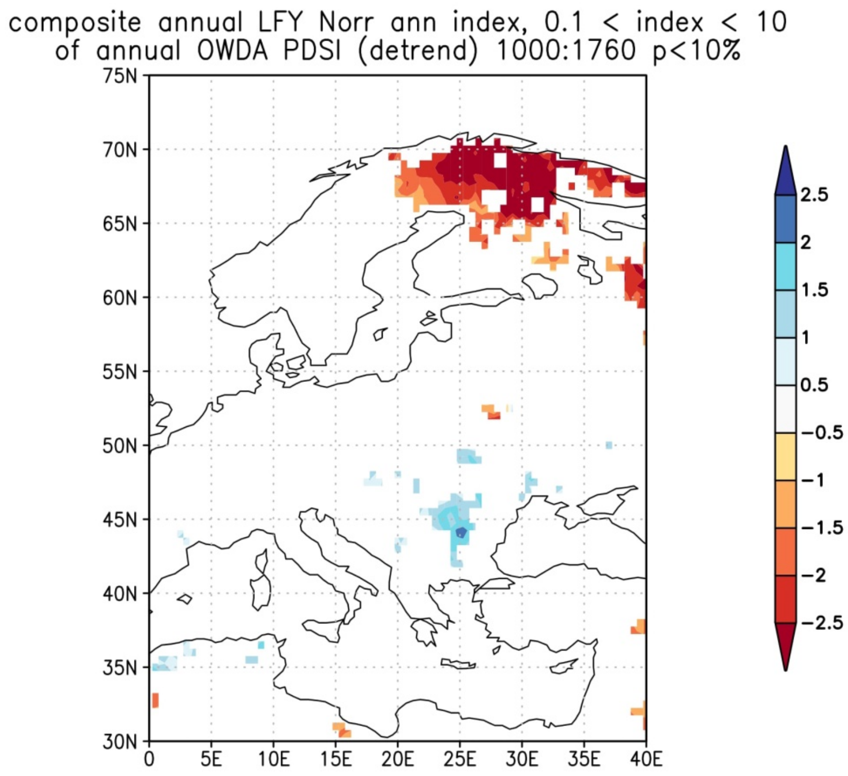

Figure 6. Superposed epoch analysis of the ten largest fire years in the study area and the PDSI reconstruction (Cook, 2015). Coloured cells represent areas with significant departures of PDSI values from the expected values (the mean for that cell).

4.5. Seasonal pattern of fire activity and probability of fire occurrence

Seasonal dating of fire scars indicated that nearly 50% of the recorded fires occurred in July and 40% in May or June (Fig. 7). The remaining ones (10%) occurred in the dormant period.

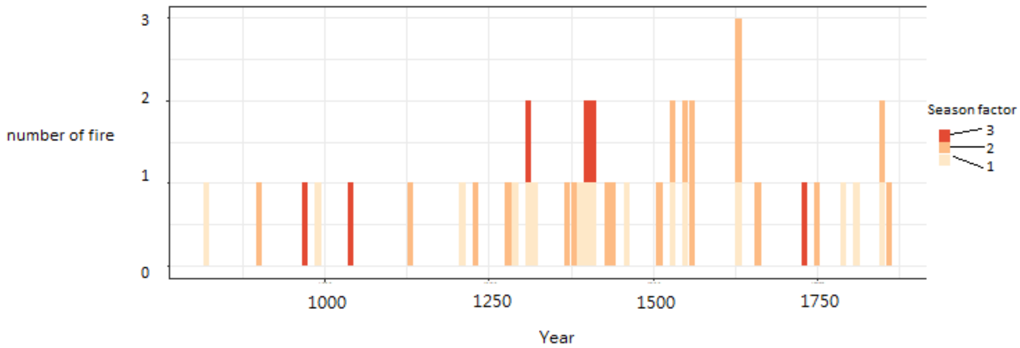

Figure 7. Seasonality of fire occurrence. Light pink (1) represents May or June fires, light orange (2) is mid-season (possibly July), and dark orange (3) represents late season fires (possibly late July through September).

5. Discussion

General information

Understanding the past dynamics of fire occurrence is crucial for identifying the range of variability in the climate sensitivity of boreal fire regimes. In this study, I present a millennial multi-site chronology of fire activity for a northern Swedish landscape. The chronology covers the period between 508 AD and 2020 AD.
Fire return intervals on the site scale are generally long, in average around 105 years. Chronology is characterized by significant temporal variability, that is represented by five fire regimes indicated at the centurial scale. Distribution of LFY is mainly focused around the coldest periods: second (1300-1440 AD) and third (1450-1670 AD) fire regime. The year 1640 was the largest LFY on record. Additional information, gives us seasonal pattern of fire activity, revealed that around 50% of fires took place in July, and 40% around May and June. Probability of fire occurrence was defined for each regime.

Association between fire activity and climate and human population

Even generally wet and cold landscapes may feature fire activity during periods of strong droughts, fire activity has been changing at centurial scales, as witnessed by changes in the decadal occurrence of fires. Mean frequency differs from 0 fires per decade in 5th regime (1900-2020) to 1,1 fire per decade in regime 4th (1680-1890).

What is the driver of this activity? It is impossible to answer this question conclusively. Current knowledge, proxies and data acquisition techniques are not able to circumstantiate the reason for fire regime shifts completely, we can only guess with some sort of credibility. However, the joint analyses of human population records and climate data can be instrumental in addressing that question. Throughout analysis of climate proxy (SEA), I discovered that fire years were occurring when conditions were more fire-prone, therefore for example drought exposure, that creates more fire-prone conditions shows a direct influence of the climate.

On the other hand, there is a question about the influence of people on fire activity. Data shows, decrease in fire activity take place while population is growing. I suspect that the low impact force may be that the soils of the area may not be favourable for agricultural production. Therefore, the use of fire for slash-and-burn agriculture was limited and did not result in detectable amount of human-related ignitions. In addition, when people arrived in Norrbotten, the economic value of wood was significantly increasing, so wood was seen as a resource, which was an incentive to extinguish fires. Fire suppression is often pointed out as a reasons for the decline in activity in the 1800s. However, a review of the methods and technologies of that time allows us to conclude that the firefighting activities were ineffective. Thus, the fire suppression activities did not have a significant impact on the change of the fire regime. This leads to the conclusion, that climate is significant factor shaping the dynamics of fire.

Fire activity in cold periods - Little Ice Age

Overview of fire occurrence suggests that colder periods in northern Scandinavia might be more prone to climatic extremes than warmer periods. The cool down of climate in the twelfth century is the starting point of a prolonged cold period that continued to the first decade of the twentieth century. This period is called 'Little Ice Age' (LIA) and is known from historical and proxy records (Grove, 1988). There is an ongoing discussion about the exact timeframe of the Little Ice Age (LIA), and there is no commonly defined period (Grove, 2001; Maasch et al., 2005; Matthews & Briffa, 2005). According to Jong et al. (2007), LIA has two main phases: the first phase took place around 1180-1650 and was predominantly wet. The first phase coincides with the second epoch (1300-1440) and an increase in fire activity in our reconstruction. Cooling of air temperature during this phase of LIA is associated with reducing solar activity and swell volcanic activity (Shnidell et al., 1999). The second phase of LIA around 1650-1900 is colder and drier. The review of the periods before and after the LIA shows the trend of fire activity in Norrbotten favouring the colder periods.

The frequency of fire-prone conditions increases due to unstable weather incidence and extreme weather phenomena that are more common under the cooler periods. Additional information supporting the theory is the most fire-prone year, 1640, occurred during the coldest period of LIA. The many dendrochronological reconstructions revealed that the largest LFY are often located in the coldest period in Scandinavia. This pattern is well-known in northern landscapes, where LFY took place in the coldest period (Barhoumi et al., 2019). Based on that, speculation about climate as the main driver seems to be correct.

Superposed epoch analysis

Fire regimes and vegetation patterns are controlled by topography and by regional climatic variability (Bessie & Johnson 1995, Schoennagel et al. 2004). Fires may also be dependent on extremely dry weather and fuel quantity (Veblen, 2000). Superposed epoch analysis on Norrbotten data revealed an association between drought and fire activity at the annual scale. The significant negative difference between PDSI value during LFYs and the respective mean for a cell indicated that dry conditions made the whole landscape more fire-prone. Due to that, LFY occurrence was likely climatically forced. In other words, LFY was a product of combined climate variability. This is an example of a top-down control, with the climate controlling the fire activity. Summing up, the climate is the main factor that forced fire activity in Norrbotten county.

Discussing the challenges of chosen method, the calculation protocol for PDSI has several drawbacks. The algorithm lacks information on essential drivers of evapotranspiration, vegetation curing and dead fuel moisture, including relative humidity, solar radiation and wind speed (Sheffield et al., 2012). All precipitation is assumed to be rain, meaning the algorithm is potentially ill-suited for areas where a significant proportion of the precipitation is snowfall. Despite these shortcomings and lack of a precise mechanism relating PDSI to fire occurrence, the PDSI is the most commonly used to assess drought in the fire literature (Baisan & Swetnam, 1990; Swetnam & Betancourt, 1998). For fire history studies, PDSI is often the best available metric because of finer-scale reconstructions than those available for precipitation and temperature.

Sensitivity of northern European boreal forest to climatic variability

Historical observations, climate modelling, and dendrochronological analyses provided compelling evidence for climate-fire solid relationships in the boreal forest biome (Rolstad et al., 2017). Modelling suggests that future warming in northern Fennoscandia will reduce the risk of possible fire ignition and spread due to the rising summer rainfall (Flannigan et al., 1998). The sensitivity of the boreal-fire regime to climatic change is also evident in the dendro-record, which has revealed significant fire-frequency shifts in response to millennial-scale climatic variation. However, climate-fire relationships are complex, and predicting responses of boreal fire regimes to future climate change is not straightforward. This complexity stems from the multiple biological and physical controls of fire occurrence, whose relative importance may vary across a wide range of spatial and temporal scales. For example, weather conditions may override the importance of fuels as a regulator of fire occurrence. However, the direct impacts of climate on the fire regime may be dwarfed by the effects of vegetation composition, which can exert a crucial control through changing the abundance, structure, and flammability of fuels (Rupp et al. 2002).

The European climate is affected by atmospheric and ocean circulation of the North Atlantic domain (Trouet, 2012). Northern boreal forests may correspond more sensitive to climate variability due to their proximity to arctic regions with their dry air and dynamic weather systems. Regional fire regimes stay under control of summers temperatures and precipitation, defining the significant role of climate as a factor.

The dominance of coniferous species could also facilitate forest exposure to fires and their susceptibility to fires. However, warming trends may change the forest composition favouring broadleaves or specific for study area Norway spruce and make them less fire-prone. Furthermore, global climate models (GCM) point out that climate changes at higher latitudes (Meehl et al., 2007) will become more intense, making vegetation future uncertain (Hu et al., 2006). Projections of the IPCC 2021 report indicate changes in precipitation and temperature that would affect summer aridity levels. Those drivers are expected to define future trends in LFY return intervals and regional fire cycles.

Today's fire activity

Extended discussion on historical drivers on fire activity raises a question, what is the cause of today's fire regime? Addressing this question is challenging due to the generally long fire intervals. In terms of future forecasts, the higher sensitivity of northern forests to climate impact is associated with higher forest cover in the north, less forest fragmentation and greater availability of forest fuels compared to forests in the south of Scandinavia. This may strengthen the climate-forcing regimes in the northern region, representing a general tendency for ecosystems to become increasingly vulnerable to climate change with increasing latitude (Serreze & Barry 2011).

6. Conclusions

- A millennium long fire chronology revealed a significant increase in fire activity during the Little Ice Age. The largest LFY (1640) happened during that period.
- Large fire years in the chronology were significantly drier, suggesting a climate forcing upon fires during these years.

7. References

Ahti, T. ., Hämet-Ahti, L., & Jalas, J. (1968). Vegetation zones and their sections in north-western Europe. Annales Botanici Fennici, 5, 169–211.

Agee, J. K. (1998). The landscape ecology of western forest fire regimes. Northwest Science, 72, 24.

Angelstam, P., & Kuuluvainen, T. (2004). Boreal forest disturbance regimes, successional dynamics and landscape structures: a European perspective. Ecological Bulletins, 51,117-136.

Baisan, C. H., & Swetnam, T. W. (1990). Fire history on a desert mountain range: Rincon Mountain Wilderness, Arizona, USA. Canadian Journal of Forest Research, 20(10), 1559-1569.

Balch, J. K., Bradley, B. A., Abatzoglou, J. T., Nagy, R. C., Fusco, E. J., & Mahood, A. L. (2017). Human-started wildfires expand the fire niche across the United States. Proceedings of the National Academy of Sciences, 114(11), 2946-2951.

Barhoumi, C., Peyron, O., Joannin, S., Subetto, D., Kryshen, A., Drobyshev, I., ... & Ali, A. A. (2019). Gradually increasing forest fire activity during the Holocene in the northern Ural region (Komi Republic, Russia). The Holocene, 29(12), 1906-1920.

Bergeron, Y., Flannigan, M., Gauthier, S., Leduc, A., & Lefort, P. (2004). Past, current and future fire frequency in the Canadian boreal forest: implications for sustainable forest management. AMBIO: A Journal of the Human Environment, 33(6), 356-360.

Bessie, W. C., & Johnson, E. A. (1995). The relative importance of fuels and weather on fire behaviour in subalpine forests. Ecology, 76(3), 747-762.

Blanken, P. D., Black, T. A., Yang, P. C., Neumann, H. H., Nesic, Z., Staebler, R., ... & Lee, X. (1997). Energy balance and canopy conductance of a boreal aspen forest: partitioning overstory and understory components. Journal of Geophysical Research: Atmospheres, 102(D24), 28915-28927.

Bowman, D. M. J. S., Balch, J., Artaxo, P., Bond, W. J., Cochrane, M. A., Antonio, C. M. D., Defries, R., Johnston, F. H., Keeley, J. E., Krawchuk, M. A., Kull, C. A., Mack, M., Moritz, M. A., Pyne, S., Roos, C. I., Scott, A. C., Sodhi, N. S., & Swetnam, T. W. (2011). The human dimension of fire regimes on Earth. 2223–2236..

Cook, E. R. (2006). Dendrochronology and Dendroclimatology. Encyclopaedia of Environmetrics, 2.

Cook, E. R., Seager, R., Kushnir, Y., Briffa, K. R., Büntgen, U., Frank, D., & Zang, C. (2015). Old World megadroughts and pluvials during the Common Era. Science Advances, 1(10), e1500561

De Jong, R. (2007). Stormy records from peat bogs in south-west Sweden - implications for regional climatic variability and and vegetation changes during the past 6500 years, LUNDQUA thesis 58.
Drobyshev, I, Bergeron, Y., Linderholm, H. W., Granström, A., & Niklasson, M. (2015). A 700-year record of large fire years in northern Scandinavia shows large variability and increased frequency during the 1800s. Journal of Quaternary Science, 30(3), 211-221.
Drobyshev, I, Bergeron, Y., Vernal, A. D., Moberg, A., Ali, A. A., & Niklasson, M. (2016). Atlantic SSTs control regime shifts in forest fire activity of Northern Scandinavia. Scientific Report 6: 22532.
Drobyshev, I, Granström, A., Linderholm, H. W., Hellberg, E., Bergeron, Y., & Niklasson, M. (2014). Multi-century reconstruction of fire activity in northern European boreal forest suggests differences in regional fire regimes and their sensitivity to climate. Journal of Ecology, 102(3) 738-748.
Drobyshev, I, Niklasson, M., & Linderholm, H. W. (2012). Forest fire activity in Sweden: Climatic controls and geographical patterns in 20th century. Agricultural and Forest Meteorology, 154–155, 174-186.
Drobyshev, I., Niklasson, M., & Angelstam, P. (2004). Contrasting tree-ring data with fire record in a pine-dominated landscape in the Komi Republic (Eastern European Russia): recovering a common climate signal. Silva Fennica, 38(1), 43-53.
de Groot, W. J., Flannigan, M. D., & Cantin, A. S. (2013). Climate change impacts on future boreal fire regimes. Forest Ecology and Management, 294, 35-44.
Elkie, P. C., & Rempel, R. S. (2001). Detecting scales of pattern in boreal forest landscapes. Forest Ecology and Management, 147(2-3), 253-261.
Fernandes, P. M., Vega, J. A., Jimenez, E., & Rigolot, E. (2008). Fire resistance of European pines. Forest Ecology and Management, 256(3), 246-255.
Flannigan, M. D., Bergeron, Y., Engelmark, O., & Wotton, B. M. (1998). Future wildfire in circumboreal forests in relation to global warming. Journal of Vegetation Science, 9(4), 469-476.
Flannigan, M., Cantin, A. S., De Groot, W. J., Wotton, M., Newbery, A., & Gowman, L. M. (2013). Global wildland fire season severity in the 21st century. Forest Ecology and Management, 294, 54-61.
Flohn, H. (1967). Bemerkungen zur Asymmetrie der atmosphärischen Zirkulation. Ann. Meteor. NF, 3, 76-80.(in German)
Granström, A. (1993). Spatial and temporal variation in lightning ignitions in Sweden. Journal of Vegetation Science, 4(6), 737-744.
Granström, A., & Niklasson, M. (2008). Potentials and limitations for human control over historic fire regimes in the boreal forest. Philosophical Transactions of the Royal Society B-Biological Sciences, 363(1501), 2353–2358.
Grissino-Mayer, H. D. (2001). Evaluating crossdating accuracy: a manual and tutorial for the computer program COFECHA.
Groven, R., & Niklasson, M. (2005). Anthropogenic impact on past and present fire regimes in a boreal forest landscape of southeastern Norway. Canadian Journal of Forest Research, 35(11), 2719-2726.
Grove, J. M. (2001). The initiation of the" Little Ice Age" in regions round the North Atlantic. Climatic Change, 48(1), 53-82.

Grove, J. M. (1988). 1988: The Little Ice Age. London: Methuen.
Hansen, B. C. S., Rodbell, D. T., Seltzer, G. O., León, B., Young, K. R., & Abbott, M. (2003). Late-glacial and Holocene vegetational history from two sites in the western Cordillera of southwestern Ecuador. Palaeogeography, Palaeoclimatology, Palaeoecology, 194(1-3), 79-108
Haurwitz, M. W., & Brier, G. W. (1981). A critique of the superposed epoch analysis method: its application to solar–weather relations. Monthly Weather Review, 109(10), 2074-2079.
Hallsby, G. (1995). Hyggesbränningens inflytande på virkesproduktionen i boreala skogar. Institutionen för skogsskötsel, Sveriges lantbruksuniversitet. Umeå. Arbetsrapporter No. 109: 1-22 (In Swedish)
Hörnsten, L., Nohlgren, E. & Aldentun, Y. (1995). Brand och bränning - en litteraturstudie. Skogforsk. Redogörelse No. 9, 1995: 1-36 (In Swedish)
Holmes, R. L. (1983). Computer-assisted quality control in tree-ring dating and measurement. Tree-Ring Society. Tree-Ring Bulletin, 43, 69-78.
Holmes, R. L. (1999). Dendrochronology program library (DPL) user's manual. LTRR University of Arizona, Tuscon.
Heinselman, M. L., & Wright, H. E. (1973). The ecological role of fire in natural conifer forests of western and northern North America. Quaternary Research, 3(3), 317-318.
Hellberg, E., Niklasson, M., & Granström, A. (2004). Influence of landscape structure on patterns of forest fires in boreal forest landscapes in Sweden. Canadian Journal of Forest Research-Revue Canadienne de Recherche Forestiere, 34(2), 332–338.
Hu, F. S., Brubaker, L. B., Gavin, D. G., Higuera, P. E., Lynch, J. A., Rupp, T. S., & Tinner, W. (2006). How climate and vegetation influence the fire regime of the Alaskan boreal biome: the Holocene perspective. Mitigation and Adaptation Strategies for Global Change, 11(4), 829-846.
Humlum, O., Solheim, J. E., & Stordahl, K. (2011). Identifying natural contributions to late Holocene climate change. Global and Planetary Change, 79(1-2), 145-156.
https://media.istockphoto.com/vectors/grey-map-of-regions-of-sweden-vector-id1156505290?k=20&m=1156505290&s=612x612&w=0&h=TwM9_e7sjMgxs7LyebOVY6VvnfOsQx7AaNwVeb4apIg= (source for map)
https://mapchart.net/europe.html (source for map)
IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.
IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T.

Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press. In Press.
Kirby, K. & Watkins, C. (2015). Europe's Changing Woods and Forests. From Wildwood to Managed Landscapes.
Kelly, P. M., & Sear, C. B. (1984). Climatic impact of explosive volcanic eruptions. Nature, 311(5988), 740-743.
Keeley, J. E., & Zedler, P. H. (1998). Characterization and global distribution of vernal pools. In Ecology, conservation, and management of vernal pool ecosystems, proceedings from 1996 conference (Vol. 1, p. 14).
Keeley, J. E. (2012). Ecology and evolution of pine life histories. Annals of Forest Science, 69(4), 445-453.
Kouki, J., Löfman, S., Martikainen, P., Rouvinen, S., & Uotila, A. (2001). Forest fragmentation in Fennoscandia: linking habitat requirements of wood-associated threatened species to landscape and habitat changes. Scandinavian Journal of Forest Research, 16(S3), 27-37.
Kuuluvainen, T. (2009). Forest management and biodiversity conservation based on natural ecosystem dynamics in northern Europe: the complexity challenge. Ambio, 38. 309-315.
Larson J., (2009). Fäbodväsendet 1550-1920. Jamtil forlag.
Lehtonen, H., & Huttunen, P. (1997). History of forest fires in eastern Finland from the fifteenth century AD-the possible effects of slash-and-burn cultivation. The Holocene, 7(2), 223-228.
Lehtonen, H. (1998). Fire history recorded on pine trunks and stumps: influence of land use and fires on forest structure in North Karelia. Scandinavian Journal of Forest Research, 13(1-4), 462-468.
Lough, J. M., & Fritts, H. C. (1987). An assessment of the possible effects of volcanic eruptions on North American climate using tree-ring data, 1602 to 1900 AD. Climatic Change, 10(3), 219-239.
Maasch, K. A., Mayewski, P. A., Rohling, E. J., Stager, J. C., Karlen, W., Meeker, L. D., & Meyerson, E. A. (2005). A 2000-year context for modern climate change. Geografiska Annaler: Series A, Physical Geography, 87(1), 7-15.
Matthews, J. A., & Briffa, K. R. (2005). The 'Little Ice Age': re-evaluation of an evolving concept. Geografiska Annaler: Series A, Physical Geography, 87(1), 17-36.
Meehl, G. A., Covey, C., Delworth, T., Latif, M., McAvaney, B., Mitchell, J. F., ... & Taylor, K. E. (2007). The WCRP CMIP3 multimodel dataset: A new era in climate change research. Bulletin of the American Meteorological Society, 88(9), 1383-1394.
MSB. (2011). Database on fires in Sweden. http://www.msb.se
Niklasson, M., & Granström, A. (2000). Numbers and sizes of fires: long-term spatially explicit fire history in a Swedish boreal landscape. Ecology, 81(6), 1484-1499.
Nurtaev, B. S., & Nurtaev, L. (2016). Long Term Trends in Climate Variability of Caucasus Region. Journal of the Georgian Geophysical Society, 19.
Orwig, D. A., & Abrams, M. D. (1997). Variation in radial growth responses to drought among species, site, and canopy strata. Trees, 11(8), 474-484.
Palmer, W. C. (1965). Meteorological drought (Vol. 30). US Department of Commerce, Weather Bureau.

Pausas, J. G., & Keeley, J. E. (2009). A burning story: the role of fire in the history of life. BioScience, 59(7), 593-601.
Pinto, G. A. S. J., Niklasson, M., Ryzhkova, N., & Drobyshev, I. (2020). A 500-year history of forest fires in Sala area, central Sweden, shows the earliest known onset of fire suppression in Scandinavia. Regional Environmental Change, 20(4), 130.
Raab, B., & Vedin, H. (1995). Klimat, sjöar och vattendrag. Sveriges Nationalatlas. SNA Förlag.
Rolstad, J., Blanck, Y. L., & Storaunet, K. O. (2017). Fire history in a western Fennoscandian boreal forest as influenced by human land use and climate. Ecological Monographs, 87(2), 219–245.
Rupp, T. S., Starfield, A. M., Chapin, F. S., & Duffy, P. (2002). Modeling the impact of black spruce on the fire regime of Alaskan boreal forest. Climatic Change, 55(1), 213-233.
Ryzhkova, N., Pinto, G., Kryshen', A., Bergeron, Y., Ols, C., & Drobyshev, I. (2020). Multi-century reconstruction suggests complex interactions of climate and human controls of forest fire activity in a Karelian boreal landscape, North-West Russia. Forest Ecology and Management, 459, 117770.
Schoennagel, T., Veblen, T. T., & Romme, W. H. (2004). The interaction of fire, fuels, and climate across Rocky Mountain forests. BioScience, 54(7), 661-676.
Sheffield, J., Wood, E. F., & Roderick, M. L. (2012). Little change in global drought over the past 60 years. Nature, 491(7424), 435-438.
Shindell, D., Rind, D., Balachandran, N., Lean, J., & Lonergan, P. (1999). Solar cycle variability, ozone, and climate. Science, 284(5412), 305-308.
Söderström, V. 1981. Ekonomisk skogsproduktion. Del 2. Föryngring. Borås: Centraltryckeriet AB, pp. 340-3 (In Swedish)
Storaunet, K. O., Rolstad, J., Toeneiet, M., & Blanck, Y. L. (2013). Strong anthropogenic signals in historic forest fire regime: a detailed spatiotemporal case study from south-central Norway. Canadian Journal of Forest Research, 43(9), 836-845.
Swetnam, T. W., Farella, J., Roos, C. I., Liebmann, M. J., Falk, D. A., & Allen, C. D. (2016). Multiscale perspectives of fire, climate and humans in western North America and the Jemez Mountains, USA. Philosophical Transactions of the Royal Society B: Biological Sciences, 371(1696), 20150168.
Swetnam, T. W., & Betancourt, J. L. (1998). Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate, 11(12), 3128-3147.
SOS, Swedish Official Statistics (2020) https://www.scb.se/ http://pxweb.skogsstyrelsen.se/pxweb/en/Skogsstyrelsens%20statistikdatabas/search/?searchquery=mires
Syphard, A. D., & Keeley, J. E. (2019). Factors associated with structure loss in the 2013–2018 California wildfires. Fire, 2(3), 49.
Trouet, V., Scourse, J. D., & Raible, C. C. (2012). North Atlantic storminess and Atlantic Meridional Overturning Circulation during the last Millennium: Reconciling contradictory proxy records of NAO variability. Global and Planetary Change, 84, 48-55.
Wallenius, T. H., Kuuluvainen, T., & Vanha-Majamaa, I. (2004). Fire history in

relation to site type and vegetation in Vienansalo wilderness in eastern Fennoscandia, Russia. Canadian Journal of Forest Research, 34(7), 1400-1409.
Wallenius, T. H., Lilja, S., & Kuuluvainen, T. (2007). Fire history and tree species composition in managed Picea abies stands in southern Finland: Implications for restoration. Forest Ecology and Management, 250(1-2), 89-95.
Wallenius, T. H., Kauhanen, H., Herva, H., & Pennanen, J. (2010). Long fire cycle in northern boreal Pinus forests in Finnish Lapland. Canadian Journal of Forest Research, 40(10), 2027-2035.
Veblen, T. T. (2000). Disturbance patterns in southern Rocky Mountain forests. Forest fragmentation in the southern Rocky Mountains. University Press of Colorado, Boulder, Colorado, USA, 31-54.
Zackrisson, O. (1977). Influence of forest fires on the North Swedish boreal forest. Oikos, 29, 22-32.
Zin, E. (2016). Fire history and tree population dynamics in Białowieża Forest, Poland and Belarus. PhD thesis, SLU.

Appendix 1 – supplementary table

Tab. S1. Site properties

No.	Site name	Amount of samples per site	Latitude	Longitude
1	REIMA1	10	66,1187	19,3477
2	REIMA2	18	66,1336	19,3079
3	PALL2	26	66,9242	18,6352
4	SKOR1	50	66,3421	19,6633
5	MABA1	10	66,2144	18,4448
6	MABA2	8	66,2462	18,4304
7	DIPP1	24	65,9901	18,6768
8	IKS1	23	66,3089	17,4372
9	KVIQ1	12	66,8880	17,9666
10	BAKT2	5	66,4521	19,8963
11	LILL	22	66,3050	18,4811
12	120	15	66,6735	19,2461
13	121	42	66,6633	19,2619
14	122	41	66,6584	19,2714
15	123	32	66,6490	19,2709
16	124	11	66,6299	19,2682
17	125	25	66,6279	19,2182
18	126	21	66,6380	19,2294
19	127	9	66,6125	19,2871
20	128	11	66,6605	19,1404
21	129	9	66,6571	19,1276
22	130	9	66,6398	19,1270
23	131	20	66,6264	18,8328
24	132	11	66,6664	18,7174
25	133	12	66,6297	18,7985
26	134	17	66,6278	18,8510
27	135	20	66,6080	18,9846
28	136	31	66,9128	18,6696
29	137	12	66,9684	18,6015

Site size: 3-5 ha
Sampling data: August 2020
Protection type: most of the sites with no formal protection, portion of sites are natural reserve
Forest type: pine dominated dry forest
Source: https://www.lansstyrelsen.se/norrbotten/other-languages/english/nature-and-rural-areas/protected-nature.html