Spatial analysis of forest fires in Norra Kvill National park

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Master Thesis no. 237
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Abstract

The spatial aspect of the fire history of Norra Kvills national park in south eastern, hemi boreal Sweden was reconstructed by cross dating of trees, stumps and snags of Scots pine (*Pinus sylvestris*).

Between 1401 and 1798 forty eight different fires were recorded and 35 of these could be spatially reconstructed. The burned areas range from 20 ha to 422 ha with an average of about 130 ha.

Keywords: Forest-fire, fire-history, Norra Kvill NP, Scots pine *Pinus sylvestris*

Contents

Introduction

Forest fires is an important ecological disturbance in temperate and boreal forests (Wikars, 1992; Gromtsev, 2002). In northern Sweden fire history and past fire regimes have been well studied and documented (Kohh, 1975; Zackrisson, 1977; Engelmark, 1984; Linder, 1998; Niklasson and Granström, 2000). The most commonly reconstructed and described variables of fire regimes are fire years and fire intervals. Such data often results in analyses of fire frequencies in relation to location and climate. Fire years and fire activity is also commonly analysed in relation to climate (Drobyshev et al, 2012, Calvin et al, 2010). Less analysed is the spatial aspect of fires in the past. In Scandinavia, Niklasson & Granström studied spatial and temporal fire regimes in northern Sweden (Niklasson and Granström, 2000) and recently in Norway another landscape scale fire history has focused on the spatial reconstruction of fires (Storaunet et al, 2013). For the hemi boreal situation no spatial reconstructions have been done. This is much because of a generic lack of wood material due to a longer history with forestry practices (Niklasson et al. 2001). However in N. Kvill and its surrounding areas a unique abundance of material is still to be found due to the parks early establishment as a protected area. The richness of boulders and generally varying topography has left many "pockets" unaffected by modern forestry.

Aim

The aim of this study was to spatially reconstruct historical fires in the landscape of Norra Kvill national park to get a better insight to the spatial aspect of historical fire regime in the eastern part of southern Sweden.

Study area

Norra Kvills national park is located in the hemi boreal zone (according to Sjörs, 1965) of the south Swedish highland at 57 30´N, 15 36´E and between 120m and 230m above sea level.

It was established in 1927 and originally covered only 27 ha. In 1994 it was expanded to cover 114 ha. It is a hilly, boulder rich area comprised of old growth forest dominated by Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*) and silver birch (*Betula pendula*).

The original area has not been affected by forestry for the last 150 years (Länsstyrelserna 2011) and an old description of the area states that "no logging has been conducted during living memory" (Sterner, 1929). The Park contains some, for southern Sweden, unusually old pines. One living pine has been cored and shown to be over 500 yrs. and shows scaring from at least 12 different fires, possibly a record for south Sweden (Niklasson and Drakenberg, 2001).

The later added areas incorporate some younger stands of pine, 60-90 years, regenerated after loggings in the early 20:th century and after a small fire in 1917. Trees with fire scars and old stumps and snags, which in most other areas of southern Sweden have been destroyed by modern forestry methods, are common within the park and can still be found in the adjoining managed forests surrounding the park. There are a number of small lakes and wetlands both within the park and in the surrounding areas. Such wetlands may or may not have acted as natural fire limits. Evidence of past fires on wetlands is occasionally seen on pines growing among Marsh Labrador tea (*Ledum palustre*) in the wettest parts of the park. The fire history within the park borders has been studied earlier (Niklasson and Drakenberg, 2001) and forty different fires between 1401 and 1770 have been recorded. Two fires were recorded in 1819 and 1923 but these were probably smaller than 1ha each. Niklasson and Drakenberg conclude that "Spatial patterns were possible to detect for some fires, but very few fires were totally contained within the park. The larger fires may therefore have exceeded 100 ha". The surrounding landscape is of quite varied topography. Wetlands cover approx. 10 % of the area covered by this study. Two large-scale depressions may have acted as fire breaks in the past, these are just to the E and W of the studied area.

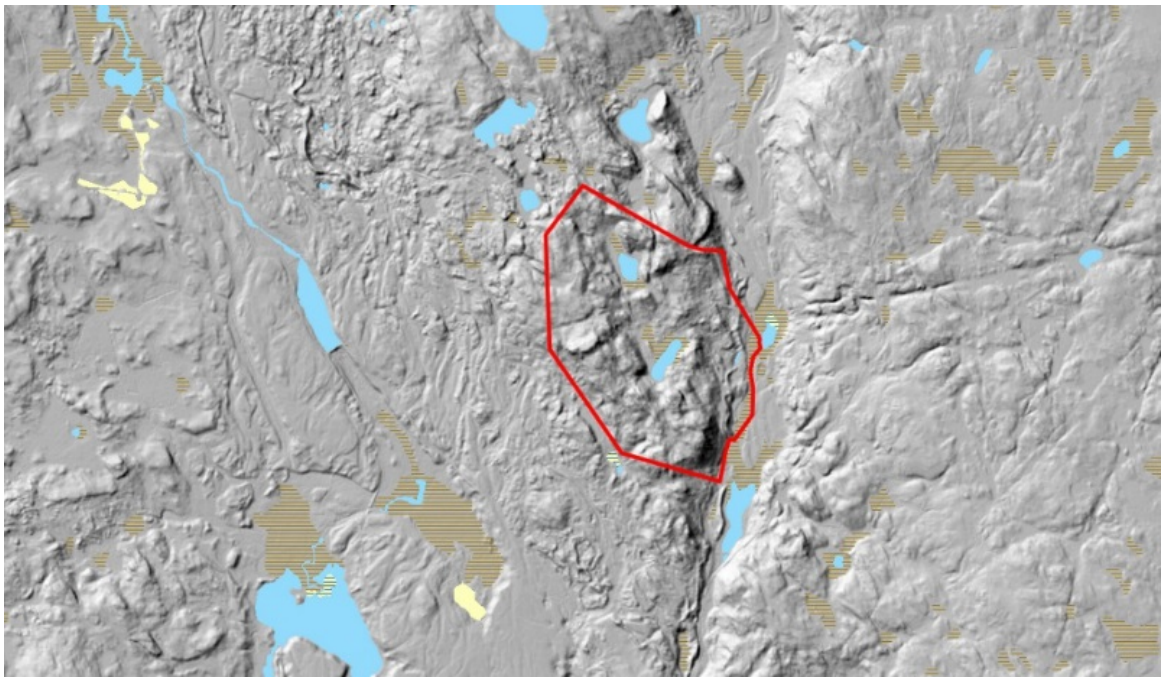


Figure 1.

This is a laser scanned image of the study area which shows topography as a three dimensional representation. Lakes are shown as a solid colour and wetlands are represented as horizontally striped areas. The polygon marks the border of the 114 ha national park.

The two large-scale depressions that may have acted as fire breaks, just to the E and W of the studied area, can be visualized by low lying terrain with almost continuous stretches of lakes and wetlands.

Method

Wood samples with obvious or suspected fire scars were collected from stumps, snags and fallen logs of Scots pine (*Pinus sylvestris*) by cutting cross sections or partial cross sections with chainsaw (Arno and Sneck 1977) during the autumn of 2014 at seven locations around the park. Sampling locations were first evenly distributed on the map around the park creating a study area of approximately 500 ha due to the limited time available for this study. In field the exact locations for sampling were subjectively selected according to accessibility and occurrence of possible samples. The chosen locations were between 400 and 1000m from the park border. From one of the locations no samples could be cross dated so they were not included in the study. The total area encompassed by the sample points was 407 hectares which also includes the national park area of 114 hectares. Where possible samples were also taken from living pines in order to determine the tree ring chronology up to the present day and also to determine the date of the last fire. The samples were sanded down with 400 grit sand paper and cross dated (Douglass 1941; Stokes and Smiley, 1968) against known pointer years from the Niklasson & Drakenberg study (2001) using a 20x stereo microscope. The location of dated fire scares was plotted on a map together with the location of samples from corresponding years without visible scaring in the same year. Locations where samples had been searched but not found were also shown on the map. Maps of individual fires were drawn in the following way, largely following the methodology in Niklasson & Granström (2000). Fire borders were drawn in between recording and non-recording points from the same year where no obvious topographical or hydrological changes occurred. Continuous line was drawn when borders were more certain and dashed line when borders were less certain or uncertain. When clear shifts in wetness or topography occurred, probable borders were drawn along such (wetlands, lakes or ridges) and where applicable, along burns less than 5 years of age (fire border due to fuel limitation). A rough and largely subjective classification of border certainty was based on the absence/presence of sampling points outside the drawn border. The certainty of the border estimation was classed into rough 25% classes as follows: 1 = 0-24 %, 2 = 25-49 %, 3 = 50-74 %, 4 = 75-100 %.

The minimum estimated burned areas and amount of certain border were then measured using GIS-software.

Results

In the six new sampling plots a total of 27 fires were recorded from a total of 16 samples that were successfully dated, table 1. Of these, 19 fires had been recorded in the Niklasson & Drakenberg (2001) study. A total of eight fires were new for this study, thus the total number of fires for the two studies combined is 48. It was possible to make estimates of the size of burned area for 35 of these fires.

The new sampling had fire years from 1471 to 1798, the previously undocumented eight fires were recorded in 1510, 1550, 1677, 1723, 1726, 1738, 1742, and 1798.

Seasonal data was recorded for a total of 40 fires. Out of the 48 recorded fires 18 had occurred during the dormant stages of the trees annual growth and 16 had occurred during the early stages of the trees annual growth.

The estimated minimum size of the burned area is rather evenly distributed with eight fires <50 ha, eight fires 50-100 ha, nine fires 100-150 ha, six fires 150-200 ha and six larger than 200 ha. Two fires stand out (1667 and 1652) with a minimum burned area of 422 ha and 387 ha (figure 2.).

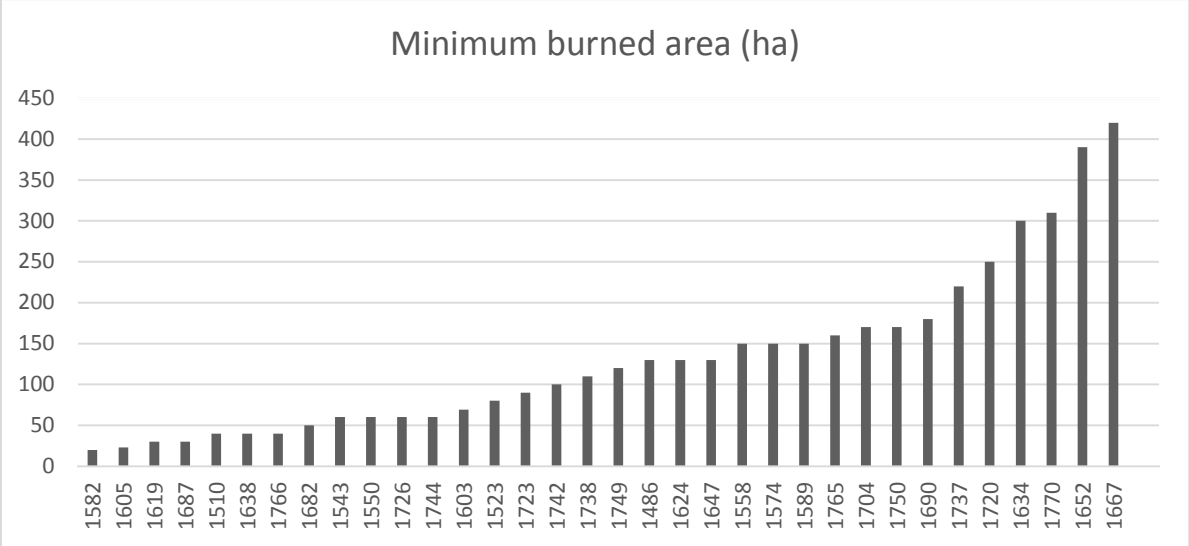


Figure 2. Fires sorted according to size.

There also seems to be no obvious trend in fire sizes over time (Figure 3.).

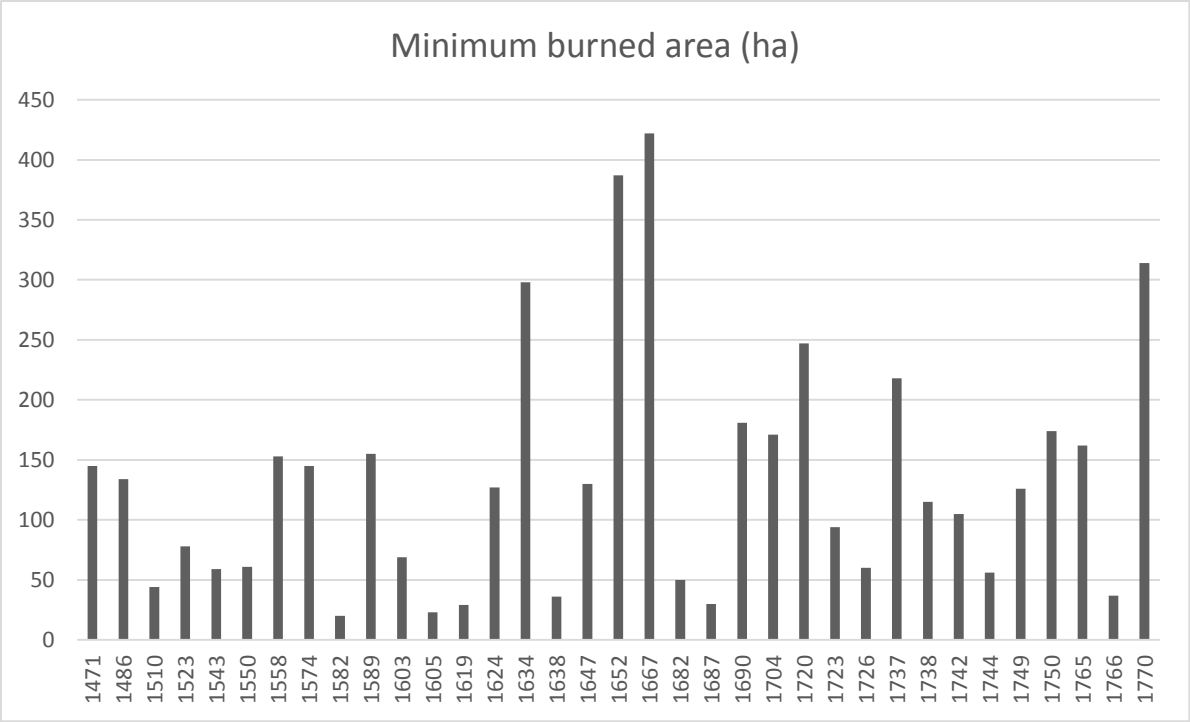


Figure 3. Fires in chronological order from oldest to youngest.

Table 1. contains data about fire year, amount of certain border, minimum area, year recorded and fire season.

"Fire year" shows the year the fire scares occurred according to cross dating.
"Amount of certain border" is a classification of how certain the drawn borders are and is given in percentage border of the whole burn with a certain border classification.
*This is displayed as **1**= 0-24%, **2**=25-49%, **3**=50-74% and **4**=75-100% estimate of total length.*
The "minimum area" is the measured area within the subjectively drawn border for a certain fire year.
"Year recorded" is when the samples that showed fire scaring for that year were collected. Samples collected in 2001 were done by Drakenberg and Niklasson and samples collected in 2014 were done by me. Some fires were recorded in samples collected in both years.
The "fire season" is determined by the stage in the development of the annual growth ring at which the fire scaring occurred.
*This is defined as **De** – dormant/early, **Eew** – early early wood, **Ew** - early wood, **Mew** – medium early wood, **Lew** – late early wood, **Lw** – late wood.*

Fire year	Amount of certain border*	Minimum area (ha)	Year recorded	Fire season
1798			2014	Ew
1770	2	314	2001 & 2014	De
1766	3	37	2001	De
1765	3	162	2001 & 2014	De
1750	3	174	2001 & 2014	De
1749	2	126	2001 & 2014	De
1744	3	56	2001	De
1742	2	105	2014	De
1738	3	115	2014	Eew
1737	3	218	2001 & 2014	De
1726	3	60	2014	
1723	3	94	2014	De
1720	3	247	2001 & 2014	De
1704	3	171	2001 & 2014	De
1690	2	181	2001 & 2014	De
1687	3	30	2001	Lw
1682	2	50	2001	De/ew
1677			2014	
1667	1	422	2001 & 2014	Ew
1652	1	387	2001 & 2014	Ew

1647	2	130	2001 & 2014	Ew
1638	2	36	2001	Ew
1635			2001	Ew
1634	1	298	2001 & 2014	Lw/mew/lew
1624	1	127	2001 & 2014	De/ew
1619	2	29	2001	De
1613			2001 & 2014	De
1605	3	23	2001	Ew
1603	1	69	2001	De/ew
1589	1	155	2001 & 2014	Ew
1582	3	20	2001	Lw
1574	1	145	2001 & 2014	Ew
1558	1	153	2001 & 2014	Ew
1550	1	61	2014	
1543	1	59	2001	Ew
1523	1	78	2001	Eew/ew
1510	1	44	2014	
1508			2001	Elw
1494			2001	
1491			2001	
1486	3	134	2001 & 2014	Ew
1471	1	135	2001 & 2024	Ew
1457			2001	De/eew
1442			2001	Lew
1429			2001	Mew
1421			2001	
1409			2001	Lew
1401			2001	
Avarage:		132,7		
Median:		126		

Maps

The maps show an overview of the studied area with topography and land types. The boundary of the national park is also shown. The symbols show the location for samples with data for the specific year noted below each map.

Legend;

Filled circle = Sample with fire scar for that year

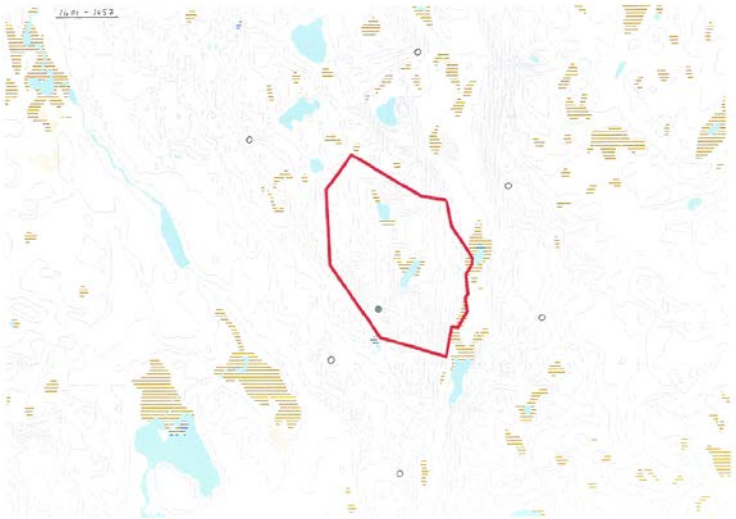
Crossed circle = Sample with no fire scar for that year

Empty circle = No sample found for that year

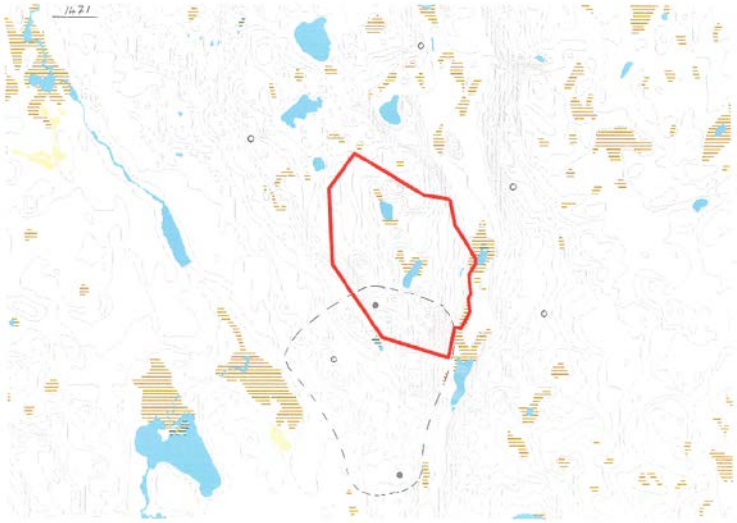
Polygon = National park border

Solid colour = Lakes

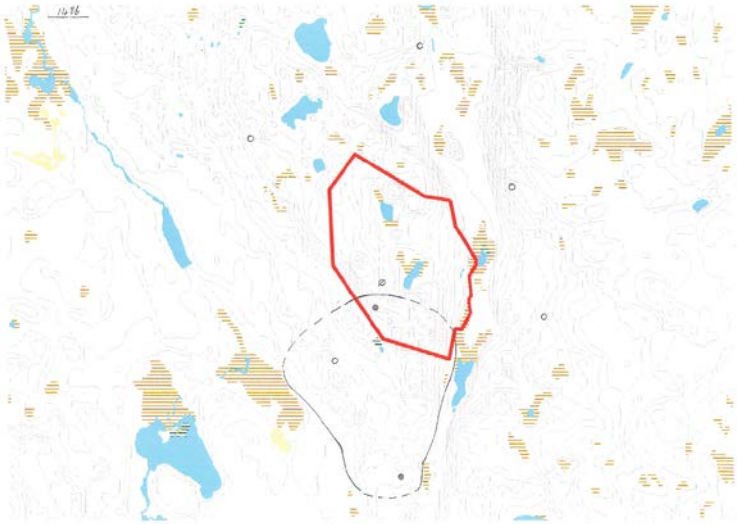
Horizontal stripes = Wetlands



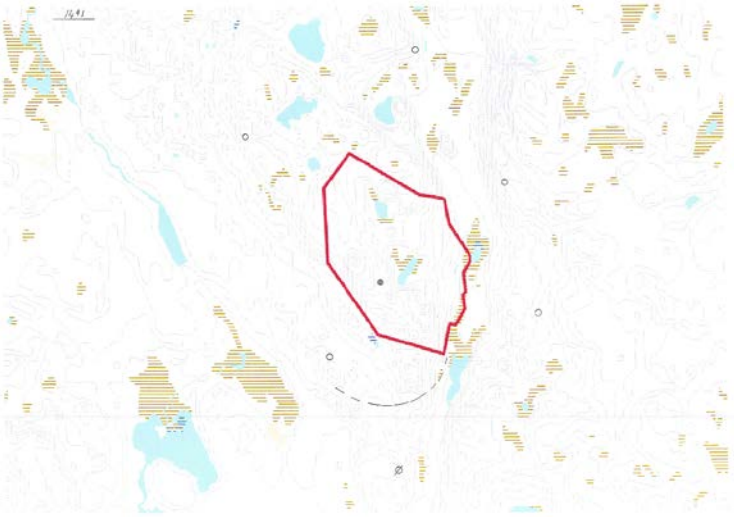
Year: 1401, 1409, 1421, 1429, 1442 and 1457.



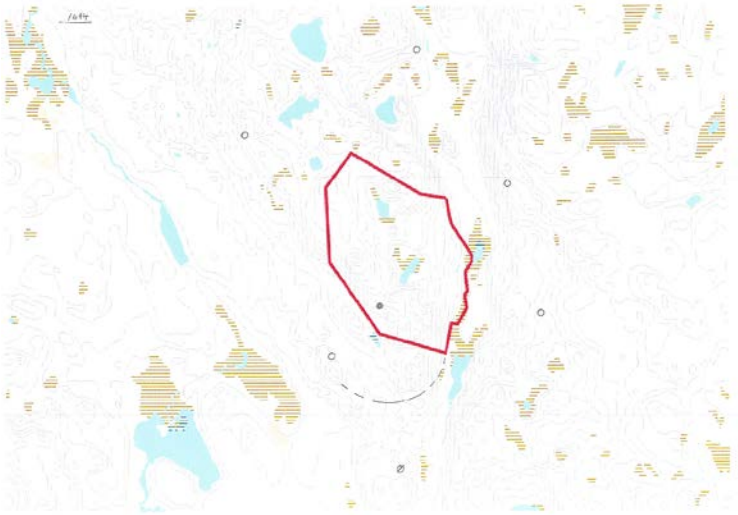
Year: 1471, minimum area: 135 ha.



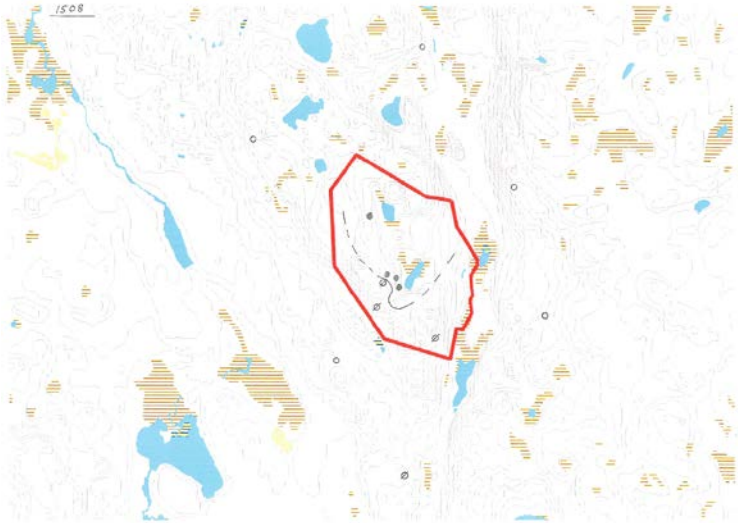
Year: 1486, minimum area: 134 ha.



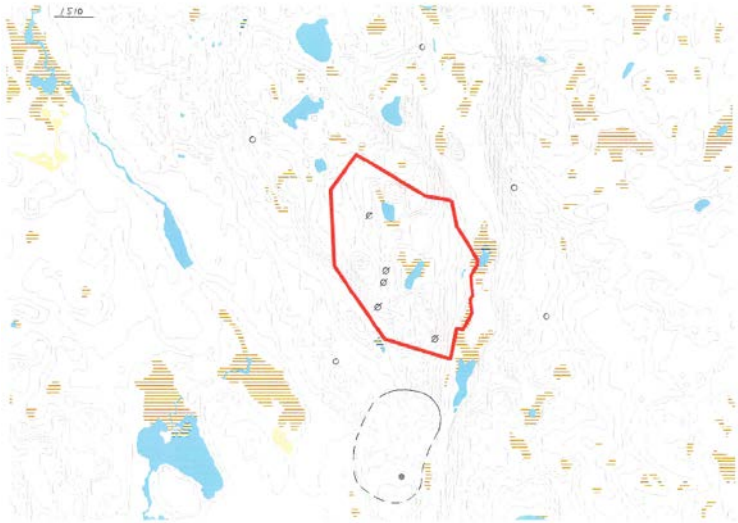
Year: 1491.



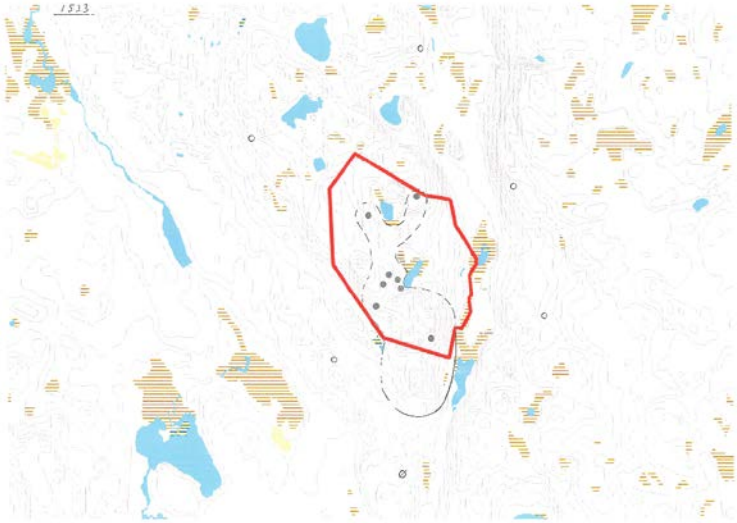
Year: 1494.



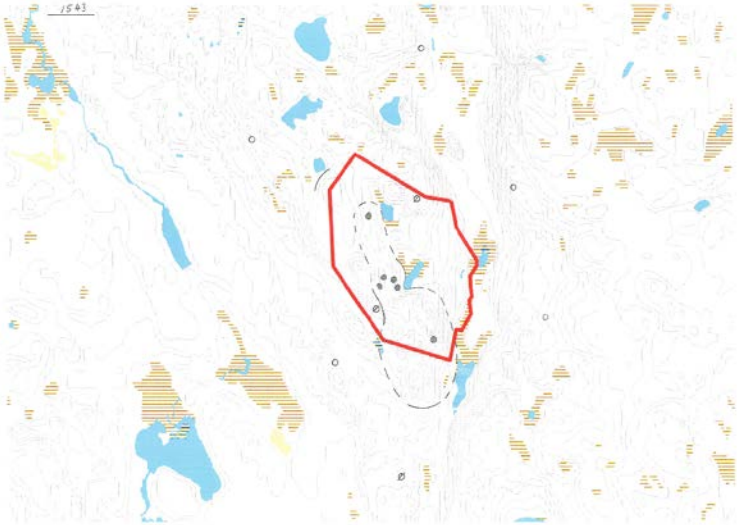
Year: 1508.



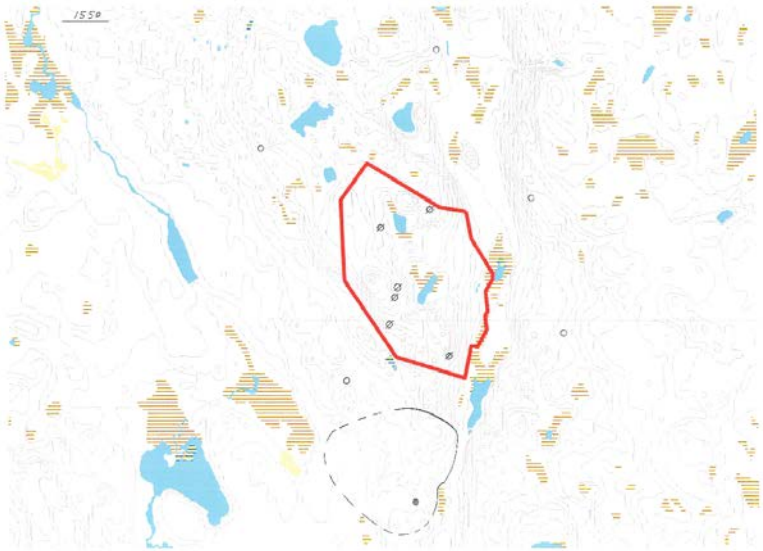
Year: 1510, minimum area: 44 ha.



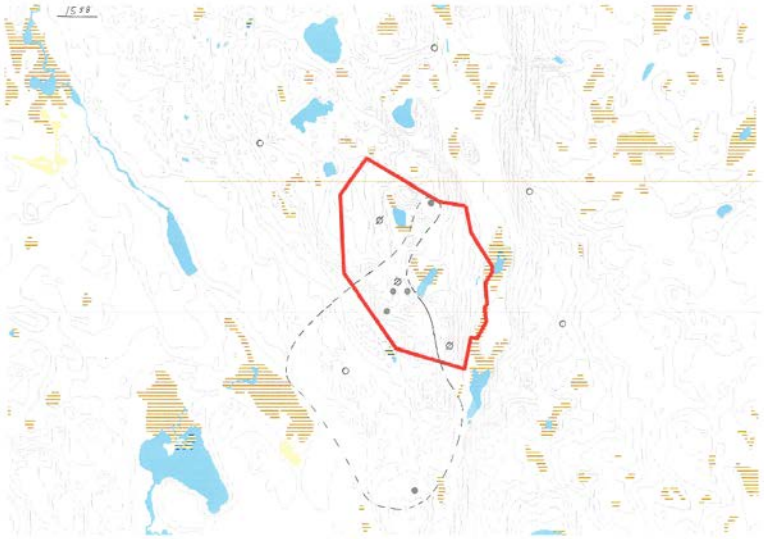
Year: 1523, minimum area: 78 ha.



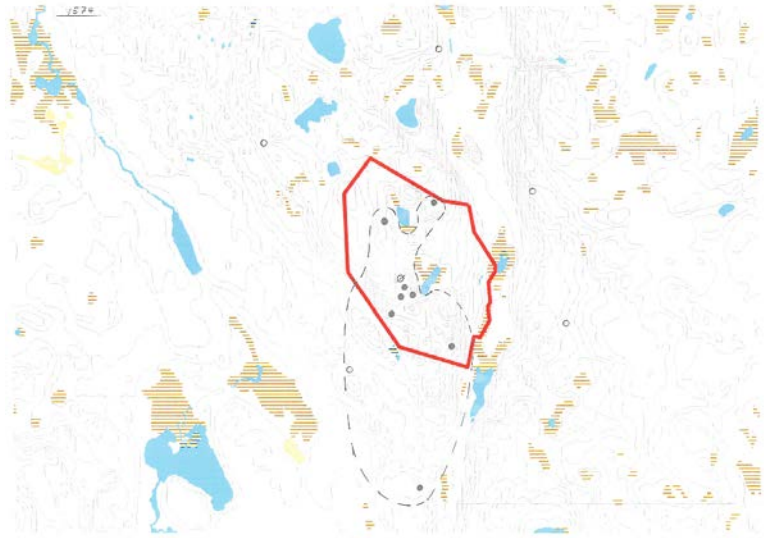
Year: 1543, minimum area: 59 ha.



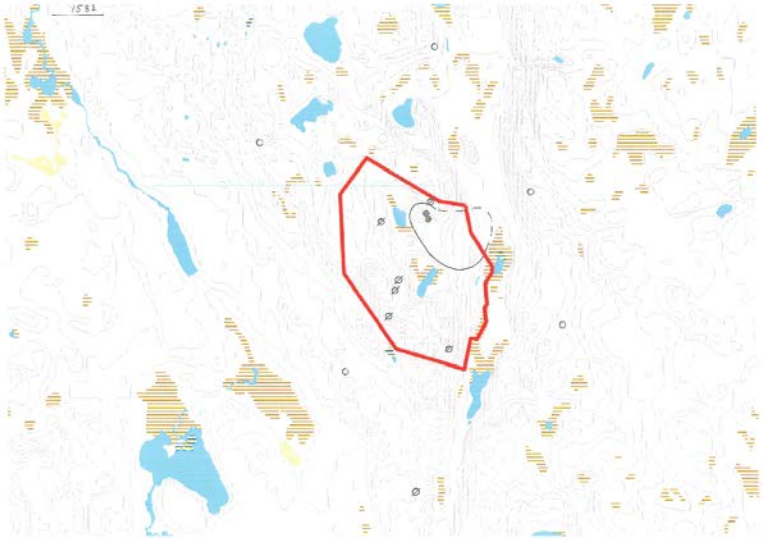
Year: 1550, minimum area: 61 ha.



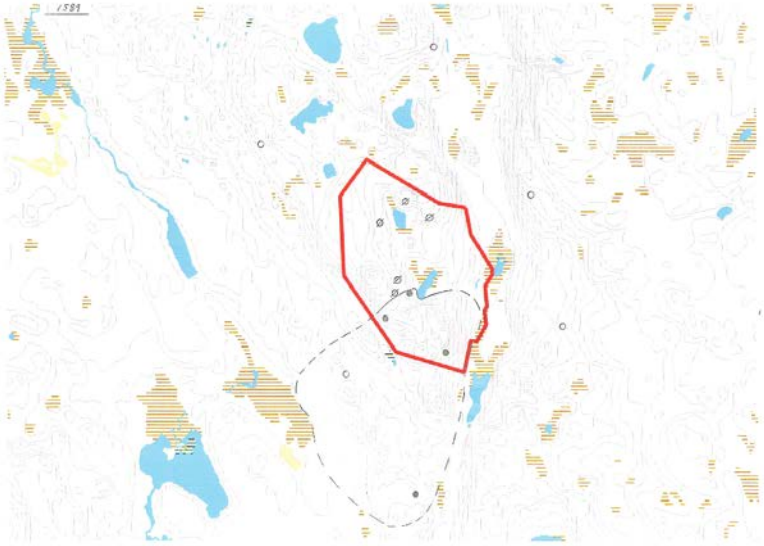
Year: 1558, minimum area: 153 ha.



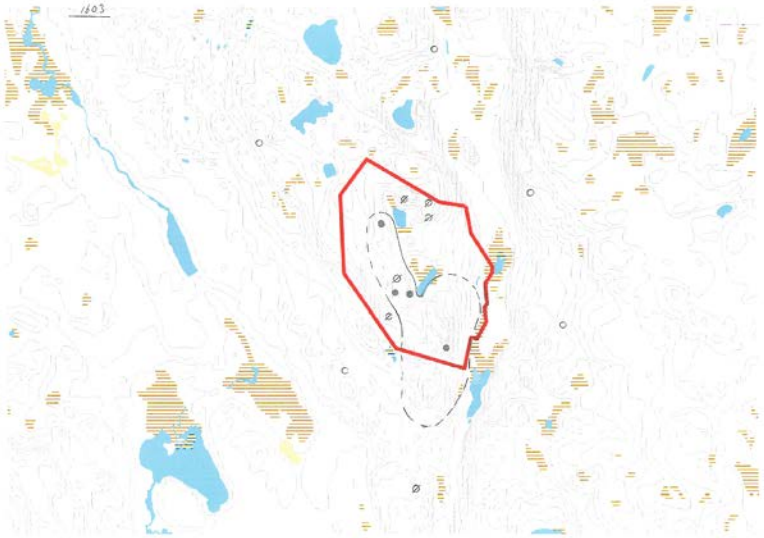
Year: 1574, minimum area: 145 ha.



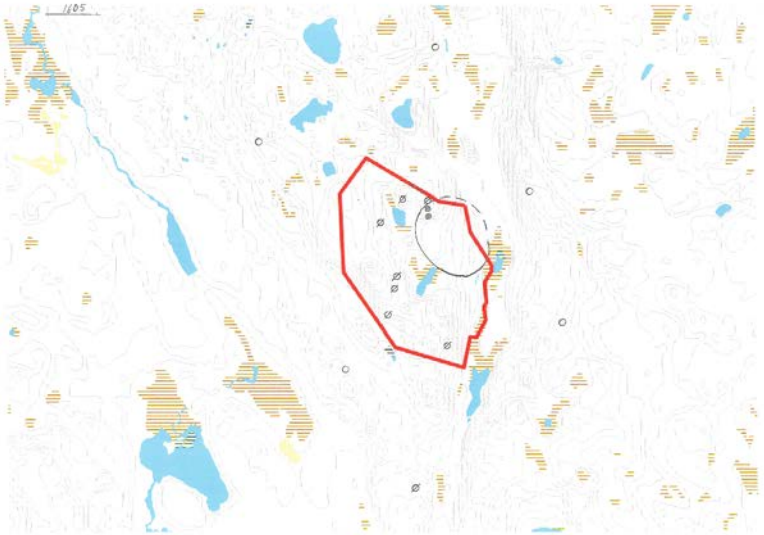
Year: 1582, minimum area: 20 ha.



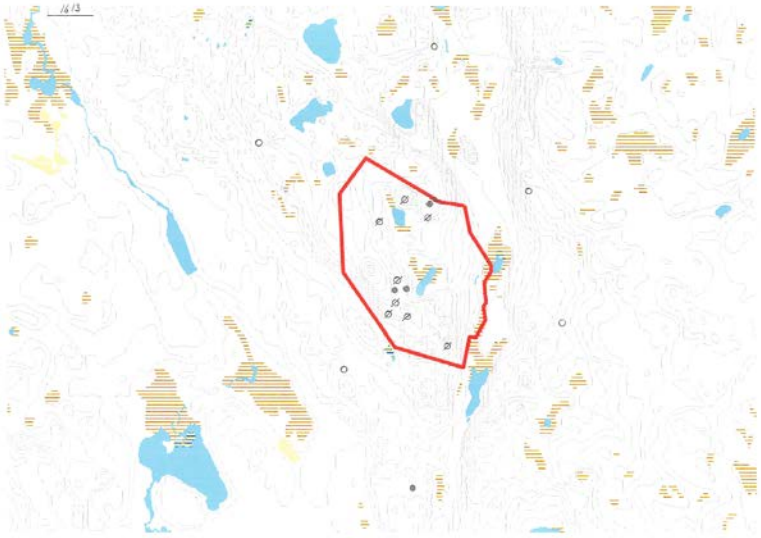
Year: 1589, minimum area: 155 ha.



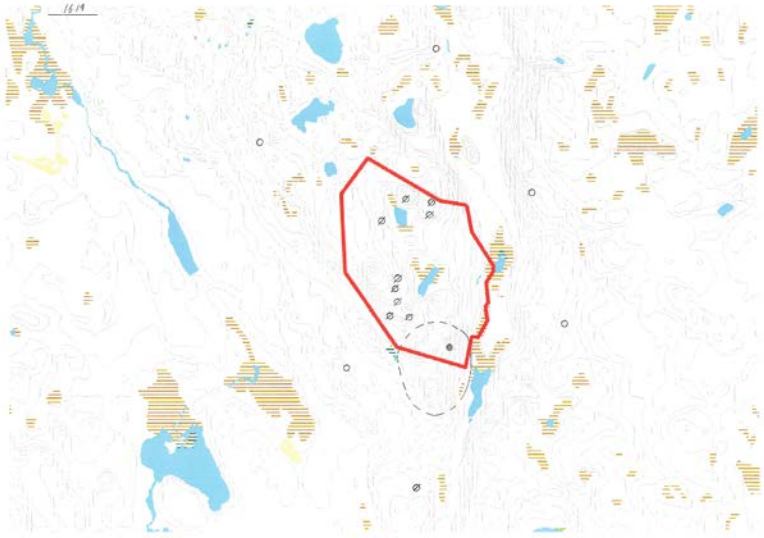
Year: 1603, minimum area: 69 ha.



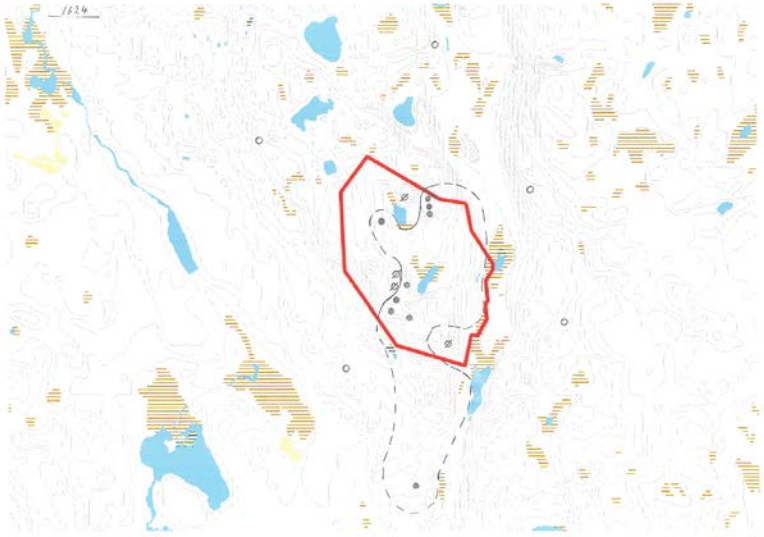
Year: 1605, minimum area: 23 ha.



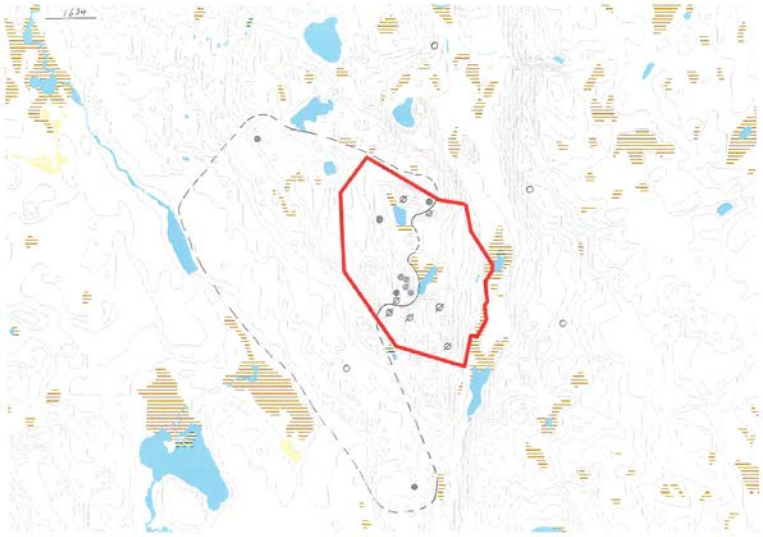
Year: 1613.



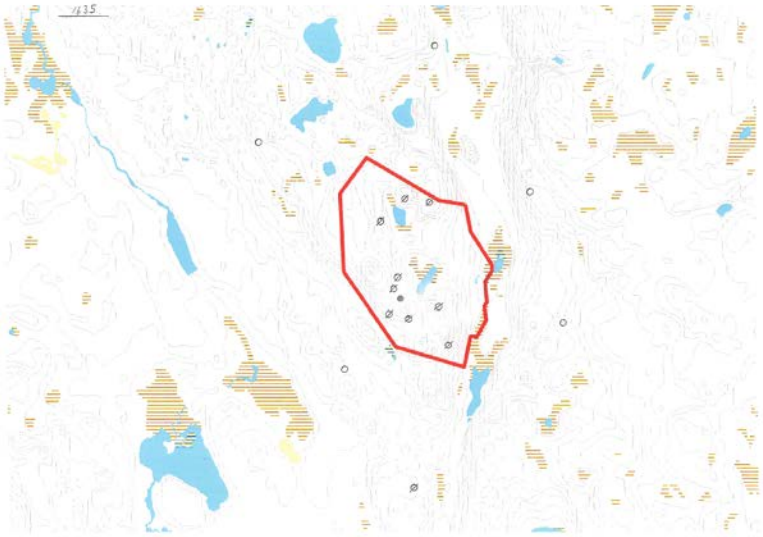
Year: 1619, minimum area: 29 ha.



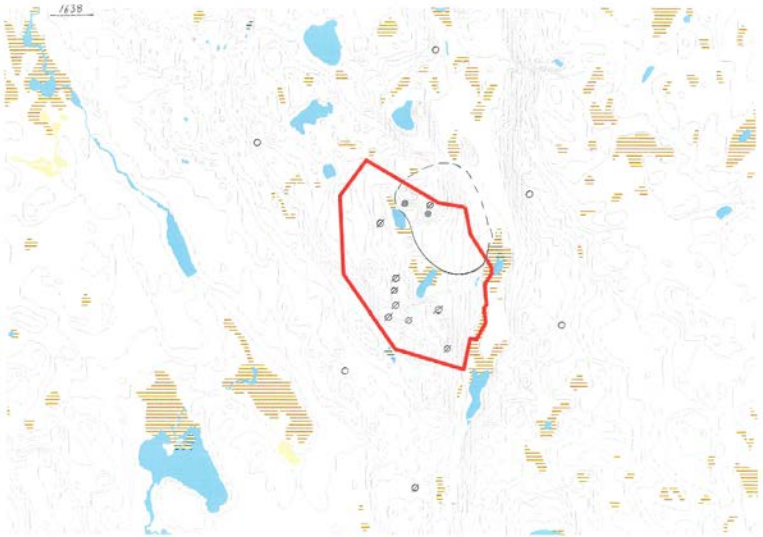
Year: 1624, minimum area: 127 ha.



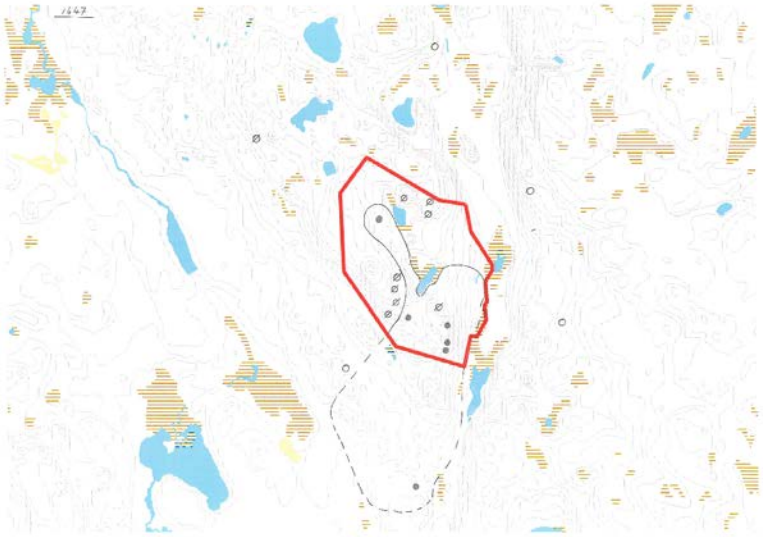
Year: 1634, minimum area: 298 ha.



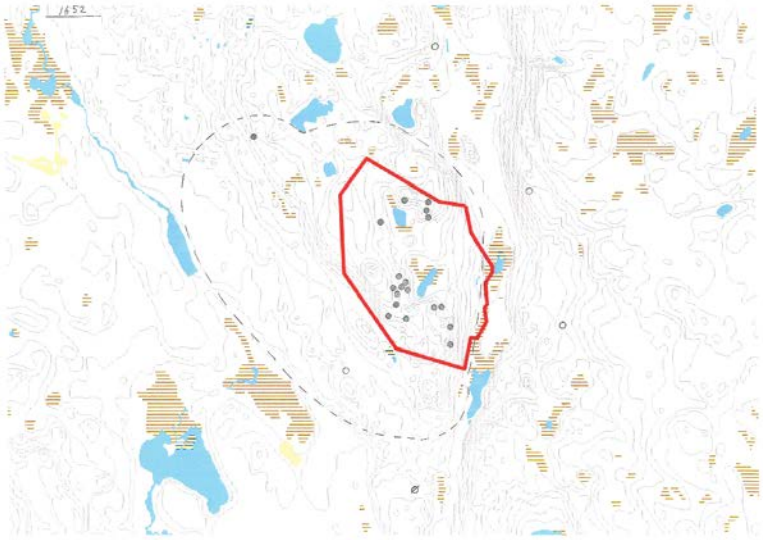
Year: 1635.



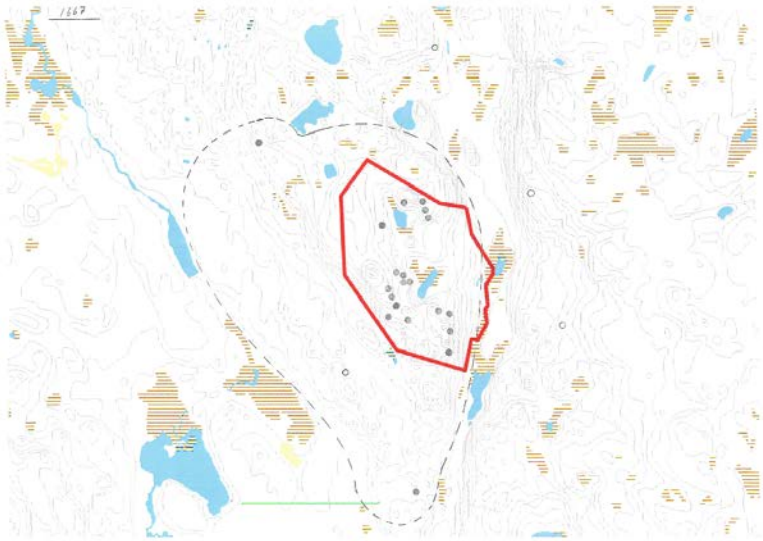
Year: 1638, minimum area: 36 ha.



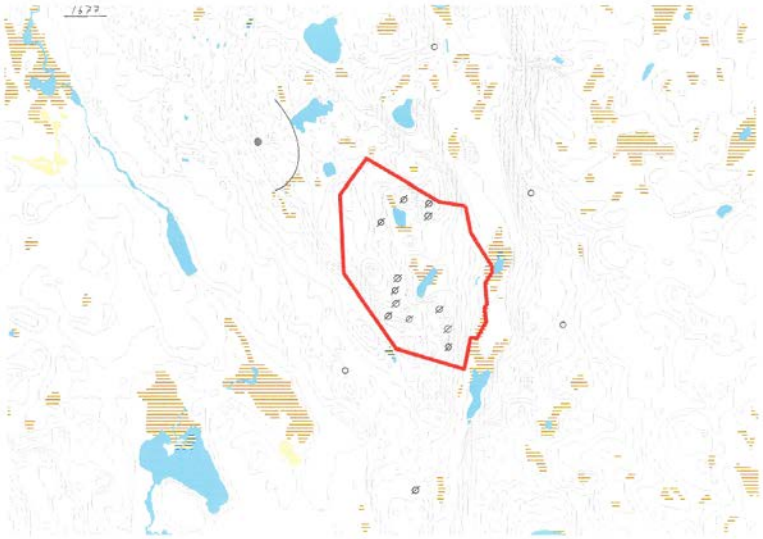
Year: 1647, minimum area: 130 ha.



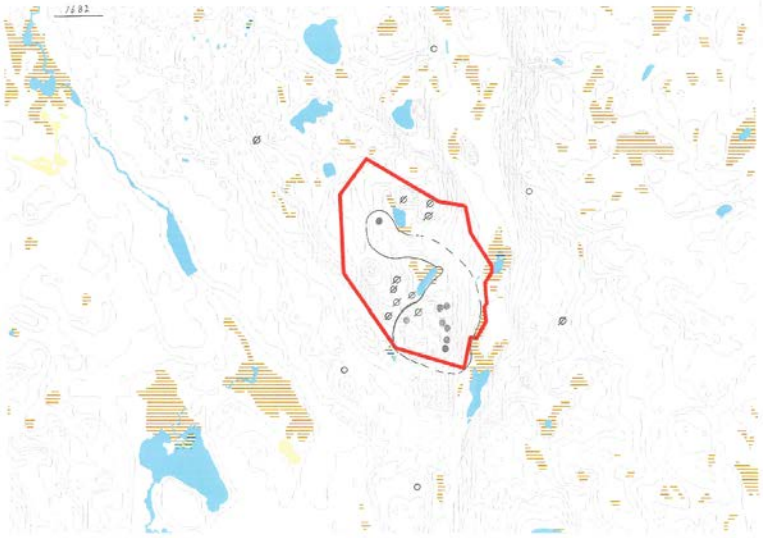
Year: 1652, minimum area: 387 ha.



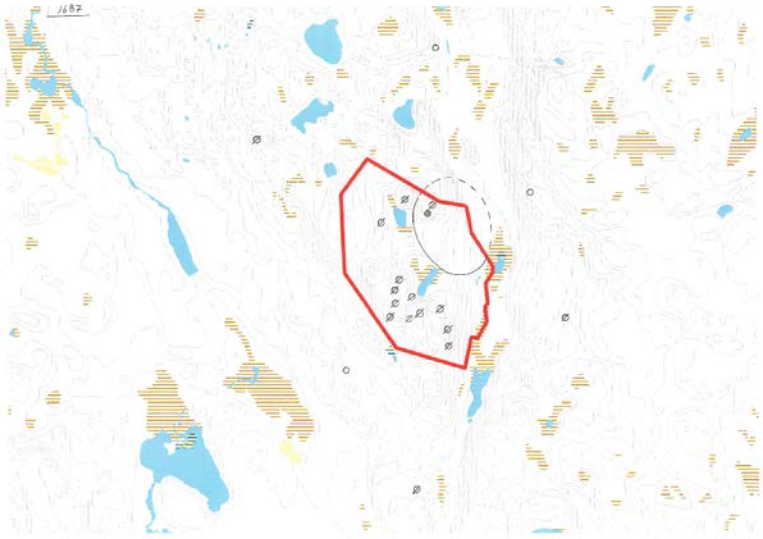
Year: 1667, minimum area: 422 ha.



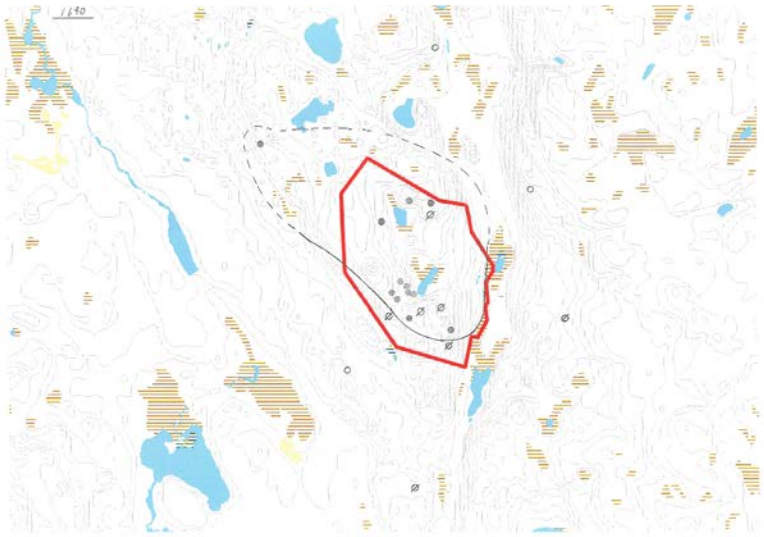
Year: 1677.



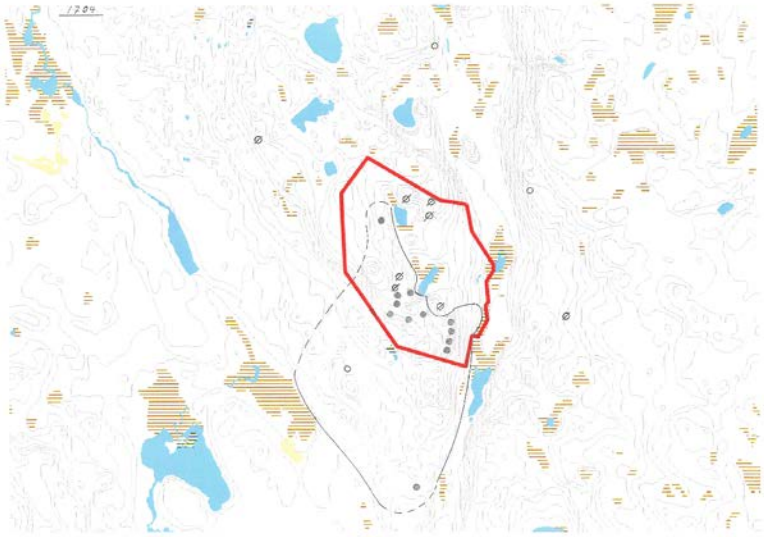
Year: 1682, minimum area: 50 ha.



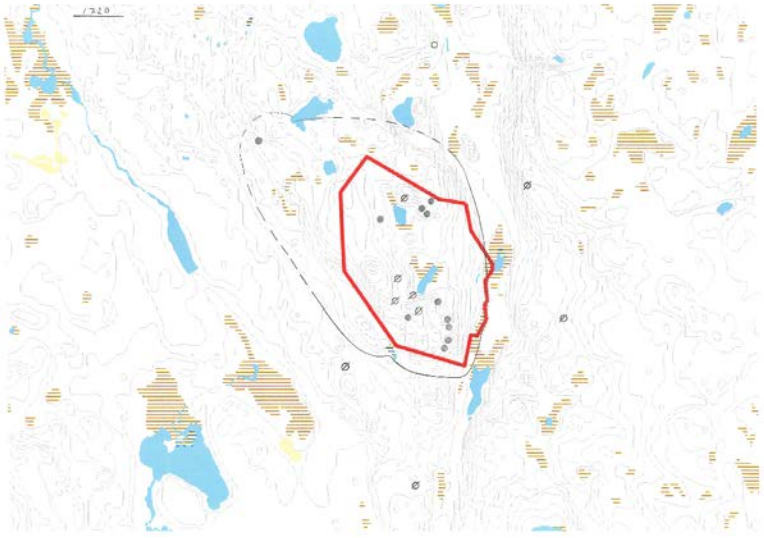
Year: 1687, minimum area: 30 ha.



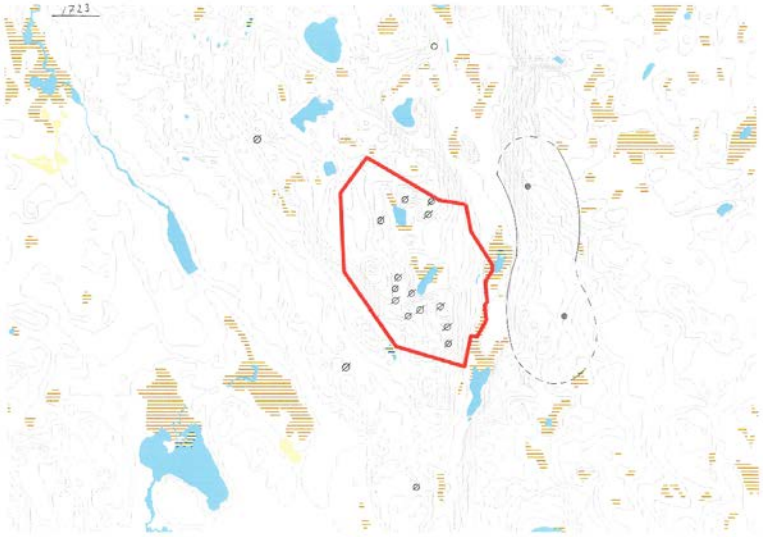
Year: 1690, minimum area: 181 ha.



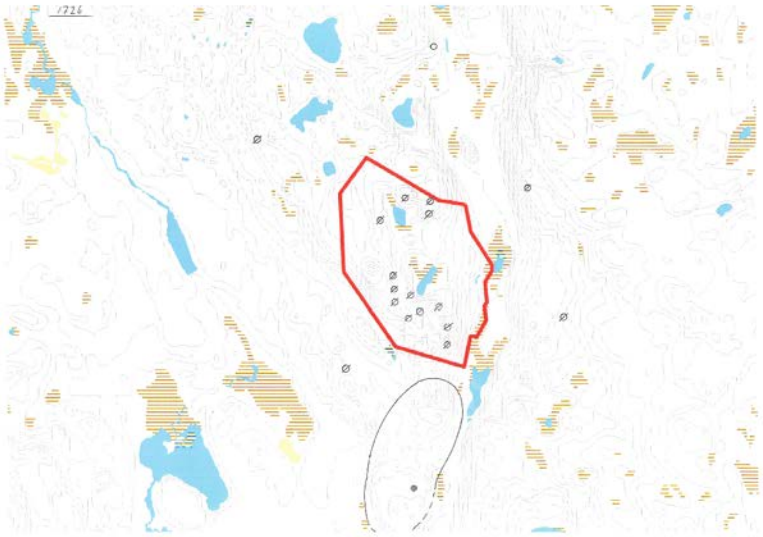
Year: 1704, minimum area: 171 ha.



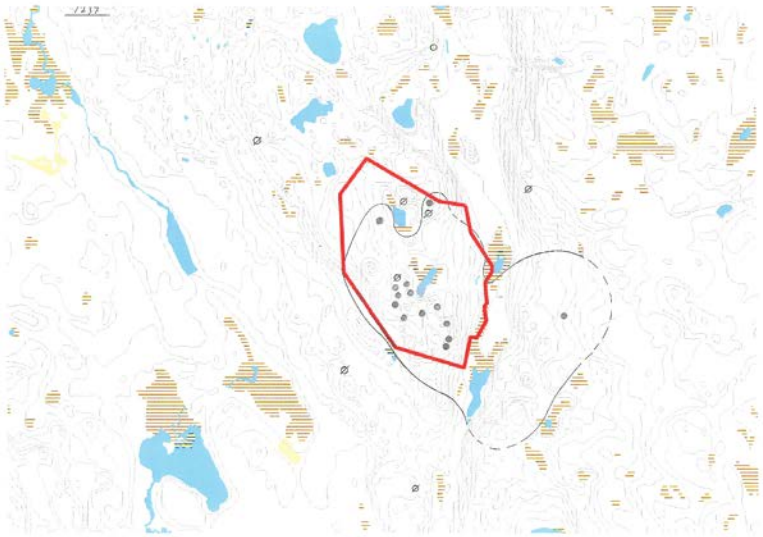
Year: 1720, minimum area: 247 ha.



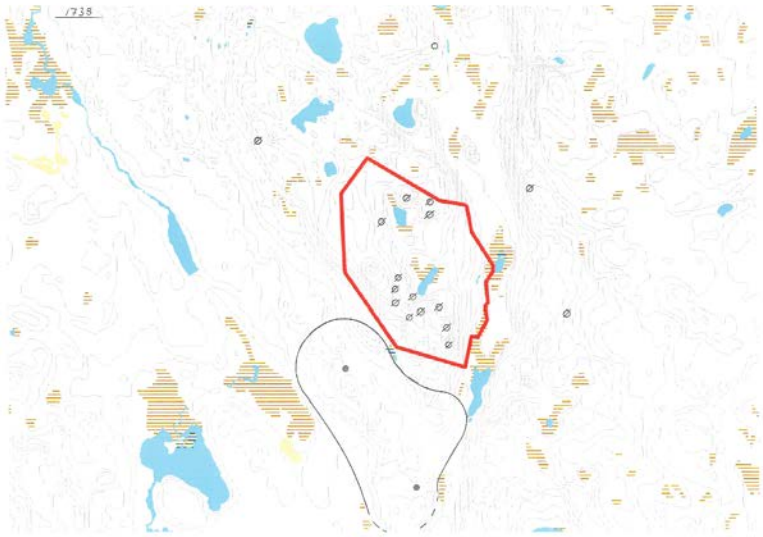
Year: 1723, minimum area: 94 ha.



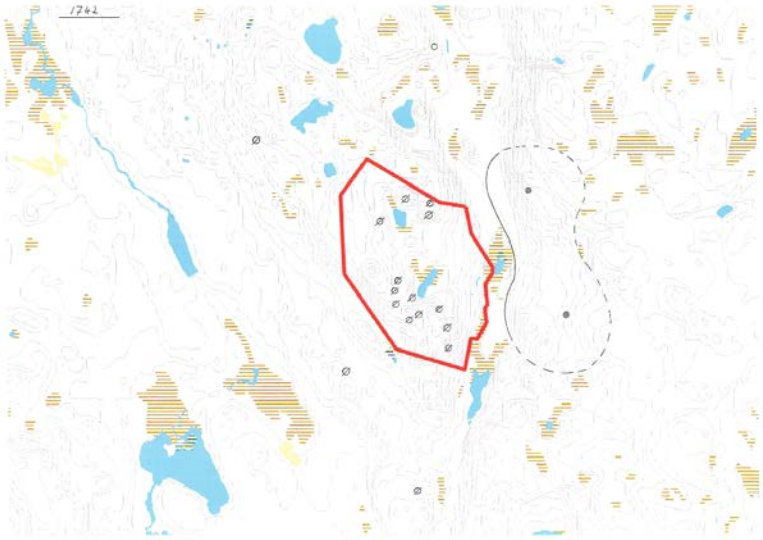
Year: 1726, minimum area: 60 ha.



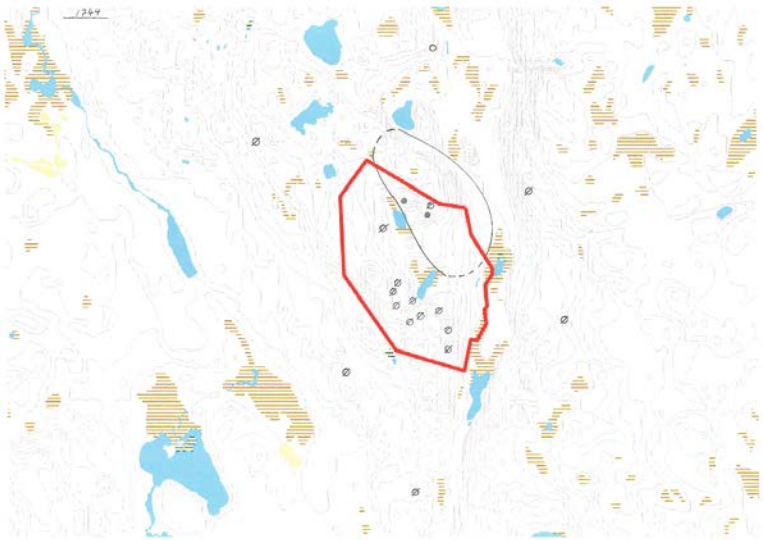
Year: 1737, minimum area: 218 ha.



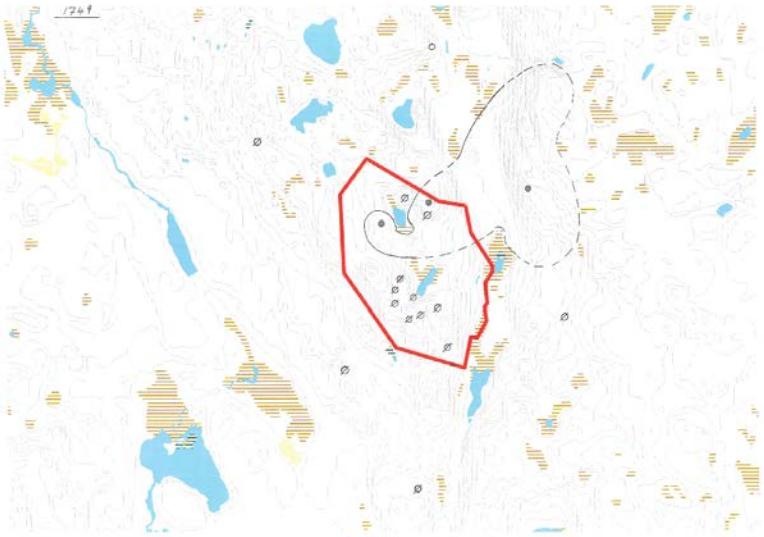
Year: 1738, minimum area: 115 ha.



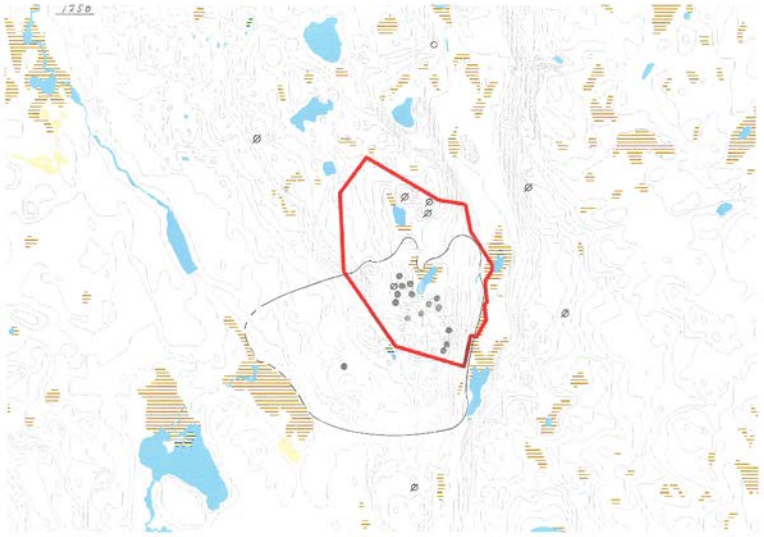
Year: 1742, minimum area: 105 ha.



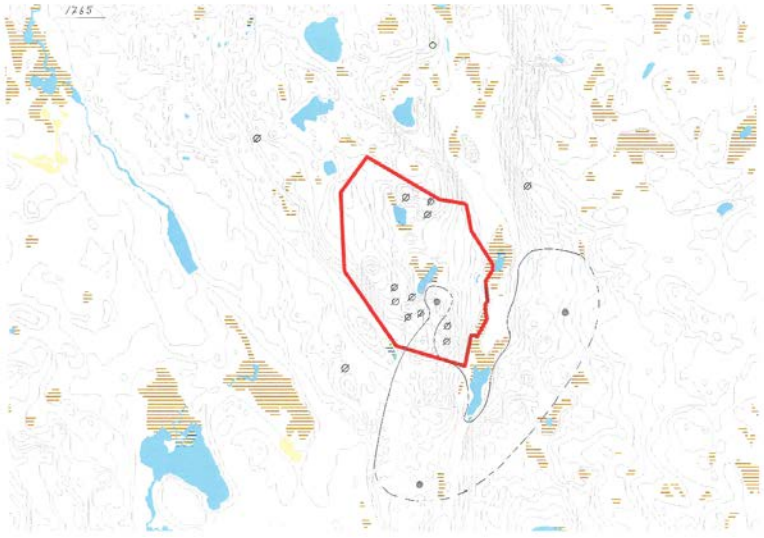
Year: 1744, minimum area: 56 ha.



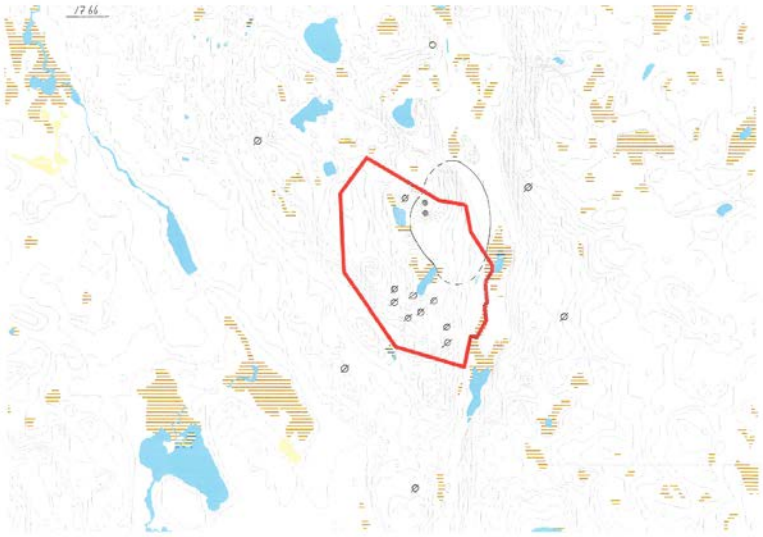
Year: 1749, minimum area: 126 ha.



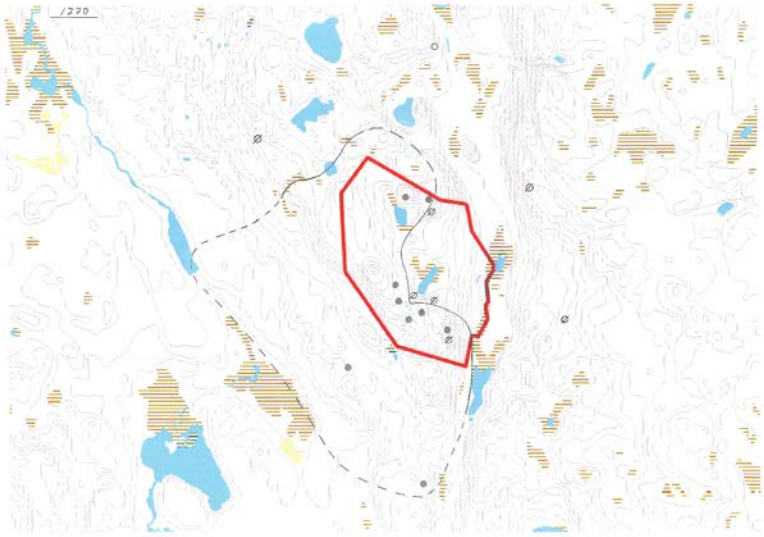
Year: 1750, minimum area: 174 ha.



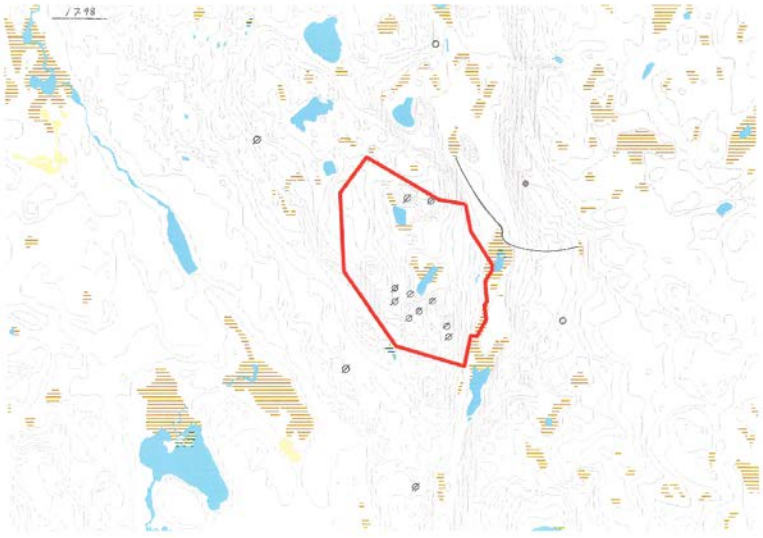
Year: 1765, minimum area: 162 ha.



Year: 1766, minimum area: 37 ha.



Year: 1770, minimum area: 314 ha.



Year: 1798.

Discussion

The sizes of burned areas found in this study range from 20 ha to 422 ha with the average being about 130 ha.

The relatively small number of samples and sampling locations makes it valid to question the accuracy of the results of this study. A sample showing a fire scar is positive proof of a fire in that year but a sample showing no scaring that same does not necessarily mean no fire occurred in the area. It may have been that the fire was at such a low intensity that there was no effect on the tree sampled. The frequent fires suggested by this study points to most fires probably being of low intensity and therefore not all trees will have shown signs of scaring or even weak growth due to the fires. Indeed some samples showed small fire scars on small diameter trees which is typical for a low intensity fire.

A recent study comparing the corroboration between known forest fire data and data gathered by sampling using the same method as in this study (Farris et al. 2010) showed a strong positive linear relationship between percentage of samples recording fire scars for a given year and total burned area for that year. Further sampling in N. Kvill could thus either show proof of a larger burned area than found here or it can strengthen the evidence of this study showing the correct size. It is almost certain that for fires with only a small proportion certain border, the estimates are underestimating actual sizes. Further sampling may also show evidence of additional fires that have so far been undetected inside the present network of sample points. In the cases of well-established borders, many fires seem to have covered areas of 50 to 150 ha which is similar to the results of a study in Norway (Storaunet et al, 2013).

Another factor is that the borders are to some extent assumptions based on topography, fire behaviour and natural fire breaks such as lakes and wetlands. While lakes are normally a sure fire break wetlands may be transcended by dry grass carrying the fire across the wetland. A study on the effect of wetlands on fire regimes (Hellberg et al, 2004) showed that wetlands stop a large proportion, but not all fires. Another quite certain fire break is an area that has been burned only a few years previously. Although regrowth of fuel most likely occurs faster than in northern Sweden the frequency of fires in the study area suggests that this may actually have been a limiting factor of fire sizes. In the fires 1603/1605, 1737/1738,

1749/1750, 1765/1766 and possibly 1574/1582 and 1634/1638 there seems to have been a situation of fuel limitation creating a fire break.

Niklasson and Drakenberg point out in their study within the park that “some fires were dated by only one sample but were absent in surrounding sample points, possibly indicating low-intensity fires that covered just a few ha. On the other hand, some fires, like those in 1652 and 1667, scarred nearly all sampled trees, and were the only scars on a stump found standing in the wet section of the creek. These two fires are noteworthy when comparing the proportions of trees scarred by different fires.”

These two fires, 1652 and 1667, also stand out in this study by being the two largest fires. They are more than three times the average size, suggesting that they were severe and may have been very large. The year 1652 is known from published records as a large fire year (Kohh, 1975) and several local records in south Sweden for large forest fires causing loss of life, farms and churches (Ljungby sockens krönika, 1977).

Although not primarily the focus of this study it is worth noting the probable cause of ignition.

An earlier analysis of the variation of lightning ignitions as a cause of forest fires (Granström, 1993) showed a steep gradient over different parts of Sweden. The Norra Kvill study area is located on the border between two areas where Granström found lightning ignitions to be 0,09-0,12/10.000ha/year to the W and 0,21-0,24/10.000ha/year to the E. Since the study area is only 500 ha only a very rough calculation of fires per area and year can be done. 48 fires over 397 years and 500 ha would result in 2,42 fires/10.000ha/year.

The ignition density is one order of magnitude higher than the highest lightning ignition density in the area (Granström 1993) and out of the 48 detected fires, 34 (71 %) were determined to have been during the dormant or early stages of tree ring development indicating early- to mid-summer. The seasonal variation in lightning ignition shows a strong peak in July (Granström 1993). This points to human activities being a main source of ignition.

Although the material was rather restricted it gave valuable insight into fire sizes in the warmer part of Fennoscandia, in a region known for very high natural lightning ignition frequencies (Granström 1993). It is still unknown what maximum fire sizes may have been in

this region (Niklasson 2011). Very likely the 1652 and 1667 were exceeding 500 ha in size judging from the outline of fire scars. Another question is the minimum fire sizes which is probably better estimated. It seems to be in the scale of 10s of hectares based on the sampling done by Drakenberg within the park where the 43 sampling points are clustered in three major groups. This makes it possible to outline even small fires such as 1635 and 1638 even though the accuracy is difficult to determine because of the lack of samples at this scale. A future study of these parameters within the 407 ha study area is likely to need at least 7 sample points, evenly distributed, in order to accurately map all fires >100 ha (Farris et al, 2010) and more to detect smaller fires. As the forests surrounding N. Kvill are soon to be clear cut with subsequent mechanical site preparation it is urgent that further studies are done before the areas unique data is ultimately lost.

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