Occurrence of Fires in the Eastern Saariselkä Area, North-West Russia

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The occurrence of fires was studied in the eastern Saariselkä area, North-West Russia, by using satellite images and topographical maps. In total, more than 330 burned areas were pinpointed in the study area of 4770 km^2. Old burns were concentrated in the eastern part of the study area, but young burns were more common in the west. Sites affected by fires in the more recent past were much smaller than those burnt over earlier. The abundance of burns along rivers and the border surveillance road provided evidence of human impact. The most significant changes in the landscape were found in the eastern part of the study area, where spruce forests had been replaced by birch woodlands.

Keywords anthropogenic fire, burn, fire, Russia, satellite image, vegetation mosaic
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1 Introduction

Fire is the most significant natural factor controlling succession in boreal forests (Zackrisson 1977). Small and large fires of varying intensity control the age structure of forests, their species composition, and nutrient cycling (Lehtonen and Kolström 2000). Fire creates a mosaic of burned and unburned forest patches, thus maintaining vegetation diversity at the landscape level. Patchiness is also found within a single fire-affected area, because large fires seldom if ever kill all vegetation within the main fire perimeter (Eberhart and Woodard 1987). From the biodiversity point of view, fire history information is an important aspect in the management of protected areas and in maintaining and restoring the features of pristine forests in managed stands.

The occurrence of wildfires in Finland has decreased considerably during the past one hundred years because of efficient fire prevention and control systems. The number of fires has been very low for a long time (Zackrisson 1977, Lehtonen and Huttunen 1997), and the median size of burns has markedly decreased. The oldest statistics in Finland on the numbers of forest fires and on the areas swept over by them go back some 130 years (Saari 1923). In the 19th century, forest fires were common on crown land. The median size of burns was 131 ha in 1865–1870, but early in the 20th century it was reduced to 40 ha in North Finland and 18 ha in South

Finland. Since 1980, the median size of burns in the country as awhole has been a mere 0.9 ha (Metsätilastollinen vuosikirja 1999).

Due to the near absence of fire, young successional stages are rare in unmanaged forests in Finland. For example, the large protected areas in northern Finland are dominated by old-growth forests. Nowadays, the forest environment of the conservation areas should be enriched with young successional stages. From the biodiversity point of view, there is a need to burn areas of standing forest here and there, and thus create natural forests in their early stages of development (Parviainen 1996).

Unlike in Finland, the boreal forests in the western part of the Kola Peninsula, in North-West Russia, are characterised by their fire-induced vegetation mosaic. Near to the border between Finland and Russia, there are extensive areas of natural forests (Kotljakov et al. 1999), which provide prime opportunities to study the effects of fire on boreal forests in an area with climatic and geographical conditions similar to those in northern Finland.

The aim of the present study was to investigate the occurrence of fires in a wilderness area in North-West Russia lacking effective fire prevention and to assess the role of fire on the landscape structure.

2 Material and Methods

2.1 Study Area

The study was conducted in the eastern Saariselkä area, located in the northern boreal zone, north of latitude 68°N (Fig. 1). The study area is bordered by Finland in the west, the Nuorti reservoir in the east, the River Lutto in the north, and the River Nuorti and its tributary Paadesjoki in the south. The area covers about 4770 km^2. The bedrock underlying the area is composed of granulite, which varies considerably in its mineral composition. Due to its high aluminium content, the granulite arch differs distinctly from the surrounding rock type areas (Manner and Tervo 1988). Among the granulite there are oblong lenses of igneous rocks parallel with schistosity. These are composed of hyperstene quartz diorites and norites. The bedrock is covered by till deposits. The biggest esker chains run along the rivers Lutto, Kallojoki and Lounasjoki. Glacifluvial deposits are also to be found in the valleys of the rivers Jauri and Nuorti. The elevation varies between 80 and 716 m a.s.l. The lowest-lying areas are in the east close to the Nuorti Reservoir and the highest in the western mountain region.

The climate is characterised by long winters and short summers. Snow covers the area from late October to late May, and the thermal winter (daily mean temperature below 0 °C) lasts approximately 195 days (Alalammi 1987). The mean temperature in January is –13 °C and in July +13 °C (Atlas Murmanskoi Oblasti 1971). The duration of the growing season (daily mean temperature above +5 °C) is about 120 days. The annual precipitation varies between 500 mm and 700 mm. The most abundant precipitation falls on the highest fells close to the border with Finland.

The central parts of the study area have always been outside the sphere of intensive utilisation by man, but in the peripheral area the human impact has been stronger. On the Nuorti Peninsula, timber was felled as recently as at the beginning of the 20th century. Some families of Skolt sámi people spent the summers in the region of Vuonnijärvi until the 2nd World War. Geologists have conducted ore prospecting in the area for several decades and there is a base camp on the western shore of Lake Lounasjärvi, which served the needs of geological activity since the 1950s until the late 1980s. Four decades ago, the area was a roadless wilderness. Timber felling began along the River Lutto in the 1960s after a road was constructed from the border with Finland to Verhnetulomski. Later on, timber felling was started in the south, in the area bounded by the rivers Nuorti and Jauri. Since the 2nd World War and until 1993, the western part of the study area belonged to the frontier zone, which meant that access by civilians to the area was fairly restricted. Apart from the River Lutto and the Nuorti Reservoir, only a few fishermen have used the remote rivers and lakes.

The Saariselkä mountain chain, with some smaller mountain groups, creates a variable relief. The mountains are skirted by forested lowlands. The timberline lies at some 400 m a.s.l. On the

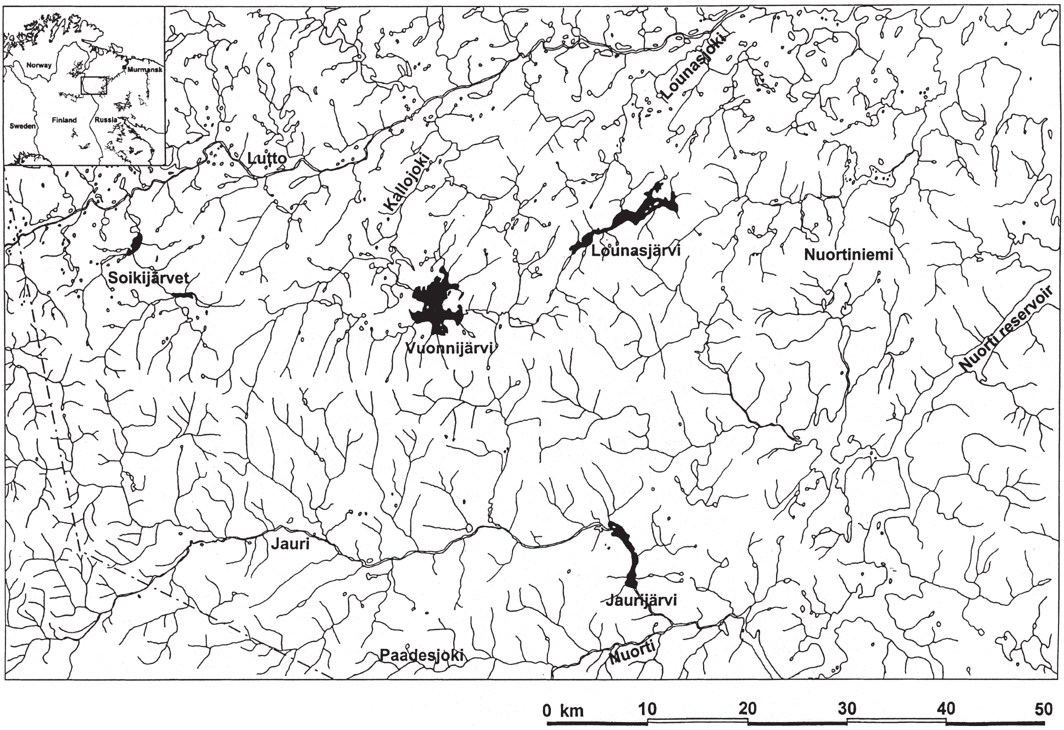

Fig. 1. Location of the study area in the western part of the Murmansk region, NW Russia.

northern side of the fell chain there spreads out the vast lowland area of Vuonnijärvi with its numerous mires and lakes. There are river systems all over the study area. Treeless fell tops, open mires, lakes and rivers create a mosaic landscape pattern.

The western part of the study area is characterised by forests dominated by Scots pine (*Pinus sylvestris* L.) with Norway spruce (*Picea abies* L. Karst.) taking over towards the east. Broadleaved woodlands, dominated by pubescent birch (*Betula pubescens* Ehrh.), are very common on the lowlands east of Lake Vuonnijärvi. Another type of broadleaved woodland, this time formed by mountain birch (*Betula pubescens* ssp. *czerepanovii* (N. I. Orlova) Hämet-Ahti), occurs on the upper slopes of numerous fells.

2.2 Methods

The burns in the area were mapped by using satellite images and topographical maps. The satellite images interpreted by visual inspection were as follows: Landsat-2 from 1979 (Punkari 1984), Landsat-5 from 1984 and 1985, and Landsat 5 TM from 1993 (Mikkola 1995). The information provided by Russian topographical maps was compared with and integrated into that provided by satellite imagery. The maps used in the study were 1:50 000 printed in 1969–1988, 1:200 000 from 1992, and two sheets of an old map (1:100 000) from the 1940s. Numerous burned areas with boundaries are described on these maps. Furthermore, fire-induced forest stands without clear boundaries are presented by a special map symbol on the map 1:50 000.

Most of the young burns were distinguished by using the map material. The youngest and oldest burns were found from satellite images. Information on the succession of north-boreal forests were used in pinpointing the old burns. According Pushkina (1960) and my own field observations, primary birch forests occur along rivers and in the subalpine belt. Large birch forests on lowlands and on lower mountain slopes are of secondary origin. These forests were interpreted as post-fire forests after stand replacement fires in spruce-dominated areas, and they were used to distinguish old burns. Since the post-fire return of spruce is slow, successional birch forests at least 100 years old can be recognized in satellite imagery. Old fires affecting *Pinus sylvestris* forests can not be recognized with this method, because stand replacement fires are relatively rare in pine forests. The oldest fires (pre-19th century) are not included in this survey, because they could not be located by means of remote sensing. The largest burn in the study area was analysed in detail: patches of remained vegetation were drawn on a map and the areas of these refugia were measured. Forests surrounded by mires and waters may escape from fire, but most of the refugia include more biotopes other than forests. Mires, spruce swamps, boulder fields and rocky hilltops belong to the range of fire refugia.

In order to survey forest fires and draw thematic maps of the burns, the vegetation patches were classified into the following two classes (Fig. 2). The classes were determined according to the impact of fire on the vegetation.

Class 1. Young burns (YB), less than 60 a. These areas were easily recognised in the field by means of scarred stems, fire-killed trees and young post-fire stands. The patches belonging to this class were easily recognised on the satellite imagery as well.

Class 2. Old burns (OB), sites razed by fire 60–120 a ago. Fire-scars, charred stumps and root-systems were good indicators of old fires, but recognition of these patches needs expertise. Broadleaved woodlands in lowland areas originated after stand-replacing fires were included in this class. These kinds of patches clearly differ from the other biotopes on satellite images.

Field observations on forest fires were made 1993–2000, and data on fire scars were collected in 1998–2000. Information on past fire history was obtained by applying the fire scar method (Arno and Sneck 1977, Zackrisson 1977), in which fire dates are determined from scars on living trees or stumps. Twenty five samples of annual rings were collected from 22 different locations in order to check the age of the burns distinguished on the topographical map drawn to 1:50 000 scale. Medium-size living trees with a good fire scar were subjectively chosen for sampling, and cross-sections were sawn by handsaw from the scarred area of the trees (Lehtonen et al. 1996). Most of the samples were collected from the surroundings of Lake Vuonnijärvi and River Kallojoki. The numbers of growth rings after the fire were counted under a microscope, and the widths of the growth rings were measured for cross-dating (Fritts 1976). Field observations on the development of the post-fire forests were also used for classifying the burns into old (OB) and young burns (YB).

The areas of YBs were measured in two subareas in the western part of the study area (Figs. 3 and 4). These data were used for estimating the fire-return interval using the ‘natural fire rotation’ method (Heinselman 1973). Natural fire rotation (NFR) is calculated as the quotient of a time period and the proportion of a study area burned in that time period, and it may be expressed by the formula

NFR (a) = (Time period) / (Proportion of the study area burned in that period)

Water bodies were excluded from the total area. Due to the limitations of remote sensing in recognition of the old burns the fire-return interval was not calculated for the period of OBs.

3 Results

More than 330 burns were pinpointed in the study area (Fig. 2), and 82% of them bore the signs of young burns and 18% those of old burns. The burned areas were found all over the study area, but they were particularly abundant in the north-west, north-east and south. The highest proportion of burned areas were on the Nuorti Peninsula. The number of burns were high close to the rivers Lutto, Lounasjoki and Jauri, and close to the roads. The unburned areas in Fig. 2 consists of fells and wet peatlands (e.g. north-west of Vuonnijärvi).

Sites affected by old fires were concentrated on the Nuorti Peninsula and in the catchment area of River Kallojoki. As evidence of old fires, the majority of the lowland areas in the east are

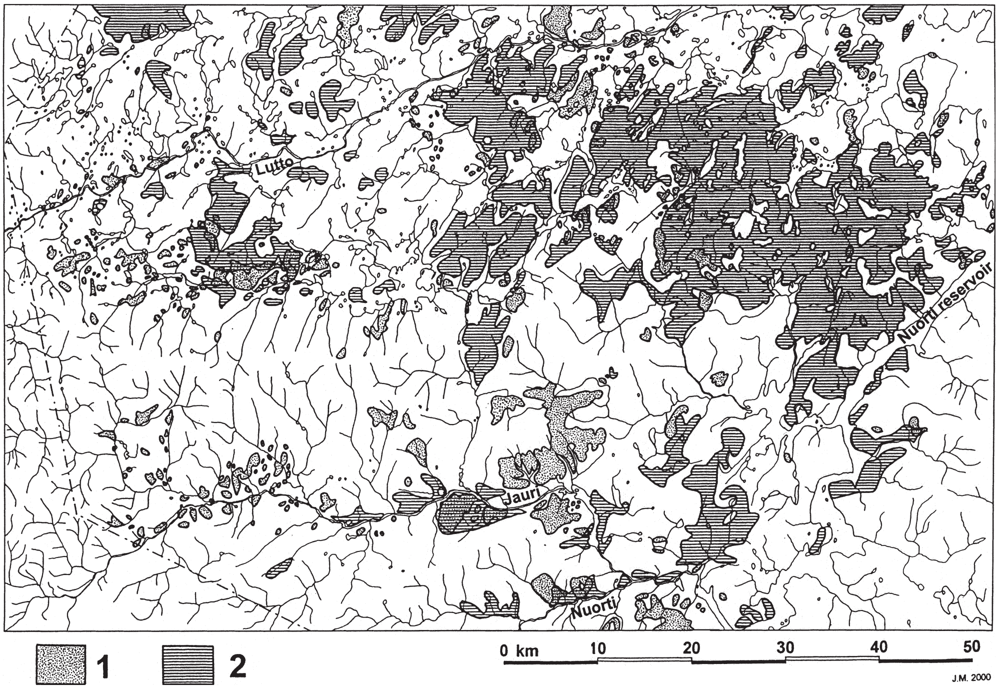

Fig. 2. Locations of the fires in the study area as an interpretation of satellite images and topographical maps. 1) Sites razed by young fires (<60 a), 2) Sites razed by old fires (>60 a).

covered by broadleaved woodlands. Most of the sites of young fires are close to the border with Finland in the surroundings of the Soikijärvet Lakes and in the valley of River Jauru.

These past fires were highly variable in size. In the main, the OBs were larger than the young ones. The largest burn located on the Nuorti Peninsula totalled some 56 240 ha (Fig. 2). The area of burnt vegetation without the unburnt patches amounts to some 50 170 ha. Large fires have also occurred between Lake Vuonnijärvi and River Lutto.

The YBs were much smaller than those burnt over earlier. The concentrations of the YBs in the surroundings of the Soikijärvet Lakes (Fig. 3) and along the upper course of River Jauri (Fig. 4) were subjected to a closer examination. There were 55 burns totalling 2687 ha in the former locality and 74 burned patches with a total area of 3105 ha in the latter. The mean size of the burns was found to be 49 ha for the Soikijärvi area, and 42 ha for the Jauri area. The largest burns were 422 ha and 560 ha, respectively. The largest of all the YBs, located north of Lake Jaurijärvi, was about 5700 ha.

The mean number of years required for an area equivalent in size to the total sample plot area, to be affected by fire is called the fire rotation (Zackrisson 1977). For the Soikijärvi area the natural fire rotation (NFR) was about 588 a and that for the Jauru area about 552 a. These numbers indicate that, on an average, 588 a and 552 a are required to burn the total areas under consideration with the fire frequency found for the latest 60 a period (1939–1998). The calculated NFR is only an approximation of the actual time-span, and it does not reveal much about the degree of fire disturbance in any particular biotope (Heinselman 1973).

Analyses of maps and satellite images showed that the fires had not burned all the vegetation. A closer survey of the largest burn revealed a great number of unburned patches, i.e. fire refugia (Fig. 5). These refugia consisted of lakes and

Fig. 3. Locations of sites razed by young fires in the surroundings of Soikijärvet Lakes, in the NW corner of the study area.

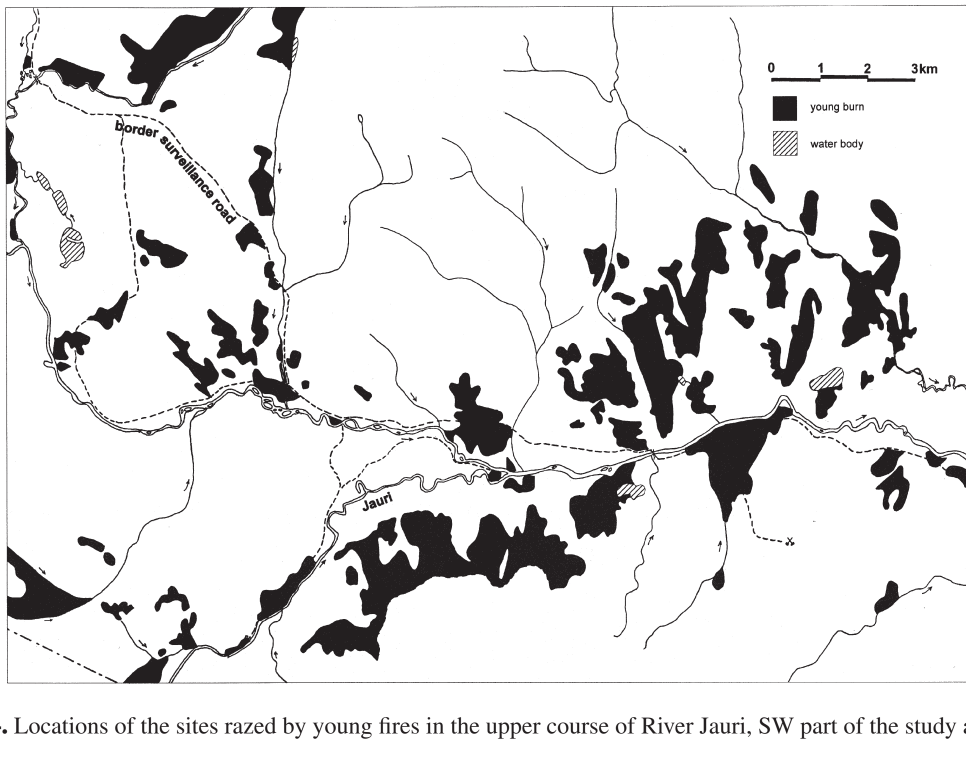

Fig. 4. Locations of the sites razed by young fires in the upper course of River Jauri, SW part of the study area.

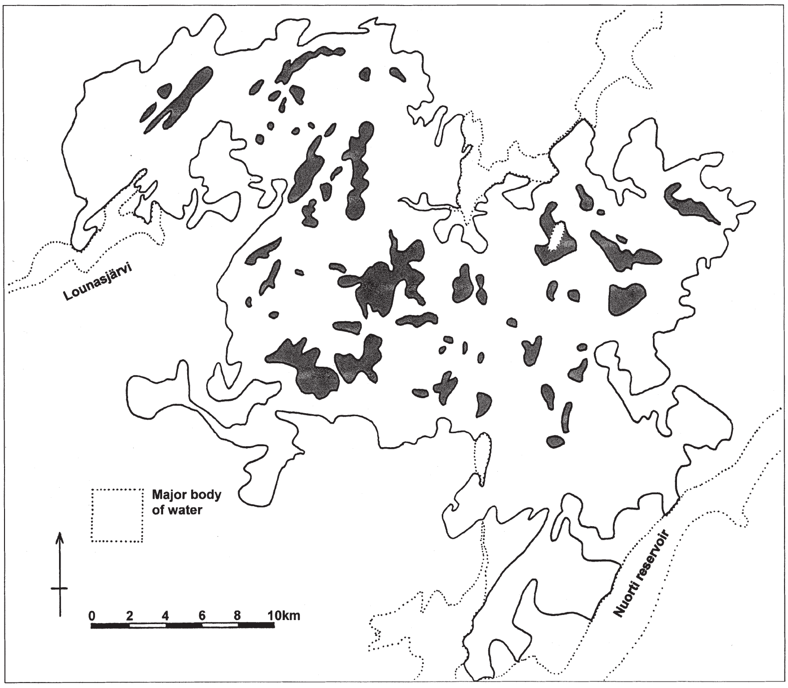

Fig. 5. An areal presentation of the great Nuorti Peninsula fire with the unburned fire refugia in the burned forest matrix.

ponds, various types of wetlands (mires, spruce swamps, etc.), boulder fields and rocky fell summits. Patches of forest had also escaped the ravages of fire, e.g. those surrounded by mires or water. Also mountain birch woodlands, i.e. a narrow ecotones between coniferous forests and alpine heaths, were mainly unburned. Altogether 56 refugia were found within the large burn of the Nuorti Peninsula. The total area of the refugia was approximately 6070 ha and their mean size was 108 ha.

According to the topographical map used in the study, the fires had been frequent along rivers and around lakes. Fell slopes and summits had also been commonly burned. On some fells, ground fires had proceeded up to the summit, burning the well-developed bottom layer of the ground vegetation dominated by *Cladonia* lichens.

The most significant changes in the landscape were found in the eastern part of the study area, where spruce forests were replaced by birch woodlands. The remnants of former forests were found along creeks, rivers and lake shores, and on upper slopes of fells, close to the timberline. Patches created by intensive fires were fairly common in the western pine forests as well. There, many burns were characterised by a grey overstorey, composed of standing dead trees with a green dense regeneration underneath. The lack of a living overstorey of trees is without doubt a good indication of an intense fire. This kind of landscape was common along the upper course of River Kallojoki and around Lake Vuonnijärvi.

4 Discussion

The analysis of satellite imagery and topographical maps linked to field observations indicated that the majority of the forests in the eastern Saariselkä area, NW Russia, have been razed by fires during the last 100–150 years. In fact, fire may have swept over even larger areas than those presented in Fig. 1, as the method used did not reveal the sites of the oldest fires.

The results of this study show that, a hundred years ago, fires were far larger in size than during the past 60 years. The present landscape pattern in NW Russia may partly be explained by large, continuous forests preceding a truly great fire. In a landscape covered by large homogenous forests, fires can grow to cover large areas if nourished by the coincidence of high temperatures, drought, dry lightning storms, wind, and accumulated fuel (Rowe and Scotter 1973). Keltikangas (1977), who visited the study area in 1939, reported a great fire that had burned almost all the forests on the shore and extensively in the surroundings of Lake Lounasjärvi. Only a few forest stands escaped that fire. On the other hand, Keltikangas (ibid.) presumed that the spreading of the fire was hindered by fells, boulder fields, mires and watersheds. A likely explanation is that the huge fire on the Nuorti Peninsula consisted of several fires of different ages, but the lack of field data from that area did not make it possible to distinguish them from each other.

Natural fires of high intensity are common in the boreal forests of North America (Johnson 1992), but in Fennoscandia fire intensity has mostly been low or moderate (Saari 1923, Granström 1996). In eastern Saariselkä, in NW Russia, the abundance of broadleaved woodlands provides evidence to the effect that intensive crown fires have been common in spruce forests. Judging from the occurrence of standing dead forests, intensive fires have razed pine forests as well.

Due to its remoteness, the study area has been outside the sphere of intensive human activity for a long time. Nevertheless, a considerable number of the fires may be of anthropogenic origin. The abundance of young burns along rivers and the border surveillance road provides evidence of human impact. An example is the area of Soikijärvet Lakes. Previously, a frontier guard station was located close to the upper Lake Soikijärvi, but it was destroyed by fire. Nowadays, the site of a former fire of 55 ha surrounds the abandoned station. Also, the fires in the valley of River Jauru may have some connection with the activity of geologists, frontier guards and fishermen. Negligence in putting out campfires may have been the main cause behind fires (Parviainen 1996). Cigarette butts may also have lit numerous fires. The large fires in the east are, at least in part, attributable to logging activity in the beginning of the 20th century.

Convex surfaces are more conducive to burning than concave ones, because the former tend to dry rapidly whereas the latter collect water and remain moist longer (Rowe and Scotter 1973). In the present study area, fires were found to have been common also on concave sites. There are plenty of signs of former fires along the River Kallojoki, though the valley bottom and the shores of the river are highly paludified. This is further evidence of anthropogenic activity. Fires in remote areas, and especially those at high altitudes, were probably ignited by lightning.

Different types of forests have different fire frequencies (Zackrisson 1977, Tande 1979, Zackrisson 1980, Engelmark 1983). Fire return intervals in boreal forests are most commonly estimated by means of point frequency methods. A point frequency represents repeated occurrences of fires at a single location. Zackrisson (1977) indicated that in northern Sweden, before fire suppression started in the 19th century, forest had burned at a mean interval of 80 a. For the forest of the *Vaccinium* type, Zachrisson (ibid.) obtained a mean value of 55 a, and Engelmark (1983) 110 a, while in the northern part of North Karelia, Haapanen and Siitonen (1978) obtained a mean value of 112 a. Lehtonen and Kolström (2000) reported a mean fire interval of 62 a in Viena Karelia.

The values of NFR for the period 1939–1998 obtained in this study, 588 a in the northern sub-area and 552 a in the southern sub-area, can best be compared with those reported by Heinselman (1973) and Zackrisson (1977). Heinselman reported a NFR of about 100 a for the period 1727–1910 in southern Canada. In northern Sweden, Zackrisson obtained a NFR of about 100 a for the period 1551–1875, i.e. before the efficient fire suppression movement. With the fire frequency Zackrisson found for the period 1901–1975 it would take ca 3500 a to burn an area equivalent to the whole study area. As compared to the results of Zackrisson (ibid.), the NFR obtained in this study, indicates that fire suppression does not play any significant role in eastern Saariselkä.

Natural fire rotation is an area frequency technique that evaluates fire-return intervals in the study area based on total area burned over time.

It does not imply that every stand in the study area burns with the same frequency within the calculated time period. Some stands used in the calculation may have burned more than once and some not at all. NFR is typically used in areas where fires are severe and kill most of the trees. As low-severity fires are typical of *Pinus sylvestris* forests, it is conceivable that all the fires in the studied sub-areas could not be recognized by means of remote sensing. This undoubtedly has an impact on the NFR obtained. To some extent, the long fire interval may be dependant on the occurrence of wetlands and timberline areas, which burn very seldom, if ever.

In the eastern Saariselkä, NW Russia, fire has left a powerful impact on the landscape. These areas, previously dominated by spruce forests, are now characterised by a special vegetation pattern with birch woodlands dominating on well-drained soils, and bands of spruce forests occurring along brooks and rivers. The remaining bands of spruce forests also occur on the upper slopes of mountains, where the spread of fire is controlled by seeping water. This is in accordance with the results of Kullman (1986), who found no evidence of past fire at the tree limit in the Scandes Mountains of central Sweden. The forest patchwork pattern in the west is mainly due to spot fires in an unburned matrix, but in the east the mosaic pattern is due to isolated remnants in a burned matrix (cf. Rowe and Scotter 1973).

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