Surviving the Winter in Northern Forests: An Experimental Study of Fuelwood Consumption and Living Space in a Sami Tent Hut

Authors: Östlund, Lars, Liedgren, Lars, and Josefsson, Torbjörn

Surviving the Winter in Northern Forests: an Experimental Study of Fuelwood Consumption and Living Space in a Sami Tent Hut

Lars Östlund*

Lars Liedgren† and

Torbjörn Josefsson*†‡

*Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, SE-901 83 Umeå, Sweden
†Institute for Subarctic Landscape Research, Torget, SE-93 831 Arjeplog, Sweden
‡Corresponding author: torbjorn.josefsson@slu.se

Abstract

Subsistence in northern regions with cold climate and long winters relies to a large extent on fuelwood access and logistics. The preferred sources of fuelwood in pre-industrial times in northern Scandinavia were dead standing Scots pine trees. To assess historical impacts of Sami settlement sites on surrounding forests, and effects of burning wood on living conditions inside their huts, we burned pine wood in a Sami tent hut during winter, as realistically as possible, then analyzed fuelwood consumption, temperatures, and CO levels inside it. Hourly wood consumption rates ranged from 5.0 to 7.4 kg, corresponding to an estimated average annual consumption of ca. 22,000 kg or 42 m^3 per hut. The smoke created by the fire and the low indoor temperature at the periphery of the hut limited the comfortable living space to approximately a third of the total space. We estimate that areas up to 300 m from settlements were used for fuelwood collection, but deliberate, recurring tree girdling to produce snags suitable for fuelwood might have reduced this area. Overall, the landscape impact of settlements was low, affecting less than 2.2% of the utilized lands. We conclude that experimental simulations of historical resource uses can provide valuable quantitative data for verifying or challenging qualitative interpretations and thoroughly modeling human effects on ecosystems over time.

Introduction

In pre-industrial times the acquisition and use of wood as fuel was crucial for subsistence in northern boreal and subarctic regions. Indeed, wood was used more for fuel than for construction, industrial purposes, and all other types of uses until the late 19th century or beginning of the 20th century in many regions (Arpi, 1959; Clawson, 1979; Perlin, 1989; Whitney, 1994; Kristinsson, 1995; Ludemann et al., 2004). The intensity of fuelwood cutting led to long-lasting deforestation in areas with high human populations and sparse forests, but even in areas with abundant forests and fewer people it affected forest ecosystems in subtler ways. Hence, there were clear latitudinal deforestation gradients; temperate areas, with higher population densities, were generally deforested earlier and much more intensively than northern, boreal, and subarctic areas (Kaplan et al., 2009; Ludemann, 2010).

The importance of the availability and use of fuelwood historically increased towards the north, as the duration of the winter increases, except in treeless subarctic and Arctic regions. The quantities and types of fuelwood consumed were also influenced by the types and sizes of dwellings, and the designs of the fireplaces used. The nomadic Sami groups in Scandinavia, many living north of the Arctic Circle, developed unique strategies for subsistence and survival under adverse climatic conditions. Different types of wood were used as fuel in different ecosystems. In the subalpine areas, mountain birch (*Betula pubescens* ssp. *tortuosa* (Ledeb.) Nyman) was commonly used (Ryd, 2005:7; Liedgren and Östlund, 2011), along with various shrubs (Læstadius, 1831:226; von Düben, 1873:38; Pettersson, 1979:215f). At lower elevations, where the winter camp sites were generally located, dead Scots pine (*Pinus sylvestris*

L.) trees were important sources of fuelwood for heating the huts during the long, cold winters, but other types of wood were also used, including Norway spruce (*Picea abies* (L.) Karst.) and various deciduous tree species. Sami huts of all types had an open smoke hole in the roof and a stone-lined hearth located in the center. Usually the fire was maintained throughout most days, and could also be maintained during the night in very cold periods (Grape and Weinz, 1969; Pettersson, 1979). As noted by numerous travelers in Lapland during the 17th century and later (Taylor, 1859:115; von Düben, 1873:120; Leem, 1975:102; Pettersson, 1979:215; Ehrenmalm and Stenmark, 2001:138; Linné, 2003:122), this created large amounts of noxious smoke inside the huts. In areas immediately adjacent to the settlements the density of standing dead trees were heavily reduced.

Trees that had died of natural causes, for example forest fires or windthrow, were prominent features of the forests in northernmost Europe during pre-industrial times (Linder and Östlund, 1998). In pine-dominated, late-successional forests with low human impact, typical volumes of dead trees reportedly range from tens to more than 100 m^3 per hectare (Linder and Östlund, 1998; Karjalainen and Kuuluvainen, 2002; Josefsson et al., 2010b). Dead pine trees were widely used, and during winters they were the preferred sources of fuelwood in northern Scandinavia (Kinnman, 1928). Nevertheless, little attention has been paid to the quantities of fuelwood consumed and the numbers of dead pine trees cut, despite their potentially profound effects on forest ecosystems. Liedgren and Östlund (2011) found evidence that ~86 kg (dry weight) per day (24 h) of fuelwood (fresh birch wood) was used at the site of a high mountain 12th century stállo-hut (an ancient Sami hut construction with a sunken floor and covered with birch-bark held

in place by birch wood), situated above the present tree line in the Scandinavian mountain range (see Liedgren and Bergman, 2009). In another study, Karlsson et al. (2009) showed that human activities carried out centuries ago near such camp sites could result in deforestation. However, no previous investigations have specifically examined the amounts of wood consumed in the tent huts that were commonly used by the Sami up to the mid-20th century.

The aim of this study was to examine the effects of using, as realistically as possible, pine wood as fuel in two kinds of hearths in a Sami tent hut during winter conditions. Wood derived from standing dead pine trees was burnt in a repeated experiment, on three separate occasions, and the following variables were monitored: wood consumption, temperature (indoors, outdoors, and in the hearth), and carbon monoxide levels in the hut. The following specific questions are addressed. How much fuelwood (derived from standing dead pine trees) was consumed per unit time, in relation to outdoor temperature and wood properties? What kind of living conditions are achieved by using certain (measured) amounts of fuelwood of certain quality by considering the outdoor temperature and the difference in hearths used? What restrictions on the size of the living space did the temperature and CO gradients impose in a Sami tent hut during winter? The analyses made in this study forms the basis for a more general discussion of the effects of low-intensity, long-term activities such as cutting of standing dead trees, on subarctic forest ecosystems near settlement sites.

Material and Methods

SAMI SETTLEMENT PATTERNS AND HUT CONSTRUCTION

Today many Sami are urbanized and the nomadic lifestyle has been replaced by a modernized, semi-nomadic standard of living, but the reindeer herds are still moved between different grazing lands on a seasonal basis. Historically, the Sami groups moved between specific resource areas on a yearly cycle, utilizing different kinds of natural resources at each location. The harsh Scandinavian winter usually lasts for more than six months each year, thus access to sufficient wood fuel at each camp site was essential. The forest Sami stayed year-round in the coniferous forests, utilizing mostly pine and spruce. They lived in movable tent huts or permanent wooden huts of different types (Ruong, 1944; Manker, 1968). The mountain Sami stayed in the coniferous forest during the winter as it offered both shelter and plenty of firewood—the mountain birch forest during spring and autumn, and the mountain heath during the summer (Josefsson et al., 2010a). From medieval times (A.D. 1050) onwards they lived in movable tents covered by cloth, birch bark, or hides (Manker, 1944; Ruong, 1945; Schefferus, 1956; Liedgren and Bergman, 2009). During the 19th century they also started to use permanent turf huts.

EXPERIMENTAL DESIGN

The repeated experiment was performed in the Åsarna Forest Reserve situated in the vicinity of the Scandinavian mountain range ~10 km north of Arjeplog (66°N, 18′E). This region has a cool temperate climate with a mean annual temperature of $-2\,°C$ (Alexandersson and Eggertsson Karlström, 2001). Wood was burnt in a tent hut for three days (after a day's preparation) in three separate tests (denoted tests 1–3). On each of the burning days, we started a fire at 08:00 in the morning and kept adding fuel to it until 18:00, in a cone-shaped tent hut (supplied by Moskoselkåtan, model 7), 2.75 m high (2.2 m to the smoke hole) and 4.2 m in diameter at floor level (Fig. 1). This hut is a modern version of a traditional Sami tent hut, but slightly modified for practical reasons for this particular experiment. The tent pole in the middle of the hut was replaced with a split tent pole made of iron to allow space for a typical Sami hearth, *árran*, in the middle of the tent. The tent hut has an open smoke hole, the size of which can be regulated (0.4 m diameter when fully open), and ducts for air ventilation at several places along the floor. The smoke hole was fully opened during all three tests.

Two different hearths were used in the tests. During the first test a hearth consisting of an oval ring of stones (outer dimensions, 1.3×0.9 m) laid directly on the soil was used. In the second and third tests a similar hearth was used, but with a stone packing inside the stone lining. The hearth types used correspond to traditional

FIGURE 1. The tent hut during test 3. Photo: Lars Östlund.

Sami hearth types in tent huts from this region. We used independent-sample *t*-tests to analyze differences in variables (daily means of temperatures near the hearth, close to the canvas and below the smoke hole) that conformed to the requirements of normality between the two hearth constructions. The tests were conducted during 12–16 October 2009 (test 1), 3–6 October 2010 (test 2), and 15–18 November 2010 (test 3). The conditions varied during the three tests. During tests 1 and 3 there was 0.1–0.2 m of snow on the ground, but during test 2 there was no snow. During tests 1 and 3 the snow was removed from the floor and the canvas closest to the ground was covered with snow on the outside.

The wood used in the experiments came from six dead pine trees, ranging in size from 14.4 to 23.5 cm diameter at breast height (dbh) and in age from 99 to 139 years (Table 1). The selected trees all met the following criteria: most of their bark had gone, they had solid wood, and no obvious rot in their lower parts. However, one of them had rot in the top section of the stem, thus only the lower parts of this tree were used in the tests. The wood volume in the five entire trees varied between 0.08 m^3 and 0.35 m^3. The trees had been dead for 22 to 41 years when they were cut for this experiment. Parts of some trees were rich in resin. The trees were cut and transported to the experimental site between one and three weeks prior to the experiments and stored outdoors before use. At the experimental site the stems were first cut into ~50 cm pieces. The weight and length of each piece, as well as the diameter at each end of every piece, were recorded. Three small samples from each tree were also collected for later analyses of water content, fuel properties, and wood density. After the dimension measurements, the wood was split into smaller pieces using an axe, and both the volume and weight of wood used each day during each test were recorded.

During the tests the outdoor and indoor temperatures were measured and logged at two-minute intervals with Tinytag (TGI-3250 and TGP-4017) instruments. Outdoor temperatures were measured 1.2 m above the ground, ~25 m from the tent hut. Inside the hut the temperature was measured at several points along a gradient from the floor: 0.4 m horizontally from the hearth and 0.35 m above the ground, by the canvas 1.6 m from the hearth and 0.65 m above the ground, and below the rim of the smoke hole 1.7 m above the ground. The temperature at floor level was measured at eight points where the tent fabric met the ground, four times (14:

15, 14:45, 15:15, and 15:45) during the third day of the third test. The measurements were made with an IR thermometer (model TN425LBE, set to emissivity 1) during test 3. During tests 2 and 3 the carbon monoxide concentration in the hut was also measured every 15 min, from 8:15 to 18:00, at ground level 0.1 m from the hearth, and 0.25, 0.5, 0.75, 1.0, and 1.25 m above the hut floor. During the second test especially resin-rich pine wood was set aside and burnt during the last day from 15:00 to 16:30 to assess the effects of using this kind of fuel.

After the tests, 2–3 wood samples from each tree (14 samples in total) were weighed, dried at 60 °C for two weeks and then re-weighed. Smaller subsamples of ~50 g were taken from these samples and further processed for a complete fuel analysis at Bränslelaboratoriet in Umeå. Two additional samples were also taken from birch wood used in a previous experiment (Liedgren and Östlund, 2011) to compare the fuel quality of birch wood and pine wood. For this purpose, 1 g subsamples from each larger sample were dried at 105 °C, and then their calorimetric fuel values were measured (according to standard method ISO 1928). Effective fuel value, ash, sulfur, nitrogen, and oxygen contents of subsamples were also measured (data not shown).

Results

FIRE, FUEL PROPERTIES AND WOOD CONSUMPTION

The relative dryness of the wood (water content, 13–32%) derived from the standing dead pine trees allowed a slow-burning fire to be maintained by simply adding fuel when needed (i.e. the fire was kept in a steady state and never allowed to be reduced to embers). The calculated calorimetric fuel values of completely dry wood samples (excluding the resin-rich pieces) varied between 20.2 and 21.9 MJ kg^{-1}, but that of the partially dried wood used in the tests was much lower and varied substantially more (12.9–17.0 MJ kg^{-1}). The resin-rich wood pieces had considerably higher values (23.5–26.2 MJ kg^{-1} fully dried, and 19.5–22.2 MJ kg^{-1} partially dried, the latter values corresponding to those of fully dried ordinary pine wood). The fully dried birch wood samples had a comparable fuel value to ordinary dry pine wood (Table 2), but unseasoned birch wood had a substantially lower fuel value (11.96–12.64 MJ kg^{-1}) due to much higher water content. The results of burning

TABLE 1

Characteristics of the six trees used for fuel during the three experiments.

	Age (years)	Dbh (cm)	Wood volume (m^3)	Time since death (years)	Wood characteristics	Resin-rich wood in tree
Test 1	121	23.5	0.35	31	Hard wood, some discoloration lower part	–
Test 2	99	14.0	0.08	24	Ibid., minor rot in lower part (one tree)	Top section, ca. 1 m
	121[a]	14.5[a]	0.05[a]	30[a]		
	139	21.0	0.24	30		
Test 3	101	14.5	0.11	22	Hard wood, some discoloration lower part	Top section, ca. 1.5 m
	112	17.5	0.15	41		
Mean	116	17.5	0.16	30		

[a] Only the lower section of this tree (3.5 m) was used due to stem rot in the uppermost part.
dbh = diameter at breast height.

TABLE 2

Water content of the wood, calorimetric fuel values, and effective fuel values (including water content).

	Water content (%)	Calorimetric fuel value, dry wood (MJ kg^{-1})	Fuel value as burnt (MJ kg^{-1})
Pine wood			
Test 1			
Sample 1	15	20.24	16.80
Sample 2	14	20.23	17.00
Sample 3	16	20.20	16.56
Sample 4	15	21.87	18.15
Test 2			
Sample 1	23	21.02	15.55
Sample 2	26	20.17	14.12
Sample 3	28	20.23	13.76
Sample 4	23	20.24	14.98
Sample 5 (resin-rich)	15	23.45	19.46
Test 3			
Sample 1	24	20.42	14.91
Sample 2	26	20.34	14.23
Sample 3	32	20.15	12.90
Sample 4	25	20.39	14.68
Sample 5 (resin rich)	13	26.15	22.23
Birch wood			
Sample 1	38	20.99	11.96
Sample 2	35	21.08	12.64

resin-rich wood during a limited time in test 2 showed that much more heat was released than when burning ordinary pine wood. Residual charcoal in the hearth was also completely burnt away during these events. The amount of wood consumed during the three tests varied from 5.0 kg hour^{-1} in test 1 to 7.4 kg hour^{-1} in test 3 (mean = 6.3 kg hour^{-1}), equivalent to an estimated consumption during a full winter of 16 000 kg or 31 m^3, and annual consumption of 21 700 kg or 42 m^3 (Table 3).

OUTDOOR TEMPERATURE AND INDOOR CLIMATE

The outdoor temperature varied greatly among the tests; the mean temperatures (between 10:00 and 18:00) were −8.0 °C

During tests 1 and 3 the snow on the ground thawed in a circular area around the hearth, but not at the rim of the tent, where the temperature by the canvas at ground level during test 3 (day 3) ranged from −1.3 to −22.5 °C. The mean indoor temperature varied between 11.6 and 19.1 °C near the hearth, 15.0 and 28.4 °C at ca 0.65 m height close to the canvas, and 42.4 and 60.9 °C below the smoke hole (Fig. 3). The highest mean temperatures near the hearth were reached during test 2, when the outdoor temperature was highest (Figs. 2 and 3). Furthermore, during the second test the temperature was very similar (~17 °C) near the hearth and close to the canvas. During tests 1 and 3, however, the temperature was considerably higher (~20–24 °C) close to the canvas than near the hearth, where the mean temperature never exceeded 18 °C (Fig. 3). During the third day of test 3 the maximum temperature close to the canvas was almost 87 °C (Fig. 3). The highest mean temperatures (42.4–80.9 °C) were reached below the smoke hole. Here the maximum temperature was just above 126 °C. The variation in recorded minimum and maximum temperatures inside the hut was high in tests 1 and 3. The overall difference in mean temperature outdoors and inside the hut near the hearth varied between 19.3 and 23.0 °C (test 1), 9.8 and 11.1 °C (test 2), and 27.6 and 34.7 °C (test 3) (Figs. 2 and 3).

The mean temperature near the hearth during days 1–3 was significantly higher in test 3 (15.9 °C) than in test 1 (12.9 °C) ($t = −5.690$; $p < 0.000$). The mean temperature recorded below the smoke hole was also significantly higher in test 3 (57.7 °C) than in test 1 (51.4 °C) ($t = −3.190$; $p < 0.01$). Close to the canvas there was no significant difference in mean temperature between test 3 (25.0 °C) and test 1 (26.5 °C). During the last day of test 2 the temperatures near the hearth, close to the canvas (and to some extent below the smoke hole), were elevated during the 1.5 h that we used especially resin-rich pine as fuelwood (Fig. 4).

The noxiousness of smoke generated by burning wood in a hearth is closely related to the amount of carbon monoxide in the air (see Liedgren and Östlund, 2011). During tests 2 and 3 carbon monoxide was measured every 15 min at heights from ground level up to 1.25 m. The results show that levels of carbon monoxide increased with increases in height from the floor. However, concentrations of carbon monoxide were low (<3.5 ppm) up to 1.0 m from the floor during test 2, but in test 3 they exceeded 80 ppm

TABLE 3

Average and approximated wood consumption (weight and volume) derived from the three tests.

	Average consumption per hour		Approximated consumption per day[a]		Approximated winter consumption per hut[b]		Approximated annual consumption per hut[c]	
	kg	m^3	kg	m^3	kg	m^3	kg	m^3
Test 1	5.0	0.011	70.0	0.147				
Test 2	6.4	0.012	89.3	0.174				
Test 3	7.4	0.014	103.3	0.190				
Mean	6.3	0.012	87.6	0.170	15,978	31.0	21,668	42.2

[a] 14 hours of burning per day.

[b] Assuming that fires were maintained all day 14 hours for six months during the winter.

[c] Assuming that fires were maintained 14 hours for six months during the winter, 7 hours for three months during the spring and autumn, and 3.5 hours for three months during the summer (cf. Liedgren and Östlund, 2011).
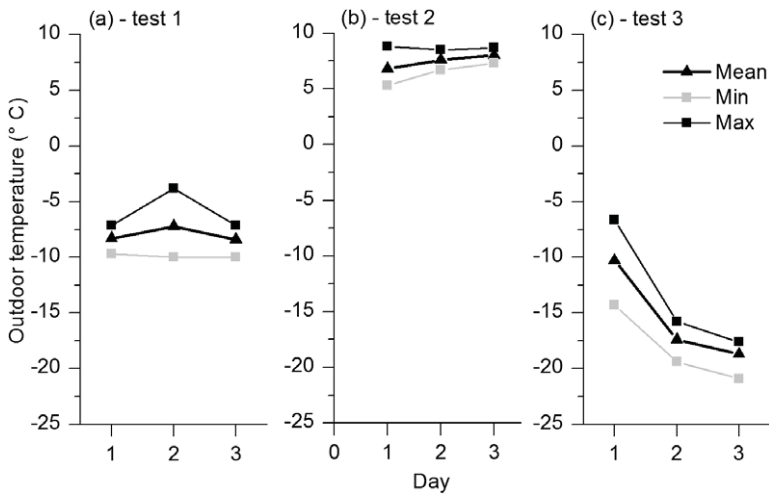
FIGURE 2. (a–c) Outdoor temperatures during tests 1–3, respectively, measured at 2-min intervals from 10:00 to 18:00, ~25 m from the tent hut at 1.2 m height above ground.

even at 0.75 m height (Fig. 5). The outlines of the smoke cloud in the hut were generally quite distinct and readily visible.

Discussion

FUELWOOD CONSUMPTION

In this experimental study we found that a large quantity of pine wood was needed to keep a fire going during entire days in a Sami tent hut. The average amount of wood consumed during the three tests was 6.3 kg h^{-1}. The difference in mean temperature outdoors and inside the hut near the hearth was highest in test 3 and lowest in test 2. As expected, the wood consumption was the highest during test 3 (7.4 kg h^{-1}) when outdoor temperature was the lowest (mean -15.5 °C). In this part of Scandinavia the winters are long and cold—the temperature often drops below -20 °C, and the mean temperature in January is about -15 °C (Alexan-
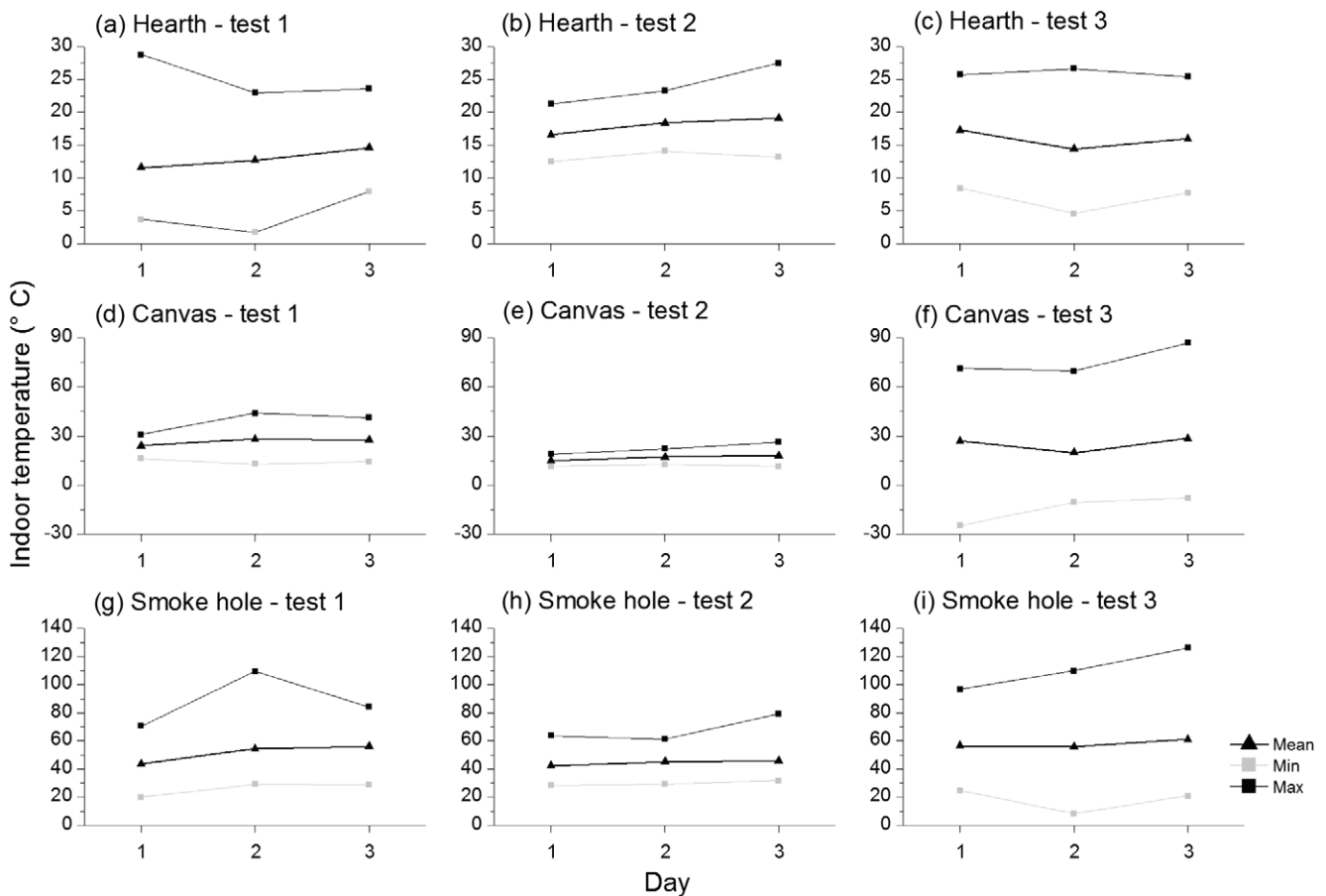
FIGURE 3. Indoor temperatures during tests 1–3 derived from four loggers measured at 2-min intervals from 10:00 to 18:00. (a–c) 0.4 m from the hearth at 0.35 m height, (d–f) close to the canvas at 0.65 m height, and (g–i) below the smoke hole.

376 / Arctic, Antarctic, and Alpine Research
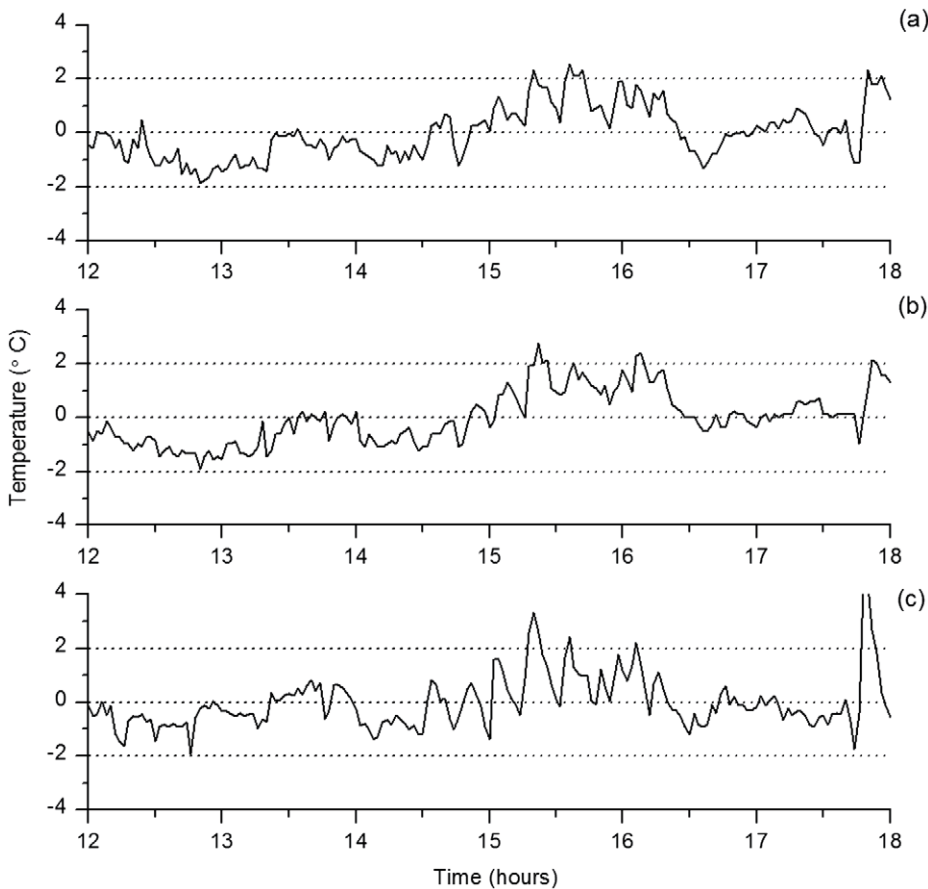
FIGURE 4. Temperature measurements (standardized) from the last day of test 2 (a) near the hearth, (b) close to the canvas at 0.65 m height, and (c) below the smoke hole. Resin-rich pine wood was used as fuel from 15:00 to 16:30.

dersson and Eggertsson Karlström, 2001). However, more fuel-wood was consumed in test 2 (6.4 kg h^{-1}) than in test 1 (5.0 kg h^{-1}) although the outdoor temperature during test 2 (7.5 °C) was high compared to test 1 (-8 °C). During test 2, the lower part of the canvas was not covered with snow, which may have increased the inflow of air into the hut, thereby affecting wood combustion and indoor temperature. Consequently, in this study we did not find any consistent relationship between wood consumption and outdoor temperature.

Our results indicate that total consumption during winters (i.e. 6 months) was ~31 m^3 of wood per hut, i.e. ~6.9 m^3 per person. When extrapolated to an approximate annual consump-
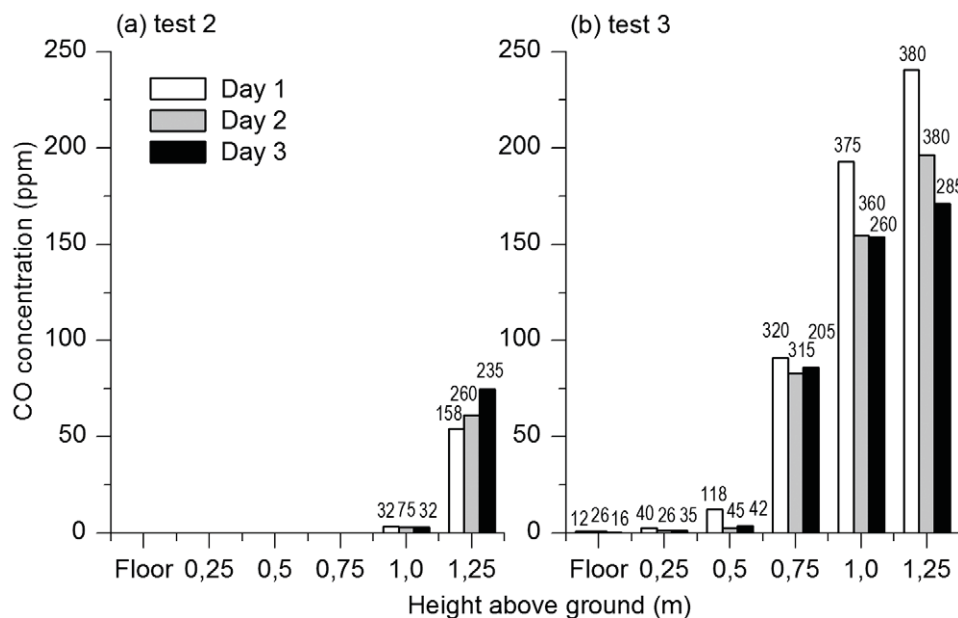
FIGURE 5. Mean carbon monoxide concentrations recorded at indicated levels in the tent hut from 8:15 to 18:00 ($n = 41$ day^{-1}) during (a) test 2 and (b) test 3. Values show the maximum carbon monoxide concentration recorded each day.

LARS ÖSTLUND ET AL. / 377

tion, our results indicate that more than 42 m^3 of wood was needed per hut, or approximately 9.3 m^3 per person, assuming that 4.5 people lived in each hut on average (see Bergman et al., 2008; Josefsson et al., 2010a). This is 60% higher than the amount derived from a previous experiment (also in a Sami hut, but using unseasoned birch wood) by Liedgren and Östlund (2011). It is also much higher than the average fuelwood consumption calculated by Arpi (1959)—7 m^3 per person in agrarian societies in Sweden—and by Anonymous (1924:48) (3.4 m^3 per person). However, more than twice as high consumption (0.043 m^3 vs. 0.02 m^3 per day and person) was derived from a detailed investigation of firewood consumption in loggers' cabins (also uninsulated, with open smoke holes) during the early 20th century, although it should be noted that up to 36 loggers lived in a logging cabin at a given time (Anonymous, 1924:48).

Data on fuelwood consumption in other regions in pre-industrial times vary considerably. For example, in Paris (France) Randet (1944) found that approximately 1.2 m^3 of dry wood was consumed per person annually in 1850, while Whitney (1994) estimated that 70 to more than 200 m^3 was consumed per family and year in the eastern United States (rough estimates, with no indications of family size). Clearly, many previous studies do not provide enough detail for robust comparisons. However, the high fuelwood consumption in this experimental study indicates that quite intense fires were needed to maintain a tolerable indoor climate in the uninsulated tent huts used by the Sami. Accordingly, substantial amounts of wood were needed.

Fuelwood derived from standing dead pine trees, which have been dead for decades or even longer, has several distinct qualities. Notably its relative dryness (13–32% water content; Table 2) allows it to be immediately burnt (even the wood with the highest water content burnt well during the tests). We expected the wood used in our experiments to have lower water contents, but evidently there was large variation (the wood used during the first test was considerably drier, 14–16% water content, than the wood used in the subsequent two tests, 15–32% water content; Table 2). Consequently, the fuelwood consumption was lowest in test 1, although the outdoor temperature was the second lowest of the three tests (Table 3, Fig. 3). The relative dryness of the wood compared to unseasoned wood (with a water content up to 50%) also makes these trees much easier to cut, haul to a settlement site, and split. Furthermore, pine wood has a higher fuel value per kilogram, burns more easily, and generates less smoke than the unseasoned birch wood used by Sami people in the high-altitude forest dominated by deciduous trees (Table 2; cf. Liedgren and Östlund, 2011). Another important difference between pine wood and birch wood is that it is impossible to start and maintain a fire with unseasoned pine wood, in contrast to unseasoned birch wood, due to differences in cell structure and the way water evaporates from the wood during burning (Ryd, 2005).

INDOOR CLIMATE

Key variables of the climate in a tent hut are the temperature and smokiness in the ''comfort-zone'' around the hearth. Although the outside temperature varied greatly (from −20.9 to 8.8 °C) during the 9 days of experimental burning, the mean temperature near the hearth varied much less (and was much more comfortable),

ranging from 11.6 to 19.1 °C. Clearly, maintaining a tolerable indoor climate would be heavily dependent on an even supply of fuelwood, but it may also be related to other factors. In this experimental study two different types of hearths were used, one with (in tests 2 and 3) and one without (in test 1) stone packing, to test the hypothesis that a hearth with stone packing may contribute to a more stable or higher indoor temperature. Comparison of the overall mean temperatures recorded in tests 1 and 3 (excluding the data from test 2, since there was no snow and exceptionally high outdoor temperatures, exceeding 0 °C), show that temperatures near the hearth and below the smoke hole (but not close to the canvas) were significantly higher when the hearth with stone packing was used. During test 3 the outside temperature was considerably lower than during test 1, which could explain the low temperatures recorded close to the canvas. On the other hand, the fuelwood consumption was much higher in test 3, which may have contributed to the higher temperatures recorded during this test. Consequently, more information is required to determine whether stone packing of an *árran* hearth creates a more stable indoor climate during firing.

Our experiment also included burning of resin-rich wood (test 2). This kind of fuelwood was commonly derived from trees that had been standing for several decades or longer. Important findings from the experiment are that resin-rich pine wood can raise the temperature and provide abundant light as it produces very bright flames (Fig. 4). During the 1.5 h resin-rich pine wood was used, the indoor conditions were warmer. However, burning resin-rich pine wood also has a negative side-effect as it generates large amounts of soot within the tent hut. This soot will blacken the canvas inside and also clothes, people and utensils. Therefore, resin-rich pine-wood was probably used only occasionally, e.g. to provide light during the long, dark winter and to increase the indoor temperature during very cold periods (cf. Ryd, 2005).

The results from our tests strongly indicate that the living space in Sami tent huts was restricted during winter, mainly due to reductions in the intake of fresh air, and high consequent concentrations of carbon monoxide and smoke. Levels of carbon monoxide exceeded noxious thresholds (35 ppm; Anonymous, 2005) at heights greater than 0.5–0.75 m above the ground generally during the tests, but varied according to the intensity of the fire and time since new fuel was added (Fig. 5). Reducing the fresh air intake also clearly increased the scope for maintaining comfortable temperatures in the floor area, which would have been important during cold winter days. These findings explain why travelers visiting Sami tent dwellings frequently commented on the unpleasant smoky conditions and noted that the smoke made some of the Sami blind when they became old (Leem, 1975:102; Ehrenmalm and Stenmark, 2001:138; Linné, 2003:122).

Our results also indicate that the floor-level temperature at the outer periphery of the huts was usually very cold, probably close to the outdoor temperature. Thus, when living in a tent hut during winter the Sami presumably had to balance two conflicting requirements, for warmth versus clean air. In essence there is a limited living space inside a tent hut in winter which is neither too cold nor too smoky, approximately a meter from the fire and reaching up to about 0.75 m above the floor. Thus, this tolerable living space
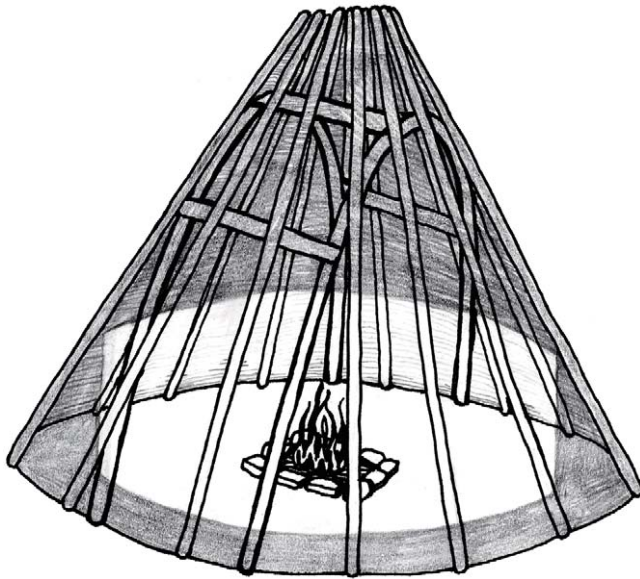
FIGURE 6. The living space inside a Sami tent hut estimated from temperature and carbon monoxide data. Note that the drawing depicts a traditional Sami tent hut with beams supporting the tent, not the modern type used in the tests. Illustration: Gerd Aurell.

is only around a third of the total space inside the hut (Fig. 6). Still, it should be noted that the concept of ''comfort-zone'' and tolerable indoor climate can have a different meaning to different people. Naturally, the Sami people residing year-round in these tent-huts were used to these living conditions and could tolerate temperatures and smokiness that were too detrimental for the health of people occasionally traveling through these parts of Scandinavia.

ECOLOGICAL EFFECTS OF CUTTING TREES FOR FUELWOOD

Deciphering the relationships between past utilization of natural resources and the structure and functions of ecosystems is one of the most intriguing tasks for archaeologists and history-oriented ecologists (Östlund and Bergman, 2006; Johnson and Miyanishi, 2012). In order to elucidate the environmental effects of pre-industrial land use in northern subarctic forests, assessing the magnitude of fuelwood consumption and related tree cutting at landscape scales is crucial. Our results indicate that ~31 m³ of fuelwood was consumed during the winter, and ~11 m³ during the rest of the year, per Sami hut, assuming that wood from standing dead pines was burned in fires that were maintained all day for 6 months during the winter, half the day for 3 months during the spring and autumn, and irregularly (for 25% of the time on average) for 3 months during the summer (Table 3). As discussed above, wood taken from standing dead pine trees was ideal as fuel, thus such trees were commonly cut close to settlement sites.

Central issues to consider when interpreting the ecological impact across landscapes of this form of land use are the quantities of trees that were cut annually in an area used by a Sami family, and the distances that the fuelwood was transported to the camp sites. The trees used as fuelwood in this study had an average volume of 0.16 m³ and an average dbh of 17.5 cm (Table 1), which is smaller than the likely average size of pine trees in the pre-industrial landscape (cf. Rouvinen et al., 2005; Josefsson et al.,

2010b). According to detailed forest landscape data derived from Josefsson et al. (2010b), the mean volume of pine trees with a mean height of 12 m and mean diameter of 25 cm dbh growing in the Tjeggelvas Nature Reserve, ca 80 km north of our study site (66°N, 17°E), is approximately 0.3 m³. Assuming that the trees were of this size and that approximately 42 m³ was consumed annually in pre-industrial times, about 140 trees were cut for fuel per tent hut, but almost certainly this figure is too conservative for a settlement, since a Sami family commonly consisted of 2–4 households, each residing in separate huts (Hultblad, 1968:122; Bergman et al., 2008; Josefsson et al., 2010a).

As in other pastoralist economies throughout the northern hemisphere, the population density in the study region was very low in the past, i.e. about one person or less per square kilometer (Mulk, 1994:189–194). Previous studies on Sami social organization have provided estimates for the average size of a household during the 18th and 19th centuries of approximately 4–5 persons (Hoppe, 1945:54; Kvist and Wheelersburg, 1997). Taking family size into account, the annual consumption of fuelwood was more likely between 80 and 160 m³, i.e. about 240 to 480 trees. However, to examine the ecological effects on the forest structure of cutting trees for fuelwood, and estimate the distance the fuelwood was transported, we need data on the spatiotemporal availability of dead pine trees.

In the following sections we compare our estimates of fuelwood consumption with actual volumes of dead standing wood available in similar pine forests (situated in nature reserves with a history of low impact by modern land use such as logging). Before the introduction of modern forestry, trees generally died of natural causes, for example forest fires with intervals from 30–100 years (Zackrisson, 1977; Niklasson and Granström, 2000) up to 300 years (Carcaillet et al., 2007; Wallenius et al., 2010). Trees would also die due to old age, pathogen attacks, and windthrow, which occurred at irregular intervals, resulting in varying distributions of downed trees over various spatial scales (Gromtsev, 2002; Shorohova et al., 2009). According to detailed field surveys of tree mortality in old pine-dominated forests in northeast Finland by Ilvessalo (1967), dead pine wood is generally formed at rates ranging from 1.4 to 1.8 m³ ha⁻¹ yr⁻¹. Similarly, Rouvinen et al. (2002) found that the mortality rate of pine trees in a late-successional forest with no history of commercial logging in northwest Russian Karelia is ~1.4 m³ ha⁻¹ yr⁻¹. Based on this mortality rate and an approximate annual consumption of fuelwood between 80 and 160 m³ (240 to 480 trees), we estimate that the total area required to sustain one Sami family (using 2–4 huts) with enough fuelwood was ca 60–120 ha. However, what does this figure imply when extrapolated to the larger landscape?

Generally, the Sami groups were not stationary but moved between different settlement sites on an annual basis (cf. Ruong, 1944; Schefferus, 1956; Manker, 1968), using and affecting different parts of the landscapes at various magnitudes and times of the year. The number of settlement sites that were used varied from year to year, due to both seasonal and inter-annual fluctuations in access to specific resources, e.g. good pasture lands for their reindeer (*Rangifer tarandus* L.), edible plants and berries, and possibly fuelwood (Andersson et al., 2005). An approximation of the number of settlement sites used each year is crucial for robustly estimat-

Lars Östlund et al. / 379

TABLE 4

Total area (ha) required to access sufficient fuelwood—calculated for different radii from the center of a settlement, assuming that the indicated numbers of sites were used by the Sami on an annual basis.

No. Settlement sites	Radius from center of settlement site (m)				
	100	150	200	250	300
1	3.1	7.1	12.6	19.6	28.3
2	6.3	14.1	25.1	39.3	56.5
3	9.4	21.2	37.7	58.9	*84.8*
4	12.6	28.3	50.3	*78.5*	*113.1*
5	15.7	35.3	*62.8*	*98.2*	**141.4**
6	18.8	42.4	*75.4*	*117.8*	**169.6**
7	22.0	49.5	*88.0*	**137.4**	**197.9**
8	25.1	56.5	100.5	**157.1**	**226.2**
9	28.3	*63.6*	113.1	**176.7**	**254.5**
10	31.4	*70.7*	**125.7**	**196.3**	**282.7**

Note: Values in italics and bold indicate that enough area is covered to support the annual need for fuel wood in two huts/household (i.e. >60 ha) and four huts/household (i.e. >120 ha), respectively.

ing the distances fuelwood was transported as well as the overall impact across the forested landscape. However, we can obtain crude estimates of the foraging areas needed to collect the required fuelwood, assuming that specified numbers of settlement sites were used annually, from the assumed volumes of standing dead trees. As shown in Table 4, sufficient fuelwood to support one family with up to 4 households (i.e. 4 huts) could be putatively collected from within a radius of 300 m—supposing that at least 5 settlement sites were used. Furthermore, assuming that the winter consumption of pine wood during one year was ca 31 m^3 per hut, and that the mortality rate of pine trees is ca 1.4 m^3 ha^{-1} yr^{-1}, the estimated radius for collecting standing dead pine trees around a settlement site with one tent-hut was approximately 266 m (equal to 22 ha), and for two huts ca 376 m (equal to 43 ha).

Based on these results and on past population data/spatial extent of pine forest (derived from Josefsson et al., 2010a), we can also extrapolate the ecological impacts of winter fuel wood acquisition to the larger landscape. Within an area covering almost 500 km^2, today encompassing the Tjeggelvas Nature Reserve, ca 10 Sami households were present during the 18th and 19th centuries (Josefsson et al., 2010a). During the winter, these households lived and moved within a pine forest that covers an area of ca 100 km^2. According to our results, each household used ca 31 m^3 of dead trees for fuel each winter, corresponding to ca 22–44 ha of utilized forest land around each settlement (i.e. 1–2 huts/households per settlement). Hence, the total firewood collection zones within this landscape account for only 2.2% of the pine forest land, indicating a minor impact at the landscape level. Although the density of Sami settlements has varied geographically, as well as over time, it is reasonable to interpret the settlements as more intensively used smaller islands in a sea of forest with minor human impact (cf. Berg, 2010).

Naturally, the acquisition of fuel-wood around the winter settlements required transportation over greater distances due to the higher consumption of wood during this period. It is plausible,

however, that the impact on the forest by firewood cutting at some winter settlements was large, which may have caused more frequent inter-annual relocation of these camps. Furthermore, killing trees by girdling or damaging the cambium layer underneath the outer bark was a common practice among peoples in northern Scandinavia, and e.g. was used in order to create firewood and open up dense forests for grazing (Ericsson, 2001). This practice has also been documented in the vicinity of Sami settlements (Andersson et al., 2005). It is quite likely that this was also a common practice around Sami settlements when the natural resource of dead standing pines had diminished due to cutting. If so, the ''fire-wood collection zone'' around a settlement was more limited in size. This would also imply that a forest management perspective on historic Sami forest use must be considered.

Consequently, the ecological implications of this form of land use are difficult to assess. Dead wood is an important substrate for many forest-dwelling species and thus a focus of many restoration projects (Siitonen, 2001). Although the immediate effect of a certain land use (such as cutting standing dead trees for fuel wood) may seem insignificant, its cumulative effects locally may be extensive if carried out over long periods of time (Foster et al., 2003). Our estimations indicate that standing dead trees were sparse in the vicinity of Sami settlement sites, but not in the surrounding forest.

EXPERIMENTAL APPROACHES FOR ANALYZING PAST RESOURCE UTILIZATION

Pre-industrial land use in northern subarctic forests varied in strength and intensity, both seasonally and annually (cf. Nelson, 1983; Vitebsky, 2005; Josefsson et al., 2010a), creating a complex mosaic of human disturbance. Such land use can be described and analyzed by using palynological (Hicks, 1993; Josefsson et al., 2009), dendrochronological (Niklasson et al., 1994; Berg et al., 2011), and historical records (Josefsson et al., 2010a). Retrospective experiments designed (for example) to assess differences in areas subjected to different land uses can also be valuable for elucidating gradients of land use (Foster et al., 1999) and long-term trends in human impact on ecosystems. To date, there have been few experimental studies aimed at acquiring quantitative data on historical resource use. However, as shown in this study they can provide specific data that can be used to verify (or refute) qualitative interpretations. Modeling of historical human impact, e.g. deforestation in the past, also relies on good quantitative data on resource use (Lev-Yadun et al., 2010). Most historical records provide little (if any) information on the acquisition of non-commercial resources by activities such as fishing and hunting for food, extraction of fuelwood, and timber for local construction. Therefore, these activities and their effects on ecosystems tend to be underestimated, even though they might be the most prominent forms of land use over longer time periods. Thus, we believe that a combination of methods and approaches is required to decipher human disturbance of northern low-productivity ecosystems with historically low densities of people (cf. Josefsson, 2009).

Acknowledgments

References Cited

Alexandersson, H., and Eggertsson Karlström, C., 2001: *Temperaturen och nederbörden i Sverige 1961–1990: Referensnormaler*. 2nd edition. Norrköping: SMHI, 71 pp.

Andersson, R., Östlund, L., and Törnlund, E., 2005: The last European landscape to be colonised: a case study of land-use change in the far north of Sweden 1850–1930. *Environment and History*, 11: 293–318.

Anonymous, 1924: *Förbrukning av virke till husbehov på Värmlands läns landsbygd: betänkande* [*Consumption of Wood for Household Requirements in the Rural Areas of Värmland County: a Report*]. Statens offentliga utredningar 1924:42. Stockholm: P.A. Norstedt & Söner, 78 pp. (in Swedish).

Anonymous, 2005: *Occupational Exposure Limit Values and Measures against Air Contaminants*. Statute Book of the Swedish Work Environment Authority 1650–3163; 2005:17. Solna: Swedish Work Environment Authority, 134 pp.

Arpi, G., 1959: *Sveriges skogar under 100 år: en sammanfattande redogörelse över det svenska skogsbruket 1859–1959, del 1* [*Swedish Forests during 100 Years: a Summary of Swedish Forestry 1859–1959, Part I*]. Stockholm: Domänverket, 241 pp. (in Swedish).

Berg, A., 2010: Reindeer herding and modern forestry: the historical impacts on forests of two main land users in northern Sweden. PhD doctoral dissertation, Swedish University of Agricultural Sciences, Umeå, Sweden.

Berg, A., Josefsson, T., and Östlund, L., 2011: Cutting of lichen trees: a survival strategy used before the 20th century in northern Sweden. *Vegetation History and Archaeobotany*, 20: 125–133.

Bergman, I., Liedgren, L. G., Östlund, L., and Zackrisson, O., 2008: Kinship and settlements: Sami residence patterns in the Fennoscandian alpine areas around A.D. 1000. *Arctic Anthropology*, 45: 97–110.

Carcaillet, C., Bergman, I., Delorme, S., Hörnberg, G., and Zackrisson, O., 2007: Long-term fire frequency not linked to prehistoric occupations in northern Swedish boreal forest. *Ecology*, 88: 465–477.

Clawson, M., 1979: Forests in the long sweep of American history. *Science*, 204: 1168–1174.

Ehrenmalm, A., and Stenmark, G., 2001: *Renskrift av Arwid Ehrenmalms resa till Åsele Lappmark 1741* [*Fair Copy of Arwid Ehrenmalms Journey to Åsele Lapland 1741*]. Ramsele: SVAR, 64 pp. (in Swedish).

Ericsson, T. S., 2001: Culture within nature: key areas for interpreting forest history in boreal Sweden. Acta Universitatis Agriculturae Sueciae. Silvestria 227. Doctoral dissertation, Department of Forest Vegetation Ecology, University of Agricultural Sciences, Umeå, Sweden.

Foster, D. R., Fluet, M., and Boose, E. R., 1999: Human or natural disturbance: landscape-scale dynamics of the tropical forests of Puerto Rico. *Ecological Applications*, 9: 555–572.

Foster, D. R., Swanson, F., Aber, J. D., Burke, I., Brokaw, N., Tilman, D., and Knapp, A., 2003: The importance of land-use legacies to ecology and conservation. *Bioscience*, 53: 77–88.

Grape, E. J., and Weinz, E., 1969: *Utkast till beskrifning öfver Enontekis sokn i Torneå lappmark* [*Draft for a Description of the Enontekis Parish in Torneå Lapland*]. Tornedalica 7. Luleå: Tornedalica (in Swedish).

Gromtsev, A., 2002: Natural disturbance dynamics in the boreal forests of European Russia: a review. *Silva Fennica*, 36: 41–55.

Hicks, S., 1993: Pollen evidence of localized impact on the vegetation of northernmost Finland by hunter-gatherers. *Vegetation History and Archaeobotany*, 2: 137–144.

Hoppe, G., 1945: *Vägarna inom Norrbottens län: studier över den trafikgeografiska utvecklingen från 1500-talet till våra dagar* [*The Roads of Norrbotten: Studies of the Traffic–Geographical Development from the 1500s until Today*]. Uppsala: Lundequistska bokhandeln (in Swedish).

Hultblad, F., 1968: *Övergång från nomadism till agrar bosättning i Jokkmokks socken* [*Transition from Nomadism to Farming in the Parish of Jokkmokk*]. Acta Lapponica XIV. Stockholm: Almqvist & Wiksell/Gebers, 451 pp. (in Swedish).

Ilvessalo, Y., 1967: On the development of natural normal forest stands in south-eastern north-Finland. *Acta Forestalia Fennica*, 81: 1–85 (in Finnish with English summary).

Johnson, E. A., and Miyanishi, K., 2012: The boreal forest as a cultural landscape. *Annals of the New York Academy of Sciences*, 1249: 151–65.

Josefsson, T., 2009: Pristine forest landscapes as ecological references: human land use and ecosystem change in boreal Fennoscandia. Doctoral dissertation, Department of Forest Ecology and Management, Swedish University of Agricultural Sciences, Umeå, 70 pp.

Josefsson, T., Hörnberg, G., and Östlund, L., 2009: Long-term human impact and vegetation changes in a boreal forest reserve: implications for the use of protected areas as ecological references. *Ecosystems*, 12: 1017–1036.

Josefsson, T., Bergman, I., and Östlund, L., 2010a: Quantifying Sami settlement and movement patterns in northern Sweden 1700–1900. *Arctic*, 63(2): 141–153.

Josefsson, T., Gunnarson, B., Liedgren, L., Bergman, I., and Östlund, L., 2010b: Historical human influence on forest composition and structure in boreal Fennoscandia. *Canadian Journal of Forest Research*, 40: 872–884.

Kaplan, J. O., Krumhardt, K. M., and Zimmermann, N., 2009: The prehistoric and preindustrial deforestation of Europe. *Quaternary Science Reviews*, 28: 3016–3034.

Karjalainen, L., and Kuuluvainen, T., 2002: Amount and diversity of coarse woody debris within a boreal forest landscape dominated by *Pinus sylvestris* in Vienansalo wilderness, eastern Fennoscandia. *Silva Fennica*, 36: 147–167.

Karlsson, H., Shevtsova, A., and Hörnberg, G., 2009: Vegetation development at a mountain settlement site in the Swedish Scandes during the late Holocene: palaeoecological evidence of human-induced deforestation. *Vegetation History and Archaeobotany*, 18: 297–314.

Kinnman, G., 1928: Virke för husbehov [Wood for household requirements]. *In* Wahlgren, A., and Schotte, G. (eds.), *Sveriges skogar och huru vi utnyttja dem*. Del II [*The Forests of Sweden and How We Use Them*. Part II]. Stockholm: Hökerbergs, 1361–1396 (in Swedish).

Kristinsson, H., 1995: Post-settlement history of Icelandic forests. *Journal of Icelandic Agricultural Sciences*, 9: 31–35.

Kvist, R., and Wheelersburg, R. P., 1997: Changes in Saami socioeconomic institutions in Jokkmokk parish 1720–1890. *Arctic Anthropology*, 34(2): 1–11.

Læstadius, P., 1831: *Journal af Petrus Laestadius för första året af hans tjenstgöring såson missionaire i Lappmarken* [*Journal of Petrus Laestadius' First Year as Missionary in Lapland*]. Stockholm: Haeggström, 480 pp. (in Swedish).

Leem, K., 1975: *Beskrivelse over Finmarkens Lapper 1767* [*Description of the Lapps in Finmarken 1767*]. København: Rosenkilde og Bagger, 82 pp. (in Danish).

Lev-Yadun, S., Lucas, D. S., and Weinstein-Evron, M., 2010: Modeling the demands for wood by the inhabitants of Masada and for the Roman siege. *Journal of Arid Environments*, 74: 777–785.

Liedgren, L., and Bergman, I., 2009: Aspects of the construction of prehistoric Stállo-foundations and Stállo-buildings. *Acta Borealia*, 26: 3–26.

Liedgren, L. G., and Östlund, L., 2011: Heat, smoke and fuel consumption in a high mountain stállo-hut, northern Sweden: experimental burning of fresh birch wood during winter. *Journal of Archaeological Science*, 38: 903–912.

Linder, P., and Östlund, L., 1998: Structural changes in three mid-boreal Swedish forest landscapes, 1885–1996. *Biological Conservation*, 85: 9–19.

Linné, C. v., 2003: *Iter Lapponicum = Lappländska resan: 1732* [*Iter Lapponicum = The Lapland Journey: 1732*]. Umeå: Skytteanska samf., 199 pp. (in Swedish).

Ludemann, T., 2010: Past fuel wood exploitation and natural forest vegetation in the Black Forest, the Vosges and neighbouring regions

in western Central Europe. *Palaeogeography Palaeoclimatology Palaeoecology*, 291: 154–165.

Ludemann, T., Michiels, H. G., and Nolken, W., 2004: Spatial patterns of past wood exploitation, natural wood supply and growth conditions: indications of natural tree species distribution by anthracological studies of charcoal-burning remains. *European Journal of Forest Research*, 123: 283–292.

Manker, E., 1944: *Lapsk kultur vid Stora Lule älvs källsjöar: en etnografisk inventering inom uppdämningsområdet vid Suorva* [*Sami Culture at the Great Lule River Source Lakes: an Ethnographic Inventory within the Damming at Suorva*]. Acta Lapponica IV. Stockholm: Geber, 280 pp. (in Swedish).

Manker, E., 1968: *Skogslapparna i Sverige: fältanteckningar* [*The Forest Lapps in Sweden: Field Notes*]. Stockholm: Almkvist & Wiksell, 281 pp. (in Swedish).

Mulk, I. M., 1994: Sirkas: a Sami hunting society in transition AD 1–1600. Doctoral dissertation, Department of Archaeology, Umeå University, Umeå, Sweden, 305 pp.

Nelson, R. K., 1983: *Make Prayers to the Raven: a Koyukon View of the Northern Forest*. Chicago: University of Chicago Press, 292 pp.

Niklasson, M., and Granström, A., 2000: Numbers and sizes of fires: long-term spatially explicit fire history in a Swedish boreal landscape. *Ecology*, 81: 1484–1499.

Niklasson, M., Zackrisson, O., and Östlund, L., 1994: A dendroecological reconstruction of use by Sami of Scots pine (*Pinus sylvestris* L.) inner bark over the last 350 years at Sädvajaure. *Vegetation History and Archaeobotany*, 3: 183–190.

Östlund, L., and Bergman, I., 2006: Cultural landscapes in northern forests: time, space and affiliation to the land. *In* Agnoletti, M. (ed.), *Conservation of Cultural Landscapes*. Wallington: CABI Publishing, 30–40.

Perlin, J., 1989: *A Forest Journey: the Role of Wood in the Development of Civilization*. Woodstock: The Countryman Press, 445 pp.

Pettersson, O. P., 1979: *Kristoffer Sjulssons minnen: om Vapstenlapparna i början af 1800-talet* [*Kristoffer Sjulsson's Memoirs: about the Vapsten Lapps in the Early 1800s*]. Acta Lapponica XX. Stockholm: Nordiska Museet, 341 pp. (in Swedish).

Randet, P., 1944: Le bois de feu dans l'économie générale [Firewood in the general economy]. *Revue des Eaux et Forets*, 82: 433–457 (in French).

Rouvinen, S., Kuuluvainen, T., and Siitonen, J., 2002: Tree mortality in a *Pinus sylvestris* dominated boreal forest landscape in Vienansalo wilderness, eastern Fennoscandia. *Silva Fennica*, 36: 127–145.

Rouvinen, S., Rautiainen, A., and Kouki, J., 2005: A relation between historical forest use and current dead woody material in a boreal protected old-growth forest in Finland. *Silva Fennica*, 39: 21–36.

Ruong, I., 1944: Något om den gamla skogsrenskötseln i Arvidsjaurs socken [Facts about old forest reindeer herding in the Arvidsjaur parich]. *In* Enequist, G., and Hjulström, F. (eds.), *Geografiska studier tillägnade John Frödin den 16 april 1944* [*Studies in Geography Dedicated to John Frödin 16th of April 1944*]. Geographica 15. Uppsala: Appelbergs, 92–101 (in Swedish).

Ruong, I., 1945: *Studier i lapsk kultur i Pite lappmark och angränsande områden* [*Studies in Sami culture in Pite Lapland and neighboring areas*]. Stockholm: P.A. Norstedt & Söner, 123–194 pp. (in Swedish).

Ryd, Y., 2005: *Eld: flammor och glöd—samisk eldkonst* [*Fire: flames and glowing coal—Sami fire-making*]. Stockholm: Natur och kultur, 428 pp. (in Swedish with English summary).

Schefferus, J., 1956: *Lappland (Lapponia) 1673* [*Lapland (Laponia) 1673*]. Acta Lapponica VIII. Uppsala: Almqvist & Wiksell, 472 pp. (in Swedish).

Shorohova, E., Kuuluvainen, T., Kangur, A., and Jogiste, K., 2009: Natural stand structures, disturbance regimes and successional dynamics in the Eurasian boreal forests: a review with special reference to Russian studies. *Annals of Forest Science*, 66: 1–20.

Siitonen, J., 2001: Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. *Ecological Bulletins*, 49: 11–41.

Taylor, B., 1859: *Nordisk resa: sommar- och vinterbilder från Sverige, Lappland och Norrige* [*Northern Travel: Summer and Winter Pictures of Sweden, Lapland, and Norway*]. Stockholm: Berg, 339 pp. (in Swedish).

Vitebsky, P., 2005: *The Reindeer People: Living with Animals and Spirits in Siberia*. New York: Houghton Mifflin Company, 464 pp.

von Düben, G., 1873: *Om Lappland och lapparne, företrädesvis de svenske: ethnografiska studier* [*About Lapland and the Lapps, Especially the Swedish: Ethnographic Studies*]. Stockholm: Norstedt, 528 pp. (in Swedish).

Wallenius, T. H., Kauhanen, H., Herva, H., and Pennanen, J., 2010: Long fire cycle in northern boreal *Pinus* forests in Finnish Lapland. *Canadian Journal of Forest Research*, 40: 2027–2035.

Whitney, G. G., 1994: *From Coastal Wilderness to Fruited Plain: a History of Environmental Change in Temperate North America, 1500 to the Present*. Cambridge: Cambridge University Press, 451 pp.

Zackrisson, O., 1977: Influence of forest fires on the north Swedish boreal forest. *Oikos*, 29: 22–32.

MS accepted May 2013