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VANISHED VILLAGES – IMPRINT OF TRADITIONAL AGRICULTURE IN FOREST LANDSCAPE OF WESTERN WHITE SEA KARELIA

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The traditional way of living has affected forest landscapes surrounding the villages. We analyzed forest structure of old landscapes using satellite images and forestry maps, in the Kostomuksha region, in the western White Sea Karelia. The signs of past agricultural communities were still clearly visible in the forests surrounding the old villages. Using the population data from the two population censuses done in the early 20th century, we created scaled land use zones based on the results of our forest data analysis and put them on the map in order to reconstruct the past landscape. Finally, we discuss the activities that have affected forest structure around the villages.

K e y w o r d s: forest landscape structure, forest history, environmental history of Karelia, GIS analysis of historic landscapes.

О.-П. Тикканен, И. А. Чернякова, Р. Хейккиля. ИСЧЕЗНУВШИЕ ДЕРЕВНИ – ОТПЕЧАТОК ТРАДИЦИОННОГО СЕЛЬСКОГО ХОЗЯЙСТВА В ЛАНДШАФТАХ ЗАПАДНОЙ ЧАСТИ БЕЛОМОРСКОЙ КАРЕЛИИ

Традиционный уклад жизни существенно повлиял на лесной ландшафт вблизи деревень. При помощи спутниковых изображений и лесных карт нами был проведен анализ существовавших ландшафтных форм в Костомукшском округе и в западной части Беломорской Карелии. На территориях лесов вокруг деревень до сих пор отчетливо видны следы сельскохозяйственной деятельности людей, ранее населявших данные местности. На основе двух переписей населения, проведенных в начале XX века, а также результатов проведенного нами анализа данных по лесам было осуществлено масштабное зонирование землепользования. Эти зоны были нанесены на карту для наглядного восстановления исторического ландшафта. В заключении рассмотрены те виды деятельности, которые оказали влияние на структуру леса вокруг деревень.

К л ю ч е в ы е с л о в а: структура лесного ландшафта, история леса, экологическая история Карелии, ГИС-анализ исторических ландшафтов.

Introduction

Human activity has shaped forests in Europe since the end of the last glaciation [Williams, 2003]. In the boreal forests of the eastern Fennoscandia the human impact on the forest landscape started to increase after the adoption of effective slash and burn agricultural methods in the 15th and 16th century [Taavitsainen et al., 1998; Orrman, 2003]. Since the crop plants grown on burned soils depleted available nutrients already in a year, the need for the forests and thus the forest area, affected by slash and burn agriculture, was high in the end of the 19^{th} century [Heikinheimo, 1915], which can be considered the endpoint of the traditional agriculture era in Fennoscandia. New, nontraditional cultivation methods started to take place [Soininen, 1974] and there were some official attempts to inhibit forest use to slash and burn agriculture [Rytteri, 2006] in order to save firewood and timber for the needs of industry. In Russia slash and burn agriculture was banned in 1870's.

Forest clearance for agricultural land and shifting slash and burn agriculture are obvious and well known examples of the effects of traditional way of living on forest landscape [Berg, 1988; Heikinheimo, 1915]. However, early Finnish records on the use of wood suggest that some other purposes may have been even more important, particularly in the remote northern areas where climate is less favorable for agriculture [Soininen, 1974]. The effect of fire wood extraction on the landscape has probably been especially substantial [Soininen, 1974]. Active measures to control slash and burn agriculture could not affect the use of wood for heating houses and crofts. Moreover, in the perimeter of the agricultural zone of the Eastern Fennoscandia, houses largely constituted black crofts without chimneys up to the early 20th century. Apparently, this heating method demanded lots of firewood.

Based on the previous knowledge about the forest use in the communities practicing traditional agriculture, it could be assumed that there are land use zones with varying forest structure around the villages, in the Eastern Fennoscandia. Especially in Karelia, dwellings formed compact villages. The fields are located in the centre because field cultivation takes the largest continuous effort (ploughing, harrowing, manure hauling, harvesting etc.). Behind the fields there probably are old slashes and burn areas which may have been transformed to pastures due to livestock grazing. We can also assume that the livestock was kept close to the settlements because of the need for daily milking and guarding from large carnivores. Behind the fields there should also be a zone, where all the trees suitable for firewood have been logged due to a big demand of firewood and close hauling distance to the houses. Depending on the size and age of settlements these fire wood collection zone have penetrated deep in the surrounding matrix of natural forest. The outermost impact zone might have consisted of the sites of selective loggings of highly preferred building timber.

If we assume that preferences for firewood and building timber are selective, the last zone should be diluted in the matrix without a clear edge, and in practice there is a gradient of decreasing human impact on the forest structure, rather than separate zones assigned for different land use purposes, if we exclude cultivated fields. Moreover, the expansion of impact zone has not been straightforward. At some point, growth of regenerating trees has compensated the need to extract firewood from longer distances. On the other hand, livestock grazing may have hindered the regeneration of trees. These multiple factors, affecting forest structure surrounding old villages, make *ad hoc* calculations of impact zones difficult. Therefore, we need some empirical data. Since tree regeneration, growth, and death is a slow process in the north [Rouvinen et al., 2002], current forest structures may still retain useful information about the past landscape.

Forest structure consists of a few main elements, such as tree age, tree species and, in stand level, also a number of canopy layers and stand size. The inventories and mappings of forest resources offer one information source. In addition to these traditional methods, remote sensing data is very useful in the analyses of landscape structure. Normalized Difference Vegetation Index (NDVI) is a commonly used index that describes the vigor of vegetation. The NDVI values can be used to separate coniferous trees from early successional deciduous trees [Cuevas-Gonzáles et al., 2009]. In addition to the species composition, satellite imagery has been used to analyze forest stand volume [Tokola, 2000; Mäkelä, Pekkarinen, 2004; Muukkonen et al., 2005]. However, it is not exactly known which possible observed pattern, e.g. in NDVI values, is the most indicative in terms of forest structure and age. Therefore there is a need for supportive information from other sources. The best option is to use reference areas in field, but field studies are expensive. Alternatively we can compare the information from the satellite images to the information from more traditional sources i.e. forestry maps. A minimum requirement for the maps is the average age of stands indication. Unfortunately forest age is not the same thing as forest naturalness [Stokland, 2001]. Usually the information about forest structure in forestry maps is limited. Therefore, the information from the satellite images and forestry maps may supplement each other.

The aim of this study was to evaluate the intensity of human influence on the forest structure in relationship to the distance from the centres of former villages in the Kostomuksha region, in the

White Sea Karelia, in Russia. We analyzed the forest structure using the satellite images and forestry maps. Using population data from the two censuses done in the early 20th century, we created scaled land use zones based on the results of our forest data analysis and put them on the map in order to reconstruct the past landscape. Finally, we discuss the activities that have affected the forest structure around the villages.

Methods

Study area

In Russian Karelia, there are 20–30 settlements located in the vicinity of the Finnish border, varying between the larger villages of several dozen households to hamlets composed of a few houses. The villages are old, probably originating from the 16th century. Their livelihood has based on farming and slash, and burn agriculture of surrounding forests. However, it ended in the mid 19th century, when the burning of forests was prohibited by the government, although this probably continued in these remote areas illegally in somewhat smaller scale [Korablev, 1999]. Commercial tar production did not exist in the area. During the WW2 a part of the villages and hamlets were evacuated. In 1958 the government decided that that remaining villages are "perspectiveless" and they were emptied by force, but, in the best fields of some villages, haymaking probably continued to the end of 1980. Ever since, the human activity on the area has limited to the presence of border patrols and a small garrisons of the frontier guard. In 1983 the Kostomuksha Zapovednik (Strict Nature Reserve) was established on the area followed by the Kalevala National Park in 2007. After 1990 small scale farming and recreational activity started again in a few villages near the Kalevala NP.

Population of villages

We selected two 10 000 km^2 study areas where the landscape has still remained largely unchanged by the modern industrial forestry. The first area was the Kostomuksha Zapovednik and its surroundings and the second area was the Kalevala National Park and its surroundings. The locations of these study areas are shown in the Fig 1. These areas do not exactly match the areas of modern day nature reserves, but are considerably larger. We obtained the size of human population and the number of houses in the villages from two different sources. In Härkönen [1920], there is an appendix referring to the census done in 1905. The second source is the list of inhabited places compiled by Sergejev [2011], which is based on the census of 1926 done in the Autonomic Socialistic Republic of Karelia. We included a few solitary dwellings in the population of the nearby villages.

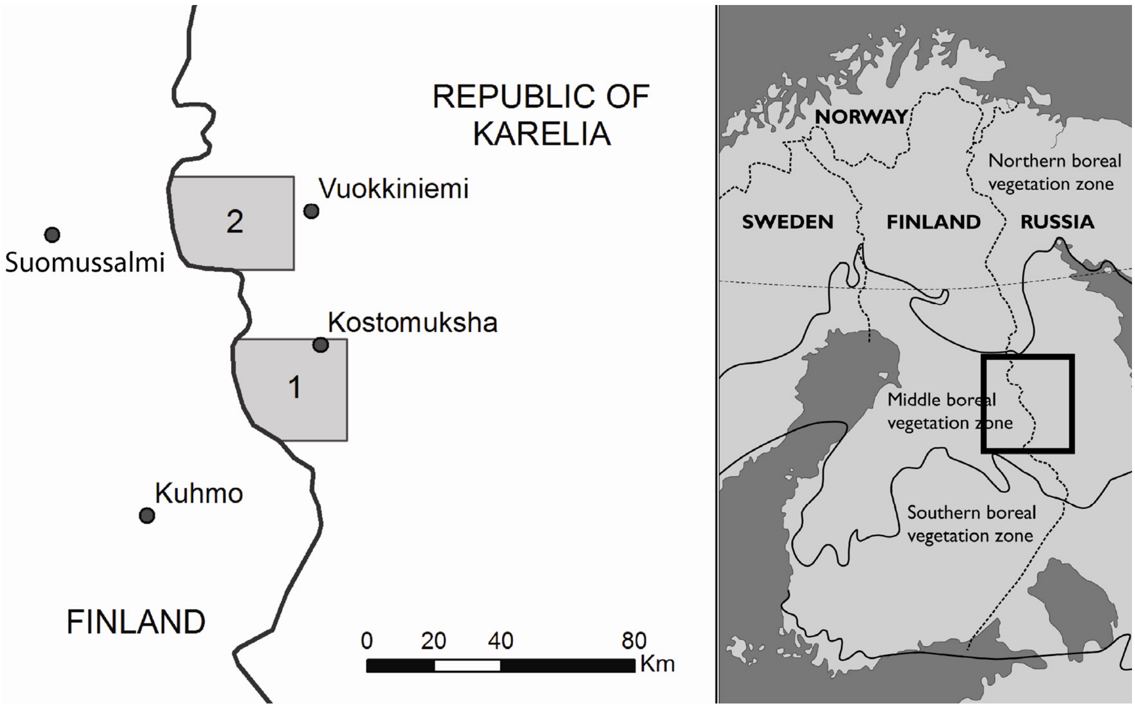

Fig. 1. The locations of the study areas in the western border of the Republic of Karelia. 1 = Kostomuksha Zapovednik and its surroundings, 2 = Kalevala National Park and its surroundings. Modern time population centers are placed and named on the map

Satellite image and vegetation index analysis

We obtained a Landsat 5 TM image data, which was taken on July 2005, from the web pages of U.S. Geological Service [2011] (PATH = 187, row 15). From this data, we produced two images, covering the study area using ERDAS imagine 2011 software; a false color image (RGB bands 4, 3 and 2) and non differentiated vegetation index image [NDVI = (band 4 – band 3) / (band 4 + band 3)]. Calculations of NDVI for a given pixel always result in a number between minus one and plus one. The NDVI value zero means no vegetation and values close to +1 (0.8–0.9), indicating the highest possible density of green leaves [NASA..., 2011]. Pixel size of the images was 30 m x 30 m. From the area shown on the satellite image, we selected eight villages for the further analyses. The main selection criterion was the absence of modern clear cut loggings within the distance of 6–8 km from the villages. Two of the villages were close to the present Kalevala NP (Haapovuara and Kivijärvi), five were on the area of Kostomuksha Zap. (Jehrimänvaara, Miinoa, Munankilahti, Sappovaara and Tetriniemi) and one on the buffer zone of Kostomuksha Zap. (Luvajärvi).

We marked out the village centres from the false color images visually and created raster layers for each village, which gave distance from the village centres in ESRI ArcGis 10 software. Then we created a five km buffer layer around the villages and a “point grid transect” (x-y point layer) starting from the village centres and ending in the buffer ring. We determined the x-y coordinates of points in MS Excel spread sheet with uniform distance of 150 m. A transect had three collinear point lines. For each transect, we choose a direction that was away from larger lakes and peat land areas. Because of systematic sampling, some points were located on small lakes and mires, and we removed these points manually. After the creation of point grid transects, we picked the distance and the NDVI values for each point using distance and NDVI rasters.

We produced the distance and NDVI value tables from the eight villages and analyzed the data using General Additive Model (GAM) with GRASP 3.2 extension of S-plus statistical package [Lehmann et al., 2011]. GAM is a semiparametric version of Generalized Linear model [Guisan et al., 2002]. It responds very flexible to nonlinear trends in data, but it still is a statistically robust analysis method [Austin, 2002].

Forestry map data

The second data set we used for analyses of forest structure was forestry maps from the area of Voknavolokskogo Lesnitsestva dated 1979 and forest map of the Kostomuksha Zapovednik. The original maps were in printed form. First, we scanned smaller 4 x 5 km areas, where the village center was in one side of the scanned area. Then we delineated all the forestry compartments showed on 4 x 5 km areas and created a polygon layer. For each polygon we picked a respective soil type and forest age class from an original map and added this information in the attribute table of the polygon layer. Then we created eight buffer zones with 500 m intervals (distance 0–4000 m) using the village fields as center areas. Finally, we calculated the proportions of different forest age classes in different distance zones. We added + 30 years to all the age classes of the original map to match the current age of forests. Altogether, surroundings of six villages were analyzed from forestry maps (Nauvaara, Haapavaara, Tsena and Venehjärvi from the northern study area; Sappovaara and Jehrimänvaara from the southern study area). The software we used here was ESRI ArcGis 10.0.

Results

Population of villages

There were 24 villages in our study areas; 14 in the southern and 10 in the northern study area (Table). Four of the villages had more than 25 households. Five villages had 15–24 houses, nine 5–14 houses and six had 2–4 houses. In the southern Kostomuksha Zap., Akonlahti, which had 36 houses in 1926 census, was clearly the largest village. Akonlahti was comparable to Kontokki, the administrative center of the municipality, which lied 25 km east from Akonlahti. The population of Akonlahti was approximately 300 and the population of the whole southern area almost 1100 people before the Great War and the Russian civil war (1914–1921). In the north (surroundings of Kalevala NP), Latvajärvi was the largest village with the population of 195 and 29 houses in maximum. The population of the northern area achieved 799 inhabitants in 1905 but did not increase according to the census of 1926 (see Table). Between 1905 and 1926 the population growth stopped (in the northern area) or declined (in the southern area). However, the number of houses increased by 9 % between the two censuses. The density of population was slightly higher in the southern area (1.1 inhabitants/km^2) than in the northern area (0.8 inhabitants/km^2).

Vegetation index and distance from village centers

The mean NDVI value along the 5 km transects showed a clear trend in the forest structure (Fig. 2). The NDVI values close to the village centers were the highest, but started to decline rapidly with an increase in the distance within 1000 m. Within 1000–2500 meters from the village centers, the decline of the NDVI values was less pronounced. After 2500 m, the NDVI values achieved a plateau. According to the GAM analysis, there is a culmination point within 2500–3000 meters from the village centers, after which the NDVI value start to rise very slowly again. The GAM model explaining the change in the NDVI value by distance from the village center was statistically significant (F-test, df = 975, P < 0.001).

Table 1. The number of houses and the size of population in the southern and in the northern study area, in the first quarter of the 20^{th} century [Härkönen, 1920; Sergejev, 2011]. In the census of 1905 Jehrimänvaara is probably included in Akonlahti. The numbers after the names of villages refers to their locations in the map of Fig. 4

		Census year			
		1905		1926	
Area	Village	Houses	Population	Houses	Population
1 south	Akonlahti 1	53	358	36	144
	Jehrimänvaara 2 *§			19	89
	Lyttä 3	6	24	4	25
	Mäkrävaara 4	10	48	8	46
	Munankilahti 5 *	9	75	13	74
	Sappovaara 6 *§	7	60	9	41
	Tetriniemi 7 *	11	69	14	76
	Vorna 8	3	17	4	19
	Lusma	2	6	3	10
	Miinoa 9 *	14	84	21	102
	Härköniemi 10	3	12	3	20
	Ristiniemi	2	11	2	15
	Kontokki 11	36	235	37	176
	Luvajärvi 12 *	14	74	22	91
	Total sum	**170**	**1073**	**195**	**928**
2 north	Vasonvuara	7	57	10	47
	Nauvuara§	7	37	9	48
	Haapovuara*§	10	64	14	76
	Latvajärvi	27	195	29	165
	Kossi	1	4	2	12
	Lapukka	2	3	2	17
	Kivijärvi*	22	142	20	116
	Paahkomienvuara	11	63	11	71
	Tsena§	23	127	18	100
	Venehjärvi§	27	107	25	142
	Total sum	**137**	**799**	**140**	**794**

* villages of satellite image analysis; § villages of forestry map analysis

Analysis of forestry maps

The analysis of forestry map data showed similar trend as the NDVI analysis from the satellite image (Fig. 3). The mean age of forests was the youngest (125 yr.) next to the open fields within the distance of 250 m. The mean age increased steadily up to 2250 m from the fields (180 yr) and was the highest (195 yr) at the distance of 3250 m from the village fields.

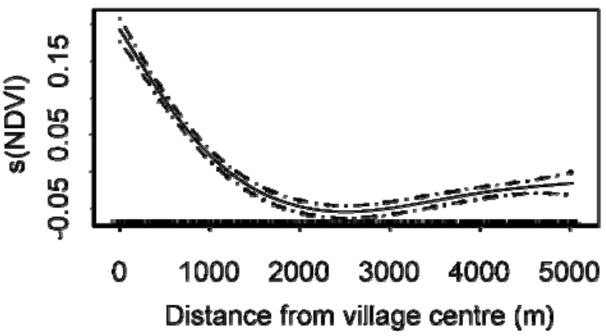

Fig. 2. Response shape of NDVI in relationship to the distance from the village centers. The upper and lower dashed lines are approximate 95 % point-wise confidence intervals

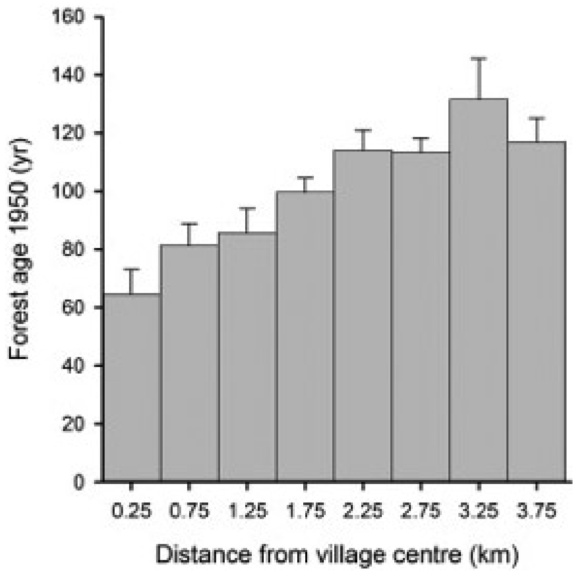

Fig. 3. Forest age (mean +S.E.) in distances of 0–4 km from the village centers (open fields). Stand ages were calculated backwards to the 1950's

Reconstruction of the past landscape

According to our results, the width of zone of intensive land use was 1 km and the width of extensive use 1.5 km, in general. However, it is evident that the size of population influences the area affected by human activity. Therefore, we calculated the widths of the impact zones for each village separately by weighting the width of zones by a relative number of households in the village. The width of the 1st zone (intensive use) for a village was calculated as Zone 1 = 1 km * (h / haver), where h = a number of households in the village and haver was the average number of households in the studied villages (16 households, see Table) and, respectively, Zone 2 = 2,5 km * (h / haver) – Z1. We can calculate that from the land area the zones of intensive use cover 2.2 % and zones of extensive use 6 % in this southern area. The respective figures from the northern area are

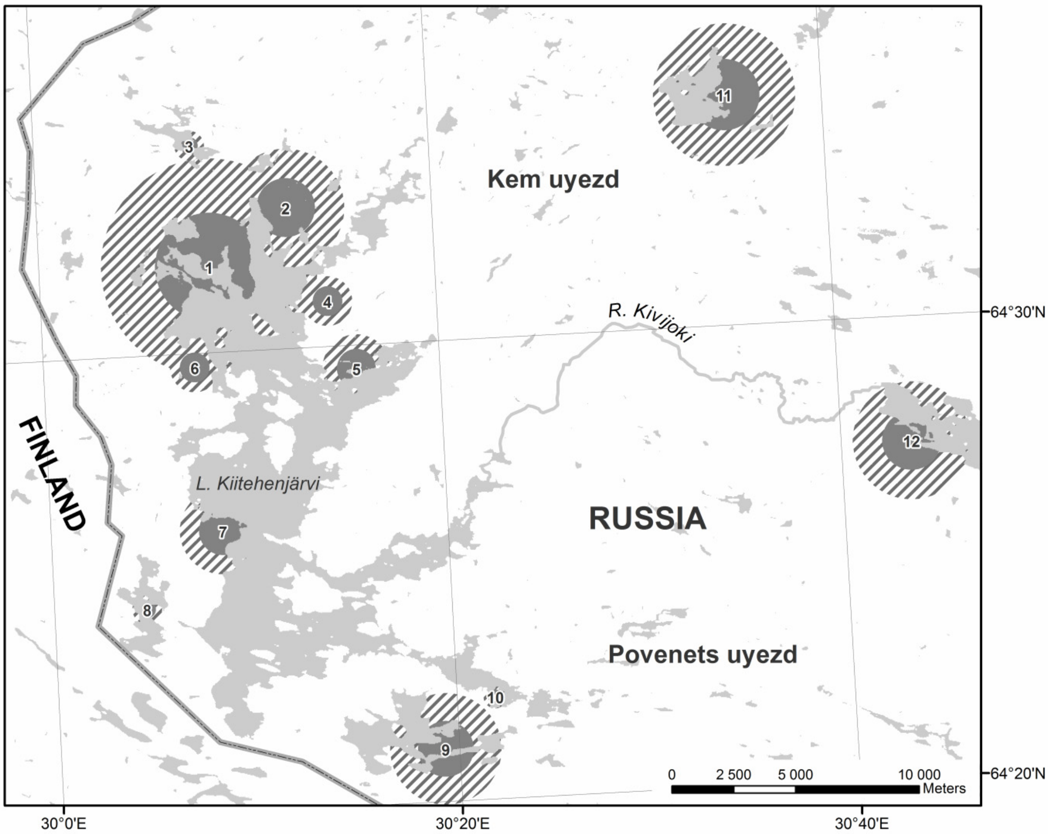

Fig. 4. The reconstruction map showing the effect of forest use on the forest landscape surrounding the old farming communities of the Kostomuksha region (Area 1 in Fig. 1.). The size of impact zones is scaled in relation to the number of houses in the villages. The three smallest settlements (1–2 houses) are not shown on the map because of their negligible effect on the landscape. Numbers in the map refer to the village names in Table 1

similar. The human influence on the forest stand structure was probably very limited outside the impact zones (91.8 % of the land area). In Fig. 4 we present a map of the southern area, showing the historic forest landscape from the beginning of the 20th century, using these village specific values for the different land use zones surrounding the villages. The map also shows us that the most of this study area was unpopulated as was also the case in the northern area.

Discussion

Field agriculture and slash and burn agriculture

The impact of agriculture on the landscape structure in general was relatively low in our study area compared to the far southern regions. In Volost of Rukajärvi, which reaches in the southern half of the study area 1 and includes the villages of Miinoa and Luvajärvi, the area of wooded meadows, and slash and burn sites was the smallest in the whole Povenez Uezdt (only 31.8 ha [Homén, 1918]). According to Heikinheimo [1915], in the adjacent Finnish municipal of Kuhmo, less than 9 % of the forest land was used for slash and burn agriculture and an equal area was used for fields and meadows in the mid 19th century. The area of fields and meadows in Kuhmo is about four times higher than the area of intensive use zone.

The area used for slash and burn agriculture may have been small but, very likely, it and the other human activity increased the fire frequency in the forests surrounding the villages. The dendrochronological studies done in the study area and elsewhere in the eastern Finland, show that the average interval between forest fires has been less than 60 years in the 1500–1800s [Lehtonen, Huttunen, 1997; Lehtonen, Kolström, 2000]. Fires may have spread accidentally from slash and burn sites and, in addition, from camp fires; people have spent lot of time fishing and making hay in the surrounding lakes and mires. However, the forest stands have developed without any management. The fire intensity has also varied [Pitkänen et al., 2002] and as the result the forests have been structurally complex compared to the forests actively managed for silvicultural purposes. As a result, the mature forests surrounding the villages may have also retained their natural structural composition but have been younger than if the landscape would have been totally unaffected by human activity and fire resistant pine have become the dominant tree species [Pennanen, Kuuluvainen, 2002].

Firewood

Early Finnish records on the use of timber suggest that firewood demand may have been even a more important factor, than slash and burn agriculture, in shaping the landscape, especially in the further northern areas where the climate is less favorable for agriculture. According to C. W. Gyldén [in Soininen, 1974] the fire wood was the most important forest commodity, comprising approximately 50 % of all the wood consumption, exceeding clearly the amount of wood used for slash and burn agriculture (8 %) in the mid 19th century. Even the need of wood for construction of buildings and fences (18 %) exceeded the demand of wood for slash and burn agriculture. Soininen [1974] estimates that the average annual need of firewood and construction timber including fences was 12 m^3 per person in Finland in the mid 19th century. Myllyntaus and Mattila [2002] ends up to the quantity of 9 m^3 annual per capita consumption of firewood in rural Finland. However, we need to be cautious with these figures. There are more detailed figures about the consumption of firewood from the northern Värmland, Sweden. According to the detailed study done in 1920–21, the annual consumption of wood was 22.3 solid m^3 for heating in farms [Lindmark, Anderson, 2010].

In the eastern Fennoscandia, the demand of firewood probably continued to be high even though the average household consumption started to decrease in the end of the 19th century [Myllyntaus, Mattila, 2002]. The winters were long and cold and the land was poor. There was no place for expensive improvements in housing like double-glazing or heating owns made of bricks. Black crofts without chimneys were energy deficient, but still common dwellings in the beginning of the 20th century. Yet there were plenty of forests – at least in a reasonable distance from the villages.

Wood harvesting for heating purposes has probably not been a straightforward clearance of the surrounding forests. Available dry standing kelo trees have been logged first (mostly pine; *Pinus sylvestris*) and afterwards – trees from a reasonable distance. This has changed the quality of forests but not the size of forested area. After depletion of this source from the vicinity of the villages, people have started logging nearby stands starting from those growing birch (*Betula* spp.).

Other use of timber and forests

Fences. Fields were fenced in order to prevent domestic animals from eating crop plants. Tupamäki [1914] has calculated the consumption of wood in fences. Consumption of wood (spruce, *Picea abies*) for 100 meters of a fence was 270 pieces of 5–6 m long poles, 230 pieces of 2–3 m long posts and 150 young spruce saplings (1 m tall) for binding material. Moreover, he calculated that a typical croft had 2.6 km of fence and the fence was replaced every 20 years. Thus, the total consumption of wood for the fences was 6 m^3 per year [Tupamäki, 1914]. This calculation has been made in the southwestern Finland. Other calculations have shown a similar quantity (5.1 m^3 per year, based on the estimate of [Jäntti, 1948]). The fields and the need of fencing material have probably been smaller in the White Sea Karelia, where both the numbers of life stock and the size of fields were smaller than in the further southern areas.

Building material. Old pine logs have been a preferred material for house construction. The proportion of decay resistant heart wood increases until pines are 150 year old. The building material have probably been logged and transported from the nearby old forests. We do not have detailed information about the annual consumption of logs for houses and other buildings, but its effect on forests has probably been relatively small compared to the other needs of wood.

Based on the photographs and blueprint of the house of Dobrinin of Munankilahti [Kaukonen, 1984], a very rough calculation that 3300 meters of logs were needed just for the walls of the house can be made. The roof, ceiling and floor were also made of wood. The base area of the house was approximately 300 m^3. If we make a rough estimate that the house was made from 10 m logs of 28 cm diameter, 330 logs have been needed. The volume of such log is 0.65 m^3 and the total volume of timber is approximately 215 m^3. In addition, there is need of timber for roofing etc. Thus, we could make a guess that the total volume of wood consumption for such a house is 250 m^3. Moreover, there is a need of wood for auxiliary farm buildings, let's assume 100 m^3. If the buildings were made for 100 years, it is reasonable to assume that logs were often recycled when making new buildings, then the wood consumption for buildings was approximately 3.5 m^3 per year.

Winter forage for domestic animals. Bundles of ramets of deciduous shrubs were cut and stored for winter forage of domestic animals, especially for sheep. Korablev [1999] notes that in the nearby village of Vuokkiniemi (Voknavolok) this was done in large quantities; the number of stored bundles was 4000–5000 per a household per winter.

Supplementary food. Harsh northern climate caused frequent failure of crops. Thus, famine was endemic and there was a constant need of supplementary nutrition. However, it is very difficult to estimate the effect of pine flour extraction on forest and landscape structure, because the same trees may later have been used for firewood.

Conclusions

Based on the results of the satellite image analysis and forestry map data, we conclude that the past human influence on the forest structure has penetrated 2500–3000 meters in the forest matrix surrounding the villages in general. Moreover, in the center, there has been a zone of intensive forest use which width has been approximately 1000 meters. Need of firewood in large quantities and browsing by sheep and cattle (including the harvesting of winter fodder) have kept the land surrounding the villages relatively open in this zone of intensive use. This can be seen in the old photographs taken from these villages in the end of the 19^{th} century [Laaksonen, 1990], and the openness of landscape is still visible in the pictures taken in the 1940's [Kaukonen, 1984].

The zone of extensive use has probably been formed by harvesting of kelo trees for fire wood, high quality timber for buildings and from old slash and burn sites on the most productive sites. It is obvious that not all the forest stands were productive enough for grain cultivation. The growth season is short in this area. In modern climate, the effective temperature sum is approximately 950 day degrees. There can be night frosts in August, and only the southern slopes in sheltered sites, such as lakesides and hill tops, were warm enough for ripening of the grain in most years. Therefore slash and burn agriculture was not so common and its effect on the landscape was smaller here, compared to the further southern areas in the Eastern Fennoscandia [Heikinheimo, 1915]. Obviously, there has been slash and burn sites further away from the villages, but they are no longer clearly visible in the current forest structure by the used methods. However, it seems that the local agricultural population has had only a relatively slight effect on the forest landscape and pristine forests have dominated the landscape.

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