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Forest Fire and Indigenous Sami Land Use: Place Names, Fire Dynamics, and Ecosystem Change in Northern Scandinavia

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Abstract

During the last two centuries, fire suppression has critically modified boreal ecosystems in northern Scandinavia and has undoubtedly affected indigenous Sami land use. We inventoried Sami toponyms referring to fire in a municipality located in Swedish Sápmi, and investigated their past and present meanings by analyzing Sami dictionaries and conducting semi-structured interviews with Sami reindeer herders. We use toponyms based on the Sami word '*roavve*' - a lichen-rich pine-heath that has burned - as a description of past ecosystems to inventory understory and tree vegetation and date the last occurrence of fire in 15 '*roavve*' places. The inventories showed that some '*roaave*' places have developed a late succession vegetation type, reducing their suitability for reindeer grazing. We argue both that fire suppression strongly influences the ecological trajectory of these sites and that one must take into account ethnoecological considerations when using toponyms as ecological markers to fully understand their meanings and avoid misinterpretation.

Keywords Toponym · Fire suppression · Sami reindeer husbandry · Indigenous knowledge · Boreal Sweden · Forest history

Introduction

Although fire suppression has been a standard management practice in boreal forests for over a century, fire is today seen as an important ecological disturbance factor that structures the functioning and dynamics of boreal forest ecosystems (Niklasson and Granström 2000; Nilsson and Wardle 2005). It is also acknowledged that fire regimes constitute intertwined natural and cultural phenomena resulting from interactions between humans and the living world (Bowman *et al.* 2011; Coughlan and Petty 2012; Pyne 1998). In Northern Sweden, fire suppression measures implemented since the late nineteenth century have greatly reduced the number of fires in boreal forests and the extent of burned areas, increasing the mean interval between fire events from 80 years to centuries (Carcaillet *et al.* 2007; Granström and Niklasson 2008; Wallenius 2011; Zackrisson 1977). Conversely, the boreal landscapes of pre-industrial Sweden were characterized by a mosaic of habitats heavily structured by fire regimes that maintained diverse, open, multi-storied stands (Nilsson and Wardle 2005; Östlund *et al.* 1997; Zackrisson 1977). Because fire's beneficial long-term effects on commercial forest productivity (Nilsson and Wardle 2005; Wallenius 2002) and biodiversity conservation are increasingly acknowledged (Halme *et al.* 2013; Linder 1998; Östlund *et al.* 1997), fire restoration is now commonly performed in the Swedish boreal forest during conservation and prescribed burnings.

Fire management measures and the associated changes in fire regimes also affect indigenous peoples' livelihoods (Natcher 2004). In northern Fennoscandia, the indigenous Sami people practice reindeer husbandry, relying on lichen-rich forestlands for winter grazing, and are therefore significantly impacted by fire regime shifts. Sandström *et al.* (2016) showed that the area of lichen-rich forests in Northern Sweden has declined by 71% over the last six decades. Some studies have suggested that fire suppression during the twentieth century reduced the abundance of ground reindeer lichen (*Cladonia* spp.) (Berg *et al.* 2008; Moen and Keskitalo 2010) by reducing the abundance of old, open, low productivity pine forests (Esseen *et al.* 1997).

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Although fire initially destroys ground lichens, it can promote their long-term persistence by suppressing competing vegetation and maintaining suitable conditions for their establishment. The post-fire chronosequence, which describes the vegetation dynamics of ecosystems on broad geographic and time scales, predicts that ground lichens become established after an average of 30–40 years following a fire, and reach maximum coverage after 40 to 120 years depending on geographical conditions (Coxson and Marsh 2001; Crittenden 2000; Kumpula *et al.* 2000). Organic matter subsequently accumulates, creating moister soil conditions that initially favor the establishment of ericaceous dwarf shrubs such as lingonberry (*Vaccinium vitis-idaea*) and bilberry (*Vaccinium myrtillus*), followed by crowberry (*Empetrum nigrum*), heather (*Calluna vulgaris*), and feather mosses. After a period of 80–100 years on average, these species are expected to become dominant over lichens unless a new perturbation occurs (Ahti and Oksanen 1990; Miller 1996; Nilsson and Wardle 2005).

Indigenous peoples around the world, including those in boreal regions, manage fire for various purposes (Kimmerer and Lake 2001; Lewis and Ferguson 1988; Miller and Davidson-Hunt 2010). However, little is known about the historical relationships between Sami livelihoods and fire. Consequently, there is a need to better understand how the Sami historically made use of entire forest landscapes and how central resources were used and managed (Norstedt 2018). Studies of Sami toponyms can provide critical information on their livelihoods and relationship with fire that can complement ecological investigations in reindeer grazing areas. A few studies have used place names as historical landmarks to study ecological change in other geographical areas (Conedera *et al.* 2007; Henshaw 2006; Jones 2016; Sousa and García-Murillo 2001; Sousa *et al.* 2010). Sami toponyms often describe the places they refer to, such as the configuration of the terrain, or the possibility of finding specific plants and animals, and are frequently linked to reindeer husbandry (Korhonen and Anderson 2010). Some toponyms refer to forest fires or their consequences – an important example is place names incorporating the Sami category *roavve*, which refers to a burned forest suitable for reindeer grazing.

Our overall objective was to understand how places named *roavve* have evolved over time, their current status, and how fire and fire suppression have impacted the vegetation. We conducted an interdisciplinary study encompassing forest history and ethnoecology to (i) clarify the current and historical meanings of *roavve* to Sami reindeer herders; (ii) determine how places named *roavve* have evolved in the last ca. 100 years, using the indigenous definition of *roavve* as an ecological reference; and (iii) evaluate the role of fire and fire suppression in this evolution by linking vegetation characteristics to time since the last fire (TSLF). More broadly, we aim to determine how connecting place names, ethnoecological studies, and ecological investigations can shed light on ecological changes and trends in indigenous people's land use.

Material and Methods

The study area was limited to the borders of Jokkmokk municipality, Norrbotten County, Sweden. The municipality covers an area of 19,334 km^2 centered at approximately 66°37′0°N; 19°50′0° E, and includes commercial forestlands, protected forest areas, and mountain lands. The forests have two main coniferous species: Scots Pine (*Pinus sylvestris*) and Norway Spruce (*Picea abies*). The most common deciduous trees are birches (*Betula pendula, B. pubescens*). Less abundant deciduous trees include willows (*Salix caprea*), aspen (*Populus tremula*), and alder (*Alnus incana*). Indigenous Sami people practice reindeer husbandry over the whole area. The municipality is home to five of the 51 Swedish herding communities: three mountain-based communities (Sirges, Jåhkågasska, and Tuorpon), and two forest-based communities (Udtja and Slakka). Mountain-based communities conduct yearly migrations with their reindeer between the winter pastures in the lowland forests, and the summer pastures in the high mountains near the Norwegian border. The forest communities keep their reindeer in the lowland forests all year round, although they also undertake migrations between winter and summer pastures. The Sami reindeer herding communities have a right of use over their herding territories. However, most of these territories is owned by public and private forestry companies, with a smaller proportion belonging to private smallholders. Reindeer herders are facing increasing encroachment of their winter grazing areas because of the activities of various industries in northern Sweden, including forestry, mining, wind power, and hydropower. These encroachments and the fact that Sami reindeer herders do not own the land they use for grazing, are imposing severe pressures on their communities. The area of Jokkmokk corresponds to the historic linguistic area of Lule Sami, one of the 10 Sami languages still spoken today. Despite restrictions imposed by early twentieth century colonial policies and practices, Lule Sami remains in active use, especially among reindeer herders' communities. However, the North Sami language is also widely spoken in the area since the forced displacement of Sami families from the North in the early twentieth century.

Identification of Sami fire Toponyms

Our first step was to identify Sami terms referring to forest fires that occur in place names in the study area. Sami place names, like those in many other languages, are often compound words consisting of a generic term that designates a topographic feature and an additional term that describes its physical properties (often metaphorically) or refers to the presence of plants, animals, resources, or associated socio-cultural elements (Rankama 1993). Sources used for vocabulary identification were dictionaries for North Sami (Nielsen and Nesheim 1979 [1932–1962]; Svonni 2013) and Lule Sami (Grundström

1946–1954; Korhonen 1979), and records of place names (Collinder 1964; Grundström 1927–1934; Korhonen and Anderson 2010). Three words related to fire and their derivatives were found in place names of the area: *buollem* or *buollám*, *guorbba*, and *roavve*. *Buollem* and *buollám* derive from the verb *buollet*, to burn, and mean burned, or burned forest area (Grundström 1946–1954; Korhonen 1979); *guorbba* means burned place, or terrain that has been destroyed by forest fire (Grundström 1946–1954; Korhonen 1979); and *roavve* refers to the type of vegetation found after a forest fire (Nielsen and Nesheim 1979 [1932–1962]).

To find place names containing these words and their derivatives, we used the Swedish National Land Survey's (Lantmäteriet (2017)) online map of place names and the place name records of the Swedish Institute for Language and Folklore (Institutet för Språk och Folkminnen (2017)). We identified 39 place names incorporating these three words (30 for *roavve*, 5 for *buollem* or *buollám*, and 4 for *guorbba*) (Table A, Annex). We found one *roavve* place name, Tjájároavve, which was absent from place names records or maps, in Ruong (1964). We then used place name registers and the first ordnance maps of the area (published in 1890 and 1893) to locate the identified place names (Grundström 1927–1934; Pellijeff 1992 [1936]). We follow the official Lule Sami orthography, in accordance with the 2001 Swedish Heritage Conservation Act, for the spellings of the place names (Nyström *et al.* 2007). We chose to focus on *roavve* place names because they were the most numerous in the study area and because it allowed us to maintain a degree of homogeneity in the sites we inventoried.

Semi-Structured Interviews

Semi-structured interviews were conducted with reindeer herders to investigate how Sami native speakers who interact closely with their environment understand the word *roavve*, and to deepen the definitions given by the dictionaries. An additional goal was to clarify the role and importance of *roavve* places in reindeer herding practices. The interviews were based on a set of themes addressed through open-ended questions, enabling interviewees to explore specific topics or introduce new ones. The main themes addressed were the meaning of *roavve*, the role of fire in its definition, and the role of these places in reindeer herding today as well as in the past. Ten reindeer herders from five reindeer herding communities around Jokkmokk municipality were interviewed (nine men and one woman aged from 53 years old to over 80): seven Lule Sami speakers, one who spoke a dialect of Lule Sami from the Flakaberg area (about 140 km East of Jokkmokk), and two North Sami speakers. An interview was also conducted with a consultant in Lule Sami at the Sami parliament in Jokkmokk. The 11 interviews were conducted in Swedish, recorded, and fully transcribed.

Sampling Strategy

Since the purpose of the ecological inventories was to characterize the vegetation composition at *roavve* sites, we based our sampling strategy on place names and their locations. Study sites were defined as the surfaces encompassed by the topographic feature designated in the place names. Sampling areas were then selected within each study site. The sampling areas were 200x200m squares with their centers located as close as possible to the coordinates assigned to the place name. In cases where the study site was a hill or a mountain, this position usually corresponded to the top. In a few cases, the coordinates provided by Lantmäteriet did not correspond to the feature referred to in the place name. In such cases, the sampling area and its center coordinates were determined using aerial photographs and topographic maps. In some cases, the place names recorded designated non-forested land features, such as bodies of water and mires. Because of the ambiguity of the locality of the forest stand designated by the *roavve* place name in such cases, they were excluded from the potential inventoried sites. The remaining sites were prioritized according to their accessibility (distance from a road). In total, 15 sites were inventoried (Fig. 1).

Estimation of the Time Since Last Fire from Fire Scars

To determine the time since the last fire (TSLF) at the study sites, we used dendrochronology (Arno and Sneck 1977; Niklasson and Granström 2000; Stokes and Smiley 1996; Tirén 1937; Zackrisson 1977). We conducted searches at each study site along transects covering the sampling areas, separated by 100 m intervals, to find fire scars on living trees. If no fire scars were encountered, we extended the search to a 400x400m square. The presence of other signs of fire such as charred stumps, branches, or roots was also recorded. One or more tree cores were taken with an increment borer from the first fire scar encountered on a living tree inside the sampling area. In three sites where modern clear-cutting had deeply modified the stand structure, we found no living trees with fire scars and so took cross-sections from dead trees or snags with fire scars, to be cross-dated using a pre-established master-chronology from the Torneträsk area (Arno and Sneck 1977; Grudd *et al.* 2002). Tree cores were measured using a LINTAB™ tree-ring measuring station with a resolution of 1/100 mm, and the measurements were analyzed using the TSAP-Win™ software package (Rinntech technologies).

Ground and Tree Vegetation Inventories

We made a vegetation inventory in each study site at three randomly selected points where we took a tree core from the presumed oldest tree to estimate the stand age in even-aged stands. If the stand contained several age-classes, we took a core for each age-class. The ground vegetation was

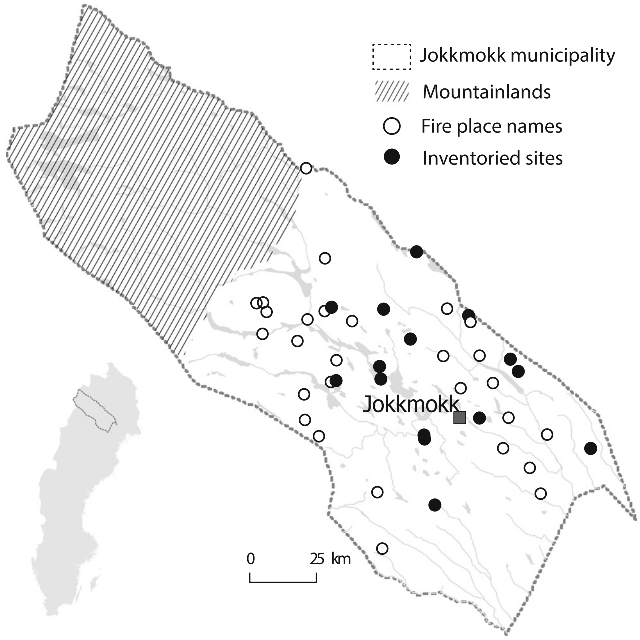

Fig. 1 Location of Jokkmokk municipality in Sweden, and positions of inventory sites

characterized according to Hägglund and Lundmark (2004). We evaluated the percentages of cover for reindeer lichen, bilberry, lingonberry, and crowberry inside a circle of 10 m radius centered on the sampling point. In addition, the characteristics of the tree layer (i.e., tree density and basal area for each tree species) were measured in a circle of 11.28 m radius (400 m^2) at each sampling point.

Statistical Analysis

To characterize the variability of the study sites' vegetation and establish a typology, we performed a principal component analysis (PCA) in conjunction with hierarchical clustering using the ade4 package (Chessel *et al*. 2004) with the R 3.4.0 software (R Core Team 2013). The variables included in the PCA were vegetation variables structuring the definition of *roavve*. The bilberry, lingonberry, and crowberry covers were also included in the analysis because these species are the dominant dwarf shrub species in Fennoscandian boreal forests and their abundance can be indicative of edaphic conditions. The variables used to construct the PCA were therefore lichen cover (% of inventory area), pine basal area (m^2/ha), spruce basal area (m^2/ha), bilberry cover (% of inventory area), lingonberry cover (% of inventory area), and crowberry cover (% of inventory area). We constructed a biplot in which we plotted the position of each study site with respect to the first two principal components. To represent the vegetation composition at each site within the scores plot, radar charts showing the values of the vegetation variables for each site were generated using the fmsb package. We tested the correlation between the PCA scores and two measured variables supposed to be explanatory, namely time since last fire and tree density, to interpret the distribution of the sites along the principal components' axes. We also performed linear regressions to determine the extent to which TSLF could explain the variability of the vegetation variables among the sites.

Results

Definitions of *Roavve*

Every dictionary we consulted other than the most recent (Svonni 2013) gives a first definition of *roavve* as a place where there has been a forest fire (Table 1). Three dictionaries also give a second meaning of *roavve* as a morphological feature (a camber) that may be associated with the curvature of a ski (Grundström 1946–1954; Korhonen 1979) and can designate a topographical feature (Nielsen and Nesheim 1979 [1932–1962]). However, Svonni (2013) defines this word only as a type of forest – a heath.

Seven of the herders were able to clearly define the term *roavve*, two were uncertain of its meaning, and one did not know it. The definitions given by those who knew the term included several criteria and collectively revealed all the dimensions that can be included in the meaning of *roavve*. All of the herders stated that *roavve* always referred specifically to a pine heath; one of them noted in passing that he had "never heard anyone talk about a guossaroavve [a spruce-roavve]." Moreover, they all associated *roavve* with richness in reindeer lichen and thus good winter pasture for reindeer. Four of them regarded fire as a defining element of *roavve*, always designating a pine heath that had burned. These herders considered the fire responsible for the richness in reindeer lichen and high pasture suitability of *roavve* places, suggesting that it

Table 1 Definitions of *roavve* according to Sami dictionaries and reindeer herders (authors' translations). Some dictionaries offer several meanings for *roavve;* for clarity, we only show the two common to most dictionaries

Source	Language	Definitions
Sami dictionaries		
Collinder 1964	Lule Sami	*Roavve, gen. Roave*: place where forest fire has gone through, burn
Grundström 1946–1954	Lule Sami	*R å̄vvē*: place where forest fire has gone through, burn. rå̄vvē- tnam: terrain where forest fire has gone through; Flakaberg area: also, ridge. Rå̄vvē: the even upwards bending in the middle of a ski
Korhonen 1979	Lule Sami	*Roavve*: camber, the even upwards bending in the middle of a ski *Roave*: burn, burned area, burned place (where there has been a forest fire)
Korhonen and Anderson 2010	Lule Sami	*Roavve, gen. Roave*: burn, burned aera, burned place (where there has been forest fire). The name element refers to mountains or heaths with coniferous forest, where forest fires can come up through lightning strikes. The name element roavve is therefore missing from the mountain area naming register. […]
Nielsen and Nesheim 1979 [1932–1962]	North Sami	*Roavve*: 1) area where there was once a forest fire and which is now for the most part covered with young trees; 2) In the region of Kautokeino (Norway): long, not very high wooded mountain, rather extensive hilly country which is mostly covered with dense forest, rather extensive wooden čorro [lengthy eminence, ridge, edge which sticks up]; some informants from Kautokeino also state that roavve means a place where there was once a forest fire.
Svonni 2013	North Sami	*Roavvi:* heath, pine heath
Herders' definitions		
Herder	**Language**	**Definitions**
Herder 1	Lule Sami	"*Generally, it's pine forests that have burned.*"
Herder 2	Lule Sami	"*Roavve, it is a heath where there has been forest fire, and… it is an old forest-fire place, which, after many years can become very good for reindeer pasture, but it takes many years before it becomes a reindeer pasture at such a place. So, my interpretation of roavve is that it has been a forest heath, with an old forest, which has burned away. And then, the lichen and everything has grown and reindeer pasture begins to grow, lichen for example, and wavy hair-grass [Deschampsia flexuosa] as well. It is a grass that often grows at burned places. (…) An old fire-place, it is often, today, good pasture conditions, good lands for reindeer pasture.*"
Herder 3	Lule Sami (Flakaberg)	"*A little round, long pine heath. Not totally flat, a little plump. Smooth but not flat. A little round. Not like a mountain, more even.*"
Herder 4	Lule Sami	"*A pine ridge... roavve... pine ridge, a little longer ridge, or height. The height goes down. (...) It is a pine heath, it can be a ridge, with a lot of pine there. A good pastureland, roavve. If you say roavve, then you know that it is a good pastureland for the reindeer. (...) When you hear the word roavve, then you know that it is a pine forest with lichen. (...) It does not mean that it has burned, roavve, but it can have happened that it has burned. It is a pine forest, so it can burn, so to say. But roavve itself means only this ridge, nothing to do with fire.* "

prevented the growth of competing vegetation. Herder 2 (Table 1), who was over 80 years old and mindful of knowledge transmission issues, as he used to map and teach place names to his children, provided a very precise definition of *roavve* and its relationship to fire. To him, it was not merely a pine heath that had burned: it designated a stage of the forest after the fire, when the vegetation had started to return and the ground reindeer lichen had become established. His definition increases the term's complexity because it implies a temporal dimension: as he understood it, a place could not be named *roavve* immediately after a forest fire, but only once the vegetation had reached a specific state:

> "It is the result, they do not call it just when it has burned, but when it has been a few years, and vegetation begins to come back in the area. And reindeer lichen grows, and a young forest takes over, I think it is then one calls such a place roavve."

Conversely, herders 3 and 4 provided definitions of *roavve* that did not include fire as a defining criterion (Table 1). One of them stated that *roavve* had "nothing to do with fire." For them, it was the topography that defined *roavve:* it designated a pine heath on a long ridge. One specified how *roavve* were usually situated on southeastern mountain slopes. Thus, two meanings of *roavve* emerged from the reindeer herders' definitions: a main meaning as a lichen-rich pine heath that has burned, and a second meaning as a lichen-rich pine heath on a long ridge having no particular association with fire. Some dictionaries include both meanings, which they associate with specific dialects in certain cases (Grundström 1946–1954; Korhonen 1979; Nielsen and Nesheim 1979 [1932–1962]). The languages spoken by the interviewees, namely Lule Sami or North Sami, did not seem to influence their preference for one definition of *roavve* or the other.

The herders also noted that places called *roavve* were changing, causing the typical *roavve* vegetation to disappear, and losing their potential as good reindeer pastures. One herder, who was very interested in observing and understanding vegetation dynamics, said:

> "They do not need to be lichen-rich today, but, in the favorable period in the cycle, then they were very good reindeer pasturelands, I believe. (…) They have surely been lichen-rich. Then the years have gone by and they have become richer in nutrients, it has changed the vegetation, so that the reindeer lichen is gone."

To him, the vegetation in the vast majority of lichen-productive lands, including *roavve* places, was changing and becoming unsuitable for lichen, for example by becoming bilberry dominated. Others noted that in many areas the forest was becoming denser and darker, preventing lichen persistence and enabling the establishment of competitor plants. They attributed this to non-commercial forests growing older, and dense planting practices in commercial forests.

Time Since Last Fire

The last fire was accurately dated using dendrochronology at seven of the 15 inventoried sites (Table 2). At three sites, fires were dated (to 374, 272, and 427 years ago) using the master-chronology; these dates are probably earlier than the actual dates of the last fires at these sites. Indeed, many signs of past fires, such as charred stumps, branches, or roots were observed at these sites, indicating more recent fires. Moreover, all three sites contained young stands (the stands at sites 2, 8, and 13 were 53, 35, and 77 years old, respectively) under intensive forestry management that had recently been clear-cut and regenerated naturally or by planting. The felling of older trees during forestry operations would explain the absence of living trees bearing fire scars. In three other sites, the trees with fire scars encountered were rotten inside, and we could only determine a minimum time since the last fire, corresponding to the age of the overlapping part of the fire scar. The time since last fire at these sites must thus be greater than these estimates. Consequently, these estimates are henceforth referred to as minimum estimates. For the two remaining sites, no fire scars on living trees were detected, and cross-dating with master-chronologies gave non-significant results. We therefore used the age of the spruce trees in the stand as a proxy for the TSLF in these cases. The most recent fire across all sites was in 1971, and the oldest in 1643. The mean TSLF, excluding the fires dated with the master-chronology, was 134.4 years (SD = 70.4). The mean TSLF for the seven fires dated accurately by dendrochronology was 124 years (SD = 50.8).

Vegetation Composition and Its Relationship to Time Since Last Fire

At the time of inventory, the 15 sites exhibited high variability in terms of their vegetation composition (Table B Annex), particularly with respect to the two variables defining *roavve,* i.e., reindeer lichen cover and tree composition. Some sites were covered with an extensive reindeer lichen mat with scattered pine trees (Fig. 2a). Others had less or no lichen cover but were dominated by ericaceous dwarf shrubs with a denser tree layer consisting of spruces and a few old large-diameter pines (Fig. 2b). There were also sites dominated by ericaceous dwarf shrubs with the tree vegetation dominated by pines (Fig. 2c). Finally, some sites had young pine stands that had been clear-cut and regenerated, resulting in low ground reindeer lichen cover (Fig. 2d). Across all sites, the lichen cover ranged from 1% to 70% with a mean of 24% (SD = 20.5), while the basal areas of pine and spruce ranged from 0.5 to 13.9 m^2/ha and 0 to 6.5 m^2/ha, respectively, with means of 6.7 m^2/ha (SD = 4.1) and 1.68 m^2/ha (SD = 2.2), respectively.

The PCA structured the heterogeneity in the sites' vegetation; the first and second dimensions of the PCA explained 42.3% and 30.2% of the variation in the data, respectively. Hierarchical clustering revealed some common trajectories, enabling the determination of a typology that separated the inventoried sites into four groups (Fig. 3). The vertical axis of the PCA distinguished sites characterized by an association between spruce and bilberry (group 1) from sites displaying an association between lichen, pine, and lingonberry (groups 2 and 4). Within the lichen-pine-lingonberry association, the horizontal axis distinguished sites with lichen-rich vegetation (group 4) from sites rich in crowberry and lingonberry at the expense of lichen (group 2). This axis also distinguished sites within group 3 that have intermediate levels of crowberry, lingonberry, and lichen cover.

The two explanatory variables used to interpret the PCA dimensions, TSLF and tree density, were uncorrelated (Pearson correlation = 0.01; p value = 0.96). However, the

Table 2 Time since last fire at the study sites. NB. Some sites bear the same names

Site code	Site name	TSLF	Last dated fire year	Earlier dated fire year	Method of dating
1	Roavve	>110	<1907		fire scar, uncomplete core
2	Roavvenjárggá	NA	NA	1643	master-chronology
3	Roavvevárásj	161	1856		fire scar, complete core
4	Roavvevárre	187	1830		within-tree crossdating
5	Roavvoajvve	>227	<1790		spruce age
6	Roavvoajvve	149	1868		fire scar, complete core
7	Nuortap Roavvoajvve	>153	<1864		fire scar, uncomplete core
8	Oarjep Roavvoajvve	NA	NA	1745	Master-chronology
9	Nuortap Roavvevárásj	>116	<1901		fire scar, uncomplete core
10	Rievsároavve	77	1940		fire scar, complete core
11	Tjiednekroavve	46	1971		fire scar, complete core
12	Ámmákroavve	149	1868		within-tree crossdating
13	Roavvoajvve	NA	NA	1590	Master-chronology
14	Tjáhppisroavásj	>139	<1878		spruce age
15	Tjájároavve	99	1918		within-tree crossdating

first axis of the PCA was explained by TSLF (simple regression: coefficient = −0.02; F-Test: p value = 5.21×10^{-2}). This relationship became statistically significant ($p = 8.65 \times 10^{-4}$) if the sites for which only minimum estimates of the TSLF were available (i.e., sites 1, 7, and 9) were excluded from the analysis. Additionally, the tree density (after being logarithmically transformed to establish a normal distribution of residuals) explained the second axis of the PCA (Simple regression: coefficient = 1.32; F-Test: p value = 0.03) (Fig. 4). Finally, the model relating TLSF to lichen cover showed a tendency to significance (Fig. 5) and became significant (coefficient = −0.28; $p = 4.65 \times 10^{-2}$) upon exclusion of data corresponding to the three sites for which only minimum estimates of the TSLF were available.

Discussion

The Category *Roavve* and Its Meaning for Reindeer Herders

All our interviewees interpreted the term *roavve* as referring specifically to a pine heath. Prior lexicological analyses lack this precision: with the exception of Svonni (2013), the dictionaries refer more broadly to a "place" or a "forest". The herders also considered the richness of ground reindeer lichen at the site (and thus the site's potential quality as a winter pasture for reindeer) to be an important aspect of the definition of *roavve,* notably absent from both old and recent dictionaries.

Most of the herders also considered forest fire to be a defining criterion of *roavve*. This was reflected by all of the dictionaries other than the most recent North Sami dictionary (Svonni 2013). However, some herders defined *roavve* without reference to fire, focusing instead on topography as a defining feature, a definition also reported by some dictionaries (Grundström 1946–1954; Korhonen 1979; Nielsen and Nesheim 1979 [1932–1962]). The presence of both meanings in dictionaries from the early twentieth century together with the use of both meanings by the interviewees suggest that the two definitions have coexisted for at least a century. Grundström (1946-1954) notes that the meaning of *roavve* as a topographic feature is associated with the Flakaberg Lule Sami dialect, which was confirmed by the definition given by our interviewee (herder 3). However, it should be noted that the two definitions are not mutually exclusive and can describe the same type of features. Indeed, studies on fire ecology have shown that forest stands on ridges are more likely to burn than those on flat land because lightning strikes are more likely on convex surfaces (Engelmark 1987; Zackrisson 1977). Because such environments are usually drier than lower sites, it is perhaps unsurprising that the term *roavve* incorporates this double meaning: a pine heath that has burned is most likely to be found on a ridge, and vice versa. This is well known by Sami herders, who are keen observers of the forest. However, without further linguistic analysis, it is impossible to establish whether both meanings were forming only one in the past or to determine why they have diverged into two different interpretations. Finally, some herders' definitions included a dynamic element: they considered *roavve* to refer to vegetation at a burned site after a certain

Fig. 2 Different types of vegetation at the study sites: **a** sparse pine stand with an extensive lichen mat (site 6 - Roavvoajvve); **b** dense mixed conifer forest composed of spruces and fewer old large-diameter pines, with ground vegetation dominated by ericaceous dwarf shrubs (site 9 – Nuortap Roavvevárásj); **c** pine forest with ground vegetation dominated by ericaceous dwarf shrubs (site 12 - Ámmákroavve); **d** young pine stand regenerated after clear cutting with little ground reindeer lichen cover (site 2 – Roavvenjárggá)

time period. This was noted by Nielsen and Nesheim (1979 [1932-1962]): *roavve* designates an "area where there was once a forest fire and which is now for the most part covered with young trees."

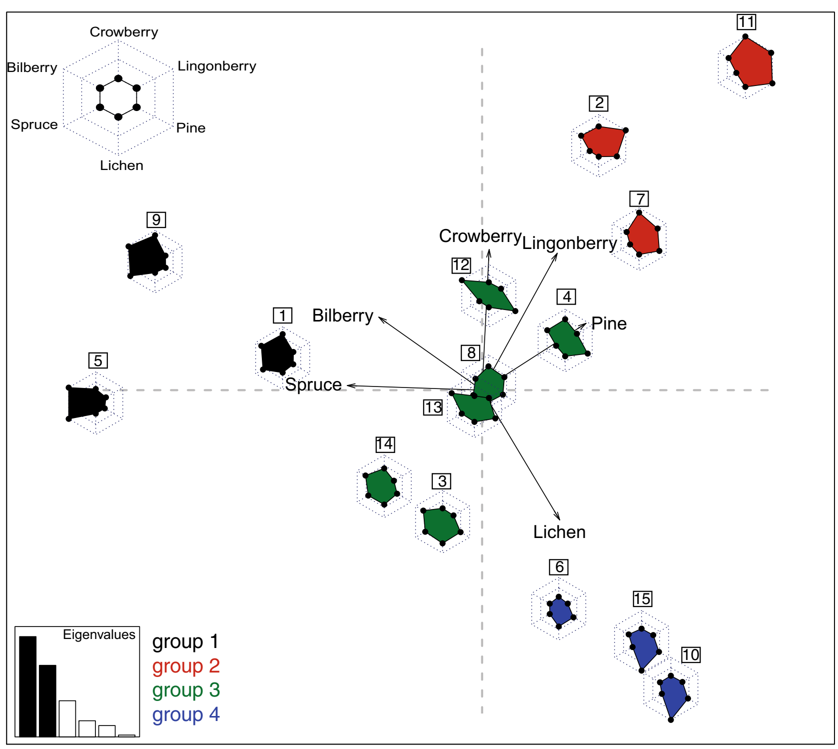

Fig. 3 PCA results showing the division of the study sites into four groups, and the contribution of the vegetation variables to the PCA dimensions. Each site is represented by a radar chart displaying the value of each vegetation variable

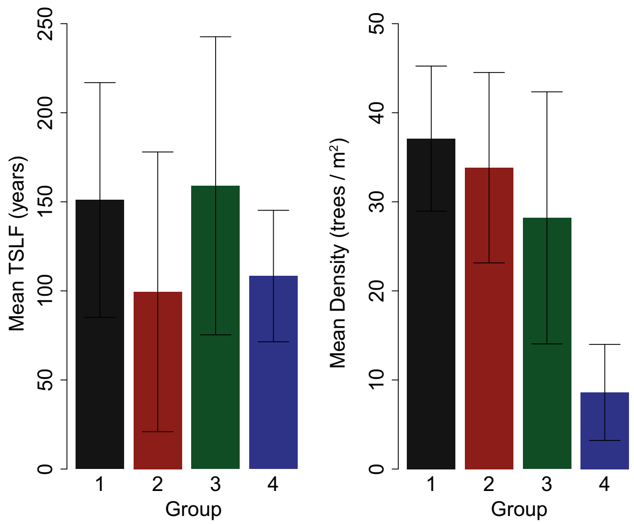

Fig. 4 Mean TSLF and density values for each PCA-derived group

To summarize, herders' understandings of the term *roavve* are structured by several criteria based on Sami modalities of categorizing the environment linked to potential reindeer grazing. A *roavve* is not simply a lichen-rich pine heath (referred to as *gielas*). It is also an environment generated through fire that may be found on ridges and is associated with good winter grazing for reindeer. *Roavve* is thus a semantic category that connects multiple domains: botanical, ecological, topographical, and land use. As such, it is a "complex category" in the terminology of ethnoscience, the study of indigenous classification systems (Friedberg 1999; Roturier and Roué 2009). The definition of *roavve* implies that the Sami who named these places had a detailed understanding of dynamic ecological processes and were well aware of forest fires' long-term effects on vegetation and reindeer pasture. Furthermore, the many locations within the study area that have names incorporating the word *roavve* suggest that such environments were historically important for Sami livelihoods.

Vegetation Changes Compared to the *Roavve* Reference

It is impossible to know precisely when *roavve* places were named. However, of the 15 we considered in this research, five are recorded in ordnance maps from the 1890s, and five are listed in place name records from the 1920s and 1930s, indicating that the names were assigned before fire suppression became common in forest management. Therefore, based on the assumption that the 15 study sites were named because they once exhibited the characteristics of *roavve,* we used its Sami multi-criteria definition as an ecological reference to estimate vegetation changes during the fire suppression period. Our results show that some of the sites no longer exhibit key *roavve* characteristics according to the Sami definition.

While all of the sites presented signs of past fire, the results displayed in the radar charts (Fig. 3) reveal their heterogeneity with respect to understory vegetation and forest structure. Ten sites still contain pine-dominated forest, but five had become mixed-coniferous or spruce-dominated forests. In addition, the reindeer lichen cover was above 25% at six sites but below this level at the remaining nine. The PCA we constructed on the basis of the *roavve* definition structured the sites' heterogeneity and revealed a typology that divided them into four groups (Fig. 3). Sites in Group 4 display the key vegetation characteristics that the Sami use to define *roavve*, i.e., they contain pine-dominated forests with extensive lichen cover. Conversely, sites in Groups 1, 2, and 3 have understory vegetation and forest structures that are deviating or have deviated from these. On-site observations were particularly important in this respect. Sites 5 and 9 (Group 1) contained a few old-growth, large-diameter pine trees (diameter > 40 cm) with large crowns growing among a younger spruce population, suggesting that the forest composition was very different in the recent past, when it was probably dominated by low-density pines and thus would have had high lichen cover. In addition, no signs of more recent fires (e.g., fire scars on young trees) were detected, but many signs of historical fires such as burned stumps or roots were visible, indicating that fire suppression has played a role in changing vegetation composition, and its deviation from the *roavve* definition.

Time Since the Last Fire at *Roavve* Sites

It should be taken into account that the TLSF dataset generated during our research is incomplete. For instance, the TSLF values for sites 2, 8, and 13 were estimated to be over 250 years based on cross-dating of fire scars on dead trees using the master-chronology. However, these dates are unlikely to correspond to the most recent fires in these stands. Before the advent of fire suppression, the average fire interval in the Jokkmokk region was around 80 years, with the lowest being 46 years (for lichen-*Calluna* type pine forests on flat, sandy river terraces), and the highest 122 years (for mixed *Vaccinium myrtillus*-type coniferous forests on north-facing slopes with moraine soils (Zackrisson 1977). In cases where stand regeneration has been driven by forestry operations, it is often impossible to date the last fire based on fire scars because all live trees with fire scars have been felled. For some sites, we used spruce age as a proxy of TSLF. Zackrisson (1977) argues that the inability of spruce to survive forest fires has been overstated because topographic conditions may allow some to survive fire events. However, an abundance of spruce trees in a stand covering a wide area is strong evidence that the stand has not burned during its lifespan.

It is also worth noting that historical documents can complement TSLF measurements. For example, Grundström (1934) indicated in his place name register that Tjiednekroavve (site 11)

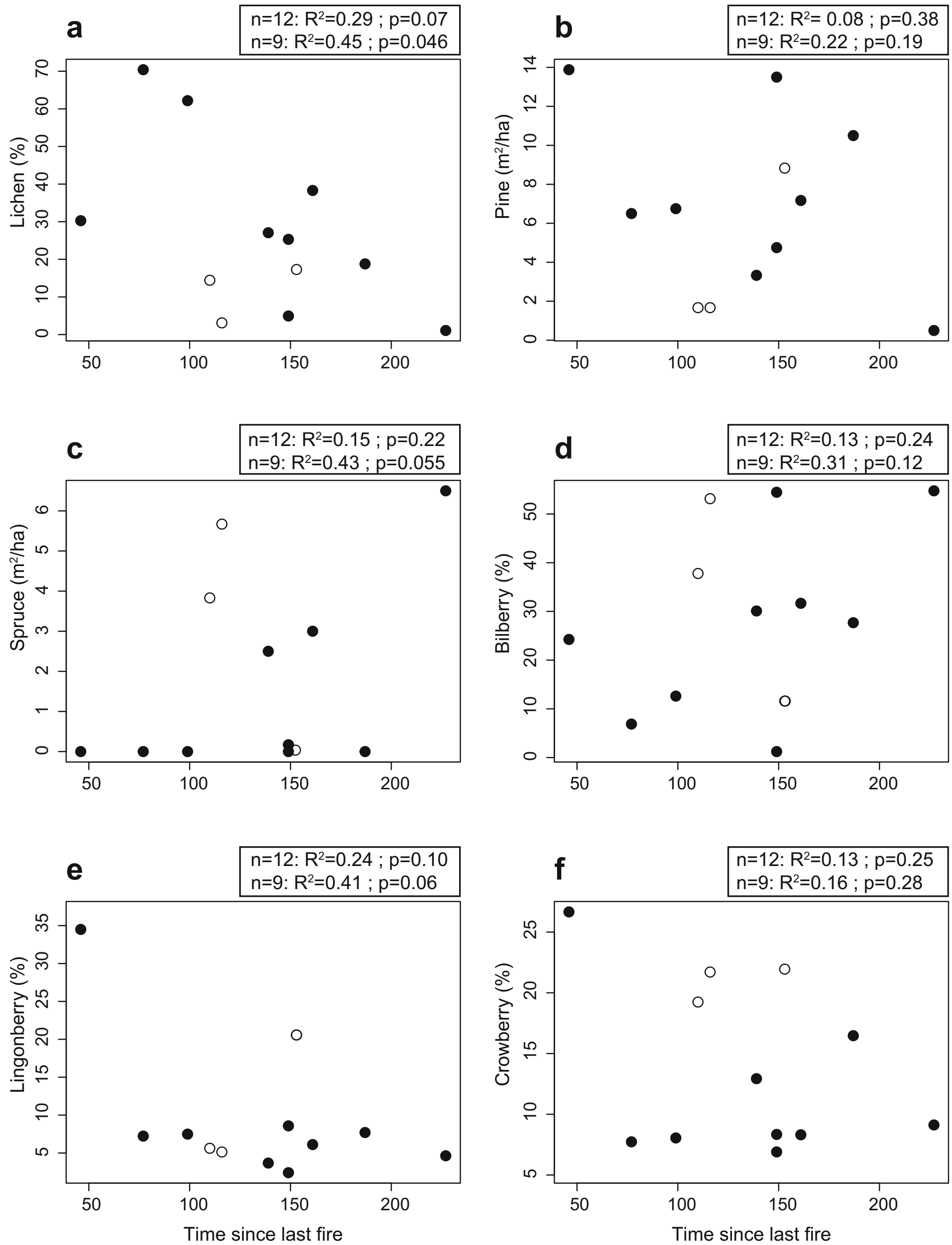

Fig. 5 Relationships between the vegetation variables and the TSLF. Black points correspond to the nine sites for which TSLF values were accurately determined by dendrochronology or estimated by spruce age. White points correspond to the three sites for which only a minimum estimate of TSLF could be obtained

had "burned 65 years ago," i.e., ca. 100 years before the fire we dated at the site. Field observations confirmed the occurrence of successive fires at the inventory sites: multiple fire scars were identified on dead stumps or living trees. Notably, our results indicate that at least seven of the 15 sites have not burned since the advent of fire suppression, which was progressively applied in Jokkmokk from the end of the nineteenth century. Another three sites burned only once during the last century (1918, 1940, 1976).

Fire Suppression as a Driver of *Roavve* Trajectories?

In this study we used a Sami toponym referring to fire to select study sites and investigate the role of fire suppression in the variability of the understory vegetation composition at 15 selected sites. A principal component analysis indicated that TSLF values and tree density could explain the variation in vegetation cover between sites. The PCA-derived group with the lowest lichen cover, the highest spruce basal area, and the highest bilberry cover (Group 1, Fig. 4) had a mean TSLF of 151 ± 66 (the second highest of the four groups even though the TSLF values for two sites in this group were minimum estimates). Conversely, Group 4, with the highest lichen cover, had a TSLF of 108.3 ± 37 years. Groups 2 and 3 had intermediate levels of lichen cover and mean TSLF values of 99.5 ± 79 and 159 ± 84 years respectively. This is consistent with the literature, which indicates that spruce becomes dominant in the absence of perturbations such as fire (Esseen *et al.* 1997; Steijlen and Zackrisson 1987). Our results also indicate a negative correlation between the lichen cover and TSLF (Fig. 5a). While there are few data on sites with low TSLF values, it appears that the lichen cover peaks around 100 years after burning and then decreases as the TSLF increases. This trend is strengthened by the fact that the TSLF values for three sites are known to be underestimated (Fig. 5), and is consistent with the expected pattern of lichen recovery after burning (Ahti and Oksanen 1990; Kumpula *et al.* 2000). There is a striking convergence between this pattern established by ecological studies and the detailed descriptions of vegetation dynamics after forest fires provided by some of our Sami informants.

Differences in tree density may explain the different vegetation compositions of the lichen-rich group (4) and the group rich in crowberry and lingonberry (2), which have similar TSLF values (Fig. 4). Sites belonging to Group 2 were subject to active forest management, which may account for their high tree density compared to Group 4. This greater tree density would be expected to reduce lichen cover because it would create light conditions that are not optimal for lichen growth (Čabrajič et al. 2010). Group 1 sites, characterized by an association between spruce and bilberry, also exhibited relatively high tree densities despite not having recently been actively managed. In unmanaged forests, increasing tree densities have been linked to the abandonment of selective cutting practices together with fire suppression (Esseen *et al.* 1997; Hedwall and Mikusiński 2014).

The variability of understory vegetation between the sites was also certainly influenced by soil conditions, which we did not consider in this research. For instance, sites 3, 6 and 14 had relatively high TSLF values but also had quite extensive lichen cover. The persistence of high lichen cover in the absence of major natural disturbances such as fire can be explained by sustained nutrient-poor edaphic conditions that prevent vascular plants from outcompeting ground lichen (Nilsson and Wardle 2005; Taylor and Chen 2011).

In conclusion, our data and our sampling design based on fire toponyms did not allow us to demonstrate fully the role of fire on understory vegetation and *roavve* trajectories. However, there were converging results and field observations showing that, with few exceptions, *roavve* sites exhibit the "sprucification" seen in Scandinavian protected forest areas, which has been linked to fire suppression and non-active management (Hedwall and Mikusiński 2014; Linder *et al.* 1997; Linder 1998; Zackrisson 1977). Simultaneously, they can undergo densification, a phenomenon that reindeer herders have identified as a cause of ground lichen loss in both unmanaged forest stands and commercial forests. Our results thus indicate that most of our study sites no longer exhibit the defining characteristics of *roavve*.

Place Names as Markers of Ecological Change

Place names with social and cultural significance for a community can persist over time and remain in use even after the environment referred to has disappeared or changed (see Ruotsala 2004 for examples from the Finnish Sami area). They can thus become markers of environmental change (Sousa and García-Murillo 2001).

The use of place names as ecological markers is not without difficulties and has raised many debates in the scientific community. First, it is generally impossible to know what motivated the original assignation and interpretations of a name's meaning in a contemporary context may be little more than guesswork (Sousa and García-Murillo 2001). Moreover, place names are often assigned according to a few salient features (Chessex 1945). It is then impossible to know whether a place was named because it exhibited *all* or merely *some* of these features. Additionally, a particular name may have originally referred to a circumscribed area and later been extended over a wider area. Some names might also be missed from the place names' inventory, because within societies with oral traditions, such as those of many indigenous peoples, all the names might not have been recorded on maps or otherwise documented, and might have faded from memory (Cogos *et al.* 2017). Finally, Kadmon (2000) also suggests that toponyms can lose the transparency of their meaning due to changes in the features that inspired them.

Our interviews with reindeer herders suggest that such effects could be occurring with place names based on *roavve*. Indeed, two of our 10 interviewed herders did not know the meaning of the term or gave somewhat simplified definitions, and two noted that it was an old word not in regular use. To account for this, one herder suggested:

> "They have disappeared, these expressions… Because then there were surely names for different stages after forest fires for example. (…) But we have been extinguishing forest fires for so long, so that they have simply disappeared. (…) And surely there were some expressions in Sami for the smoke from fire, I am certain about that. Because it had a strong signification for people who lived at that time."

As suggested by Korhonen and Anderson (2010), the absence of fire may also explain shifts in the meaning of the word. Contemporary definitions focus on the vegetation resulting from the fire, i.e., pine heaths, omitting the burning process itself since it no longer occurs; this is consistent with the most recent definition given by Svonni (2013) in North Sami.

Ultimately, toponyms are created in a socio-cultural context and carry a set of social and cultural values (Basso 1988; Hunn 1996; Jett 2011; Jones 2016). As such, they represent far more than ecological markers: they are testimonies of past livelihoods and their links to the environment (Jett 2011). Indigenous toponyms are based on alternative classifications of the environment to those developed by ecological scientists (Johnson 2000). A central aim of ethnoscience is to holistically study indigenous classifications, thus providing access to the indigenous way of understanding, representing and experiencing the environment. The interdisciplinary approach we adopted here followed this path, and aimed to combine the use of place names as ecological markers with a deeper analysis of their meaning based on herders' own definitions and interpretations to better understand the dimensions embedded in the associated places in modern and historical Sami livelihoods. Places names incorporating the term *roavve* are thus testimonies of types of environment that are important for Sami reindeer husbandry and are associated with fire, which remains a key factor governing the dynamics of the boreal forest.

Conclusion

The definitions of the category *roavve* provided by reindeer herders indicate that such areas were especially important for reindeer herding because they provide good winter pasture for reindeer, and that fire played a central role in establishing these characteristics. Our vegetation inventories at the study sites show that some no longer exhibit their original characteristics, probably because of long-term fire suppression. Some are currently dominated by spruce and ericaceous dwarf shrubs, making them unsuitable for reindeer lichen. We argue that Sami place names, since they reflect the relationship between land use and the environment, could serve as a basis for implementing fire management practices that ensure the sustainability of reindeer husbandry. In broader terms, studies on indigenous place names related to forest fires can provide a basis for understanding the effects of fire regime shifts on indigenous livelihoods.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

Ahti, T., and Oksanen, J. (1990). Epigeic lichen communities of taiga and tundra regions. Vegetatio 86(1): 39–70.

Arno, S.F., and Sneck, K.M. (1977). A method for determining fire history in coniferous forests of the mountain West. USDA Forest Service general Technical Report. INT-42. Intermountain Forest and Range Experiment Station. Forest Service, U.S. Department of Agriculture.

Basso, K. H. (1988). "Speaking with Names": Language and landscape among the Western Apache. Cultural Anthropology 3(2): 99–130.

Berg, A., Östlund, L., Moen, J., and Olofsson, J. (2008). A century of logging and forestry in a reindeer herding area in northern Sweden. Forest Ecology and Management 256(5): 1009–1020.

Bowman, D. M. J. S., Balch, J., Artaxo, P., Bond, W. J., Cochrane, M. A., D'Antonio, C. M., Defries, R., Johnston, F. H., Keeley, J. E., Krawchuk, M. A., et al (2011). The human dimension of fire regimes on Earth. Journal of Biogeography 38(12): 2223–2236.

Čabrajič, J., V, A., Moen, J., and Palmqvist, K. (2010). Predicting growth of mat-forming lichens on a landscape scale: comparing models with different complexities. Ecography 33(5): 949–960.

Carcaillet, C., Bergman, I., Delorme, S., Hornberg, G., and Zackrisson, O. (2007). Long-Term Fire Frequency Not Linked To Prehistoric. Ecology 88(2): 465–477.

Chessel, D., Dufour, A., and Thioulouse, J. (2004). The ade4 Package – I: One-Table Methods. R News 4(1): 5–10. https://cran.r-project.org/doc/Rnews/. Accessed Oct 2018.

Chessex, P. (1945). L'origine et le sens des noms de lieux : ces noms qui nous parlent [The origin and meaning of place names : names that speak to us]. 24 Heures, Neuchâtel-Paris.

Cogos, S., Roué, M., and Roturier, S. (2017). Sami Place Names and Maps: Transmitting Knowledge of a Cultural Landscape in Contemporary Contexts. Arctic, Antarctic, and Alpine Research 49(1): 43–51.

Collinder, B. (1964). Ordbok till Sveriges lapska ortnamn [Dictionary of Sweden's lapp place names]. Kungl. Orntamnskommissionen.

Conedera, M., Vassere, S., Neff, C., Meurer, M., and Krebs, P. (2007). Using toponymy to reconstruct past land use: a case study of "brüsáda" (burn) in southern Switzerland. Journal of Historical Geography 33(4): 729–748.

Coughlan, M. R., and Petty, A. M. (2012). Linking humans and fire: a proposal for a transdisciplinary fire ecology. International Journal of Wildland Fire 21(5): 477–487.

Coxson, D. S., and Marsh, J. (2001). Lichen chronosequences (postfire and postharvest) in lodgepole pine (Pinus contorta) forests of northern interior British Columbia. Canadian Journal of Botany 79: 1449–1464.

Crittenden, P. D. (2000). Aspects of the ecology of mat-forming lichens. Rangifer 20(2–3): 127–139.

Engelmark, O. (1987). Fire history correlations to forest type ad topography in northern Sweden. Annales Botanici Fennici 24: 317–324.

Esseen, P.-A., Ehnström, B., Ericson, L., and Sjöberg, K. (1997). Boreal Forests. Ecological Bulletins 46: 16–47.

Friedberg, C. (1999). Diversity, order, unity. Different levels in folk knowledge about the living. Social Anthropology 7(1): 1–16.

Granström, A., and Niklasson, M. (2008). Potentials and limitations for human control over historic fire regimes in the boreal forest. Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences 363(1501): 2353–2358.

Grundström, H. (1927–1933). Ortnamnsuppteckningar. Svenska Ortnamnsarkivet, Uppsala.

Grundström, H. (1946–54). Lulelappisches Wörterbuch. Lulelapsk ordbok [Lule Sami dictionary]. Based on contributions by K.B. Wiklunds, B. Collinder, and H. Grundström, 1–4. Landsmåls- och folkminnesarkivet, Uppsala.

Grudd, H., Briffa, K. R., Karlén, W., Bartholin, T. S., Jones, P. D., and Kromer, B. (2002). A 7400-year tree-ring chronology in northern Swedish Lapland: natural climatic variability expressed on annual to millennial timescales. The Holocene 12(6): 657–665.

Hägglund, B., and Lundmark, J.-E. (2004). Handledning I Bonitering med Skogshögskolans boniteringssystem. Del 3 Markvegetationstyper – Skogsmarksflora. Skogsstyrelsen. Jönköping.

Halme, P., Allen, K. A., Auniņš, A., Bradshaw, R. H. W., Brumelis, G., Čada, V., Clear, J. L., Eriksson, A. M., Hannon, G., Hyvärinen, E., et al (2013). Challenges of ecological restoration: Lessons from forests in northern Europe. Biological Conservation 167: 248–256.

Hedwall, P.-O., and Mikusiński, G. (2014). Sprucification in protected forests: myth or veracity? – Evidence from 60 years survey data. Applied Vegetation Science 19(3): 371–380.

Henshaw, A. (2006). Pausing along the Journey: Learning landscapes, environmental change, and toponymy amongst the Sikusilarmiut. Arctic Anthropology 43(1): 52–66.

Hunn, E. (1996). Columbia Plateau Indian place names: What can they teach us? Journal of Linguistic Anthropology 6(1): 3–26.

Institutet för språk och folkminnen. (2017). Website. Accessed April 7 2017. http://www.sprakochfolkminnen.se/sprak/namn/ortnamn/ortnamnsregistret/sok-i-registret.html

Jett, S. (2011). Landscape Embedded in Language: The Navajo of Canyon de Chelly, Arizona, and Their Named Places. *In* D. Mark, A.G. Turk, and N. Burenhult (eds.), Landscape in Language. 327–342.

Johnson, L. M. (2000). "A place that's good", Gitksan landscape perception and ethnoecology. Human Ecology 28(2): 301–325.

Jones, R. (2016). Responding to modern flooding: Old English place-names as a repository of traditional ecological knowledge. Journal of Ecological Anthropology 18(1).

Kadmon, N. (2000). Toponymy: The Lore, Laws and Language of Geographical Names, Vantage Press, New York.

Kimmerer, R. W., and Lake, F. K. (2001). The role of indigenous burning in land management. Journal of Forestry 99(11): 36–41.

Korhonen, O. (1979). Bákkogir'je: julevusámes dárrui dáros julevusábmái. Lulesamisk svensk, svensk lulesamisk ordbok [Lule Sami Swedish, Swedish Lule Sami dictionary]. Almqvist & Wiksell.

Korhonen, O., and Anderson, H. (2010). Samiska ortnamn vid vägar och färdleder i Lule lappmark [Sami place names along roads and trails in Lule Samiland]. Hans Anderson. Jokkmokk.

Kumpula, J., Colpaert, A., and Nieminen, M. (2000). Condition, potential recovery rate, and productivity of lichen (Cladonia spp.) ranges in the Finnish reindeer management area. Arctic 53(2): 152–160.

Lantmäteriet. (2017) Kartsök och Ortnamn. Website. Accessed April 7, 2017. https://kso.etjanster.lantmateriet.se/#

Lewis, H. T., and Ferguson, T. A. (1988). Yards, corridors, and mosaics: How to burn a boreal forest. Human Ecology 16(1): 57–77.

Linder, P., Elfving, B., and Zackrisson, O. (1997). Stand structure and successional trends in virgin boreal forest reserves in Sweden. Forest Ecology and Management 98(1): 17–33.

Linder, P. (1998). Structural changes in two virgin boreal forest stands in central Sweden over 72 years. Scandinavian Journal of Forest Research 13.

Miller, D. (1996). Lichens, wildfire, and caribou on the taiga ecosystem of northcentral Canada. Rangifer Special issue 12: 197–207.

Miller, A. M., and Davidson-Hunt, I. (2010). Fire, agency and scale in the creation of aboriginal cultural landscapes. Human Ecology 38(3): 401–414.

Moen, J., and Keskitalo, E. C. H. (2010). Interlocking panarchies in multi-use boreal forests in Sweden. Ecology and Society 15(3).

Natcher, D. C. (2004). Implications of Fire Policy on Native Land Use in the Yukon Flats, Alaska. Human Ecology 32(4): 421–441.

Nielsen, K., Nesheim, A. (1979 [1932–1962]). Lappisk (samisk) ordbok—Lapp Dictionary, I–V. Universitetsforlaget, Instituttet for sammenlignende kulturforskning, Oslo.

Niklasson, M., and Granström, A. (2000). Numbers and sizes of fires: Long-term spatially explicit fire history in a Swedish boreal landscape. Ecology 81(6): 1484–1499.

Nilsson, M. C., and Wardle, D. A. (2005). Understory vegetation as a forest ecosystem driver: Evidence from the northern Swedish boreal forest. Frontiers in Ecology and the Environment 3(8): 421–428.

Norstedt, G. (2018). A land of one's own – Sami resource use in Sweden's boreal landscape under autonomous governance. Doctoral thesis, Sveriges Lantbruksuniversitet, Faculty of Forest Science, Umeå

Nyström, S., Nilsson, L., and Torensjö, A. (2007). Toponymic guidelines. Riktlinjer för läsning av kartornas ortnamn - Sverige. Toponymic guidelines for Cartography – Sweden. LMV-rapport 2007:6. Gävle, Lantmäteriet.

Östlund, L., Zackrisson, O., and Axelsson, A.-L. (1997). The history and transformation of a Scandinavian boreal forest landscape since the 19th century. Canadian Journal of Forest Research 27(8): 1198–1206.

Pellijeff, G. (1992 [1936]). Ortnamnen i Norrbottens län. Övre Norrlands ortnamn. Institute for Language and Folklore, Dialekt-, ortnamns-, och folkminnesarkivet i Umeå.

Pyne, S.J. (1998). Forged in fire: History, land, and anthropogenic fire. *In* W. Ballée (ed.), Advances in Historical Ecology. 63–103.

R Core Team (2013) A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.

Rankama, T. (1993). Managing the landscape: A study of Sámi place-names in Utsjoki, Finnish Lapland. Études/Inuit/Studies 17(1): 47–69.

Roturier, S., and Roué, M. (2009). Of forest, snow and lichen: Sámi reindeer herders' knowledge of winter pastures in northern Sweden. Forest Ecology and Management 258(2009): 1960–1967.

Ruong, I. (1964). Jåhkågasska sameby. Svenska Landsmål och Svenskt Folkliv.

Ruotsala, H. (2004). In the reindeer forest and on the tundra. Modern reindeer management and the meaning of ecological knowledge. Pro Ethnologia 18: 23–48.

Sandström, P., Cory, N., Svensson, J., Hedenås, H., Jougda, L., and Borchert, N. (2016). On the decline of ground lichen forests in the Swedish boreal landscape: Implications for reindeer husbandry and sustainable forest management. Ambio 45(4): 415–429.

Sousa, A., and García-Murillo, P. (2001). Can place names be used as indicators of landscape changes? Application to the Doñana Natural Park (Spain). Landscape Ecology 16(5): 391–406.

Sousa, A., García-Murillo, P., Sahin, S., Morales, J., and García-Barrón, L. (2010). Wetland place names as indicators of manifestations of recent climate change in SW Spain (Doñana Natural Park). Climatic Change 100(3–4): 525–557.

Steijlen, I., and Zackrisson, O. (1987). Long-term regeneration dynamics and successional trends in a northern Swedish coniferous forest stand. Canadian Journal of Botany 65(5): 839–848.

Stokes, M. A., and Smiley, T. L. (1996). An introduction to tree-ring dating, University of Arizona Press, Tucson.

Svonni, M. (2013). *Davvisámegiela – ruotagiela. Ruotagiela - Davvisámegiela Sátnegirji – Nordsamisk – svensk. Svensk – nordsamisk Ordbok* [North Sami – Swedish dictionary], ČálliidLágádu - ForfatternesForlag, Karasjok.

Taylor, A. R., and Chen, H. Y. H. (2011). Multiple successional pathways of boreal forest stands in central Canada. Ecography 34(2): 208–219.

Tirén, L. (1937). Forestry historical studies in the Degerfors district of the provice of Västerbotten. Meddelanden från Statens Skogsförsöksanstalt 30(1–2): 67–322.

Wallenius, T. (2002). Forest age distribution and traces of past fires in a natural boreal landscape dominated by Picea abies. Silva Fennica 36(1): 201–211.

Wallenius, T. (2011). Major decline in fires in coniferous forests - reconstructing the phenomenon and seeking for the cause. Silva Fennica 45(1): 139–155.

Zackrisson, O. (1977). Influence of forest fires on the North Swedish boreal forest. Oikos 29: 22–32.