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Role of 19th-century rotational slash-and-burn cultivation in the development of boreal forests in southern Estonia and implications for forest management

Pille Tomson[a,*], Tanel Kaart[b], Kalev Sepp[a]

[a] Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Kreutzwaldi 5, Tartu 51014, Estonia
[b] Institute of Veterinary Medicine and Animal Sciences, Estonian University of Life Sciences, Fr. R. Kreutzwaldi 62, 51014 Tartu, Estonia

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ABSTRACT

Slash-and-burn cultivation has been a widespread practice in Northern Europe and large portions of modern forests have developed on former slash-and-burn land. After the decline of slash-and-burn sites, forests regenerated. The aim of the present study was to compare the environmental factors and forest ground vegetation of former rotational slash-and-burn sites and continuous forest land to determine the effects of different land-use history and discuss the results in the context of conservation management. The study was based on analyses of vegetation and environmental factors of different areas, which had been mapped as slash-and-burn land and forests during the 19th century. The results demonstrated that the differences in ground vegetation between slash-and-burn sites and continuous forests are small and up to 5.2% of vegetation variability can be explained by different land use during the 19th century. There were no differences in soil characteristics among sites. The differences in vegetation could be connected to 20th century developments as sections of former slash-and-burn sites were utilised as open fields during the opening decades of the 20th century. In terms of conservation management, forests in former slash-and-burn sites must be considered as well-restored post-agricultural forests without specific features or requirements for management.

1. Introduction

Forest management and historical agricultural land use have changed environmental conditions and directly influenced plant cover. Fire has been utilised for agricultural purposes in landscapes for a long time, e.g., to prepare pastures, to prevent wildfires, or to clear land for crop cultivation. While the impacts of traditional agricultural practices in Europe, such as pasturing or haymaking, on plant diversity are well-studied, less attention has been given to the consequences of slash-and-burn cultivation. A specific feature of slash-and-burn cultivation was use of fire that caused changes in soil characteristics (Delgado-Matas, 2004; Pyne et al., 1996; Reintam and Moora, 1983; Vanha-Majamaa et al., 2007; Viro, 1974).

Slash-and-burn cultivation (swidden) was applied in ancient times, and it persisted up to the late modern period in northern Europe. Up to the early 20th century, the slash-and-burn technique was utilised in Germany, Finland, Sweden, Russia, Latvia, and Estonia (Goldhammer and Bruce, 2004; Hamilton, 1997; Jääts, et al., 2010). The practice of regularly burning young forests created in Estonia a special land category named "*buschland*" (Ligi, 1963; Meikar and Uri, 2000). The forests, mainly composed of birch and alder, were cut and burned and then used for crop cultivation for 2–5 years depending on the site's fertility. Then, the land was left fallow and used as pasture until being recolonised by trees, rotation length being 15–20 years (Ligi, 1963).

Previous studies (Raet et al., 2008; Tomson, et al., 2015) have reported that the areas that had been regularly utilised for slash-and-burn cultivation are now mostly covered by forests.

The differences between ancient and post-agricultural forest vegetation and the historical development of forests in Europe have been under discussion for a long time (Dupouey et al., 2002; Hermy et al., 1999; Hermy and Verheyen, 2007; Matuszkiewicz et al., 2013; Ohlson et al., 1997; Peterken and Game, 1984; Verheyen et al., 2003; Wulf, 2003, 2004). Lists of ancient forest plant species or ancient woodland indicators have been created for different regions (Hermy et al., 1999; Honnay et al., 1998; Schmidt et al., 2014; Wulf, 1997). Ancient forest species groups, which contain coexisting species with similar ecological demands, have recently been defined (Stefańska-Krzaczek et al., 2016). Recovery processes of forest plant communities in post-agricultural landscapes have been described by different authors, as reviewed by Flinn and Vellend (2005).

* Corresponding author.
E-mail addresses: pille.tomson@emu.ee (P. Tomson), tanel.kaart@emu.ee (T. Kaart), kalev.sepp@emu.ee (K. Sepp).

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In northern Europe, natural and old-growth forests have been given more attention (Brūmelis et al., 2011). Ohlson et al. (1997) reported a high correlation between the number of vascular plants and forest continuity, and a dependence of species richness of fungi and bryophytes on the persistence of structural elements of old-growth forests. Studies of forest landscape history are numerous (Axelsson and Östlund, 2001; Eriksson et al., 2010; Lindbladh, 1999; Linder and Östlund 1998, Östlund et al., 1997), and several studies of boreal areas have described how historical human impacts have affected forest tree composition (Axelsson and Östlund, 2001, Ericsson et al., 2005; Eriksson et al., 2010; Lindbladh and Bradshaw, 1998) or have even changed the forest type (Lindbladh, 1999).

In Estonian forests, historical continuity of forest patches and former open land has been shown to affect species composition (Paal et al., 2011). Several studies have analysed the effect of forest management and different successional stadia of forest herb layer vegetation (Aavik et al., 2009; Kohv and Liira, 2005; Meier et al., 2005; Moora et al., 2007). Most Estonian forests have been altered by forest management and the general opinion in Estonian forestry is that forests as old as 180 years have been clear-cut at least once (Etverk, 1974).

Though attracting less attention than some other historical land-use practices such as grazing and haymaking, several studies have analysed the possible effects of slash-and-burn cultivation at the landscape level. Many authors have reported an increase in the abundances of birch and alder in slash-and-burn areas, as observed in the case of regeneration after natural fires (Heikinheimo, 1915; Hokkanen, 2006; Lehtonen, 1998; Linkola, 1987; Parvieinen, 1996; Sarmela, 1987; Vasari 1992). Using pollen diagrams, Lindbladh and Bradshaw (1998) showed that original broad-leaved forests were replaced by coniferous forests after slash-and-burn cultivation in southern Sweden outfield areas. The increase of spruce in forest vegetation is attributable to a combination of climate changes and the decline of slash and burn cultivation (Bradshaw and Hannon, 1992; Lindbladh et al., 2014).

In Finland, former slash-and-burn forests are regarded as semi-natural forests by Uotila and Kouki (2005). Hokkanen (2006) described “man-made” herb-rich forests that have been created by slash-and-burn cultivation. Numerous vascular plant species have been noted as typically present at former slash-and-burn sites (Myllyntaus et al., 2002).

In Estonia, the prevailing opinion is that slash-and-burn cultivation has caused considerable impoverishment of vegetation. Laasimer (1958) suggested on the basis of pollen data that soil depletion caused by regular slash-and-burn cultivation, followed by permanent cultivation, led to the formation of dry oligotrophic pine forests and *Oxalis* spruce forests. Recent Estonian studies have asserted that species-poor spruce forests could grow in former slash-and-burn sites (Paal, 1997; Rõuk, 1995). Tomson et al. (2016) analysed the forest composition in former slash-and-burn sites in southern Estonia using the State Forest Management Database (FMD) and discovered that the most common was the *Oxalis* forest type.

The aim of the present study was to analyse the environmental and vegetational differences between former rotational slash-and-burn sites, and sites which have been continuous forest land since the 19th century. Legacies of historical land use and former rotational slash-and-burn fields are discussed with respect to biodiversity protection and conservation management.

2. Material and methods

2.1. Environmental conditions

The study was carried out in southern Estonia in Valga and Võru counties, in the Boreal Region as defined by Metzger et al. (2005). The climate in the region is moderately continental; the average temperature is −5 °C in winter and 16 °C in summer. The average annual precipitation is approximately 700 mm (Tarand et al., 2013). The sandy and loamy soils are mainly acidic and overlie various Quaternary sediment moraines, covering the Devonian bedrock (Astover et al., 2012). The region is mainly hilly, with moraine kames.

2.2. Selection of study sites

Field work was carried out during the summer months in 2014 and 2015 in five protected areas: Karula National Park (47 forest stands), Pikkjärve (three forest stands), Paganamaa Landscape Protection Area (eight forest stands), Pähni Nature Protection Area (three forest stands) and Haanja Nature Park (19 forest stands; Fig.1).

Former slash-and-burn sites (*buschlands*) and continuous forest land were identified using 19th-century maps, including the maps of Karula (1867), Vana-Antsla (1871–1872), Boose (1871–1872), Haanja (1851), Vana-Roosa manor (1886), Krabi manors (1878), and different farm maps (Appendix A). Historical maps were geo-referenced and raster maps were compared with digital layers from the FMD (Environment Agency, 2017) to locate suitable areas for a vegetation survey of forest patches. Stands older than 90 years were preselected to ensure that the ground vegetation was representative. Forest patch sizes greater than 0.5 ha were preferred. Various forest types located in former *buschlands* were selected for vegetation analyses: of these study areas 31 (68.9%) were *Oxalis* main type, 10 (22.2%) were transitional *Oxalis-Vaccinium myrtillus* subtype forests, two (4.4%) were *Oxalis-Vaccinium vitis-idaea* subtype, and two (4.4%) belonged to *Hepatica* type, according to FMD. Based on a previous study (Tomson et al., 2016) the *Oxalis* forest site type was considered typical of slash and burn cultivation sites. Therefore, *Oxalis* type stands, which had been mapped as forest during the 19th century, were selected for comparison. The stands with fresh signs of forest cutting were excluded to avoid any influence of recent human impact. Of the 80 observed forest stands, 45 were former *buschlands*, and 35 were forest land stands. In most observed forest stands, five vegetation plots were examined. The slash and burn cultivation areas were named “*buschland*” in the 19th century maps; therefore, the forests located in the former slash-and-burn sites are named as *buschlands* in the present study. The stands located in areas mapped as forest in the 19th century are hereafter named former forest.

2.3. Field studies

For vegetation surveys, the methodology of Bunce and Shaw (1973) was applied. Plots of 200 m^2 were utilised in the present study and were selected randomly within the preselected forest stands. The abundances of trees regeneration and of bushes were recorded by species. The general coverage of the bryophyte layer and presence of species were also recorded. Unknown bryophytes were collected and identified by staff at the Herbaria of Estonian University of Life Sciences. Vascular plants were identified based on Leht (2010), and bryophytes were identified based on Ingerpuu and Vellak (1998). In the observed stands, 151 species of vascular plants (Appendix B) and 51 species of bryophytes (Appendix C) were recorded, with 92 vascular plant species present in more than 5% of stands. In the herbaceous layer 85 vascular plant species were registered in more than 5% of stands.

The diameter of trees measured at a height of 1.3 ms was recorded by species. In addition, in every forest stand, the effect of former human impact was estimated, using the timescale factor (late: 5 years, medium: 5–20 years, and old: greater than 30 years) and strength (missing, weak, medium, and strong effect). The types of human impact were previous fellings, roads, hiking trails, traces of former resin collections, and effect of being adjacent to clear-cut areas. In subsequent analyses, the