Forest Ecology and Management 330 (2014) 67–74

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Low levels of tree retention do not mitigate the effects of clearcutting on ground vegetation dynamics

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ARTICLE INFO

Article history:
Received 27 March 2014
Received in revised form 24 June 2014
Accepted 26 June 2014

Keywords:
Boreal forest
Bryophytes
Forest fire
Lichens
Prescribed burning
Vascular plants

ABSTRACT

Several new forestry practices directed at mitigating the influence of clear-cutting on biodiversity and other ecosystem properties have been launched recently. Retention forestry is the most widespread of these practices, but so far most studies have evaluated effects of retention levels that are higher than commonly applied by forestry in many parts of the world. Furthermore possible interaction effects between retaining forest structures and other common forestry practices, such as prescribed burning are still largely unexplored. Here we present results from a ten year stand-level factorial forestry experiment in Eastern Finland (FIRE[1]) with retention levels full (100%), elevated (50 m^3/ha), low (10 m^3/ha) and no retention (0%) combined with or without prescribed burning. We show that neither low, nor elevated retention is sufficient to influence the vegetation composition, or dynamic relative to no retention in unburned sites at stand level. However, retention in combination with prescribed burning influenced post-harvest community composition, so that species composition of the elevated retention treatment differed from low- and no retention treatments. When prescribed burning was applied, the functionally important species *Vaccinium vitis-idaea* had two times higher cover in stands with elevated retention compared to stands with low or no retention. We conclude that at the stand level, low retention levels do not mitigate clear-cut induced disturbance and retention can neither preserve the pre-harvest vegetation nor change the post-harvest vegetational dynamic.

1. Introduction

Intensified forestry is known to have adverse effects on biodiversity and ecosystem functions (Butchart et al., 2010; Bengtsson et al., 2000; Puettmann et al., 2009). Consequently, initiatives from the forest industry to also embrace non-economic goals, such as preservation of ecological values, are becoming increasingly common. To be able to reach such goals, several new forestry models and practices have been proposed, including increased use of selective logging, prolonged rotation periods, retention of trees during clear-cutting and the use of prescribed burning (Kohm and Franklin, 1997; Larsson and Danell, 2001).

An aspect that have been stressed as important when designing new forestry systems which take biodiversity conservation into account is the role of natural disturbance regimes (Lindenmayer and Franklin, 2002; Bengtsson et al., 2000). Retention forestry (sometimes referred to as "tree retention" or "variable retention"), i.e. the practice of retaining trees during clear-cut harvest, is arguably the conservation practice within forestry that has grown most rapidly in the last decades (Gustafsson et al., 2012). A key foundation of retention forestry is the idea that the retention of structures can mimic the effects of natural disturbances which are rarely as uniform as the effects of clear-cutting (Franklin et al., 1997). Ideally the model of retention is therefore tailored to follow habitat requirements of the local biota and the disturbance to which it is supposed to mimic (Bergeron et al., 2002; Gustafsson et al., 2012).

In many regions of the Boreal forest biome, the predominant disturbance has been fire (Esseen et al., 1997; Zackrisson, 1977). Nowadays however, effective fire control suppresses fires in managed forests, a phenomenon especially evident in Fennoscandia (Östlund et al., 1997). Before the introduction of intensive forest management, the role of fire in this region was probably comparable to that of other parts of the boreal biome. However, unlike continental regions, i.e. central Canada, the fires were not necessarily stand replacing, but also of lower intensity (Kuuluvainen, 2009). It is thus likely that the importance of fire has varied in both space and time and the most important influence on the landscape was the creation of heterogeneity on multiple scales (Kuuluvainen, 2002). This heterogeneity, caused in part by the variation in fire intensity, was likely of great importance for the vegetational dynamics. Under

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[1] http://wanda.uef.fi/jarikouki/project_fire.htm.

http://dx.doi.org/10.1016/j.foreco.2014.06.031
0378-1127/

natural conditions, forest fires reoccurring at different time intervals, created a mosaic of vegetation successional stages in the boreal landscape (Johnson, 1992; Esseen et al., 1997). Within stands, fires were often of variable intensity which maintained local spatial heterogeneity in the vegetation (Kafka et al., 2001).

In comparison to clear-cuts, retention forestry mimics natural disturbances by retaining some living and dead trees, which may generate successional mosaics in the vegetation at the stand level. Studies on the effects of tree retention on ground vegetation generally confirm that it alleviates the negative effects of harvest, and that higher retention level will have less impact on both the composition and abundance of the plant species (Beese and Bryant, 1999; De Graaf and Roberts, 2009; Lencinas et al., 2011; Halpern et al., 2012). A complication with many these studies however, is that most report only short-term results, i.e. effects a few years after harvest (but see Halpern et al., 2012; Craig and Macdonald, 2009). Plant communities may show strong inertia and it can take many years before the full effects of the disturbance becomes visible, suggesting that short-term studies may potentially fail to notice biodiversity response.

The effect of tree retention should, at least in theory, resemble the effect of the predominant disturbance, i.e. in this case fire. However, certain organisms depend on burned substrates, which cannot be created by only retaining forest structures, and it is therefore often argued that the implementation of prescribed burning is an important measure for biodiversity conservation (Granström, 2001). The combined effect of tree retention and prescribed burning is, however, still largely unexplored. There are several possibilities how retention can interact with burning to form the residual vegetational composition. Retained structures may act as refugia for species less resistant to fire, thus mitigating the effect of the disturbance. Moreover, retaining structures may also influence the fire intensity by altering fuel levels, i.e. reducing the amount of logging residues (Hyvärinen et al., 2005).

We studied the vegetational response in a ten year old experiment in Finland (the FIRE-experiment[2]) which is unique as it includes the combination of tree retention and fire treatment as well as focusing on low retention levels (10 m^3 ha^{-1} and 50 m^3 ha^{-1}) and is replicated at stand-level. Our aims with this study are (1) to explore the response of ground vegetation to comparably low levels of tree retention over longer time period and (2) to assess if the combination of retention forestry and prescribed burning has interactive effects on vegetation patterns. We expect that the vegetation dynamics in the experiment will be dictated by the differences in disturbance severity of the different treatments. Severe disturbance will lead to dynamics driven by species with high dispersal capacity, i.e. wind dispersed species. At moderate intensity, the dynamic will be driven by seed bank species and species with deep rhizomes that can survive in-situ. At the lowest intensity, disturbance will only lead to a general thinning of the vegetation resulting only in a halted, or slightly reversed, natural succession dynamic. In the harvest treatment, we expect that higher levels of retention will lead to less intensive disturbance. The most severe disturbance will be when fire and harvest is combined, and we expect higher levels of retention to alleviate the fire intensity, as clear-cuts with retained structures will contain less logging residues, and thereby fuel for the fire.

2. Materials and methods

2.1. Study area

The study was conducted in Lieksa and Ilomantsi municipalities in Eastern Finland (Fig. 1), an area belonging to the middle boreal vegetation zone (Ahti et al., 1968). Average mean temperature is +2 °C, averaging −12 °C in January and +15.8 °C in July and yearly precipitation is 500–800 mm of which about half falls as snow (Ilmatieteen laitos, 1991). The sites chosen for the study were all initially covered with about 150 year old coniferous forest of dry *Vaccinium–Empetrum* heath type. Scots pine (*Pinus sylvestris*) dominated the tree layer but Norway spruce (*Picea abies*) and birch species (*Betula pendula* and *Betula pubescens*) were also common. The sites had previously been exposed to very low intensity selective harvesting during the late 1800s and early 1900s but no intensive modern forestry had been conducted prior to the experiment (Hyvärinen et al., 2006).

The experiment consists of 24 different sites of approximately 3–4 ha in size each, subjected to 8 different treatments in a factorial manner, with burned or unburned as the first factor and level of harvest intensity as the other ($n = 3$ for each treatment combination). The pre-harvest volumes in the stands was, on average, 288 m^3/ha. There were no significant differences in the forests that were designated to different treatment combinations. The harvest of the sites was conducted during the winter of 2000/2001. The different levels of harvest include no retention (0%), low retention (10 m^3 ha^{-1} or 3.5% of the pre-harvest volume), elevated retention (50 m^3 ha^{-1}, 17.4% of the pre-harvest level) and full retention (100%; Fig. 2). The two intermediate levels were designed so that a majority of the retained trees are aggregated into either three (low retention) or five (elevated retention) evenly sized circular groups. None of the sites included in this study were exposed to stand level post-harvest silviculture practices, such as soil scarification or planting. The dynamics of retention trees in harvested areas are reported by Heikkala et al. (2014).

The prescribed burnings were performed in similar weather conditions during two consecutive days at the end of June 2001 (for more details, see Hyvärinen et al., 2005). The intensity of the fire, measured as the change of the depth of the humus layer before and after fire, was higher in harvested sites which had a 27% reduction in humus layer, compared to unharvested sites which had an 8% reduction in the humus layer. In the retention treatments, the average flame height, measured as the height of continuously blackened and charred bark, was also measured to evaluate fire effects. In full retention, the charred height was 2.2 m, in elevated retention it was 3.9 m and in low retention it was 5.8 m. The data indicates that the fire intensity, at least inside retention groups, was dependent on the amount of logging residue in the sites (Hyvärinen et al., 2006). In open parts of each site, there was always a lot of variation in fire intensity, probably because of the small-scale topographical and moisture variation in the soils.

2.2. Data collection

In 2000, the summer before the treatment, 15 plots, 2×2 m^2 in size and evenly spaced in three rows ca. 40 m apart from each other, were marked out in all of the sites. In the intermediate harvest treatments with retained groups of trees, vegetation plots were not placed within a retention group although a few were located directly next to one. The plots were inventoried for all ground living vascular plants, macrolichens and bryophytes (mosses and liverworts). The inventory focused on species of the ground and field layer growing on soil, and species clearly growing on dead wood, bark and rock were therefore excluded. Specimens were, when possible, identified down to species level in the field and percentage cover was visually estimated. If species identification in the field was not possible, specimens were taken for microscopic identification in the laboratory. The same inventory was repeated in 2003, two years after treatment, and finally in 2011, ten years after, adding up to an observation time of 11 years. The nomenclature for vascular plants follows Karlsson (1998), for bry-

[2] http://wanda.uef.fi/jarikouki/project_fire.htm.