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Continuous cover management reduces wind damage

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ABSTRACT

Wind damage causes significant economic losses in boreal forests and elsewhere. Climate change may increase the occurrence of strong storms and decrease tree anchorage, making wind risk management an important aspect of future forest management. This study modeled the probability of wind throw as a function of thinning type, time since previous cutting, characteristics of the subject tree and stand, and shelter provided by adjacent upwind stands. The data were collected from two long-term silvicultural experiments, which experienced strong storm events during the past few years. The analyses showed that the most risky cutting was shelterwood cut, followed by even-aged silviculture characterized by repeated low thinnings. Cuttings where the probability of wind throw was lowest were selective high thinnings of uneven-sized stands, and dimension cutting. Very dense un-thinned stands had very low probability of wind damage. Increasing tree size, increasing height/diameter ratio, decreasing stand basal area, and decreasing basal area of adjacent upwind stands increased the probability of wind throw. Stands were most vulnerable to wind damage immediately after thinning. Uneven-sized stand structure was associated with low probability of wind throw. It was concluded that continuous cover management decreases wind damage, as compared to even-aged management.

1. Introduction

Wind damage plays a significant role in forestry (Gardiner et al., 2013). Most wind damage occurs in stands adjacent to newly clear-cut areas or in recently heavily thinned stands (e.g. Laiho, 1987; Zubizarreta-Gerendiain et al., 2012). The damage causes economic losses since many wind thrown trees are left unharvested. There are also economic losses when the damaged trees are harvested since parts of the trees are broken and harvesting is more costly than in normal cutting. Further, wind damages may lead to non-optimal timing of harvesting.

One positive consequence of wind damage is that broken and wind thrown trees are a source of coarse woody debris providing habitat for many species (Tikkanen et al., 2007). However, harmful bark beetles such as *Ips typographus* also benefit from damaged trees, and severe damages may lead to bark beetle outbreaks. Trees which remain standing may experience internal injuries and become less resistant to bark beetles, increasing the likelihood of severe outbreaks (Schroeder and Lindelöw, 2002).

Previous research has shown that forest management can significantly influence the risk of wind damage (Zeng et al., 2007; Heinonen et al., 2009, 2011). An efficient means is to avoid clear-felling such stands which are adjacent to conifer stands of tall and slender trees (Heinonen et al., 2009; Forsell et al., 2011). In forest planning, an easy way to reduce wind risk is to minimize height differences between adjacent stands (Heinonen et al., 2011). In even-aged management, minimization of wind risk often leads to reduced area of regeneration harvesting and increased area of thinning treatments. Meilby et al. (2001) showed that increasing risk of wind damage shortens the optimal rotation length of an isolated stand. However, if a stand provides shelter to other stands, it is optimal to increase its rotation length compared to a stand which does not protect other stands against strong winds.

Although most damage occurs near stand edges, damage also occurs in the inner parts of stands. Strong storms are particularly capable of causing damage throughout the stand. Wind damage within stands can also be affected by forest management (Cremer et al., 1982). General conclusion is that heavy thinning leads to a temporary increase in the probability of wind damage (Cremer et al., 1982; Hanewinkel et al., 2013). This can be seen in newly cut seed tree and shelterwood stands, which are very vulnerable to wind damages (Jalkanen and Mattila, 2000). Slender conifers are more likely to become damaged than birches and less slender trees (Peltola et al., 1999; Martín-Alcón et al., 2010; Zubizarreta-Gerendiain et al., 2012).

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Uneven-sized forests are commonly assumed to be less vulnerable to wind damage than even-sized stands of the same density (Dobbertin, 2002; Hanewinkel et al., 2013). This is because wind cannot penetrate as easily a stand consisting of several canopy layers. It is obvious that continuous cover forestry reduces the overall risk of wind damage since it decreases the length of vulnerable stand edges (Zeng et al., 2007). On the other hand, uneven-sized stand structure increases canopy roughness, which may increase the risk of wind damage among dominant trees.

It is not clear how climate change will affect the frequency of storms and maximum wind speeds (Haarsma et al., 2013). However, a warming climate will shorten the period of frozen soil, thus weakening tree anchorage (Blennow et al., 2010; Gregow et al., 2011). As a result, winter storms are likely to cause more wind damage in boreal forests in the future. Thus, the importance of wind risk management will likely increase in the future (Schuck and Schelhaas, 2013).

This study analyzed the probability of wind damage in the inner portions of stands. The analysis is based on empirical data from two silvicultural experiments which have recently experienced several storm events. The measurements from the experiments provided data for analyzing the effect of past management, stand structure and tree characteristics on the probability of wind throw. The results of the study provide straightforward information for forest managers with the aim of reducing the likelihood of wind damage.

2. Material and methods

The data were collected from the silvicultural experiments of Vessari and Honkamäki located in Central Finland. The area of the Vessari site (N 62°02′; E 24°16′) is 16 ha while the Honkamäki site (N 62°05′; E 24°21′) covers 6 ha. The elevation of both experiments is slightly over 100 m above sea level. The terrain is flat in both experiments and the soil type is coarse moraine, which is the most common soil type in Finland.

Natural regeneration trials of Norway spruce were established at the experimental sites during the 1940s. Around 200 dominant trees per hectare, mostly spruces, were left as shelter trees. The stands had advance regeneration of Norway spruce which was not removed in the shelterwood cut. Both sites are surrounded by spruce-dominated mixed forest.

The stands regenerated well and the shelter trees were removed at the end of the 1950s. The experiment at Vessari was divided into 57 $50 \times 50\ m^2$ plots and the Honkamäki experiment into 36 $40 \times 40\ m^2$ plots (Lähde, 1991). Seven plots were left as untreated control plots (Fig. 1). Pre-commercial thinning was conducted on the other plots leaving mainly spruce and pine to continue growing. Birch was left in places where the density of conifers was low.

Twenty-five years after the shelterwood cuts the experimental sites were covered by young uneven-sized mixed forest. The first commercial thinnings of these forests were conducted at the end of the 1980s in all plots except the seven control plots (and one rejected plot). The thinning type was low thinning (44 plots), single

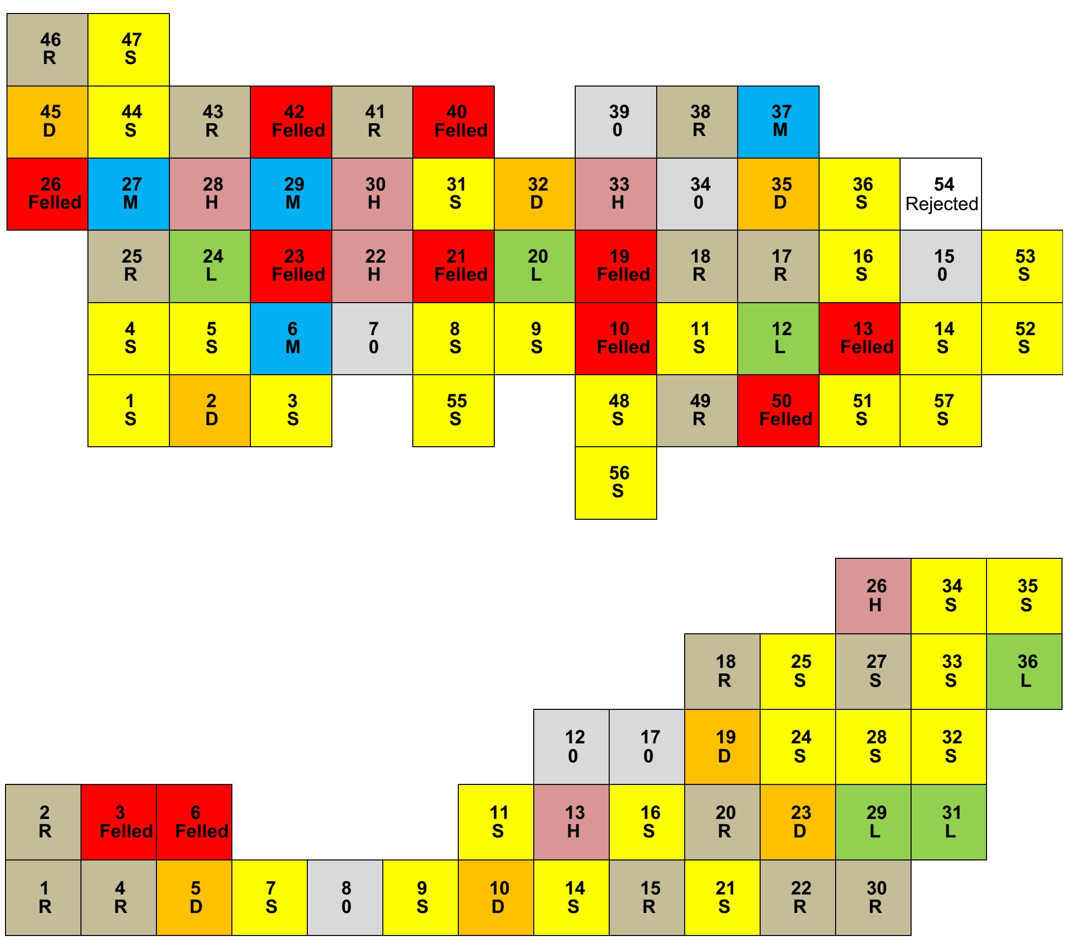

Fig. 1. Maps of the experimental sites of Vessari (top) and Honkamäki (bottom); 0 = control (no cuttings); D = dimension cutting; S = selective high thinning of previously high-thinned stand; L = low thinning of previously low-thinned stand; H = high thinning of previously low-thinned stand; M = thinning of a mature previously low-thinned stand; R = regenerative shelterwood cut; Felled = clear-felled (not used in this study).