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Plenterwald, Dauerwald, or clearcut?

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ABSTRACT

Forest landowners are interested in management alternatives which do not involve clearfelling and planting. Also many citizens that do not own forest are against clear-felling do to its harmful effects on amenity values and ecosystem services. Most studies on continuous cover forest management (CCF) deal with regular, steady state uneven-aged forests (Plenterwald), or with the conversion of stands into steady-state structure. However, people who want CCF management seldom want Plenterwald in particular; continuous tree cover would in most cases be sufficient. This type of management corresponds to the German Dauerwald concept. This study compared the profitability of Plenterwald, Dauerwald and clear-cutting schedules in Finnish spruce forests. As expected, Dauerwald was more profitable than cutting schedules that converted the stand into steady-state Plenterwald structure. The difference in net present value decreased with increasing number of conversion cuttings. Clear-cutting and planting was more profitable than optimal CCF only in a mature initial stand when the planted spruces were assumed to grow 20% faster in dbh and height, compared to naturally regenerated spruces. In young, medium-aged and uneven-aged initial stands, CCF was more profitable even when 20% tree breeding benefit was assumed in the plantation that was established in the clear-felling site.

1. Introduction

Continuous cover forestry (CCF) is one of the current megatrends in forest management (O'Hara et al., 2007; Schütz et al., 2012). CCF corresponds to the German Dauerwald concept, which according to Alfred Möller (Möller, 1922; Helliwell, 1997) can be characterized as follows: avoid clear-felling; minimize capital; maximize production; remove trees of decreased vigor; do not aim at any pre-defined steady-state forest structure; leave cutting residues in the forest; and rely on natural regeneration. Dauerwald is different from Plenterwald (Schütz, 2001), or uneven-aged management, which aims at a certain steady-state forest structure and often assumes that exactly similar cuttings can be repeated at regular intervals to infinity.

Few forest landowners actually want Plenterwald or a certain forest structure. What they want is in most cases a continuous cover of trees with no clear-felling and planting, more natural-looking forests, and less intensive forest management (Valkeapää et al., 2009; Diaci et al., 2011; Asikainen et al., 2014). Therefore, studies which optimize the steady-state management of uneven-aged forest (Chang, 1981) or aim at finding the optimal sequence of transformation cuttings to steady-state forest structure (Haight et al., 1985) may not be the most useful for forestry practice.

When the management objective is to maintain continuous tree cover and use less intensive management the task of forest planning is simply to find the most profitable management schedule that meets these criteria. This schedule may or may not converge to steady-state stand structure. Steady-state structure is a constraint, which can only decrease profitability compared to non-constrained management (Haight, 1987). The sooner the steady-state structure must be reached the lower is the profitability of forest management. Constrained management regimes that involve obligatory clear-cutting and planting are also sub-optimal relative to more general problem formulations (Haight, 1987).

Legislation may set limits to the optimization of forest management. For instance in Finland and Sweden, the national forest law forbids the landowner to reduce the growing stock volume (Sweden) or stand basal area (Finland) below certain limits (Wikström, 2008; Laki

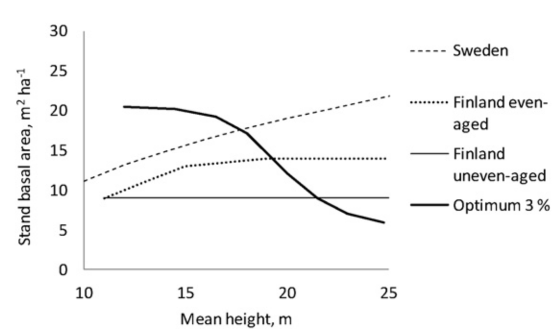

Fig. 1. Minimum stand basal area according to Finnish and Swedish legislation (the Swedish volume limit has been converted into basal area limit). The thick line shows the basal area which maximizes the difference between annual value increment and opportunity cost in a spruce stand growing in Central Finland. Opportunity cost is equal to 3% of the stumpage value of growing stock and bare land value (1000 €/ha).

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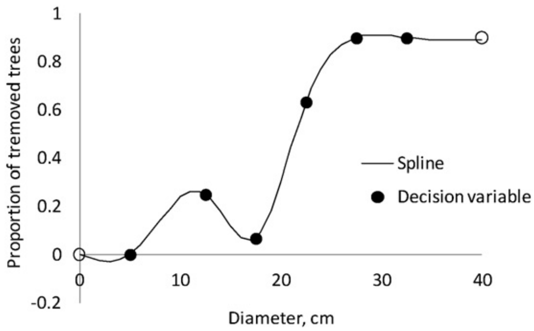

Fig. 2. Optimized decision variables (filled dots) and a cubic spline function used to calculate the harvest percentage for individual trees. Negative values were replaced by zero and values greater than 1 were replaced by 1. Open circles are additional points (one at both ends) used for fitting the spline.

metsälain muuttamisesta, 2013). Interestingly, the minimum allowed volume or basal area of an even-aged stand increases with increasing tree size, although the economically optimal stocking level would decrease with increasing tree size (Fig. 1). This means that legislation constraints economically optimal management more in mature stands than in stands of young and small trees.

Thinning treatments improve profitability if they reduce the opportunity cost of growing stock relatively more than they decrease value increment. Thinnings from above (high thinnings) are the best means to achieve the wanted effect since they remove mainly trees with high opportunity cost and low relative value increment, and leave trees with low opportunity cost and high relative value increment (Knoke, 2012).

When tree size increases the opportunity cost of the capital invested in wood production also increases, but the inherent growth rate of trees usually decreases, calling for decreasing the growing stock volume with increasing tree size. Since the minimum legal stand volume or basal area increases with mean tree size, legislation reduces the possibilities to improve profitability through thinning treatments especially in mature stands. Legislation forces the landowner to face so high opportunity costs in mature stands that clearfelling may become optimal even when it is followed by obligatory planting, which as such would not be profitable. Without legislation, the true optimum would in most cases be to thin the stand below the legal limit and let it regenerate naturally (Pukkala et al., 2014a). Natural regeneration is not forbidden, but the Finnish forestry legislation sets another constraint requiring that a sufficient regeneration must be obtained within a certain time frame. This may not always be possible, or there is a high probability that regeneration is not fast enough from the legal point of view.

Cheaper harvesting and the possibility to benefit from tree breeding are the advantages of clear-felling and planting. If the savings in harvesting and the increase in growth rate are large enough, clear-felling and planting may be the most profitable management option even without legislation and despite the fact that it includes additional silvicultural costs as compared to CCF.

This study compared the profitability of three management options in different initial stands under the current forest legislation of Finland (1) CCF, (2) conversion of the stand into steady-state uneven-aged structure; and (3) clear-felling and planting. The effect of tree breeding was considered in the analysis. It was hypothesized that increasing tree size in the initial stand increases the relative profitability of clear-felling and planting. CCF (Dauerwald) as a less constrained management system was assumed to be more profitable than conversion into steady-state uneven-structure (Plenterwald). The sooner the steady-state structure must be reached the lower should the profitability of the conversion schedule be.

2. Materials and methods

Four Norway spruce stands growing on fertile site in Central Finland were selected for the analyses (Table 1). In the young stand no trees had reached the saw-log size, and in the mature stand all the trees were already saw-log sized. In the medium-aged stand, about half of stand basal area was in pulpwood-sized trees and the rest was in saw-log sized trees. The fourth stand was uneven-aged (two layered), consisting of two strata, both of which had plenty of variation in tree size.

The trees harvested in cuttings were partitioned into saw-logs, mini logs, and pulpwood pieces (Table 2). The income from harvesting was calculated as the difference between roadside timber prices (Table 2) and harvesting cost. Harvesting costs were calculated with the models of Rummukainen et al. (1995). These models predict lower unit costs in clear-felling than in thinning when the removal per hectare and the mean size of harvested trees are the same. Harvesting cost per cubic meter decreases with increasing size and per hectare volume of harvested trees.

The stand data were used to predict the diameter distribution of each stratum of the stand. Then, 50 representative trees per stratum were drawn from the distribution to represent the stand in simulation. The models of Pukkala et al. (2013) for diameter increment, survival and ingrowth were used to simulate stand dynamics:

Diameter increment:

$$id = \exp(-9.645 + 0.455\sqrt{d} - 0.0574d + 1.455\ln(TS) + 0.291OMT - 0.049VT - 0.404CT - 0.308\ln(G)$$
$$-0.029\frac{BALp}{\sqrt{d+1}} - 0.142\frac{BALs}{\sqrt{d+1}} - 0.083\frac{BALh}{\sqrt{d+1}})$$

where *id* is the future 5-year diameter increment (cm), *d* is diameter at breast height (cm), *TS* is temperature sum (degree days), *G* is stand basal area (m^2ha^{-1}), *BALp*, *BALs* and *BALh* is the basal area in larger pines, spruces and hardwood species, respectively (m^2ha^{-1}), and *OMT*, *VT* and *CT* are indicator variables for herb-rich, sub-xeric and xeric site, respectively.

Table 1
Initial stands.

Stand "name"	Stratum	Basal area, m^2 ha^{-1}	Mean height, m	Diameter, cm		
				Minimum	Mean	Maximum
Young	1	15.0	11	5	12	18
Medium	1	25.0	16	11	18	26
Old	1	25.0	22	18	25	30
Uneven	1	15.0	21	18	22	28
	2	7.6	6	1	8	16