Economics and productivity in selection harvesting in Norway spruce stands in Sweden

- summary of results from a simulation study

Peder Wikström

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SVERIGES LANTBRUKSUNIVERSITET
Institutionen för skoglig resurshushållning
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Contents

Introduction

This report is a summary of results from a study (Wikström 2008) carried out within the project "Kontinuitetsskogar och kontinuitetsskogsbruk" ("Ancient woodlands and continuous cover forestry") headed by the Swedish National Board of Forestry. This short version is written on behalf of the Baltic Forest project, WP2 (www.balticforest.net).

The purpose of the study was to compare two types of management systems for Norway spruce, selection harvesting and even-aged management, with respect to economic value and growth. To do this, analysis were done using a stand management growth-and-yield model. Mature forest stands were the starting point for analysis, stands that could be clear-cut immediately if only economics goals apply, but where selective harvesting may be an alternative. The reasons for not clear-cutting may vary; they could be aesthetic, recreational or to promote certain species threatened by even-aged management. The question is what the consequences are with respect to economy and productivity for a forest owner who chooses, for some reason, to apply a less intensive form of management than clear-cutting followed by a new plantation regime?

Data and methods

The sensitivity to different conditions was investigated by using different discount rates, different assumptions on timber quality, two different growth models, and different stocking levels required after harvest for selection harvesting (see Wikström 2008 for further details). Twelve experimental plots established long time ago, the earliest one in 1918, were used both for model validation and as input data for the analysis. The plots were multistoried spruce stands located in northern Sweden (see Lundqvist 1989 for further details).

Existing models were used for computing tree growth, natural ingrowth of new trees, mortality, timber values, and harvesting cost. Simulation of strip roads were included by making duplicates of sample plots, giving in this case two plots per stand, and then weighting the plots proportionally to the area of striproads versus the area between striproads. In selection harvesting, the selection of trees was simulated so that the oldest trees were harvested first. The reason for choosing the oldest trees first was to keep the residual stand "vital" after harvesting. Of course, in reality these older trees may be the ones one would like to retain, for example to promote biological diversity, but the purpose here was to focus on economical values.

The stocking levels tested were guided by the Swedish Forestry Acts (5 and 10 §), which regulates the wood volume that should be left after some form of harvesting. The purpose of these regulations is to prevent an overexploiting, non-sustainable use of forest resources. The regulations are given in form of diagrams, giving the minimum wood volume required as a function of mean height after harvesting. Here, these rules were translated, so that the minimum wood volume was a function of site index (figure 1). A restriction was added to the simulations, so at most 30 % of the standing volume (40 % in the first harvest as long as the lower bound was not violated) could be extracted at the same time. This was to simulate what is considered as "sound" management in thinnings; harvesting too large proportion of the standing stock leaves a residual stand great risk of being damaged by wind (Persson 1972). However, for comparison, an additional run ("SVL5_U60") allowing 60 % of the standing volume being at the same time was simulated.

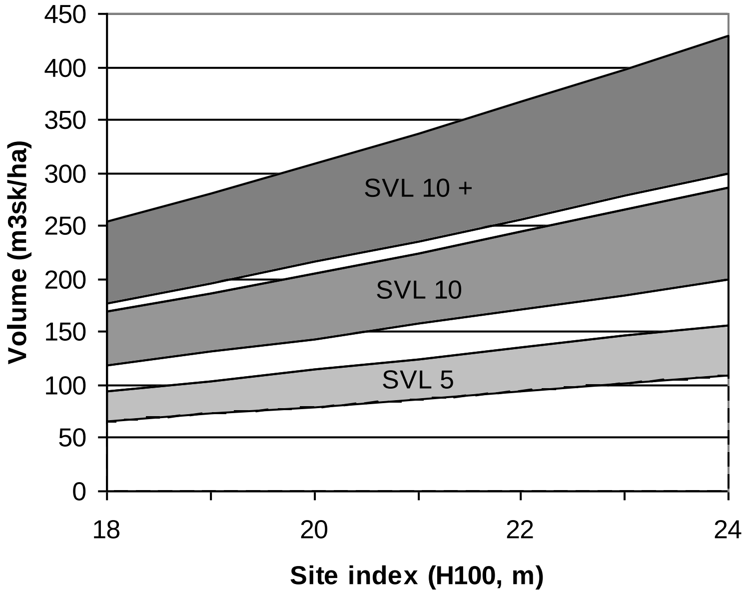

Figure 1. *Target standing stock (m3/ha) for three different applications of selection harvesting, as simulated in the study, assuming 30 % extraction rates of standing volume. The target stock levels are given as functions of site index. Harvesting was triggered if the stocking was close to the upper bound of a field, and then down to the lower bound. The "SVL" number refers to the paragraph in the Swedish Forestry Act used for deriving the lower bounds. The lower bound for "SVL 10+" is obtained by adding 50 % to "SVL 10".*

In the experimental series, all trees were measured at the first inventory. Plot sizes varied between 0.25 and 1 ha. The number of trees actually measured in a plot was as much as 2300. In subsequent inventories, the trees measured at the first inventory were re-measured, but, unfortunately, new ingrown trees were not measured, at least not in all inventories. Neither were tree ages measured, which is also a problem since the growth function include tree age as an explanatory variable. However, the series are still useful for validation and for representing realistic initial states. The missing tree ages were dealt with by using age functions and a calibration procedure described in Wikström (2008). As a first step, observed and predicted development was compared. Missing trees (naturally ingrown but not registered trees) were handled by comparing only trees at least 4 cm (dbh) at the first inventory. In the simulations, ingrowth functions were used meaning that both in the simulation and in the real experiments the potential influence from ingrown trees on the growth of older trees are accounted for. When comparing the calculated development with observed development, the actual management regimes were applied in the simulations. These regimes describe exactly which trees were cut and when. Ending diameter distributions in the last period showed a good correspondence between observed and calculated values (figure 2).

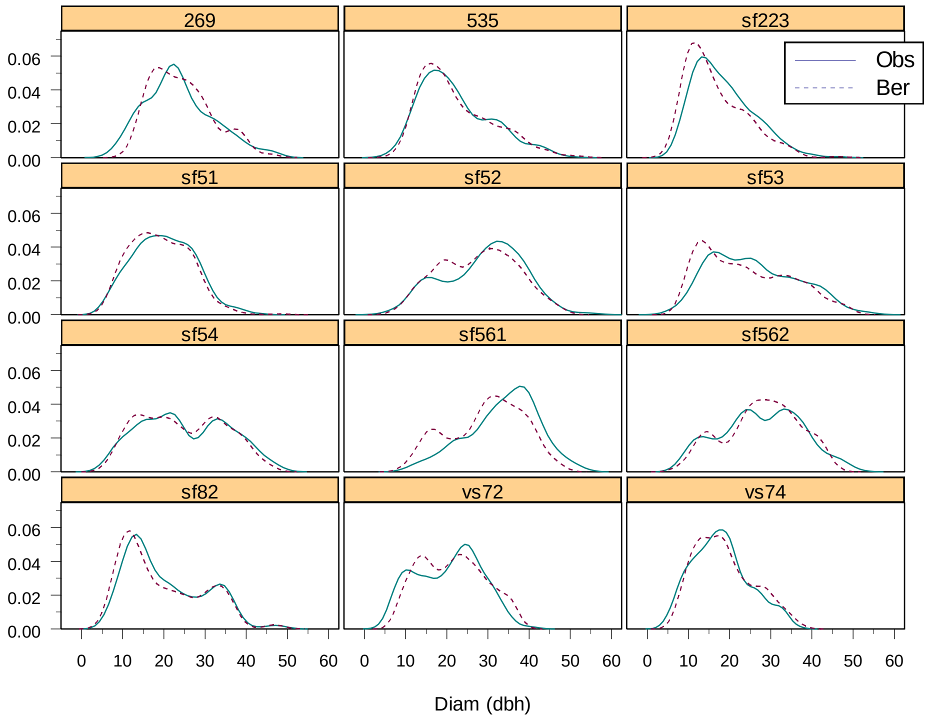

Figure 2. *Comparison between diameter distributions according to measurements (obs) and simulation models (ber). Graphs show the diameter distribution in the final inventory period for each survey plot. In the simulation results, the actual management regimes as registered were applied.*

Results

In most cases even-aged management gave the largest net present value (figure 3). The average loss in net present value is presented in table 1. In absolute terms, there was a large variance between stands (figure 4). The relative loss in net present value was positively correlated with:

- discount rate,
- stocking level target,
- time for the first harvest,
- site index

Hence, the larger the discount rate, stocking level and site index, the larger was the loss in net present value of applying selection harvesting compared to even-aged management. To decrease loss in net present value, the first selection harvest should be done as soon as possible, if the stand is ready for clear-cutting. Also, the lower the stocking level target, the first harvest could be carried out immediately since the density trarge

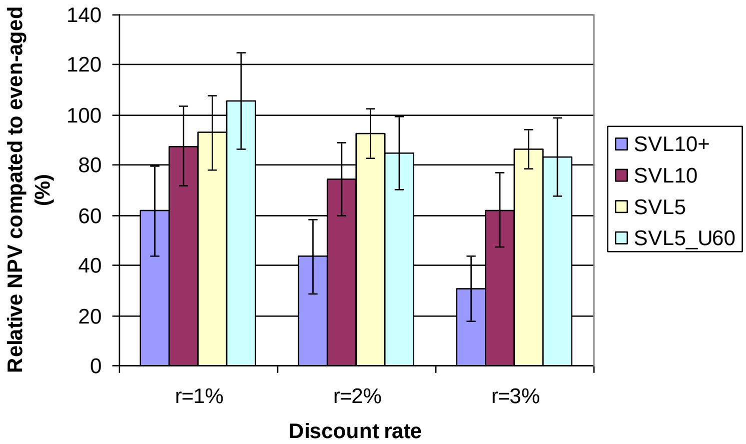

Figure 3. *Relative net present values (%) for selctive harvesting compared to even-aged management, for different stocking levels and discount rates. Error bars represent standard deviations.*

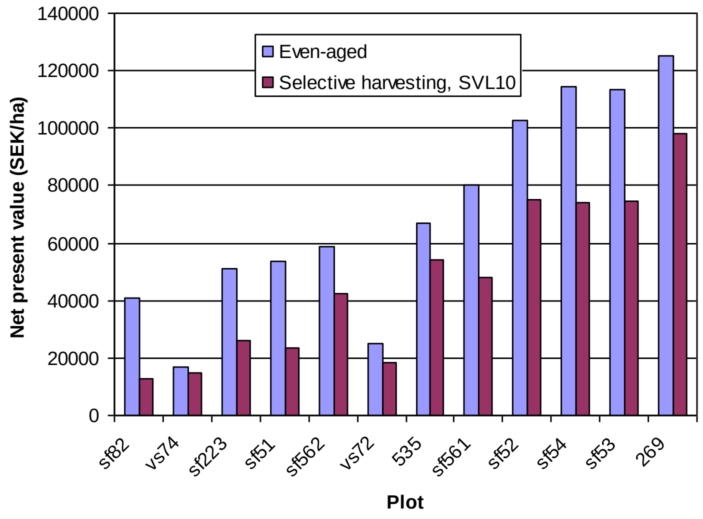

Figure 4. *Net present values (SEK/ha) for each plot. Discount rate 3 %, selective harvesting with stocking level SVL10.*

Table 1. Average loss (%) in net present value for selective harvesting compared to even-aged management, under different stocking levels and discount rates. Standard deviations are given in brackets.

	Discount rate					
Alternative	r=1%		r=2%		r=3%	
SVL10+	38	(18)	56	(15)	69	(13)
SVL10	12	(16)	25	(15)	38	(15)
SVL5	7	(15)	7	(10)	14	(8)
SVL5_U60	–6	(19)	5	(15)	17	(15)

Under the larger stocking levels (SVL 10+ and SVL 10), stand volume and mean diameter was larger when harvesting, giving larger harvest volume, cheaper harvesting and more valuable timber. Also, the fixed entry cost per volume unit decreased with the size of the harvest. Despite this, the capital cost (i.e. the loss in net present value) of not harvesting trees with low value increment was more important. Even-aged management combined both; low harvesting costs and low capital cost.

The mean annual net increment was about the same for even-aged management, starting from bare land, and management under selection harvesting, starting from an existing stand. However, the net annual increment decreased over time in selection harvesting. The main reason for this was that ingrowth was less than harvesting and mortality, leading to a declining stem density over time.

When evaluating net present value, one must be aware of the many uncertainties not handled by the simulation model. In table 2, an effort has been made to list important uncertainty factors and how these affect the comparisons. As a conclusion, it appears most probable that the loss in net present values for selection harvesting compared to even-aged management have been underestimated rather than overestimated in the results presented, if compared what would be in a real case.

Table 2. Factors that may result in that the net present values have been over- or underestimated in the simulations.

Factor	Comment	Effect on net present value loss of uneven-aged management of spruce compared to even-aged management
Injuries on remaining trees due to harvesting	Generally there is a higher risk for injuries on remaining trees after harvesting in old and dense stands than in young stands (cf. Fjeld och Granhus 2001 and Wallentin 2007, p. 54). Unlike even-aged management, the uneven-aged management system evaluated is dependent on the success of ingrowth of new trees meaning that the minimization of injuries of advance growth is important. Granhus & Fjeld (2001) and Fjeld & Granhus (2001) studied injuries after selective harvesting. See Wallentin (2007) for an overview of injuries in conventional thinnings.	Greater loss in reality
Risk of butt rot, snow damages, and windthrow.	In selective harvesting in mature stands, there is a general risk that remaining trees will be damaged in the future due to snow, wind, or butt rot. Damages on residual large trees will have a more negative effect on net present value than future damages on trees planted today. Also, if harvesting is carried out more frequently in uneven-aged management than in even-aged management, the risk for butt rot may increase (Vollbrecht & Jørgensen 1995). When the risk for butt rot is large, even-aged management can be applied without thinnings, with no or little impact of net present value, at least when the price for coarse timber is not promoted as the case was in these analysis. Uneven-aged management does not offer this alternative. Concerning the risk of windthrow, there is no evidence that multi-storied stands are more resistant than even-aged. On the other hand, uneven-aged management on a large scale would lead to less number of edges in the landscape, which could lead to less risk of windthrow (Olofsson & Blennow 2005). Such a large-scale transformation of the landscape is another issue than the addressed here, but would be extremely costly.	Greater loss in reality
Plantation	The risk for unsuccessful artificial regeneration is not considered in the analysis, but could be important, especially at some soil types and under certain climatic conditions.	Loss in net present value could be less in reality or net present value could be the highest for unven-aged management
Sustainable growth	The yield capacity in even-aged management was probably underestimated in the analysis (Elfving & Nyström 1996), while there is a risk for overestimation for uneven-aged management due to insufficient ingrowth – the assumption on a maintained growth level after year 60 is too optimistic.	Greater loss in reality
Continuous ingrowth through natural regeneration	Even-aged management in the form analyzed here (without seed trees) is independent of natural ingrowth, while uneven-aged management relies on a continuous ingrowth of new trees. If additive planting is required in uneven-aged management after each harvest, costs will increase.	Greater loss in reality
Timber quality	Timber quality was assumed to be better when applying uneven-aged management than in even-aged management. If this turns out to be false, the net present value for uneven-aged management is overestimated	Greater loss in reality

Conclusions

- The net present value for selection harvesting management was generally less than for even-aged management. For some plots the net present value was larger for selective harvesting, especially for low discount rates, small stocking levels, and larger harvest intensities.
- The loss in net present value as compared to even-aged management was larger if:
    - the first harvesting took place late in time,
    - the required stocking level was high,
    - the discount rate was high,
    - site index was high,
    - harvest volume in the first harvest was small
- The number of ingrown trees in the last prognosis period, according to the ingrowth functions, was lower than the number of trees that died or was harvested. Therefore there is a risk that the stem density, and as a consequence the productivity, decreases over time.
- Without considering a probable underestimation of site productivity in young plantations in northern Sweden, as reported by Elfving & Nyström (1996), the productivity in even-aged management, starting from bare land, was comparable to that for selective harvesting. However, one should have in mind that the initial investment, in the form of leaving more trees in the first period versus plantation costs, for this productivity was considerably higher for selective harvesting. If a correction of site index for young plantation was done according to Elfving & Nyström (1996), productivity for even-aged management would be higher than for selection harvesting.

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