Economic consequences of three silvicultural methods in uneven-aged mature coastal spruce forests of central Norway

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Summary

Six experimental sites in the coastal spruce (*Picea abies* L. Karst.) forest of central Norway were used as the basis of an economic investigation of three silvicultural systems: a single tree selection system, a group system and clearcutting. The mean tree volume removed in the selection system was 0.6 m^3, and ~0.3 m^3 for the other two methods. The harvesting cost was ~14 euro/m^3 for clearcutting, and about 10 per cent higher for the group and selection systems. In simulations of future revenues and expenses, the net present value (NPV) was approximately 15 per cent lower for the group and selection systems compared with clearcutting. Lower volume production in uneven-aged stands and higher administration and harvesting costs had only a minor influence on the NPV. All calculations were carried out using a 2 per cent discount rate, a 3 per cent rate lowered the NPV of the group and selection systems to 75 per cent of the clearcutting method.

Introduction

In Norway, silvicultural methods have been discussed for centuries. Recently, special attention has been given to threatened and vulnerable species in the coastal forests and to harvesting methods for conserving these. It is well known that the clearcutting system involves a dramatic change for several shade-demanding species and excludes them from the harvested area for several decades (Rolstad *et al*., 2001). The climate in the boreal rain forest is humid with an annual rainfall of about 1200–1800 mm, with more than 200 days of at least 0.1 mm rain and an annual mean temperature of 4–6°C. Most of the forest in central Norway has been regularly cut for more than 300 years. So far only a few Norwegian studies have objectively compared the economics of different silvicultural methods.

There were four objectives of this study:

1 To investigate forest structure before cutting at six experimental sites of coastal spruce forest in central Norway.
2 To perform an experimental cutting and study stand properties after harvesting.
3 To estimate harvesting costs of three different cutting regimes.
4 To estimate and compare the net present value (NPV) of three silvicultural systems.

Materials and methods

The six sites were located at Trøndelag (64°–64°30′ N, 10°–12°30′ E). The two main vegetation types were bilberry-type (*Eu–Piceetum myrtilletosum* K.-Lund 81) and small fern type (*Eu–Piceetum dryopteridetosum* K.-Lund 81). The sites were subjectively selected in large homogeneous areas, in order to be able to compare different silvicultural methods. All stands considered were classified as development class V; i.e. they are mature and ready to be harvested (Tveite and Braastad, 1981; Eid, 1990). In addition to classical forest inventory data (see Table 1), crown height, tree age, annual diameter growth and quality aspects such as waste timber, proportion of pulpwood/sawtimber and thickness and amount of branches, were measured on 20 randomly sampled trees. The slope, length of hillside, extraction distance and proportion of bog areas were also determined. These data were used to estimate the timber price and harvesting costs. The amount of recruitment (tree height of 0.2–3 m) was investigated by use of 20 m^2 plots, randomly located at each site (total of 80 plots).

Experimental cutting

Three silvicultural methods were performed close to each other in the terrain: clearcutting (0.5–1 ha), single tree selection system and group system (400, 600, 900 and 2000 m^2 gaps). In the selection system, the trees were subjectively chosen to maintain a continuous irregular structure (see Schütz, 1989; Andreassen, 1994b). However, a greater part of the volume than intended was removed, since many of the trees were large. The harvesting costs were estimated by measurements of the time taken for cutting and extraction of a total of 654 trees (Dale and Kjøstelsen, 1997), cost analysis models (Dale and Stamm, 1994; Fjeld, 1994) and measurements of tree crowns, branches, topography and extraction distance using a forwarder.

Economic calculations

In an economic comparison of future cash flows from different silvicultural systems, proposed options are to examine the bare land value (BLV), or to calculate the net present value (NPV) of existing stands, adding the long-term BLV (Clutter *et al.*, 1983). In our case, where one of the goals was to maintain the structure of existing stands, we decided to use the latter method based upon detailed inventory data.

Several assumptions from harvesting knowledge or experience had to be made. An infinite time horizon was used and all future revenues and expenses were estimated and discounted to year 2000, including the BLV. The volume increment, costs and prices were calculated by use of the growth estimator BESTPROG (Blingsmo and Veidahl, 1994). This model, based on mean tree prognosis, is not optimal for describing the growth of trees in selectively cut stands. However, since no other simulators that take into account conditions in Norway were available, we adjusted the volume increment of the selection forest to 85 per cent of the even-aged models based on information from long-term experiments with the selection system (Andreassen, 1994a). Furthermore, we estimated the volume increment of the group system to be somewhere between 85 and 100 per cent (of the even-aged models) depending on the stand structure, gap size and edge effects;

Table 1: Site properties before cutting

Site	Area (ha)	Volume (m^3/ha)	Stems d.b.h. <25 mm (n/ha)	Recruitment 2–30 dm Norway S.	Mean diameter (mm)	Mean tree volume (dm^3)	Site class (m^3 ha^{-1} a^{-1})	d.b.h. age (years)
B1	1.2	230	1000	1200	180	230	7.0	84
F1	6.0	355	1265	1600	190	280	5.0	107
F2	4.5	190	680	950	195	280	5.5	116
G1	15	260	650	900	230	400	3.5	138
H1	2.5	330	1360	1750	180	240	7.0	82
Ø1	8.5	300	1080	1200	190	280	6.0	136
All sites	6.3	277	1006	1250	194	285	5.7	109

95 per cent was finally used in the calculations. In the group system we assumed that one-third of the area is cut immediately, one-third after 20 years and the remaining third is cut after 40 years. Consequently, the entire area has been cut after 40 years, and then after another 40 years the first cutting of the new forest occurs. Due to the presence of many large old trees, 30–40 per cent of the volume is cut in the first year using the selection system. Twenty years later a second cutting is performed harvesting 30–35 per cent of the volume, and after this the cutting cycle is approximately 20 years with 30 per cent of the standing volume being cut each time.

There was great uncertainty in the results of the simulations after 60 years. However, due to the long discounting time, these revenues are assumed to be less important for the NPV. The tree mortality (due to windthrow, insects, fungi etc.) is estimated to be 0.4 per cent of the standing trees annually up to 100 years of age, 0.8 per cent between 100 and 150 years and 1.2 per cent for trees older than 150 years (Øyen, 2000). After clearcutting, most recruitment is destroyed, and since advance growth is sparse and requires ~20–50 years to reach breast height, we decided to plant 2000, 1500 and 300 trees/ha in clearcutting, group system and selection system, respectively. The expense of administration is 50 euro/ha for each cutting. Fifteen years after clearcutting and group cutting, a pre-commercial thinning is carried out at a cost of 150 euro/ha. Twenty-five years after tending we perform a thinning where 25 per cent of the standing volume is cut. In the calculations we assume the potential timber prices to be 55 and 35 euro/m^3 for sawmill timber and pulpwood, respectively.

Results

Information for each site before cutting is shown in Table 1. The diameter distribution for each site was investigated and displayed the classical reverse-J shape at five of the sites. The exception was Site G1, which showed a flat curve for small and medium-sized trees. It was also observed that there were a lot of seedlings, but the number of 2–3 m tall saplings was heavily reduced in the cuttings for all systems. In the clearcutting and the group system, most of the recruits were destroyed during the felling and the extraction; however, in the selection system, a considerable number survived the harvesting. The mean volume of trees removed was almost twice as large for the selection system than for the clearcutting and group system (Table 2).

The mean harvesting costs was 14 euro for clearcutting, 16 euro for the group system and 15 euro for the selection system. The lowest cost was observed at site G1 for clearcutting (11 euro). This site was flat and the ground was dry and firm. Additionally, the mean tree volume was large and the off-road extraction distance was short. The costs of the group and selection systems were also small at this site. The highest costs observed for the group system was at site F2 with 20 euro/m^3. This site was steep, much of the ground was wet and the forwarding distance was up to 700 m, far greater than for the other stands.

Clearcutting showed the highest net present value for all sites (Figure 1). *t*-Tests showed that NPVs for clearcutting were significantly higher than the NPV of the selection system (pr $>|t|$ 0.02); the NPVs of the selection system and group system were not different (pr $>|t|$ 0.98). The NPV of the group and selection systems were found to be almost equal at most sites except site G1. The diameter distribution of site G1 was different, with a larger proportion of medium-sized and large trees. The first cutting with the selection system was about 5 per cent higher in volume at this site, and early revenues are important in the NPV calculations. The mean NPV was 8500 euro for clearcutting, 7100 euro for the group system

Table 2: Area, volume and mean tree in the harvesting (mean of all sites, standard deviations in parentheses)

Cutting method	Mean area of plots (ha)	Volume (m^3/ha)	Number of trees (stems/ha)	Mean diameter (cm)	Mean tree volume (dm^3)
Selection system	0.61 (0.36)	99 (11)	160 (38)	28 (2)	620 (99)
Group system	0.06 (0.05)	298 (52)	940 (373)	21 (3)	350 (92)
Clearcutting	0.70 (0.21)	280 (60)	1000 (276)	20 (3)	310 (102)

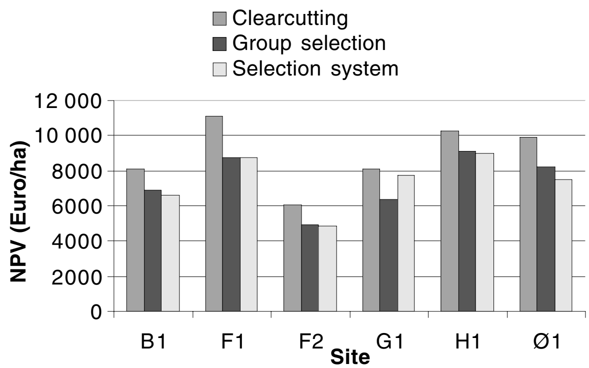

Figure 1. Net present value (NPV) of three silvicultural systems at 2 per cent discount rate.

and 7200 euro for the selection system using a discount rate of 2 per cent (Figure 1).

The revenues and expenses were based on both observed and estimated values. Some of these values are uncertain and the results must be interpreted with great care. The importance of the different components in the calculation was studied using sensitivity analysis. One of the most important factors is the discount rate. An increased rate from 2 to 3 per cent decreased the NPV of the group and selection systems by about 10 per cent in relation to clearcutting (Table 3). Calculations also revealed that if the alternatives to clearcutting had been performed 20 years ago, this would have equalled the differences in NPV. A subsidy of ~6 euro/m^3 on the timber price over an infinite time horizon for the group cutting or the selection cutting will equal the NPV differences between the three systems. However, the amount of subsidy needed to equal the differences varies between the sites. A shorter cutting cycle lowered the NPV. Administration and harvesting costs and lower volume production of uneven-aged forest had only a minor influence on the NPV.

Discussion

In this investigation, experimental cutting was performed at six uneven-aged sites in the coastal spruce forest of central Norway. The site properties before and after cutting were analysed. Most of the sites showed a reverse-J shaped diameter distribution, which is important if a conversion to an uneven-aged forest is the main goal. However, to convert from an even- to an uneven-aged forest, a long time is needed and the transformation can be expensive and risky (Schütz, 1989; Andreassen, 1992). Weed competition for the seedlings is also high locally and the slow breakdown of the forest litter means that supplementary planting may be necessary, especially in large gaps.

Table 3: Sensitivity analyses (percentage net present value of the clearcutting method)

Changed assumption	Group system	Selection system
No changes (2% discount rate)	84	85
Discount rate of 3%	73	75
Discount rate of 4%	63	67
Additional admin. cost of 100 euro per cutting	81	82
Equal harvesting costs	89	88
Equal volume production in even- and uneven-aged forest	85	88
10 years cutting cycle except for clearcutting	78	78
20 years previous cuttings except for clearcutting	98	99
Subsidy of 6 euro/m^3 except for clearcutting	99	100

Results from the experimental cuttings revealed that all three methods are reasonable options in the coastal spruce forest. At these sites, no additional roads had to be built to perform the cuttings. However, the harvesting costs of the group and selection systems were about 10 per cent higher than clearcutting. Most of this was due to a greater distance between the harvested trees and operational difficulties because of restricted space between the remaining trees, which delayed the cutting and the transport operations. The higher costs of the group and selection systems are in agreement with the results of other studies in Norway (Dale and Flatland, 1992; Dale *et al*., 1993; Fjeld, 1994; Dale and Stamm, 1994). However, there have been few studies in other countries and no clear consensus about the harvesting costs for alternatives to clearcutting, and this should be further investigated (Arnott and Beese, 1997; Hanewinkel, 2001). Several authors underline the fact that both the mean volume of the harvested trees and the price of the timber are relatively good in areas where the selection system is performed (e.g. Schütz, 1989; Hanewinkel, 2001). However, in Norway at present large-sized timber has about the same price as medium-sized timber (20–30 cm diameter at breast height) and at most modern sawmills the processing of large timber is probably more expensive.

The estimated NPVs of all future expenses and revenues of both the group system and the selection system are considerably lower than for clearcutting, about 15 per cent at a 2 per cent discount rate. An even greater difference was found in another comparison between even-aged and uneven-aged management in Norway (Hoen, 1996). Analyses in other countries, for instance Sweden and Germany, have come to the opposite conclusion (e.g. Hagner, 2001; Hanewinkel, 2001; Knoke and Plusczyk, 2001). However, the assumptions made in their studies are not comparable with the assumptions or the inventory data from our study. Sensitivity analysis revealed that some components in the NPV analysis for the coastal spruce forest are more important than other components. Special attention should be given to the initial condition of the stand. A delayed harvesting of economically mature stands is rarely profitable, and whilst the mature trees increase the NPV, more small trees will reduce the NPV. Achieving a NPV for uneven-aged management similar to that for clearcutting seems to involve starting the conversion process at an earlier stage than suggested in our study.

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