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Changes in the Vascular Plant Vegetation after Different Cutting Regimes on a Productive Peatland Site in Central Sweden

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We studied the changes in vascular plant vegetation in the first five years after final felling of a mature Norway spruce (*Picea abies* (L.) Karst.) forest on a productive peatland. Vegetation changes following clearcutting and selective cutting (shelterwoods with the density 140 and 200 stem ha^{-1}) were compared. The total cover of the understory increased three times on the clearcut and more than twice in the shelterwoods. The relative decrease of the three most common species was from 73% to 3% on the clearcut and 79 to 28% under the shelter trees. Six of the 16 most common species in the mature forest almost disappeared on the clearcut. In contrast, in the shelterwoods, few species decreased and twelve of the most common species remained the same or increased their cover. *Key words: Vegetation changes, peatland, clearcut, selective cutting, shelterwoods, species diversity.*

INTRODUCTION

Forestry practices such as clearcutting, site preparation, drainage or fertilization all affect the natural forest vegetation to some extent. Studies on these effects are not only important in a silvicultural sense, but also for the preservation of the flora. However, few studies on the influence of different forestry measures on the flora have been carried out in Sweden. Most studies have been concerned with vegetation changes after forest fertilization (e.g. Backeus, 1980; Persson, 1981; Gerhardt & Kellner, 1986; Nohrstedt, 1988; Nohrstedt et al., 1988; Finér & Braekke, 1991) or forest drainage (e.g. Holmen, 1964). Few studies have concentrated on different harvesting and reforestation regimes. Ingelög (1974) studied vegetation dynamics after clearcutting in mesic bilerry forests with respect to timing of final felling, amount of logging residue, and scarification of mineral soil. Influences of silvicultural practices, including thinning, fertilization, clearcutting and site preparation, on the production of berries were analysed by Kardell & Eriksson (1983).

Productive wetlands, with a thin or deep peat layer, cover one fifth of forest lands in Sweden. About one million ha of these wetlands support mature Norway spruce (*Picea abies* (L.) Karst.) forests registered for final felling (Hånell & Sugg, 1989). Final fellings on such sites have been carried out as clearcuts. This has led to difficulties in forest renewal. To solve these problems, experiments with different forest regeneration methods on productive peatlands were established in 1985–86 in nine mature spruce forests in the southern, central, and northern Sweden (between latitudes 57°03′ N and 64°13′ N). The experiments include clearcutting and selective cutting in shelterwoods at two densities, 140 and 200 stem ha^{-1}. We discuss changes in vascular plant vegetation the first five years after final felling from the experimental site, Fallet in Central Sweden. The objective of our study was to compare the changes in the understory vegetation dynamics after clearcutting and shelterwood harvesting.

MATERIALS AND METHODS

Study site

The study site, Fallet, is a mature Norway spruce forest located in the county of Gävleborg, Central Sweden (60°30′ N, 17°11′ E, 40 m above MSL). The site type is *Maianthemum-Viola*/low herb with an estimated postdrainage forest productivity of 9.5 $m^3\ ha^{-1}\ yr^{-1}$ (Hånell, 1991*a*). The average standing volume before final felling was 381 $m^3\ ha^{-1}$, distributed over 656 trees. The site has been drained more than 50 years ago. After drainage, the vegetation changed from an assumed wet-moist low herb type to the present moist-mesic low herb type. In spite of this change, many of the original species probably still remain. The dominant vascular species in the field layer are *Oxalis acetosella*, *Dryopteris carthusiana* and *D. assimilis*. Other common species are *Gymnocarpium dryopteris*, *Thelypteris phegopteris*, *Lactuca muralis*, *Viola epipsila*, *V. riviniana*, *Rubus saxatilis*, *Equisetum sylvaticum* and *E. pratense*. The most abundant moss genera are *Brachythecium*, *Plagiochila* and *Dicranum*. The peat soil is 130 cm on average and well humified. Peat samples for nutrient analyses were taken at various depths before final felling (cf. Hånell, 1991*b*). The concentration of nitrogen, phosphorus, potassium and calcium in the peat at 0–40 cm from the soil surface was respectively 2.4%, 0.085%, 0.040% and 2.64%, dry matter.

Treatments

Half of the study area was clearcut. On the other half sparse and dense shelterwoods (140 and 200 stems ha^{-1}) were left. The final feeling was done in May 1987 with a feller-limber machine (Logma). Later, windthrow in the shelterwoods were processed with chain-saws. In October 1990, the remaining number of shelter trees were 105 and 140 ha^{-1}. Although some of the forest regeneration methods tested in the experiment included site preparation (mounding), this study is restricted to treatments without site preparation.

Experimental design

Each of the three treatments is represented by two sample plots. The plot size is 40 × 25 m on the clearcut and 20 × 25 m in the shelterwoods (cf. Fig. 1). The vegetation was analysed in temporary (1 × 1 m) subplots. The number of subplots analysed each year on the clearcut and in each of the shelterwood treatments were 42 and 24, respectively. A detailed description of the subplot pattern is given by Hannerz (1988).

Measurements and analyses

The cover of each species in the field layer was estimated as per cent of horizontal projection. The lowest cover registered per subplot was 0.01%, or 1 cm^2. The cover of the logging residue was also estimated. The vegetation was analysed before final felling (1986) and at the end of the first and fifth growing season after final felling (1987 and 1991). All inventories were made between the end of August and the beginning of September.

We calculated the mean cover and frequency (% of plots in which the species occurred) of each species as well as total (additive) cover of all species per subplot. From this, estimates of mean values per sample plot and per treatment were made. The relative cover was calculated as a single species share of total cover. Species diversity (D) was expressed by using Simpsons index, $D = 1 - \Sigma p_i^2$ (Krebs, 1985), where p_i is the relative cover for species *i*. Richness was expressed as number of species per subplot (1 m^2). Both diversity and

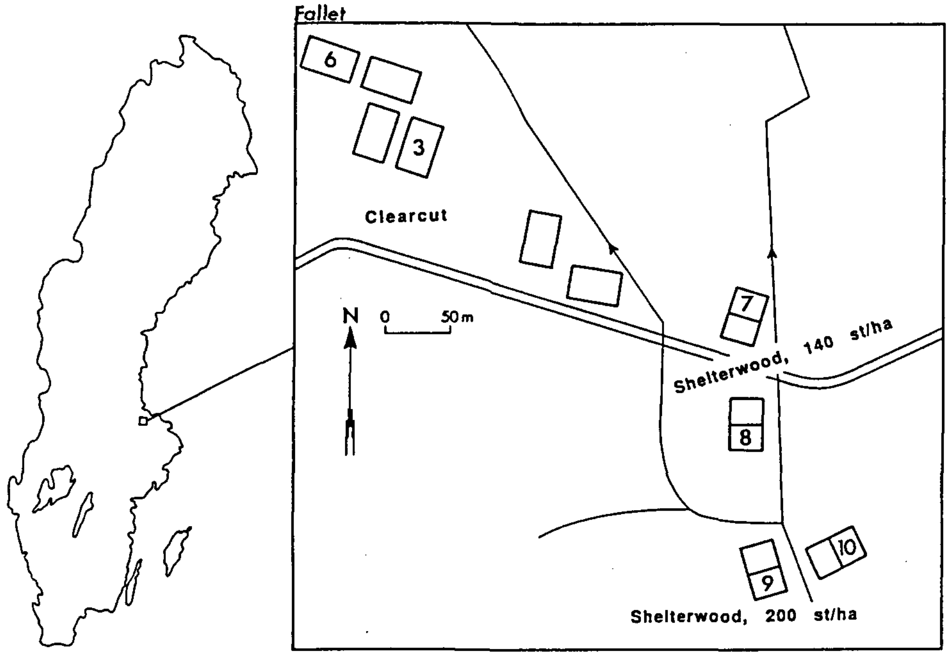

Fig. 1. The study site, Fallet, in Central Sweden. Experimental design. Vegetation change was studied on the numbered plots.

richness were calculated for each subplot. *Dryopteris carthusiana* and *D. assimilis* were grouped as *D. carthusiana*.

Analysis of variance was used to test for differences between treatments. The difference between the cover before and five years after harvesting was used as the dependent variable. LSD-tests were performed for the species that had no missing values at the plot level before and after treatment as well as for total cover, diversity and richness.

RESULTS

Ground cover and diversity

All harvesting treatments resulted in a major initial decline in ground cover (Fig. 2). Five years later (1991) the total cover was three times larger in the clearcut and twice as large in the sparse and dense shelterwoods than before the harvesting. The difference in ground cover change between clearcut and dense shelterwood was significant ($p = 0.01$).

Both diversity and richness decreased in the clearcut (Fig. 3), but increased substantially in the dense shelterwood. The richness increase was smaller in the sparse shelterwood, while diversity remained almost the same. The dense shelterwood was significantly separated ($p = 0.01$) from clearcut in richness and diversity change.

Species composition

The vegetation in the clearcut became dominated by a few immigrants. Five years after final felling the four most abundant species accounted for 82% of the total cover in the clearcut. Before cutting, these were absent (*Chamaenerion angustifolium* and *Cirsium arvense*) or had a minor role (*Rubus idaeus* and *Filipendula ulmaria*). Other newcomers on the clearcut were

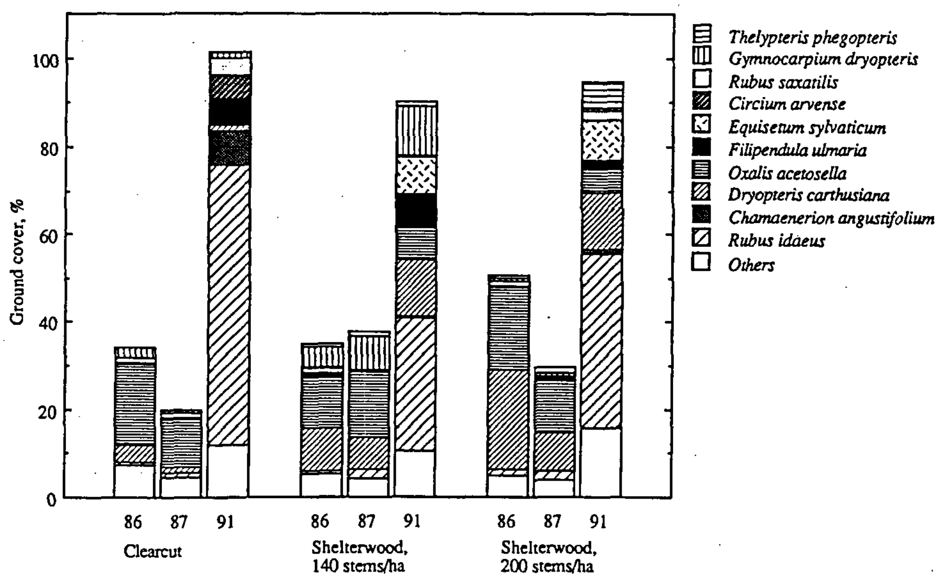

Fig. 2. Total ground cover of the field layer before (1986) and after (1987, 1991) final felling on the clearcut and in the shelterwoods. Species with > 4% cover are separated.

Cirsium vulgare, *Potentilla norvegica*, *Rumex acetosella* and *Senecio sylvaticus*. A few species that mainly spread vegetatively (*Fragaria vesca*, *Rubus saxatillis* and *Viola riviniana*) increased substaintially in the clearcut, but did not change much in the shelterwoods.

Newcomers had a minor role after cutting in the shelterwoods, compared to that of the clearcut. The increased cover in the shelterwoods was caused mainly by *Rubus idaeus*, but many of the species that were abundant before cutting also increased their cover. Under the shelter trees the relative cover of the dominant species before harvesting (*Oxalis acetosella*, *Dryopteris carthusiana* and *Gymnocarpium dryopteris*) decreased from 75 to 35% (sparse shelterwood) and from 83 to 21% (dense shelterwood). In the clearcut the relative cover of the same species decreased from 73% to 2.6%.

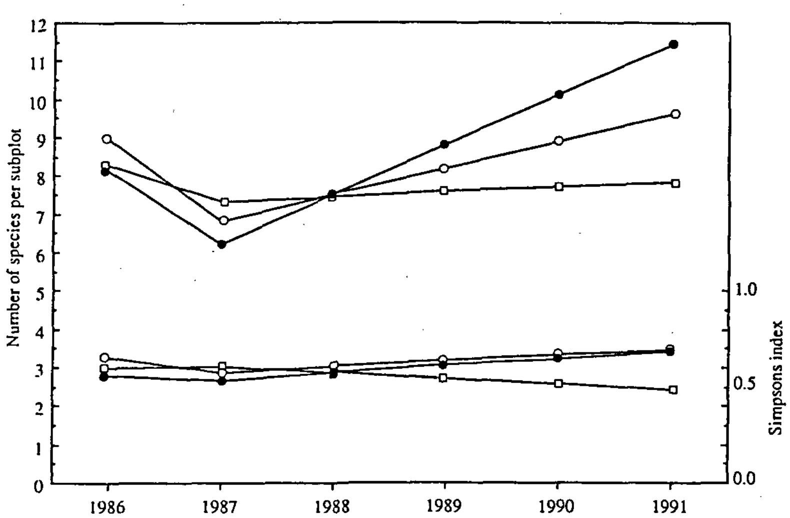

Fig. 3. Average number of species per subplot (above) and diversity according to Simpsons index (below) on the clearcut and in the shelterwoods. Symbols: □ = clearcut, ○ = 140 stems ha^{-1}, ● = 200 stems ha^{-1}.

The original species were reduced in the clearcut, while the effect of the shelterwood harvesting was almost negligible. Before felling, 16 species were present at two or more subplots in all treatments. Only one of these, *Anemone nemorosa*, had disappeared from all plots five years after cutting. By then eight species on the clearcut had their ground cover reduced to $<10\%$ of their before final felling cover. Six of these species (*Linnaea borealis*, *Lactuca muralis*, *Paris quadrifolia*, *Trientalis europaea*, *Vaccinium myrtillus* and *Oxalis acetosella*) decreased even more, to $<1\%$.

In the shelterwoods, as a contrast, none of the original species (except *Anemone nemorosa*, see above) were reduced to $<10\%$, and only three to $<50\%$ of the before harvesting cover. The remaining 12 species remained the same or increased their ground cover after the cuttings.

Logging residue

The logging residue covered approximately 10% of the ground in the clearcut, and 30% in the shelterwoods. The impression was that the logging residue was gathered more in piles in the clearcut, thus covering a relatively small area. In the shelterwoods there was a thinner more spread out layer, covering a larger area.

The difference in cover of logging residue between the clearcut and the shelterwoods might have influenced the effect of the treatments. The cover of the logging residue was negatively correlated ($p = 0.05$) with richness. Positive correlations between the cover of the logging residue and the total ground cover, as well as the cover of *Rubus idaeus*, were indicated. A negative correlation was indicated between the cover of logging residue and the cover of grasses and sedges.

DISCUSSION

Ground cover

A substantial increase of ground layer biomass after cutting was obvious in this study. Environmental conditions change drastically after clearcutting of a mature spruce forest on productive peatland. Factors that affect the vegetation include an increase of light, nutrient release from logging residue, the drying of the soil surface and a rise in the ground water level.

A biomass increase after cutting has been reported by Alaback (1982). He found that the production of herbs and shrubs increased constantly during 20 years after logging in *Tsuga-Picea* forests in southeast Alaska. Dyrness (1973) showed that the ground cover increased from 15 to 80% five years after logging and burning in the Cascades of Oregon. After clearcutting in mesic bilberry forests in Sweden, biomass of herbs increased three times and grass up to seven times than before the cutting (Kardell & Eriksson, 1983). Outcalt & White (1981) found that the net production of understory biomass two years after final felling of a balsam fir forest was four times as great as before logging, and almost equal to total net production in a mature (60 year old) balsam fir stand.

In general, there is no direct correlation between the ground cover and species biomass. In our study the ground cover had increased 2–3 times compared to the situation before cutting. The species biomass increased even more. Many of the dominant species after cutting were tall and had leaves in several layers (e.g. *Rubus idaeus* and *Filipendula ulmaria*). In contrast, the species dominating the cover before cutting included thin-leaved, short species (e.g. *Oxalis acetosella* and *Gymnocarpium dryopteris*). In a defined plant society, linear equations may give a fair representation of the relation between cover and biomass (Persson, 1975). However, these relationships change greatly with seasonal development.

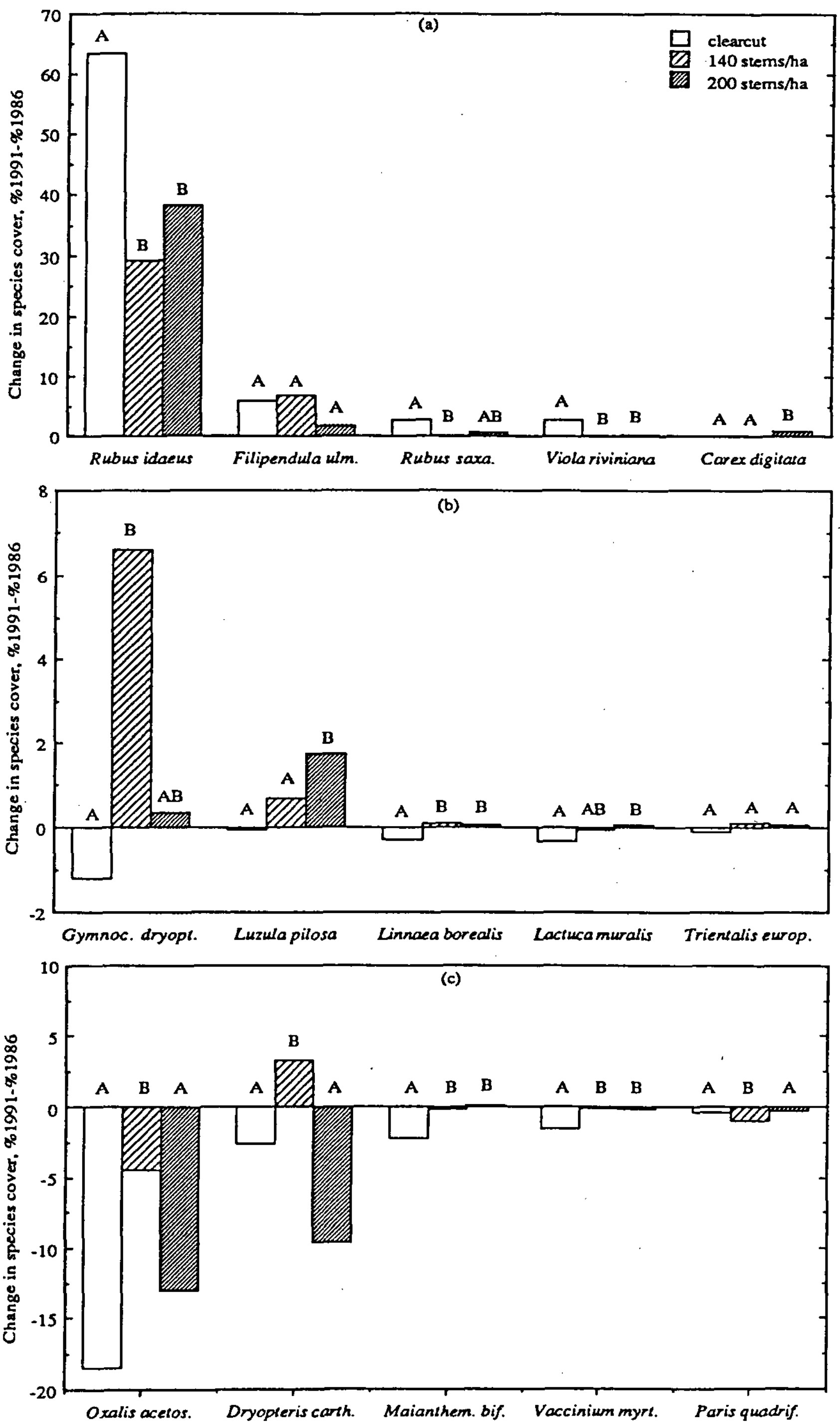

Fig. 4. Change in species cover before final felling (1986) and five growing seasons after (1991), %1991–%1986. Species which have (a): increased their cover on the clearcut and in the shelterwoods, (b): decreased on the clearcut but increased in the shelterwoods, and (c): decreased on the clearcut as well as in most shelterwoods. Note the different scales. Bars with the same letter represent values that are not significantly different at the 5% error level.

Persson (l.c.) proposed that cover and height of the species would give a better estimate than just species cover.

Diversity trends

During the first five years following final felling at Fallet the species diversity decreased on the clearcut and remained unchanged or increased in the dense and sparse shelterwoods respectively. An immediate drop in diversity after disturbance by clearcutting and burning in *Tsuga-Pseudotsuga* stands has also been reported by Schoonmaker & McKee (1988). After this initial drop, the species diversity tended upward with diversity peaking 15 years and richness at 20 years after clearcutting. After closure of the tree canopy, species diversity declined reaching its lowest values at 40 years.

Effects on species composition

One species, *Rubus idaeus*, dominated all treatments five years after harvesting. A few other pioneer species also invaded the clearcut area, but these had a minor role in the shelterwoods. The increase of pioneer species at the expense of others has been reported by Ingelög (1974), Gholz et al. (1985) and Dyrness (1973). The species that eventually dominate on the clearcut are either pioneer species capable of producing abundant seeds (that germinates well on bare land), seed bank species (cf. Granström, 1982), or species with small populations in the mature forest that can spread vegetatively after the clearcut. Dyrness (1973) found that immigrant species dominated the site from the second to the fourth year after clearcutting, while residual species dominated from year five. Ingelög (1974) stresses that annual pioneer species like *Galeopsis* and *Senecio* can dominate during the first two years after logging, but thereafter are completely eliminated by competition from perennial species such as *Chamaenerion angustifolium* and *Rubus idaeus*. At our study site *Galeopsis bifida* was found in small numbers, both one and five years after cutting, but it cannot be excluded that it had a more important role in the intermediate years. Observations supporting this have been made on other similar sites by the authors.

The effect of disturbance by clearcutting and burning on the original flora have been reported by Schoonmaker & McKee (1988). Late seral species, that accounted for 99% of ground cover in old *Tsuga-Pseudotsuga* stands, were nearly eliminated immediately after disturbance, but accounted for almost 40% and 83%, 5 and 20 years later.

In our study, the shelterwoods are obviously more favourable for the original flora compared to the clearcut. The shelterwoods offer a better environment for the survival of plant species typical to the mature forest compared to that of the clearcut conditions. Positive effects of nurse crops on the temperature conditions were shown by Leikola (1975). Species sensitive to intense sunlight or demanding quite consistent dampness and temperature conditions, decrease or disappear in the clearcut. Kardell & Eriksson (1983) found that *Oxalis acetosella*, *Linnaea borealis* and *Pyrola* decreased initially after clearcutting. They also showed that thinning of forest stands (similar to shelterwoods) increased the biomass of herbs after 3 to 5 years. This they explained was a result of more light since a combination of thinning and fertilization was disadvantageous to the herbs.

Estimates of single species cover is highly dependent of sampling date during the growth period (cf. Persson, 1975). Consequently, a species reaching its maximum cover in early summer, e.g. *Anemone nemorosa*, could be underestimated in our study. The apparent disappearance of this species may be explained by late sampling date.

Effects of logging residue

The logging residue was gathered in piles on the clearcut, thus covering a smaller portion of the ground, while it was more evenly spread out, in thinner layers, in the shelterwoods. This

Table 1. Mean cover and frequency of species per treatment

Cov = ground cover (%) and f = frequency (% of subplots where the species occur). t = trace (cover less than 0.01%)

Treatment	clearcut						sparse shelterwood						dense shelterwood					
No of subplots studied	42		42		42		24		24		24		24		24		24	
Date of inventory	860821		870910		910824		860821		870910		910824		860821		870910		910824	
	cov	f	cov	f	cov	f	cov	f	cov	f	cov	f	cov	f	cov	f	cov	f
Herbs																		
Alchemilla vulgaris	–	–	–	–	–	–	0.08	4	–	–	–	–	–	–	–	–	–	–
Anemone nemorosa	0.12	29	–	–	–	–	0.09	21	t	4	–	–	0.04	21	t	4	–	–
Anthriscus sylvestris	–	–	–	–	–	–	–	–	–	–	–	–	0.08	4	–	–	0.13	8
Cerastium fontanum	–	–	–	–	t	5	–	–	0.02	4	–	–	–	–	–	–	–	–
Chamaenerion angustif.	–	–	t	5	7.64	83	0.03	8	0.03	8	0.54	13	–	–	–	–	1.08	21
Chrysosplenium altern.	–	–	–	–	–	–	0.03	13	0.06	8	0.17	4	–	–	–	–	–	–
Cirsium arvense	–	–	–	–	5.15	71	–	–	–	–	–	–	–	–	–	–	–	–
Cirsium vulgare	–	–	0.01	5	0.92	24	–	–	–	–	–	–	–	–	–	–	0.09	8
Convallaria majalis	–	–	t	2	–	–	–	–	–	–	–	–	–	–	1.05	8	0.02	4
Daphne mezereum	–	–	–	–	–	–	0.02	4	–	–	–	–	–	–	–	–	–	–
Epilobium alsinifolium	–	–	–	–	–	–	–	–	–	–	t	4	–	–	–	–	–	–
Filipendula ulmaria	0.05	12	0.35	21	5.83	21	0.05	29	0.31	13	7.34	25	0.15	21	0.07	13	1.88	21
Fragaria vesca	0.01	2	0.10	10	2.12	24	0.23	29	0.23	25	0.33	29	0.15	13	0.06	8	0.45	42
Galeopsis bifida	–	–	–	–	0.02	2	–	–	–	–	0.01	8	–	–	0.02	4	1.38	17
Galium trifidum	–	–	–	–	–	–	t	4	–	–	–	–	–	–	–	–	–	–
Galium uliginosum	–	–	–	–	–	–	–	–	–	–	0.04	4	–	–	–	–	0.33	4
Geum rivale	–	–	0.02	2	0.24	5	0.44	17	0.50	13	1.72	21	t	4	–	–	0.13	4
Goodyera repens	–	–	–	–	–	–	–	–	–	–	t	4	–	–	–	–	–	–
Hepatica nobilis	0.22	19	0.12	17	0.58	10	0.17	8	0.08	4	0.33	8	–	–	–	–	–	–
Lactuca muralis	0.32	38	0.34	36	t	2	0.08	8	–	–	0.02	4	0.13	17	–	–	0.20	29
Linnaea borealis	0.30	45	0.25	33	–	–	0.04	21	t	4	0.13	13	0.06	8	0.18	17	0.13	8
Maianthemum bifolium	2.29	86	0.50	55	0.09	29	1.26	63	0.68	50	1.11	58	1.35	83	0.30	50	1.49	83
Melampyrum pratense	–	–	–	–	–	–	–	–	–	–	0.44	8	–	–	–	–	t	4
Melampyrum sylvaticum	0.01	5	t	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Melandrium rubrum	–	–	–	–	0.21	2	0.38	13	–	–	1.55	29	–	–	–	–	0.02	4
Moehringia trinervia	–	–	–	–	–	–	–	–	–	–	t	8	–	–	t	4	–	–
Oxalis acetosella	18.52	100	10.70	100	0.03	26	11.92	100	15.04	100	7.46	96	18.67	100	12.23	100	5.66	100
Paris quadrifolia	0.34	31	–	–	t	2	1.11	63	0.13	8	0.15	17	0.30	33	0.02	4	0.04	8
Peucedamum palustre	–	–	–	–	–	–	0.02	4	–	–	–	–	–	–	–	–	–	–
Potentilla erecta	0.01	2	–	–	0.21	5	–	–	–	–	–	–	–	–	–	–	–	–
Potentilla norvegica	–	–	–	–	0.17	5	–	–	–	–	–	–	–	–	–	–	–	–
Pyrola rotundifolia	–	–	–	–	–	–	–	–	–	–	–	–	–	–	t	4	–	–
Ranunculus acris	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.04	4
Ranunculus repens	–	–	–	–	–	–	0.05	8	0.02	4	0.04	8	–	–	–	–	0.02	4

Rubus idaeus	0.61	17	1.01	26	64.12	100	1.00	38	2.10	54	30.25	100	1.50	33	2.27	29	39.73	100
Rubus saxatilis	1.33	69	1.22	60	4.10	62	0.15	8	0.15	17	0.13	13	1.15	42	0.46	42	1.88	33
Rumex acetosella	–	–	–	–	0.12	7	–	–	–	–	–	–	–	–	–	–	–	–
Senecio sylvaticus	–	–	–	–	t	5	–	–	–	–	–	–	–	–	–	–	t	4
Solidago virgaurea	0.32	19	0.25	14	1.60	52	–	–	1.09	29	–	–	–	–	0.04	4	0.44	25
Stellaria longifolia	–	–	t	2	0.02	5	0.01	13	0.15	17	0.61	29	0.01	8	0.05	8	0.53	21
Trientalis europaea	0.11	24	0.29	48	t	2	0.11	17	0.18	38	0.21	46	0.11	17	0.03	21	0.19	21
Urtica dioica	–	–	–	–	0.08	7	t	4	0.15	13	0.69	29	0.17	4	0.25	8	0.92	17
Vaccinium myrtillus	1.59	60	0.66	45	t	7	0.05	8	0.13	17	–	–	0.32	13	0.26	21	0.17	8
Vaccinium vitis-idaea	0.18	24	0.04	19	0.15	17	–	–	–	–	–	–	0.03	8	0.01	4	0.02	4
Veronica officinalis	–	–	0.02	2	–	–	0.04	4	0.06	8	0.29	4	–	–	0.02	4	–	–
Viola epipsila	–	–	–	–	–	–	0.24	25	0.46	21	1.42	38	0.30	25	1.00	46	1.25	38
Viola palustris	0.03	5	–	–	0.19	14	–	–	–	–	–	–	0.04	4	–	–	–	
Viola riviniana	0.73	41	1.10	52	3.39	43	0.08	17	0.10	13	0.03	8	0.37	33	0.08	21	0.52	54
Σ herbs	27.09	–	16.98	–	96.98	–	18.13	–	21.67	–	55.01	–	24.93	–	18.40	–	58.74	–
Grasses and sedges																		
Agrostis spp.	–	–	0.02	7	0.07	7	0.01	4	0.07	13	t	4	–	–	–	–	0.03	13
Calamagrostis spp.	–	–	–	–	–	–	–	–	–	–	0.21	4	0.09	13	t	4	1.00	17
Carex brunnescens	–	–	–	–	0.24	10	–	–	–	–	–	–	–	–	–	–	–	–
Carex digitata	0.31	60	0.34	52	0.37	19	0.15	25	0.06	8	0.17	13	0.29	54	0.08	17	1.11	46
Carex echinata	–	–	–	–	0.02	2	–	–	–	–	–	–	–	–	–	–	–	–
Carex vaginata	t	2	–	–	0.29	24	–	–	–	–	t	4	–	–	–	–	–	–
Deschampsia caespitosa	–	–	–	–	0.29	5	–	–	–	–	–	–	–	–	–	–	–	–
Deschampsia flexuosa	t	5	–	–	0.40	17	–	–	t	4	t	4	–	–	0.01	4	0.02	4
Luzula pilosa	0.09	31	0.32	36	0.01	2	0.06	38	0.03	13	0.75	42	0.07	38	0.08	8	1.82	67
Melica nutans	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.09	13
Milium effusum	–	–	–	–	–	–	0.21	8	–	–	t	4	0.02	4	–	–	0.94	29
Roegneria canina	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.08	4	–	–
Σ grasses and sedges	0.4	–	0.68	–	1.69	–	0.43	–	0.16	–	1.13	–	0.47	–	0.25	–	5.01	–
Ferns, horsetails and club mosses																		
Athyrium filis-femina	–	–	0.06	5	–	–	–	–	t	4	–	–	0.29	4	–	–	0.54	8
Dryopteris carthusiana	3.99	69	1.42	52	1.35	38	9.60	88	7.13	83	12.92	71	22.60	92	8.83	79	12.98	88
Equisetum pratense	–	–	–	–	–	–	0.12	21	–	–	0.09	21	0.74	46	0.08	21	1.33	42
Equisetum sylvaticum	–	–	–	–	–	–	1.23	71	0.18	25	8.60	83	0.21	21	0.09	13	8.98	63
Gymnocarpium dryopteris	2.45	14	0.70	14	1.24	21	4.67	71	7.67	46	11.27	63	0.63	17	0.53	17	1.00	8
Lycopodium phegopteris	0.43	17	0.08	7	–	–	–	–	–	–	–	–	–	–	0.01	4	0.25	8
Thelypteris phegopteris	–	–	–	–	–	–	0.63	13	0.73	13	1.21	17	0.75	29	1.42	25	5.96	38
Σ ferns etc	6.87	–	2.26	–	2.59	–	16.25	–	15.71	–	34.09	–	25.22	–	10.96	–	31.04	–
Logging residue	–		–		10.43		–		–		28.96		–		–		28.96	–
No of species/subplot	8.24		7.31		7.83		8.92		6.79		9.58		8.08		6.21		11.42	
Diversity, Simpson index	0.59		0.60		0.48		0.65		0.57		0.64		0.55		0.53		0.68	
Σ cover	34.39		19.94		101.28		34.79		37.56		90.25		50.63		29.60		94.77	

could have contributed to a damper and more constant climate in the shelterwoods compared to that of a clearcut. The smaller cover of the residue could have supported the biomass increase in the clearcut, and the bare ground between the piles could have offered a good place for germination of immigrants.

Fahey et al. (1991) studied clearcuts of Sitka spruce in North Wales and found the increase in field layer biomass (mainly grass-species) to be 50% higher after whole-tree harvesting, without logging waste, compared to conventional final felling where stumps and branches remained. After clearcutting in a bilberry spruce forest in central Sweden, Ingelög (1974) found a substantail increase of *Rubus idaeus*, *Chamaenerion angustifiolium* and *Galeopsis* where logging residue were left, while the grass *Deschampsia flexuosa* soon dominated on areas where the logging waste was removed. In our study subplots with a small cover of logging waste tended to have the highest cover of grass-species.

CONCLUSIONS

In this area the positive effect of the shelterwood for the survival of the original flora during the critical postlogging stage has been demonstrated. The difference in species composition between the clearcut and the shelterwoods will probably become smaller as the planted spruce seedlings on the clearcut develop into a closed stand. It remains to be seen whether the decrease or disappearance of some species can be regarded as permanent or not.

The use of the results concerning single species are probably limited to vegetation type and geographic region. Similar studies, on different vegetation types and in different regions, of consequences on the flora of different forestry practises would contribute to the development of more lenient forestry methods.

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