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Field experiment data available for studies of pre-commercial thinnings

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Abstract

Between 1953 and 1961 a series of pre-commercial thinning experiments were established in Sweden, in which selective thinning removals to various numbers of stems per hectare were applied. During the years 1970-1985 complementary pre-commercial thinning experiments were established, in which (inter alia) selective pre-commercial thinning treatments were applied at various mean tree heights, in strips, with and without fertilization and/or pruning, and with or without removal of cut trees. In total, experiments were established in 140 stands in Sweden, mainly in Scots pine and Norway spruce sites. The experiments have usually been assessed every five years up to the first thinning (at a dominant height of 12-15 m). Most data from the assessments have now been compiled in a digitized format for convenient computer analyses and results from several analyses are being prepared for publication. The main objectives of this paper are to provide a detailed report of the structure of the experiments and the accessibility of the data. A summary of previously published results based on the experiments is also presented.

Keywords: Norway spruce, Scots pine, pre-commercial thinning, stand treatment and silvicultural management.

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Introduction

Sven-Olof Andersson, Professor at the Department of Forest Yield Research at the Swedish University of Agricultural Science (SLU) and the former Royal College of Forest Research from 1976-1987, dedicated his career to studying factors that affect forest yields, especially pre-commercial thinnings (PCT). From the beginning of the 1950s until the 1980s he had more responsibility for the pre-commercial thinning research at these institutions than anyone else. Hence, he had a major input in the design and implementation of a major series of PCT experiments that were established in Sweden from 1953 to 1985. We thank the late Prof. Sven-Olof Andersson for his commitment, foresight and energy in establishing the experiments, without which the abundant data described below would not be available.

Between 1953 and 1961 a series of pre-commercial thinning experiments were established in Sweden, in which selective thinning removals to various numbers of stems per hectare were applied. Most of the experimental sites were established at sites with Scots pine stands that had naturally regenerated from seed trees. The experiments were established at 28 localities in Sweden. The applied treatments were selective PCT to different densities of stems: 1500, 2500, 3000, 4000, 5000 or 6000 stems ha-1. In most cases an unthinned plot was also established.

Partly due to ongoing logging mechanization, in the 1960s there was a need for experiments with broader objectives than in previous times, so more experiments were established during the years 1970-1985. Treatments in the later series included leaving fewer stems per unit area after selective PCT, selective PCT at different mean tree heights, PCT in strips, PCT in combination with fertilization and/or pruning, and PCT with or without removal of cut trees. The experiments established at 112 localities in Sweden in this period were partly established in cooperation with regional departments of the Swedish Forest Agency.

Professor Sven-Olof Andersson

In total, PCT experiments were initiated in 140 stands in Sweden, at the typical time for PCT, i.e. at a dominant height 0.5-7.5 m, mainly in Scots pine (Pinus sylvestris L.) and Norway spruce (Picea abies L. Karst.) stands. The experimental design was usually randomized blocks. The experiments have been assessed approximately every five years up to the first thinning (dominant height, 12-15 m), which was the planned end of the observation period. Almost all of the experimental stands have now passed this stage, and in most cases no further assessments are planned. Just before the 1970-1985 establishment period Sven-Olof Andersson wrote instructions for the experiments “Instruktion för anläggning av röjningsförsök” (Instructions for establishment of pre-commercial thinning experiments). It is an unpublished monograph, but it is available from the SLU University Library (Andersson, 1970). The overall objectives of the experiments were to apply treatments to stands of pure Scots pine or Norway spruce, from a young age onward, to acquire information that would be valuable, in combination with knowledge obtained from existing thinning experiments, for optimizing stand management strategies and predicting both the quality and quantity of future harvests from specific stands. During the years 2006-2009 intense efforts have been made to compile the assessment data in a convenient form for computer analyses. Results from several studies based on the experiments will be published in the near future. The main objectives of this paper are to provide a detailed report on the structure of the experiments and the accessibility of the data acquired, and to summarize previously published results from the experiments.

Material and Methods

During the years 2006-2009 metadata in archives concerning the PCT experiments have been thoroughly investigated and much of the information has been converted into a computer-accessible format for use in scientific evaluations and data analyses. Diverse kinds of background information have thus been made available; such as methodology instructions and descriptions, correspondence between department members, official letters, maps, plot site sketches, descriptions of the vegetation and soil in selected sites, stand and tree characteristics before the first PCT treatment, photographs of selected plots, notes concerning treatments of stands and sample plots, etc. Metadata concerning experimental group assignment, numbers of sites and plots, year of establishment, experimental design, species, locality, latitude, longitude, altitude, regeneration method, plot area, map code and year of stand establishment are provided in Appendices 1 and 5. The information in these Appendices is digitally accessible via the database hosting data from the faculty's long-term field trials and/or the Unit for Field-based Forest Research's system for assessments of plots.

The experimental design was mainly randomized blocks, with some exceptions among experimental sites that were established by forest companies and later included in the experiments (Appendix 1). The main objectives of the experiments were to compare the effects of varying the density of remaining stems per unit area after PCT, in combination with one or more complementary treatments. The experimental sites were established at the typical time for PCT (dominant height, 0.5-7.5 m), and were each assigned to one of the following 15 groups according to the treatments that were to be assessed:

1. Selective PCT
2. Timing of selective PCT
3. Multi-stage selective PCT
4. PCT in naturally generated broadleaved stands (oak or beech)
5. Selective PCT in combination with nitrogen fertilization
6. Selective PCT in combination with nitrogen fertilization and pruning
7. Comparison of selective PCT and strip thinning
8. Selective PCT with differing specifications for evenness of the areal distribution of stems and deviations of the height of individual trees from mean tree height
9. Treatments of Scots pine and Norway spruce stands mixed with birch *(Betula pubescens* Erth*, and B. pendula* Roth)
10. Selective PCT with increased attention to promoting growth of trees selected as candidate saw-log trees
11. Treatment of stands with omitted (delayed) PCT
12. Selective PCT combined with removing or not removing PCT residues
13. Treatments of gapped and/or low density stands
14. Yield after PCT to a small number of stems per unit area
15. Others

Summary statistics from the experimental sites are given in Appendix 1.

Selection of experimental stands

The experiments focused on pure Scots pine or Norway spruce stands established from seed trees, seeds or planting. In addition, mixed stands of Scots pine and Norway and/or birch were included (Appendix 1). Birch stands established from stump shoots were excluded. The site fertility was intended to be constant within, but vary between, selected stands. Each selected stand was also intended to have reasonably homogenous soil within the experimental area.

Experimental design

Replicates were generally arranged in randomized block designs. The area of each treatment unit (plot) was generally 0.04-0.06 ha, ranging from 0.025 to 0.09 ha. The plots were usually rectangular (20 x 25 m), but circular plots were also used in some cases. If a selected stand was sufficiently large, the treatments were replicated, i.e. more than one block in the same stand was established. If the stand was too small to accommodate all desirable treatment plots, a restricted number of the desired plots was established.

Registrations

Site and plot level

At the time the experiments were established, the forest owner, locality name, latitude, longitude, altitude, regeneration method, year of regeneration, mean tree height, number of stems per unit area before treatment and the areas of the plots were registered. In addition, the degree to which the experimental sites were exposed to wind, their vegetation type and the gradient of the ground surface and its orientation were usually recorded.

Assessments

When each experiment was established, the number of stems and their diameter distribution just before PCT was recorded, and PCT was then applied to the treatment-dictated number of stems, but removed trees were not recorded, so the quantity of the removed trees had to be estimated from the differences between the stand statistics before and after treatment. However, at later assessments removed trees were also recorded. All trees that were not removed were generally permanently numbered and their diameter at breast height was measured to the nearest millimeter. The height of selected sample trees was also measured to the nearest decimeter. The height of selected sample trees was also measured to the nearest decimeter, and the height to the first living branch of samples trees thicker than 45 mm at breast height was recorded (in decimeters), and the bark thickness of Scots pine and birch trees was measured, in millimeters.

At some sites, a treatment was included in which nothing was done before the time for the first thinning, i.e. at the dominant height of 12-15 m. When the number of stems per unit area was large the conditions in plots at these sites were assessed by a more rapid method than the one used on thinned plots. Three methods were applied : 1) the stand conditions were measured in 12-24 circular subplots (radius, 1.4 m) systematically distributed over the plot; or 2) the diameter of all trees was measured and recorded in 1-cm classes; or 3) methods 1 and 2 were used in combination.

The time intervals between assessments were about five years at the beginning of the observation period, but the assessment intervals were extended somewhat in later stages.

Preliminary calculations

After an assessment the numbers of stems (N), basal area (BA) and volume (V) per hectare were calculated, and from the second assessment onwards periodical increment values for diameter (D), (BA) and (V) were recorded. The calculated values, together with general information abut the site and plot, were arranged for easy readability and displayed in "Plot statistics" documents (Appendix 5). Values of V were calculated according to the Department of Forest Yield Research's general volume estimation method.

Procedures for volume calculations

For selected sample trees with $D \geq 4.5$ cm, the stem volume was calculated using volume functions developed by Brandel (1990), using diameter at breast height (D), height (H) and crown height (CH) for Norway spruce and D, H, CH and thickness of the bark (B) for Scots pine as independent variables. For trees with $D < 4.5$ cm volume functions adapted for estimating the volume of small trees, with D and H as independent variables, were used (Andersson 1954). Different functions were used for northern and southern Sweden. The volumes of all callipered trees was estimated using a method based on the assumption that there is a linear relationship within a stand between basal area at breast height and tree volume, and hence between D^2 and tree volume. The assumption is based on old results, further analysed by Hummel (1955). The following steps describe how the total stem volume for a species category (remaining, removed, and dead) was calculated:

1. The stem volume for each sample tree was estimated using an appropriate volume function for individual trees. The sample trees were grouped into 2-cm D-classes. The following variables were then calculated for the represented classes:
   - Number of sample trees (N_{cp})
   - Sum of squared diameters (D_{cp})
   - Sum of volumes (V_{cp})
   - Mean squared diameters (D_{mcp}); $D_{mcp} = D_{cp}/N_{cp}$
   - Mean volume (V_{mcp}); $V_{mcp} = V_{cp}/N_{cp}$

2. All callipered category stems on the plot were also grouped into DBH-classes, in an analogous fashion to the sample-tree D-classes. The following variables were calculated for the represented classes:
   - Number of stems (Ncs)
   - Sum of squared diameters (Dcs)
   - Mean squared diameters (Dmcs); Dmcs = Dcs/Ncs
3. The mean volume in a D-class (Vcmean) was calculated as Vcmean = Vmcp*Dmcs / Dmcp
4. The total volume of a diameter class (Vctot) was calculated as Vctot = Vcmean*Ncs
5. If there were no sample trees for a class in which one or more callipered trees were present, Vcmean was calculated using the formula Vcmean = Vmcp*Dmcs / Dmcp, using Vmcp and Dmcp values from the nearest class for which there was at least one sample tree.

The calculations described above were repeated for all diameter-classes, species and categories represented on each sample plot. Separate computations were carried out for the groups remaining, removed and dead trees. The volume estimation of the dead trees was based on the sample trees in the category removed trees, where such trees were available. If none were available, it was based on the remaining trees. The total stem volume on the plot was obtained by summing the volumes of all the represented diameter classes, groups and species.

Calculations of dominant height

Dominant height was estimated by estimating a height-curve for each plot and measurement occasion using an equation developed by Näslund (1936):

$$H = (D/(a + bD))^x + 1.3$$

where: H is tree height (m), D is diameter at breast height (cm), a and b are coefficients. Näslund (1936) applied the value 2 for x in Scots pine evaluations, but Petterson (1955) found that improved estimates of H were obtained if the value of 3 for x was used in Norway spruce evaluations. Thereafter, the dominant height was estimated using the height function based on the height corresponding to the arithmetic mean diameter of the 100 thickest trees per hectare (largest by diameter at breast height). Since the areas of the experimental plots were about 0.05 ha, about five trees were available per plot for estimating dominant height. The Site index (SI) was determined from tree species-specific site index curves (Hägglund 1972, 1973, 1974).

Average diameter (cm) was calculated as the diameter of the average basal area tree from:

$$D_{BA} = 100\sqrt{(BA/n)4/\pi}$$

where D_{BA} is the diameter of the average basal area tree, BA is the stand basal area (m^2) and n is the corresponding number of stems.

Data accessibility

Data from assessments executed prior to ca. 1970 (before computers were used to compile the assessment data originally) were still not available on computer files in 2006.Therefore, before any further analyses could be attempted, a major effort was required to transfer data stored in old documents into computer files. Before this work started, in 2006, some of the experiment Groups (1, 2, 5, 7, 9 and 12) were considered to have higher priority than the others. At the time of writing (May 2010) assessment data, i.e. recorded diameters for all trees and tree height, the distance from the ground to the first living branch and bark thickness 1.3 m above ground of sample trees, have now been transferred from old documents to computer files for high priority groups. Only some quality checking remains to be done. Assessment data for non-prioritized Groups will not be transferred from old documents to computer files before the information is required for some as yet unknown project. For prioritized Groups, Excel files with the following data are now available, or will be very soon:

- Diameter data (Appendix 2)
- Sample tree data (Appendix 3)
- Assessment statistics: basal area, volume, yearly increment, etc. (Appendix 4).

In addition to the Excel files a Word file with assessment statistics together with other plot and site level information is available (Appendix 5).

Specific information about each experimental group

Group 1a: Selective PCT experiments, established 1953-1961

The experiments established in the period 1953-1961 at 28 localities (site nos. 953-986) comprise a subset within Group 1 (Appendix 1). Most of the experimental stands (24) were pure Scots pine stands, three were Norway spruce stands and two were mixed Scots pine and Norway spruce stands.

The applied treatments were selective PCT to 1500, 2500, 3000, 4000, 5000 or 6000 stems ha^{-1} after thinning. In most stands an unthinned plot was also established (0). Different numbers of plots were established, depending on the stand size and number of stems per unit area. Detailed information about the treatments established at different localities (plot numbers) is displayed in Table 1 a,b.

Table 1a. Numbers of assessments and observation time (years) for sites, blocks and treatments

a) Group 1a, Scots pine

		Treatments (no. of stems ha^{-1} after PCT)							
Site no.	Block	0[1)]	6000	5000	4000	3200	2500	1500	Observation time
953	A	8		8	8		8		43
	B	8		8	8		8		43
954	A				8		8		40
	B	8		8	8		8		40
956	A				8		8		43
	B				8		8		43
957	A	7	7		7		7[2)]		41
	B	7	7		7		7[2)]		41
961	A	8					8		37
	B	8				8[2)]			37
962		6				8[2)]			45
963						9[3)]			45
965		9	9	9		9			45
966					8	8[4)]			31
967		8			8				44
970	A	9	9		9[2)]		9		44
	B	9	9		9[2)]		9		44
	C							9	44
	D					9			44
971	A	8			8		8		42
	B	8			8		8		42
	C							8	42
972	A	7	7		7		7		36
	B	7	7		7		7		36
973		6					6[2)]		26
974	A				8	8	8		38
	B				8	8	8		38
975	A	7			7		7		30
	B	7			7		7		30
	C	7			7		7		30
976		9	9	9		9	9		45
977	A	9			9		9		45
	B	9			9		9		45
978	A	9	9		9		9[2)]	9	43
	B	9	9		9		9[2)]	9	43
981							8[5)]	8[6)]	45
983	A	9					9	9[7)]	46
	B	9					9	9[7)]	46
984	A	9				9[2)]			41
	B	9				9[2)]			41
	C				9[2)]				41
985	A						6[8)]	6[8)]	20
	B						6[8)]	6[8)]	20
	C						6[8)]	6[8)]	20

Remarks: [1)] No treatment before first thinning; [2)] Replicated twice; [3)] Mixture of Scots pine and Norway spruce; [4)] Initially PCT to 4000 stems ha-1; [5)] PCT to 2200 stems ha-1; [6)] PCT to 1900 stems ha-1; [7)] PCT to 1400 and 1800 stems ha-1; [8)] Early and late PCT to 1900 and 1200 stems ha-1, respectively.

b) Group 1a, Norway spruce

		Treatments (no. of stems ha^{-1} after PCT)							
Site no.	Block	0[1)]	6000	5000	4000	3000	2500	1500	Observation time
955	A	7			7	7	7		29
	B	7			7	7	7		29
960	A		7		7		7		42
	B		7		7		7		42
964		8[1,2)]		8[2,3)]	8[2,3)]	8[2,3)]			42
969	A				8[2)]	8[2)]	8[2)]	8[2)]	40
	B				8	8	8	8	43
986	A	7	7		7		7		35
	B	7	7		7		7[3)]		41

Remarks: [1)]No treatment before first thinning; [2)] Mixture of Scots pine and Norway spruce; [3)] Replicated twice

Group 1b: Selective PCT, experiments established 1970-1985

In the later series, established during 1970-1985, studies of the effects of leaving fewer stems per unit area after selective PCT were included in Group 1. To include the effect of timing, at the time the experiments were established the dominant height could vary between sites, from 0.5 to 7.5 metres. Treatment plots in which 600, 1000, 1400, 1800, 2500 and 3200 stems ha^{-1} were left after selective PCT were established, and in several stands an unthinned treatment plot was also established. Quite often only a reduced number of desired treatments could be applied in selected stands, due to a lack of space. In such cases, at fertile sites higher numbers of stems per unit area after PCT were preferred, while at poorer sites treatments with low numbers of stems per unit area after PCF were preferred. Detailed information about the treatments applied at different localities (plot numbers) is displayed in Table 1b. Data from experimental Groups 1a and 1b were intended to be jointly analysed and, altogether, these data provide information on the effects of selective PCT treatments that left numbers of stems ranging from 0 (in unthinned control plots) to 6000 ha^{-1}.

Table 1b. Numbers of assessments and observation time (years) for sites, blocks and treatments

a) Group 1b, Scots pine

		Treatments (no. of stems ha^{-1} after PCT)							
Site no.	Block	0[1)]	3200	2500	1800	1400	1000	600	Observation time
5001	A			4	4	4	4[2)]	4[2)]	18
	B			4	4		4[3)]	4	18
5014		4		4	4	4	4[2)]	4[2)]	20
5016		3				3	3	3[2)]	20
5035	A	3			3	3	3	3	16
	B	3			3	3	3	3	16
5039				4	4	4	4[2)]	4	22
5072				5	5	5	5	5	31
5073					4		4		19
5074		5			5	5	5	5	31
5092					5	5	5		34
5100			5	5	5	5			20
5200		4		4		4	4	4	34
5208				3	3[2)]	3	3	3[2)]	22
5213		3		3	3		3	3[2)]	13
5218		3		4		4	4	4[2)]	32
5221		4		4	4	4	4	4[2)]	32
5228		4		4	4	4	4	4	33

Remarks: [1)] No treatment before first thinning; [2)] Replicated twice; [3)] Replicated three times

b) Group 1b, Norway spruce

		Treatments (no. of stems ha^{-1} after PCT)							
Site no.	Block	0[1)]	3200	2500	1800	1400	1000	600	Observation time
5007		5		5	5	6[1)]	5	5	33
5018	A	4			4	4	4	4[1)]	32
	B				4	4	4	4[1)]	32
5037				4				4	29
5038				3	3			3	20
5070						4	4	3	34
5203		4		4	4	4	4	4[1)]	25
5206		4		4	4	4	4	4[1)]	31
5207		5		5	5[2)]	5	5	5	32
5216		4		4	4	4	4	4	29
5217	A	3		3	3	3	3	3[1)]	30
	B	3		3	3	3	3	3[1)]	30
	C	3		3	3	3	3	3[1)]	30

Remarks: [1)] No treatment before first thinning; [2)] Replicated twice; [3)] Replicated three times

Group 2: Timing of selective PCT

The main objective of the Group 2 experiments was to study the combined effects of the number of stems remaining per unit area after PCT and the timing of PCT. Timings were defined in terms of the mean height of the remaining stems and four different timings were chosen, with differences between timings of 1.5-2.0 m: < 1.5 m (T1), 2.0-3.5 m (T2), 3.5-5.5 m (T3) and 5.5-7.5 m (T4). In order to keep the total number of treatments within manageable limits, the number of treatments based on numbers of stems after PCT had to be restricted. At fertile sites (Site Index > 26 m) 1000, 1800 and 2500 stems ha^{-1} remaining after PCT were chosen and at poorer sites 600, 100 or 1800 numbers of stems ha^{-1} remaining after PCT. Detailed information about the treatments established at different localities (plot numbers) is displayed in Table 2.

Table 2. Numbers of assessments and observation time (years) for sites, blocks and treatments

a) Group 2, Scots pine

		Treatments (Timing/nos. stems after PCT)																
Site no.	Block	0[1)]	T1/ 2500	T1/ 1800	T1/ 1000	T1/ 600	T2/ 2500	T2/ 1800	T2/ 1000	T2/ 600	T3/ 2500	T3/ 1800	T3/ 1000	T3/ 600	T4/ 2500	T4/ 1800	T4/ 1000	T4/ 600	Observation time
5002					4				4										26-36
5003	A			4				3				4				4			21-31
	B			4				4				4				4			21-31
5015				4	4[2)]	4[2)]		4	4[2)]	4[2)]		4	4[2)]	4					19-28
5017				3[3)]	3[2) 3)]	3[2) 3)]		3[3)]	3[2) 3)]	3[2) 3)]									5-19
5020								4	4	4		4	4	4		3	3	3	17-28
5103		2	3	3				3	3						2	2			8-25
5104		2	2	2				1	1										0-13
5201		4[2)]	4	4	4		4	4	4		4	4	4		4	4	4		17-29
5222		3		4	4			3	3			3	3			3	3		15-26
5223		3						3	3	3		3	3	3					8-14
5227		2		3	3	3		3	3	3		3	3	3		2	2	2	13-27
9249				5[2)]								4[2)]							15-26

Remarks: [1)] No treatment before first thinning [2)] Replicated twice; [3)] Moose damaged

b) Group 2, Norway spruce

		Treatments (Timing/nos. stems after PCT)													
Site no.	Block	0[1)]	T1/ 2500	T1/ 1800	T1/ 1000	T2/ 2500	T2/ 1800	T2/ 1000	T3/ 2500	T3/ 1800	T3/ 1000	T4/ 2500	T4/ 1800	T4/ 1000	Observation time
5204		4				4	4	4	4	4	4	4	4	4	17-28
5211		4	4	4	4	4	4	4	4	4	4	4	4	4	20-28

Remarks: [1)] No treatment before first thinning

Group 3: Multi-stage selective PCT

The pre-defined numbers of stems after PCT in the treatments included in Groups 1 and 2 were established after a single PCT. In the Group 3 experiments, two thinnings were applied to reduce the numbers of stems to pre-decided levels. These experiments were limited to self-generated Scots pine stands. Four two-stage treatments were defined to assess the effects of one- and two-stage PCT, and each staged treatment was applied to two different numbers of remaining stems after the last PCT, usually 1800 or 1000 per hectare. Thus, since an unthinned plot was also established, in total there were nine treatments (Table 3). The four two-staged treatments (S1-S4) were defined as follows:

S1: The first stage PCT was executed as soon as sufficient seedlings were established, preferably when the expected canopy level after PCT was 0.3 m above ground, but not later than when the canopy level was 1 m above ground. Only leading stems (in height) that had more than two annual shoots and were more than 1.25 times taller than the expected canopy after the first PCT were removed. The second PCT, to the pre-defined numbers of stems after PCT, was executed when the expected canopy was 2.0-2.5 m high.

S2: The first stage PCT was executed when the expected canopy level after PCT was < 1.5 m high. Wolf trees and stems 1.5 times taller than the expected canopy level above ground after PCT were removed. Furthermore, in order to decrease the competition between the seedlings in high density parts of the plots, seedlings in such parts were removed schematically. The second PCT, to the pre-defined numbers of stems after PCT, was executed when the expected canopy was 3-4 m high.

S3: The first stage PCT was executed when the expected canopy level after the first PCT was 1 - 2 m high. This was a conventional PCT in terms of the selection of seedlings, but the number of stems after PCT was intended to be high (ca. 4500 stems ha^{-1}). The second PCT, to the pre-defined numbers of stems after PCT, was executed when the expected canopy level was 3-4 m high.

S4: The first stage PCT was executed when the expected canopy level after PCT was 1-2 m high, directly to the pre-defined numbers of stems after PCT. In a second operation, executed when the canopy level was 3-4 m high, harmful understory stems were removed.

A detailed description of treatments S1-S4 is given in Andersson (1970).

Table 3. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 3, Scots pine

		Treatments (Timing/nos. stems after the last PCT)													
Sites no.	Block	0[1)]	S1/ 1800	S1/ 1400	S1/ 1000	S2/ 1800	S2/ 1400	S2/ 1000	S3/ 1800	S3/ 1400	S3/ 1000	S4/ 1800	S4/ 1400	S4/ 1000	Observation time
5019	A	3[2)]	3[2)]		3[2)]	3[2)]		3[2)]	3[2)]		3[2)]	3[2)]		3[2)]	21-30
	B	3[2)]	3[2)]		3[2)]	3[2)]		3[2)]	3[2)]		3[2)]	3[2)]		3[2)]	21-30
5029		3	3	3		3	3		3	3		3	3		12-17
5202		3	3		3	3		3	3		3	3		3	18-26
5219		3	3		3	3		3	3		3	3		3	16-29
5229		3	3		3	3		3	3		3	3		3	12-17
9244		4	4		4	4		4	4		4	4		4	28-31

Remarks: [1)] No treatment before first thinning [2)] Moose damaged

Group 4: PCT in naturally generated broad-leaved oak (*Quercus robur* L.) or beech (*Fagus sylvatica* L.) stands

The intention for this group of experiments was to assess the effects of different removal strategies combined with timing of the PCT. However, treatment plots were only established for oak in one stand and beech in two stands (Table 4). The intended removal strategies were:

BL1: Removals only of dominant (wolf) trees and trees with forked stems, trees with other defects and trees of species other than the main species. This treatment started when the mean height of the stand was 4-6 m, and was repeated after 4-5 years.

BL2: Removals of all trees in 2 m wide parallel strips separated by 0.5 m wide unthinned strips. This treatment was to be executed before the mean stand height had reached 2 m, followed by more removals (after 4-5 years) in the strips according to BL3, and after a further 4-5 years, again according to BL3.

BL3: Removals according to BL1 plus significant removals of sub-dominant trees, amounting in total to removal of 20-30 % of the basal area.

BL4: First removals according to BL1, but preferably at lower stand mean height, followed by a second removal to 1400 stems ha^{-1} at a stand height at which leaving main stems with forks less than 6 m above ground could be avoided.

1400: Selective removals to 1400 stems ha^{-1}.

2500: Selective removals to 2500 stems ha^{-1}.

Timings were defined in terms of the mean height of the remaining stems and four different timing chosen, with differences between timings of 1.5-2.0 m: < 1.5 m (T1), 2-3.5 m (T2), 3.5-5.5 m (T3) and 5.5-7.5 m (T4). A detailed description of the removal strategies is given in Andersson (1970).

Table 4. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 4

			Treatments (removing strategy/timing)						
Site no.	Species	Block	2500/ T2	1400/ T2	BL1/ T2	BL1/ T4	BL3/ T4	BL4/ T4	Observation time
5006	Oak	A	4	4	4	4	4		16
		B	4	4	4	4	4		16
5032	Beech		4	4					16
5033	Beech	A	6	6	6			5	24
		B	6		6			5	24

Group 5: Selective PCT combined with nitrogen fertilization

In the group 5 experiments treatment plots with 600, 1400 and 2500 stems ha^{-1} after selective PCT were established (with, in most stands, an unthinned treatment plot) and these stem density treatments were combined with four nitrogen fertilization treatments (Table 5). The fertilization treatments were:

F0: Unfertilized

F1: Fertilization with 150 kg N ha^{-1}, repeated every five years, the first fertilization two years after PCT

F2: Fertilization with 150 kg N ha^{-1}, not repeated, two years after PCT

Group 6: Selective PCT combined with fertilization and pruning

These experiments were limited to Scots pine stands, and the treatments were intended to be applied when ca. 500 dominant stems with an average height of 4-6 m were available. Three densities of stems were left after PCT (600, 1400 and 2500 per hectare), and the PCT treatments were intended to be combined with pruning and/or nitrogen fertilization. In pruning treatments (P) 500 stems were pruned up to 60-65 % of the tree height. In fertilization treatments the dosage was 150 kg N ha^{-1} every five years according to the Group 5 F1-treatment. In most stands an unthinned plot was also established (Table 6).

Table 5. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 5

			Treatments (Nos. of stems after PCT/fertilization treatment code)										
Site No.	Species	Block	0[1)]	2500/ F0	1400/ F0	600/ F0	2500/ F1	1400/ F1	600/ F1	2500/ F2	1400/ F2	600/ F2	Observation time
5010	Scots pine		4	4	4	4	4	4	4				31
5226	Scots pine		5	5	5	5	5	5	5				33
9245	Scots pine	A		5	5	5				5	5	5	27
	Scots pine	B	5		5			5			5		27
5008	Norway Spruce		4		4	4		4	4				32

Remarks: [1)] No treatment before first thinning

Table 6. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 6, Scots pine

		Treatments: Nos. of stems after PCT/fertilization treatment code (F1)/code (P).													
Site no.	Block	0[1)]	1800	1400	600	1800 /P	1400 /P	600 /P	1800/ F1	1400/ F1	600 /F1	1800 /P /F1	1400 /P /F1	600 /P /F1	Obser-vation time
5005		4	4	4	4	4	4	4	4	4	4	4	4	4	30
5013		4		4	4		4	4					4	4	20
5053							4	4							31
5064						5	5	5							31
5069	A	5		5	5		5	5							30
	B	5		5	5		5	5							30
9265			4	4	4	4	4	4							19

Remarks: [1)] No treatment before first thinning

Group 7: Comparison of selective PCT and strip thinning

Removing all trees in strips may provide a way to reduce PCT costs, so experiments were established to compare the effects of strip PCT and selective PCT. The experiments were intended to be established before the mean stand tree height reached 3 m.

In naturally generated Scots pine stands the following treatments were applied:

0: No further actions before the first thinning.

ST1: All trees removed in 2 m wide parallel strips, separated by 1.5 m wide unthinned strips. No further actions before the first thinning.

ST2: All trees removed in 2 m wide parallel strips, separated by 0.75 m wide unthinned strips. No further actions before the first thinning.

ST3: All trees removed in 2 m wide parallel strips, separated by 1.5 m wide strips in which selective PCT was executed to 1400 stems ha^{-1} according to the plot area. No further actions before the first thinning.

ST4: All trees removed in 2.78 m wide parallel strips, separated by 1.5 m wide unthinned strips. No further actions before the first thinning.

ST5: All trees removed in 2.78 m wide parallel strips, separated by 0.75 m wide unthinned strips. No further actions before the first thinning.

ST6: All trees removed in 2.78 m wide parallel strips, separated by 1.5 m wide strips in which selective PCT was executed to 1400 stems ha^{-1} according to the plot area. No further actions before the first thinning.

ST7: All trees removed in 2 m wide parallel strips in two directions perpendicular to each other, separated by 1.5 m wide unthinned strips. Hence, squares with 1.5 m sides were unthinned. No further actions before the first thinning.

ST8: All trees removed in 2.5 m wide parallel strips, separated by 3 m wide unthinned strips. No further actions before the first thinning.

1000: A selective removal to 1000 stems ha^{-1}.

1400: A selective removal to 1800 stems ha^{-1}.

1800: A selective removal to 1800 stems ha^{-1}.

In stands generated by planting the following treatments were also applied:

R2: Removal of every second row.

R3: Removal of every third row.

R3/1400: Removal of every third row and selective removals to 1400 stems ha^{-1}.

A detailed description of each of these removal strategies is given in Andersson (1970). Established plots/blocks and treatments applied, numbers of assessments and observation times are displayed in Table 7a.

Table 7a. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 7, Scots pine

		Treatments															
Site no.	Block	0	1800	1400	1000	ST1	ST2	ST3	ST4	ST5	ST6	ST7	ST8	R2	R3	R3/ 1400	Obser- vation time
5023		4		4	4		4	4	4	4	4						30
5220		4		4	4	4	4	4	4	4	4	4					21
5224	A	3		3	3	3	3	3	3	3	3	3		3			25
	B	3		3	3	3	3	3	3	3	3	3		3			25
5225		5	5	5											5	5	29
5231	A	3		3	3	3	3	3	3	3	3	3	3				29
	B	3		3	3	3	3	3	3	3	3	3	3				29
9252			4			4											25

In Norway spruce stands generated by planting the following treatments were applied:

0: No further actions before the first thinning.

1400: A selective removal to 1400 stems ha^{-1}.

R2: Removal of every second row.

R3: Removal of every third row.

SR2: A selective removal to the same number of stems ha^{-1} as the number of developable stems in treatment R2.

SR3: A selective removal to the same number of stems ha^{-1} as the number of developable stems in treatment R3.

R3/1400: Removal of every third row and selective removals to 1400 stems ha^{-1}.

D2: Removal of every second diagonal.

D3: Removal of every third diagonal.

A detailed description of each of these removal strategies is given in Andersson (1970). Established sites/blocks and treatments applied, numbers of assessments and observation times are displayed in Table 7b.

Table 7b. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 7, Norway spruce

	Treatments									
Site no.	0	1400	R2	R3	SR2	SR3	R3/ 1400	D2	D3	Observation time
5205	3	3	3	3	3	3	3	3	3	10
5214	5	5	5	5			5	5	5	26
5215	3	3	3	3			3	3		18

Group 8: Selective PCT with varying demands for evenness of the areal distribution of stems and deviations of the height of individual trees from mean tree height

In three Scots pine stands, at the time when mean tree height after PCT was 3-4 m, sets of treatment plots were established to investigate the combined effects of the number of stems per unit area, the evenness of the areal distribution of trees and tree height distribution on the future stand development. Three densities of stems ha^{-1} were left after PCT (1000, 1400 and 1800), and those treatments were combined with three levels of strictness for even areal distribution (D1-D3) of stems and tree height distribution (H1 - H3). In two stands an unthinned plot was also established, treatment code 0, in which no further actions were supposed be taken before the first thinning (Table 8a).

The following treatments were applied:

D1: Low demands for even areal stem distribution

D2: Moderate demands for even areal stem distribution

D3: Strict demands for even areal stem distribution

H1: Low demands for even tree height distribution. No removals of trees that had grown substantially more than the stand-average.

H2: Moderate demands for even tree height distribution. Some removals of of trees that had grown substantially more than the stand-average.

H3: Strict demands for even tree height distribution. Substantial removals of of trees that had grown substantially more than the stand-average.

A detailed description of each of the removal strategies is given in Andersson (1970). In two Norway spruce stands treatments were applied to plots in which 1400 and 2500 stems ha^{-1} were left, in combination with the D1-D2 and H1-H3 treatments, as listed in Table 8b.

Table 8a. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 8, Scots pine

Site no.	Treatments															Observation time
	0[1)]	1000/ D1/ H1	1000/ D2/ H1	1000/ D3/ H1	1400/ D1/ H1	1400/ D2/ H1	1400 D3/ H1	1400/ D1/ H2	1400/ D2/ H2	1400 D3/ SH2	1400/ D2/ H3	1400 D3/ H3	1800/ D1/ H1	1800/ D2/ H1	1800/ D3/ H1	
5004		5	5	5									5	5	5	34
5011	4				4	4	4	4	4	4	4	4				34
5031	4				4	4	4	4	4	4	4	4				36

Remarks: [1)] No treatment before first thinning

Table 8b. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 8, Norway spruce

Site no.	Block	Treatments												Observation time
		1400/ D1/ SK1	1400/ D2/ SK1	1400/ D1/ SK2	1400/ D2/ SK3	2500/ D1/ SK1	2500/ D2/ SK1	2500/ D3/ SK1	2500/ D1/ SK2	2500/ D2/ SK2	2500/ D3/ SK2	2500/ D2/ SK3	2500/ D3/ SK3	
8123						4	4	4	4	4	4	4	4	21
9242	A	4	4	4	4									26
9242	B	4	4	4	4									26
9242	C	4	4	4	4									26

Group 9: Treatments of Scots pine and Norway spruce stands mixed with birch

In this group of experiments the stands included were rather disparate, but two main types can be identified: 1) Scots pine mixed with birch, and 2) stands of Norway spruce mixed with birch, where the birches were suppressing the conifers that were intended to provide the basis of the future stand. Three types of treatments were assessed in these stands.

1. Leaving birch shelters of various densities versus no shelter
2. Chemical versus mechanical removal of birches combined with various treatments of the stumps to reduce the number of stump sprouts.
3. Selective PCT around the future main conifer stems versus normal PCT.

The established treatments were not always harmonized among the experimental stands within subgroups, so the treatment codes below do not always exactly reflect the treatments actually applied.

Subgroup 9a: Birch shelter over Scots pine

The treatment codes indicate the "total number of stems ha^{-1} after PCT/percent of the total number of stems that were birch shelter trees". For this subgroup experimental plots were established in only three stands and in stand 5021 an unthinned experimental plot (0) was also established (Table 9a).

Subgroup 9b: Birch shelter over Norway spruce

The treatment codes in this subgroup indicate the "number of Norway spruce stems ha^{-1} after PCT/ number of birch shelter stems ha^{-1}". Experimental plots were established in nine stands, in four of which unthinned experiment plots (0) were also established (Table 9b).

Table 9a. Numbers of assessments and observation time (year) for sites and treatments

Group 9, subgroup: Birch shelter over Scots pine

	Treatments (total number of stems ha^{-1}/ total nos. of stems as birch shelter, percent)												
Site no.	0[1)]	2500 /25	1800 /25	1400 /0	1400 /15	1400 /25	1400 /50	1000 /15	1000 /25	1000/50	1000/ 100	600 /25	Observation time
5021	5	5	5	5		5			5			5[2)]	33
5027			4		4	4	4		5				29
5028								4	4[2)]	4	4		30

Remarks: [1)] No treatment before first thinning; [2)] Replicated twice.

Table 9b. Numbers of assessments and observation time (year) for sites and treatments

Group 9, subgroup: Birch shelter over Norway spruce

		Treatments (number of spruces ha^{-1}/number of birch shelter stems ha-1, percent)															
Site no.	Block	0[1)]	0/ 1300	1300 /0	1300 /600	1300 /1000	1300 /1800	1300 /2500	2000 /0	2000 /600	2000 /1000	2800 /1000	3200 /600	3200 /1000	3400 /800	3800 /800	Observation time
5024			5	5[2)]	5	5			5								33
5087												2	2	2	2[2)]	2[1)]	9
5108		4							4	4		4					16
5111	A	3							3	3	3						15
	B	3								3	3						15
5113									4	4	4						21
5125									2	2							14
5210	A	2		3	3	3		3									17
	B			3	3	3		3									17
9250		5		5[3)]	5[3)]	5[3)]	5	5									20
9625											3						14

Remarks: [1)] No treatment before first thinning; [2)] Replicated twice; [3)] Replicated three times

Subgroups 9c and d: Spring versus autumn PCT, chemical versus mechanical removal of birches combined with different treatments of the stumps to reduce the number of stump sprouts

In Scots pine/birch stands, subgroup 9c, treatment plots were only established at one site (No. 5088) with six treatments: two spring PCTs and four autumn PCTs to 1900 stems ha^{-1} after PCT, of which 100-150 stems ha^{-1} were shelter birches. Two assessments were performed and the treatment plots were observed for seven years.

In Norway spruce/birch stands, subgroup 9d, treatment plots were established at two sites (Nos. 5086 and 9250). Both have eight treatment plots that have been assessed twice and observed for seven years. Treatments applied were intended to compare chemical versus mechanical PCT, and spring versus autumn PCT with varying shelter densities.

Subgroups 9e and f: Selective PCT around future main conifer stems versus normal PCT

In Scots pine/birch stands, subgroup 9e, treatment plots were established at only one site (No. 9262) with three blocks and two treatments (hence, in total, there were six treatment plots). The treatments were: PCT around the future main conifer stems and normal PCT to 1800 stems ha^{-1}. Two assessments were performed and the treatment plots were observed for 11 years.

In Norway spruce/birch stands, subgroup 9f, treatment plots were established at three sites (Nos. 5105, 5109 and 5110) and the treatments applied were selective PCT around the future main Norway spruces compared to normal selective PCT. Four out of 13 treatment plots at site 5105 met criteria for inclusion in group 9f, and they were assessed four times and observed for 20 years. The numbers of stems ha^{-1} after PCT were 1400 or 2500. At site 5109 there were four treatment plots, at which normal selective PCT was applied to 1800 stems ha^{-1}. Two assessments were performed and the treatment plots were observed for eight years. At site 5110 there were three treatment plots, in which normal selective PCT to 1800 or 2500 stems ha^{-1} was applied. Two assessments were performed and the treatment plots were observed for six years.

Group 10: Selective PCT with increased attention to promoting growth of trees selected as saw-log tree candidates

This experimental group was intended to assess whether it was possible to take measures at the time for an early PCT that would keep branches on trees selected as candidate saw-log trees small, and hence enhance the trees' future saw-log quality. Two possible strategies to achieve more thin-branched saw-log stems were tested. In one (designated Q1) it was postulated that leaving candidate saw-log trees closely surrounded by 3-4 trees of similar size could accelerate the increase in crown height of the candidate trees and/or decrease growth of their branches. In the other (Q2) it was postulated that thin-branched trees should be preferred during the selection, and thick-branched trees avoided, hence high volume production per area unit should have less priority than selecting saw-log candidate trees of high quality.

The experiment was limited to naturally generated Scots pine stands and the following treatments were applied:

0: No further actions before the first thinning.

Q1/1400: At the PCT, 200 candidate saw-log trees ha^{-1} were selected, preferably surrounded by 3-4 trees of similar size. In total 1400 stems ha^{-1} were supposed to remain after PCT.

Q2/1400: At the PCT, 500 thin-branched candidate saw-log trees ha^{-1} were selected. In total 1400 stems ha^{-1} were supposed to remain after PCT.

Q1/1800: At the PCT, 200 candidate saw-log trees ha^{-1} were selected, preferably surrounded by 3-4 trees of similar size. In total 1800 stems ha^{-1} were supposed to remain after PCT.

Q2/1800: At the PCT, 500 thin-branched candidate saw-log trees ha^{-1} were selected. In total 1800 stems ha^{-1} were supposed to remain after PCT.

Q1/2500: At the PCT, 200 candidate saw-log trees ha^{-1} were selected, preferably surrounded by 3-4 trees of similar size. In total 2500 stems ha^{-1} were supposed to remain after PCT.

Q2/2500: At the PCT, 500 thin-branched candidate saw-log trees ha^{-1} were selected. In total 2500 stems ha^{-1} were supposed to remain after PCT.

1400: Normal selective PCT to 1400 stems ha^{-1}.

1800: Normal selective PCT to 1800 stems ha^{-1}.

2500: Normal selective PCT to 2500 stems ha^{-1}.

A more detailed description of the treatments is given in Andersson (1970). Established plots/blocks and treatments applied, numbers of assessments and observation time are displayed in Table 10.

Table 10. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 10, Scots pine

		Treatments										
Site no.	Block	0[1)]	1400	Q1/ 1400	Q2/ 1400	1800	Q1/ 1800	Q2/ 1800	2500	Q1/ 2500	Q1/ 2500	Obser-vation time
5005		4	4		4							30
5012	A	3	3	3	3	3	3	3				14
	B		3	3	3[2)]	3	3	3				14
5083		4	4	4[2)]	4	4			4	4	4	23
9259										3		23
9266		4				4	4					22

Remarks: [1)] No treatment before first thinning; [2)] Replicated twice

Group 11: Omitted (delayed) PCT

It can be difficult to decide the best way to treat stands that should have been, but were not, previously subjected to PCT. Data from plots in two Scots pine stands are available to assess the problems. At site 5026, doing nothing (0) until the first thinning was compared to treatments in which 800, 1200 and 1400 stems ha^{-1} were left after PCT, combined with fertilization by 150 kg N ha^{-1} every five years, the first fertilization two years after PCT. The fertilization treatment was designated F, hence the combined treatments were designated 800/F, 1200/F and 1400/F, respectively. In addition, a treatment involving PCT with no fertilization (1400/NF) was included. At plot 5036, doing nothing until the first thinning was compared to three treatments in which all stems with DBH of either < 10.0 (DBH/>10) or < 12.5 cm (DBH/>12) were removed, plus a PCT to 600 stems ha^{-1} with or without N-fertilization (600/F and 600/NF, respectively) (Table 11).

Table 11. Numbers of assessments and observation time (year) for sites, blocks and treatments

Group 11, Scots pine

Site no.	Block	Treatments									
		0[1)]	800/F	1200/F	1400/NF	1400/F	600/NF	600/F	DBH/ >10	DNH/ >12	Obser-vation time
5026		3	3	3	3	3					13
5036	A	3					3	3			14
	B	3					3	3	4	4	14

Remarks: [1)] No treatment before first thinning

Group 12: Selective PCT and removal versus non-removal of PCT residues

The objective of these experiments was to compare the effects on growth of removing and not removing the PCT residues. Two treatments were applied, in which PCT residues were either removed (ResR) or not removed (ResNR). Experimental sites were established in five Scots pine stands (Table 12).

Table 12. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 12, Scots pine

		Treatments		
Site no.	Block	ResR	ResNR	Observation time
5118	A	4	4	20
	B	4	4	20
	C	4	4	20
5119	A	4	4	22
	B	4	4	22
	C	4	4	22
5124	A	4	4	19
	B	4	4	19
	C	4	4	19
	D	4	4	19
5128	A	4	4	19
	B	4	4	19
	C	4	4	19
	D	4	4	19
9260	A	4	4	15
	B	4	4	15

Group 13: Treatments of gapped and/or low density stands

Experimental sites were established in four gapped stands and stands with too few trees capable of satisfactory development. These plots were established solely in naturally generated Scots pine stands. Three treatments, omitted PCT and PCT combined with two levels of demand for evenness of areal distribution of the stems after PCT) were applied (Table 13), with the following designations:

GL/0: No further actions before the first thinning.

GL/F1: Weak requirements for even areal stem distribution

GL/F1 Moderate demands for even areal stem distribution

Table 13. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 13, Scots pine

		Treatments			
Site no.	Block	GL/0	GL/F1	GL/F2	Observation time
5129	A	2	2		17
	B	2	2		17
5130	A	2	2	2	17
	B	2	2	2	17
	C		2	2	17
9258	A	4	4		23
	B	4	4		23
	C	4	4		23
9270	A	2	2	2	7
	B	2	2		7

Group 14: Yield after PCT to a small number of stems per unit area

In six stands one plot, and in another stand three plots, were established to study growth after heavy PCT. Stem numbers ha^{-1} after PCT varied between 400 and 2000 (Table 14).

Table 14. Numbers of assessments and observation time (years) for sites, blocks and treatments

Group 14, Scots pine

Site no.	Nos. of stems after PCT	Nos. of accessments	Observation time
5090	1200	4	17
5091	400	5	17
5093	2000	5	34
5091	900	5	34
5093	700	5	34
5095	400	5	26
5096	1100	5	32
5097	500	4	25
5099	600	4	25

Group 15: Others

In total, there were three stands in group 15: site 5065, in which there were two blocks and three treatments (three levels of evenness of diameter distribution after PCT to 1400 stems ha^{-1}); site 5082, in which PCT to 1800 stems ha^{-1} was combined with N-fertilization; and site 9254 in which a single subplot of aspen, regenerated by sprouts, was established with 1400 stems ha^{-1} after PCT (Table 15).

Table 15. Numbers of assessments and observation time (years)
Group 15

Site no.	Block	Species	Number of subplots	Number of accessments	Observation time
5068	A	Scots pine	3	3	26
	B	Scots pine	3	3	26
5082		Scots pine	2	3	20
9254		Aspen	1	3	11

Supplementary observations and measurements

At selected sites and assessments the following additional information has been recorded:

- For selected plots coordinate data for the remaining stems after PCT are available in computer files (Appendix 6).
- In order to study in greater detail the impact of different stand densities on the future timber quality, branch thicknesses of trees on selected plots have been recorded in whorls up to 4 m above ground (Appendix 7). These supplementary recordings are not yet fully available in computer files.
- On unthinned plots (treatment code 0) in Group 1, a PCT was simulated, leaving the same number of stems as in a real PCT in the same stand (usually to 2500 stems ha^{-1}). These recordings allow the effect of thinning on the growth of the remaining trees to be studied in more detail. The recordings are not yet fully available in computer files (Appendix 8).
- On selected plots the diameters of sample trees at greater height than breast height, usually 6 m above ground, have been recorded (Appendix 9).

Results

Brief summaries of studies published to date based on the PCT-experiments are presented below.

Based on data acquired from some sites from the Group 1a experiment, analysed 10 years after PCT, Andersson (1968) discussed the dilemma that loss of volume growth per unit area cannot be avoided when promoting fast diameter growth of the remaining stems by leaving fewer stems after PCT.

Based on the Group 1 experiments Andersson (1973, 1974) concluded that total volume yield decreases after increased PCT removals, but nevertheless increased PCT removal can lead to increased timber volume at the first commercial thinning

Andersson (1976a) described the background of the Group 1a experiment and presented comprehensive analyses, eight years after PCT, of diameter and height growth following different PCT treatments. The diameter growth increased with decreasing numbers of stems after PCT, and the diameter growth of thicker stems increased more than that of thinner stems. The height growth was not clearly affected by different PCT treatments.

Andersson (1976b) exploited information from the Group 1a experiment, in combination with another dataset, when developing yield tables for Scots pine stands, planted or naturally regenerated from seed trees.

Based on results from some of the sites in the Group 9 experiment Andersson (1985a) recommended leaving a birch shelter at PCT in Norway spruce stands to reduce the risk of frost damage to the spruces. The birch shelter did not decrease the height growth of the spruces and could lessen the occurrence and growth of stump sprouts.

Several studies have shown that the diameter of the thickest branch increases with decreased densities of stems and the height to the first living branch increases more rapidly in dense stands. Andersson (1985b) concluded that delaying the PCT will reduce both branch growth and the future diameter of branches on the lower part of the stem.

Pettersson (1986) analysed the Group 7, strip thinning experiment, in naturally regenerated Scots pine stands. Ten years after the PCT the growing stock was correlated with the proportion of the clear-felled area in which the highest growing stock was present in cases where there were low proportions of clear-felled area.

Ekö and Petterson (1992) examined data from site 5033, established in a beech stand. The stand age at the latest assessment was 35 years and the plot was observed for 19 years. Selective removal to 1400 and 2500 stems after PCT was judged to result in poorer timber quality stems than traditional stand treatments of young beech stands, such as treatments BL1 and BL3 (see Group 4).

Petterson (1992) utilized the Group 1a and 1b experiments to study the effects on volume and structure of density after PCT. An increase in number of stems up to 4000 stems ha^{-1} resulted in higher yields for pine and (to a lesser degree) spruce. Increased numbers per unit area were related to greater positive skewness, i.e. higher percentages of the total volume were expected to be found in small diameter stems.

Fahlvik (2005) and Fahlvik et al. (2005) studied aspects of PCT in heterogeneous forests in southern Sweden, using data from selected sites from Groups 1, 2, 8 and 10. The effects of stand density after PCT and timing of thinning on the diameter of the thickest branch were studied for naturally regenerated Scots pine. The branch diameter was found to decrease with increasing numbers of remaining stems after PCT. However, leaving very dense stands (> 3000 stems ha^{-1}) resulted in only minor reductions of the branch diameter. The branch diameter was thinner following late PCT than following early PCT.

Ulvcrona et al. (2007) analyzed the effects of PCT on tree and branch characteristics at two experimental sites in northern Sweden (5015 and 5227). The study showed that the diameter at breast height and living crown to height ratio decreased, while the stem form was improved with increasing stand density, and generally with increased height at thinning. No treatment effect was found on the number of branches per whorl or branch angle,

but branch diameter was significantly influenced by both stand density after thinning and height at thinning. Branch diameter decreased with increases in stand density and decreased with increases in height at pre-commercial thinning. Relative branch size, defined as the ratio between the sum of the diameters of branches in a whorl and stem perimeter under bark at the location of that whorl, was significantly influenced only by stand height at the time of treatment. The results indicate that the number of stems per unit area after pre-commercial thinning has a greater impact on tree size and shape than the timing of pre-commercial thinning.

Discussion

Currently ongoing studies

Much of the available data is currently being used in scientific analyses within the Forest Management project of the "Future Forests" research program at the Swedish University of Agricultural Sciences. Currently, data from groups 1 and 2 are being investigated and analyzed in several research projects. For example, Ulvcrona et al. (in prep.) are analyzing mortality rates in Scots pine stands subjected to PCT at different spacings and timings using data from these experimental groups. Other research questions are also currently being addressed using data from Groups 1 and 2, mainly concerning production of wood substrates and biomass in relation to timing and spacing of PCT. Research projects currently being designed and planned will focus (*inter alia*) on branch development, stem taper and theoretical PCT. Furthermore, data from experimental groups 7, 9 and 12 are also being examined within several research projects.

Future studies

Since a great deal of recorded data from the PCT experiments is now computer-accessible, new research opportunities are emerging, for example simultaneous analyses of datasets showing effects of various kinds of pre-commercial and commercial thinnings, and the ability to explore in greater detail than previously possible the connections between silvicultural operations and traits of interest in wood science and technology.

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Appendixes

Appendix 1

General statistics for experimental sites. Gr. no. is the experimental Group number; Experimental design is randomized blocks (RB) or not randomized blocks (NRB); Lat. is Latitude; Long. is longitude.

Gr. no.	*Site no.*	*No. of plots*	*Earlier site identity*	*Year of establishment*	*Experimental design*	*Species*	*Locality*	*Lat.*	*Long.*	*Altitude*	*Regeneration*
1	953	8	SD401	1954	RB	Scots pine	FLODA	59.1	16.3	80	Natural
1	954	6	SD402	1955	RB	Scots pine	BÄRBO	58.8	16.8	40	Natural
1	955	8	SD403	1955	RB	Norway spruce	NYKÖPING	58.8	16.9	30	Planting
1	956	4	SF401	1953	RB	Scots pine	BYARUM	57.5	14.1	200	Natural
1	957	12	SF402	1955	RB	Scots pine	NORR UNNARYD	57.6	13.7	200	Natural
1	960	6	SK402	1954	RB	Norway spruce	BRÄKNE HOBY	56.2	15.2	20	Planting
1	961	6	SS401	1953	RB	Scots pine	SUNNE	59.8	13.1	160	Sowing
1	962	3	S462	1951	RB	Scots pine	VINDELN	64.2	19.6	260	Natural
1	963	1	S463	1951	RB	Scots pine	LOCKNE	63.0	14.9	330	Natural
1	964	8	S464	1951	RB	Scots pine/ Norway spruce	BOLLNÄS	61.4	16.5	140	Natural
1	965	4	S465	1952	RB	Scots pine	BOLLNÄS	61.4	16.5	160	Sowing
1	966	2	S466	1952	RB	Scots pine	OVANÅKER	61.4	15.7	180	Natural
1	967	2	S467	1952	RB	Scots pine	LJUSDAL	61.8	16.0	140	Natural
1	969	8	S769	1957	RB	Norway spruce/ Scots pine	ALFTA	61.2	15.8	295	Natural
1	970	12	S770	1957	RB	Scots pine	LUDVIKA	60.3	15.0	180	Natural
1	971	7	S771	1957	RB	Scots pine	FÄRILA	61.9	15.8	180	Natural
1	972	7	S776	1960	RB	Scots pine	PITEÅ	65.4	21.3	10	Natural
1	973	3	S773	1958	RB	Scots pine	NÄSHULT	59.2	16.1	70	Natural
1	974	6	S774	1958	RB	Scots pine	KJULA	59.3	16.7	50	Natural
1	975	9	S775	1959	RB	Scots pine	ARVIDSJAUR	65.9	19.2	340	Natural
1	976	5	S476	1953	RB	Scots pine	LJUSDAL	61.8	16.1	120	Natural
1	977	6	S476	1953	RB	Scots pine	LJUSDAL	61.8	16.2	140	Natural
1	978	12	S478	1953	RB	Scots pine	DELSBO	61.7	?	140	Natural
1	981	2	S481	1953	RB	Scots pine	MORA	60.9	14.4	270	Natural
1	983	8	S483	1953	RB	Scots pine	MORA	60.9	14.4	260	Natural

Gr. no.	*Site no.*	*No. of plots*	*Earlier site identity*	*Year of establ-ishment*	*Ex-peri-mental design*	*Species*	*Locality*	*Lat.*	*Long.*	*Alti-tude*	*Rege-nera-tion*
1	984	7	S484	1953	RB	Scots pine	GÄVLE	60.6	17.3	30	Natural
1	985	24	S777	1961	RB	Scots pine	LUDVIKA	60.3	14.9	190	Natural
1	986	7	S778	1961	RB	Norway spruce	BJÖRKVIK	58.8	16.4	50	Natural
1	5001	14	R01	1969	RB	Scots pine	FRÖSUNDA	59.7	18.2	40	Natural
1	5007	7	R07	1969	RB	Norway spruce	ENSLÖV	56.8	13.1	180	Planting
1	5014	8	R14	1969	RB	Scots pine	ARVIDSJAUR	65.7	19.8	400	Planting
1	5016	5	R16	1969	RB	Scots pine	JOKKMOKK	66.0	20.1	175	Natural
1	5018	11	R18	1969	RB	Norway spruce	LYCKSELE	64.7	17.8	450	Planting
1	5035	10	R35	1072	RB	Scots pine	LINSELL	62.0	12.6	540	Sowing
1	5037	3	R37	1971	RB	Norway spruce	HIDINGE	59.3	14.9	115	Planting
1	5038	3	R38	1971	RB	Norway spruce	LÄNNÄS	59.1	15.6	60	Planting
1	5039	6	R39	1961	NRB	Scots pine	STRÖM	64.0	15.5	300	Sowing
1	5070	3	R70	1960	NRB	Norway spruce	JUNSELE	63.6	16.8	220	Natural
1	5072	5	R72	1960	NRB	Scots pine	LYCKSELE	64.9	18.6	260	Natural
1	5073	2	R73	1960	NRB	Scots pine	LYCKSELE	64.9	18.7	240	Natural
1	5074	5	R74	1972	NRB	Scots pine	DEGERFORS	64.4	19.6	250	Natural
1	5092	3	S102	1957	NRB	Scots pine	ÄLVSBY	65.7	21.0	55	Natural
1	5100	5	S110 R100 5245	1951	NRB	Scots pine	BRÄCKE	62.7	15.5	300	Natural
1	5200	7	RB1 R09	1970	RB	Scots pine	SKEDERID	59.7	18.5	55	Natural
1	5203	7	RD1	1970	RB	Norway spruce	ÅRDALA	59.0	16.7	30	Planting
1	5206	7	RF1	1970	RB	Norway spruce	ADELÖV	58.0	14.7	210	Planting
1	5207	8	RG1	1970	RB	Norway spruce	GÅRDSBY	57.0	15.0	215	Planting
1	5208	7	RH1	1970	RB	Scots pine	SÖDRAVI	57.8	15.8	130	Sowing
1	5209	6	RH2	1971	RB	Scots pine	RYSSBY	56.9	16.4	15	Planting
1	5212	7	RO1	1971	RB	Scots pine	NAVERSTAD	58.8	11.5	125	Planting
1	5213	6	RP1	1971	RB	Scots pine	TORRSKOG	59.2	12.9	165	Natural
1	5221	7	RX1	1970	RB	Scots pine	BOLLNÄS	61.4	16.5	170	Natural
1	5228	6	RBD1	1971	RB	Scots pine	TÖRE	65.9	22.7	30	Natural

Gr. no.	*Site no.*	*No. of plots*	*Earlier site identity*	*Year of establishment*	*Experimental design*	*Species*	*Locality*	*Lat.*	*Long.*	*Altitude*	*Regeneration*
2	5002	2	R02	1969	RB	Scots pine	SKEDERID	59.7	18.5	40	Natural
2	5003	6	R03	1969	RB	Scots pine	SKEDERID	59.7	18.5	40	Natural
2	5015	15	R15	1969	RB	Scots pine	DEGERFORS	64.4	19.8	240	Natural
2	5017	10	R17	1969	RB	Scots pine	JOKKMOKK	66.0	20.1	180	Natural
2	5020	11	R20	1970	RB	Scots pine	BJÖRNA	63.7	18.2	400	Planting
2	5103	7	R103	1981	RB	Scots pine	VÄSTANFORS	59.9	15.8	135	Natural
2	5201	14	RB2	1970	RB	Scots pine	FRÖTUNA	59.7	18.8	30	Planting
2	5204	10	RD2	1971	RB	Norway spruce	ST MALM	58.9	16.3	50	Planting
2	5211	13	RK1	1970	RB	Norway spruce	NÄTTRABY	59.2	15.6	40	Planting
2	5222	9	RX2	1970	RB	Scots pine	GNARP	62.2	17.3	145	Planting
2	5223	7	RY1	1971	RB	Scots pine	SKORPED	63.3	17.7	330	Sowing
2	5227	13	RZ2	1971	RB	Scots pine	STUGUN	63.3	15.3	365	Sowing
2	9249	4	S249	1973	RB	Scots pine	MORA	60.9	14.4	230	Natural
3	5019	21	R19	1970	RB	Scots pine	N RÅDA	59.8	13.5	125	Natural
3	5029	9	R29	1971	RB	Scots pine	JUNOSUANDO	67.4	22.3	245	Natural
3	5202	9	RC1	1974	RB	Scots pine	ÄLVKARLEBY	60.6	17.4	20	Natural
3	5219	9	RW1	1970	RB	Scots pine	ORE	61.2	12.9	225	Natural
3	5229	9			RB	Scots pine	JUNOSUANDO	67.4	22.3	250	Natural
3	9244	9	S244	1971	RB	Scots pine	MORA	60.9	14.3	230	Natural
4	5006	10			RB	Oak	SÖDRA VRAM	56.1	13.0	55	Planting
4	5032	2	R32	1970	RB	Beech	RISEBERGA	56.0	13.2	155	Planting
4	5033	7	R33	1970	RB	Beech	GENARP	55.6	13.5	105	Sowing

Gr. no.	*Site no.*	*No. of plots*	*Earlier site identity*	*Year of establishment*	*Experimental design*	*Species*	*Locality*	*Lat.*	*Long.*	*Altitude*	*Regeneration*
5	5008	5	R8	1969	RB	Norway spruce	SKÄRV	58.4	13.6	130	Planting
5	5010	7	R10	1970	RB	Scots pine	RAMNÄS	59.9	16.0	95	Natural
5	5226	7	RZ1	1970/1971	RB	Scots pine	HEDE	62.4	13.6	410	Natural
5	9245	11	S245	1972	RB	Scots pine	MORA	60.9	14.4	220	Natural
6	5005	17	R05	1969	RB	Scots pine	HÄLLEBERGA	56.9	15.7	180	Sowing
6	5013	10	R13	1969	RB	Scots pine	BODSJÖ	62.8	14.9	350	Natural
6	5053	2	R53	1971	NRB	Scots pine	ÄLGARÅS	58.8	14.2	130	Planting
6	5064	3	R64	1971	NRB	Scots pine	HABO	57.9	14.1	165	Planting
6	5069	10	R69	1972	RB	Scots pine	EDSELE	63.5	17.3	370	Planting
6	9265	6	S265	1978	RB	Scots pine	MORA	60.9	14.4	260	Natural
7	5023	8	R23	1970	RB	Scots pine	LYCKSELE	64.7	18.6	225	Natural
7	5205	9	RE01	1974	RB	Norway spruce	VIST	58.2	15.8	120	Planting
7	5214	7	RP2	1972	RB	Norway spruce	HÅLANDA	58.1	12.4	100	Planting
7	5215	6	RR1	1973	RB	Norway spruce	AMNEHÄRAD	58.9	14.2	100	Planting
7	5220	10	RW2	1972	RB	Scots pine	HUSBY	60.4	16.0	200	Natural
7	5224	20	RY2	1972	RB	Scots pine	TIMRÅ	62.5	17.4	20	Natural
7	5225	6	RY3	1972	RB	Scots pine	SKORPED	63.5	17.3	360	Planting
7	5231	22	RBD4	1972	RB	Scots pine	ARVIDSJAUR	65.9	20.1	175	Natural
7	9252	3	S252	1975	RB	Scots pine	MORA	60.9	14.4	225	Natural
8	5004	6	R04	1969	RB	Scots pine	VENDEL	60.1	17.5	50	Planting
8	5011	9	R11	1970	RB	Scots pine	N RÅDA	60.0	13.6	120	Natural
8	5031	9	R31	1970	RB	Scots pine	REFTELE	57.3	12.6	155	Planting
8	8123	8	T123	1978	RB	Scots pine	BREARED	56.7	13.1	115	Natural
8	9242	12	S242	1970	RB	Scots pine/ Norway spruce	MORA	60.9	14.4	260	Natural

Gr. no.	*Site no.*	*No. of plots*	*Earlier site identity*	*Year of establishment*	*Experimental design*	*Species*	*Locality*	*Lat.*	*Long.*	*Altitude*	*Regeneration*
9	5086	14	R86		RB	Norway spruce/ Birch	GARPENBERG	60.3	16.3	220	Planting
9	5087	7	R87	1980	RB	Norway spruce/ Birch	ÖVERTORNEÅ	?	?	?	Sowing
9	5088	6	R88	1980	RB	Scots pine/ Birch	SVINHULT	57.8	15.3	210	Planting
9	5105	13	R105	1977	RB	Norway spruce/ birch	DOROTEA	64.5	15.9	440	Planting
9	5108	4	R108	1982	RB	Norway spruce/ birch	FOLKÄRNA	60.2	16.3	110	Natural
9	5109	4	R109	1982	RB	Norway spruce/ birch	BINGSJÖ	61.9	15.5	335	Planting
9	5110	3	R110	1982	RB	Norway spruce/ birch	SÖDRA VIST	57.8	13.3	150	Planting
9	5111	7	R111	1982	RB	Norway spruce/ birch	STENGÅRDSHULT	57.6	13.8	260	Planting
9	5112	5	R112	1982	RB	Scots pine/ birch	HAMNEDA	56.7	14.8	155	Natural
9	5113	3	R113	1982	RB	Norway spruce/ birch	LJUNGBY	56.8	13.9	145	Planting
9	5116	4	R116		RB	Scots pine	SÄRABY	57.0	18.9	180	Planting
9	5125	2	R125	1983	RB	Norway spruce/ birch	RYSSBY	56.8	16.4	10	Planting
9	5210	9	RH3	1971	RB	Norway spruce/ birch	RYSSBY	56.9	16.4	15	Planting
9	9250	15	S250	1974	RB	Norway spruce/ birch	MORA	60.9	14.3	220	Natural
9	9262	6	S262	1985	RB	Scots pine/ birch	MORA	60.9	14.4	225	Natural
9	9625	7	S625 SF625 R80	1973	RB	Norway spruce/ birch	MORA	60.9	14.4	225	Planting
10	5012	14	R12	1969	RB	Scots pine	HUSBY	60.4	16.2	190	Planting
10	5083	10	R83	1976	RB	Scots pine	LERBÄCK	58.9	15.3	115	Planting
10	9259	1	S259	1976	RB	Scots pine	MORA	60.9	14.4	250	Natural
10	9266	3	S266	1978	RB	Scots pine	MORA	60.9	14.4	255	Natural
11	5026	5	R26	1971	RB	Scots pine	KUMLA	59.1	20.1	55	Natural
11	5036	10	R36	1972	RB	Scots pine	LINSELL	62.2	13.8	440	Natural

Gr. no.	*Site no.*	*No. of plots*	*Earlier site identity*	*Year of establishment*	*Experimental design*	*Species*	*Locality*	*Lat.*	*Long.*	*Altitude*	*Regeneration*
12	5118	6	R118	1983	RB	Scots pine	GRYTNÄS	60.2	16.1	105	Natural
12	5119	8	R119	1983	RB	Scots pine	LYCKSELE	64.8	18.9	215	Natural
12	5124	8	R124	1984	RB	Scots pine	LINDESBERG	59.8	15.3	205	Natural
12	5128	8	R128	1984	RB	Scots pine	ALGUTSBODA	56.8	15.6	210	Sowing
12	9260	3	S260	1977	RB	Scots pine	MORA	60.9	14.4	225	Natural
13	5129	4	R129	1985	RB	Scots pine	SVINHULT	57.7	15.4	245	Natural
13	5130	8	R130	1984	RB	Scots pine	VINDELN	64.4	19.4	230	Natural
13	9258	6	S258	1976	RB	Scots pine	MORA	60.9	14.4	235	Natural
13	9270	5	S270	1985	RB	Scots pine	MORA	61.1	14.5	170	Natural
14	5090	1			RB	Scots pine	ÖSTER-FÄRNEBO	60.3	16.8	65	Sowing
14	5091	1	S101	1961	RB	Scots pine	ÖSTER-FÄRNEBO	60.3	16.8	65	Sowing
14	5093	3	S103	1951	RB	Scots pine	DEGERFORS	64.4	19.5	235	Natural
14	5095	1	S105	1968	RB	Scots pine	DEGERFORS	64.4	20.1	260	Natural
14	5096	1			RB	Scots pine	ÄLVSBY	65.7	21.0	65	Natural
14	5097	1			RB	Scots pine	BJÖRNA	63.5	16.1	170	Sowing
14	5099	1			RB	Scots pine	ANUNDSJÖ	63.7	16.1	285	Natural
15	5068	6	R68	1972	RB	Scots pine	TIMRÅ	62.5	17.4	20	Natural
15	5082	2	R82	1975	RB	Scots pine	ÖSSEBY-GARN	59.5	18.2	55	Planting
15	9254	1	S254	1975	RB	Aspen	MORA	60.9	14.4	240	Natural

Appendix 2

Layout description, Excel files, stem data for numbered stems

Column no.	Explanation
1	Site no.
2	plot no.
3	Assessment no.
4	Assessment year
5	Assessment month
6	Assessment day
7	Tree no.
8	Diameter 1, mm, 1.3 m above ground
9	Diameter 2, mm, 1.3 m above ground (perpendicular to diameter 1)
10	Species code (according to Andersson, 1970)
11	Treatment code (according to Andersson, 1970)
12	Tree class code (according to Andersson, 1970)
13-15	Codes for deviations from normal (according to Andersson, 1970)

Layout description, Excel files, stem data for unnumbered stems

Column no.	Explanation
1	Site no.
2	plot no.
3	Assessment no.
4	Assessment year
5	Assessment month
6	Assessment day
7	Ordinal tree no.
8	Treatment code (according to Andersson, 1970)
9	Species code (according to Andersson, 1970)
10	Diameter class, cm (nearest diameter of 1 cm class width)
11	Number of stems in the cm-class above

Appendix 3

Layout description, Excel files, sample tree data, numbered trees

Column no.	Explanation
1	Site no.
2	plot no.
3	Assessment no.
4	Assessment year
5	Assessment month
6	Assessment day
7	Tree no.
8	Species code (according to Andersson, 1970)
9	Treatment code (according to Andersson, 1970)
10	Sample tree code (1=remaining, systematically selected) 2 and 3=dominant trees; 4 and 5=removed
11	Tree height, dm
12	Distance from ground to the first living branch, mm
13	Double bark 1 thickness (mm) at 1.3 m above ground
14	Double bark 2 thickness (mm) at 1.3 m above ground (perpendicular to double bark 1)

Layout description, Excel files, sample tree data, unnumbered trees

Column no.	Explanation
1	Site no.
2	plot no.
3	Assessment no.
4	Assessment year
5	Assessment month
6	Assessment day
7	Ordinal tree no.
8	Species code (according to Andersson, 1970)
9	Treatment code (according to Andersson, 1970)
10	Sample tree code (7=remaining, systematically selected; 8=removed, systematically selected)
11	Tree height, dm
12	Distance from ground to the first living branch, mm
13	Double bark 1 thickness (mm) at 1.3 m above ground
14	Double bark 2 thickness (mm) at 1.3 m above ground (perpendicular to double bark 1)
15	Diameter 1, mm, 1.3 m above ground
16	Diameter 2, mm, 1.3 m above ground (perpendicular to diameter 1)

Appendix 4

Layout description, Excel files with assessment statistics, basal area, volume, yearly increment, etc.

The files have 250 columns. Explanation of the file structure

Columns 1-19 **General information about the plot:**
Site no., plot no., assessment no., assessment date, stand age, subplot area, county, latitude, longitude, altitude, code for regeneration method.

Columns 20-35 **Assessment data, total for all species.**
Remaining trees: Basal area mean diameter (D), mean tree height, D-weighted (H), number of stems ha^{-1} (N), basal area ha^{-1} (BA) and volume ha^{-1} (V)
Removed trees: D, N, BA and V
Total yield: BA and V
Yearly increment: D, BA and V

Columns 36-66 **Assessment data for the main species**
Species code and site index (SI).
For remaining trees: D, H, N, BA and V.
Removed trees: D, N, BA and V.
Total yield: BA and V
Yearly increment: D, BA and V
Self-thinned trees (subset of removed trees): D, N, BA and V
Missing trees (subset of removed trees): D, N, BA and V
Wind-thrown trees (subset of removed trees): D, N, BA and V

Columns 67-97 **Assessment data for supplementary species no. 1**
Column structure, see assessment data for main species

Columns 98-128 **Assessment data for supplementary species no. 2**
Column structure, see assessment data for main species

Columns 129-159 **Assessment data for supplementary species no. 3**
Column structure, see assessment data for main species

Columns 160-190 **Assessment data for supplementary species no. 4**
Column structure, see assessment data for main species

Columns 191-202 **Assessment data for unnumbered trees, species no. 1**
Species code.
For remaining trees: D, H, N, BA and V.
Removed trees: D, N, BA and V.
Total yield: BA and V

Columns 191-202 **Assessment data for unnumbered trees, species no. 2**
Column structure, see assessment data for unnumbered trees, species no. 1

Columns 191-202 **Assessment data for unnumbered trees, species no. 3**
Column structure, see assessment data for unnumbered trees, species no. 1

Columns 191-202 **Assessment data for unnumbered trees, species no. 4**
Column structure, see assessment data for unnumbered trees, species no. 1

Columns 191-202 **Assessment data for unnumbered trees, species no. 5**
Column structure, see assessment data for unnumbered trees, species no. 1

Columns 191-202 **Assessment data for unnumbered trees, species no 6**
Column structure, see assessment data for unnumbered trees, species no. 1

Appendix 5

Site statistics

Examples of output from a Word file with site, plot and assessment data

SLU, Department of Forest Yield Research.
Site no.: 5072
Plot no.: 2
Area: 0,0483 hectare
County: Lappland
Landowner: SCA Skog AB, Västerbottens Skogsförvaltning, Box 43, 921 21 Lycksele
Land property: Fahlström
Parish: Lycksele
Altitude: 260 m
Map code: 22I
Latitude: 64° 51'
Longitude: 18° 33'
Species: Scots pine
Site index: 18.3 m
Year of stand birth: 1928
Regeneration method: Established from seed trees

		Remaining stand								Removal						Total yield		Current annual increment				
Assessment no.	Assessment date year-m-d	Species	Stand age	1) Mean DBH, cm	2) Mean height, m	Dominant height, m	No. of stems per hectare	Basal area per hectare, m^2	Volume per hectare, m^3	1) Mean DBH, cm	No. of stems per hectare	Basal area per hectare, m^2	Volume per hectare, m^3	Thinning % Basal area	Thinning % Volume	Basal area per hectare, m^2	Volume per hectare, m^3	1) Mean DBH, mm	Basal area per hectare		Volume per hectare	
																			m^2	*3)* %	m^3	*3)* %
1	1972-09-01	Scots pine	45	9.3	8.4	10.0	1035	7.1	31.7							7.1	32					
2	1977-09-05	Scots pine	50	11.0	9.7	11.2	1035	9.9	54.1							9.1	54	3.4	0.56	6.9	4.5	11.3
3	1983-06-16	Scots pine	55	12.2	11.0	12.4	1035	12.1	67.2							12.1	67	2.4	0.45	4.2	2.6	4.4
4	1990-08-03	Scots pine	63	13.6	12.2	13.6	1014	14.8	88.8													
	Dead	Scots pine								9.9	21	0.2	0.8									
	Total	Scots pine		13.6	12.2		1014	14.8	88.8	9.9	21	0.2	0.8	2	1	15.0	90	1.7	0.36	2.7	2.8	3.7
5	2002-10-11	Scots pine	75	15.5	13.9	15.4	994	18.8	132.7													
	Dead	Scots pine								11.1	21	0.2	1.3									
	Total	Scots pine		15.5	13.9		994	18.8	132.7	11.1	21	0.2	1.3	2	1	19.2	135	1.5	0.35	2.1	3.8	3.5

[1] Diameter corresponding to mean basal area [2] Mean height, DBH-weighted [3] According to compound interest

Appendix 6

Coordinate data on computer files

Group no.	Site no.	Plot numbers
1	956	11, 15, 25
1	962	1
1	963	0
1	964	4, 6
1	965	1-3
1	966	1, 2
1	967	1
1	970	11, 15, 21, 25, 30
1	975	11, 35
1	976	2-4
1	977	11, 15, 21, 25
1	978	15, 16, 17, 21, 25-27
1	983	15, 16, 18, 26, 28
1	984	19, 28, 29
1	5016	4
1	5221	2-7
2	5003	21
5	9245	1, 3
7	5220	1, 2, 8
8	5004	1-6
8	5011	1-8
8	5031	1, 3, 5-9, 11
8	9242	11-14, 21-24, 31-34
9	5024	2, 4
9	5027	1, 4, 6,
9	5210	1, 11-13, 21-23
13	5130	11-13, 21-23, 31, 32
14	5096	0

Appendix 7

Sites selected for branch thickness measurements on sample trees

Group no.	Site no.	Plot numbers	Measurements at assessment numbers
1	953	11, 14-16, 21, 24-26	3-6
1	954	11, 15, 21, 24-26	6, 7
1	955	11,-14, 21-24	3-6
1	956	11, 15, 21, 25	5
1	957	11-15, 17, 21-25, 27	3-6
1	960	11, 12, 15, 21, 22, 25	3-5
1	961	11-13, 21-23	2-6
1	962	2, 3	3-4
1	964	1, 3, 6	6-7
1	966	1, 2	6
1	967	1	6
1	969	11, 15, 16, 18, 21, 25,26, 28	1, 3-7
1	970	10-15, 20-25	3-6
1	971	11, 14, 15, 21, 24, 24, 30	4-5
1	972	11, 12, 14, 15, 21, 22, 24, 25	3, 4
1	976	1-5	4, 5
1	977	11, 14, 15, 21, 24, 25	4, 6
1	978	11, 12, 14-17, 21, 24-27	4-7
1	981	1	4, 5
1	983	14-16, 18, 24-26, 28	4,5
1	984	14, 18, 19, 24, 28, 29	4-6
1	985	11-18, 21-28, 31-38	2-5
1	5070	1-3	1, 2
1	5092	1-3	2-3
1	5218	1-7	3
1	5221	1-7	2
2	5015	1-15	2
2	5020	1-11	2
2	5204	1-11	3
2	5211	2-4, 7, 9-13	3
2	5222	1-9	2
2	5223	1-7	2
2	9249	1-4	1
5	5226	1-7	3
5	9245	11-16, 23-29	2
7	5023	1-10	3
7	5205	1-9	3
7	5214	1-8	3
7	5215	1-6	2
7	5220	4, 5, 8	3
7	9252	1-3	2
8	5004	1-4	3
8	5011	1, 2, 4, 6-8	3
8	5031	1, 3, 5-11	3
9	5021	1-4, 7-9	3
9	5027	1, 3-6	3
9	5028	1-4	3

Appendix 8

Imaginary PCT sites to be compared in the same stand to corresponding, real PCT

Group no.	Site no.	Plot no., real PCT	Plot no., imaginary PCT	Number of stems after PCT
1	953	15	14	2500
1	954	25	24	2500
1	961	12	13	3000
1	961	22	23	3000
1	964	1	2	4800
1	967	1	2	4400
1	971	25	24	2500
1	978	15, 17	14	2500
1	978	25, 27	24	2500
1	983	18	14	1400
1	983	28	24	1400
1	5218	1	7	2500
1	5221	2	1	2500

Appendix 9

Sites selected for upper diameter measurements (6 m above ground) on sample trees

Group no.	Site no.	Plot numbers	Measurements at assessment numbers
1	955	11,-14, 21-24	6
1	956	11, 15, 21, 25	5[1)]
1	957	11-15, 17, 21-25, 27	6
1	961	11-13, 21-23	6
1	962	2, 3	4
1	969	11, 15, 16, 18	6, 7
1	970	10-15, 20-25	6
1	5092	1-3	3
1	5100	1-5	3, 4
2	5204	1-11	3[2)]
5	5010	1-7	3[2)]
12	9260	1-3	2-3

Remarks: [1)] 4 m above ground; [2)] 5 m above ground