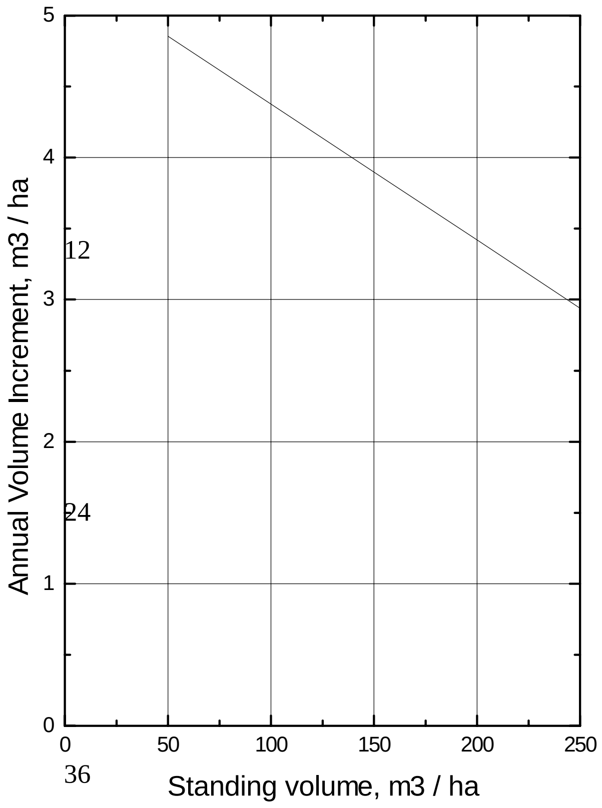
Effects of standing volume, harvest intensity and stand structure on volume increment in plots managed with long-term, single-tree selection.

Mats Hagner and Sören Holm, 2003-08-10



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UBICON, Blåbärsvägen 19, 903 39 Umeå. Tel 090-141620. Epost mats.hagner@telia.com
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Abstract

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Eleven plots in central Sweden were selectively cut 2-7 times in periods spanning 20-63 years, and in cutting intervals of 5-13 years. The average standing volume was 147 m^3ha^{-1} (range, 41 to 287 m^3ha^{-1}). Norway spruce (*Picea abies* (L.) Karst.) dominated, and in some plots pine (*Pinus sylvestris* L.) and birch (*Betula pendula* Roth. + *Betula pubescens* Ehrh.) were also present. *Vaccinium myrtillus* L. dominated the field layer.

Multiple regression analyses revealed that annual volume increment decreased with increasing harvest intensity, and with increasing standing volume. In plots where thinning was carried out in such a manner that a multi-storied structure was preserved, the volume increment was stable over time. In other plots, treated in such a way that the structure became more single-storied, the productivity decreased over time.

The results were not consistent with those of other studies, probably because the data relate to plots that varied in standing volume over time, while previous studies compared productivity in plots with differences in standing volume. Hence this is a temporal comparison while most researchers have examined spatial differences.

The regression functions suggest that substantial gains in volume production can be made if low standing volume is combined with frequent thinnings of low intensity. It also indicates the importance of preserving a multi-storied structure.

Key words: polycyclic, uneven-aged, continuous cover, tree selection, stand structure, productivity, standing volume, frequent thinnings, multiple, regression.

Authors' address. SLU, 901 83 Umeå, Sweden. E-mail Mats.Hagner@telia.com and Soren.Holm@resgeom.slu.se

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1 Introduction

A general goal of forest management is to optimise potential benefits in a wide sense, including economic returns, biodiversity and multiple uses. The Swedish government has expressed two major goals for Swedish forestry: one environmental and the other related to productivity. The Forest Act defines the second goal as being to keep the standing volume higher than a function, correlating standing volume and the average height of the trees, derived from a study by Elfving 1993, in which he analysed several thousand temporary plots enumerated by the National Forest Inventory. In a multiple regression, including site index as one of the variables, he found a statistically significant and positive correlation between standing volume and volume increment. Based on the same material, Fridman (1995) found a very similar, positive relationship indicating that high volume increment was maintained in the Swedish forests when standing volume was kept high.

Hagner et al. (2001) proposed that an effective principle for forest management would be to “maximize the present net value for every group of trees that compete for the same resources”. The authors also presented a computer-aided model for choosing trees to be harvested. In practise, application of this principle led to stands with uneven-sized structure and low standing volume. Hence, there was a risk that forest owners adopting the principle would violate the rule stated by the Swedish Forest Act.

In Sweden, even-aged forest management has been generally practiced since 1950 and, hence, the results presented by Elfving and Fridman were valid for forests managed under such a system. Accordingly, it was of great interest to study the volume increment and its relation to standing volume in plots with uneven-aged structure. Therefore, eleven plots with such a structure were studied in detail. They had been subjected to single-tree selection over very long periods: 20-60 years, and monitored by the Swedish University of Agricultural Sciences. The results were presented by Lundqvist (1989), who stated that the relation between volume increment and standing volume was positive and that “The relative annual volume increment is approximately 3 %.” (of standing volume). Andreassen (1994) also found a positive correlation between standing volume and volume increment in plots managed with a single-tree selection system over long periods. Further corroboration was supplied by Lähde et al. (2002) and Lundqvist (1994), who also reported positive correlations for plots with uneven-aged structure.

However, since none of the studies cited above had considered thinning intensity, we believed there was an obvious risk that the low volume increment found in stands with low standing volume could be due to the low leaf area index that follows an intense thinning (O’Hara et al 1999), rather than from low standing volume *per se*. We also believed that site fertility could influence the results, as standing volume is kept higher in plots on fertile sites. Variations in fertility might continue to have an impact even if site index is introduced as a covariate in multiple regression analyses, since site index is known to be an imprecise tool that leaves a large portion of the variance in “fertility” unexplained.

The study presented here is based on the material mentioned above in the eleven Swedish plots subjected to single-tree selection and monitored over long periods. The statistical analyses extend evaluations of earlier studies, and the following hypothesis was tested: “Volume increment increases with standing volume”.

2 Material

Eleven experimental plots in Sweden, averaging 0.63 ha in area (range, 0.25-1.0), at latitudes between 61^0 and 64 ºN, were subjected to single-tree selection over long periods: 20-63 years (Anon.1974). All plots were dominated by Norway spruce (*Picea abies* (L.) Karst.), while other species present included Scots pine (*Pinus silvestris* L.), silver birch (*Betula pendula* Roth) and white birch (*Betula pubescens* Ehrh). The ground vegetation was dominated by *Vaccinium myrtillus* L. Additional information is given in Table 1.

Volume and increment refers only to trees with a diameter (dbh) of 8.5 cm or more.

Data on annual increment were published by Lundqvist (1989 b), but unfortunately the results were presented simply as points in diagrams. As the exact figures were lost we digitised the 58 values from Fig. 1. We have been able to compare our data with 42 figures collected from other sources, and they correlated extremely well (r = 0.99). Hence, we are confident that the statistical results presented here would also be valid for the original material.

For plot S4 the last cutting and the following period of growth were excluded, as there were clearly errors in the data. Some extremely small harvests at the S5, S6, V2 and J sites were not separately considered, but in each case the harvested volume was added to the following harvest.

As Lundqvist did not present any values for mortality at each harvest within the plots, the loss of wood from mortality was not included in the following estimations. The volume lost from mortality was on average 10.4 % (Table 1).

3 Methods

The meanings of the abbreviations used for the tested variables are given in Table 2. Standing volume, *Standvol*, was equivalent to the volume at the beginning of the growth period between two harvests. Annual volume increment, *Volincr*, was estimated from the difference between the standing volumes at the start and end of the growth period, divided by the length of the period in years. Harvest intensity, *Harvint*, was the volume, in m^3ha^{-1}, harvested before the growth period. The relative harvest intensity, *Harvint%*, was *Harvint* as a percentage of standing volume before harvest. Years from start of treatment, *Yearsfst*, is the number of years elapsed since the first harvest.

The statistical analyses were based on the regression model

$$y_{ij} = \beta_{0j} + \beta_1 x_{1ij} + \beta_2 x_{2ij} + ... + \beta_p x_{pij} + e_{ij}$$

where y_{ij} is the value of the dependent variable for the *i*th observation in time of the *j*th plot, x_{rij} for $r = 1,...p$ are values of independent variables and the random effects associated with y_{ij}, e_{ij}, are assumed to be $NID(0,\sigma^2)$.

The intercept β_{0j} for each plot, which reflects its general volume increment, was estimated by use of indicator (dummy) variables. Different sets of reasonable, independent variables were tested, as well as some interactions among the original variables. The final choice of variables was dictated by simplicity and logic rather than by the statistical residual sums of squares.

The model was applied not only to the entire data set obtained for all eleven plots, but also separately to the two groups of four plots mentioned below. F-tests were used to test equality between sets of β_r values for the two groups. In cases of rejection, group-specific parameter values were obtained by use of group indicators multiplied by the variables in question.

The assumptions about the deviations e_{ij} were checked by inspecting the residuals, both visually and by computation. The independence assumption should be scrutinised especially carefully, since the within-plot observations constitute time series. This was checked by estimating the pooled within-plot autocorrelation coefficient and the estimated value was found to be low and even negative (around -0.25, depending on the model and data set), so it should be valid to use the formal p-values for tests.

A cross-validation of the final regression model was performed.

The calculations were carried out, and the presented figures were prepared, using the Minitab package (Minitab 13). The SAS package (SAS 8, Proc Mixed) was used for estimating the autocorrelation, and for more general models, with random regression coefficients.

Skewness in *Harvint%* was eliminated by natural logarithm transformation, but in the analyses this transformation did not increase the efficiency. Hence, the original values were used. The same was also true for arcsine√p transformation of the percentages. Insignificant variables were eliminated by backward, stepwise selection.

Two groups of four plots were formed after a study of diameter distributions at the start and end of the treatment period (Lundqvist 1989a). Group 1 (G1) "Well" included plots in which the treatment preserved the negative exponential distribution and kept the stand multi-storied (Plots S1, V2, V3, J). Group 2 (G2) "Wrong" comprised plots in which the treatment altered the negative exponential distribution, causing the stand to be more single-storied (Plots S3, S5, S6, V1). The three remaining, intermediate plots were placed in a third group, G3. For one regression it seemed logical to combine the two groups G2 and G3 to form a larger group, G23 (see below).

4 Results

A simple linear regression analysis of *Volincr* on *Standvol* covering all of the material revealed a statistically significant positive correlation between the two variables (Table 3). However, when the same analysis was carried out on each plot separately, the correlation was negative in nine out of eleven plots (Table 3), although only one of the eleven regression coefficients was statistically significant ($p < 0.039$).

A second multiple regression analysis was carried out to check whether including *SI* as a covariate would alter the positive correlation initially found for the whole material. However, a positive correlation between *Volincr* and *Standvol* remained (Tables 4 and 5). Due to correlations between residuals, the p-values are only approximate. According to these regressions, *Volincr* peaked close to a *Standvol* of 200 m^3 ha^{-1}.

Multiple regression analyses with the whole material, and with plots as dummy variables, revealed a statistically significant negative partial correlation between *Volincr* and *Standvol* (Fig. 1 and Table 6, Regression 1).

The regressions also showed that *Volincr* significantly declined as either *Harvint%* or *Yearsfst* increased (Table 6; Fig. 2). Interactions with groups were found (Table 6 Regression 1). The variable *Yearsfst* was only significant for G23, showing that volume increment was reduced over time for this group. The variable *Standvol* was only significant for G1, showing that volume increment declined as standing volume increased for the group of plots treated “well”.

To make sure that a detected correlation between *Harvint%* and *Standvol* (-0.323*) did not interact with the results of the multiple regression, an analysis like Regression 1 (Table 6) was carried out without *Harvint%*. In this analysis, the partial correlation between *Volincr* and *Standvol* was negative, but statistically insignificant. This indicated that the two variables could not replace one another in the analyses.

Regression analyses revealed that *Volincr* was reduced ($p < 0.000$) with increasing *Yearfst* in group G2, but for group G1 *Volincr* was stable over time (Table 6, Regressions 2 and 3; Fig. 3). *Standvol* decreased in group G1, while it increased in group G2 over time (Table 7), but these trends were not statistically significant. G1 had lower Volincr and lower *Standvol* values, on average, than G2 (Table 8)

A sensitivity analysis on plots in group G1 revealed that different combinations of the two variables *Standvol* and *Harvint%* had a strong influence on *Volincr* and, thus, productivity (Table 6 Regression 1, G1). With *Standvol* = 50 and *Harvint%* = 10, *Volincr* was 5.34 m^3 ha^{-1} a^{-1}. If *Standvol* was changed to 200 and *Harvint%* to 50 %, *Volincr* fell to 2.62 m^3 ha^{-1} a^{-1}. Hence, high stand density combined with high harvest intensity decreased the volume production to 49 % of that obtained with low standing volume and low harvest intensity.

5 Discussion

Cross validation was performed here, using the Minitab Press option, by comparing sum of squares of predictions (PRESS) with the sum of squares of residuals (SSRES) to avoid spurious effects of single observations. In our case, the PRESS value considerably exceeded SSRES, but this was mostly an uninteresting consequence of the high variability of the estimate for plot effects, due to the low number of observations per plot. To study the reliability of the parameter estimates of the true explanatory variables, the cross validation procedure (deleting one observation at a time) was carried out for the two groups of four plots (Regressions 2 and 3 in Table 6). Of the 23 and 22 regressions involved, respectively, the estimates of all parameters (all except for that of the insignificant *Yearsfst* in G1) had the same sign and about the same size.

In non-experimental data, correlations between independent variables cannot be avoided. In the present case it was found that the variables *Harvint%* and *Yearsfst* are negatively correlated (–0.36). This means that the effects of the two variables on *Volincr* cannot be completely separated. In addition, the indicators of each plot are correlated to the site quality index. However, the results of an F-test applied to check whether the indicators could be exchanged for site quality strongly rejected this hypothesis. Less straightforward is the interpretation of the effects of the variables *Standvol* and *Harvint%* on *Volincr* since a high value for either one of them will generally imply a low value for the other. However, as reported in the *Results* section, the two variables were found to cover different variance components.

The functions reported in Table 6 were not the best found, according to the respective standard deviations, S, of their residuals. In fact, the interaction variable *Yearsfst*Standvol* proved to explain a considerable amount of the residual variation, giving S values of 0.668, 0.610 and 0.603 for the regressions 1, 2 and 3 (Table 6) if inserted. However, we were unable to detect any causal link explaining this correlation. An attempt to exchange *Yearsfst* in the product here for the correlated variable *Harvint%* did not improve the S values as compared to those listed in Table 6.

In the traditional regression model, the effects of the independent variables are expressed by constant parameters. The effects probably vary between plots, which would generate a more realistic model with random parameters, with a fixed common population mean. An attempt to test such a complete model (using the SAS package) failed, likely due to the limited number of observations. However, when testing random parameters, one at a time, the general results of Table 6 seemed to hold for such models too, even if single estimated values differed from those derived using the traditional model.

Many scientists have carried out spatial studies in which productivity and structure have been compared in a large number of plots that were observed on a single occasion. A problem with such studies is that it is difficult to extract information on a number of potentially important interactions from such data. Stand density in natural forests is higher on fertile ground than on infertile sites, and lower in the far north and close to the tundra (irrespective of fertility) than further south. These interactions also occur in managed forests. Elfving (1993) and Fridman (1995) used thousands of temporary plots measured by the Swedish National Forest Survey, in attempts to identify stand features that had an influence on *Volincr*. They added *SI* and latitude as covariates, and still found a positive correlation with *Standvol*. When *SI* was introduced in the data studied here (Table 5), the positive correlation with *Standvol* still remained. It was not until the true productivity was introduced as a dummy variable, that the negative correlations were discovered (Table 6). A possible reason for this is that *SI*, measured from ground vegetation, is imprecise, as previously found by Hägglund and Lundmark (1977). Hence, *SI* reflects just a fraction of the true variance in site productivity. The remainder of the variance component is probably sufficient to give a positive correlation with stand density.

Site productivity is probably the common basis for the correlation between *Volincr* and *Standvol* found in superficial statistical analyses, like those summarised in Table 4 and the top row of Table 3. The statement by Lundqvist (1989 b) that “The relative annual volume increment is approximately 3 %” (of the standing volume), is thus statistically correct, but rather misleading.

A similar drawback applies to an analysis by Andreassen (1994), who studied 16 permanent plots in Norway subjected to single-tree selection over long periods. He concluded that the *Volincr* was equal to 3.7 % of *Standvol*, but did not extract plot effects from his analyses.

The volume increment was found to be strongly correlated with harvesting intensity (Table 6, Fig. 1), indicating that frequent and low intensity thinnings are best, if the aim is high productivity. The partial correlation shows that if the harvest intensity was increased from 8 % to 50 % of the volume, the volume increment in the following period was reduced by 35 %. Removal of a large portion of the volume is equivalent to removing a large portion of the assimilating leaf area. This naturally leads to decreased productivity until leaf area is restored.

Selective cutting successively reduced the volume increment in the studied material (Table 6). More narrow analyses of groups of plots (Table 6) showed that the plots managed in such a way that a multi-storied structure was preserved did not show any decline in productivity over time. In the other group, in which a build-up of standing volume was combined with a transformation of stand structure towards a single-storied pattern, the reduction of productivity over time was strong (Fig. 3).

For even-aged stands there seems to be a general agreement that stands with full density that are not thinned have higher volume increments over the rotation period than more open stands. However, opinions differ about the size of the decrease in volume increment that reductions in density cause. Möller (1954) found that a 50 % reduction in density did not lower the total yield, and stands could still produce 85 % of maximum yield even after a 70 % reduction. Braastad (1975) found the total yield decreased with decreasing density, while Carbonnier (1957) and Assman (1970) reported that lowering stand density by thinning had differing impacts on young and older spruce stands. Assman describes this as being due to the tendency of growth to accelerate in young stands that have been heavily thinned, since in periods following such thinning productivity was 10 % higher in young stands than in corresponding, unthinned stands. The same degree of thinning carried out at a later stage of the rotation reduced volume increment by 20 %. According to Assman, this pattern was observed in many different thinning trials. He believed that the accelerated growth observed following thinning in young stands represented merely an earlier peak of growth, that would be followed by an earlier retardation, hence no extra volume would be gained overall. However, if the accelerated growth he referred to was due to a shift in the allocation patterns of photosynthetic products, typical of small trees following high degrees of release, it could explain why the plots in this material combined high volume increment with low standing volume. O’Hara et al. (1999) presented data concerning volume increment per unit sapwood area (which is strongly correlated with leaf area) for individual trees in a multi-storied spruce forest. Overstory trees showed a larger volume increment per cm^2 sapwood than understory trees. This does not support the presented hypothesis. However, low standing volume was combined with high volume increment in the group of plots treated well, G1, but not in the other plots. This supports the hypothesis as small trees were liberated in G1. Öyen and Nilsen (2002) presented results from 16 permanent plots selectively cut in mountain forests of Norway. The thinnings were heavy, with 55-81 % of the volume removed. Only a slight reduction in volume increment with increasing volume removed was noted, and no correlation was found between volume increment, standing volume or basal area. The plot with the lowest basal area after thinning, 3 m^2, was one of the four highest-producing plots over a 25-year period. These results support the theory that the volume increment tends to remain constant within a wide range of densities.

Lundqvist (1994) found a positive relationship between standing volume and volume increment in three stands assessed 15 and 10 years after selective cutting. The analysis was carried out without any consideration of variations in site productivity, harvest intensity or stand structure. In addition, observations were done in small plots that were influenced by competition from surrounding trees. Trees on plots with small trees are, of course, generally exposed to competition from bigger trees outside the plot, and vice versa. Lundqvist (1989 b) refers to Barth (1929) and Böhmer (1957) and states that they also found positive correlations between volume increment and standing volume. However, these authors do not appear to us to have found any positive relation. On the contrary, Barth (1929) clearly expresses, in his summary, that the standing volume could be heavily reduced without loss of productivity.

Lähde et al (2002) presented a diagram showing that volume increment increases with standing volume in 23 plots subjected to single-tree selection in Finland. As site index and harvest intensity were not included in the simple linear regression, the author’s inference that growth is better in plots with higher density could be wrong.

As it is very difficult to finance repeated measurements on permanent plots over very long periods, few such temporal studies have been published globally, and studies describing the long-term effects of single-tree selection are especially scarce. One exception is a study of 16 Norwegian plots subjected to single-tree selection over longer periods than the plots analysed here. The Norwegian plots were laid out on sites similar to those in Sweden. Hence, the results should be comparable. Andreassen and Öyen (2002) found a positive partial correlation between basal area and volume increment when they used site index and average tree height as covariates. The R^2 value was 0.72. Their function gives similar estimates of *Volincr* to our function in Table 5. This shows that the Norwegian material might show very different results, if site index was replaced by plot indicators and *Harvint%* was introduced as a covariate.

For a long time it has been considered important for the efficiency of selective management for stands to be kept open and multi-storied. A number of observations have indicated that such a structure promotes sustainability by affluent recruitment (Schütz 1989, Andreassen 1994, Lähde 1992). It is satisfying that this empirical study now confirms the validity of these hypotheses, by finding high, long-term volume productivity in plots with such structure.

5.1 Conclusions

Analyses of volume increment in uneven-aged forests should include variance components such as actual site productivity, relative harvest intensity (percent of volume), and stand structure. Site index seems to be such an imprecise tool that the remaining variance still leads to the misleading conclusion that high standing volume is a prerequisite for high productivity. Temporal, long-term studies with repeated assessments in each plot are needed to obtain a measure of true productivity. Hence, spatio-temporal analyses of volume increment should not be based on data gathered by observing large numbers of plots on single occasions.

With respect to correlation between volume increment and standing volume, these results differ from the findings of many earlier studies. The hypothesis tested must be rejected, as volume increment decreased with standing volume in plots with preserved structure. In the other plots, standing volume had no impact on productivity.

These results suggest that the Swedish Forest Act should be revised, and its focus shifted away from stand density.

The results show that single-tree management was most successful in terms of volume production if management concentrated on low intensity thinnings carried out in a manner promoting multi-storied structure and low standing volume. In other words, high volume production was obtained where the forest had widely spaced dominants over a large number of small trees.

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Table 1. Data from Lundqvist 1989b.

Plot name	Number of obs.	Observation Period Years	Site index m^{3}ha^{-1} year^{-1} 1)	Accumulated Cut m^{3}ha^{-1}	Annual vol.incr. m^{3}ha^{-1}	Mortality % 2)
S1	7	62	5.3	157	2.78	8.1
S2	2	20	6.1	58	4.37	3.1
S3	6	57	6.1	265	6.19	12.5
S4	5	57	6.1	228	5.92	19.6
S5	5	30	6.1	89	3.68	6.9
S6	6	38	6.1	232	7.59	3.3
S7	6	30	6.1	205	5.75	23.2
V1	5	63	3.6	146	4.40	16.5
V2	5	63	3.6	132	4.23	19.8
V3	6	49	3.3	144	3.52	1.4
J	5	39	4.9	301	4.09	4.4
Average						10.4

1) Site index measured from site properties (Hägglund and Lundmark 1977)
2) Accumulated mortality/Accumulated cut

Table 2. Variables tested in multiple regressions with *Volincr* as dependent variable.

Name	Description
Volincr	Annual volume increment, m^{3}ha^{-1}
Volincr%	*Volincr/Standvol* in percent
Harvint	Harvesting intensity before the period in which *Volincr* was measured, m^{3}ha^{-1}
Harvint%	*Harvint* in percent of standing volume before harvest
Yearsfst	Years from start of selective cutting in the plot
Standvol	Standing volume at start of period in which *Volincr* was measured, m^{3}ha^{-1}
SI	Site index, m^{3}ha^{-1} year^{-1}

Table 3. Simple linear regression of *Volincr* on *Standvol* at the start of the study period

Plot name	Number of obs.	Constant = a	Regr. coeff. = b	p for regr.coeff.
S1-J	58	2.08	+0.015	0.000
S1	7	3.63	-0.021	0.462
S2	2	(5.68)	(-0.013)	(1.000)
S3	6	10.74	-0.026	0.604
S4	5	8.64	-0.012	0.400
S5	5	7.79	-0.663	0.222
S6	6	6.34	+0.004	0.925
S7	6	1.63	+0.414	0.414
V1	5	6.87	-0.018	0.496
V2	5	6.66	-0.022	0.262
V3	6	4.03	-0.005	0.892
J	5	4.64	-0.897	0.039

Table 4. Regression analysis with *Volincr* as dependent and *Standvol* as independent variables. All experimental plots taken together.

Dependent *Volincr*		
Indep.	Coeff	Sig
Const	0.262	0.802
Standvol	0.0445	0.004
$Standvol^2$	-1.01E-04	0.046
N	58	
F	11.870	0.000
R Sqr adj	0.276	
Culmination	*Standvol*	220

Table 5. Regression analysis with *Volincr* as dependent and *Standvol* and *SI* as independent variables. All experimental plots taken together.

Dependent *Volincr*		
Indep.	Coeff	Sig
Const	-2.87	0.032
Standvol	0.052	0.000
$Standvol^2$	-1.33E-04	0.005
SI	0.554	0.001
N	58	
F	13.6	
R Sqr adj	0.398	
Culmination	*Standvol*	194

Table 6. Regression analyses with all the plots (regression 1) and with two groups of plots (regressions 2 and 3): those with a negative exponential diameter distribution after treatment (Group treated “well”, S1, V2, V3, J), and those with a tendency to display a normal diameter distribution (Group treated “wrong”, S3, S5, S6, V1). For consistency, **the** same variables are used for both groups. For regression 1 the variable *Yearsfst**G23 means *Yearsfst* if plot does not belong to group 1 (indicator) and 0 otherwise, and in the same way *Standvol**G1 means *Standvol* if plot belongs to group 1 and 0 otherwise.

Regression no 1			Regressions no 2 and 3		
Dependent *Volincr*			Dependent *Volincr*		
			Group treated “Well”		
Indep.	Coeff	p	Indep.	Coeff	p
Const	4.102	0.000	Const	3.682	0.000
S2	1.590	0.012	V2	1.757	0.004
S3	3.538	0.000	V3	1.324	0.028
S4	3.561	0.000	J	2.012	0.002
S5	0.602	0.221	*Harvint*%	-2.04E-02	0.126
S6	4.585	0.000	*Yearsfst*	1.5E-04	0.990
S7	1.241	0.012	*Standvol*	-9.27E-03	0.034
V1	1.896	0.001	N	23	
V2	1.649	0.002	S	0.718	
V3	1.177	0.030	F	3.53	0.020
J	2.034	0.000	R sqr adj	0.408	
Harvint%	-3.21E-02	0.000	Group treated “Wrong”		
*Yearsfst**G23	-5.740E-02	0.000	Const	9.763	0.000
*Standvol**G1	-9.57E-03	0.016	S5	-3.576	0.002
N	58		S6	1.073	0.009
S	0.707		V1	-1.846	0.001
F	21.13	0.000	*Harvint*%	-6.18E-02	0.001
R sqr adj	0.821		*Yearsfst*	-6.11E-02	0.000
			Standvol	-7.47E-03	0.477
			N	22	
			S	0.608	
			F	28.88	0.000
			R sqr adj	0.888	

Table 7. Regression analyses of *Standvol* on *Yearsfst* in the two groups “Well” and “Wrong” with plots as dummy variables. For further explanation see Table 6.

Dependent *Standvol*					
Group treated “Well” Reference: Plot S1			Group treated “Wrong” Reference: Plot S3		
Indep.	Coeff.	P	Indep.	Coeff.	p
Constant	66.63	0.008	Constant	175,99	0,000
V2	70,92	0.012	S5	-82,94	0,000
V3	84,38	0.003	S6	3,12	0,726
J	87,47	0.003	V1	-28,89	0,006
Yearsfst	-0.466	0.444	*Yearsfst*	0,619	0,026
N	23		N	22	
F	4.92	0.007	F	31,55	0,000
R sqr adj.	0.416		R sqr adj.	0,853	

Table 8. Data for all material and for two groups of plots.
For description of groups, see Table 6.

	N	Harvest intensity m^3ha^{-1}	Standing volume m^3ha^{-1}	No of years from start of treatment	Volume Increment. m^3year^{-1}
Total material					
Mean	58	48.8	146.8	17.8	4.33
Min		11	41	0	1.13
Max		154	287	52	8.33
Std		35.3	54.3		1.67
Group treated “Well”					
Mean	23	47	113	21.2	3.23
Min		11	41	0	1.13
Max		148	287	52	5.00
Group treated “Wrong”					
Mean	22	50	162	17.2	5.17
Min		12	93	0	2.41
Max		154	211	46	8.33

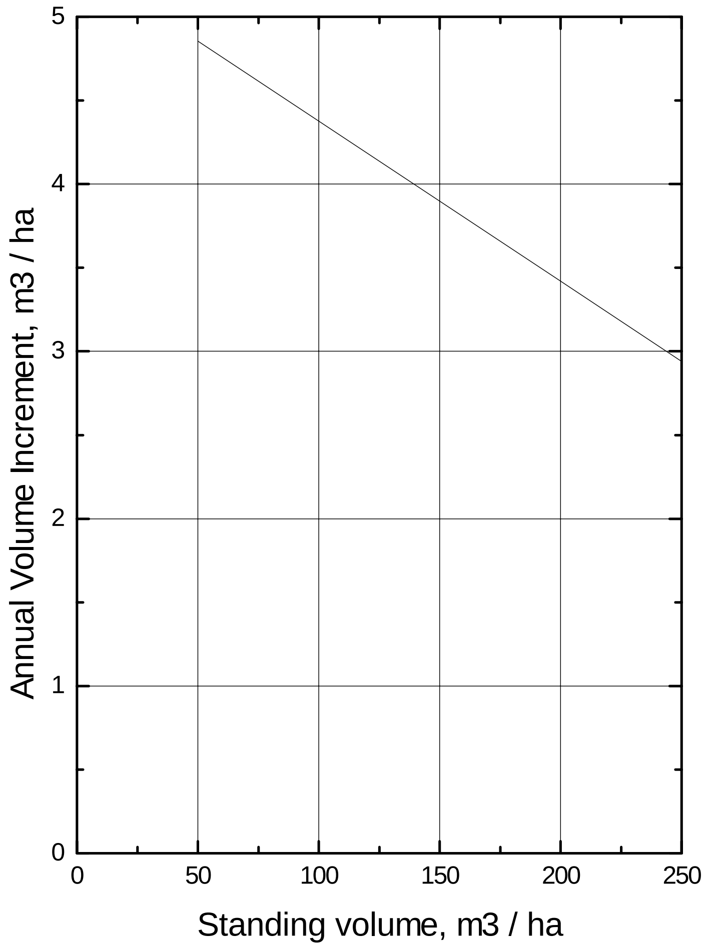

Fig.1. Partial regression of Annual volume increment on Standing volume for the group treated “Well”. (Table 6, Regression 1). Estimated values for plot J.

Fig. 2. Partial regression of annual volume increment on harvest intensity in percent of standing volume. (Table 6, Regression 1). Estimated values for plot V1.

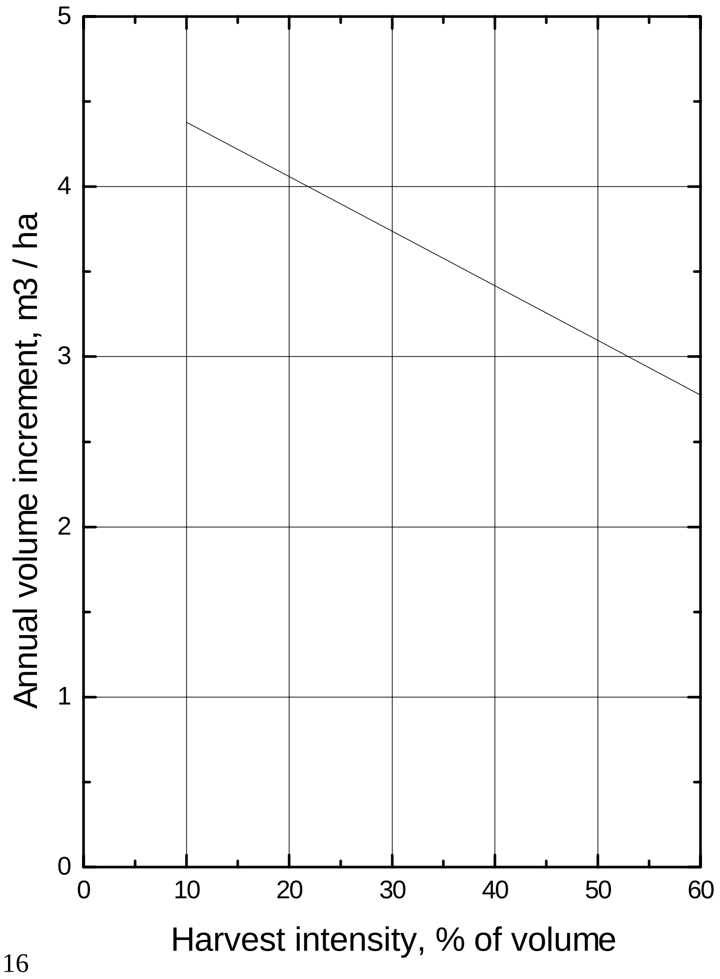

Fig. 3. Partial correlations of Volume increment on Years from start of treatment. The two lines refer to the two groups of plots, i.e. those treated “well” and those treated “Wrong” with respect to stand structure. The “Well” group is represented by plot J and the “Wrong” group by plot V1.