SUSTAINED HIGHER YIELD OF HUMID TROPICAL FOREST THROUGH SILVICULTURAL TREATMENT

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1. INTRODUCTION

Recent developments that concern forest and forestry, in Surinam will illustrate serious forestry problems for Surinam and other forestry belts of the same type. Only 20 years ago the forest of Surinam became accessible because of large scaled construction of forest roads. The harvested yield was about 10 cubic metre pro ha, just a fraction of standing biomass.

At this moment all of the forestry belt has been cut once. A second exploitation is taking place since some years. From that time, production felt back dramatically because regrowth had been very low.
Only about 5 species are economically important. They are relatively dominant in the virgin forest and of a high commercial quality. The present situation of these 5 species ranges from dying out (in the forestry belt) to commercially spoken of no importance because of the absence of mature trees. Pressure on the remaining species gets very high and these species will die out very soon.
At this moment export is minimal and of a very low quality. Local market's very unstable because of the lack of desired species and dimensions. Often only 2 choices are left : softer woods and harder woods.
Further road building is not economical because of the low and decreasing output.
Surinam depends more on forest production every day and it has even a high mortgage on it.

2. THE NEED FOR A SILVICULTURAL SYSTEM

The use of more species, after intensive research and education about potential species, is only a partial (*) and temporary (**) solution for the herebove mentioned problems and it's even dangerous for the forest ecosystem.
It will result in a wood packet of lower quality over time. Species composition will change constantly which will result in an unstable woodmarket. It requires continuing and intensive research and more expensive techniques and machines. A well controlled silvicultural management which limits extraction will reduce the ecologic problems.
It will make however forest economically more inaccessible and the extremely low output is not reasonable in the recent socio-economic situation.
The best solution is an efficient silvicultural system that guarantees a high and sustained yield. The yield has to be of a good quality and of a sustained species composition. The higher and sustained yield, as a result of the silvicultural treatment, makes investments and silvicultural management a lot more realistic and it also protects forest against other utilisations which destruct forest ecosystem.
A higher yield will create far better possibilities for green - end dry - end sawmills, key to produce high quality timber at low prices and to compete with it on the international markets. It will lower economic inaccessibility " which is presently the main impediment to the management of the humid tropical forest with low population pressure " (F.A.O. 1985 ; Tropical Forestry Action Plan).

(*) It requires continuing and profound research about more expensive techniques.

(**) The best species of the moment will die out.

3. ANALYSIS OF THE PRESENT MOST PROMISING SILVICULTURAL TREATMENTS

3.1 Introduction

This report is a brief evaluation of the present most promising silvicultural systems suited for humid tropical forest under selective exploitation (as far as it concerns exploitation of non secondary species).
Most of the results which are being used here, were obtained out of research done in the forestry belt of Surinam. A 20 year old experiment " experiment 67 9/A" and a 3 year old more complete and large scaled experiment, were the main sources.
The recent experiment was a new set-up of the most promising silvicultural treatments in Surinam or elsewhere.
A new silvicultural treatment was introduced, the so called S-system.
This research is of direct importance for all forests situated on the Guyana - Schield (Surinam, Guyana, French Guyana, E-Venezuela and N-Brasil). With little adaptation the much more flexible selective systems could also be of great importance in the entire tropical world.

3.2 Brief explanation on silvicultural systems

There are two main groups, the aselective or blind operations and the selective operations. Both follow up a standard exploitation.

The aselective operations

The aselective operations remove well described groups of big trees out of the forest ecosystem and have an intensive impact and modification upon it. The removed basal area in one cycle varies between 10 into more than 40 square metres pro ha.

The selective operations

The selective operations select and liberate future elements,following well defined rules and have a rather extensive impact upon the forest-ecosystem as a whole.
The removed basal area varies between3 to 10 square metres

In both groups there is a wide range of intensity of the treatment. This intensity is an other important factor. For practical reasons we'll discuss in each group an intensive and extensive variant.

The intensive aselective treatment will not be discussed, however it has proved to destruct the forest ecosystem within one cycle (see 3d).
So an evaluation is being done of : the D-system, the V-system and the S-system.

The extensive aselective system or "D-system"

The D system has been developed by the Surinam Forest Service and put in research by Celos. It's called " 20 + D8 ", " 40 + D8 " or later " The Celos Silvicultural System ".
All trees, except about 50 so called worth-full species, are poisoned if they are bigger than 20 to 40 cm dbh. About 8 and 16 years after that, an intensive liberation thinning will be taking place. The poisoned bruto volume is about 422 cubic metres pro ha (from which an important part is potentially harvestable). This means a removal of much more than 50 % of the standing biomass in a period of 18 years.

The intensive selective system or "V-system "

This system has been put into practice by Celos. A basal area about 10 square metres is poisoned to liberate on one ha more or less 25 future trees bigger than 15 cm dbh from direct competition of crowns.
An estimation of the removed bruto volume is 130 cubic metres pro ha (also in the V system an important part of this is harvestable because most of the trees are bigger than 30 cm dbh.)

The extensive selective system or " S-system "

It has been developed and put into practice by the author when he was a member of the Surinam Forest Service. To liberate about 50 future trees, which were all bigger than 15 cm dbh, a basal area about 3 square metres has been eliminated without poison. (Most trees were smaller than 30 cm dbh and thus a relatively and absolutely lower volume of potentially harvestable wood).
Restrictions in elimination are commun, this to avoid direct mortality, quality losses and growth losses caused by unjustified, unnecessary or unefficient eliminations.
Also competitions differing from crowncompetitions, mainly in the lower ranks, are leading to elimination. The removed bruto volume is about 23 cubic metres pro ha, which is very low in comparison to the V- and certainly to the D-system. What's more, the impact on the whole ecosystem is extremely low.

3.3 Step by step analysis of the silvicultural systems

The results of the silvicultural systems are being analysed from a partial, but accurate calculation into more overall, but lesser accurate calculations.

3.3.1.The main annual yield of the worthfull species in the first two years after treatment (fig. 1).

This is the only estimate for yield that has been measured directly for all treatments involved. Only trees bigger than 15 cm dbh are potential yield in the next extraction (*).

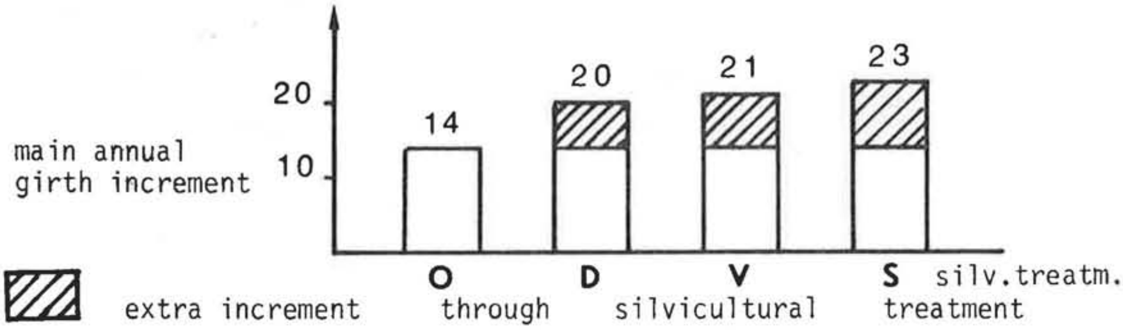


fig. 1 : main annual increment in mm in the first two years after treatment. Although extra yield does not differ very much, yet the last intensive and most selective silvicultural treatments (V and S) have the highest yield.

3.3.2. The main annual yield of the worthfull species in the second year after treatment (fig. 2).

Enormous dying of the eliminated trees only starts more than 3 months after the treatment and it reaches a level of 75 % only after one year. Extra growth with the surviving trees just occurs months later. Therefore extra growth in the second year gives a far better indication of future growth.

(*) Trees smaller than 15 cm dbh react faster than trees higher than that, unestimated silvicultural treatment. However after the more intensive treatments, a very high competition occurs from the stronger reacting secondary species.
This leads to a very high mortality and a loss of quality (see also continuity of production), which results in a low yield after the second cycle.

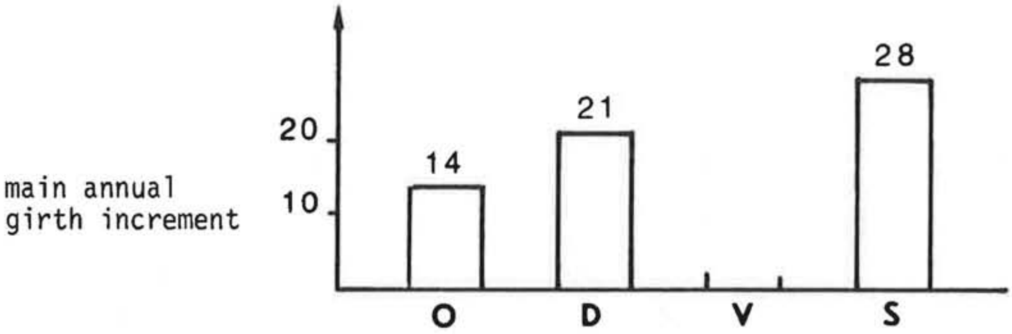


Fig. 2 : Main annual girth increment in the second year after the treatment.

A comparison of fig.1 and 2 illustrates that extra increment has raised higher in the second year and it has reached a top level after the S treatment.

3.3.3. Main annual girth increment in 1 cycle of 20 years of the surviving worthfull individuals + ingrowth bigger than 15 cm dbh (fig.3).

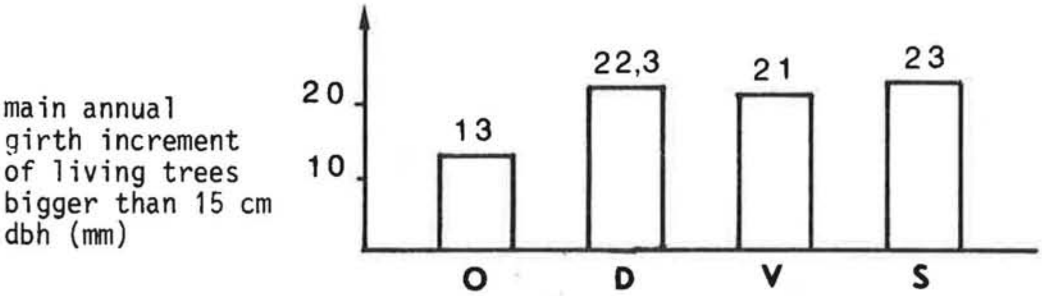


Fig.3 : Main annual girth increment in one cycle of 20 years.

The relatively better position of the D system compared to fig1 and 2, is caused by a second and a third treatment about 8 and 16 years after initial liberation.
With only one extensive treatment, the S system still obtains the highest yield.

3.3.4. Bruto yield in cubic metres in one cycle (20years) after the treatment (fig.6).

The calculation includes a correction for mortality and ingrowth of defects (fig. 5 and 6).

Mortality (%) / year

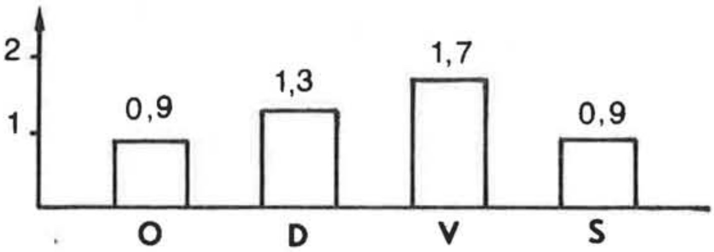


Fig. 4. : Main mortality rate (%) in one year during one cycle.

Elimination because of degradation of form, mainly caused by falling timber, has not been included.
It will however lower yield mainly with intensive system D and V.

natural ingrowth of defects % / year

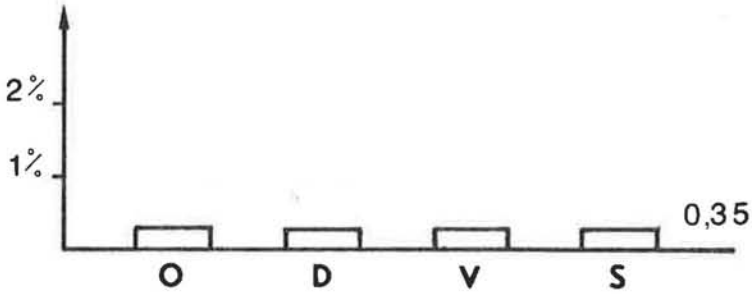


Fig. 5. : Natural ingrowth of defects (%) in one year (hollow and putrid).

- Here the ingrowth of defects on R. Sali (Tetragastris altissima) is estimated representing the whole population because it's a dominant species and it has a normal defect ingrowth.
- The natural ingrowth of defects is estimated the same as for untreated forests.

brutto yield (in
cubic metres pro ha)
in one cycle

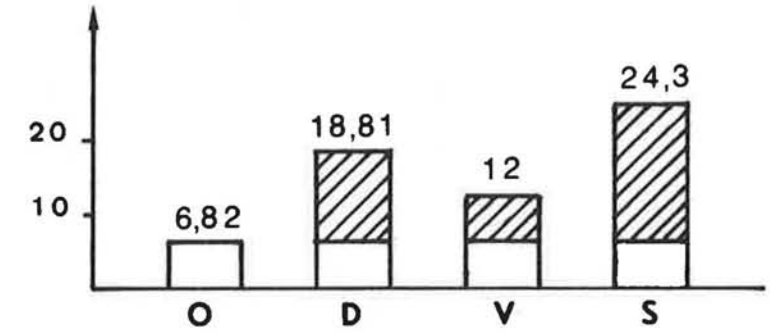


Fig. 6 : Bruto yield after one cycle

Extra yield through silvicultural treatment

Only half of the worthfull trees were liberated (about 25 pro ha instead of 50 pro ha with the S system). If all worthfull trees were liberated, the yield would be 15.6, but the input and removed basal area would have doubled. Efficiency of the treatment in the first cycle would differ very little. Production and efficiency in the second cycle however would drop faster.
(See also continuity of production).

Only the 5 system results in a yield of more than 20 cubic metres each 20 years, which is favorable for economical extraction every 20 years. Besides this extraction rate, the S system offers space for species conservation and stimulation (4,3 cubic metres after the first cycle).
Species composition of the yield of the more intensive systems (D and V) is lesser known and it's less durable than the yield after O- and S system.

3.3.5. Output - input rate (fig 8)

removed bruto volume
(cubic metres)
in one cycle

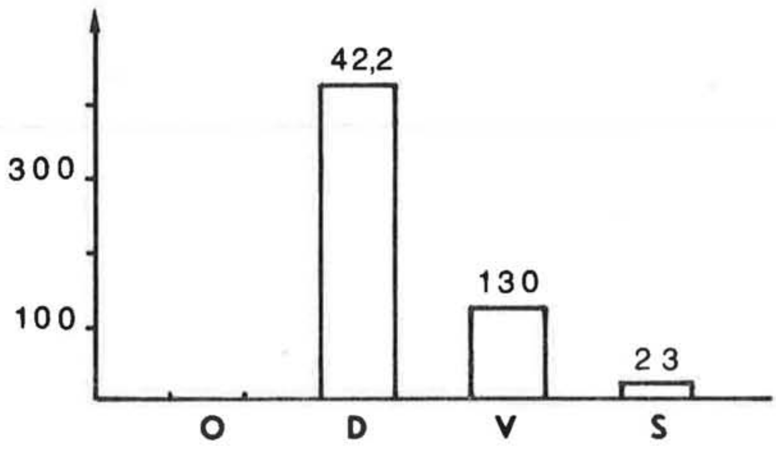
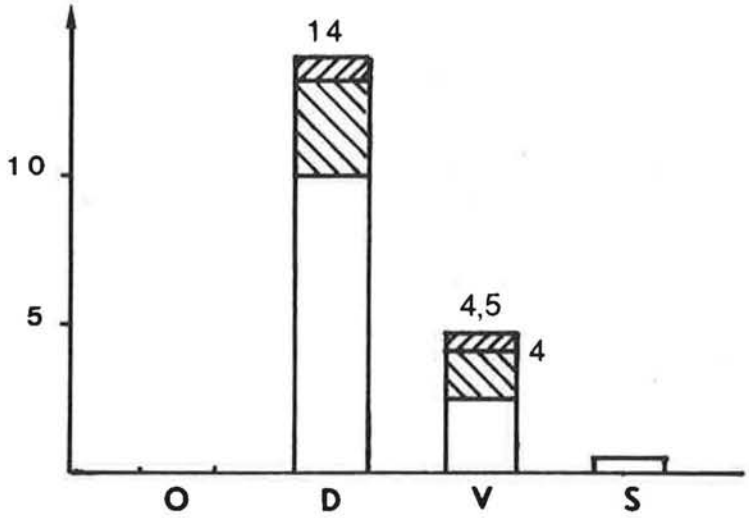


Fig. 7 : removed bruto volume (cubic metres) in one cycle

The removed bruto volume gives an idea of the impact of the system upon the forest ecosystem and about the input of labour and materials for the silvicultural treatment.

* A part of this volume is removed in a second and third treatment but within the same cycle.

input in manday



input through human labor

input through arboricide

transport of chemicals from town to treated trees under large scaled condition (Surinam situation).

Fig.8 : Input in manday

° In Surinam, all factors but human labour were converted into manday at prices at the beginning of 1987.

° S treatment eliminates without poison because a technique has been found to eliminate non dominant trees without it.
Dominant trees (bigger than 30 cm dbh) could survive the treatment but they were not eliminated in the S treatment.

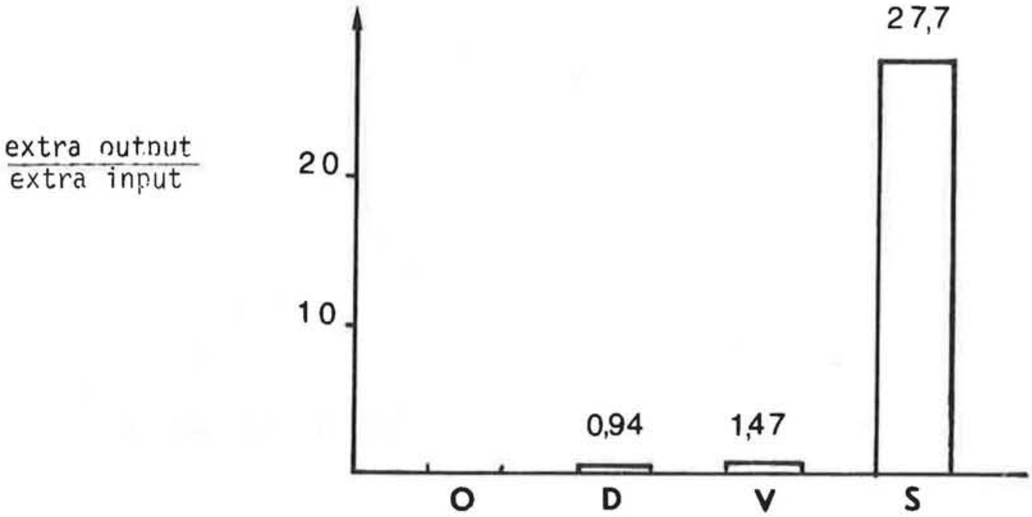


Fig.9 : Rate of extra output (extra yield through silvicultural treatment) versus extra input (extra investments for carrying out the silvicultural treatment).

On the level of the practical organisation the extra output - extra input rate is a bit negative for the D- and positive for the V system.
On the macro-economical level all treatments seem to be promising during the first cycle. The S system however is far-out the most efficient system, about 30 times more efficient than the D system and about 20 times more efficient than the V system.

3.4. Continuity of production

In order to evaluate a silvicultural system, one has to know whether the ecosystem itself and thus the production will be sustained.
The author has developed practical and cheap techniques to answer to these important questions for the first three cycles . He has also designed a more complex technique for the longer periods.
Important to mention here remains the fact that the D system with an equal input as in the first cycle, has a lower output than an untreated forest in the second cycle.
The reason for this is situated in the drastic changing of the ecosystem with high direct and indirect mortality and very low or even no successful regeneration of the worthfull species as a result.
It's true that the impact of the D system on the forest ecosystem, compared to a plantation or a strip planting, is much lower. The D system however changes the ecosystem too much to have enough natural regeneration of the desired species.

The author suggests not to practise aselective systems like the D system on large scale, because it damages the ecosystem and it doesn't offer a sustained yield.
The S system on the contrary will result in a steady forest with a composition, structure and forest climate close to that of a virgin forest.
This enables abundant and sound regeneration also with a composition which is very simular to that of a virgin forest, but with a lower mortality.
Bruto and even more netto yield and quality will increase every cycle, as a result of faster (*) and symmetrical (**) growth which leads to much younger harvestable trees with relatively small crowns and thin branches (***).

4. CONCLUSIONS

The new S system is far-out the most efficient system (about 30 times more efficient than the popular D system) and is the only way to guarantee a sustained high yield of good quality.
At least for the forest belts on the Guyana-Schield, it's an essential part of every silvicultural management. However, further follow-up of the research done in Surinam, reorganisation of the starting-up, large scaled research done in Venezuela and setting-up of other replications of this kind of research in other countries, are of direct importance for tropical forestry.

5. APPENDIX

The author has developed practical, cheap and complete research techniques suited for the replication in other forest belts.
The most important extra investments for the research are a 4-wheel traction car, one bus, a very small power-plant and temporary technical assistance.
Although this research has a high priority in Surinam, the Surinam Forest Service recently expressed not to be able to afford last mentionned investments any longer.
Drawnings, that illustrate the techniques used in the silvicultural treatments that visually explain the efficiency of the S system and the relative unefficiency and structure degeneration of the D system and in a lesser content of the V system, are in preparation.

(*) lesser ingrowth of defects and lesser damages from outside.
(**) lower losses due to internal tensions and lesser bole defects
(***) lower active and passive felling damage

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STRUCTURE AND PRODUCTIVITY OF A THICKET OF BLACK ALDER

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1. INTRODUCTION AND PROBLEMS

Up till now little research has been done on black alder. When it was well done, several topics were treated, such as the potential of nitrogen fixation, the phenomenon of symbiose, the influence of the origin, the growth on marginal sites, the result of interplantings, etc.

More specific silvicultural research on black alder, however, is rare. BEHRENS (1979) as well as VERWAY (1877) concluded in their examinations on different origins, that the results of the different origins are finally more or less the same. Several authors point out the positive results by interplanting black alder. SCHEBITZ (1977) describes a successful planting pattern, consisting of 3 rows of Norway Spruce spaced at 2 m between and 1.25 m within the rows, alternating with single rows

of alder spaced at 1 m within the row and 2.50 m from the spruce. The method provides the advantages of an alder nurse crop without the risk of suppressing the spruce. Positive results with spruce were also obtained by HOLSTENER-JORGENSEN and JOHANSEN (1977). CLARCK and WILLIAMS found an increased growth for a planting of Black walnut from the 8th year on. The result, however, was still much better by interplanting, of Black walnut from the 8th year on. The result, however, was still much better by interplanting of autumn olive (Elaeagnus umbellata).
The possibilities of black alder on marginal sites are also stressed. Examples of this are the studies of Plass (1977) on a coal spoil in Kentucky, of Keleberd (1981) on industrial waste lands and of LEHNARDT & BRECHTEL (1980) on unfavourable hydrological situations. A more extensive study on black alder was done in the Netherlands by van den BURG (1978). The black alder reaches the best results on soils with a peaty upper layer and with the groundwater on 50 to 80 cm beneath the surface. For a good growth PH-Kcl should be higher than 3.5 to 4, with an optimum between 4 and 6.5 and the organic nitrogen contents in sandy and loamy soils must be higher than 2.5 %.

For the first yield class and a rotation period of 90 years, WIEDEMANN-SCHOBER (1957) as well as ERTELD (1962) reckon with a mean annual increment of 8 m^3/ha. VAN DEN BURG (1978) measured on suitable and good sites mean annual increment of 6 to 8.5 m^3. Values higher than 9.5 m^3/ha/y were nowhere found. In accordance with the above mentionned yield tables the average height after 90 years amounts to 28.8 m on the best sites. A remarkable tree with a height of 34 m and 5.7 m g.b.h. was measured in Poland (Poland, 1980). DENNINGTON & CHADWICK (1981) calculated for black alder a mean annual increment of aerial biomass = 11.2 t/ha on pulverized fuel ash.

The present research deals with a small homogeneous group of black alder, with an age of 13 y and belonging to the thicket phase. Especially the following questions are put and examined :

- How did this group grow up and how is its structure nowadays ?
- To what degree are the dominant trees differentiated and distinguished from the co-dominant and the dominated trees ?
- What are the characteristics of the crown, an important producing element of the tree ?
- What relationship does there exist between some important tree features ?

The research aims at a better understanding of the growth phenomena, which occur normally in the forests and especially in artificial stands of black alder.
Black alder is a tree species, which has largely disappeared from the forests. It is, however, a species, that can be very usefull on marginal sites. It is advisable to use it for afforestations on new soils,

such as grounds jumped with sludge or collieries. It can be planted in mixture as well as in small homogeneous groups. This tree species is likely to become again in the future more valuable. Maybe it even will be possible by selection and breeding to improve the growth and the wood quality to the extent, that black alder can take in the place of other species, such as poplar. The nitrogen fixation capacity, the fast decomposition of the litter, together with the formation of a good humus layer and also the relative resistence against diseases are all arguments in favour of this species.

2. OBJECT AND METHODOLOGY

In the experimental Aelmoeseneie-forest at Gontrode, Belgium, a complete soil preparation was executed on a parcel of pasture in the autumn of 1968. The soil consists of recent alluvial depositions of heavy loam to clay, resting on tertiary Panisselian sand. The parcel lies on an altitude of 10 m above MSL. The average annual temperature is approximately 10°C and the average annual precipitation equals to 820 mm.

As a consequence of the soil preparation a small natural regeneration of black alder started in 1969. It originated from some seed-trees in the N.E. When the seedlings had grown up for 2 years, they are transplanted in the surroundings. The planting was carried out in a triangular pattern, with a space of 2 m betweeh and within the rows.

In all, 425 seedlings were transplanted in two nearly equal groups, separated from each other by a small way. Consequently, there is to be reckoned with a relative high number of edge trees.
In the present research the diameter of all trees was assessed and also the social position was determined. At the same time the total height of 40 % of the trees was measured.
The remaining research took place exclusively in so called cells. A cell consists of a central tree and the six surrounding trees. Each time a dominant tree was chosen as central tree. The cells were situated in such a way that they don't enclose edge trees, don't overlap each other and that at most 1 tree per parcel was dead.
Finally 5 cells were selected with a total amount of 32 trees. Of all these trees the crowns were measured accurately :

- the length of the light and shade crown.
- the diameter in N,E,S and W exposition.

3. BASIC CHARACTERISTICS OF THE STAND

Eleven years after the transplantation of the 425 two year old natural seedlings, 95 plants had disappeared, so that still 330 trees of black alder remained. A loss of 22 % must be judged as high, since the soil is of good quality and the treatment of the sapplings was executed quite well.
In this way the number of the remaining stand attained 1941/ha.

3.1. Diameter

The average diameter of the trees ($\bar{d}$) = 9·5 cm. This corresponds to an average annual diameter increment of 0·73 cm and with a mean annual circumference increment of 2.29 cm. These data indicates a fast youth growth. Indeed, according to WIEDEMANN-SCHOBER the average diameter after 20 years for the 1st yield class reaches 11·5 cm.

The involved population of black alder, however, can be divided in several subunits depending on the isolation of the tree. First of all there are edge trees, which are isolated for at least 50 %. Besides these are a lot of trees in the centre of the group, which are more or less isolated due to the disappearance of one or more neighbours. Since the plantation was carried out in a triangular pattern, all the central trees were surrounded initially by 6 trees. Meanwhile one or more of these neighbours can be lost. If e.g. 3 surrounding trees have disappeared, then the tree is 50 % isolated. The question arises if the presence or absence of neighbours affects the diameter growth at this age already. Therefore the mean diameter was calculated for each separated situation.

	N	d	s.
- all trees	330	9.47	3·11
- edge trees	78	9.58	4.91
- trees completely surrounded	83	9.51	2·19
- trees isolated on 1 site	85	9.26	2.37
- trees isolated on 2 sites	56	9.16	2.20
- " " 3 sites	17	10.06	2.93
- " " 4 or 5 sites	11	9.95	2.23

No significant differences can be noticed between the average diameter of the different sub-units. It means, that the average diameter is up to now independent from the isolation of the tree.

The variance of the average diameter is rather large (s % = 33). In this respect a better insight is given by the distribution of the stem number over the different diameter classes (Table 1).

In spite of the early age the diameter has grown from 2 cm to 15 cm. The variance is for the greater part the same, independant of the kind of isolation. Strongly isolated trees as well as not isolated trees can remain in growth. It is remarkable, however, that 32 % of the most isolated trees belongs already to the diameter class 12.5 and higher, while this is only 17 % for the totally surrounded trees. But this might already be an indication of the effect sorted by the degree of isolation.
There are about 200 trees/ha in a final stand of black alder with a mean diameter of 40 cm. The 200 largest trees of the involved thicket belong nowadays to the diameter class 12 and up. They have an average diameter of 13.7 cm, it means that the mean annual diameter increment amounts to more than 1 cm.
It is evident that the final stand will not be formed by the present 200 largest trees. The 500 largest trees belong now to the diameterclass 11 and more and have an average diameter of 12.7 cm. This corresponds with a mean annual diameter increment = 0.98 cm.

3.2. Height

Height can be presented in several ways. The average height $\bar{h}$ = 11.7 m, which corresponds with an average yearly growth of 0.90 m. This is a very high number which proves at the same time not only the growth potential of the alder but also the quality of the site.

According to WIEDEMAN-SCHOBER (1957) the mean height after 20 years for the first yield class equals 15.1 m. In the Netherlands, VAN DEN BURG (1978) found after 13 years a maximal height of 12.5 m for alder, originating from coppice, and a maximal height of 11.5 m for alder originating from seedlings. TARASENKO & SVISTULA (1978) found after 10 years on the lower Dnieper sands on fertile sites an average height and diameter of 5.4 m and 5.5 cm.

The variance on the mean height is rather large (1 % = 22), but it is nevertheless lower than these on the diameter. It proves that the differentiation started very early and is already well formed. A figure of this is shown by the distribution of stem number per height class (Table 2).
The distribution is not normal. The classes 12.5 en 13.5 have a much higher number than the class 11.5 m which corresponds with the average height. The highest classes are not yet very differentiated. This will certainly increase in the future.

Table 1 : Distribution of the stem number per diameter class.

D cl(cm)	2.5	3.5	4 5	5.5	6.5	7.5	8.5	9.50	10.5	11.5	12.5	13.5	14.5	15.5	
All trees															
N/ha	5.9	5.9	11.8	88.2	100.0	176.4	188.2	346.9	370.4	300.0	211.7	64.7	35.3	35.3	1941
%	0.3	0.3	0.6	4.5	5.2	9.1	9.7	17.9	19.1	15.5	10.9	3.3	1.8	1.8	
Edge trees															
N/ha	-	5.9	-	5.9	11.8	23.5	29.4	94.1	105.8	64.7	64.7	17.6	17.6	17.6	459
%	-	1.3	-	1.3	2.6	5.1	6.4	20.5	23.1	14.1	14.1	3.8	3.8	3.8	
Trees completely surrounded															
N/ha	-	-	-	23.5	11.8	76.4	47.0	88.2	82.3	70.6	58.8	5.9	11.8	5.9	482
%	-	-	-	4.9	2.4	15.8	9.7	18.3	17.1	14.6	12.2	1.2	2.4	1.2	
Trees isolated at least along 3 sides (= 50 %).															
N/ha	-	-	5.9	11.8	5.9	5.9	-	35.3	29.4	17.6	29.4	17.6	-	5.9	165
%	-	-	3.6	7.2	3.6	3.6	-	21.4	17.9	10.7	17.9	10.7	-	3.6	

Table 2 : Distribution of the stem number per height class.

height class (m)	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5
N/ha	30.8	77.0	15.4	77.0	107.8	154.0	123.2	246.5	446.7	338.9	231.0	61.6	30.8
%	1.6	4.0	0.8	4.0	5.6	7.9	6.3	12.7	23.0	17.5	11.9	3.2	1.6

It is not to be expected that the height of the trees is affected by the degree of isolation. This might be the case for the edge trees :

	N	$\bar{h}$	s
- all trees	120	11.7	2.59
- central trees	108	11.7	2.53
- edge trees	22	11.4	2.94

It appears, however, that no significant differences exist between the average height of the edge trees and this one of the central trees.

An idea of the big variation and of the early differentiation is given by the distribution of the stem number of the different diameter and height classes (Table 2). At most only 4.8 % of the plants occurs in a certain class. Within a same diameter class the variation of height can be rather high, e.g. the height is varying from 8.4 to 14 m in the diameter class 9.5. Yet, the variation of the diameter within a certain height class is still higher, e.g. in height class 12.5 the diameter is varying from 7 cm to 15 cm (Table 3).

The dominant height, which gives also an idea of the height of the future trees, can be calculated in several ways :

- the average height of the 100 tallest trees/ha = 15.42 m
- the average height of the 10 % tallest trees/ha = 15.06 m.

The latter number concerns 194 trees/ha,large part of which presumably stay in the final stand. This dominant height of 15.06 m corresponds with a mean annual height growth of 1.16 m.
The height of tree increases, statistically, nearly linearly, in accordance with diameter growth. (Table 4). The equation of the stand height curve can be expressed as follows :

$$y = -3.58 + 2.54\,x - 0.09\,x^2$$

with $r = 0.98$ and $F = 89.7$

y = height and x = diameter

Table 3 : Distribution of the stem number, in % over the different diameter- and height classes.

height class	<5.5	5.5	6.5	7.5	8.5	9.5	10.5	11 5	12.5	13.5	14.5	15.5
4.5	1.6											
5.5	1.6	1.6	0.8									
6.5				0.8								
7.5		2.4	0.8	0.8								
8.5		3.2	3.2			0.8						
9.5		0.8	4.8	1.6		0.8						
10.5			0.8	1.6	1.6		0.8		1.6			
11.5				4.0	4.8	1.6	0.8		0.8		0.8	
12.5				3.2	1.6	4.0	0.8	4.0	4.0	1.6	2.4	0.8
13.5					1.6	2.4	2.4	4.0	4.0	1.6		1.6
14.5						0.8	1.6	-	3.2	4.0	0.8	1.6
15.5							0.8	0.8			0.8	0.8
16.5							0.8			0.8		

Tab. 4. : The average height per diameter class

diameter class	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5
N	10	11	15	12	14	9	12	17	10	6	6
average height	7.4	8.6	10.6	11.7	12.1	13.0	13.3	12.7	14.0	13.1	13.9
s	1.27	1.37	1.82	1.03	1.54	1.34	1.16	1.30	1.04	1.58	0.96

3.3. The formation of strata

The variation in diameter, but mainly in height, has already shown that the differentiation in social classes is going on intensively.

If the dominant height (average height of the 100 tallest trees/ha) is taken as a basis, the limits between the strata are determined as follows :

- upper stratum (U) = > 2/3 or 15.42 m = > 10.28 m
- lower stratum (L) : < 1/3 or 15.42 m = < 5.14 m
- middle stratum (M) : between 5 .14 m and 10.28 m.

In this way the repartition in strata is characterised as follows :

	N/ha	N/%	$\bar{h}$(m)	$\bar{d}$(m)
- upper stratum	1438	74.1	12.9	10.7
- middle stratum	446	23.0	8.3	6.3
- lower stratum	57	2.9	4.5	3.6

The upper stratum takes up 3/4 of the stem number, whilst the lower stratum is practically inexistant. It is a typical example of the development of a young homogeneous and even-aged stand.

But, since that method was especially developed for natural, mixed and uneven aged stands, the following repartition was also tested :

- upper stratum : includes the dominant and co-dominant trees
- middle stratum : includes the dominated trees
- lower stratum : includes the suppressed trees

It is evident that this method, based on the extent of the crown isolation, is subjective. The results however equal for the greater part the former (table 5).

Table 5 : Characteristics of the different social classes

	Number of stems		height (m)			diameter		
	per ha	%	N	$\bar{h}$	s	N	$\bar{d}$	$\bar{s}$
Upper stratum	1488	76.7	88	13.1	1.36	253	10.4	1.84
- dominant	559	28.8	44	13.7	1.13	95	11.6	1.52
- co-dominant	929	47.9	44	12.4	1.27	158	9.7	1.64
Middle stratum	306	15.8	25	10.3	1.29	52	7.6	1.26
Lower stratum	147	7.6	20	6.9	1.65	25	5.3	1.09

The upper stratum contains as well 3/4 of the stem number and the lower stratum is stil practically inexistant. It is, however, interesting to divide the upper stratum in dominant and codominant trees. So the greatest part of the stem number belongs to the co-dominant group : 62 % - 38 %.
The dominant group, nearly 40 % of the total stem number, still consists of 554 trees/ha, which is of cause amply sufficient to later form on the mature stand.
Taking into account the generally descending movement, certainly within even aged homogeneous stands, it might be expected that the co-dominant trees will fall out more and more. Nowadays the height differences between the dominating and co-dominating trees are already that important, that they are statistically very significant ($t = 5.07^{+++}$).
The dominant trees are on average 10 % higher than the co-dominant ones.
The height differences between the upper stratum at one side and the middle and lower stratum at the other side are respectively 27 % ($t = 9.18^{+++}$) and 90 %. The height differences between the strata are, in accordance with this method, rather high, but they are much smaller in comparison with the first used method (55 % and 187 %).
The diameter differences between the strata are generally larger than the height differences. The diameter of the dominant trees is 20 % larger than the one of the co-dominant trees. The differences are statistically very significant ($x = 0.17^{+++}$). Between the upper stratum and the middle and lower stratum they amount to respectively 37 and 96 %.

In accordance with the above results the repartition into strata should be independent from the nature of isolation of the trees. Indeed this is proved by the repartition of the trees dependent on the degree of isolation. (Table 6). The upper stratum, which contains normally 77 % of the stem number, is practically proportionally distributed over the different classes

Table 6 : The social position and the way of isolation.

	upper stratum dominant	upper stratum co-dominant	middle-stratum	lower stratum	Tot.
Edge trees	17	47	10	4	78
trees completely surrounded	30	34	13	6	83
Trees isolated along 1 side	25	35	17	8	85
Trees isolated along 2 sides	13	29	10	4	56
Trees isolated along 3 sides	8	6	1	2	17
trees isolated along 4 or 5 sites	3	4	3	1	11

of isolation : 82 % for the edge trees, 77 % for the completely surrounded trees, 71 % for trees isolated on 1 side and further on successively 75 %, 82 % en 64 %. The most remarkable herewith is, that the most isolated trees only take up the smallest part of the upper stratum. However, one must be very careful, since the absolute stem number is rather low. Therefore it is likely, that the social position is not affected by the degree of density, at least in this first phase and under the given starting position.

3.4. Basal area

The average diameter $\bar{d}$, as mentioned above, was calculated on 9.5 cm. The diameter of the model tree, determined as $\sqrt{\bar{d}^2 + s^2}$, equals 9.9 cm. The basal area of the model tree $\bar{g}$ amounts to 78 cm².

The basal area of the stand, $G = N\,\bar{g}$, equals 14,8 m². This is to be judged as a high value. For black alder, 1st yield class and strong thinnings, ERTELD reckons with a basal area of about 16.4 m² at an age of 20 y.

If a regular growth is accepted for the black alder on the parcel involved, the following determinations can be derived.

- current annual increment of the basal area : 2.15 m²
- increment percentage of the basal area = 17 %.

It is evident that the upper stratum dominates more in basal area than it does in stem number. The basal area of this stratum takes up 88 % of the total, against 77 % for the stem number :

	basal area (m^2)	%
- upper stratum	13,02	88,1
- middle stratum	1,42	9,6
- lower stratum	0,34	2,3

Within the upper stratum the position of the dominant trees is very important. With respect to the codominating stratum its basal area represents 46 %, while its stem number represents only 38 %.

4. TREE CHARACTERISTICS

Special attention has been given to the development of the crowns. Indeed the size and the position of the crowns determine for a great part the productivity or the growth of the individual trees. It is important to know to what degree parameters such as diameter and height are related to the tree crown.

The research took place in the 5 selected cells, which consist, in all, of 32 trees. These trees have an average diameter of 9.2 cm and an average height of 12.3 m. The upper stratum takes up 65 %, the dominant trees of which represent 43 % and the co-dominant ones 57 %. All these figures show that the trees concerned are to be considered as representative for the whole parcel.

4.1 Crown characteristics

During the research work a distinction was made between light and shade crown. Hereby it was accepted that the light crown is to be considered as the part of the crown situated above the greatest crown diameter and that the shade crown takes up the lowest part.
Because of the limited stem number, the middle and lower strata were taken together in the calculations.

4.1.1. Crown length

The crown length equals 5.8 m, which corresponds with 48 % of the total tree height. (Table 7). It means that the natural pruning of the black alder stem comes about very fast. It is facilitated by the fineness

Tab. 7. Crown length.

	Sum		Upper stratum		co-dominant		dominated + suppressed	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
crown length	5.8	1.76	7.6	1.14	5.4	1.47	4.8	1.41
crown in % of height	47.9	13.09	53.1	8.48	41.9	10.40	50.1	16.78
length of light crown	3.1	1.22	4.3	1.12	2.8	0.67	2.4	1.05
length of shade crown	2.7	1.45	3.2	1.59	2.7	1.30	2.5	1.51
light crown/ shade crown	1.9	2.42	2.7	3.76	1.5	1.18	1.7	2.15

of the branches. There is every indication that black alder behaves as a very light demanding tree and that a large planting distance is permitted.

It is quite normal, that the total crown length has the largest value for the dominating trees. As to the tree height, however, the situation is not clear. Certainly there is a statistical difference between the dominant and the co-dominant class (t = 3.67^{++}), unlike for the dominant class and the dominated or suppressed one. This shows that the natural pruning of the stem of the black alder has little or no relation with the social position, but probably well with the reached height or the age of the plants.

Generally spoken the length of the light crown is larger than this one of the shade crown (3.07-2.74), but the differences are statistically not significant (t = 0.99 ; N = 62). The differences between the length of the light and shade crown are the largest for the dominant trees. (4.32-3.24), but they are not statistically significant either (t = 1.67 ; N = 16). The difference is completely inexistant in the co-dominant, dominated and suppressed layer.
The rate light crown/shade crown, however, could lead one to the conclusion light crown dominates in each social class. This misleading impression is to be declared by the very high value of the relation occuring on some individuals (till 12.2).

Crown length generally is a very variable parameter, especially the length of light and shade crown can vary very strongly. This is showed quite clearly by the frequency distribution :

a) Crown length in % of the total tree height.

- classes	< 35	35-45	45-55	55-65	65-75	> 75
- N	3	8	13	5	2	1
- %	9.4	25	40.6	15.6	6.3	3.1

b) Relationship light crown/shade crown.

- classes	< 0,75	0,75-1.00	1.00-1.25	1.25-1.50	1.50-2.00	2.00-5.00	> 5.00
- N	9	7	3	3	4	3	3
- %	28.1	21.9	9.4	9.4	12.4	9.4	9.4

The relationship light crown/shade crown is very irregularly distributed. It is evident that this affects the values of the crown area as well as the crown volume. Perhaps it shows also a certain inexactitude of the proposed definition of light and shade crown.

4.1.2. Crown diameter

The measurements permit to calculate several parameters. Since the trees were planted in a triangular pattern of 2 x 2 m, the tree crowns must have a diameter of at least 2 m before they touch each other. Taking into account the exposition of the planting rows, the trees are spaced at 2 m of each other in the direction N-S and ONO-WSW. In the direction E-W however they are spaced on 3.5 m.

On average the crown diameter equals 2.85 m. There is no difference if the exposition is altered : 2.88 m in N.S. direction and 2.81 m in E.W. direction (table 8). Any influence by planting distance cannot be showed. Generally the variance is rather large.

The crown diameter value is the largest in the upper social classes. Any significant differences between the dominant and the co-dominant class cannot be determined among other things due to the large variance. Yet there are differences between the dominant group and the group of the dominated and suppressed trees (D_{N-S} : t = 2.53* ; D_{E-W} : t = 2.93**).

Table 8. Crown radius R (m^2), diameter D(m), crown asymmetry and crown projection (m^2).

	Sum		dominant cl.		co-dominant cl.		dominated + suppl. cl.	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
R_N	1.42	0.61	1.62	0.65	1.33	0.61	1.35	0.61
RS	1.46	0.60	1.74	0.61	1.45	0.71	1.25	0.39
R_E	1.39	0.42	1.51	0.45	1.53	0.37	1.13	0.36
R_W	1.43	0.64	1.84	0.84	1.27	0.47	1.26	0.50
D_{N-S}	2.88	0.77	3.37	0.80	2.78	0.80	2.61	0.54
D_{E-W}	2.81	0.75	3.36	0.94	2.79	0.51	2.39	0.52
Crown asymm. N-S	111.2	155.4	87.0	100.4	135.6	199.3	104.3	147.6
E-W	58.7	49.1	55.3	46.7	45.9	18.4	75.5	69.5
NS-EW	22.6	13.6	22.5	13.6	19.3	14.1	26.2	22.6
Crown projection	6.41	2.55	8.19	2.44	6.35	2.63	5.02	1.66

The crown diameter is on average 42 % larger than the distance between the plants. The crcwn have grown clearly in each other in such a way that it is obvious that the period of crown competition has already started, even if this can not be deduced directly fr m the dimensions of the trees. The crowns of the dominant trees have grown more strongly in each other than the ones of the other trees : the rate crown diameter/planting distance equals for the several social classes respectively 1.68-1.39 and 1.25.

The annual increase of the crown diameter amounts to 22 cm on average, and in the different social classes respectively 26 cm, 21 cm and 19 cm. So the crown closure comes about at 10 years on average and within the dominant trees mutually about the 8th year.

The crown radii are developed even strongly in the 4 expositions. Yet the variance has become so large, that it is practically impossible to show any significant differences between the social classes. Only for R_S still significant differences exist between the dominant group and the group of the dominated and suppressed trees ($t = 2.18^+$).

The crown asymmetry has been determined as followed = $\frac{(D1-D2)}{D2} \times 100$, whereby :

- D_1 = diameter of the largest crown part ;
- D_2 = diameter of the smallest crown part.

The calculated value is analogous to the relation : (D_1/D_2) x 100.

The asymmetry of the crown diameter has acceptable values : 2.6 on average. Generally speaking, there is little difference between the crown width in N-S and E-W. The asymmetry is the same in the different social classes. Yet the asymmetry is very large between the corresponding crown radii. This is especially the case between R_N and R_S, where the value reaches 111. These value is to be explained for the greater part by the large variance. A clearer picture of this is given by the frequency distribution :

asymmetry classes	0-10	11-25	26-50	51-75	76-100	101-250	251-500	> 500
N-S	4	6	7	2	2	7	3	1
E-W	1	6	8	11	3	3		

In both cases there is only a limited number of trees which are more or less symmetrical. On the contrary a high number is characterised by a very strong asymmetry.

For a certain number of trees the crown development in the mainly isolated part was examined and compared to the one in the opposite direction, which is completely surrounded by trees. In this regard the N- and the S-exposition are to be considered, the following results are obtained :

- crown radius along the isolated side : 1.98 m
- crown radius along the surrounded side : 1.26
- t-value : 2.91^+ ; N = 16

So the difference due to the degree of isolation becomes apparent. Analogous results, however, are not become for the E and W side, which are sometimes partially isolated. In this case the average crown radius is even larger along the least isolated side (but statistically not significant).

In any case, it can be concluded crowns grow very asymmetrically and this from the youth on. A special cause herefore cannot be indicated. The exposition appears not to have any effect at all. The degree of isolation on the other hand does seem to have a certain influence. The crown symmetry is likely to be an individual feature, determined by certain physiological situations, which can occur in the stem and the root as well as in the crown.

The crown diameter also allows to determine the area of the crown projection. Since there exists on average just a small difference in the length of the crown radii, crown projection was calculated as the surface of a circle with a diameter equal to the average value of D_{N-S} and D_{E-W}. The average crown projection attains 6.41 m². The values decrease with descending social position. The differences between the dominant and the co-dominant class are not significant, which is quite obvious between the dominant and the dominated and suppressed class ($t = 3{,}44^{++}$).

Taking into account the number of stems in the several classes, the following sum of the crown projections can be made :

	N/ha	sum crown projections	%
- dominant class	559	4,578.2 m²	35.9
- co-dominant class	929	5,899.2 m²	46.3
- dominated+suppressed class	453	2,274.1 m²	17.8
		12,751.4 m²	

Calculated in this way, the sum of the crown projections exceeds with 27.5 % the available area. The closure is complete, the crowns are growing in each other and thinning is necessary.

Next to the crown projection the covered area was determined.
This was calculated starting from the horizontal projection of the five selected cells (fig. 1).

As already said, the centre of a cell is taken in by a dominant tree. Besides there are still four other dominant trees in the cells. On average nearly each central dominant tree is surrounded by one dominant tree. Next to the central dominant tree there are also on average 2.4 trees of the co-dominating class and 2.1 trees of the dominated or suppressed class. However it may occur, that the central tree is surrounded by two dominant trees or that it is the only dominant tree of the cell.
The sum of the covered area, determined for these cell trees by means of planimetry, gives the following results per ha :

	sum of the covered area (m²)	%
- dominant class	4,870	39
- co-dominant class	5,419	44
- dominated and suppressed class	2,092	17
	12,381	100

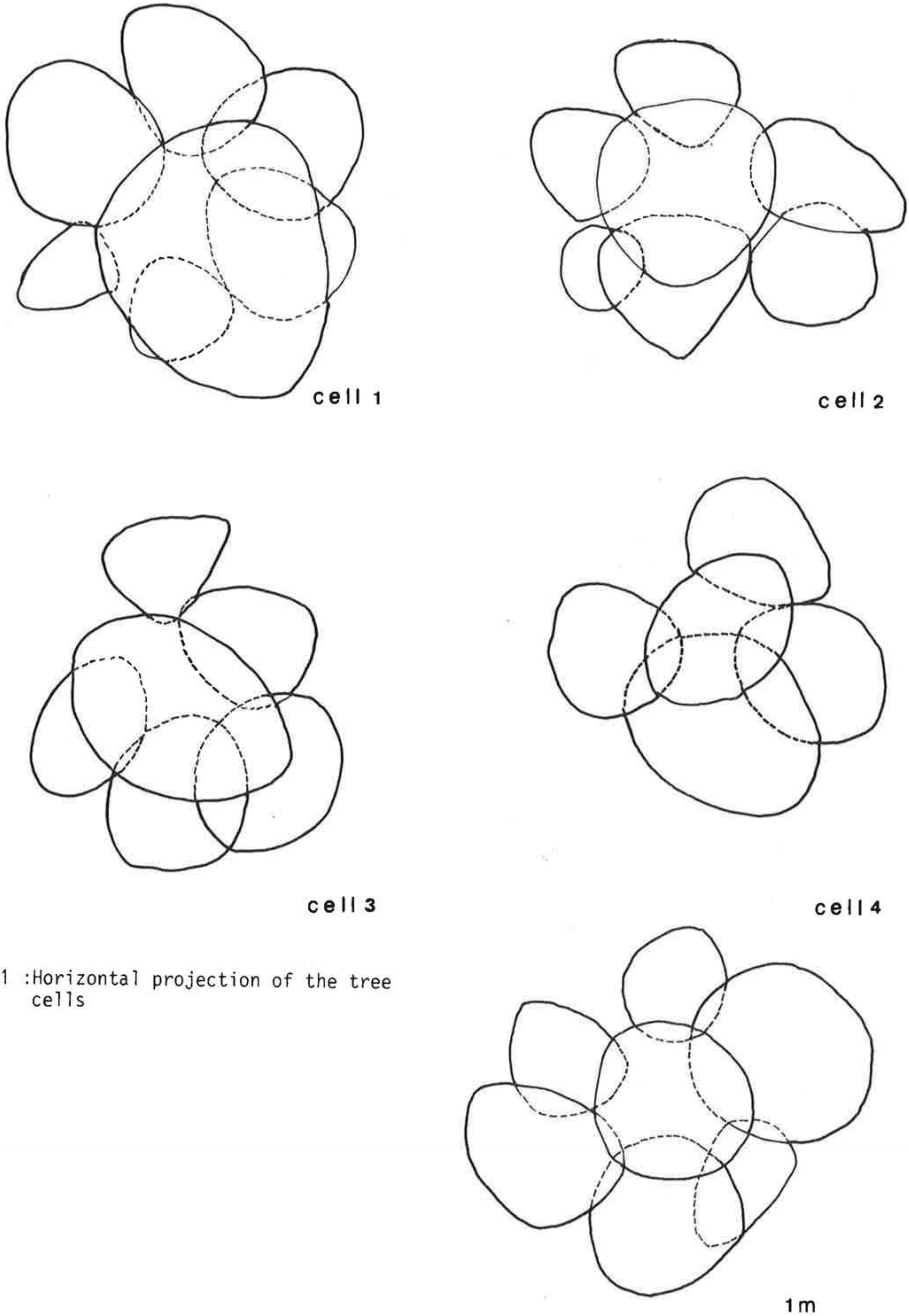

Fig.1 :Horizontal projection of the tree cells

It is evident, that these results correspond for the greater part with those of the crown projections.
The covered area of the dominant central trees attains on average 10.8 m^2.
The covered area of the other dominant trees however only reaches 6.12 m^2.
The rate between the cover of the central tree and the one with the greatest value after that tree, is as follows :

cell 1	cell 2	cell 3	cell 4	cell 5
2.39	1.75	1.65	0.91	0.77

In three of the five cells the central tree has the greatest covered area by far. On the contrary in the other two cases it is each time a tree of the codominated class, which has the greatest cover.

Figure 1 show crowns obviously overlapping each other. Yet the figure gives only a partial picture of the covered area, since the trees growing up next to the cell are not taken into account here.

If only the trees in the cell are considered, the covered area is to be characterised as follows (in m^2).

	cell 1	cell 2	cell 3	cell 4	cell 5
- sum of the covered area	50.9	33.8	38.5	33.4	42.5
- cover pér cell.	39.1	28.6	29.9	25.3	36.3
- 2 x covered area	10.2	5.0	7.2	6.9	5.9
- 3 x covered area	1.6	0.2	1.4	1.2	0.2

On average the covered area per cell amounts to 80 % of the sum of the individual covers. It means that 20 % is covered twice or three times, namely 18 % and 2 %. Figure 1 shows also, that not all areas are already covered.

The central trees can already cover a large part of the surrounding trees. In cell 1 e.g., the central tree covers 40 % of the surrounding trees. In cell 5 on the contrary, it takes up only 11 %.

It is to be expected, that in most cases the dominant central trees will dominate more and more and that they will soon push aside the other dominant trees of the cells.

4.1.3. Crown area and crown volume

The crown area was calculated starting from the premise that the light crown as well as the shade crown form a cone. So the used formula is : $C_S = \pi R \sqrt{R^2 + H^2}$. The total area was determined as the sum of the light crown and the shade crown, whereby each crown part was divided in 4 parts according to the exposition (Table 9).

Table 9 : Crown area (m²)

	Sum		dominant cl.		co-dom.cl.		dominated + suppresed cl.	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
area light crown R_N	3.99	2.42	5.83	2.56	3.34	1.81	3.18	2.25
area light crown R_E	3.81	1.80	5.36	1.51	3.89	1.34	2.44	1.43
area light crown R_Z	4.32	2.83	6.56	2.76	4.00	3.04	2.85	1.22
area light crown R_W	4.19	3.06	7.07	4.04	3.23	1.79	2.88	1.41
tot.area light crown	16.31	7.68	24.81	6.42	14.47	5.56	11.35	4.46
area shade crown R_N	3.75	2.34	5.13	3.10	3.29	2.07	3.12	1.48
area shade crown R_E	3.49	2.04	4.57	2.47	3.72	2.00	2.35	1.06
area shade crown R_S	3.93	2.67	5.51	3.31	3.78	2.61	2.82	1.49
area shade crown R_W	3.98	3.64	6.18	5.25	3.14	2.39	3.10	2.57
tot.area shade crown	15.15	8.83	21.39	11.80	13.93	7.15	11.38	4.67
area light or/ar. sh. cr.	1.04	0.93	0.85	1.58	1.05	0.37	1.18	0.69
tot. crown area	31.46	14.73	46.20	16.40	28.39	11.06	22.74	5.70

The total crown area attains on average 31.5 m². There are, however, big differences from tree to tree, even though the trees belong to the same social class. The variance explains for the greater part why there are hardly or no significant differences between the several strata. The crown area of the dominant class is 63 % higher than the one of the co-dominant class (t = 2.98++), although height and diameter are only 10 %, respectively 20 % larger. Therefore it appears very important to be able to distinguish the individual trees at an early stage. The crown area differences between the dominant class and the co-dominant one are even much greater than the differences between the co-dominant class and the dominated and suppressed one (25 % ; t = 1.52).
Taking into account the number of stems in each tree class, the crown area per ha can be distributed as follows :

A more detailed distribution per diameter class gives the following result :

- diameter class (cm)	< 7 cm	7-8.9	9-10.0	11-12.9	> 13
- average crown area (m^2)	22.6	20.8	27.4	38.7	64.1
- crown area/ha (m^2)	4784	7574	19790	19820	9673
- %	7.9	12.5	32.6	32.7	14.3

The crown area increases strongly, as the diameter becomes larger.
The increase from the class 11-12.9 to > 13 amounts to 68 %. It is obvious that in the future the difference between the social classes will become larger and larger.
The total crown area can be divided in nearly 2 equal parts. The area of the light crown takes up on average 16.31 and the one of the shade crown on average 15.15 m^2. Statistically significant differences can not be indicated, the more so as the variance is again larger. Yet there is maybe a trend that light crown becomes more important as the social class is higher (24.8-21.4 ; 11.4 - 11.4).
The area of the crown parts is independent from the exposition. The differences between N, E, S and W are small and not significant and the variance is large. The average value of the rate light crown area shade crown area, equalling 1.04, is characterised by a very large variance (1 = 0.93). A frequency distribution gives a better insight in this relation :

- classes	< 0.75	0.75-1.00	1.00-1.25	1.25-1.50	1.50-2.00	2.00-5.00	> 5.00
- stem number	8	6	5	5	4	3	1
- %	25.0	18.8	15.6	15.6	12.4	9.4	3.1

It is obvious that the results of the crown volume measurements are analogous to the ones of the crown area. The used formula is $C_v = \pi/3\ h\ R^2$. The volume was calculated as the sum of four parts light crown and four parts shade crown (table 10).

The crown volume amounts on average to 15.4 m^3. Yet there is a big difference from tree to tree. The crown volume of the dominant class is practically twice as great as the one of the co-dominant class ($t = 2.56^+$), and nearly four times as great as the one of the dominated and suppressed class ($t = 3.60^{++}$).
The volume of the light crown is on average 10 % greater than te one of the shade crown. Yet the differences are statistically not significant.
As expected, there is not a significant difference between the various expositions either for the light crown nor for the shade crown. Nevertheless for the light crown the sum of the S + W side is on average 20 % higher than the sum of the N + E side, and for the shade crown even 27 %. These differences are greater for the light crown as the social position is higher. This is not so, however, for the shade crown.

Table 10. Crown volume (m³)

	sum		dominated cl.		co.dom.cl.		dominated + suppressed cl.	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Vol.light crown R_N	1.95	1.84	3.19	2.35	1.48	1.20	1.45	1.62
V. light crown R_E	1.71	1.20	2.58	1.27	1.80	0.97	0.91	0.85
" " " R_S	2.26	2.19	3.79	2.30	2.18	2.42	1.09	0.73
" " " R_W	2.14	2.75	4.37	4.35	1.41	1.13	1.10	0.78
Tot.V.light xrown	8.06	5.69	13.92	6.20	6.87	3.88	4.55	2.61
V.shade crown R_N	1.69	1.69	2.86	2.48	1.43	1.16	1.01	0.81
" " " R_E	1.54	1.33	2.27	1.69	1.73	1.23	0.73	0.56
" " " R_S	1.93	1.95	3.10	2.82	1.83	1.55	1.07	0.82
" " " R_W	2.18	3.45	4.14	5.72	1.44	1.58	1.37	1.77
tot.vol.shade crown	7.33	6.83	12.37	10.31	6.43	3.96	4.19	2.77
tot. crown vol.	15.39	11.69	26.29	15.85	13.29	6.83	8.75	3.22

- light crown = : 41 % in the dominant class and 8 % in the dominated and suppressed class.
- shade crown : respectively 41 % and 40 %.

Calculated per ha, crown volume is distributed as follows :

	dominant class	co-dom. class	dominated and suppressed class	total/ha
m³	14,696	12,346	3,963	31,005
%	47.4	39.8	12.8	100

Once again the great value of the dominant trees is remarkable. Although they take up only 29 % of the stem number, their crown volume nearly amounts to 50 %.
It is not surprising, that the production and the growth of the dominant trees largely surpasses the one of the other trees.

The repartition per diameter class is as follows :

diameter class (cm)	< 7cm	7-8.9	9-10.0	11-12.9	> 13
average crown vol. (m^3)	8.4	7.8	11.6	19.4	43.2
crown vol./ha (m^3)	1773	2825	8362	9924	5847
%	6.2	9.8	29.1	34.4	20.4

The highest diameter class, which has only 6.9 % of the stem number, takes up more than 20 % of the crown volume.

All the most important crown characteristics point out the big differences between the trees of the dominant class and the one of the co-dominant class (table 10). Nevertheless in accordance with the I.U.F.R.O. classification they still belong to the same social class. So the results of the present research confirm that the I.U.F.R.O.-classification concerning social stratification just has little sense. They prove that generally a more accurate analysis is necessary and that individual trees should be taken into account. Parameters such as diameter and height, which are normally measured in the first place, are insufficient to classify the trees.

The results also show, that a descendent movement is the normal rule in an even-aged thicket. The co-dominant trees will fall off more and more, for lack of producing mass. Within the dominant class, in which there is also a large variation, normally these elements will fall out, having the least producing mass at their disposal. In the co-dominant class however, there are a certain number of trees the crown volume of which is equal or greater than the one of the dominant class :

crown volume class (m^3)	3-6	6-9	9-12	12-15	15-18	18-21	21-24	> 24
% N of the dominant cl.			11.1		22.2	22.2		
% N of the co-dom. cl.	16.7	8.3	25.0	8.3	8.3	25.0		
% N of the dominated and suppressed class	18.2	36.4	27.3	18.2				

The 44 % trees of the dominant class with a crown volume greater than 24 m^3 represent 248 trees/ha. Normally speaking they must form the greatest part of the mature stand. It is,however, not to be excluded that a certain number of the 25 % of the co-dominant trees, viz. 232 trees/ha ,the crown volume of which is situated between 21 and 24 m³, will overgrow in the future the presently dominating trees having a lower crown volume. So they can become dominant and take in a place in the final stand. It is obvious that the differentiation is still going on intensively. Competition will still increase, hence the great importance of the individual treatment in thickets, originating from artificial plantations.

4.2.Relations between the different parameters

The study of the relations between the different parameters largely contributes to a beter insight into the treatment. For instance, the degree of slenderness h/d is a measure for competition and stability and points out the necessity of thinning.

4.2.1.Degree of slenderness h/d, quotient of crown -width D/d and crown-index of Mayer K_L/D.

The plantation generally exists of slender to very slender trees. The average value of the degree of slenderness equals 132.7 (table 11). The stem diameter is, in relation to height, to small. This is particularly so in the lower sicial classes, where the trees are very unstable. The isolation of the best dominating trees is a necessity in order to favour diameter growth and to increase the stability.Therefore it is necessary to cut trees belonging to the same social level. The cutting of suppressed trees apparently has no or just a little influence on the growth of the dominant trees.

Statistically significant differences for the values of the degree of slenderness are only found between the group of the dominant class and the one of the dominated and suppressed class ($t = 2,94^+$). There is not yet a difference between the dominating plants and the co-dominating one. True, the variance is larger in the co-dominant class, which means that a certain number of trees already have a high degree of slenderness.

The quotient of crown-width D/d is quite high, on average 32.0. This is due for the greater part to the low values of the stem diameter,which is mostly the case in the lower social classes. Here no differences exist between the dominating trees and the co-dominating ones. The value equals 28.0, which is higher than normal.
It is to be expected that the value will decrease with increasing age.

The crown-index of Mayer has a rather low value. There are no statistical differences between the social classes, among other things as a consequence of the large variance. The low value is mainly due to the limited crown-length (sec table 7).

4.2.2.Productivity indices

In order go get a better insight in the growth-pattern, some productivity indices were calculated, namely C_p/d (C_p = crown projection), C_s/d and C_v/d (table 12).

Table 11. The values of h/d, D/d and K_L/D

	Sum		dominant cl.		co-dom.cl.		dominated + suppressed cl.	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Degree of slenderness h/d	132.7	33.7	122.2	18.4	124.4	42.8	151.2	24.4
Quotient of crown width D/d	32.0	8.21	28.0	3.38	28.3	3.68	39.3	9.76
Crown index of Mayer K_L/D	2.8	0.57	2.31	0.41	1.99	0.53	1.99	0.71

Table 12. Productivity-indices K_P/d, K_S/d and K_V/d

	Sum		dominant cl.		co-dom. cl.		dominated + suppressed cl.	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
K_P/d	0.70	0.23	0.68	0.14	0.63	0.20	0.78	0.29
K_S/d	3.36	1.04	3.82	0.96	2.82	0.86	3.57	1.09
K_V/d	1.55	0.78	2.13	1.03	1.30	0.56	1.36	0.52

The values are indications of the growth efficiency.
A difference between light- and shade crown could be made for the crown and for the crown volume. Yet the above showed that both crown parts have nearly the same value (table 9 and table 10).
The index Cp/d attains on average 0.70. This can be considered as a low value. Similar measurements on beech and oak, with a diameter less than 20 cm, gave as results 3.30 and 1.28. There is no difference among the social classes.

Also the index C_p/d has a low value, namely nearly 3.36, whereas for similar beeches and oak values of 15.3 and 6.8 were noted. In this case there is a statistical difference between the dominant and the co-dominant class,

although the values of the dominant class are not higher than the one in the lowest class. The C_v/d index is proportionally, the smallest, namely only 1.550. For beech, values up to 13 times greater were found and for analogous oaks the value was 4.4 times greater. For this parameter the value of the dominant class is significantly higher than the one in the other social classes.
The registered low values of the productivity indices are above all due to the relative small crown dimensions. The black alder has in all respects a little developped crown. The diameter is small and also crown area and crown volume are rather small as a consequence of the small diameter and crown depth.

All these values show the high light demand of the black alder and so the necessity of early strong thinnings.
The determined values give, in comparison with the different indices, partially other results. The social classes have the same value for Cp/d, the co-dominant class has the lowest value for C_s/d, whereas the dominant trees have clearly the largest values for C_v/d.

5. CONCLUSIONS

The examination of a 13 year old thicket of black alder showed in particular that it is insufficient to measure only the normal parameters for a stand analysis, namely d and h, in order to be able to classify the trees.
It is important to attach much attention to the crown, which is for the greater part, responsible for the growth and production of the tree. The crown area and the crown volume are parameters which show more clearly than diameter and height the differences between the social classes.

In the 13 year old thicket which was examined, the differentiation between the trees is going on fully. It started already before crown closure was a fact. In the future there must be reckoned nearly only with a descendent social movement.
Black alder behaves as an extreme light tree. Also because of the fast natural stem pruning they can be planted at large distances. Nevertheless it will be necessary, certainly on the better soils, to thin early and strongly. An individual evaluation of the trees must permit to select the future trees and to supply sufficient energy for a valuable and stable forest.

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